# EXHIBIT Q
# THREATENED AND ENDANGERED SPECIES
# OAR 345-021-0010(Q)

## CONTENTS

## TABLE

## FIGURES



## APPENDICES

# 1.0 INTRODUCTION

The Jordan Cove Energy Project (JCEP) proposes to construct and operate the South Dunes Power Plant (SDPP), located in Coos Bay, Oregon, at the former Weyerhaeuser North Bend containerboard mill site. The mill was demolished in 2003 and the site is currently being used as an industrial waste landfill. Prior to the commencement of construction on the SDPP, the landfill will be closed and pre-construction activities will be conducted, including the placement of clean sand fill to approximately 46 feet in elevation on the majority of the site. Impacts to habitat and wildlife as result of these activities are discussed in this Exhibit.

The site of the proposed SDPP is located on the North Spit of Coos Bay, adjacent to Jordan Cove. Coos Bay/North Bend is the largest urban area located in the Coast Range Ecoregion, and is a center for the fisheries, forestry and transportation industries (ODFW 2006). Within the Coast Range Ecoregion, Coos Bay is located in the Coastal Lowlands, which are characterized by beaches, dunes and marine terraces below 400 feet in elevation (Thorson et al. 2003).

## 1.1 DEFINITION OF TERMS

The following terms are outlined in detail to provide context for the information presented in Exhibit Q. Figures 1, 2 and 3 of Exhibit C illustrate the site boundary and analysis area in closer detail.

### 1.1.1 Site Boundary

The Energy Facility Siting Council (EFSC) site boundary is defined as the area encompassing the temporary and permanent direct impact footprint of the project. The site boundary consists of 137.86 acres, and includes the area of the former mill site, along with all temporary laydown and staging areas, utility corridor, heavy haul road, and barge berth.

### 1.1.2 Analysis Area

The analysis area for state and federally listed species and associated habitat includes the area within the site boundary as well as a five-mile buffer in all directions.

## 1.2 EXHIBIT OVERVIEW

Exhibit Q identifies and evaluates state and federally threatened and endangered plant and animal species, in addition to federally listed critical habitat, that may be affected by the construction and operation of the proposed SDPP. Candidate and proposed species have been included in this analysis as they have the potential for listing during the application process. Potential impacts to threatened and endangered species and existing conditions from pre-construction activities at the site will be analyzed.

Exceptions to fill areas within the site boundary are shown in Exhibit P on Figures P-2 and P-3 and include narrow areas of dune forest other native habitats, some more weedy habitats, and Department of State Lands (DSL) jurisdictional wetlands and estuarine habitat. Please refer to Exhibit J for a discussion of jurisdictional wetlands, estuarine habitat and associated permits.

## 2.0 THREATENED AND ENDANGERED PLANT AND ANIMAL SPECIES

**OAR 345-021-0010(1)(q)** *Information about threatened and endangered plant and animal species that may be affected by the proposed facility, providing evidence to support a finding by the Council as required by OAR 345-022-0070.*

**OAR 345-021-0010(q)(A)** *Based on appropriate literature and field study, identification of all threatened or endangered species listed under ORS 496.172(2), ORS 564.105(2) or 16 USC §1533 that may be affected by the proposed facility.*

The State of Oregon and the federal government maintain separate lists of threatened and endangered species. Under Oregon Revised Statutes (ORS) 496.171-496.192, the Fish and Wildlife Commission, through the Oregon Department of Fish and Wildlife (ODFW), maintains the list of native wildlife species in Oregon that are threatened or endangered, according to criteria set forth by rules for the Wildlife Diversity Plan under OAR 635-100-0105. Plant listings are handled through the Oregon Department of Agriculture (ODA). Most invertebrates are handled through the U.S. Fish and Wildlife Service (USFWS) and the Oregon Biodiversity Information Center (ORBIC). Under federal law, the USFWS and National Marine Fisheries Service (NMFS) share responsibility for implementing the federal Endangered Species Act (ESA). In general, the USFWS has oversight over terrestrial and freshwater species, and NMFS over marine and anadromous species.

Twenty-three state listed species and 26 federally listed species occur, or have the potential to occur, in the analysis area evaluated for Exhibit Q. Figure Q-1 shows the analysis area for threatened and endangered plant and animal species, including the EFSC site boundary and the five-mile analysis area buffer. The assessment of impacts to listed species includes species within the SDPP site boundary and the larger analysis area

The construction, operation and retirement of the SDPP may affect, but is not likely to adversely impact, 18 state listed and 21 federally listed species and/or their designated critical habitat. Impact determinations, as well as a summary of justification for these determinations, are provided in Table Q-1 below.

**Table Q-1. State and Federal Threatened and Endangered Species Effects Analysis in the SDPP Analysis Area**

| ***Species*** | ***State Status***[1] | ***Federal Status***[2] | ***Effect***[3] | ***Potential to Occur***[4] | ***Justification***[5] |
|---|---|---|---|---|---|
| **Plants** | | | | | |
| Pink sand verbena *Abronia umbellata ssp. breviflora* | E | SOC | No Effect | Low | Habitat for the species may be found within the analysis area. Based on areas surveyed, however, the species is absent inside the site boundary, and suitable habitat would not be affected by the project. |
| Point Reyes bird's-beak *Chloropyron maritimum ssp* | E | SOC | NLAA | Present | Multiple occurrences were detected along the shoreline of Jordan Cove below the highest measured tide. Appropriate conservation and mitigation measures will be developed and implemented through consultation with the ODA to ensure that Point Reyes bird's-beak and potential suitable habitat for the species will not be impacted. |
| Silvery phacelia *Phacelia argentea* | T | SOC | No Effect | Low | Habitat for the species may be found within the analysis area. Based on areas surveyed, however, the species is absent within the site boundary and suitable habitat would not be affected by the project. |
| Western lily *Lilium occidentale* | E | E | NLAA | Low | The species has not been found in the SDPP site boundary found during focused surveys, and the areas to be impacted by the SDPP are not expected to include western lily habitat. |
| Wolf's evening primrose *Oenothera wolfii* | T | SOC | No Effect | Unlikely | Based on areas surveyed and lack of documented species in Coos County, the species is absent from the analysis area and would not be affected by the project. |
| **Amphibians and Reptiles** | | | | | |
| Green sea turtle *Chelonia mydas* | E | T | NLAA | Low | Shipping and barge traffic would be traveling at slow speeds within the analysis area (10 knots or less) |

[1] ORBIC July 2013, ODA 2013, ODFW 2013
[2] USFWS 9/11/13, NMFS 8/21/13
[3] SHN 2014 and JCEP/PCGP Draft Biological Assessment April 2014
[4] SHN 2014
[5] SHN 2014 (all species) and JCEP/PCGP Draft Biological Assessment April 2014 (federal species)

| ***Species*** | ***State Status***[1] | ***Federal Status***[2] | ***Effect***[3] | ***Potential to Occur***[4] | ***Justification***[5] |
|---|---|---|---|---|---|
| Leatherback sea turtle *Dermochelys coriacea* | E | E | NLAA | Low | making the potential for ship-strike extremely low. Ship noise would be detectable but would not permanent or temporarily impair hearing. |
| Loggerhead sea turtle *Caretta caretta* | T | E | NLAA | Low | |
| Olive Ridley sea turtle *Lepidochelys olivacea* | No Listing | T | NLAA | Low | |
| **Birds** | | | | | |
| Brown pelican *Pelecanus occidentalis* | E | Delisted | NLAA | Moderate (nearshore waters, foraging, non-breeding) | Incremental noise and human activities associated with the project are not likely to directly affect the brown pelican in the project area due to the pelicans' acclimation to current human-generated sounds and facilities in the bay area. Overhead transmission lines located inland will have bird flight diverters installed, and collisions are not anticipated during the pelican's flight path along Coos Bay. |
| Marbled murrelet (MAMU) *Brachyramphus marmoratus* | T | T | NLAA | Low (overhead, transient, possible foraging) | Suitable nesting habitat does not occur within the project footprint or within a range that could potentially affect the species by construction of the SDPP. Exposure to incremental noise by transient and foraging MAMUs in the analysis area is not expected to cause behavioral effects. Overhead transmission lines located inland will have bird flight diverters installed, and collisions are not anticipated. |
| Northern spotted owl *Strix occidentalis caurina* | T | T | No Effect | Unlikely | No suitable habitat occurs within the project vicinity that will be affected by construction, operation or retirement of the SDPP and the species is unlikely to be encountered in the analysis area. |
| Short-tailed albatross[(6)] *Phoebastria (Diomedea) albatrus* | No Listing | E | NLAA | Low (foraging off the coast) | The species is not expected other than possibly foraging off the coast. Shipping/barge traffic would be traveling at slow speeds within the analysis area (10 knots or less) making the potential for ship-strike extremely low. |

[6] Pacific Coast population

| ***Species*** | ***State Status***[1] | ***Federal Status***[2] | ***Effect***[3] | ***Potential to Occur***[4] | ***Justification***[5] |
|---|---|---|---|---|---|
| Streaked horned lark<br>*Eremophila alpestris strigata* | SC | T | NLAA | Low<br>(foraging along the shoreline) | Based on areas surveyed, the species is absent, and no suitable habitat occurs in or near the SDPP site boundary. Suitable habitat could occur on the north spit in the analysis area and while an occasional individual may show up on a sandflat to forage, the species would likely keep a distance and avoid close interactions with areas of human activity. Overhead transmission lines located inland will have bird flight diverters installed and collisions are not anticipated. |
| Western snowy plover<br>*Charadrius alexandrinus nivosus* | T | T | NLAA | Low<br>(foraging along the shoreline) | The primary nesting areas on the North Spit used by the western snowy plover are more than 4.5 miles from the Site boundary. Noise at nesting areas and critical habitat would not be above ambient levels. Avoidance and conservation measures will be in place to decrease the possibility of adverse effects to the species due to attraction of predators to the vicinity. |
| **Fish** | | | | | |
| Coho salmon [7]<br>*Onchorhynchus kisutch* | SC | T | NLAA | Nearshore waters<br>(foraging/migrating) | For all three species: The SDPP does not require water intake, and no entrainment or impingement would occur. Storm water from the SDPP site will be managed under Best Management Practices and either |
| Eulachon [8]<br>*Thaleichthys pacificus* | No Listing | T | NLAA | Nearshore waters<br>(foraging/migrating) | |

[7] Oregon Coast Evolutionarily Significant Unit (ESU)
[8] Southern Distinct Population Segment (DPS)

| *Species* | *State Status*[1] | *Federal Status*[2] | *Effect*[3] | *Potential to Occur*[4] | *Justification*[5] |
|---|---|---|---|---|---|
| Green sturgeon [(9)]<br>*Acipenser medirostris* | No Listing | T | NLAA | Nearshore waters (foraging) | (1) retained on site for infiltration in vegetated bioswales and ponds constructed to treat stormwater, or (2) collected in a separate system for treatment and discharge under the National Pollutant Discharge Elimination System ("NPDES") Individual Permit. Construction Stormwater will be managed under the revised NPDES Stormwater Construction General Permit No. 1200-C program managed by Oregon Department of Environmental Quality (ODEQ) for the Environmental Protection Agency (EPA). The permit regulates stormwater runoff to surface waters from construction activities that disturb one or more acres in Oregon. During operations on-site stormwater from impervious surfaces will be collected for infiltration on-site in bio-swales and ponds. Stormwater that comes in contact with industrial process, roof areas, maintenance areas, or chemical or petroleum storage areas will be collected in a separate stormwater system for treatment and discharge under the JCEP Individual NPDES permit to the ocean outfall as described in the SDPP Storm Water Management Plan developed in the 401 Certificate. All water quality criteria will be addressed through consultation with the ODEQ, ODFW, and NMFS during approval of the NPDES Individual permit and the Storm Water Management Plan required for the 401 Water Quality Certification. Potential impacts and mitigation, if necessary, will also be addressed during formal ESA consultation with NMFS for the overall JCEP LNG project that includes the construction, operation and retirement of the SDPP. |
| **Terrestrial Mammals** | | | | | |

[9] Southern Distinct Population Segment

| ***Species*** | ***State Status***[1] | ***Federal Status***[2] | ***Effect***[3] | ***Potential to Occur***[4] | ***Justification***[5] |
|---|---|---|---|---|---|
| Fisher<br>*Pekania pennanti*<br>(previously called *Martes pennanti)* | SC | C | NLAA | Unlikely | No fisher was observed during focused wildlife surveys of the area and there are no records of its presence. Moderate habitat for this species was found in the forested hillsides west of the facility; however, it is assumed that there is too much disturbance and that the forest is too immature and fragmented for the site to be used by fishers. |
| Gray wolf<br>*Eschrichtius robustus* | E | E | No Effect | Unlikely | Current ODFW tracking and distribution data available documents the gray wolf as occurring in four counties in Eastern Oregon. In the unlikely occurrence of a gray wolf within the SDPP analysis area, the species would likely keep a distance and avoid close interactions with areas of human activity. |
| **Marine Mammals** | | | | | |
| Blue whale<br>*Balaenoptera musculus* | E | E | NLAA | Coastal waters | For all eight species: limited barge traffic delivering construction materials for the SDPP would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales for the JCEP) making the potential for ship-strike extremely low. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. This traffic for the SDPP would be temporary and occur during the construction phase of the project. There will be approximately 38 trips for construction of the SDPP over a period of 3 years, on average this will be about 13 trips per year.[10] |
| Fin whale<br>*Balaenoptera physalus* | E | E | NLAA | Coastal waters | |
| Gray whale<br>*Eschrichtius robustus* | E | Delisted | NLAA | Coastal waters | |
| Humpback whale<br>*Megaptera novaeangliae* | E | E | NLAA | Coastal waters | |
| Orcas [(11)]<br>*Orcinus orca* | No Listing | E | NLAA | Coos Bay (rare), coastal waters | |
| North Pacific right whale<br>*Eubalaena glacialis* | E | E | NLAA | Coastal waters | |
| Sei whale<br>*Balaenoptera borealis* | E | E | NLAA | Coastal waters | |
| Sperm whale<br>*Physeter macrocephalus* | E | E | NLAA | Coastal waters | |

[10] The following trips are estimated for the SDPP: 12 trips for the heat recovery steam generator, 6 trips for large process modules, and 20 trips for aggregate and road materials.
[11] Eastern North Pacific Southern Resident Stock

| *Species* | *State Status*[1] | *Federal Status*[2] | *Effect*[3] | *Potential to Occur*[4] | *Justification*[5] |
|---|---|---|---|---|---|

**Species Status:**
T = Threatened
E = Endangered
C = Candidate
SC = Sensitive-Critical
SOC = Species of Concern

**Effect Determination:**
NLLA = May Affect, Not Likely to Adversely Affect
LAA = Likely to Adversely Affect

## 2.1 METHODOLOGY USED TO IDENTIFY THREATENED AND ENDANGERED SPECIES

### 2.1.1 Agency Consultation

Information about potential effects to listed species from the construction, operation and retirement of the SDPP is based on coordination and consultation, as applicable, with the following agencies and data resources: ODFW, ODA, USFWS and NMFS and ORBIC.

At the state level, consultation was conducted with the ODA for state-listed plant species and the ODFW for fish and wildlife species. State regulations pertaining to the protection of botanical resources are limited to ORS 564 and OAR Chapter 603, Division 73. State threatened and endangered plant species that could be present within the site boundary have no legal protective status in Oregon, as they would occur on private land, and Oregon regulations only apply on non-federal public lands (state, county, city, etc.). However, all lands below the highest measured tide are considered “waters of the state” under the jurisdiction of the Oregon DSL and are therefore protected.

For state-listed fish and wildlife species, consultation was conducted with the ODFW under the Oregon ESA (ORS 496, 506, and 509) and the Oregon Fish and Wildlife Habitat Mitigation Policy (OAR 345-022-0060) to ensure conservation of fish and wildlife resources, and to develop a fish and wildlife habitat mitigation plan, as appropriate.

### 2.1.2 Literature Review

Current state and federal threatened and endangered species lists were obtained for Coos County,[12] as well as an ORBIC list of rare, threatened, and endangered plants and animals within five miles of the site boundary.[13] In addition, the ORBIC list of Rare, Threatened, and Endangered Species of Oregon was reviewed for species that occur within the coastal range or are known to occur in Coos County (ORBIC 2013). The appropriate literature and field studies were used for each identified species to determine the nature, extent, locations, and timing of potential occurrences in the analysis area.

The species lists consulted are included as appendices for Exhibit Q, with the exception of the ORBIC data, which is site-specific and confidential per the data use agreement signed with ORBIC. The list of species included in Table Q-1 reflects the ORBIC data acquired, along with species known to occur, or with the potential to occur, from threatened and endangered species lists provided by the ODFW, ODA, USFWS, and NMFS. Additional state-sensitive species, federal species of concern, and other special-status species are addressed in Exhibit P.

## 2.2 FIELD SURVEYS

Site evaluations and surveys for listed species known to be present or potentially present within the general JCEP site boundary were conducted during the appropriate season for individual listed species as part of larger surveys for fish, wildlife, and vegetation in 2005, 2006, 2012 and

[12] USFWS 9/11/13, NMFS 8/21/13.
[13] Per ORBIC, the data provided is confidential for the specific purposes of the project and not to be distributed.

2013 (see Appendices P-2 through P-5).[14] The surveys conducted were designed to identify potential threatened and endangered species and associated habitat that may be affected by the construction, operation, and retirement of the SDPP.

### 2.2.1 Plants

Plant surveys for threatened and endangered species in or near the SDPP site boundary were conducted by SHN Consulting Engineers & Geologists, Inc. (SHN) from 2005-2006[15] and again in 2012 and 2013.[16] The survey methodology is described in the August 2013 Botanical Resources Assessment Report provided in Appendix P-3 (SHN 2013). More focused surveys were conducted in July and August 2013, which is a floristically appropriate time to identify the plant species of concern. A literature search for each species was also conducted to determine habitat requirements and current range information.[17]

Currently, there are 59 plant species that are administratively protected in the State of Oregon. Of these 59 species, 29 are listed as endangered and 28 are listed as threatened. Two species have been federally listed, but Oregon Administrative Rules have not yet been updated to grant the state protection conferred by federal listing (ODA 2013). In addition to threatened and endangered plant species, Oregon has 77 candidate species (ODA 2013).

Five listed plant species were identified as having the potential to occur in the SDPP analysis area.[18] Of the five listed species, the western lily is the only federally-listed species. The four state-listed species identified were the pink sand verbena (*Abronia umbellata* ssp. *breviflora*), Point Reyes bird's-beak (*Chloropyron maritimum* ssp. *Palustre*), silvery phacelia (*Phacelia argentea*), western lily (*Lilium occidentale*), and Wolf's evening primrose (*Oenothera wolfii*). Only one state-listed species – the Point Reyes bird's-beak – has been observed adjacent to the SDPP site boundary along the Jordan Cove shoreline (SHN 2013), along with documented occurrences along other Coos Bay shorelines (ORBIC 2013).

### 2.2.2 Wildlife

Wildlife surveys were conducted in 2005, 2006 and 2012. For the 2005 and 2006 wildlife surveys, LBJ Enterprises (LBJ) biologists visited the JCEP site on 15 separate occasions for one to two days each from late June 2005 to early November 2006. Rigorous surveys were conducted from late July 2005 to mid-April 2006. LBJ designed their survey methodology based on a preliminary site reconnaissance visit in June 2005, and coordinated with relevant agency personnel from the ODFW, USFWS and Bureau of Land Management (BLM). They designed and utilized a variety of survey techniques to document or assess the potential for occurrence of listed and other sensitive wildlife species (amphibians, reptiles, birds and mammals).

In 2012, surveys and associated research were conducted by SHN to reassess and update the LBJ surveys conducted in 2005 and 2006, and to determine whether any changes in conditions had

[14] LBJ Enterprises 2005-2006, SHN 2005, 2013, ABA 2006
[15] SHN Botanical Resources Assessment Report August 2006; SHN Addendum No. 1 August 2006; SHN Addendum No. 2 October 2006
[16] Botanical Resources Assessment Report August 2013
[17] Botanical Resources Assessment Reports are attached as appendices and the literature reviewed is included in the reference section of each.
[18] SHN Botanical Resources Assessment Report August 2006; SHN Addendum No. 1 August 2006; SHN Addendum No. 2 October 2006; SHN Botanical Resources Assessment Report August 2013

occurred at the project site. The surveys included the addition of sites within and adjacent to the SDPP site boundary to address changes in the proposed JCEP footprint. SHN biologists conducted field surveys from October 9-12, 2012 and consulted with the ODFW prior to conducting the surveys. During the course of the surveys conducted by SHN, biologists identified significant terrestrial biological resources, including significant habitats, state-listed species, and federally-listed species (SHN 2012). Wildlife survey reports produced by LBJ and SHN are included in Appendices P-2 and P-4.

#### 2.2.2.1 Birds

Six special status bird species have been identified within the analysis area: the brown pelican, marbled murrelet, northern spotted owl, short-tailed albatross, streaked-horned lark and western snowy plover (ORBIC 2013). The brown pelican is listed as endangered by the State of Oregon. The marbled murrelet, northern spotted owl, streaked-horned lark and western snowy plover are federally listed as threatened, while the short-tailed albatross is federally listed as endangered.

#### 2.2.2.2 Mammals

Two listed mammal species also are included in this exhibit. The fisher is a federal candidate species and the gray wolf population west of highways 395, 78 and 95 is federally listed as endangered.

#### 2.2.2.3 Fish

Three listed fish species have previously been observed in Coos Bay and have the potential to occur in the analysis area – the Oregon Coast ESU of Coho salmon, the southern distinct population segment (DPS) of Pacific eulachon, and the southern DPS of green sturgeon (ORBIC 2013). Alice Berg & Associates, LLC (ABA) produced a Fisheries Report in October 2006 describing the habitat subsystems that occur in Coos Bay, fish and invertebrate species known to occur, and habitat assessments for those species (see Appendix P-5).

#### 2.2.2.4 Marine Mammals

Eight listed whales have been identified as occurring, or having the potential to occur, in the analysis area for the SDPP. Of these eight species, only orcas have been observed entering Coos Bay on rare occasions. While the remaining seven whale species may occasionally occur along the Pacific Coast within the analysis area, their potential to occur within Coos Bay and be affected by the construction, operation or retirement of the SDPP is discountable and does not warrant further analysis (SHN 2013). However, extensive analysis of potential impacts to whales has been conducted for the JCEP LNG project, and JCEP will undergo formal consultation with NMFS for compliance with the federal ESA and the Marine Mammal Protection Act (MMPA).

# 3.0 NATURE, EXTENT, LOCATIONS, AND TIMING OF SPECIES OCCURRENCE

**OAR 345-021-0010(1)(q)(B).** *For each species identified under (A), a description of the nature, extent, locations and timing of its occurrence in the analysis area and how the facility might adversely affect it.*

The SDPP site, as a previously developed and extensively disturbed industrial site, has a low potential for the occurrence of threatened and endangered plant and animal species within the site boundary. The potential for impacts to listed species that are either known to occur, or have the potential to occur, within the five-mile analysis area is discussed below. The discussion focuses on species habitat requirements and existing conditions.

## 3.1 PLANTS

The five plant species with the potential to occur in the SDPP analysis area are discussed below. Surveys conducted at the SDPP site and adjoining areas that might be affected by the SDPP have not found threatened or endangered plant species, with the exception of the state endangered Point Reyes bird's-beak, observed outside the SDPP project footprint on state land along the shoreline (SHN 2006, 2013).

### 3.1.1 Pink Sand Verbena (State Endangered, Federal Species of Concern)

The pink sand verbena (*Abronia umbellata* ssp. *breviflora*) is the only pinkish-purple-flowered coastal *Abronia* species in Oregon. The historic range of pink sand verbena occurs from California to British Columbia, Canada. Its present range is predominantly from to Point Reyes National Seashore in Marin County, California to Cape Blanco in Curry Country, Oregon. The species does, however, sporadically occur along Oregon's northern and central coast. In the northern portion of its range, most populations occur on broad beaches and/or near the mouths of creeks and rivers. The species usually occurs on beaches in fine sand between the high-tide line and the driftwood zone, and in areas of active sand movement below the foredune. Associated species include sea rocket (*Cakile maritina*), silver burweed (*Ambrosia chamissonis*), European beachgrass (*Ammophila arenaria*), beach silvertop (*Glehnia littoralis*), and yellow sand verbena (*Abronia latifolia*).[19]

There is a successful population of pink sand verbena that was introduced to the North Spit within the western snowy plover habitat restoration area, approximately 2.6 miles away from the SDPP site boundary.[20] Not all species observed were flowering. Pink sand verbena is not likely to occur within the SDPP site boundary due to its distance from the coast (approximately 1.3 miles from its westernmost point). Botanical surveys conducted by SHN in 2006 and 2012, followed by surveys in 2013 in previously un-surveyed portions of the SDPP site, did not result in the detection of any pink sand verbena (SHN 2006, 2013).

[19] ODA website 2013
[20] SHN 2006, 2013; ODA website 2013; USFWS website 2013

Based on areas surveyed, pink sand verbena is absent from the project site and the construction, operation and retirement of the SDPP would not directly affect the species, or its potential habitat. Thus, impacts to pink sand verbena are not anticipated from construction, operation, or retirement of the SDPP.

### 3.1.2 Point Reyes Bird's-Beak (State Endangered, Federal Species of Concern)

Point Reyes bird's-beak (*Chloropyron maritimum* ssp. *Palustre*, formerly *Cordylanthus maritimus* ssp. *palustris*) is an annual gray-green and purple-tinged herbaceous species with pinkish to purplish red flowers that grows 4 to 16 inches tall and has few branched stems. The species flowers from June to October. Also referred to as salt marsh bird's beak, it occurs in coastal salt marshes, typically within the zone that is periodically or frequently inundated by high tides. Point Reyes bird's-beak habitat requirements are specific: approximately 7.5 to 8.5 feet above mean lower low water, sandy soils with soil salinity of 34 to 55 parts per thousand, and less than 30 percent bare soil in summer. Associated species include those that are tolerant of high salinity levels such as salt grass (*Distichlis spicata*), pickleweed (*Salicornia virginica*), fleshy jaumea (*Jaumea carnosa*), sea lavender/western marsh rosemary (*Limonium californicum*), and dodder (*Cuscuta salina*). Point Reyes bird's-beak occurs along the Pacific Coast from Tillamook County, Oregon south to Santa Clara County, California. In Oregon, the species is restricted to Netarts Bay, Yaquina Bay and Coos Bay, with the majority of known occurrences located in Coos Bay.[21]

Occurrences documented by ORBIC include multiple sites along the Coos Bay shoreline (ORBIC 2013) within the analysis area (Figure Q-2). These sites include each side of the bay closer to the harbor entrance; along the western and eastern shore of Jordan Cove; north and south of the Trans Pacific Parkway causeway bridge on the western side of Haynes Inlet; up to the west side of U.S. Highway 101 along Haynes Inlet; in the marsh on the east side of the airport; at multiple locations along Pony Slough across the bay; and on a dredge spoil island east of the Coquille Indian Tribe casino in Coos Bay (ORBIC 2013). In general, all detections occurred near the high tide line in open light with inundated moist sandy soil.

Focused botanical surveys were conducted during July and August of 2013 by SHN during the appropriate blooming period to document occurrences of Point Reyes bird's-beak in or near the JCEP project footprint. Multiple occurrences were detected along the shoreline of Jordan Cove, near Wetland J, and on the shoreline east of the SDPP site boundary, as shown in Figure Q-2. The habitat where Point Reyes bird's-beak was detected was below the highest measured tide, with pickleweed as the dominant associate species (SHN 2013). All detections were low lying and averaged 4-6 inches in height. Detections ranged from small patches of 3 to 9 individual plants, to large patches with an estimated 500 to 1,000 individuals.

All detections of Point Reyes bird's-beak were mapped by SHN surveyors using a Trimble R82 real time kinematic global positioning system accurate to within 0.1 foot. The surveys documented the relative abundances of the Point Reyes bird's-beak occurring within the SDPP site boundary and adjacent lands within the analysis area on the North Spit, and provided a

[21] SHN 2006, 2013; ODA website 2013; USFWS website 2013

qualitative and quantitative assessment of the populations, including information on numbers of individuals comprising the populations. Populations around the SDPP showed no obvious signs of disease or predation, or suspected negative impacts from past land actions.

The primary threat to Point Reyes bird's-beak is habitat loss due to development. The species is also threatened by off-road vehicle use, water pollution, and habitat alteration due to invasion by non-native dense-flowered cordgrass (*Spartina densiflora*),[22] which has not been observed along the SDPP shoreline.

It is not anticipated that populations of Point Reyes bird's beak outside of the site boundary would be affected by the construction, operation, or retirement of the SDPP. Within the site boundary, activities such as the construction of the power plant facility and associated infrastructure could potentially impact the species through erosion and sedimentation and encroachment on suitable habitat. The species is not anticipated to be significantly impacted by SDPP construction activities, however, because appropriate best management practices (BMPs) and mitigation measures will be implemented to ensure the species is preserved and protected. Avoidance and minimization measures are described in further detail in Section Q.6, and may include temporary and permanent erosion controls, fencing and the establishment of buffers to separate Point Reyes bird's beak populations from construction activities and a noxious weed control program. Appropriate mitigation measures will be developed and implemented through ongoing consultation with the ODA to ensure that suitable habitat for the Point Reyes bird's-beak will not be impacted by construction of the SDPP.

### 3.1.3 Silvery Phacelia (State Threatened, Federal Species of Concern)

Silvery phacelia (*Phacelia argentea*) is a hairy, fleshy perennial herb with thick leaves that are coated in long, straight, silvery hairs. It occupies open sand above the high tide line, open and partly stabilized sand dunes farther inland and coastal bluffs. It flowers from late May to early August. Silvery phacelia occurs in Coos and Curry Counties along the Oregon coast and in Del Norte County in California, from the vicinity of Bandon, Oregon south to Crescent City, California. The majority of occurrences are in Oregon.[23]

Suitable habitat for silvery phacelia exists in the analysis area and at the SDPP site in locations with active or semi-stabilized dune land and upper beach habitat where European beachgrass and red fescue-salt rush herbaceous vegetation associations occur. This habitat is considered moderate to highly suitable for supporting an occurrence of silvery phacelia. Focused surveys were conducted by SHN in 2013 in areas identified as suitable habitat that may be impacted by project activities within the JCEP project vicinity, including the SDPP site, and did not detect silvery phacelia (SHN 2013).

No silvery phacelia were detected during surveys conducted for the project. There are no anticipated impacts to suitable habitat for silvery phacelia during the construction, operation, or retirement of the SDPP, and, thus, no impacts to the species are expected.

---

[22] ODA website 2013
[23] SHN 2006, 2013; ODA website 2013; USFWS website 2013

### 3.1.4 Western Lily (State Endangered, Federal Endangered)

The western lily (*Lilium occidentale*) is one of the rarest plants on the west coast. It is a member of the perennial lily family (Liliaceae) and grows up to five feet tall with nodding red, sometimes deep orange, flowers. The species was federally listed as endangered in 1994 (USFWS 1994) and a final recovery plan was released in 1998 (USFWS 1998). Western lily inhabits 31 small, widely separated populations in freshwater marshes and swamps, coastal scrub and prairie, and openings in Sitka spruce dominated coastal coniferous forest along the coast of southern Oregon and northern California. It occurs within four miles of the coast, and is generally found on marine terraces 0 - 300 feet above mean sea level. The western lily is considered a bog plant and grows in areas with perched water tables which are associated with one or two soil types.[24]

The wetlands where western lilies occur are not traditional wetlands but are areas where the marsh is flooded in the winter and is typically very dry in the summer. The species emerges in Oregon in late March or early April and flowers in late June or July. Species typically associated with western lily include Sitka spruce (*Picea sitchensis*), Pacific reed grass (*Calamagrostis nutkaensis*), willows, false lily-of-the-valley (*Maianthemum dilatatum*), and evergreen huckleberry (*Vaccinium ovatum*). The closest known western lily occurrence to the site boundary is approximately 5.2 miles northeast at Hauser Bog (ORBIC 2013) and there are no records of the western lily north of Hauser Bog along the Oregon coast.

Seasonally timed focused surveys following USFWS protocol were conducted for the western lily by SHN from July 8-11, 2013 in areas identified as potential habitat for the species throughout the JCEP project area (Figure Q-2) and including the SDPP site (SHN 2013). The surveys yielded no detections of the species. In addition, no western lilies were observed at any time during SHN's site visits for the project. Complete information on the areas surveyed and findings are included in the August 2013 SHN Botanical Resources Assessment Report included in Appendix P-3.

The SDPP project is not likely to adversely affect the western lily. The species has not been found during focused surveys conducted for the JCEP project and the areas to be impacted by the SDPP are not expected to include western lily habitat. [25]

### 3.1.5 Wolf's Evening Primrose (State Threatened, Federal Species of Concern)

Wolf's evening primrose (*Oenothera wolfii*) is a rare species of flowering plant in the evening primrose family. It was removed by the USFWS as an ESA candidate species in1996 (61 FR 7597-7613) but continues to be listed as a federal Species of Concern, in addition to being listed by the state as threatened. It occurs in well-drained sandy soils in coastal strands, roadsides, and coastal bluffs. Wolf's evening primrose is associated with a high disturbance regime, and several occurrences in California are located along roadsides with sandy soil. Wolf's evening primrose is typically associated with low elevation coastal habitats, but there have been reported

[24] SHN 2006, 2013; ODA website 2013; USFWS website 2013 (unless otherwise noted)
[25] SHN 2013

occurrences in lower montane coniferous forest in California at elevations greater than 2,500 feet above mean sea level.[26]

The current range of Wolf's evening primrose is from Curry County in southern Oregon to the northern California coast. The closest known occurrence to the SDPP site is in Port Orford, Oregon (ORBIC 2013). The species was included in all botanical surveys conducted by SHN and is included in this analysis because suitable habitat exists within the analysis area and the SDPP footprint.

Despite the presence of suitable habitat, surveys conducted for the SDPP did not detect wolf's evening primrose and the closest known occurrence of the species is located approximately 60 miles to the south in Port Orford. Thus, the project is not anticipated to adversely affect the species (SHN 2013).

## 3.2 AMPHIBIANS AND REPTILES

No threatened or endangered amphibian species are known to occur, or anticipated to occur, within the SDPP analysis area.[27] Although the Oregon spotted frog was federally listed as threatened in August, 2014, this species does not occur, nor does it have the potential to occur within the site boundary or analysis area. No impacts to this species or potential critical habitat are anticipated, as the closest known populations of Oregon spotted frogs are located in Jackson and Klamath counties to the east (Appendix Q-8).[28]

Sea turtles are the only listed reptile species with the potential to occur in the analysis area.

### 3.2.1 Sea Turtles

Sea turtles are not known to nest on the Oregon coast, although they may occasionally be found in the Exclusive Economic Zone (EEZ), which extends from 12-200 nautical miles offshore.[29] Threatened and endangered sea turtles that have the potential to occasionally occur in the analysis area are listed below, followed by potential impact analysis for all sea turtles that may be encountered. General information, including distribution range for each species on the west coast, is provided below and was accessed through the NMFS website unless otherwise noted.[30] Potential effects to sea turtles within the analysis area are presented as a group analysis at the end of this section.

### 3.2.2 Green Sea Turtle (State Endangered, Federal Threatened)

Green sea turtles (*Chelonia mydas*) typically are found in warm tropical waters and, to a lesser extent, subtropical waters. Many facets of the green turtle's life history and ecology remain unknown, including details of its residence in, and use of, the U.S. Pacific Coast. The Pacific green sea turtle nests on tropical beaches in Hawaii and other islands of the Pacific, while the East Pacific green turtle is a separate population of the same species, nesting primarily on the

[26] SHN 2006, 2013; ODA website 2013; USFWS website 2013
[27] LBJ 2006; SHN 2006, 2012
[28] JCEP Draft Biological Assessment 2014, pages ES-6, 4-312 through 4-313
[29] NMFS website 2013
[30] http://www.nmfs.noaa.gov/pr/species/turtles/

coast of Mexico and in the Galapagos Islands. The species was listed as threatened under the federal ESA in 1978 (43 FR 32800), with the exception of the Florida and Mexico breeding populations. Except during breeding migrations, they tend to be found in shallow waters such as those inside reefs, bays, and inlets. The turtles are attracted to lagoons and shoals with an abundance of marine grass and algae. Green turtles have strong nesting site fidelity and migrate long distances between feeding grounds and nesting beaches. There is no known nesting by green turtles on the U.S. Pacific Coast.

Green turtles have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego south. The northernmost resident population is a small population of approximately 30 turtles in San Diego Bay, reported in 1990 in the waters warmed by the effluent of a power plant. Green sea turtles primarily use three types of habitat: oceanic beaches for nesting, convergence zones in the open ocean, and benthic feeding grounds in coastal areas. No critical habitat for this species is located on the U.S. Pacific Coast. They are likely infrequent visitors to the Oregon coast, but may occasionally be found in the EEZ portion of the analysis area for the SDPP.

### 3.2.3 Leatherback Sea Turtle (State Endangered, Federal Endangered)

Leatherback sea turtles (*Dermochelys coriacea*) are the largest, most migratory sea turtle species, with the widest range of all extant sea turtles. Adult leatherback turtles are capable of tolerating a wide range of water temperatures and have been sighted as far north as the Gulf of Alaska. The species was federally listed as endangered in 1970 (35 FR 8491) and critical habitat was designated for the species by NMFS in 2012 along the Oregon and Washington coasts from Cape Blanco to Cape Flattery (77 FR 4170). Critical habitat includes nearshore waters within the analysis area for the SDPP.

Nesting occurs on sandy tropical beaches and no known nesting locations occur on the U.S. Pacific Coast. Their presence in the EEZ off the Pacific coast is unknown, although they are expected to occur within this zone. Peak numbers of leatherback turtles occur from July to September in neritic (coastal) zones, when intermittent decreases in upwelling allow surface water temperatures to increase. They aggregate in warm, highly productive coastal areas to forage on prey.

NMFS has defined nine geographic areas along the west coast from Washington to Northern California that are occupied by leatherback turtles. Area 2 is considered a principal foraging area for leatherbacks and includes nearshore waters from Cape Blanco, Oregon, to Cape Flattery, Washington, extending offshore to 2,000 meters in depth. They feed on a variety of moon jellies and brown sea nettles that are present in high densities associated with the Columbia River plume and Heceta Bank to the north.

### 3.2.4 Loggerhead Sea Turtle (State Threatened, Federal Endangered)

Loggerhead sea turtles (*Caretta caretta*) occupy three different ecosystems during their lives—the terrestrial zone, the oceanic zone, and the neritic zone. Loggerhead sea turtles are circumglobal in distribution, occurring throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans. They are the most abundant species of sea turtle found in

U.S. coastal waters. There are nine distinct population segments (DPS) for loggerhead turtles under the federal ESA, with the North Pacific Ocean DPS (including the Oregon coast) listed as endangered in 2011 (76 FR 58868). Occasional sightings are reported along the coasts of Washington and Oregon, but most records are of juveniles off the coast of California. They are thought to spend much of their time in continental shelf waters closer to the shoreline looking for food.

Critical habitat was proposed for the North Pacific Ocean DPS; however, NMFS determined on July 18, 2013 that there are no areas meeting the definition of "critical habitat" for the DPS (78 FR 43005). Loggerhead sea turtles could potentially be encountered within the SDPP analysis area along the Pacific coast.

### 3.2.5 Olive Ridley Sea Turtle (No State Listing, Federal Threatened)

Olive Ridley sea turtles (*Lepidochelys olivacea*) occur within the tropical regions of the Pacific, Atlantic, and Indian Oceans. They are primarily pelagic sea turtles and have been observed as far as 2,400 miles from shore, but occasionally inhabit coastal areas. The species was federally listed as threatened in 1978 (43 FR 32800), except for the Mexican Pacific coast breeding populations, which were listed as endangered. Critical habitat has not been designated for this species.

Olive Ridley sea turtles undertake an annual migration from open ocean foraging grounds to coastal breeding and nesting grounds. Important nesting areas include the west coast of Mexico and Central America. Olive Ridley sea turtle populations have declined from former times, but are still the most abundant nesting turtle on the Pacific Coast. This species does not nest in the United States, but during feeding migrations may disperse into waters off the U.S. Pacific Coast as far north as Oregon. Although unlikely, Olive Ridley sea turtles could potentially be encountered within the SDPP analysis area along the Pacific Coast.

### 3.2.6 Sea Turtle Impacts

Sea turtles are generally found in warmer waters and occur only occasionally off the Oregon coast during migrations and foraging. There is no known nesting of any of the four species described above on the U.S. Pacific coast. Any potential effects to sea turtles would be related to offshore vessel traffic for the barge berth during construction, including ship strikes, underwater noise, and spills and releases at sea. Although they can be injured or killed when struck by a vessel, especially by an engaged propeller, such strikes are considered to be highly unlikely, given the limited number of barge trips estimated for the SDPP project, and the rarity of sea turtle occurrences in Coos Bay. Sea turtles can detect sound, and their hearing is most sensitive to lower frequencies within the same range of the low frequencies generated by vessels, therefore enabling sea turtles to avoid collisions. The noise produced by vessel traffic en route to Coos Bay is not expected to cause temporary or permanent threshold shifts in turtles' hearing given the limited number of barge trips and the limited occurrence of sea turtles in the analysis area. Any petroleum products released by vessels would include engine oil, lubricating oils, diesel fuel and/or gasoline. The background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, and this frequency is expected to continue into the foreseeable future (Appendix Q-8).[31] Given the low population numbers and limited occurrence of sea turtles in Oregon coastal waters, it is considered unlikely that sea turtles would be affected by the SDPP project, and potential effects are judged to be insignificant.[32]

## 3.3 BIRDS

Five bird species listed as threatened or endangered occur, or have the potential to occur, in the analysis area and are discussed in the following paragraphs.

### 3.3.1 Brown Pelican (State Endangered, Federal Delisted)

The brown pelican (*Pelecanus occidentalis*), sometimes referred to as the California brown pelican, is found in nearshore waters, in large bays and river mouths, and on beaches and spits. These birds are rarely seen inland or more than 40 miles from shore, feeding mostly in shallow estuarine waters. Pelicans make extensive use of sand spits, offshore sand bars and islets for nocturnal roosting and daily loafing, especially by non-breeders and during the non-nesting season. They are most likely to be encountered in the coastal nearshore waters out to 0.3 mile.

In Coos Bay, brown pelicans are commonly known to occur from river mile (RM) 6 to the open ocean and are considered a common post-breeding migrant on the North Spit. They arrive from the south along the Oregon coast in April and become abundant by August and September. Although most brown pelicans have migrated to the south by December, small numbers now over winter most years in the Coos Bay area.

Coos Bay is considered foraging and roosting habitat for the brown pelican, with roosting occurring on the north side of the bay on the sunken jetty close to the bay mouth, on the sand spit of the North Spit, and on dredge spoil islands around RM 3 to 4. Onshore fish cleaning stations, often associated with boat ramps, may also attract brown pelicans to feed on offal. Coos Bay, adjacent to the SDPP site boundary, provides excellent habitat for this species. The species was recorded foraging near the SDPP site boundary more than 500 feet from the shore and loafing daily across the bay in moderate numbers during surveys conducted by SHN in October 2012. The species was also observed until early September during surveys conducted in 2005 and 2006 by LBJ. The analysis area provides no nesting habitat for the brown pelican. Nesting sites within the Coos Bay estuary have not been documented, and the species is not believed to breed in or near the project vicinity.[33]

It is likely that the brown pelican would be present within Coos Bay over the period of SDPP construction, operation, and retirement; however, no adverse impacts to brown pelican roosting and feeding habits are expected. The incremental noise, human activities, and low-level facility lighting associated with the SDPP are not likely to directly affect the brown pelican in the project area due to the pelicans' acclimation to current human-generated sounds and facilities already occupying the area.

[31] JCEP Draft Biological Assessment 2014, page 4-21
[32] JCEP Resource Report 3 2013; SHN 2013
[33] LBJ Enterprises 2006; SHN 2012, 2013; JCEP RR3 2013

Oil, gasoline or diesel spills are not likely to adversely impact the brown pelican since the background rate of spills by fishing, recreational and other vessels in Oregon is generally low and expected to continue to be low in the future (Appendix Q-8). Additionally, the current number of barge trips related to construction of the SDPP is estimated to be 38trips. All barges entering the bay will be pushed by tug boats with fuel capacities ranging from approximately 12,000 to 250,000 gallons (Ocean Class 2014, Tug Boat Sizes 2014). Tug boat contractors will have spill prevention and emergency response plans in place, and will be responsible for reporting any spills to the appropriate agencies. In addition to spill prevention and response plans maintained by vessel operators, a Geographic Response Plan (GRP) for Coos Bay has been developed by the ODEQ, United States Coast Guard (USCG) and EPA that prioritizes resources to be protected in the event of a spill, and allows for immediate and proper action (ODEQ 2004). All vessel operators in Coos Bay would follow the procedures outlined in the GRP in the event of a spill.

Overhead transmission lines located inland will have bird flight diverters installed, and collisions are not anticipated as pelicans fly along the bay. Pelicans appear unaffected by industrial activity already taking place in and around the bay, and no impact to this species is anticipated from construction, operation or retirement of the SDPP. [34]

### 3.3.2 Marbled Murrelet (State Threatened, Federal Threatened)

The marbled murrelet (*Brachyramphus marmoratus*) is a small, robin-sized, diving seabird that has a very short neck. It spends the majority of its time on the ocean roosting and feeding, but comes inland up to 50 miles to nest in forest stands with old growth characteristics. It was listed as threatened under the ESA in 1992 in Washington, Oregon, and California (57 FR 45328-45337). The Final Rule cited loss and modification of nesting habitats, mostly by commercial timber harvest of late successional and old-growth forests, as the principal threat to the species, along with effects of coastal oil spills and gill-net fishing operations off the Washington coast. In addition, critical habitat was designated for the marble murrelet in 1996 (61 FR 26256-26320). Following a series of proposed revisions in 2006 and 2008, a final rule on revised critical habitat was issued in 2011 (76 FR 61599-61621).[35]

Marbled murrelets nest from Alaska to Monterey Bay, California primarily in coastal old-growth forests that are characterized by large conifer trees, multi-storied stands, and moderate-to-high canopy coverage. The sexually mature adult murrelet generally lays a single egg on a mossy limb of an old-growth conifer tree. Not all adults nest every year. Both sexes incubate the egg in alternating 24-hour shifts until the young fledge from the nest in about 28 days and appear to fly directly to the sea upon leaving the nest. Nesting adults make daily foraging trips to shallow, protected, nearshore coastal waters, feeding mostly on small fish but sometimes on euphausiids. When at sea, marbled murrelets are rarely found more than a few miles out from the shore.[32]

The USFWS consults on projects within 0.25 miles of critical habitat for effects from construction with heavy equipment and within one mile for more-complex projects (Tuerler, personal communication). The USFWS is primarily concerned about removal of MAMU habitat

[34] JCEP RR3 2013
[35] USFWS species profile website, accessed 2013 and 2014, unless otherwise noted

and impacting the land, or the ability of the land, to grow trees. It is concerned also about possible predation to the species due to predators attracted to potential habitat in the vicinity by human activities (Tuerler, personal communication).

Based on guidance provided by the USFWS (Tuerler, personal communication), potential marbled murrelet nesting habitat does not occur within the SDPP analysis area. Although no individuals were observed during wildlife surveys conducted within the vicinity of the SDPP, it is considered possible that murrelets could fly over the bay within the analysis area and, perhaps, over the SDPP site while in transit between terrestrial nesting habitat and offshore feeding sites.[36] As the project will not affect nesting habitat or marine foraging habitat, the flyways used by murrelets in between these areas are the only areas within the analysis area where murrelets have the potential to be impacted by project activities.

There are two components of marbled murrelet habitat that are biologically important: terrestrial nesting habitat and associated stands, and marine foraging habitat. The closest documented marbled murrelet nests occur in designated critical habitat in the Elliott State Forest northeast of Coos Bay in the Oregon Coast Range, over 8 miles northeast of the SDPP site boundary and outside the analysis area (ORBIC 2013).

The species is considered an uncommon, year-round, offshore resident on the North Spit (LBJ 2006) and one to four murrelets are observed most years during the annual Coos Bay Christmas bird count (LBJ, 2006). The foraging habitat and potential for obstruction of marbled murrelet fly paths are discussed in the paragraphs that follow.

Marbled murrelets that forage offshore or in Coos Bay could be directly affected by: [37]

- Underwater noise generated during construction
- Disturbance during feeding by barge traffic
- Collisions with aboveground transmission lines within the SDPP site during daily flights to and from foraging areas.

The Draft BA for the JCEP (Appendix Q-8) used USFWS guidelines in the effects analysis for foraging marbled murrelets and concluded that the species is not expected to be exposed to ship noise that would cause harm, although they would likely detect noise from barges transiting the EEZ. Since murrelets forage in shallow offshore areas, they would not be expected to be exposed to high levels of shipping noise, but could potentially be exposed to noise from tugboats guiding barges into Coos Bay and to the barge berth. Although tug boat noise levels could reach 160 dB within 15 meters of the boat, exposure to that noise level is not expected to cause potential behavioral effects given the number of estimated barge trips and predicted murrelet densities in the analysis area (Appendix Q-8).[38] In addition, no underwater noise from pile driving is expected to impact diving murrelets in the analysis area because pile driving related to the construction of the barge berth would be land-based rather than being conducted in the

[36] LBJ 2006, SHN 2012
[37] JCEP/PCGP Draft BA April 2014 (Section 4, pages 132-137)
[38] JCEP Draft Biological Assessment 2014

water.[39] Risk of impacts to marbled murrelets from oil spills is similar to that of brown pelicans. The low background rate of spills in Oregon, minimal number of barge trips, fuel capacity of tug boats and existing prevention and emergency management measures in place suggest that the risk of an oil spill is low and marbled murrelets will not be adversely impacted.

Marbled murrelets may be susceptible to power line collisions due to their rapid flight speeds, which average 65 miles per hour when flying to the sea, and 55 miles per hour on returning landward flights. Murrelets fly at an average of 807 feet above ground level, although the lowest flight height reported was 203 feet. However, less than 0.1 percent of all individuals observed flew below transmission line heights. Therefore, flight height data for marbled murrelets suggest that flights would be above the top shield wires of the power poles (between 81 and 126 feet tall). Installation of bird flight diverters on the power transmission lines, as previously discussed, will also decrease potential adverse impacts to the marbled murrelets from transmission lines (Appendix Q-8).[40]

Minimal impact to foraging murrelets is anticipated from the construction, operation, or retirement of the SDPP. Although murrelets may occasionally fly over the analysis area and SDPP site, none were observed during site surveys and no nesting habitat is located within the analysis area (LBJ 2006, SHN 2013). Thus, no timing restrictions are currently in place to reduce noise impacts from construction of the SDPP during the marbled murrelet critical breeding season (approximately April 1 through August 15).

### 3.3.3 Northern Spotted Owl (State Threatened, Federal Threatened)

The northern spotted owl (*Strix occidentalis caurina*) was federally listed as threatened in 1990 by the USFWS (55 FR 26114-26194). The Final Rule cited declining populations due to loss and adverse modification of suitable habitat from timber harvest and natural catastrophes such as wild fire and windthrow, as well as inadequate regulatory mechanisms to protect the owl or its habitat (USFWS 1990).

The northern spotted owl is dependent on old-growth components in coniferous forests, and is extremely rare on the immediate coast of Oregon and in coastal Coos County. In Oregon, the owl is found in low- and mid-elevation coniferous forests in the Coast, Siskiyou, and Cascade mountain ranges, including many spotted owl habitat areas in the forests inland of Coos Bay. The nearest documented occurrence of a spotted owl nest to the SDPP site boundary is just inside the five-mile radius of the analysis area in the Kentuck Creek drainage (ORBIC 2013). The northern spotted owl is absent from the BLM North Spit wildlife list and is unlikely to be encountered in any of the terrestrial or aquatic habitat in or near the SDPP due to a lack of suitable habitat (BLM 2006).[41]

No spotted owls were observed during wildlife surveys at the site, nor will any mature or old-growth forest be affected by construction, operation or retirement of the SDPP. Consequently, no adverse effects to the northern spotted owl are anticipated as a result of the project.

[39] JCEP Draft Biological Assessment 2014, pages 4-132 to 4-134
[40] JCEP/ Draft Biological Assessment 2014, pages 4-135 to 4-136
[41] USFWS species profile website, accessed 2013 and 2014, unless otherwise noted

### 3.3.4 Short-Tailed Albatross (State No Listing, Federal Endangered)

The short-tailed albatross (*Phoebastria albatrus*) is the largest pelagic seabird in the North Pacific. Its long, narrow wings are adapted to soaring low over the ocean. It is best distinguished from other albatrosses by its large, bubblegum-pink bill. The short-tailed albatross was federally listed as endangered throughout its range in 2000 (65 FR 46643-46654). Critical habitat has not been designated for this species given the great distances it travels over the ocean. A recovery plan was finalized for the species by the USFWS in 2009 (74 FR 23739-23741).

Historically, millions of short-tailed albatrosses bred in the western North Pacific on several islands south of the main islands of Japan. Only two Japanese breeding colonies remain active today. Single nests occasionally occur on Midway Island, west of Hawaii. Eggs hatch in late December through early January, and chicks remain near the nest for about 5 months, fledging in June. After breeding, short-tailed albatrosses move to feeding areas, with juveniles remaining at sea up to 10 years before returning to nest. The species is distributed widely throughout its historical foraging range of the temperate and subarctic North Pacific Ocean, is often found close to the U.S. coast, and has been known to forage up to 1,988 miles from its breeding ground.[42]

The short-tailed albatross population is estimated at 1,200. Of these, the total number of breeding-age birds is thought to be approximately 600. The worldwide population of short-tailed albatrosses continues to be in danger of extinction throughout its range due to natural environmental threats, small population size, and the small number of breeding colonies. Longline fishing, plastics pollution, oil contamination, and airplane strikes are considered threats to the conservation and recovery of the species. Short-tailed albatross have been noted to occur off the Oregon coast (LBJ 2006; SHN 2012); the closest observation to Coos Bay being recorded approximately 75 miles to the north, off the coast of Yachats in 2010 (ORBIC 2013).

Short-tailed albatrosses spend much of their time feeding in nutrient-rich waters of ocean upwelling, which often occur at continental shelf breaks. The short-tailed albatross would not occur in Coos Bay adjacent to the SDPP site, but could occur in the analysis area along the Pacific Ocean, approximately 1.3 miles west of the SDPP site boundary.

Within the analysis area, effects to the short-tailed albatross would be associated with barge traffic transecting the EEZ perpendicularly as they approach and depart from Coos Bay. Shipping traffic would be traveling at slow speeds (10 knots or less), making the potential for ship-strikes extremely low. Risk of oil spills impacting the short-tailed albatross is similar to that for brown pelicans and marbled murrelets. None of the factors that threaten the short-tailed albatross would result from any component of the proposed SDPP project; thus, adverse impacts to this species are not anticipated as part of the project.

### 3.3.5 Streaked Horned Lark (State Sensitive-Critical, Federal Threatened)

The streaked horned lark (*Eremophilia alpestris strigata*) was listed as a threatened species under the federal ESA in October, 2013 (78 FR 61451-61503). In addition to the listing, critical habitat was proposed for seven counties in Washington and 11 counties in Oregon, but did not

[42] USFWS species profile website, accessed 2013 and 2014, unless otherwise noted

include Coos County. The closest county with critical habitat is Lane County to the north. The population of streaked horned larks remaining in the world is estimated between 500 and 1,000 individuals, and preliminary genetic analysis suggests that the remaining birds have little genetic diversity. The remaining populations are vulnerable to all of the threats small populations commonly face such as environmental and demographic variability and the loss of genetic variability.

The streaked horned lark is a rare subspecies of the horned lark. It migrates between Oregon and Washington, with breeding populations found in the Puget Sound lowlands, Columbia River/coastal Washington, and the Willamette Valley in Oregon from late March to early August. Some individuals winter in California and occur along the Oregon coast during migration, while a few winter on the coast. The species occurs in bare and sparsely vegetated habitats such as coastal dunes, beaches, gravel roads, airport runways, grazed pastures, and dry mudflats; however, it does not occur on rolling or steep areas at these sites. Where deflation plains occur, streaked horned larks are often found behind the foredune. Larks also occur where dredge spoils have been deposited, or in areas where there is accretion (deposition) of sand causing beach areas to become wider, provided the sites are sparsely vegetated and are immediately adjacent to water. [43] For the species to inhabit sites that aren't adjacent to water, the area of expanse has to be quite large, likely 300 acres or greater, although further studies are needed (Pearson, personal communication).

During winter surveys conducted in 2004 and 2005 by the Washington Department of Fish and Wildlife (WDFW), streaked horned larks were found on the Washington coast on dune and beach habitat adjacent to open water with few or no trees and shrubs. On the lower Columbia River, they were primarily found on sparsely vegetated dredge spoils (Pearson and Altman 2005). The streaked horned lark has been documented by BLM on the North Spit and may over winter on the southern Oregon coast (BLM 2006). It spends the winter in large groups of mixed subspecies of horned larks in the Willamette Valley, and in smaller flocks along the lower Columbia River and Washington Coast (Pearson and Altman 2005).

When new unvegetated land is created by dredge spoils and sand accretion, it is not used by larks for the first year or two after deposition. Once the site becomes sparsely vegetated, it can be quickly colonized by larks, especially on fill where there is no off-road vehicle traffic. There is a fairly narrow window of time when habitat is sparsely vegetated and suitable for larks. As sandy habitats on the coast continue to be colonized by beach grasses, streaked horned larks do not use these habitats for breeding or over-wintering once the site becomes densely vegetated. Similarly, fill colonized by Scotch broom (*Cytisus scoparus*) or horsetail (*Equisetum* spp.) is not used by the species (Pearson and Altman 2005).

A focused field evaluation within the SDPP site boundary was conducted by SHN staff on April 23, 2013 to assess the presence of suitable habitat for streaked horned larks. One small area of approximately 75 by 150 feet was noted at the SDPP site; however, it is surrounded by the footprint of the former industrial mill site and is not adjacent to open water. Along the utility corridor and access road between the SDPP and JCEP sites, sparsely vegetated portions of

[43] USFWS species profile website, accessed 2013 and 2014, unless otherwise noted

rolling and, at times, steep, dunes were noted. Again, these sites were not adjacent to open water. Based on a literature review and personal communication with Dr. Scott Pearson of the WDFW, potential suitable habitat within the SDPP site boundary was discounted.[44]

The proposed SDPP project will result in the disturbance of a small amount of low grassland habitat and conversion of bare ground areas to a filled site. Construction and operation activities occurring near habitat used by streaked horned larks migrating through or over-wintering in Coos Bay could potentially affect foraging activities, causing the birds to relocate or alter their behavior to spend more time on the alert and less time foraging.

Although industrial development has reduced habitat available to breeding and wintering larks, potential adverse effects to streaked horned lark populations from construction, operation, and retirement of the SDPP are anticipated to be negligible.[45] In consultation with Dr. Scott Pearson, it was determined that suitable habitat is likely not present near the SDPP site due to the lack of open water immediately adjacent to the few locations where sparsely vegetated lark habitat potentially exists. In addition, encroachment by European beachgrass and other noxious weed species further reduces the suitability of potential lark habitat, especially given the large amounts of more suitable habitat on the North Spit and along the coast that remain relatively undisturbed by human influence (Pearson, personal communication).

In addition to a lack of suitable habitat, bird surveys conducted to date did not identify the presence of streaked horned larks within the SDPP vicinity. While fill placed on the SDPP site could become suitable habitat for the streaked horned lark, disturbance at the site from construction, operation and retirement activities will prevent it from becoming vegetated and developing into suitable habitat. An occasional individual may show up to forage; however, the ensuing development within the site boundary is likely to preclude the continued use by individuals in the project vicinity. Other more suitable habitat is available on the North Spit, including the critical habitat established for the western snowy plover. While streaked horned larks may be encountered within the SDPP analysis area, they likely would keep a distance and avoid close interactions with areas of human activity. No adverse impacts to the streaked horned lark population are anticipated from the construction, operation, or retirement of the SDPP.[46]

### 3.3.6 Western Snowy Plover (State Threatened, Federal Threatened)

The western snowy plover (*Charadrius alexandrinus nivosus*) is a small shorebird approximately six inches long with a thin, dark bill. The extent of the Pacific Coast breeding population includes Oregon, with coastal populations typically consisting of resident and migratory birds. The North Spit of Coos Bay supports the most-productive snowy plover population segment on the Oregon coast.

The Pacific Coast population of the western snowy plover has been listed as a threatened species under the federal ESA since 1993 (58 FR 12864). In addition to being listed as threatened under the ESA, critical habitat was designated for the Pacific Coast population in 2000. The most

---

[44] USFWS website http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B0B3, accessed 2013; Pearson and Altman 2005
[45] JCEP Resource Report 3, May 2013
[46] JCEP Resource Report 3, May 2013

recent revised designation of critical habitat was in 2012 and includes 273 acres on the North Spit of Coos Bay, primarily along the ocean sand beach (77 FR 36727-36869). A recovery plan for the species was finalized by the USFWS in 2007. Objectives in the recovery plan include achieving well-distributed increases in numbers and productivity of breeding adult birds, and providing for long-term protection of breeding and wintering plovers and their habitat. In 2010, the USFWS, along with other federal agencies and the State of Oregon, signed off on a statewide Habitat Conservation Plan (HCP). Consequently, the Oregon Parks and Recreation Department (OPRD) is required to submit an annual report to USFWS documenting management actions from the previous year, which includes snowy plover population data, snowy plover take occurrences, recreational use enforcement issues, and anticipated management efforts for the following year.[47]

The southwestern portion of the North Spit is designated as critical habitat for the western snowy plover from the ocean beach at Horsfall to the Coos Bay north jetty, and includes all federal lands at the south end of the spit (USFWS 2012). The SDPP site boundary is approximately 1.3 miles from the northern extent of the critical habitat, and more than 4.5 miles from primary nesting areas. The closest known snowy plover nest is more than three miles from the SDPP site (ORBIC 2013). Nesting in Oregon may occur as early as mid-March, with peak nest initiation occurring from mid-April through mid-July.

On the coast, the western snowy plover inhabits sand beaches almost exclusively. It is unlikely that this species would nest in or around the SDPP site boundary due to the lack of primary habitat for the species, as its typical coastal nesting habitat is at the upper edge beaches, below the foredunes. It also nests on bare spits at small estuary mouths and, on the North Spit, is most prevalent on restored sand habitat east of the foredune.

The western snowy plover hatch rate at the North Spit in 2012 was the highest on the coast and the highest since predator management was implemented in 2002. In 2012, the site continued to be the most productive in Oregon, with 58 broods (nine more than in 2011) and an overall brood success rate of 59 percent (Lauten et al 2012). The hatch rate in 2013 was considerably lower than the previous two years, and similar to 2010 when the lowest ever rate was recorded for the site (Lauten et al 2013). There were 29 total broods in 2013, nearly half the number recorded in 2012, and the overall fledging success rate was the lowest ever recorded for the site. Due to the relatively low number of fledglings, the productivity index was the lowest ever recorded for the site and well below the post-predator management average (Lauten et al 2013).

In the past, predation by corvids (crows, ravens, jays, magpies, etc.) has been the main cause of known nest failure noted in distribution and reproductive success reports prepared for ORBIC. In 2013, however, 15 nests were confirmed on the North Spit as being depredated by northern harriers (*Circus cyaneus)*, a medium-sized hawk, through video evidence or tracks at the nest site. Corvid activity was very low to non-existent all summer and harrier depredation is suspected for most if not all of the known depredations at the site. Wildlife Services removed two harriers toward the end of the nesting season, and it is hoped their removal will result in future benefits and better nest success in 2014 (Lauten et al 2013). Other threats to western

[47] USFWS species profile website, accessed 2013 and 2014, unless otherwise noted

snowy plovers include the introduction of European beachgrass that encroaches on available nesting and foraging habitat, and disturbance from humans, dogs, and off-highway-vehicles in important foraging and nesting areas.

Current management activities and use restrictions within the North Spit Recreation Management Area relative to the snowy plover population include predator management, symbolic fencing, habitat restoration, public outreach and education by BLM staff, monitoring of snowy plover populations, and seasonal recreational use restrictions. Beginning annually on March 15th, signs and ropes are used to inform the public of sensitive western snowy plover nesting areas and to direct the public to non-sensitive areas where recreational activities are permitted. At these marked beach areas, beachgoers still have access to the wet sand portion of the beach to enjoy passive recreational activities such as walking and horseback riding. All recreational activities within the dry sand areas, however, are prohibited. Access restrictions are in effect through September 15th, but may be lifted early if there is no more nesting by July 15th.[48]

There does not appear to be any suitable plover nesting habitat within the SDPP project area and no plovers were detected during field surveys from 2005 to the present. While an occasional individual may use the sandflats adjacent to Jordan Cove for foraging, breeding is unlikely (LBJ 2006, SHN 2012).

When the SDPP site is filled with sand, potential snowy plover habitat could be temporarily created; however, given the level of disturbance at the site from construction, operational and retirement activities, it is unlikely that snowy plovers would utilize fill areas.

The SDPP project does not add elements other than increased human activity that are likely to attract snowy plover predators identified along the Oregon coast, including corvids, harriers, and mammals such as the red fox, raccoon, striped skunk, black rat, and feral cat. Increased nest predation of western snowy plovers within the SDPP analysis area is possible, particularly if predators are attracted to construction sites by garbage or discarded food. An increase in the numbers of these predators could be detrimental to the continued recovery of snowy plover populations. However, the distance to the closest documented plover nest makes increased nest predation as a result of SDPP activities unlikely.

No threats to the western snowy plover are anticipated from the construction, operation, and retirement of the SDPP due to the lack of nesting habitat in or near the site boundary. Efforts will also be made to discourage nesting activity after fill is placed on the SDPP site. Additionally, no impacts are anticipated from collisions with transmission lines in the utility corridor, as bird flight diverters will be installed on the power lines, which have been shown to reduce collisions, increase behavioral avoidance, and decrease bird mortality (Appendix Q-8).[49] Implementation of additional mitigation measures for the project, discussed in detail in Section 7.0, will address predator species such as corvids, harriers, and mammals that may be drawn to the site by human activity.

[48] JCEP Resource Report 3, May 2013
[49] JCEP Draft Biological Assessment 2014

## 3.4 MAMMALS

### 3.4.1 Fisher (State Sensitive-Critical, Federal Candidate Species)

The fisher (*Martes pennanti)* is a large weasel that inhabits forests with high canopy closure, large trees and snags, large woody debris, large hardwoods, and multiple canopy layers. Fishers are known to have very large home ranges and to wander widely. They avoid areas lacking overhead canopy cover and disturbance by humans. Fishers also occupy and reproduce in some managed forest landscapes and forest stands not classified as late-successional that provide some of the habitat elements important to the species.

The fisher was nearly extirpated from Oregon by logging and trapping and is now very rare. Reintroductions have been attempted in several inland counties, and there have been recent sightings in the mountains east and west of the Willamette Valley. The BLM Coos Bay District wildlife sightings database contains several fisher observations in Coos County, but none of these sightings was in the vicinity of the North Spit or the SDPP site boundary. The closest sighting to the SDPP site was in 1991, when an adult fisher was seen near Daniels Creek, approximately 10 miles southeast of the site boundary. The presence of the fisher on the North Spit is unlikely given the rarity of the species and the lack of large, well-connected tracts of mature forest with continuous canopies. Most forested areas on the North Spit are interspersed with areas of open sand and fishers are reluctant to cross openings greater than 25 meters (BLM 2006). Furthermore, fishers on the North Spit would be separated from Coast Range populations by Highway 101, human development, and fragmentation of mature forests.[50]

Although the species has the potential to occur on the North Spit (BLM 2006) and porcupines, one of the fisher’s preferred prey species, are present in the SDPP area, there are no records of its presence and no fishers were observed during focused wildlife surveys of the area.[51] Moderate habitat for this species was found in the forested hillsides west of the facility; however, this habitat is likely too disturbed and the forest too immature and fragmented for the site to be suitable for fishers (LBJ 2006). Because of the lack of observation of fishers in the SDPP site vicinity and the lack of suitable habitat in the vicinity of the site boundary, no impacts to the fisher are expected from construction, operation, or retirement of the SDPP.

### 3.4.2 Gray Wolf (State Endangered, Federal Endangered)

Gray wolves (*Canis lupus*) in Oregon are listed statewide as endangered under the Oregon ESA, and wolves occurring west of Oregon Highways 395,78 and 95 continue to be federally protected as endangered under the ESA since 1978 (43 FR 9607-9615). The USFWS is in the process of evaluating the classification status of gray wolves and has proposed to delist the populations currently listed as endangered in the contiguous U.S. (79 FR 7627-7629). If delisted, the endangered status of the Mexican wolf (same species) would be maintained by listing it as a subspecies (*Canis lupus baileyi*). In the federally listed portion of Oregon, the ODFW implements an Oregon Wolf Conservation and Management Plan (OWP).

[50] ODFW and USFWS websites, accessed 2013, unless otherwise noted
[51] LBJ 2006, SHN 2012

Wolves occurring in Oregon today are part of the Northern Rocky Mountain wolf population. They are descendants of wolves originally captured in Canada and released in Yellowstone National Park and Idaho in the mid-1990s. Wolf numbers fluctuate throughout the year as wolves disperse, pups are born, and new packs are formed. The Oregon wolf population is officially documented at the end of each year. On December 31, 2013, the Oregon population was estimated at 64 wolves. The majority of documented wolves occur in Wallowa, Umatilla, Union, and Baker counties in northeast Oregon. The closest areas of known wolf activity are in Jackson, Klamath and Douglas counties, well southeast of Coos Bay. .[52]

It is very unlikely that the gray wolf would occur within the SDPP analysis area, given current tracking and distribution data available. Construction, operation, and retirement of the SDPP are not anticipated to have any impact to the gray wolf, and the gray wolf does not warrant further evaluation at this time.

## 3.5 FISH

Three federally-listed anadromous fish species spend a portion of their life cycle within the estuarine environment of Coos Bay – the Oregon Coast ESU of Coho salmon, southern DPS green sturgeon, and southern DPS Pacific eulachon, each of which are listed as threatened under the ESA. These three species have not warranted listing as threatened or endangered by the State of Oregon. Based on various ODFW seining surveys, use of the Coos Bay system by Pacific eulachon and green sturgeon is sporadic, and there is very little habitat available for Coho salmon in the immediate project area, except as they traverse the area on their migrations to and from the ocean (Mike Gray, personal communication).

### 3.5.1 Oregon Coast Coho Salmon (State Sensitive-Critical, Federal Threatened)

The Oregon Coast ESU of Coho salmon (*Oncorhynchus kisutch*) is one of several anadromous salmonid species that utilize Coos Bay as juvenile rearing habitat and during migrations to and from the ocean between marine and freshwater environments. In 2008, NMFS listed the naturally spawning populations of Oregon Coast Coho salmon as a federal threatened species under the ESA (73 FR 7816). The Coos Bay watershed, including the bay itself, was included as critical habitat. The Southern Oregon/Northern California ESU of Coho salmon is also listed as a federally threatened species; however the northernmost extent of critical habitat for this ESU is the Elk River, which is located more than 50 miles southeast of the project site near Cape Blanco, OR.

Essential physical and biological features , or primary constituent elements (PCEs), of estuaries include whether an area is free of obstruction, water quality and salinity conditions supporting juvenile and adult physiological transitions between freshwater and saltwater, natural cover, and foraging opportunities. The Coos Bay estuary adjacent to the SDPP site has one or more PCEs within the acceptable range of values required to support the biological processes for which Coho salmon use the habitat. Coho salmon adults and smolts would migrate through this area

[52] ODFW, BLM and USFWS websites, accessed 2013

and use the area to make the physiological transition between marine and freshwater environments.[53]

The SDPP does not require water intake and no entrainment or impingement of fish would occur as a result of the project. Stormwater runoff from impervious surfaces at the SDPP site could contain trace metals such as copper and zinc, which are of concern to aquatic organisms. To avoid any impacts to fish from trace metals, non-contact storm water will infiltrate through bioswales, retention ponds and approximately 30 feet of sand fill before entering into the water table. Contact stormwater will be treated prior to being discharged through the Port's ocean outfall. All stormwater will be treated or managed to meet DEQ requirements under modified NPDES Permit no. 101499 (Appendix E-4) and a DEQ-approved Conceptual Stormwater Management Plan (Appendix I-4).

Impacts to Coho salmon from lighting of the barge berth are anticipated to be insignificant. A Proposed Site Lighting Plan has been developed to minimize impacts from lighting to the maximum extent possible (Appendix R-7). Perimeter lighting will be illuminated in accordance with U.S. Coast Guard security requirements, but will utilize low-emission light fixtures and shielding of the illumination source to limit light emissions to specific areas. Whenever possible, light fixtures will be illuminated only when required for safety and security and will otherwise be turned off. Lighting specification drawings are also provided in Appendix R-7, which illustrate the limited spatial extent of illumination from planned lighting at the site.

Potential significant impacts to Coho salmon are further addressed in Section 7.

### 3.5.2 Pacific Eulachon (No State Listing, Federal Threatened)

Pacific eulachon (*Thaleichthys pacificus*) is a small, anadromous fish from the eastern Pacific Ocean that is commonly known as smelt, candlefish, or hooligan. In North America, they range from northern California into the southeastern Bering Sea. In 2010, the southern DPS of Pacific eulachon was listed as threatened under the ESA (75 FR 13012), followed by the designation of critical habitat in 2011 (76 FR 65323). The range of the southern DPS extends from Nass River, British Columbia to Mad River, California. While this range includes Coos Bay and its upper reaches, critical habitat was not designated in the Coos Bay system.

Eulachon are plankton-feeders, chiefly feeding on crustaceans such as copepods and euphausiids. They typically spend three to five years in saltwater before returning to freshwater to spawn. Spawning runs can be erratic, appearing in some years but not others (NMFS 2006). They do not feed while in freshwater and remain there only a few weeks to spawn.

There is currently little information available about Pacific eulachon presence in Coos Bay. Should they occur, adults would begin moving through the bay as early as December, and spawning typically occurs from January to mid-May, peaking in February to mid-March. When present, Pacific eulachon may utilize both shallow and deep water habitats within the estuary as they migrate to spawning grounds. They will spawn only in the lower reaches of rivers and major tributaries (i.e. the Coos River), as they require moving water and large substrate to

[53] NMFS website, accessed 2013; JCEP Resource Report 3, May 2013

spawn. Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents. When the larvae reach juvenile size, they disperse to the ocean as soon as they are able. Juveniles may migrate out of Coos Bay as early as February to as late as almost mid-summer (Chuck Wheeler, personal communication). Adult eulachon do not always die after spawning and could return to the ocean. [54]

Potential impacts to Pacific eulachon could occur during seasonal migrations by adults to spawn in inland rivers and outmigrations of larvae and juveniles after hatching. Pacific eulachon do not feed in freshwater, and their presence in Coos Bay is likely to be brief and limited (JCEP 2013). Given the number of other deep and shallow water habitats available along the bay transit route, there is a low likelihood that there would be a significant impact from the SDPP on spawning runs of eulachon in Coos Bay.

The likelihood of effects to larval and juvenile stages of eulachon as they outmigrate through the Coos Bay estuary is likewise anticipated to be minimal. As the larvae are carried by currents and tides, they would pass through the waters adjacent to the SDPP relatively quickly and would not spend any substantial length of time in the area. Once the larvae have grown to juvenile size, they naturally disperse to the ocean as soon as they are able. Thus, any juveniles occurring near the site would be migratory in nature.

Impacts to Pacific eulachon from lighting of the barge berth are anticipated to be minimal. A Proposed Site Lighting Plan has been developed to minimize impacts from lighting to the maximum extent possible (Appendix R-7). Perimeter lighting will be illuminated in accordance with U.S. Coast Guard security requirements, but will utilize low-emission light fixtures and shielding of the illumination source to limit light emissions to specific areas. Whenever possible, light fixtures will be illuminated only when required for safety and security and will otherwise be turned off. Lighting specification drawings are also provided in Appendix R-7, which illustrate the limited spatial extent of illumination from planned lighting at the site. As Pacific eulachon presence in Coos Bay is brief and limited, and mitigation measures will be taken to minimize the illumination of aquatic areas, no adverse impacts to Pacific eulachon from lighting are anticipated.

The risk of impacts to larval eulachon from oil spills is also anticipated to be low. The presence of all stages of Pacific eulachon that are likely to be in Coos Bay is minimal, the background rate of oil spill in Oregon is low, and the anticipated number of barge trips associated with the project will be approximately 38 trips over 42 months, which would suggest that the overall risk to Pacific eulachon from oil spills is negligible. In the unlikely event of a spill, vessel operators would follow the guidelines outlined in the Coos Bay GRP (ODEQ 2004) to prioritize the protection of resources in the bay. Consequently, no adverse effects to eulachon are anticipated from the construction, operation, and retirement of the SDPP.[55]

[54] NMFS website, accessed 2013; JCEP Resource Report 3, May 2013
[55] JCEP Resource Report 3, May 2013

### 3.5.3 Green Sturgeon (No State Listing, Federal Threatened)

Green sturgeon (*Acipenser medirostris*) are long-lived, slow-growing fish and are the most marine-oriented of the sturgeon species. They are believed to spend the majority of their lives foraging in nearshore oceanic waters, bays, and estuaries ranging from nearshore waters in Baja California to those in Canada. They utilize both freshwater and saltwater habitat, and spawn in deep pools or holes in large, turbulent, freshwater river mainstems.

There are two DPS defined for green sturgeon—the Northern DPS and the Southern DPS. The Northern DPS is a federal species of concern (SOC) with spawning populations in the Klamath and Rogue rivers. The Southern DPS was federally listed as threatened in 2006 (71 FR 17757) and includes all spawning populations of green sturgeon south of the Eel River in California. The principal factor in the decline of the southern DPS is the reduction of their spawning area in California. Critical habitat for the Southern DPS was designated in 2009 and includes Coos Bay (74 FR 52300). The species has not warranted protective listing status by the State of Oregon.[56]

The distribution of green sturgeon ranges from the U.S.-Mexico border to the Bering Sea in Alaska. Southern DPS green sturgeon are reported to congregate in coastal waters and estuaries and are known to occupy Coos Bay. Because Coos Bay is not their natal stream, Southern DPS green sturgeon are likely to be present outside of the spawning season from June through October. While in Coos Bay, they likely seek out the deepest habitats to rest during low tides and feed on invertebrates in shallow water during high tides. Both Southern and Northern DPS green sturgeon may occur in Coos Bay; however, if a green sturgeon spawns in Oregon, it is not considered part of the southern DPS and not considered threatened under the ESA.[57]

Southern DPS green sturgeon occurring in the analysis area are expected to reside primarily in the deeper waters of the bay, depending on the time of day, tidal cycle, and activity (Mike Gray, personal communication). Thus, project-induced impacts from stormwater are discountable given the migratory nature and distribution range of the species. While larval and juvenile sturgeon have some sensitivity to the copper and zinc concentrations (Vardy 2013) that may be associated with stormwater discharge, only adult and sub-adult Southern DPS green sturgeon occur in Coos Bay. Also, all stormwater discharged from the SDPP site will be treated or management to meet DEQ requirements for modified NPDES Permit no. 101499. Thus, adverse impacts to Southern DPS green sturgeon from stormwater discharge is considered unlikely.

Construction of the barge berth will reduce a small portion of shallow water habitat for green sturgeon prey species such as ghost shrimp and clams, which could indirectly impact green sturgeon. However, there is extensive shallow water habitat available for foraging throughout the bay.

Lighting of the barge berth area also has the potential to impact green sturgeon, and as such, measures will be taken to minimize the amount of light that reaches the aquatic areas around the barge berth. A Proposed Site Lighting Plan has been developed to minimize impacts from lighting to the maximum extent possible (Appendix R-7). Perimeter lighting will be illuminated

[56] NMFS website, accessed 2013, unless otherwise noted
[57] Mike Gray, ODFW, personal communication, 2013

in accordance with U.S. Coast Guard security requirements, but will utilize low-emission light fixtures and shielding of the illumination source to limit light emissions to specific areas. Whenever possible, light fixtures will be illuminated only when required for safety and security and will otherwise be turned off. Lighting specification drawings are also provided in Appendix R-7, which illustrate the limited spatial extent of illumination from planned lighting at the site.

The risk of impacts to green sturgeon from oil spills is also anticipated to be low. Larval and juvenile green sturgeon – the life stages most vulnerable to oil spills – generally do not occur in Coos Bay. Additionally, the background rate of oil spill in Oregon is low (JCEP 2013), and the anticipated number of barge trips associated with the project will be approximately 38 trips over 42 months, which would suggest that the overall risk to green sturgeon from oil spills is negligible. In the unlikely event of a spill, vessel operators would follow the guidelines outlined in the Coos Bay GRP (ODEQ 2004) to prioritize the protection of resources in the bay. Consequently, adverse effects to green sturgeon from the construction of the barge berth are not anticipated.

## 3.6 MARINE MAMMALS

The estuarine and open ocean habitats of the analysis area support a variety of marine mammal species. Of these species, the harbor seal, Steller sea lion, gray whale and orca would potentially enter into Coos Bay. The harbor seal is not a state or federally listed species, and the Steller sea lion was federally delisted in 2013 and is not listed by the state of Oregon. Although the gray whale was federally delisted in 1994, it remains listed as endangered by the state of Oregon. Lastly, the Southern Resident DPS of orcas are federally listed as endangered. Thus, the only state and/or federally listed marine mammals with the potential to occur in Coos Bay are the gray whale and the orca, which are discussed in more detail below.

### 3.6.1 Southern Resident Orcas (No State Listing, Federal Endangered)

Orcas (*Orcinus orca*) are wide-ranging predators of the open ocean that have a worldwide distribution, although they are most common found in subarctic, temperate, and subantarctic waters. Along the North Pacific coast, resident orcas occur from Oregon and Washington to the Bering Sea. Their distribution is correlated to food supplies, and they feed primarily on fish (salmon, cod, and herring). [58] Southern resident orcas are typically found in the inland waterways of Washington and British Columbia during the spring, summer and fall, but are occasionally observed in Oregon and as far south as central California in the winter. Orcas occasionally enter bays in pursuit of salmon and have on occasion been observed inside Coos Bay, although such sightings have not been formally recorded with NMFS.

The southern resident DPS of orcas was federally listed as endangered in 2005 (70 FR 69903). Critical habitat was subsequently designated in 2006, and encompasses the inland waters of northern Washington, including Haro Straight, the San Juan Islands and Puget Sound (71 FR 69054). [59]

[58] Center for Whale Research, www.whaleresarch.com, last accessed June 25, 2014.
[59] NMFS website, accessed 2013; JCEP Resource Report 3

Orca presence in Coos Bay or along the Pacific Coast within the analysis area may occasional occur, but given the rarity of these occurrences, vessel traffic related to construction of the SDPP is unlikely to impact the species. Although orcas can be injured or killed when struck by a vessel, such strikes are considered to be highly unlikely given the limited number of vessel visits to the barge berth and the reduced speeds at which barges will be travelling through the analysis area (JCEP 2013). Additionally, orcas can detect the sound of vessels, enabling them to avoid collisions.

The risk of oil spills adversely impacting the southern resident DPS is also low. Any petroleum products released by vessels would consist of engine oil, lubricating oils, diesel fuel and/or gasoline. However, the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, and this frequency is expected to continue into the foreseeable future. Therefore, it is considered unlikely that orcas would be affected by the SDPP project, and potential effects to southern resident orcas are judged to be insignificant.[60]

### 3.6.2 Gray Whales (State Endangered, Federal No Listing)

Gray whales are found mainly in the shallow coastal waters of the North Pacific Ocean. Two isolated geographic distributions of gray whales are found in the North Pacific – the Eastern North Pacific stock, which is found along the west coast of North America, and the Western North Pacific stock, which is found along the coast of eastern Asia.

The Eastern North Pacific stock spends the summer months feeding primarily in the northern Bering and Chukchi Seas in Alaska, although some whales will remain farther south, feeding in the waters along the west coast from southeast Alaska to California, including Oregon. In the fall and winter, gray whales migrate from their summer feeding grounds to winter breeding grounds and calving areas off the coast of Baja California, Mexico. The height of the winter gray whale migration in Oregon typically occurs between late December and early January. From mid-February to May, the Eastern North Pacific stock migrates back north along the U.S. west coast. Females with calves typically migrate north beginning in April, and travel closer to the shore. Additionally, there is a population of approximately 200 resident gray whales that live almost year-round in Oregon.[61]

Both the Eastern and Western North Pacific stocks of gray whales were federally listed as endangered in 1970 (35 FR 18319). The Eastern North Pacific stock was delisted from the ESA in 1994, while the Western North Pacific stock remains listed as endangered (59 FR 31094). The Eastern North Pacific stock remains listed as endangered in Oregon, and therefore warrants discussion as part of this exhibit.

While gray whales typically reside in shallow coastal waters, they may occasionally enter bays and estuaries. Local reports have documented gray whales entering Coos Bay in 2000 and 2009, and a gray whale calf was beached in July, 2014 at Bastendorff Beach, approximately one mile

[60] JCEP/PCGP Draft BA, April 2014 (Section 4, Pages 21, 36-45)
[61] NMFS website, ODFW website; accessed 2014.

south of the entrance to Coos Bay.[62] While whales have been known to enter Coos Bay, these occurrences are rare.

The risk of oil spills adversely impacting gray whales is low, given the rarity of whale occurrences in the bay and the low rate of oil spills off the Oregon coast.[63] Similarly, the risk of vessel strikes to gray whales is also low, given the limited number of barge trips projected and the speed at which the barges will be travelling. Consequently, the risk of adverse impacts to gray whales as a result of the construction, operation and retirement of the SDPP site are not anticipated.

[62] KCBY website; KVAL website; Albany Democrat-Herald website; accessed 2014.
[63] JCEP/PCGP Draft BA, April 2014 (Section 4, Pages 21, 36-45)

# 4.0 MEASURES PROPOSED TO AVOID OR REDUCE ADVERSE IMPACTS TO SPECIES

**OAR 345-021-0010(1)(q)(C)** *For each species identified under (A), a description of measures proposed by the applicant, if any, to avoid or reduce adverse impact.*

As a result of avoidance, minimization and mitigation measures proposed for the SDPP project, no significant adverse impacts to threatened and endangered species are anticipated during the construction, operation and retirement of the facility. The majority of the SDPP facility will be constructed on previously developed land to avoid and minimize as many impacts as possible to potential suitable habitat for wildlife species. No threatened or endangered plant or animal species were observed within the site boundary during field surveys. A number of threatened and endangered plant and animal species do occur within the project analysis area, and measures will be taken to avoid impacts to habitat or species that may be present by implementing best management practices (BMPs).

The Conceptual Erosion and Sediment Control Plan and Conceptual Stormwater Management Plan (Appendix I-4) will be implemented to prevent erosion, sedimentation, stormwater and water quality impacts within the site boundary and to adjacent habitats. BMPs outlined in these plans include:

- Prior to construction activities, the limits of grading, clearing and grubbing will be clearly marked with stakes and fencing to minimize the extent of disturbance
- Temporary seeding will be conducted to re-establish vegetative cover in previously disturbed areas to prevent erosion of exposed soils. Compost or peat layers will be placed on disturbed areas to absorb wind and rain forces and to develop a growing medium for vegetation
- Dust will be controlled by reducing vehicle speeds, irrigating, applying dust palliatives, installing sand fences and placing compost or peat layers on disturbed areas
- Sediment fences will be installed to pond and filter stormwater upstream of the fence and promote the settlement of soil particles
- Compost berms will be constructed to filter stormwater runoff to prevent sediment from leaving the site
- Exposed slopes in disturbed areas will be covered with a rolled erosion control fabric to prevent wind or water erosion prior to the establishment of vegetation. Peat and processed woody materials will be used to develop a seed bed on top of the fabric and subsequently planted with American dune grass to provide permanent revegetation and stabilize slopes.

As outlined in the Wildlife Habitat Mitigation Plan (Appendix P-6), exotic and invasive species control measures will be implemented to reduce invasions by non-native species at the site throughout the life of the project. Restoration and revegetation of project areas with native species will also be conducted. The project will follow noxious weed management BMPs including the following methods:

- Pre-construction surveys will be conducted to identify noxious species listed by the ODA that persist despite previous and recent control efforts
- Ongoing weed control at the site will be conducted by mechanical or manual means to prevent the spread of noxious weed species throughout the site. Herbicides may also be used in combination with other weed control methods
- Herbicides will not be used within 100 feet of a wetland or waterbody, unless allowed by the appropriate agency. Treatment buffers will be applied to noxious weed infestations in sensitive areas to avoid impacts to non-target species
- Restoration of treatment areas will be conducted using a native seed mix that conforms to BLM policy

Any discharges of stormwater or wastewater to Coos Bay will be treated or managed in accordance with the modified NPDES Permit no. 101499 and a DEQ-approved Conceptual Stormwater Management Plan (Appendix E-4). Additionally, a Stormwater Pollution Prevention Plan, including Spill Prevention and Response Procedures, will be implemented during construction in accordance with the EPA's National Stormwater Program General Permit requirements.

Transmission lines will be constructed within an existing utility corridor to avoid impacts to surrounding habitat. The transmission lines will be outfitted with bird flight diverters to reduce the risk of potential bird collisions. Additionally, in order to prevent electrocution of birds, transmission lines have been designed so that the distance between conductors, and between conductors and grounded hardware, is greater than the wingspan of any raptor. Birds are electrocuted when they contact two energized conductors or an energized conductor and grounded hardware. Among avian species, raptors are at greatest risk of electrocution because of their large wingspans and tendency to perch on power poles.

Potential impacts to estuarine species and habitat as a result of the construction of the barge berth and access triangle will be reduced by implementing BMPs and avoidance and minimization measures. As outlined in the DSL removal fill permit application (Appendix J-2), the barge berth area will be temporarily filled so that pile driving can be conducted on dry land, thereby avoiding noise impacts to aquatic species. Open Cell sheet piles will hold the fill material in place and turbidity curtains will be placed around the bill to prevent turbidity impacts from pile driving activities. Dredging of the access triangle will be conducted used a cutter-head suction dredge to minimize turbidity and noise impacts to aquatic species. All fill removal and dredging activities will take place during the ODFW in-water work window from October 1 to February 15.

All unavoidable impacts to upland habitat and non-jurisdictional wetlands at the SDPP site will be mitigated under the Wildlife Habitat Mitigation Plan (Appendix P-6). Impacts to jurisdictional wetlands and estuarine habitat will be mitigated under the Compensatory Wetland Mitigation Plan as part of the DSL removal fill permit application (Appendix J-2).

In addition to the above measures, species-specific conservation measures will be implemented for the Point Reyes bird's beak and western snowy plover. In consultation with the ODA, mitigation measures will be developed and implemented to ensure that impacts to Point Reyes bird's beak are avoided or minimized to the maximum extent possible. In consultation with the ODFW and USFWS, a western snowy plover mitigation plan will be developed and implemented to avoid or minimize potential impacts, including measures to discourage predators from entering the project area.

## 5.0 COMPLIANCE WITH ODA PROTECTION AND CONSERVATION PROGRAMS FOR LISTED PLANT SPECIES

**OAR 345-021-0010(1)(q)(D)** *For each plant species identified under (A), a description of how the proposed facility, including any mitigation measures, complies with the protection and conservation program, if any, that the Oregon Department of Agriculture has adopted under ORS 564.105(3).*

The Point Reyes bird's beak is the only state or federally listed plant species that was identified as occurring within the project analysis area during focused field surveys. The ODA has not developed a conservation, recovery, or protection plan for the Point Reyes bird's-beak; therefore, this species is addressed in Section Q.6.

# 6.0 SIGNIFICANT POTENTIAL IMPACTS TO LISTED PLANT SPECIES AND CRITICAL HABITAT

**OAR 345-021-0010(1)(q)(E)** *For each plant species identified under paragraph (A), if the Oregon Department of Agriculture has not adopted a protection and conservation program under ORS 564.105(3), a description of significant potential impacts of the proposed facility on the continued existence of the species and on the critical habitat of such species and evidence that the proposed facility, including any mitigation measures, is not likely to cause a significant reduction in the likelihood of survival or recovery of the species.*

The Point Reyes bird's-beak is the only state or federally listed plant species that has been detected during focused botanical surveys conducted for the overall JCEP (SHN, 2006, 2013). Point Reyes bird's-beak occurrences were recorded below the highest measured tide outside and below the SDPP site boundary (SHN 2006, 2013). Four additional plant species (pink sand verbena, silvery phacelia, western lily, and Wolf's evening primrose) listed as threatened or endangered, and determined to have the potential to occur, are not anticipated to be affected by the SDPP, as they were not detecting during field surveys and minimal suitable habitat is present at the site. No additional pre-construction surveys are recommended at this time for plant species other than the Point Reyes bird's-beak.

## 6.1 POINT REYES BIRD'S-BEAK

As required by the ODA under OAR 603-073-0090(5)(d)(A)(E), reasonable efforts will be made to ensure that the construction, operation and retirement of the SDPP will not significantly impact the continued existence of Point Reyes birds-beak or critical habitat near the site boundary.

The ODA has not developed a conservation, recovery, or protection plan for the Point Reyes bird's-beak. Preliminary consultation was conducted with the ODA regarding the occurrences documented along the Jordan Cove shoreline that have the potential to be affected by the project. Coordination and consultation with the ODA will be ongoing to ensure that the avoidance, minimization and mitigation measures proposed to protect the species during construction, operation, and retirement of the SDPP will ensure the likelihood of survival of the species. This will include reasonable measures taken to minimize any potential significant adverse impacts to Point Reyes bird's-beak, including brightly colored fencing to separate the populations from construction activities and to ensure there is an adequate buffer between fill placement and construction activities. In addition, avoidance and minimization measures such as erosion and sedimentation control, stormwater runoff management (Appendix I-4) and a noxious weed management program (Appendix P-6) will be implemented to minimize water quality impacts to the adjacent shoreline, prevent erosion and sedimentation in around the Point Reyes bird's beak population, and to reduce the introduction of invasive plants to the project area. All actions will be designed to be consistent with conserving and protecting Point Reyes bird's-beak populations.

In addition to the measures above, a conservation and mitigation plan that includes monitoring will be developed and approved by the ODA prior to implementation of any ground disturbing actions for the project to ensure the project is not likely to cause a significant reduction in the likelihood of survival or recovery of the species.

# 7.0 SIGNIFICANT POTENTIAL IMPACTS TO LISTED ANIMAL SPECIES AND CRITICAL HABITAT

**OAR 345-021-0010(1)(q)(F)** *For each animal species identified under (A), a description of significant potential impacts of the proposed facility on the continued existence of such species and on the critical habitat of such species and evidence that the proposed facility, including any mitigation measures, is not likely to cause a significant reduction in the likelihood of survival or recovery of the species.*

No threatened or endangered wildlife species were detected within the SDPP site boundary during focused wildlife surveys, nor did these surveys identify suitable terrestrial habitat for state or federally listed wildlife species.[64] Listed species, as well as suitable habitat, were identified within the analysis area; however, significant potential impacts to these species and habitats are not expected as a result of the SDPP project. Should listed species occur within the project vicinity or be displaced by project activities, suitable habitat is available adjacent to the site boundary and elsewhere in the analysis area that can be utilized.

## 7.1 WESTERN SNOWY PLOVER

Although western snowy plovers were not observed during wildlife surveys and there is no critical habitat located within the site boundary, activities associated with the construction, operation and retirement of the SDPP facility have the potential to attract plover predators to the area. The ODFW and USFWS have previously raised concerns that increased human presence and disturbance from project activities may attract predators such as crows, ravens, red foxes and raccoons that could impact western snowy plover populations on the North Spit. In response to these concerns, measures will be taken to avoid or minimize impacts to western snowy plovers, including the implementation of BMPs and an education and outreach program (JCEP 2013). BMPs will include:

- Staff training on western snowy plover regulations, recreational use restrictions and conservation measures such as litter control, avoidance of nesting and foraging areas and staying on established roads and trails.
- Environmental training for operational personnel to comply with existing management policies in place on the North Spit.
- Posting printed educational materials at the project site for the life of the project and posting interpretive signs, educational materials and kiosks at the SDPP or other approved locations.
- Funding a Wildlife Services position dedicated to snowy plover predator monitoring and control during construction of the SDPP.
- Keeping the site clear of construction debris, food waste and garbage that could attract predators to the site.

[64] LBJ 2006, SHN 2012

- Providing animal-proof receptacles in eating areas, parking lots and other appropriate locations.
- Monitoring of structures at the site to discourage use by avian predators and removal of any nests found at the site.

As a result of implementing the mitigation measures outlined above, significant potential impacts to western snowy plovers on the North Spit from increased predator presence are not anticipated. In the event that a clearly demonstrable and sustained decrease in snowy plover productivity is detected by ongoing monitoring, the project will coordinate with the USFWS, ORBIC, Oregon Wildlife Services, BLM, OPRD, ODFW, and other interested parties to identify adaptive management strategies, as appropriate, to help reverse any such trend.

## 7.2 OREGON COAST ESU OF COHO SALMON

Stormwater discharge to Coos Bay has been identified as a potential pollution source for metals that could impact Coho salmon. There is concern that elevated metals concentrations, copper in particular, may disrupt fish behavior or damage sensory capabilities in salmonids (Hecht et al. 2007). These impacts could in turn cause migration delays or increased susceptibility to predation in Coho salmon (Phippen, personal communication).

To minimize impacts from metals to Coho salmon and other fish species in Coos Bay, non-contact stormwater runoff from the SDPP site will infiltrate into the ground through bioswales and infiltration ponds designed for the bioretention of stormwater pollutants. As outlined in the modified NPDES Permit no. 101499 application, stormwater will infiltrate through approximately 30 feet of unsaturated sand fill before entering the underlying water table aquifer (Appendix E-4). Similar systems have been shown to remove more than 90 percent of copper from stormwater after three hours of retention time (Davis et al. 2003). Contact stormwater will be collected on-site and managed or treated before being discharged through the Port's ocean outfall. All stormwater discharges to Coos Bay will be in accordance with modified NPDES Permit No. 101499 (Appendix E-4) and a DEQ-approved Conceptual Stormwater Management Plan (Appendix I-4). Consequently, the discharge of stormwater is not anticipated to result in a change in background metals concentrations in Coos Bay, nor significantly impact the continued existence of Coho salmon, other threatened or endangered fish species or critical habitat in Coos Bay.

Potential significant impacts to Coho salmon could also result from the construction of the barge berth and access triangle. Localized turbidity and sedimentation impacts from barge berth construction and dredging of the access triangle could include trauma to gill structures, loss of foraging potential due to reduced light, and effects on salmonid physiology, behavior and habitat leading to a reduction in fitness and survival (Bash et al. 2001). Effects on foraging and predation vary, however. Some salmonid and Pollock species have been reported to continue to consume prey during periods or turbidity, while species that prey upon salmonids reduced consumption of juveniles during periods of elevated turbidity (De Robertis et al. 2003).

While the severity of impacts to fish from turbidity and sedimentation may vary, measures to reduce these impacts will be implemented regardless during construction of the barge berth and dredging of the access triangle. The installation of Open Cell sheet pile membrane walls during construction of the barge berth will isolate construction activities and result in only minor and localized levels of turbidity. A turbidity curtain will also be employed to further reduce impacts to surrounding species and habitat (Appendix J-2). Dredging of the access triangle will be performed primarily with a cutter-head suction dredge, which minimizes both turbidity and noise. Water quality monitoring will be conducted throughout construction activities to ensure compliance with federal and state standards (Appendix J-2). Most importantly, all in-water work will be conducted during the ODFW-approved in-water work window from October 1st through February 15th to avoid vulnerable fish life stages including migration, spawning and rearing (ODFW 2008).

Noise impacts are also a concern during construction of the barge berth and dredging of the access channel. Typical construction activities such as pile driving have the potential to impact fish and marine mammals in the vicinity. In order to avoid or minimize noise impacts, all pile driving will be conducted in the dry using land-based mobile cranes. The barge berth area will be back filled with sand to create a dry environment and pile driving will occur in areas of fill, which will act as a sound buffer and minimize noise impacts to aquatic species (Appendix J-2). As such, noise generated from pile driving in temporary fill areas is not expected to exceed NOAA’s current in-water acoustic threshold of 160 dB for behavioral disruption from impulsive noise (NOAA 2013).

# 8.0 PROPOSED MONITORING PROGRAM FOR IMPACTS TO THREATENED AND ENDANGERED SPECIES

**OAR 345-021-0010(1)(q)(G)** *The applicant's proposed monitoring program, if any, for impacts to threatened and endangered species.*

The proposed SDPP will be sited on previously developed land zoned as industrial and no state or federally listed species are known to reside within the site boundary. Consequently, no adverse impacts are anticipated to known populations of listed species during construction or operation of the SDPP. To further ensure there are no impacts to threatened and endangered species, habitat requirements, monitoring and mitigation measures will be implemented for the project. A Wildlife Habitat Mitigation Plan (Appendix P-6) has been developed in accordance with the ODFW Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0000 through 0025), which outlines both the mitigation and monitoring measures that will be implemented for the JCEP (Appendix Q-13).

The monitoring measures outlined in the Wildlife Habitat Mitigation Plan are designed to ensure that the goals and standards of the ODFW's Habitat Mitigation Recommendations are met, as outlined in OAR 635-415-0025. The monitoring plan for the habitat mitigation sites proposes a monitoring period of five years, with the first year of monitoring beginning upon substantial completion of mitigation construction and implementation.

Mitigation objectives and performance standards have been established for each site to ensure successful mitigation. Objectives and performance standards are described in detail in Appendix P-6 and are presented below.

## 8.1 AS-BUILT SURVEY

In the first year of monitoring, an as-built survey will be conducted to document that the appropriate contours have been attained where grading is proposed and plantings were installed as designed. An as-built report will be prepared, which will include the as-built survey, photos, and a brief synopsis of work completed, including any design changes.

## 8.2 PHOTO DOCUMENTATION

Photo locations will be established within the Panhandle, North Bank and Lagoon sites to document conditions at the sites every year for the first five years post-mitigation. Supplemental photos will be taken as appropriate to document any problem areas or enhancement actions.

## 8.3 MITIGATION OBJECTIVES AND PERFORMANCE STANDARDS

A number of mitigation objectives and performance standards have been identified to assess the success of mitigation at all project mitigation sites. Long-term monitoring and site management will be conducted at the mitigation sites to determine whether performance standards have met the mitigation objectives.

**Objective 1:** Permanent preservation of parcel.

**Performance Standard 1.1:** A legal protection instrument is in place in the form of a conservation easement.

**Objective 2:** The portion of the parcel preserved for mitigation purposes is demonstrably managed for conservation for the life of the project.

**Performance Standard 2.1:** A land manager will be endowed to monitor and maintain the parcels, demonstrate that an ecological uplift has been provided at each site, provide monitoring reports for the first five years after implementation of proposed mitigation measures, and maintain the sites throughout the life of the project.

**Performance Standard 2.2:** A long-term maintenance plan will be in place prior to the issuance of a Notice to Proceed for construction of the JCEP.

**Objective 3:** An ecological uplift has been provided at each mitigation site.

***Panhandle Site***

**Performance Standard 3.1**: Ecological uplift (in the form of Scotch broom removal over a minimum of 5.8 acres) has been completed and is reflected in monitoring reports for five years.

***North Bank Site***

**Performance Standard 3.2:** Ecological uplift (forestry activities designed to encourage succession to mature forest within a minimum of 71.2 acres) has been completed for five years based on annual monitoring reports.

***Lagoon Site***

**Performance Standard 3.3:** Ecological uplift (in the form of Scotch broom and Himalayan blackberry removal within a minimum of 10.2 acres, and construction of an educational kiosk) has been completed and maintained for five years based on annual monitoring reports.

**Performance Standard 3.4:** Placement and compaction of sand to an approximate depth of six feet has been completed and maintained over an area of at least 1.9 acres to provide at least 95% open sand cover for five years based on annual monitoring reports.

In addition to the monitoring activities outlined above, long-term maintenance will be conducted at the mitigation sites, which may include garbage and debris removal, installation of protective signage and other deterrents in the event that vandalism or other inappropriate activities are found to occur at any of the sites.

## 8.4 CONTINGENCY PLAN

Contingency plans will be developed by the endowed land manager and coordinated with ODFW should mitigation not meet performance standards. The nature of the contingency plan will depend on the problems that arise and would likely be related to weed control and potential vandalism or effects from natural disasters.

## 8.5 SPECIES-SPECIFIC MONITORING

In addition to monitoring plans developed for the habitat mitigation sites, species-specific monitoring for threatened and endangered species will also be conducted. As described in detail in Section 7.0, western snowy plover impact minimization measures will be implemented through the establishment of BMPs and an educational outreach program (JCEP 2013). BMPs related to species monitoring will include:

- Funding of a Wildlife Services position dedicated to snowy plover predator monitoring and control during the 39-month construction period.
- Monitoring of structures associated with the project to discourage use by avian predators. Frequent inspection of these areas will be conducted to ensure that nests are not being constructed; any nests found will be removed immediately.
- Monitoring of dredged material placement areas to ensure that no snowy plover denning is occurring in the hillocks.

Monitoring will also be conducted during in-water work for the construction of the barge berth and dredging of the access triangle to ensure that impacts to Coho salmon and other fish species are minimized. Water quality monitoring will be conducted to confirm that turbidity levels comply with state and federal standards (Appendix J-2). In addition, the project will comply with the requirements of the modified NPDES Permit No. 101499 to minimize impacts to Coho salmon from stormwater discharge to Coos Bay (Appendix E-4).

# 9.0 REFERENCES

Albany Democrat-Herald Website. http://democratherald.com/foot-gray-whale-swims-in-coos-bay/article_04c6be91-67bf-538a-bb08-25dd8ecbd1c9.html. Accessed August, 2014.

Bash, Jeff, Berman, Cara, Bolton, Susan. Effects of turbidity and suspended solids on salmonids. Washington State Transportation Center. November 2001.

Bureau of Land Management (BLM). Final North Spit Plan: An Update to the Coos Bay Shorelands Plan of 1995. December 2006.

Claire, Christopher. Habitat Protection Biologist, Oregon Department of Fish and Wildlife (ODFW), Charleston Field Office, Oregon, personal communication. July to September 2013.

Coos County Planning Department. Approval of conditional use for fill, former Weyerhaeuser Mill Site, File No. ACU-12-16/ACU-12-17/ACU-12-18. October 4, 2012.

David Evans and Associates, Inc. Jordan Cove Energy Project and South Dunes Power Plant Project, Oregon Department of State Lands Removal-Fill permit application. October 31, 2013.

De Robertis, Alex, Ryer, Clifford H., Veloza, Adriana, Brodeur, Richard D. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60: 1517-1526. December 2003.

Geotechnical Resources, Inc. (GRI). Revised work plan for joint program regulatory closure, Weyerhaeuser Mill Site and Ingram Yard properties, Coos County, Oregon; submitted by George Freitag, Certified Engineering Geologist, GRI Associate, Beaverton, Oregon. July 3, 2013.

GRI. Work plan for joint program regulatory closure, Weyerhaeuser Mill Site and Ingram Yard properties, Coos County, Oregon; submitted by George Freitag, Certified Engineering Geologist, GRI Associate, Beaverton, Oregon. September 21, 2012.

Hecht, Scott A., Baldwin, David H., Mebane, Christopher A., Hawkes, Tony, Gross, Sean J., Scholz, Nathaniel L. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. NOAA Technical Memorandum NMFS-NWFSC-83. U.S. Department of Commerce. October 2007.

Johnson, Michael R., et al. NOAA Technical Memorandum NMFS-NE-209, *Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States*, U.S. Department of Commerce. February 2008.

Jordan Cove Energy Project (JCEP). Resource Report 3 for Fish, Wildlife and Vegetation; prepared for the Federal Energy Regulatory Commission. May 2013. (attached)

KCBY Website. http://www.kcby.com/news/local/69713647.html. Accessed August, 2014.

Krug, Tyler. Project Manager, U.S. Army Corps of Engineers, North Bend Field Office, North Bend, Oregon, personal communication. September 2013.

KVAL Website. http://www.kval.com/outdoors/Baby-whale-beached--267719511.html. Accessed August, 2014.

Lauten, David J. et al. *The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast*, report prepared for the Oregon Biodiversity Information Center. December 21, 2012.

Lauten, David J. et al. The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast – 2013. Report prepared for the Oregon Biodiversity Information Center. December 30, 2013.

LBJ Enterprises. *2005-2006 Pre-Construction Wildlife Surveys for Proposed Jordan Cove Liquefied National Gas Plant*, Coos Bay, Oregon. December 26, 2006.

Lohn, D. Robert. Regional Administrator, NMFS Northwest Region, formal consultation letter for the Coos Bay airport expansion in North Bend, Coos County, Oregon. August 13, 2008.

Love, Stuart. Wildlife Biologist, ODFW, Charleston Field Office, Oregon, personal communication. July to September 2013.

Mason, Bill. Oregon Department of Environmental Quality, Western Region, Eugene Office, work plan approval letter for joint program regulatory closure of Weyerhaeuser Mill Site settling basins, petroleum contaminated soil, asbestos waste, mill waste, and Ingram Yard properties. June 15, 2012.

McShane, C., et al. *Evaluation Report for the 5-Year Status Review of the Marbled Murrelet in Washington, Oregon, and California*, prepared for the USFWS Region 1. March 2004. (attached)

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS). List of threatened and endangered species under NMFS jurisdiction, www.nmfs.noaa.gov/pr/species/esa/. Updated as of August 21, 2013.

NMFS. Delisting of Eastern distinct population segment of Steller sea lion under the Endangered Species Act, FR66140, Volume 78, No. 213. November 4, 2013.

NMFS. Designation of critical habitat for the southern distinct population segment of eulachon, FR65324, Volume 76, No. 203. October 20, 2011.

NMFS. Final rules for Oregon Coast coho salmon, Federal Register rules and regulations, Volume 73, No. 28. February 11, 2008.

NMFS. Finding on a petition to delist the southern resident killer whale, request for information, FR70733, Volume 77, No. 228. November 27, 2012.

NMFS. Status of ESA listings and critical habitat designations for West Coast salmon and steelhead, www.nmfs.noaa.gov. Last updated October 31, 2012.

NMFS. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California; NMFS Technical Memorandum NMFS-NWFSC-105. March 2010.

NMFS. Eulachon: a review of biology and an annotated bibliography. AFSC Processed Report 2006-12. August 2006.

Nelson, S. Kim and Hamer, Thomas E. *Nest Success and the Effects of Predation on Marbled Murrelet*. 1995. (attached)

Ocean Class. 2014. Retrieved September 4, 2014 from http://www.crowley.com/What-We-Do/Solutions/Vessel-Specifications/Tugs/Ocean-Class

Oregon Biodiversity Information Center. Institute for Natural Resources, Portland State University, data system search for rare, threatened and endangered plant and animal records within a five mile radius of the Jordan Cove Energy Project, Coos County, Oregon. July 16, 2013.

Oregon Department of Environmental Quality (ODEQ). Environmental Cleanup Site Information (ECSI) Database, site summary report, details for Site ID 1083 and 4704. Accessed April 9, 2014.

ODEQ. Former Weyerhaeuser North Bend containerboard mill, site summary report, North Bend, Oregon. September 7, 2006.

ODEQ. Partial No Further Action determination letter, former Weyerhaeuser Containerboard Mill and the Ingram Yard portion. September 15, 2006. (attached)

ODEQ. Work plan approval letter, joint program regulatory closure for *Settling Basins, Petroleum Contaminated Soil, Asbestos Waste, and Mill Waste, Weyerhaeuser Mill Site and Ingram Yard Properties.* June 15, 2012.

ODEQ. Coos Bay, Oregon Geographic Response Plan (GRP). December 2004. http://www.deq.state.or.us/lq/pubs/docs/cu/CoosBayGeographicResponsePlan.pdf

Oregon Department of Fish and Wildlife. Threatened, endangered, and candidate fish and wildlife species in Oregon, www.dfw.state.or.us/wildlife/diversity/- species/-threatened_endangered_species.asp. November 2013.

Oregon Department of Fish and Wildlife. Oregon Conservation Stategy, Coast Range Ecoregion. January, 2006.

Oregon Department of Fish and Wildlife. Oregon Guidelines for Timing of In-Water Work to Protect Fish and Wildlife Resources. June 2008. http://www.dfw.state.or.us/lands/inwater/Oregon_Guidelines_for_Timing_of_%20InWater_Work2008.pdf. Accessed September, 2014.

Oregon State Parks and Recreation Department. 2012 annual compliance report of the habitat conservation plan for the western snowy plover. January 2013.

Pearson, Scott F. and Altman, Bob. *Range-wide Streaked Horned Lark Assessment and Preliminary Conservation Strategy*, prepared for the Washington Department of Wildlife and the American Bird Conservancy. September 2005. (attached)

Phippen, Ken. Branch Chief, Oregon Coast Habitat Branch, National Marine Fisheries Service, Roseburg, Oregon, personal communication. September 2013.

Rosenberg, Paul S. Manager, Oregon Department of Environmental Quality Cleanup Program, Western Region, No Further Action determination, former Weyerhaeuser containerboard mill, North Bend, Coos County, Oregon. September 15, 2006.

SHN Consulting Engineers & Geologists, Inc. (SHN). *Botanical Resources Assessment Report*, Jordan Cove Energy Project, Coos County, Oregon. August 2013.

SHN. *Wildlife Assessment and Survey Report*, Jordan Cove Energy Project, Coos County, Oregon. January 2013.

Stelle, William W., Jr. Regional Administrator, NMFS Northwest Region, ESA Biological Opinion and EFH response for Ocean Terminals Dock Construction, Sheet Pile, and Placement of Fill, Coos Bay, Oregon. December 30, 2011.

Stelle, William W., Jr. Regional Administrator, NMFS Northwest Region, ESA concurrence letter and Essential Fish Habitat response for Southwest Oregon Airport mitigation site dike repair, Coos County, Oregon. June 22, 2010.

Thiel Engineering. *Elements of Environmental Closure for the Weyerhaeuser Containerboard Packaging Facility*, technical and cost evaluation, Coos County, Oregon. April 2004.

Thorson T.D., Bryce, S.A., Lammers, D.A., Woods, A.J., Omernik, J.M., Kagan, J., Pater, D.E., and Comstock, J.A. Ecoregions of Oregon. 2003.

Tuerler, Bridgette. ESA species coordination for marbled murrelets, U.S. Fish and Wildlife Service, Portland, Oregon, personal communication. January 16, 2013.

Tug Boat Sizes. 2014. Retrieved September 4, 2014 from http://www.dimensionsinfo.com/tug-boat-sizes/

U.S. Department of Interior Bureau of Land Management and U.S. Department of Agriculture Forest Service, Pacific Northwest Region. *Snowy Plover Nesting Season Begins March 15,* news release for the Southern Oregon Coast. March 13, 2013.

U.S. Department of the Interior, Bureau of Land Management (BLM). Coos Bay District, Umpqua Field Office, *Final North Spit Plan*, an update to the Coos Bay Shorelands Plan of 1995. December 2006.

U.S. Department of Interior, Fish and Wildlife Service (USFWS). Oregon Fish and Wildlife Office species list; federally listed, proposed, candidate species and species of concern under the jurisdiction of the USFWS which may occur within Coos County. Last updated September 11, 2013.

USFWS. Proposed rule, petition to list the West Coast distinct population segment (DPS) of the Fisher (*Martes pennanti*) under the Endangered Species Act of 1973, as amended; FR18770, Volume 69, No. 68. April 8, 2004.

USFWS. Status review of the West Coast DPS of the fisher as endangered or threatened; FR16828, Volume 78, No. 53. March 19, 2013.

USFWS. *Western Snowy Plover Nesting Season Begins on Oregon Coast*, news release, www.fws.gov/pacific/news/news.cfm?id=2144375201. March 11, 2013.

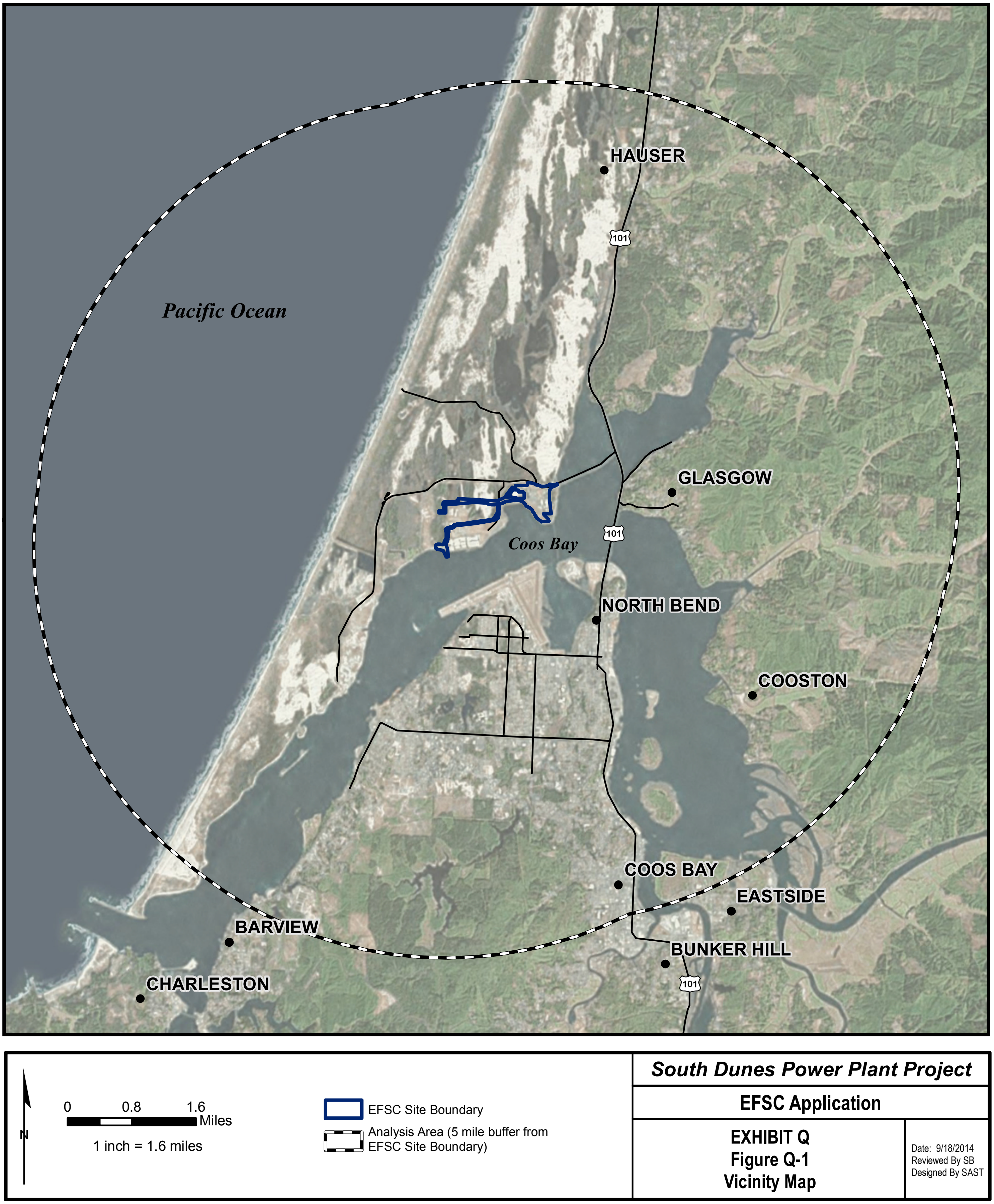
USFWS. Endangered species data, links to fact sheets and other important sites; www.fws.gov/oregonfwo/Species/Data/. November 2013.

Vardy, David W., Oellers, Johanna, Doering, Jon A., Hollert, Henner, Giesy, John P., Hecker, Marcus. Sensitivity of early life stages of white sturgeon, rainbow trout, and fathead minnow to copper. Ecotoxicology 22: 139-147. 2013.

Wheeler, Chuck. Discussions on ESA-listed species by NMFS and NMFS standards, including stormwater considerations, personal communication. May 9, 2013, and May 17-18, 2013.

Williams Pacific Connector Gas Operator, LLC. Draft Biological Assessment and Essential Fish Habitat Assessment for the Jordan Cove Energy and Pacific Connector Gas Pipeline Project, Docket Nos. CP13-483-000 and CP13-492-000. Last updated April 2014. (attached)

**Figure Q-1. Threatened and Endangered Species Analysis Area Vicinity Map**



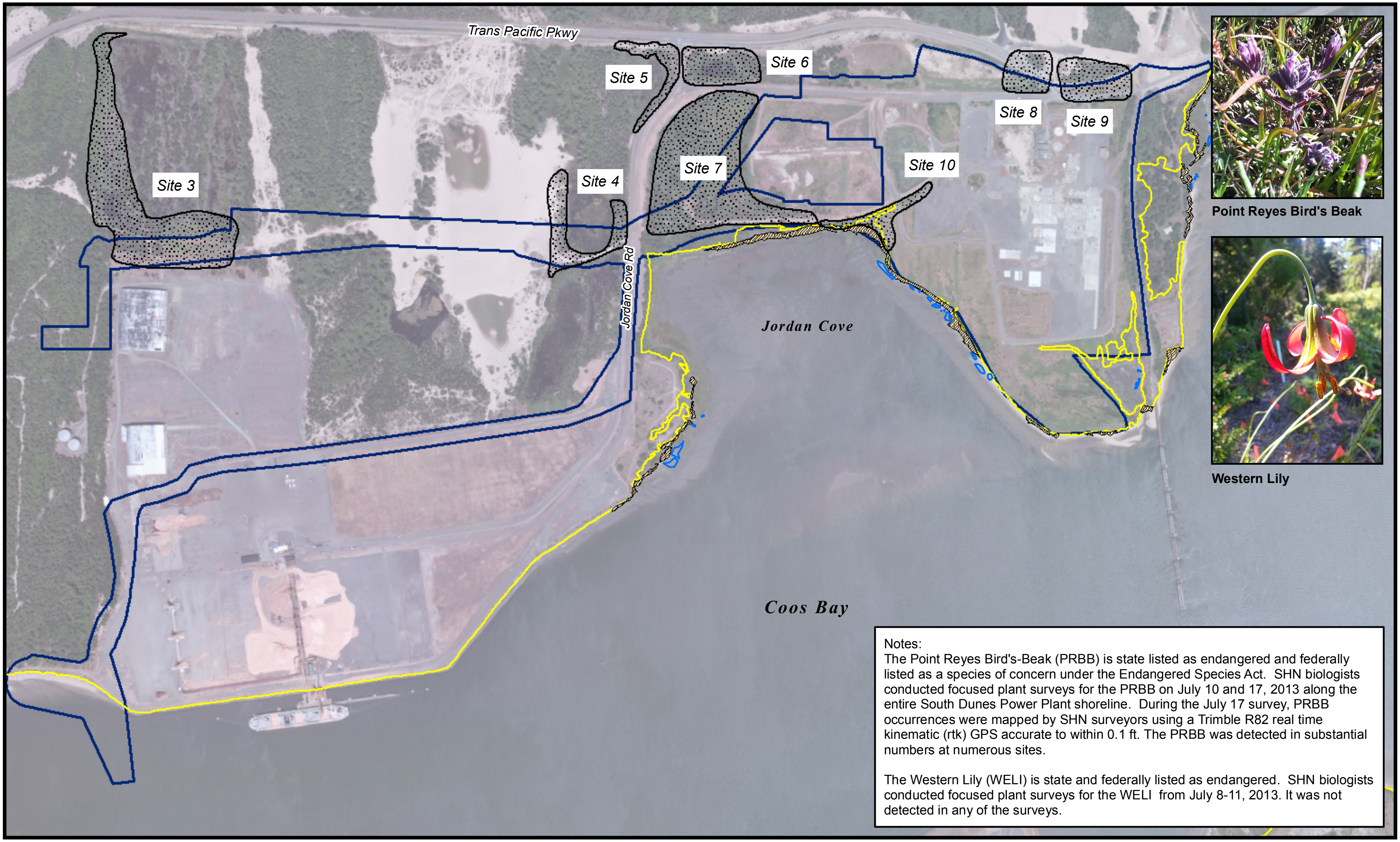

*South Dunes Power Plant Project*

**EFSC Application**

**EXHIBIT Q**
**Figure Q-1**
**Vicinity Map**

Date: 9/18/2014
Reviewed By SB
Designed By SAST

**Figure Q-2. Point Reyes Bird's-Beak and Western Lily Survey Results**




Notes:
The Point Reyes Bird's-Beak (PRBB) is state listed as endangered and federally listed as a species of concern under the Endangered Species Act. SHN biologists conducted focused plant surveys for the PRBB on July 10 and 17, 2013 along the entire South Dunes Power Plant shoreline. During the July 17 survey, PRBB occurrences were mapped by SHN surveyors using a Trimble R82 real time kinematic (rtk) GPS accurate to within 0.1 ft. The PRBB was detected in substantial numbers at numerous sites.

The Western Lily (WELI) is state and federally listed as endangered. SHN biologists conducted focused plant surveys for the WELI from July 8-11, 2013. It was not detected in any of the surveys.

N

0 450 900 Feet

1 inch = 900 feet

*Survey: SHN Consulting Engineers & Geologists, Inc., 07/08-11/2013 and 07/10-17/2013.*

- EFSC Site Boundary
- Point Reyes Bird's Beak Plant Location, 2013
- Western Lily Survey Area (No Plants Found, 2013)
- Wood Debris (2013)
- Highest Measured Tide (HMT) 10.26 ft (NAVD 88)

***South Dunes Power Plant Project***

**EFSC Application**

**EXHIBIT Q**

**Figure Q-2**

**Point Reyes Bird's-Beak and Western Lily Survey Results**

Date: 9/18/2014
Reviewed By SB
Designed By SAST

# APPENDIX Q-1

## Agency and Stakeholder Correspondence

# SHN ☒Phone ☐Conversation Log

| | | | |
|---|---|---|---|
| Date: May 9, 2013 | Time: 10:30 ☒a.m. ☐p.m. | Job #: | 611048 |
| Tel #: (541) 888-5515 | ☒ Call To ☐ Call From | | |
| Meeting at: n/a | | Job Name: | JCEP |
| Contact Name: Mike Gray, ODFW District Fish Biologist, Coos Bay | | Logged By: | Barb Gimlin |
| Subject: Eulachon, Green Sturgeon, White Sturgeon | | | |

Notes | To Do

Green Sturgeon

Mike said he wouldn't occurrences of green sturgeon in Coos Bay rare. They do occur in Coos Bay. It's a little confusing because they classify a Southern DPS which is federally listed as threatened, but the Northern DPS could also occur. In addition to green sturgeon, quite a few white sturgeon occur. Neither greens or whites have shown any evidence to reproduce in Coos Bay but they do occur here. Most anglers don't encounter green sturgeon much and they are fairly easily to distinguish by their coloration and the shape of their snout makes it fairly easy to distinguish the two.

Green sturgeon spend more time in the ocean, as they have less tolerance for freshwater, but they do come in and out of the bay. White sturgeon are able to tolerate freshwater more and go upriver. In the Columbia River, white sturgeon are found clear up in the Snake River in Idaho. Green sturgeon are strictly in estuaries and the ocean and are not known to run up into freshwater at all.

There is no evidence at all that either green or white sturgeon spawn in Coos Bay. Coos Bay gets only the medium to larger sized sturgeon, which means they're coming from somewhere else. They're a very long-lived species; likely past 100 years old for white sturgeon. It takes approximately 15 years before they're even mature enough to spawn, which is why they can be vulnerable.

Evidence from tagging studies show the fish move around quite a bit. Columbia River whites have been found in Oregon coastal estuaries and as far north as BC and the general understanding is Coos Bay is probably getting white sturgeon from the Columbia River. Whites are probably from spawning areas in the Columbia and possibly the Rogue River.

There is a sturgeon research team out of Clackamas that came down several years ago and did sturgeon tagging up and down the coast. Tom Rien, manager, fisheries research biologist and ODFW manager for the Columbia River Coordination Program (Clackamas), is the project leader for the sturgeon research team. He might also be working with NMFS regarding the eulachon listing. He is a good contact for more specific information related to green sturgeon in Coos Bay from this tagging program. The team conducted either 3 or 4 seasons of sturgeon sampling along the coast, including Coos Bay. In addition, creel sampler staff that check recreational anglers while fishing in Coos Bay record any sturgeon caught.

Where the green sturgeon that enter Coos Bay spawn is not clear. (However, according to Chuck Wheeler of NMFS, if they don't spawn in the Southern DPS they aren't considered threatened.)

ODFW estuary seining that occurs is primarily related to salmonid movement through the estuary. Occasionally they pick up a sturgeon; not so much from seining by from infrequent gillnet sampling.

The Coos River going up to where it forks to the South Coos and Millicoma, the stretch of river below the forks is pretty common for bank angling primarily targeting white sturgeon.

Eulachon

There was a basin report written back in 1990 that refers to eulachon as an occasional visitor to Coos Bay but not having a strong run (Coos Basin report). There hasn't been any sampling that tracks their population numbers. Occasionally eulachon will occur in seining conducted by the ODFW that primarily targets salmonids. Starting in the mid to late 1970s, seining has been conducted annually. ODFW is working with the Coos Watershed Association to get the data into a database that would be available for query for the public. Currently, seining data is not available other than in handwritten sheets.

Additional contact information:

Tom Rien, Fisheries Research Biologist and Manager, Columbia River Coordination Program, ODFW, (971) 673-6061, tom.a.rien@state.or.us.

# SHN ☒Phone ☐Conversation Log

| | | |
|---|---|---|
| Date: September 12, 2013 | Time: 8:10 ☒a.m. ☐p.m. | Job #: 612035 |
| Tel #: 541-888-5515 | ☐ Call To ☒ Call From | |
| Contact: Chris Claire, Habitat Protection Biologist, ODFW | | Job Name: Coos Bay WWTP No. 2 |
| Address: Charleston Field Office | | Logged By: Barb Gimlin |
| Subject: Potential affects to fisheries | | |

Notes

ODFW biologists act in a technical role as a resource advisory for DEQ, DSL, and, to a lesser extent, the USACE (due to the federal nexus and their coordination with NMFS instead). Chris is familiar with the new site for Wastewater Treatment Plant (WWTP) No. 2 and has walked along the channelized drainage on the north and northwest portions of the site with ODOT representatives. ODOT is planning on replacing the culvert for the drainage channel when they redo Empire Boulevard. He thought there is also another culvert located upstream of the site.

Chris stated if the project is going to improve the water quality of the effluent released at the outfall, ODFW is very excited about that and is a huge supporter of such actions. Although it likely isn't practical for the project due to lack of available space, ODFW is very excited about running all outfalls through a small wetland created for post water quality treatment before it gets to a primary production area (i.e., Coos Bay). Nonetheless, he is comfortable with moving forward with the planned use of the existing outfall for improved treatment of the effluent discharged for the new facility.

Impacts related to how stormwater is treated have become a big issue for water quality and fisheries management. He will be sending me a recent article in Washington State about fish dying in an area where every time it rained about half the coho salmon would die. There has been a renewed and very energetic focus on runoff that affects streams and waterways. Resource agencies are now looking at hydrocarbons and other pollutants such as bacteria and fine sediment that come off impervious surfaces during stormwater runoff, with flashiness in particular a problem. Municipal stormwater drainage in Salem and Portland is enough to affect the Willamette River. Locally, there are problems with stormwater oozing off timber lots. There are a lot of potential impacts to water quality from residues that are semi-toxic and it creates a whole new level of perceived government regulation than in previous years.

Mitigation that can be used in new construction projects includes the use nontoxic, permeable concrete for parking lots, driveways, roads, or paths so that water doesn't accumulate or runoff. Permeable surfaces allow water to percolate into the ground below, reducing runoff and filtering solids and pollutants. In Coos Bay, Sol Coast Consulting and Design, LLC, is a local firm that subcontracts to assist with impervious surface management (see: http://solcoast.com/storm-water-management/). The idea is to keep stormwater from running off the site into streams or Coos Bay. Chris said one option for the WWTP No. 2 project may be to pave one road or section that will receive the most traffic, and for the other sections use permeable concrete with collection galleries (3 or 4) that go into flower beds. Then you won't have stormwater runoff and every time it rains you wouldn't have these big releases of stormwater.

Chris mentioned Coos Bay is one of the only bays in the state that has made the commercial shellfish industry productive again. Water quality was exceeding the limits, but they have since cleaned it up.

Chris is available for technical meetings on site and mentioned it is favorable to have a concise running record of feedback from ODFW in the project record. ODFW provides technical assistance regarding stormwater runoff, including overflow management, to help manage release of pollutants. In addition, the shellfish industry doesn't want e coli or artificial nutrients in the bay.

(continued)

Drainage channel: I also asked Chris about the drainage channel and if actions to remove any of the thick riparian vegetation are allowed. He said if it its native woody vegetation, those plants don't encroach on an active stream. The riparian buffer strip helps to manage stormwater at the site and helps to shade the stream. If it has been determined there is a safety issue, ODFW recommends taking a brushhog to cut the vegetation down to approximately 6 feet tall. If any of the species are invasive (i.e., Himalayan blackberries), they can be removed and the state rules are very flexible. Of note, the county planning rules don't apply in city limits. The channel can be used as a positive aspect of the site. For example, if the City continues to maintain the riparian area, it will help to provide shade for the small stream, prevent erosion from leaving the site, and will maintain ecological function at some level despite the stream running through an urbanized area.

# SHN ☒Phone ☐Conversation Log

| | | | |
|---|---|---|---|
| Date: April 29, 2013 | Time: 10:00 ☒a.m. ☐p.m. | Job #: | 611048 |
| Tel #: (360) 902-2524 | ☒ Call To ☐ Call From | | |
| Email: scott.pearson@dfw.wa.gov | | Job Name: | JCEP |
| Contact Name: Scott Pearson, WDFW Biologist | | Logged By: | Barbara Gimlin |
| Subject: Streaked Horned Lark (ESA Proposed as Threatened) | | | Environmental Planner |

| Notes | To Do |
|---|---|
| Scott Pearson is considered an expert regarding the streaked horned lark and has published various reports, including the *Range-wide Streaked Horned lark Assessment and Preliminary Conservation Strategy* with Bob Altman in September 2005 for the Washington Department of Fish and Wildlife, Wildlife Program Science Division.<br><br>Most of Scott's work has been in Washington and in Oregon it has been in the Willamette Valley primarily. Scott has asked the snowy plover folks who monitor the North Spit to let him know if they ever encounter a streaked horned lark [Dave Lauten, deweysage@frontier.com, and Kathleen (Kathy) Castellein].<br><br>Scott said it's possible they could breed on the Oregon coast as they breed along the Washington coast. He wouldn't be surprised at all, as it seems the habitat is ideal-- particularly in areas where there are western snowy plovers, along with the habitat restoration that has occurred. Portions of the North Spit are well-suited for lark habitat. When asked if they could possibly share the same habitat with plovers, he said he found a nest of a lark within 5 meters of a plover in Washington and they use very similar habitat. He noted plovers use more extreme open habitats, whereas the lark needs some vegetation.<br><br>In the sparsely vegetated dune and beach habitats where larks are found, they do not find larks in rolling or steep areas. Where deflation plains occur, larks are often behind the foredune. They also occur where dredge spoils have been deposited or in areas where there is accretion (deposition) of sand causing beach areas to become wider (i.e., due to waves, tides, or currents).<br><br>Streaked horned larks will use small sites when they're immediately adjacent to water (habitat goes right to the open water) and it doesn't always have to be marine. Islands occurring along the Columbia River provide ideal habitat and larks occur on a number of those islands. For sites not adjacent to water, the area of expanse has to be quite large, likely 300 acres or greater, although further studies are needed. Scott is not sure how small such sites would go, but they tend to be pretty big.<br><br>Scott recommended the following additional contacts for more information related the potential of streaked horned larks to occur within the Project vicinity:<br><br>Martin Nugent, diversity division, ODFW, martin.nugent@state.or.us.<br><br>Bob Altman, American Bird Conservancy, baltman@abcbirds.org. Bob co-authored the September 2005 *Range-wide Streaked Horned Lark Assessment and Prelininary Conservation Strategy* with Scott. He also recently published the article *Historical and Current Distribution and Populations of Bird Species in Prairie-Oak Habitats in the Pacific Northwest*, Northwest Science, Issue 85, Vol. 2, 2011.<br><br>Randy Moore, randy.moore@oregonstate.edu, teaches at Oregon State; has done a lot of work in the Willamette Valley but may have been on the coast. | |

# SHN ☒Phone ☐Conversation Log

| | | | | | |
|---|---|---|---|---|---|
| Date: | September 12, 2013 | Time: | 11:30 ☒a.m. ☐p.m. | Job #: | 612035.400 |
| Tel #: | (541) 957-3385 | ☒ Call To | ☐ Call From | Job Name: | Coos Bay WWTP No. 2 |
| Contact: | Ken Phippen, Branch Chief, Oregon Coast Habitat Branch Chief, NMFS, Roseburg Office<br>Ken.Phippen@noaa.gov | | | Logged By: | Barb Gimlin |
| Subject: | City of Coos Bay Wastewater Treatment Plant No. 2 | | | | |

Notes

I called Ken Phippen, Branch Chief for the Oregon Coast Habitat Branch of the National Marine Fisheries Service (NMFS), as a follow-up after briefly discussing the proposed upgrade and expansion by the City of Coos Bay for Wastewater Treatment Plant No. 2 with Jeff Young, NMFS Fisheries Biologist, on September 10. Jeff recommended I contact Ken, as projects are not assigned so much by county as by workload. Jeff also mentioned that due to stormwater and wastewater water quality baseline issues that NMFS has been working on, the project may require formal consultation under Section 7 consultation under the Endangered Species Act.

Ken said things have changed in the last two to three years due to further findings regarding impacts from stormwater constituents. A big issue is copper that is embedded in brake pad materials and released into stormwater from vehicles. NMFS has always talked about petroleum products as sources of pollution, but now on top of that there is copper (from brake pads) and zinc (from other vehicle parts). Copper research in Seattle over the past five years has determined that even in very minute amounts it gets suspended in the water column. When fish basically breathe it in, it blocks the receptors in their skin and affects their normal behavior. An example is when a predator comes by. In normal behavior, pheromones or other such means signal the fish that, "Hey, there's a predator, go hide". Experiments have been conducted with copper concentrations in aquariums with juvenile coho salmon. In water without copper, the juveniles head straight to the bottom when a predator is added. With copper in the water, juveniles don't pick up on the predator(s) and swim around oblivious to the danger, therefore making them easy targets as prey. Ken used this as an example of the bad side effects of copper in stormwater.

Ken said NMFS has stepped up pretty intensively their approach towards stormwater and getting it treated in the last three years. Analysis for copper is carried all the way out to the ocean from inland areas, as once it goes into the system, it stays there.

Regarding use of the existing outfall for the new facility, Ken said if there is an effort being made to upgrade a plant, "all that is great". However, there are still compounds in the effluent that NMFS would want to take a look at and there may be other components in the effluent that may have adverse effects. In addition, while running wastewater from the paved areas through the wastewater collection system (as proposed) may be adequate, further analysis is needed to ensure there is adequate filtration for heavy metal, including copper and zinc.

Ken recommended that I send him a notification by email regarding the project and he will assign a fisheries biologist to the project that will assist in the review and in the development of a Biological Assessment (BA), which he also recommended. Ken said the project will likely require formal consultation to ensure NMFS has a chance to respond with a Biological Opinion to ensure potential adverse effects from the project are mitigated to the maximum extent possible. Jim Muck will likely be the biologist assigned.

# SHN ☐Phone ☐Conversation Log

| | | | |
|---|---|---|---|
| Date: May 9, 2013 | Time: 11:30 ☒a.m. ☐p.m. | | Job #: 611048 |
| Tel #: (541) 957-3379 | ☒ Call To ☐ Call From | | |
| Meeting at: | | | Job Name: JCEP |
| Contact Name: Chuck Wheeler, Fisheries Biologist, Oregon Coast Branch, Oregon State Habitat Office, NMFS | | | Logged By: Barb Gimlin |
| Subject: Eulachon and Green Sturgeon in Coos Bay | | | |

| Notes | To Do |
|---|---|

Chuck provided the following information about eulachon and green sturgeon (both listed as threatened under the ESA) in Coos Bay:

Eulachon

Eulachon spawn in the first part of rivers, i.e., the Coos River or other larger tributaries, but not in the bay. Adults begin moving through the bay as early as December. To spawn, they need moving water and large substrate. That's not going to occur in the estuary, but will occur upstream in the Coos River or other large tributaries feeding into the bay. Spawning typically occurs from January to mid-May, with the peak in February to mid-March. Eggs hatch in 30-40 days and the larvae immediately wash downstream to estuarine and ocean areas where they feed on phytoplankton and zooplankton. When the larvae reach juvenile size, they disperse to the ocean as soon as able. Juveniles may be migrating out as early as February to almost mid-summer. Adult eulachon don't always die after spawning so they could return to the ocean. There is currently little information available about eulachon movement in Coos Bay and its nearshore marine areas.

Green Sturgeon

The green sturgeon population that is listed as threatened is the population that spawns in California (Sacramento River). The Sacramento River has a lot of issues, which is why the species is threatened. If they spawn in Oregon, they are not threatened. Southern DPS green sturgeon. Green sturgeon are routinely found in Washington State estuaries, hence the likelihood of their occurrence also along the Oregon Coast. From the monitoring that has occurred, they typically occur in estuaries from June to October. Sturgeon typically occur in deep water resting and then come into shallow areas for feeding.

******

Not much is known about either species outside of the general biology for each fish.

# APPENDIX Q-2

ODFW 2012 Threatened and Endangered Species List

## Threatened, Endangered, and Candidate Fish and Wildlife Species in Oregon

The State of Oregon and the federal government maintain separate lists of threatened and endangered (T&E) species. These are species whose status is such that they are at some degree of risk of becoming extinct.

Under State law (ORS 496.171-496.192) the Fish and Wildlife Commission through ODFW maintains the list of native wildlife species in Oregon that have been determined to be either “threatened” or “endangered” according to criteria set forth by rule (OAR 635-100-0105).

Plant listings are handled through the Oregon Department of Agriculture.

Most invertebrate listings are handled through the Oregon Natural Heritage Program.

Under federal law the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration share responsibility for implementing the federal Endangered Species Act of 1973 (Public Law 93-205, 16 U.S.C. § 1531), as amended. In general, USFWS has oversight for land and freshwater species and NOAA for marine and anadromous species. In addition to information about species already listed, the USFWS-Oregon Field Office maintains a list of Species of Concern.

Additional information about the federal programs in place in Oregon can be found at the following websites:
• U.S. Fish and Wildlife-Oregon (http://www.fws.gov/oregonfwo)
• Northwest Region of NOAA-Fisheries (http://www.nwr.nmfs.noaa.gov)

**Threatened, Endangered, and Candidate Fish and Wildlife Species in Oregon**
**(T=threatened, E=endangered, C=candidate, DPS=Distinct Population Segment)**

| Common Name | Scientific Name | State status | Federal status |
|---|---|---|---|
| **FISH** | | | |
| Borax Lake Chub | *Gila boraxobius* | E | E |
| Bull Trout (Range-wide) | *Salvelinus confluentus* | | T |
| Columbia River Chum Salmon | *Oncorhynchus keta* | | T |
| Foskett Speckled Dace | *Rhinichthys osculus* ssp | T | T |
| Green sturgeon (Southern DPS) | *Acipenser medirostris* | | T |
| Hutton Spring Tui Chub | *Gila bicolor* ssp. | T | T |
| Lahontan Cutthroat Trout | *Oncorhynchus clarki henshawi* | T | T |
| Lost River Sucker | *Deltistes luxatus* | E | E |
| Lower Columbia River Chinook Salmon | *Oncorhynchus tshawytscha* | | T |
| Lower Columbia River Coho Salmon | *Oncorhynchus kisutch* | E | T |
| Lower Columbia River Steelhead | *Oncorhynchus mykiss* | | T |
| Middle Columbia River Steelhead | *Oncorhynchus mykiss* | | T |
| Modoc sucker | *Catostomus microps* | | E |
| Oregon Chub | *Oregonichthys crameri* | | T |
| Oregon Coast Coho Salmon | *Oncorhynchus kisutch* | | T |
| Pacific Eulachon/Smelt (Southern DPS) | *Thaleichthys pacificus* | | T |
| Shortnose Sucker | *Chasmistes brevirostris* | E | E |
| Snake River Chinook Salmon (Fall) | *Oncorhynchus tshawytscha* | T | T |
| Snake River Chinook Salmon (Spring/Summer) | *Oncorhynchus tshawytscha* | T | T |
| Snake River Sockeye Salmon | *Oncorhynchus nerka* | | E |
| Snake River Steelhead | *Oncorhynchus mykiss* | | T |
| Southern Oregon Coho Salmon | *Oncorhynchus kisutch* | | T |
| Upper Columbia River Spring Chinook Salmon | *Oncorhynchus tshawytscha* | | E |
| Upper Columbia River Steelhead | *Oncorhynchus mykiss* | | T |
| Upper Willamette River Chinook Salmon | *Oncorhynchus tshawytscha* | | T |

| Common Name | Scientific Name | State status | Federal status |
|---|---|---|---|
| Upper Willamette River Steelhead | *Oncorhynchus mykiss* | | T |
| Warner Sucker | *Catostomus warnerensis* | T | T |
| | | | |
| **AMPHIBIANS AND REPTILES** | | | |
| Columbia spotted frog | *Rana luteiventris* | | C |
| Green Sea Turtle | *Chelonia mydas* | E | E |
| Leatherback Sea Turtle | *Dermochelys coriacea* | E | E |
| Loggerhead Sea Turtle | *Caretta caretta* | T | T |
| Oregon spotted frog | *Rana pretiosa* | | C |
| Pacific Ridley Sea Turtle | *Lepidochelys olivacea* | T | T |
| | | | |
| **BIRDS** | | | |
| Bald Eagle | *Haliaeetus leucocephalus* | T | |
| Brown Pelican | *Pelecanus occidentalis* | E | E |
| California Least Tern | *Sterna antillarum browni* | E | E |
| Marbled Murrelet | *Brachyramphus marmoratus* | T | T |
| Northern Spotted Owl | *Strix occidentalis caurina* | T | T |
| Short-tailed Albatross | *Diomedea albatrus* | E | E |
| Streaked horned lark | *Eremophila alpestris strigata* | | C |
| Western Snowy Plover | *Charadrius alexandrinus nivosus* | T | T (Coastal population only) |
| Yellow-billed cuckoo | *Coccyzus americanus* | | C |
| | | | |
| **MAMMALS** | | | |
| Blue Whale | *Balaenoptera musculus* | E | E |
| Columbian White-tailed Deer(Lower Columbia River population only) | *Odocolieus virginianus leucurus* | | E |
| Fin Whale | *Balaenoptera physalus* | E | E |
| Fisher | *Martes pennanti* | | C |
| Gray Whale | *Eschrichtius robustus* | E | |
| Gray Wolf | *Canis lupus* | E | E |
| Humpback Whale | *Megaptera novaeangliae* | E | E |
| Kit Fox | *Vulpes macrotis* | T | |
| North Pacific Right Whale | *Eubalaena japonica* | E | E |
| Northern (Steller) Sea Lion | *Eumetopias jubatus* | | T |
| Sea Otter | *Enhydra lutris* | T | T |
| Sei Whale | *Balaenoptera borealis* | E | E |
| Sperm Whale | *Physeter macrocephalus* | E | E |
| Washington Ground Squirrel | *Spermophilus washingtoni* | E | |
| Wolverine | *Gulo gulo* | T | |

# APPENDIX Q-3

ORBIC 2013 Rare-Threatened-Endangered Species in Oregon

# RARE, THREATENED AND ENDANGERED SPECIES OF OREGON

## OREGON BIODIVERSITY INFORMATION CENTER

July 2013

# Oregon Biodiversity Information Center
# Institute for Natural Resources
# Portland State University

PO Box 751, Mail Stop: INR
Portland, OR 97207-0751
(503) 725-9950
*http://orbic.pdx.edu*



With assistance from:

U.S. Forest Service
Bureau of Land Management
U.S. Fish and Wildlife Service
NatureServe
The Nature Conservancy
Oregon Parks and Recreation Department
Oregon Department of State Lands
Oregon Department of Fish and Wildlife
Oregon Department of Agriculture
Native Plant Society of Oregon


Compiled and published by the following staff at the Oregon Biodiversity Information Center:


Jimmy Kagan, Director/Ecologist
Sue Vrilakas, Botanist/Data Manager
Cliff Alton, IS Manager
Kathy Howell, Volunteer
John Christy, Wetlands Ecologist/Bryologist
Eleanor Gaines, Zoologist
Lindsey Wise, Botanist/Data Manager


Cover Photo: *Euphydryas editha taylori* (Taylor's checkerspot butterfly). Photo by Dana Ross, used with permission.


ORBIC Street Address: Portland State University, Science and Education Center Building, 2118 SW Fifth Ave., Suite 140, Portland, Oregon, 97201

ORBIC Mailing Address: Portland State University, Mail Stop INR, PO Box 751, Portland, Oregon 97207-0751



Bibliographic reference to this publication should read:

Oregon Biodiversity Information Center. 2013. Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources, Portland State University, Portland, Oregon. 111 pp.

# CONTENTS

Extinction is a natural process. Today, however, plant and animal species are disappearing world-wide at an accelerated pace. Based on current trends, half of the species on earth will be extinct within the next 100 years. The major reasons for this are human caused changes to the environment, which continue to increase - in Oregon and throughout the world.

Once lost, a species can never be recovered, and there is no way of knowing how useful it may have been. We do know that human beings and many of their industries depend on plant and animal products. About 50% of all pharmaceuticals have a natural component as an active ingredient, yet less than one percent of the world's species have been chemically analyzed and tested. Many insects and plants contain undescribed and highly functional compounds.

*Limnanthes pumila* subsp. *grandiflora*, or wooly meadow-foam, a rare plant that grows in southwest Oregon, has been found to produce a hybrid with the more common member of the genus, *Limnanthes alba*. This hybrid grows well in the poorly drained soils of the Willamette Valley and produces a valuable oil used for soaps, plastic and rubber production. In addition, the new hybrid meadow-foam does not require the field burning necessary for other crops. This species, and many other Oregon natives, will be lost without intervention. The purpose of this publication is to provide land managers, owners and interested parties with a list of those species in Oregon which are in greatest jeopardy.

**Oregon State Endangered Species Programs**

In 1987, the Oregon Legislature passed an Endangered Species Act which gave the Oregon Department of Agriculture (ODA) responsibility and jurisdiction over threatened and endangered plants, and reaffirmed the Oregon Department of Fish and Wildlife's (ODFW) responsibility for threatened and endangered fish and wildlife. Both of these agencies have entered into cooperative (Section 6) agreements with the United States Fish and Wildlife Service (USFWS) for the purpose of carrying out research and conservation programs for animals and plants under the auspices of the federal Endangered Species Act. Oregon Parks and Recreation Department (OPRD) has a similar agreement with USFWS for invertebrates. More information on the state endangered species programs can be found at the beginning of the animal and plant sections of this booklet.

**Oregon Biodiversity Information Center**

The Oregon Biodiversity Information Center (ORBIC) is part of the Institute for Natural Resources (INR) located at Portland State University (PSU). ORBIC maintains extensive databases of Oregon biodiversity, concentrating on rare and endangered plants, animals and ecosystems.

ORBIC is managed by PSU, but has been a cooperative project, with significant support from Oregon Parks and Recreation, the Department of State Lands, The Nature Conservancy in Oregon, U.S. Fish and Wildlife Service (USFWS), the Bureau of Land Management (BLM), the U.S. Forest Service (USFS) and Oregon State University. Biologists working for these agencies, together with the state's herbaria and museums, provide most of the information that comprise ORBIC's databases. ORBIC also manages the state Natural Areas Program, for OPRD, as well as their Section 6 invertebrate program. ORBIC is also affiliated with the Natural Heritage U.S. network with information being coordinated by the NatureServe organization.

This booklet has been compiled using the most current information available on the distribution and abundance of plants and animals native to Oregon. Although based on a large volume of information, it is by no means complete. Much is known about some species, very little about others. ORBIC welcomes additional information or recommendations regarding any of the taxa listed herein. Such information, as well as data requests, should be directed to:

Oregon Biodiversity Information Center
Institute for Natural Resources
Portland State University
Mail Stop: INR
PO Box 751
Portland, Oregon 97207-0751

Or, send an e-mail to *inrdata@pdx.edu*.

On-line versions of the booklet can be found at *http://orbic.pdx.edu*.

**Outline**

This booklet is divided into animal and plant (including fungi) sections. The sections begin with a description of the animal and plant programs in the state and are followed by the main list of animals and plants. For animals, the list is first divided into major groups (fish, amphibians, reptiles, mammals, birds, and invertebrates) and then arranged alphabetically by scientific name. Invertebrates are further divided by class and order. The plant list is first divided into four groups (vascular plants, non-vascular plants, lichens and fungi) and then alphabetized by scientific name. The information for each taxa includes the scientific and common names with authorities for plants, county, ecoregion, and adjacent state distribution information; the state and federal status; and the NatureServe/Heritage Network Global and State ranks, as well as the ORBIC list. Distribution abbreviations are listed and explained below.

**Criteria and Definitions**

Inclusion of any given taxon on these lists is based on several specific criteria. The most important factors are the total number of known, extant populations in Oregon and world-wide, and the degree to which they are potentially or actively threatened with destruction. Other criteria include the number of known populations considered to be securely protected, the size of the various populations, and the ability of the taxon to persist at known sites. The taxonomic distinctness of each species also has been considered. Hybrids or questionable, undescribed species have not been included, although undescribed taxa recognized by the scientific community in Oregon are included.

Taxonomic experts who were consulted are listed in the Acknowledgments section. All of these criteria are considered in the development of NatureServe/ Heritage Network species ranks as well.

Definitions and explanations of the various ranks and federal and state status are included on page 4, and summarized on the back inside cover along with a list of abbreviations. A number of definitions and criteria specific to animals (wintering or breeding ranks in birds) are discussed in detail at the beginning of the animal section of this booklet.

## DISTRIBUTION INFORMATION

**Distribution Information**

The distribution information included on the lists represents both the current and historic, documented distribution of the taxa.

The information is in the following format: Ecoregion; State (and/or Canadian Province); and County. Out-of-state distribution information is complete for plant and animal taxa on ORBIC List 1 (which are usually Oregon or regional endemics). For all other taxa, all adjacent states or the closest state with occurrences will be listed; a plus (+) signifies that the taxa is found in additional states. Taxa with no other states noted are Oregon endemics. For the most part, the Ecoregion, County and State distribution is based on both historic and current information. Any additional input on distribution will be incorporated in future updates of this publication.

**Ecoregions**

The map on the following page divides the state into nine distinct regions based on geologic and vegetative patterns. The map and the regions are based on EPA's Level 3 ecoregions. The Ecoregions are: CR = Coast Range, WV = Willamette Valley, KM = Klamath Mountains, WC = West Cascade Range and Crest, EC = East Cascade Range, BM = Blue Mountains, BR = Northern Basin and Range, CB = Columbia Basin, and ME=Marine & Estuarine.

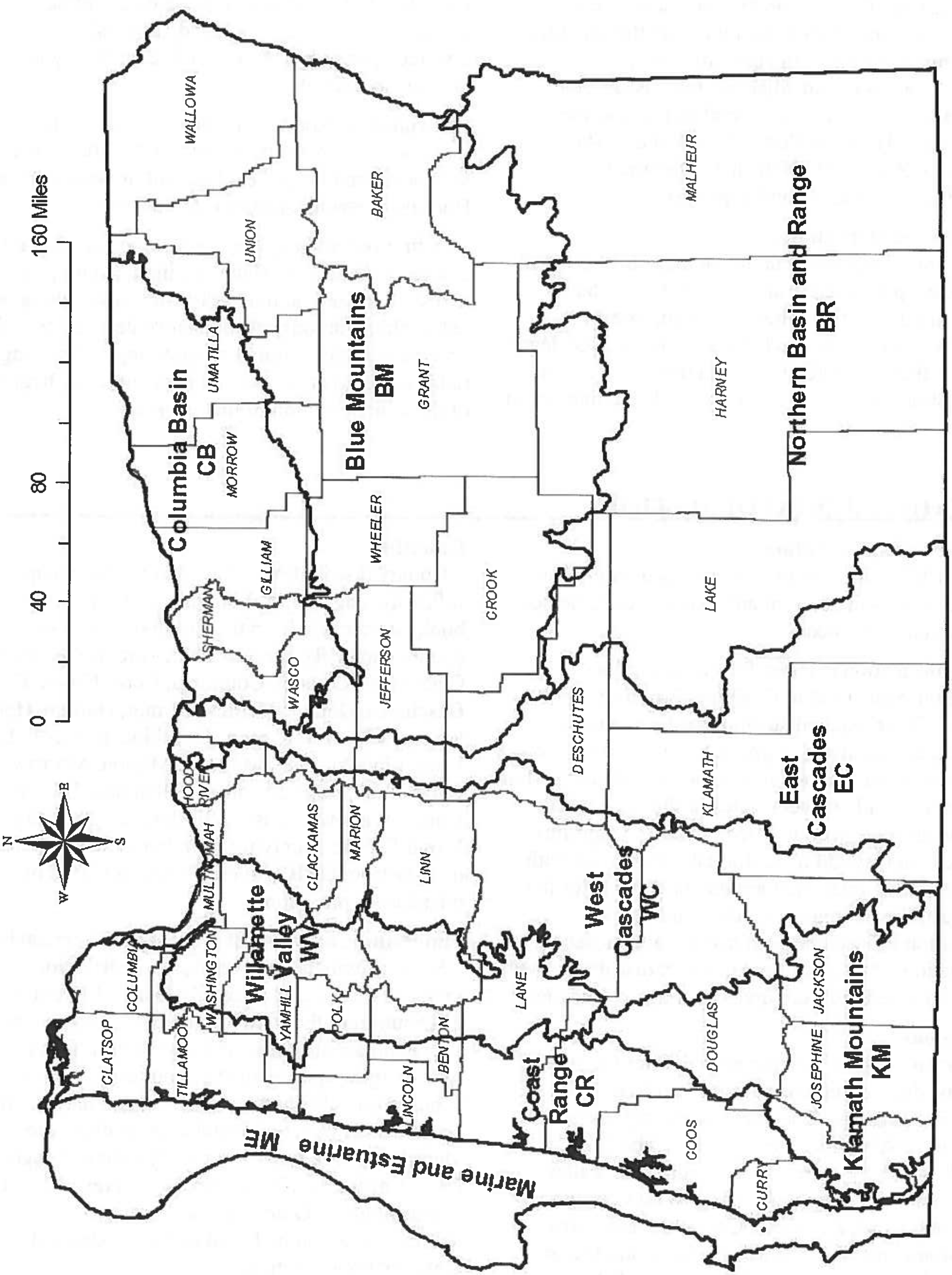
**Counties**

County distribution is keyed to the base map on the following page. The abbreviations used in the booklet are made from the first four letters of each county name. The county names are: Baker, Benton, Clackamas, Clatsop, Columbia, Coos, Crook, Curry, Deschutes, Douglas, Gilliam, Grant, Harney, Hood River, Jackson, Jefferson, Josephine, Klamath, Lake, Lane, Lincoln, Linn, Malheur, Marion, Morrow, Multnomah, Polk, Sherman, Tillamook, Umatilla, Union, Wallowa, Wasco, Washington, Wheeler, and Yamhill. The county information included is based on data from ORBIC files. Please notify us of mistakes or omissions.

**States and Canadian Provinces and Territories**

State, provincial, and territorial distribution is included on the lists primarily to alert biologists to the distribution of these rare, threatened, and endangered taxa in adjacent states. The distribution for the more wide ranging species in states not adjacent to Oregon is based on published information and may not be complete. Two-letter postal abbreviations are used to identify these regions. States adjacent to Oregon are: CA = California, ID = Idaho, NV = Nevada, and WA = Washington. Other state and province abbreviations can be found in the "Codes and Abbreviations" section.

## OREGON MAP WITH ECOREGIONS AND COUNTIES



## DEFINITIONS

**Endangered** taxa are those which are in danger of becoming extinct within the foreseeable future throughout all or a significant portion of their range.

**Threatened** taxa are those likely to become endangered within the foreseeable future.

**LE** = Listed Endangered. Taxa listed by the USFWS or the National Marine Fisheries Service (NOAA Fisheries) as Endangered under the Endangered Species Act (ESA), or by the ODA or ODFW under the Oregon Endangered Species Act of 1987 (OESA).

**LT** = Listed Threatened. Taxa listed by the USFWS, NOAA Fisheries, ODA, or ODFW as Threatened.

**PE** = Proposed Endangered. Taxa proposed by the USFWS or NOAA Fisheries to be listed as Endangered under the ESA or by ODFW or ODA under the OESA.

**PT** = Proposed Threatened. Taxa proposed by the USFWS or NOAA Fisheries to be listed as Threatened under the ESA or by ODFW or ODA under the OESA.

**C** = Candidate. Taxa for which NOAA Fisheries or USFWS have sufficient information to support a proposal to list under the ESA, or which is a candidate for listing by the ODA under the OESA.

**SOC** = Species of Concern. Taxa which the USFWS is reviewing for consideration as Candidates for listing under the ESA.

**PS** = Partial Status. Taxa for which some but not all infraspecific taxa have status.

### Lists Following Animal and Plant Sections

In addition to the main lists summarizing information on animals and plants, this booklet includes the agency lists compiled from the most recent information available:

- Federal and State, listed and proposed animals (USFWS, NOAA Fisheries, ODFW)
- Federal candidate (USFWS, NOAA Fisheries) and species of concern (USFWS) animals
- State sensitive animals (ODFW)
- Federal listed, proposed and candidate plants, and species of concern (USFWS)
- State listed and candidate plants (ODA)

The criteria for the ORBIC lists are as follows:

**List 1** contains taxa that are threatened with extinction or presumed to be extinct throughout their entire range.

**List 2** contains taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon. These are often peripheral or disjunct species which are of concern when considering species diversity within Oregon's borders. They can be very significant when protecting the genetic diversity of a taxon. ORBIC regards extreme rarity as a significant threat and has included species which are very rare in Oregon on this list.

**List 3** contains taxa for which more information is needed before status can be determined, but which may be threatened or endangered in Oregon or throughout their range.

**List 4** contains taxa which are of conservation concern but are not currently threatened or endangered. This includes taxa which are very rare but are currently secure, as well as taxa which are declining in numbers or habitat but are still too common to be proposed as threatened or endangered. While these taxa may not currently need the same active management attention as threatened or endangered taxa, they do require continued monitoring.

**Drops and Name Changes** contains taxa deleted or had their names changed from the previous edition (October 2010).

### NatureServe/Natural Heritage Network Ranks

ORBIC participates in an international system for ranking rare, threatened and endangered species throughout the world. The system was developed by The Nature Conservancy and is now maintained by NatureServe in cooperation with Heritage Programs and Conservation Data Centers in all fifty states (plus the Navajo Nation, Tennessee Valley Authority, Puerto Rico and the Virgin Islands), all of Canada except for two territories, and many Latin American countries.

**Rank Definitions**

The ranking is a 1-5 scale, based primarily on the number of known occurrences, but also including threats, sensitivity, area occupied, and other biological factors. In this booklet, the ranks occupy two lines. The top line is the Global Rank and begins with a "G". If the taxon has a trinomial (a subspecies, variety or recognized race), this is followed by a "T" rank indicator. The second line is the State Rank and begins with the letter "S". The ranks are summarized below (see page 6 for migratory bird ranks):

1 = Critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation, typically with 5 or fewer occurrences.
2 = Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction (extirpation), typically with 6-20 occurrences.
3 = Rare, uncommon or threatened, but not immediately imperiled, typically with 21-100 occurrences.
4 = Not rare and apparently secure, but with cause for long-term concern, usually with more than 100 occurrences.
5 = Demonstrably widespread, abundant, and secure.
H = Historical Occurrence, formerly part of the native biota with the implied expectation that it may be rediscovered.
X = Presumed extirpated or extinct.
U = Unknown rank.
NR = Not yet ranked.

**Rank Qualifiers**

Q = Questionable taxonomy. Global ranks sometimes have a "Q" at the end. This indicates that there are questions related to the taxonomic validity of the taxon.
? = Inexact Numeric Rank. Taxa that can be ranked, but for which the rank is not certain. Ranks with a "?" indicate that the rank is probably correct, but that either documentation is lacking or there is still some uncertainty. Such ranks are always provisional.
Range Ranks = Ranks with more than one value. These can be G1G2, G1G3, etc. These indicate that the predicted final rank would be within the range, but with no indication of preference among the possibilities.

More details on the Heritage Ranking system and more definitions can be found at the NatureServe web site: *http://www.natureserve.org/explorer/ranking.htm*

## SPECIAL ANIMALS

Information on Oregon's rare, threatened and endangered animal species is presented here in two formats. The first is a list summarizing the distribution, federal and state status, and Heritage Network rank of the species as described on pages 4 and 5. The second format breaks the species into lists based on their status.

In both formats, the special animals are divided into major groups (fish, amphibians, reptiles, birds, mammals, invertebrates), then listed alphabetically by scientific name. The invertebrate summary list is unique in being further subdivided into class and order.

The animals included in this booklet are those rare, threatened and endangered vertebrate and invertebrate species that are native to Oregon and have (or have had) sustained breeding populations within the state. Open-ocean mammals or sea turtles which generally occur offshore and do not breed in Oregon are not included in this book. Wintering bird species and those which occur on an accidental or occasional basis present special problems which are described below.

### Animal Species Tracked

ORBIC strives to serve as a clearinghouse of information regarding site-specific locations of rare, threatened and endangered species in Oregon. The goal is to obtain and computerize information for all locations of all state and federally listed animal species. Location data is also computerized for other animal species that are rare (of limited abundance or restricted distribution), threatened, endangered or otherwise vulnerable in Oregon, based on the NatureServe/Natural Heritage Network ranks. Locations for a species are tracked only if it is possible to track all sites in the state.

Ranking decisions are made based on the best available information. Comments on ranks or on the inclusion or exclusion of taxa are welcome. Funds are not currently available to track all species of concern and all ODFW Sensitive Species, although ORBIC tracks as many of these as possible.

ORBIC maintains computerized information for all animal species on ORBIC Lists 1 and 2. There are several accidental or occasional breeding birds that are not tracked, even though they rank out highly. Since most of these species are well outside their normal range, effort is better spent on species which are part of Oregon's usual fauna. Additionally, ORBIC maintains manual files and observation data for all animal species in this booklet.

ORBIC encourages everyone to send in any information, reports or observations for the special animal species listed. A form for providing animal data is available at *http://orbic.pdx.edu/documents/animalform.pdf* Information need not be limited to this format to be considered for submission.

## Animal Lists and Wildlife State Ranks

### Fish

All vertebrate taxa in this booklet have published or soon to be published valid names, except for some fish taxa. These fish are represented on the lists by their Evolutionarily Significant Unit (ESU) designation. The ESU designations are defined by NOAA Fisheries under their ESA responsibility. ORBIC tracks and ranks all listed, proposed and candidate ESUs for anadromous fish. For listed or proposed anadromous fish, spawning and rearing areas are mapped as well as, but separately from, migratory corridors. As a result, there are a few listed salmon tracked which may never have spawned in Oregon, but which travel through the waters of the state. ODFW evaluates and manages anadromous and freshwater fish populations within areas defined as Species Management Units (SMU). For salmonids, these areas generally align with ESUs identified by NOAA. In cases of a sensitive fish species which has no NOAA-identified ESU, we track the SMU as identified by ODFW.

### Birds

Avian species are usually placed on the ORBIC Lists based on breeding populations. Some species may be common in winter or migration but rare as breeders in Oregon. In these instances it is only the breeding populations that are of concern (e.g. horned grebe, bufflehead). Species that occur in Oregon in migration or as winter residents only are generally not considered here, except for especially sensitive species with critical staging or wintering locations in Oregon (e.g. Aleutian Canada goose, California brown pelican). There are several bird species that have nested in Oregon on occasion (semipalmated plover, black-chinned sparrow) but are not yet considered established breeders. For now these species are not included on the list, pending more accurate determination of their breeding status. Species of accidental occurrence are not included either.

The NatureServe/ORBIC state ranks for migratory species (mainly birds) require further explanation. State ranks for long-distance migrants are separated by the breeding and nonbreeding components of the population. State ranks followed by a 'B' refer to breeding populations, while ranks followed by an 'N' refer to a nonbreeding (often wintering) population. Thus a state rank of S1B, S2N indicates that the breeding portion of the population is extremely rare and the wintering portion is slightly more common. If a species occurs in the state only during the breeding season it will only have an S#B rank. Similarly, if a species only occurs in Oregon during the nonbreeding season it will have an S#N rank. Species which are not long-distance migrants are ranked without the B or N modifier.

### Invertebrates

Compilation of the invertebrate lists has been especially challenging. Little is known about the status and distribution of most invertebrate taxa found in Oregon, especially those which appear to be rare, threatened or otherwise vulnerable. Most invertebrate groups are under-collected and under-observed. As a result state ranks may not accurately reflect the true population status for some species. Currently ORBIC assigns these species a state ranking number but the "?" modifier is occasionally used to indicate species that may be rarely collected as opposed to truly rare.

The Natural Areas Program of the Oregon Parks and Recreation Department has been granted limited authority to assist in conserving invertebrates through a cooperative agreement with the USFWS via Section 6 of the Endangered Species Act. ORBIC provides staff to help manage this program. It is hoped that with the cooperation of conservation organizations, state agencies and federal agencies, additional information can be gathered to help understand and conserve rare, threatened and endangered invertebrates in Oregon.

## Oregon Department of Fish and Wildlife's Threatened, Endangered and Sensitive Species Program – ODFW

Martin Nugent, Threatened, Endangered and Sensitive Species Coordinator
Eric Rickerson, Assistant Administrator, Wildlife Division

The Oregon Department of Fish and Wildlife (ODFW) maintains a list of threatened and endangered species under the authority of ORS 496.172, the Oregon Endangered Species Act, 1987. The list included in this booklet reflects ODFW's revisions as of October 2013. There are currently 32 taxa on the list. The list includes 12 marine animals (i.e. whales, sea turtles, pelagic birds) that are not included in this book. The Act requires state agencies to develop programs for the management and protection of endangered species, and requires agencies to comply with guidelines adopted by the Oregon Fish and Wildlife Commission for threatened species. The Oregon Fish and Wildlife Commission has adopted administrative rules, OAR 635-100-100 to 130, which clarify the Act and provide criteria for listing, delisting and protection of listed species.

Oregon Department of Fish and Wildlife maintains a Sensitive Species list in accordance with OAR 635-100-0040 which is designed to provide a positive, proactive approach to species conservation. The Sensitive Species list focuses fish and wildlife management and research activities on species that need conservation attention. Although the intent of the Sensitive Species list is to prevent species from declining to the point of qualifying as threatened or endangered, this list is not used as a "candidate" list for species to be considered for listing under the Oregon Threatened and Endangered Species rules. The Sensitive Species list serves as an early warning system for biologists, land managers, policy makers, and the public. It helps ensure that conservation actions are prioritized, cost-efficient, and effective. The sensitive species list is updated by ODFW every five years. The sensitive species list was last revised in 2008.

"Sensitive species" are those naturally-reproducing fish and wildlife species, subspecies, or populations which are facing one or more threats to their populations and/or habitats. Implementation of appropriate conservation measures to address the threats may prevent them from declining to the point of qualifying for threatened or endangered status.

Sensitive species categories are defined as follows:

**"Critical"** sensitive species (SC) are imperiled with extirpation from a specific geographic area of the state because of small population sizes, habitat loss or degradation, and/or immediate threats. Critical species may decline to point of qualifying for threatened or endangered status if conservation actions are not taken.

**"Vulnerable"** sensitive species (SV) are facing one or more threats to their populations and/or habitats. Vulnerable species are not currently imperiled with extirpation from a specific geographic area or the state but could become so with continued or increased threats to populations and/or habitats.

All efforts towards management and protection of threatened, endangered and sensitive species in Oregon will be coordinated with other state and federal agencies and private conservation organizations. The current threatened and endangered species list is available on ODFW's website at: *http://www.dfw.state.or.us/wildlife/diversity/species/threatened_endangered_species.asp*. The sensitive species list is available at: *http://www.dfw.state.or.us/wildlife/diversity/species/sensitive_species.asp*

Copies of the Oregon Endangered Species Act or administrative rules, or the Sensitive Species rule, or lists of the threatened and endangered or sensitive species may also be requested from the department by writing to:

**Oregon Department of Fish and Wildlife**
**4034 Fairview Industrial Drive SE**
**Salem, OR 97302**

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| **FISH** | | | | | |
| *Acipenser medirostris*<br>Green sturgeon (Northern DPS) | CR, ME, WV?; CA, WA+<br>Clat, Colu, Coos, Curr, Doug, Lane, Linc, Mult?, Till | G3<br>S3 | SOC | -- | 4 |
| *Acipenser medirostris*<br>Green sturgeon (Southern DPS) | CR, ME, WV?; CA, WA+<br>Clat, Colu, Coos, Curr, Doug, Lane, Mult?, Till? | GNR<br>S2?N | LT | -- | 3 |
| *Catostomus microps*<br>Modoc sucker | EC; CA<br>Lake | G2<br>S1 | LE | SC | 1 |
| *Catostomus occidentalis lacusanserinus*<br>Goose Lake sucker | EC; CA<br>Lake | G5T2Q<br>S2 | SOC | SV | 1 |
| *Catostomus rimiculus*<br>Jenny Creek sucker | EC, KM, WC; CA<br>Jack | G5T2Q<br>S2 | SOC | -- | 1 |
| *Catostomus snyderi*<br>Klamath largescale sucker | EC; CA<br>Klam, Lake | G3<br>S3 | SOC | -- | 4 |
| *Catostomus tahoensis*<br>Tahoe sucker | BR; CA, NV<br>Malh | G5<br>S1 | -- | -- | 2 |
| *Catostomus warnerensis*<br>Warner sucker | BR; NV<br>Lake | G1<br>S1 | LT | LT | 1 |
| *Chasmistes brevirostris*<br>Shortnose sucker | EC; CA<br>Klam, Lake | G1<br>S1 | LE | LE | 1 |
| *Cottus bendirei*<br>Malheur mottled sculpin | BM, BR, CR, WC, WV; WA +<br>Colu, Gran, Harn, Lane, Linn, Wash | G4Q<br>S4 | SOC | -- | 4 |
| *Cottus marginatus*<br>Margined sculpin | BM, CB; WA<br>Morr, Umat | G3<br>S3 | SOC | -- | 4 |
| *Cottus pitensis*<br>Pit sculpin | EC; CA<br>Lake | G4<br>S1 | -- | -- | 2 |
| *Cottus tenuis*<br>Slender sculpin | EC<br>Klam, Lake | G3<br>S3 | SOC | -- | 3 |
| *Deltistes luxatus*<br>Lost River sucker | EC; CA<br>Klam | G1<br>S1 | LE | LE | 1 |
| *Entosphenus lethophagus*<br>Pit-Klamath brook lamprey | EC; CA<br>Jack, Klam, Lake | G3G4<br>S3 | -- | -- | 4 |
| *Entosphenus minimus*<br>Miller Lake lamprey | EC, WC<br>Klam, Lake | G3<br>S2 | SOC | SV | 4 |
| *Entosphenus tridentatus*<br>Pacific lamprey | BM, CB, CR, EC, KM, ME, WC, WV; CA, ID, WA +<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Doug, Gill, Gran, Hood, Jack, Jose, Klam, Lake, Lane, Linc, Linn, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Yamh | G4<br>S2 | SOC | SV | 2 |
| *Entosphenus tridentatus* ssp.<br>Goose Lake lamprey | EC; CA<br>Lake | G4T1<br>S1 | SOC | -- | 1 |
| *Gila alvordensis*<br>Alvord chub | BR; NV<br>Harn | G2<br>S2 | SOC | SV | 1 |
| *Gila bicolor eurysoma*<br>Sheldon tui chub | BR; NV<br>Lake | G4T1<br>S1 | SOC | -- | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Gila bicolor oregonensis* Oregon Lakes tui chub | BR, EC Lake | G4T2 S2 | SOC | -- | 1 |
| *Gila bicolor* ssp. Catlow tui chub | BR Harn, Lake | G4T1 S1 | SOC | -- | 1 |
| *Gila bicolor* ssp. Hutton tui chub | BR Lake | G4T1 S1 | LT | LT | 1 |
| *Gila bicolor* ssp. Summer Basin tui chub | BR Lake | G4T1 S1 | SOC | SC | 1 |
| *Gila bicolor* ssp. Warner Basin tui chub | BR Lake | G4T2Q S2 | -- | -- | 1 |
| *Gila bicolor thalassina* Goose Lake tui chub | EC; CA Lake | G4T2T3 S2 | -- | -- | 1 |
| *Gila boraxobius* Borax Lake chub | BR Harn | G1 S1 | LE | LE | 1 |
| *Lampetra ayresii* River lamprey | CR, ME; CA, WA + Clat, Colu, Coos, Doug, Linc, Till | G4 S3? | SOC | -- | 3 |
| *Lampetra richardsoni* Western brook lamprey | BM, CB, CR, EC, KM, WC, WV; CA, WA, AK, BC Clac, Clat, Colu, Coos, Curr, Doug, Gill, Hood, Jack, Jose, Lane, Linc, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4G5 S4 | -- | SV | 4 |
| *Lavinia symmetricus mitrulus* Pit roach | EC; CA Lake | G4T2 S2 | SOC | -- | 2 |
| *Oncorhynchus clarkii* Coastal cutthroat trout (Oregon Coast ESU) | CR, KM, ME, WC, WV Bent, Clat, Colu, Coos, Curr, Doug, Lane, Linc, Polk, Till, Wash, Yamh | G4T3Q S3 | SOC | -- | 4 |
| *Oncorhynchus clarkii* Coastal cutthroat trout (Southern Oregon/California Coasts ESU) | CR, KM, ME, WC; CA Curr, Jack, Jose | G4TNRQ S3? | SOC | -- | 4 |
| *Oncorhynchus clarkii* Coastal cutthroat trout (Southwestern Washington/Columbia River ESU) | CB, CR, EC, ME, WC, WV; WA Clac, Clat, Colu, Hood, Mari, Mult, Wasc, Wash | G4T3Q S2 | SOC | SV | 1 |
| *Oncorhynchus clarkii* Coastal cutthroat trout (Upper Willamette River ESU) | CR, ME, WC, WV Bent, Clac, Clat, Colu, Lane, Linc, Linn, Mari, Mult, Polk, Wash, Yamh | G4TNRQ S3? | SOC | -- | 4 |
| *Oncorhynchus clarkii alvordensis* Alvord cutthroat trout | BR; NV Harn | G4TX SX | -- | -- | 1-ex |
| *Oncorhynchus clarkii henshawi* Lahontan cutthroat trout | BR; CA, NV Harn, Malh | G4T3 S1 | LT | LT | 2 |
| *Oncorhynchus clarkii lewisi* Westslope cutthroat trout (SC in Upper John Day Basin only) | BM; ID, WA + Gran | G4T3 S3 | SOC | SC | 1 |
| *Oncorhynchus keta* Chum salmon (Columbia River ESU) | CR, ME, WC, WV; WA Clat, Colu, Mult | G5T2Q S2 | LT | SC | 1 |
| *Oncorhynchus keta* Chum salmon (Pacific Coast ESU) | CR, ME; CA, WA Clat, Coos, Doug, Lane, Linc, Till | G5T3Q S2 | -- | SC | 2 |
| *Oncorhynchus kisutch* Coho salmon (Lower Columbia River ESU) | CB, CR, EC, ME, WC, WV; WA Clac, Clat, Colu, Hood, Mari, Mult, Wasc | G4T2Q S2 | LT | LE | 1 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Oncorhynchus kisutch*<br>Coho salmon (Oregon Coast ESU) | CR, KM, ME, WC, WV<br>Bent, Clat, Colu, Coos, Curr, Doug, Lane, Linc, Polk, Till, Wash, Yamh | G4T2Q<br>S2 | LT | SV | 1 |
| *Oncorhynchus kisutch*<br>Coho salmon (Southern Oregon/Northern California Coasts ESU) | CR, KM, ME, WC; CA<br>Curr, Jack, Jose | G4T2Q<br>S2 | LT | SV | 1 |
| *Oncorhynchus mykiss*<br>Catlow Valley redband trout | BR<br>Harn, Lake | G5T1Q<br>S1 | SOC | SC | 1 |
| *Oncorhynchus mykiss*<br>Chewaucan redband trout | BR, EC<br>Lake | G5T3Q<br>S3 | -- | SV | 3 |
| *Oncorhynchus mykiss*<br>Fort Rock redband trout | BR, EC<br>Lake | G5T3Q<br>S3 | -- | SC | 3 |
| *Oncorhynchus mykiss*<br>Goose Lake redband trout | EC; CA<br>Lake | G5T2Q<br>S2 | SOC | SC | 1 |
| *Oncorhynchus mykiss*<br>Klamath Basin redband trout | EC, WC<br>Jack, Klam, Lake | G5T3T4Q<br>S3 | -- | SV | 4 |
| *Oncorhynchus mykiss*<br>Malheur Lakes redband trout | BM, BR<br>Gran, Harn | G5T3Q<br>S3 | -- | SV | 3 |
| *Oncorhynchus mykiss*<br>Redband trout Warner Valley/Warner Lakes SMU | BR, EC; CA, NV<br>Lake | G5T2Q<br>S2 | SOC | SC | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Klamath Mountains Province ESU, summer run)<br>(SV in KM ecoregion; SC in Upper Klamth) | CR, KM, ME, WC; CA<br>Curr, Jack, Jose | G5T2T3Q<br>S2S3 | -- | SC/SV | 2 |
| *Oncorhynchus mykiss*<br>Steelhead (Klamath Mountains Province ESU, winter run) | CR, KM, ME, WC; CA<br>Curr, Jack, Jose | G5T3Q<br>S2S3 | -- | -- | 2 |
| *Oncorhynchus mykiss*<br>Steelhead (Lower Columbia River ESU, summer run) | CR, EC, ME, WC, WV; WA<br>Clac, Clat, Colu, Hood, Mari, Mult | G5T2Q<br>S2 | LT | SC | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Lower Columbia River ESU, winter run) | CR, EC, ME, WC, WV; WA<br>Clac, Clat, Colu, Hood, Mari, Mult | G5T2Q<br>S2 | LT | SC | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Middle Columbia River ESU, summer run) | BM, CB, CR, EC, ME, WC, WV; WA<br>Clat, Colu, Croo, Gill, Gran, Hood, Jeff, Morr, Mult, Sher, Umat, Wasc, Whee | G5T2Q<br>S2 | LT | SC | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Middle Columbia River ESU, winter run) | BM, CB, CR, EC, ME, WC, WV; WA<br>Clat, Colu, Croo, Gill, Gran, Hood, Jeff, Morr, Mult, Sher, Umat, Wasc, Whee | G5T2Q<br>S2 | LT | -- | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Oregon Coast ESU, summer run) | CR, KM, ME, WC, WV<br>Bent, Clat, Colu, Coos, Curr, Doug, Lane, Linc, Polk, Till, Wash, Yamh | G5T2T3Q<br>S2S3 | SOC | SV | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Oregon Coast ESU, winter run) | CR, KM, ME, WC, WV<br>Bent, Clat, Colu, Coos, Curr, Doug, Lane, Linc, Polk, Till, Wash, Yamh | G5T2T3Q<br>S2S3 | SOC | SV | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Snake River Basin ESU) | BM; WA, ID<br>Umat, Unio, Wall | G5T2T3Q<br>S2S3 | LT | SV | 1 |
| *Oncorhynchus mykiss*<br>Steelhead (Southwest Washington ESU, winter run) | CR, ME, WV; WA<br>Clat, Colu | G5T3Q<br>S2 | -- | SC | 2 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Oncorhynchus mykiss*<br>Steelhead (Upper Willamette River ESU, winter run) | CR, ME, WC, WV<br>Bent, Clac, Clat, Colu, Linn, Mari, Mult, Polk, Wash, Yamh | G5T2Q<br>S2 | LT | SV | 1 |
| *Oncorhynchus mykiss gairdneri*<br>Inland Columbia Basin redband trout | BM, BR, CB, EC; ID, WA +<br>Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Malh, Morr, Sher, Umat, Unio, Wall, Wasc | G5T4<br>S3 | SOC | SV | 4 |
| *Oncorhynchus nerka*<br>Sockeye salmon (Snake River ESU) | BM; ID (migratory/non-breeder in OR, WA)<br>Unio, Wall | G5T1Q<br>SXB,S1M | LE | -- | 1-ex |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Deschutes River ESU, summer/fall run) | BM, CB, ME<br>Jeff, Sher, Wasc | G5T3Q<br>S2S3 | -- | SV | 1 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Lower Columbia River ESU, fall run) | CR, EC, ME, WC, WV; WA<br>Clac, Clat, Colu, Hood, Mult | G5T2Q<br>S2 | LT | SC | 1 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Lower Columbia River ESU, spring run) | CR, EC, ME, WC, WV; WA<br>Clac, Clat, Colu, Hood, Mult | G5T2Q<br>S2 | LT | SC | 1 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Middle Columbia River ESU, fall run) | BM, CB, EC, WC<br>Gill, Gran, Hood, Jeff, Morr, Mult, Sher, Umat, Wasc, Whee | G5TNRQ<br>SNR | -- | SV | 3 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Middle Columbia River ESU, spring run) | BM, CB, EC, ME, WC<br>Gill, Gran, Hood, Jeff, Morr, Mult, Sher, Umat, Wasc, Whee | G5T3Q<br>S3 | -- | SV | 4 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Oregon Coast ESU, spring run) | CR, ME<br>Coos, Doug, Linc, Polk, Till, Wash | G5T3Q<br>S3 | -- | SC | 4 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Snake River ESU, fall run) | BM, CB, CR, EC, ME, WC, WV; ID, WA<br>Clat, Colu, Gill, Hood, Morr, Mult, Sher, Umat, Wall, Wasc | G5T1Q<br>S1 | LT | LT | 1 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Snake River ESU, spring/summer run) | BM, CB, CR, EC, ME, WC, WV; ID, WA<br>Clat, Colu, Gill, Hood, Morr, Mult, Sher, Umat, Unio, Wall, Wasc | G5T1Q<br>S1 | LT | LT | 1 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Southern Oregon/Northern California Coast ESU, fall run) | CR, KM, ME, WC; CA<br>Curr, Jack, Jose | G5T3Q<br>S2 | -- | SV | 2 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Southern Oregon/Northern California Coast ESU, spring run) | CR, KM, ME, WC<br>Curr, Jack, Jose | G5T4Q<br>S4 | -- | SV | 3 |
| *Oncorhynchus tshawytscha*<br>Chinook salmon (Upper Willamette River ESU, spring run) | CR, ME, WC, WV<br>Bent, Clac, Clat, Colu, Lane, Linn, Mari, Mult, Polk, Yamh | G5T2Q<br>S2 | LT | SC | 1 |
| *Oregonichthys crameri*<br>Oregon chub | WC, WV<br>Bent, Lane, Linn, Mari, Polk, Yamh | G3<br>S3 | LT | SC | 1 |
| *Oregonichthys kalawatseti*<br>Umpqua chub | CR, KM, WC<br>Doug | G2G3<br>S2S3 | SOC | SC | 1 |
| *Rhinichthys cataractae* ssp.<br>Millicoma dace | CR<br>Coos, Doug | G5T2<br>S2 | SOC | SV | 1 |
| *Rhinichthys osculus* ssp.<br>Foskett Spring speckled dace | BR<br>Lake | G5T1<br>S1 | LT | LT | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Richardsonius egregius* Lahontan redside | BR; CA, NV Malh | G5 S2 | -- | -- | 2 |
| *Salvelinus confluentus* Bull trout (Deschutes SMU) | BM, CB, EC, WC Croo, Desc, Jeff, Klam, Sher, Wasc | G4T2T3 S2S3 | LT | SV | 1 |
| *Salvelinus confluentus* Bull trout (Grande Ronde SMU) | BM Unio, Wall | G4T2 S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Hells Canyon SMU) | BM Bake, Unio, Wall | G4T2 S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Hood River SMU) | EC, WC Hood | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Imnaha SMU) | BM Bake, Wall | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (John Day SMU) | BM Gran, Umat, Whee | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Klamath River population) | EC, WC Klam, Lake | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Malheur River SMU) | BM, BR Bake, Gran, Harn, Malh | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Odell Lake SMU) | EC, WC Desc, Klam | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Umatilla SMU) | BM, CB Umat, Unio | G4T2Q S2 | LT | SC | 1 |
| *Salvelinus confluentus* Bull trout (Willamette SMU) | WC, WV Clac, Desc, Lane, Linn, Mari | G4T2Q S2 | LT | SC | 1 |
| *Thaleichthys pacificus* Eulachon | CR, KM, ME, WV; CA, WA, AK, BC Clat, Colu, Coos, Curr, Doug, Lane, Linc, Mult, Till | G5 S3? | LT | -- | 2 |
| **AMPHIBIANS** | | | | | |
| *Ambystoma mavortium melanostictum* Blotched tiger salamander | BM, BR, EC; ID, WA + Desc, Harn, Klam, Malh, Wasc | G5T4 S2? | -- | -- | 3 |
| *Anaxyrus boreas* Western toad | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Clac, Clat?, Colu?, Coos?, Croo, Curr, Desc, Doug?, Gill, Gran, Harn, Hood, Jack, Jeff?, Jose, Klam, Lake?, Lane, Linc?, Linn, Malh, Morr, Mult, Sher, Till, Umat, Unio?, Wall, Wasc, Wash?, Whee, Yamh? | G4 S4 | -- | SV | 4 |
| *Anaxyrus woodhousii* Woodhouse's toad | BR, CB; ID, NV, WA + Malh, Morr, Umat | G5 S2 | -- | -- | 2 |
| *Aneides ferreus* Clouded salamander | CR, KM, WC, WV; CA Bent, Clac, Clat, Colu, Coos, Curr, Desc, Doug, Hood, Jack, Jeff, Jose, Klam, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G3G4 S3S4 | -- | SV | 4 |
| *Aneides flavipunctatus* Black salamander | KM; CA Jack, Jose | G4 S2 | -- | SV | 2 |
| *Ascaphus montanus* Rocky Mountain tailed frog | BM; ID, MT, WA, BC Bake, Unio, Wall | G4 S2 | SOC | SV | 2 |
| *Ascaphus truei* Coastal tailed frog | CR, EC, KM, WC; CA, WA, BC Bent, Clac, Clat, Colu, Coos, Curr, Desc, Doug, Hood, Jack, Jeff, Jose, Klam, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wall, Wasc, Wash, Whee, Yamh | G4 S3 | SOC | SV | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Batrachoseps attenuatus*<br>California slender salamander | CR, KM; CA<br>Coos, Curr | G5<br>S3 | -- | -- | 4 |
| *Batrachoseps wrighti*<br>Oregon slender salamander | EC, WC, WV<br>Clac, Desc?, Doug, Hood, Jeff?, Klam?, Lane, Linn, Mari, Mult, Wasc | G3<br>S3 | SOC | SV | 4 |
| *Dicamptodon copei*<br>Cope's giant salamander | CR, WC; WA<br>Clac, Clat, Colu, Hood, Mult, Till, Wasc, Wash | G3G4<br>S2 | -- | SV | 2 |
| *Lithobates pipiens*<br>Northern leopard frog | BM, BR, CB, EC, KM; CA, ID, NV, WA +<br>Bake, Croo, Gill, Gran, Hood, Jack, Jeff, Klam, Malh, Morr, Sher, Umat, Wasc | G5<br>S1S2 | -- | SC | 2 |
| *Plethodon elongatus*<br>Del Norte salamander | CR, KM; CA<br>Coos, Curr, Doug, Jack, Jose | G4<br>S4 | SOC | SV | 4 |
| *Plethodon larselli*<br>Larch Mountain salamander | WC; WA<br>Clac, Hood, Mult | G3<br>S2 | SOC | SV | 2 |
| *Plethodon stormi*<br>Siskiyou Mountains salamander | KM; CA<br>Jack, Jose | G2G3<br>S2 | SOC | SV | 1 |
| *Rana aurora*<br>Northern red-legged frog<br>(SV in WV and KM ecoregions only) | CR, KM, WC, WV; CA, WA +<br>Bent, Clac, Clat, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Klam, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G4<br>S3S4 | SOC | SV | 4 |
| *Rana boylii*<br>Foothill yellow-legged frog<br>(SC in WV ecoregion; SV elsewhere) | CR, KM, WC, WV; CA<br>Coos, Curr, Doug, Jack, Jose, Klam, Lane, Linn, Mari | G3<br>S2S3 | SOC | SC/SV | 2 |
| *Rana cascadae*<br>Cascades frog | EC, KM, WC; CA, WA<br>Clac, Desc, Doug, Hood, Jack, Jeff, Klam, Lane, Linn, Mari, Mult, Wasc | G3G4<br>S3S4 | SOC | SV | 4 |
| *Rana luteiventris*<br>Columbia spotted frog<br>(SC in BR and CB ecoregions; SV elsewhere) | BM, BR, CB; ID, NV, WA +<br>Bake, Croo, Gran, Harn, Jeff, Lake, Malh, Umat, Unio, Wall, Whee | G4<br>S2S3 | C | SC/SV | 2 |
| *Rana pretiosa*<br>Oregon spotted frog | EC, WC, WV; CA, WA<br>Bent, Clac, Colu, Croo, Desc, Hood, Jack, Jeff, Klam, Lane, Linn, Mari, Mult, Polk, Wasc, Wash, Yamh | G2<br>S2 | C | SC | 1 |
| *Rhyacotriton cascadae*<br>Cascade torrent salamander | WC; WA<br>Clac, Hood, Lane, Linn, Mari, Mult | G3<br>S3 | -- | SV | 4 |
| *Rhyacotriton kezeri*<br>Columbia torrent salamander | CR; WA<br>Clat, Colu, Polk, Till, Wash, Yamh | G3<br>S3 | -- | SV | 4 |
| *Rhyacotriton variegatus*<br>Southern torrent salamander | CR, KM, WC, WV; CA<br>Bent, Coos, Curr, Doug, Jose, Lane, Linc, Polk, Till, Yamh | G3G4<br>S3 | SOC | SV | 4 |
| *Taricha granulosa mazamae*<br>Crater Lake newt | EC<br>Klam | G5T1Q<br>S1 | -- | -- | 1 |
| **REPTILES** | | | | | |
| *Actinemys marmorata*<br>Western pond turtle | BM, CR, EC, KM, WC, WV; CA, NV, WA<br>Bent, Clac, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Klam, Lane, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G3G4<br>S2 | SOC | SC | 2 |
| *Chrysemys picta*<br>Painted turtle<br>(only C. p. bellii SC) | BM, CB, WC, WV; ID, WA +<br>Bake, Bent, Clac, Colu, Gran, Hood, Lane, Linn, Mari, Morr, Mult, Polk, Sher, Umat, Unio, Wall, Wasc, Wash, Yamh | G5<br>S2 | -- | SC | 2 |
| *Crotalus oreganus*<br>Western rattlesnake<br>(SC in WV ecoregion only) | BM, BR, CR, EC, KM, WC, WV; CA, ID, WA +<br>Bake, Bent, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Linn, Malh, Mari, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5<br>S5 | -- | SC | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Lampropeltis getula*<br>Common kingsnake | EC, KM, WC; CA, NV +<br>Curr, Doug, Jack, Jose, Klam | G5<br>S3 | SOC | SV | 4 |
| *Lampropeltis zonata*<br>California mountain kingsnake | CR, EC, KM, WC; CA, WA, Mexico<br>Curr, Doug, Jack, Jose | G4G5<br>S3S4 | SOC | SV | 4 |
| *Sceloporus graciosus graciosus*<br>Northern sagebrush lizard<br>(SV in CB ecoregion only) | BM, BR, CB, EC; CA, ID, NV, WA +<br>Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Wasc, Whee | G5T5<br>S5 | SOC | SV | 4 |
| *Sonora semiannulata*<br>Ground snake | BR; CA, ID, NV +<br>Harn, Malh | G5<br>S3 | -- | -- | 4 |
| **BIRDS** | | | | | |
| *Accipiter gentilis*<br>Northern goshawk | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Umat, Unio, Wall, Wasc, Whee | G5<br>S3S4 | SOC | SV | 4 |
| *Aechmophorus clarkii*<br>Clark's grebe | BM, BR, CR, EC, KM, ME; CA, NV, ID, WA +<br>Clat, Colu, Coos, Curr, Doug, Harn, Jack, Klam, Lake, Lane, Linc, Till | G5<br>S3B,S2N | -- | -- | 4 |
| *Aechmophorus occidentalis*<br>Western grebe | BM, BR, CR, EC, KM, ME, WC, WV; CA, NV, ID, WA +<br>Clat, Colu, Coos, Curr, Desc, Harn, Jack, Klam, Lake, Lane, Linc, Linn, Mult, Polk, Till, Wash | G5<br>S3B,S2S3N | -- | -- | 4 |
| *Aegolius funereus*<br>Boreal owl | BM, EC, WC; ID, WA +<br>Bake, Clac, Desc, Gran, Hood, Jeff, Klam, Lane, Linn, Mari, Umat, Unio, Wall, Wasc, Whee | G5<br>S3? | -- | -- | 3 |
| *Agelaius tricolor*<br>Tricolored blackbird | BM, CB, EC, KM, WV; CA<br>Jack, Klam, Lake, Mult, Umat, Wasc, Whee | G2G3<br>S2B | SOC | -- | 2 |
| *Ammodramus savannarum*<br>Grasshopper sparrow | BM, BR, CB, KM, WV; CA, ID, NV, WA +<br>Bake, Doug, Gill, Harn, Jack, Lane, Linn, Malh, Morr, Polk, Sher, Umat, Wall, Wasc | G5<br>S2B | -- | SV | 2 |
| *Amphispiza bilineata*<br>Black-throated sparrow | BM, BR, CB; CA, ID, NV, WA +<br>Croo, Desc, Harn, Klam, Lake, Malh, Morr, Whee | G5<br>S3B | -- | -- | 4 |
| *Anser albifrons elgasi*<br>Tule goose | BR, EC; WA<br>Harn, Klam, Lake | G5T3<br>S2S3N | -- | -- | 1 |
| *Aquila chrysaetos*<br>Golden eagle | BM, BR, CB, CR, EC, KM, WC<br>Bake, Clac, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Mari, Morr, Mult, Sher, Umat, Unio, Wall, Wasc, Whee | G5<br>S3 | -- | -- | 4 |
| *Artemisiospiza belli*<br>Sage sparrow<br>(SC in CB ecoregion only) | BM, BR, CB, EC; CA, ID, NV, WA +<br>Bake, Croo, Desc, Gill, Harn, Jeff, Lake, Malh, Morr, Umat, Whee | G5<br>S4B | -- | SC | 4 |
| *Asio flammeus*<br>Short-eared owl | BM, BR, CB, CR, EC, KM, WC, WV<br>Bake, Bent, Clac?, Clat?, Colu?, Coos?, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood?, Jack?, Jeff, Jose?, Klam?, Lake, Lane, Linc?, Linn, Malh, Mari?, Morr, Mult, Polk?, Sher, Till?, Umat, Unio, Wall, Wasc, Wash?, Whee, Yamh? | G5<br>S3 | -- | -- | 3 |
| *Athene cunicularia hypugaea*<br>Western burrowing owl<br>(SV in BR ecoregion; SC elsewhere) | BM, BR, CB, CR, EC, KM, WV; CA, ID, NV, WA +<br>Bake, Bent, Coos, Croo, Desc, Doug, Gill, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G4T4<br>S3B | SOC | SC/SV | 4 |
| *Baeolophus ridgwayi*<br>Juniper titmouse | BR, EC?<br>Harn?, Klam?, Lake, Malh | G5<br>S3 | -- | -- | 4 |
| *Bartramia longicauda*<br>Upland sandpiper | BM, EC; ID, WA +<br>Croo, Gran, Klam, Lake, Umat, Unio | G5<br>S1B | SOC | SC | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Brachyramphus marmoratus* Marbled murrelet | CR, KM, ME; CA, WA + Bent, Clat, Coos, Curr, Doug, Lane, Linc, Polk, Till | G3 S2 | LT | LT | 2 |
| *Branta canadensis occidentalis* Dusky Canada goose | CR, WV; WA + Bent, Colu, Lane, Linn, Mari, Mult, Polk, Till, Wash, Yamh | G5T3 S2S3N | -- | -- | 1 |
| *Branta hutchinsii leucopareia* Aleutian Canada goose | CR, KM, WV; AK, CA, WA, BC Bent, Colu, Coos, Curr, Mari, Mult, Polk, Till, Wash, Yamh | G5T3 S2N | -- | -- | 2 |
| *Bucephala albeola* Bufflehead | BM, BR, CB, CR, EC, KM, ME, WC, WV; CA, ID, WA + Bake, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Mari, Morr, Mult, Till, Umat, Wall, Wasc, Wash, Whee, Yamh | G5 S2B,S5N | -- | -- | 2 |
| *Bucephala islandica* Barrow's goldeneye | BM, BR, CB, EC, WC; CA, ID, WA + Bake, Clac, Desc, Doug, Hood, Jack, Jeff, Klam, Lake, Lane, Linn, Malh, Mari, Morr, Umat, Wall, Wasc | G5 S3B,S3N | -- | -- | 4 |
| *Buteo regalis* Ferruginous hawk (SC in CB ecoregion; SV elsewhere) | BM, BR, CB; CA, ID, NV, WA + Bake, Croo, Desc, Gill, Gran, Harn, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G4 S3B | SOC | SC/SV | 4 |
| *Buteo swainsoni* Swainson's hawk | BM, BR, CB, EC; CA, ID, NV, WA + Bake, Croo, Desc, Gill, Harn, Jeff, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5 S3B | -- | SV | 4 |
| *Centrocercus urophasianus* Greater sage-grouse (SV in EC, CB and BM ecoregions only) | BM, BR, CB, EC; CA, NV, WA Bake, Croo, Desc, Gill, Gran, Harn, Klam, Lake, Malh, Unio, Wasc, Whee | G3G4 S3 | C | SV | 2 |
| *Cerorhinca monocerata* Rhinoceros auklet | CR, ME; CA, WA + Clat, Coos, Curr, Doug, Lane, Linc, Till | G5 S2B | -- | SV | 2 |
| *Charadrius nivosus nivosus* Western snowy plover (LT (Federal) for coastal pops. only) | BR, CR, EC, ME; CA, NV, WA + Clat, Coos, Curr, Doug, Harn, Klam, Lake, Lane, Linc, Till | G3T3 S2 | PS:LT | LT | 2 |
| *Chlidonias niger* Black tern | BM, BR, EC, WV; ID, NV, WA + Bent, Croo, Desc, Gran, Harn, Klam, Lake, Lane, Linn, Malh, Polk | G4 S3B | SOC | -- | 4 |
| *Chordeiles minor* Common nighthawk (SC in WV ecoregion only) | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5 S5B | -- | SC | 4 |
| *Coccyzus americanus* Yellow-billed cuckoo | BM, BR, EC, WC, WV; CA, ID, NV, WA + Bake, Clac, Desc, Gran, Harn, Klam, Lake, Linn, Malh, Mult, Umat, Unio, Wall | G5 SHB | C | SC | 2-ex |
| *Contopus cooperi* Olive-sided flycatcher | BM, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4 S2S3B | SOC | SV | 4 |
| *Coturnicops noveboracensis* Yellow rail | EC; CA + Klam, Lake | G4 S1B | SOC | SC | 2 |
| *Cygnus buccinator* Trumpeter swan | BM, BR, CR, EC, ME, WV; NV, ID, WA + Clat, Colu, Harn, Klam, Lake, Malh, Mult, Polk | G4 S1?B,S3N | -- | -- | 2 |
| *Cypseloides niger* Black swift | WC; CA, ID, WA + Doug, Hood, Jack, Lane | G4 S2B | -- | -- | 2 |
| *Dolichonyx oryzivorus* Bobolink | BM, BR; ID, NV, WA + Bake, Croo, Gran, Harn, Lake, Malh, Umat, Unio, Wall | G5 S2B | -- | SV | 2 |
| *Dryocopus pileatus* Pileated woodpecker (SV in BM, EC and KM ecoregions only) | BM, CR, EC, KM, WC, WV Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Mari, Morr, Mult, Polk, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5 S4 | -- | SV | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Egretta thula*<br>Snowy egret | BR, EC; CA, ID, NV, WA +<br>Harn, Klam, Lake | G5<br>S2B | -- | SV | 2 |
| *Elanus leucurus*<br>White-tailed kite | CR, KM, WV; CA +<br>Bent, Clat, Coos, Curr, Doug, Jack, Jose, Lane, Polk, Till | G5<br>S2B,S3N | -- | -- | 2 |
| *Empidonax traillii adastus*<br>Willow flycatcher<br>(SV in BM, BR, CB and EC ecoregions only) | BM, BR, CB, EC, KM; CA, ID, NV, WA +<br>Bake, Croo, Desc, Gran, Harn, Hood, Jeff, Klam, Lake, Malh, Morr, Umat, Unio, Wall, Wasc, Whee | G5T5<br>S3B | SOC | SV | 4 |
| *Empidonax traillii brewsteri*<br>Little willow flycatcher | CR, KM, WC, WV; CA, WA, BC<br>Bent, Clac, Clat, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wash, Yamh | G5T3T4<br>S3B | -- | SV | 4 |
| *Eremophila alpestris strigata*<br>Streaked horned lark | CR, KM, WV; WA +<br>Bent, Clac, Clat, Doug, Jack, Jose, Lane, Linn, Mari, Mult, Polk, Wash, Yamh | G5T2<br>S2B | PT | SC | 1 |
| *Falcipennis canadensis*<br>Spruce grouse | BM; ID, WA +<br>Bake, Unio, Wall | G5<br>S3 | -- | SV | 3 |
| *Falco columbarius*<br>Merlin | BR, CB, EC; ID, WA +<br>Gill, Harn, Klam, Morr | G5<br>SHB | -- | -- | 2-ex |
| *Falco peregrinus anatum*<br>American peregrine falcon | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4T4<br>S2B | -- | SV | 2 |
| *Falco peregrinus tundrius*<br>Arctic peregrine falcon | BM, BR, CB, CR, EC, KM, WC, WV<br>Bake?, Bent?, Clac?, Clat?, Colu?, Coos?, Croo?, Curr?, Desc?, Doug?, Gill?, Gran?, Harn?, Hood?, Jack?, Jeff?, Jose?, Klam?, Lake?, Lane?, Linc?, Linn?, Malh?, Mari?, Morr?, Mult?, Polk?, Sher?, Till?, Umat?, Unio?, Wall?, Wasc?, Wash?, Whee?, Yamh? | G4T3<br>SNR | -- | SV | 2 |
| *Fratercula cirrhata*<br>Tufted puffin | CR, KM, ME; CA, WA +<br>Clat, Coos, Curr, Lane, Linc, Till | G5<br>S1B | -- | SV | 2 |
| *Grus canadensis canadensis*<br>Lesser sandhill crane | BR; ID, NV<br>Harn, Malh | G5T4<br>S3N | -- | -- | 4 |
| *Grus canadensis rowani*<br>Canadian sandhill crane | WV; WA +<br>Mult | G5T3T4<br>S2?N | -- | -- | 3 |
| *Grus canadensis tabida*<br>Greater sandhill crane<br>(SV breeding populations only) | BM, BR, EC, WC; CA, ID, NV, WA +<br>Bake, Clac, Croo, Desc, Gran, Harn, Hood, Jack, Jeff, Klam, Lake, Lane, Linn, Malh, Mari, Umat, Unio, Wall, Wasc | G5T4<br>S3S4B | -- | SV | 4 |
| *Gymnogyps californianus*<br>California condor | CR, KM, WC, WV; CA | G1<br>SX | LE | -- | 1-ex |
| *Haematopus bachmani*<br>Black oystercatcher | CR, ME; CA, WA +<br>Clat, Coos, Curr, Lane, Linc, Till | G5<br>S3 | SOC | SV | 4 |
| *Haliaeetus leucocephalus*<br>Bald eagle | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5<br>S4B,S4N | -- | SV | 4 |
| *Histrionicus histrionicus*<br>Harlequin duck | BM, CR, EC, ME, WC; ID, WA +<br>Clac, Clat, Coos, Curr, Doug, Hood, Klam, Lane, Linc, Linn, Mari, Mult, Till, Wall | G4<br>S2B,S3N | SOC | -- | 2 |
| *Icteria virens*<br>Yellow-breasted chat<br>(SC in WV ecoregion only) | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5<br>S4B | SOC | SC | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Ixobrychus exilis* Least bittern | BR, EC; CA + Harn, Klam | G5 S1B | -- | -- | 3 |
| *Lanius ludovicianus* Loggerhead shrike (SV in BM, CB, EC ecoregions only) | BM, BR, CB, EC, KM, WV; CA, ID, NV, WA + Bake, Croo, Desc, Gill, Gran, Harn, Jack, Jeff, Klam, Lake, Lane, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G4 S3B,S2N | -- | SV | 4 |
| *Leucophaeus pipixcan* Franklin's gull | BR; CA, ID + Harn | G4G5 S2B | -- | SV | 2 |
| *Leucosticte atrata* Black rosy-finch | BR; CA, ID, NV, WA + Harn | G4 S2B | -- | -- | 2 |
| *Leucosticte tephrocotis wallowa* Wallowa rosy-finch | BM Wall | G5T2T3 S2B,S2?N | -- | -- | 1 |
| *Melanerpes formicivorus* Acorn woodpecker (SV in WV ecoregion only) | CR, EC, KM, WV; CA, WA + Bent, Clac, Coos, Curr, Doug, Jack, Jose, Klam, Lane, Linn, Mari, Polk, Wasc, Wash, Yamh | G5 S3 | SOC | SV | 4 |
| *Melanerpes lewis* Lewis's woodpecker | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4 S2B,S2?N | SOC | SC | 2 |
| *Numenius americanus* Long-billed curlew (SV in BM, CB and EC ecoregions only) | BM, BR, CB, EC; CA, ID, NV, WA + Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5 S3B | -- | SV | 4 |
| *Oceanodroma furcata* Fork-tailed storm-petrel | CR, ME; CA, WA + Clat, Curr, Till | G5 S2B | -- | -- | 2 |
| *Oreortyx pictus* Mountain quail (SV in BR ecoregion only) | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5 S3S4 | SOC | SV | 4 |
| *Oreoscoptes montanus* Sage thrasher | BM, BR, CB, EC Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5 S3S4B | -- | -- | 4 |
| *Otus flammeolus* Flammulated owl | BM, BR, EC, KM, WC; CA, ID, NV, WA + Bake, Croo, Desc, Gran, Harn, Jack, Jeff, Klam, Lake, Morr, Umat, Unio, Wall, Wasc, Whee | G4 S3B | -- | SV | 4 |
| *Parkesia noveboracensis* Northern waterthrush | BM, EC, WC; ID, WA + Desc, Klam, Lane, Unio, Wall | G5 S2B | -- | -- | 2 |
| *Patagioenas fasciata* Band-tailed pigeon | CR, KM, WC, WV; CA, ID, NV, WA + Bent, Clac, Clat, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G4 S3B | SOC | -- | 4 |
| *Pelecanus erythrorhynchos* American white pelican (SV breeding populations only) | BR, EC; CA, ID, NV, WA + Harn, Klam, Lake | G4 S2B | -- | SV | 2 |
| *Pelecanus occidentalis californicus* California brown pelican | CR, ME; CA, WA + Clat, Coos, Curr, Doug, Lane, Linc, Till | G4T3 S2N | -- | LE | 2 |
| *Picoides albolarvatus* White-headed woodpecker | BM, EC, KM, WC; CA, ID, NV, WA + Bake, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Morr, Umat, Unio, Wall, Wasc, Whee | G4 S2 | SOC | SC | 2 |
| *Picoides arcticus* Black-backed woodpecker | BM, EC, KM, WC; CA, ID, NV, WA + Bake, Clac, Croo, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Klam, Lake, Lane, Linn, Mari, Morr, Mult, Umat, Unio, Wall, Wasc, Whee | G5 S3 | -- | SV | 4 |
| *Picoides dorsalis* American three-toed woodpecker | BM, EC, WC; ID, NV, WA + Bake, Clac, Croo, Desc, Doug, Gran, Jack, Jeff, Klam, Lane, Linn, Mari, Mult, Umat, Unio, Wall, Wasc | G5 S3 | -- | SV | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Pinicola enucleator*<br>Pine grosbeak | BM, EC, WC?; CA, ID, NV, WA +<br>Bake, Desc, Gran, Jeff, Unio, Wall | G5<br>S2? | -- | -- | 3 |
| *Plegadis chihi*<br>White-faced ibis | BR, EC; CA, NV +<br>Harn, Klam, Lake, Malh | G5<br>S3B | SOC | -- | 4 |
| *Podiceps auritus*<br>Horned grebe | BM, BR, CB, CR, EC, ME, WC, WV; ID, WA +<br>Clat, Coos, Curr, Doug, Harn, Klam, Lake, Lane, Linc, Linn, Till, Wall | G5<br>S2B,S5N | -- | -- | 2 |
| *Podiceps grisegena*<br>Red-necked grebe<br>(SC breeding populations only) | CR, EC, ME, WC; ID, WA +<br>Clat, Coos, Curr, Doug, Jack, Klam, Lane, Linc, Mult, Till | G5<br>S1B,S4N | -- | SC | 2 |
| *Pooecetes gramineus affinis*<br>Oregon vesper sparrow<br>(SC in KM and WV ecoregions only) | CR, KM, WV; WA +<br>Bent, Clac, Colu, Coos, Doug, Jack, Jose, Lane, Linn, Mari, Mult, Polk, Wash, Yamh | G5T3?<br>S2B,S2N | SOC | SC | 2 |
| *Progne subis*<br>Purple martin | CR, KM, WC, WV; CA, ID, WA +<br>Bent, Clac, Clat, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Klam, Lake, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G5<br>S2B | SOC | SC | 2 |
| *Ptychoramphus aleuticus*<br>Cassin's auklet | CR, ME; CA, WA +<br>Clat, Coos, Curr, Lane, Linc, Till | G4<br>S2B | -- | SV | 2 |
| *Regulus satrapa*<br>Golden-crowned kinglet | BM, BR, CB, CR, EC, KM, WC, WV<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5<br>S3 | -- | -- | 4 |
| *Selasphorus platycercus*<br>Broad-tailed hummingbird | BM, BR; CA, ID, NV +<br>Harn, Lake, Malh, Unio, Wall | G5<br>S2?B | -- | -- | 3 |
| *Sialia mexicana*<br>Western bluebird<br>(SV in CR, WV, KM and WC ecoregions only) | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5<br>S4B,S4N | -- | SV | 4 |
| *Sitta carolinensis aculeata*<br>Slender-billed nuthatch | CR, KM, WC, WV; CA, WA, BC, Mexico<br>Bent, Clac, Colu, Curr, Doug, Jack, Jose, Klam, Lane, Linn, Mari, Polk, Wash, Yamh | G5TU<br>S3 | -- | SV | 4 |
| *Spizella breweri*<br>Brewer's sparrow | BM, BR, CB, EC<br>Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5<br>S3B | -- | -- | 4 |
| *Sterna forsteri*<br>Forster's tern | BR, CB, EC, WC; CA, ID, NV, WA +<br>Desc, Harn, Klam, Lake, Malh, Morr | G5<br>S3B | -- | -- | 4 |
| *Strix nebulosa*<br>Great gray owl | BM, EC, KM, WC; CA, ID, WA +<br>Bake, Clac, Desc, Doug, Gran, Jack, Jeff, Klam, Lake, Lane, Linn, Mari, Umat, Unio, Wall, Wasc, Whee | G5<br>S3 | -- | SV | 4 |
| *Strix occidentalis caurina*<br>Northern spotted owl | CR, EC, KM, WC, WV; CA, WA, BC<br>Bent, Clac, Clat, Colu, Coos, Curr, Desc, Doug, Hood, Jack, Jeff, Jose, Klam, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G3T3<br>S3 | LT | LT | 1 |
| *Sturnella neglecta*<br>Western meadowlark<br>(SC in WV ecoregion) | BM, BR, CB, EC, KM, WV; CA, ID, NV, WA +<br>Bake, Bent, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5<br>S4 | -- | SC | 4 |
| *Tympanuchus phasianellus columbianus*<br>Columbian sharp-tailed grouse | BM, BR, CB, EC; CA, ID, MT, NV, WA, BC<br>Bake, Croo, Desc, Gill, Gran, Harn, Hood, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G4T3<br>S1 | SOC | SC | 2 |
| **MAMMALS** | | | | | |
| *Ammospermophilus leucurus*<br>White-tailed antelope squirrel | BR; CA, ID, NV +<br>Harn, Lake, Malh | G5<br>S4? | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Antrozous pallidus*<br>Pallid bat | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Croo, Doug, Gill, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Malh, Mult, Umat, Wasc, Whee | G5<br>S2 | SOC | SV | 2 |
| *Arborimus albipes*<br>White-footed vole | CR, KM, WC, WV; CA<br>Bent, Clat, Colu, Coos, Curr, Doug, Jose, Lane, Linc, Linn, Polk, Till, Wash, Yamh | G3G4<br>S3S4 | SOC | -- | 4 |
| *Arborimus longicaudus*<br>Red tree vole<br>(SV in CR ecoregion only) | CR, KM, WC, WV; CA?<br>Bent, Clac, Clat, Colu, Coos, Curr, Doug, Hood, Jack, Jose, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wash, Yamh | G3G4<br>S3 | PS:C | SV | 4 |
| *Bassariscus astutus*<br>Ringtail | CR, EC, KM, WC; CA, NV +<br>Coos, Curr, Doug, Jack, Jose, Klam, Lane | G5<br>S3 | -- | SV | 4 |
| *Brachylagus idahoensis*<br>Pygmy rabbit | BM, BR, CB, EC; CA, ID, NV, WA +<br>Bake, Croo, Desc, Gran, Harn, Jeff, Klam, Lake, Malh, Unio, Wasc, Whee | G4<br>S2? | SOC | SV | 2 |
| *Canis lupus*<br>Gray wolf | BM, BR?, CB, CR, EC?, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack?, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4G5<br>S1S2 | PS:LE | LE | 2 |
| *Corynorhinus townsendii*<br>Townsend's big-eared bat | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Malh, Mari, Mult, Till, Umat, Unio, Wall, Wasc, Wash, Whee | G3G4<br>S2 | SOC | SC | 2 |
| *Enhydra lutris*<br>Sea otter | ME; CA, WA +<br>Coos, Curr, Linc | G4<br>S1 | -- | LT | 2 |
| *Euderma maculatum*<br>Spotted bat | BM, BR, CB; CA, ID, NV, WA +<br>Croo, Desc, Gill, Gran, Harn, Jeff, Sher, Wall, Wasc, Whee | G4<br>S2 | SOC | SV | 2 |
| *Eumetopias jubatus*<br>Northern sea lion | CR, ME; CA, WA<br>Clat, Coos, Curr, Lane, Linc, Till | G3<br>S2 | LT | -- | 2 |
| *Gulo gulo*<br>Wolverine | BM, BR, CB, CR, EC<br>Bake, Croo, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Umat, Unio, Wall, Wasc, Whee | G4<br>S1 | PT | LT | 2 |
| *Lasionycteris noctivagans*<br>Silver-haired bat | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Bent, Clac, Clat, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Malh, Mari, Mult, Polk, Till, Umat, Unio, Wall, Wasc, Wash, Whee | G5<br>S3S4 | SOC | SV | 4 |
| *Lasiurus cinereus*<br>Hoary bat | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Clac, Clat, Croo, Curr, Desc, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Mult, Till, Umat, Unio, Wall, Wasc, Whee | G5<br>S3 | -- | SV | 4 |
| *Lepus californicus*<br>Black-tailed jack rabbit<br>(SV in WV ecoregion only) | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, WA +<br>Bake, Bent, Clac, Croo, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lane, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Umat, Unio, Wasc, Wash, Whee, Yamh | G5<br>S4 | -- | SV | 4 |
| *Lepus townsendii*<br>White-tailed jackrabbit | BM, BR, CB, EC; CA, ID, NV, WA +<br>Bake, Croo, Desc, Gill, Gran, Harn, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5<br>S4? | -- | SV | 3 |
| *Lynx canadensis*<br>Canada lynx | BM, BR, CB, EC, KM, WC, WV; ID, NV, WA +<br>Bake, Bent, Clac, Croo, Desc, Doug, Gran, Harn, Jack, Klam, Lake, Lane, Linn, Morr, Mult, Sher, Umat, Unio, Wall, Wasc | G5<br>S1? | LT | -- | 2 |
| *Martes caurina*<br>Pacific Marten - Coastal Population | CR, KM?; CA, WA<br>Clat?, Colu?, Coos, Curr, Doug, Jack?, Jose?, Lane, Wash?, Yamh? | G4G5T1<br>S1 | -- | SV | 1 |
| *Martes caurina*<br>Pacific Marten - Interior Population | BM, EC, KM, WC<br>Bake, Clat, Desc, Doug, Gran, Jack, Jose, Klam, Lane, Linn, Mari, Mult, Unio, Wall, Wasc | G4G5T4T5<br>S3S4 | -- | SV | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODFW Status | ORBIC List |
|---|---|---|---|---|---|
| *Myotis californicus* California myotis | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Coos, Curr, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Mari, Umat, Unio, Wall, Wasc, Whee, Yamh | G5 S3 | -- | SV | 4 |
| *Myotis ciliolabrum* Western small-footed myotis | BM, BR, CB, EC; CA, ID, NV, WA + Bake, Croo, Desc, Doug, Gran, Harn, Hood, Jeff, Klam, Lake, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5 S3S4 | SOC | -- | 4 |
| *Myotis evotis* Long-eared myotis | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Till, Umat, Unio, Wall, Wasc, Whee, Yamh | G5 S4 | SOC | -- | 4 |
| *Myotis thysanodes* Fringed myotis | BM, BR, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Curr, Doug, Gran, Harn, Jack, Jose, Klam, Lake, Lane, Linc, Linn, Till, Unio, Wall, Wash | G4 S2 | SOC | SV | 2 |
| *Myotis volans* Long-legged myotis | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Mult, Till, Umat, Unio, Wall, Wasc, Wash, Whee | G5 S3 | SOC | SV | 4 |
| *Myotis yumanensis* Yuma myotis | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G5 S3 | SOC | -- | 4 |
| *Odocoileus virginianus leucurus* Columbian white-tailed deer (LE for Columbia River DPS only; SV in CR ecoregion only) | CR, KM, WV; WA Clat, Colu, Doug, Lane, Mult | G5T2Q S2 | PS:LE | SV | 1 |
| *Ovis canadensis canadensis* Rocky Mountain bighorn sheep | BM; ID, WA + Bake, Unio, Wall | G4T4 S3 | -- | -- | 4 |
| *Ovis canadensis nelsoni* Desert bighorn sheep | BM, BR, CB, EC; CA, NV Bake, Desc, Gill, Gran, Harn, Lake, Malh, Morr, Sher, Wasc, Whee | G4T4 SX | -- | -- | 2-ex |
| *Pekania pennanti* Fisher (C in Cascade Mtns. and all areas west, SOC in Blue Mtns.) | BM, CR, EC, KM, WC; CA, ID, WA Bake, Clac, Coos, Curr, Desc, Doug, Gran, Jack, Jose, Klam, Lane, Linc, Linn, Mari, Morr, Till, Umat, Unio, Wall, Wasc, Yamh | G5 S2 | PS:C | SC | 2 |
| *Sciurus griseus* Western gray squirrel (SV in WV ecoregion only) | CR, EC, KM, WC, WV; CA, NV, WA Bent, Clac, Colu, Coos, Curr, Desc, Doug, Hood, Jack, Jeff, Jose, Klam, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wasc, Wash, Yamh | G5 S4 | -- | SV | 4 |
| *Sorex preblei* Preble's shrew | BM, BR, EC; CA, ID, NV, WA + Bake, Croo, Desc, Gran, Harn, Klam, Lake, Malh, Umat, Unio, Wall | G4 S3? | SOC | -- | 3 |
| *Tadarida brasiliensis* Brazilian free-tailed bat | EC, KM, WC, WV; CA, NV+ Doug, Jack, Jose, Klam, Lane, Wash | G5 S4 | -- | -- | 4 |
| *Thomomys bottae detumidus* Pistol River pocket gopher | CR Curr | G5T2Q S2 | SOC | -- | 1 |
| *Thomomys bulbivorus* Camas pocket gopher | WV Bent, Clac, Colu, Lane, Linn, Mari, Mult, Polk, Wash, Yamh | G3G4 S3S4 | SOC | -- | 4 |
| *Thomomys mazama helleri* Gold Beach pocket gopher | CR Curr | G4T1T2 S1S2 | SOC | -- | 1 |
| *Urocitellus elegans nevadensis* Wyoming ground squirrel | BR; ID, NV + Malh | G5T4 SH | -- | -- | 2-ex |
| *Urocitellus washingtoni* Washington ground squirrel | CB; WA Gill, Morr, Umat | G2 S2 | C | LE | 1 |

| ***Scientific Name*** <br> **Common Name** | **Ecoregion; Adjacent States** <br> **Oregon Counties** | **Heritage Rank** | **Federal Status** | **ODFW Status** | **ORBIC List** |
|---|---|---|---|---|---|
| *Ursus arctos horribilis* <br> Grizzly bear | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA + <br> Bake, Bent, Clac, Clat, Colu, Coos, Croo, Curr, Desc, Doug, Gill, Gran, Harn, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linc, Linn, Malh, Mari, Morr, Mult, Polk, Sher, Till, Umat, Unio, Wall, Wasc, Wash, Whee, Yamh | G4T3T4 <br> SX | LT | -- | 2-ex |
| *Vulpes macrotis* <br> Kit fox | BR, EC; CA, ID, NV + <br> Desc, Harn, Klam, Malh | G4 <br> S1 | -- | LT | 2 |
| *Vulpes vulpes necator* <br> Sierra Nevada red fox | EC, WC; CA <br> Clac, Desc, Doug, Hood, Jack, Jeff, Klam, Lake, Lane, Linn, Mari, Wasc | G5T1T2 <br> S1 | -- | -- | 1 |

# FEDERAL ENDANGERED SPECIES ACT STATUS*

## Animals Listed as Endangered

### Fish

*Catostomus microps* - Modoc sucker
*Chasmistes brevirostris* - Shortnose sucker
*Deltistes luxatus* - Lost River sucker
*Gila boraxobius* - Borax Lake chub
*Oncorhynchus nerka* - Sockeye salmon (Snake River ESU)

### Birds

*Gymnogyps californianus* - California condor (extirpated)

### Mammals

*Canis lupus* - Gray wolf (Western Oregon)
*Odocoileus virginianus leucurus* - Columbian white-tailed deer (Columbia River population)

### Invertebrates

*Icaricia icarioides fenderi* - Fender's blue butterfly

## Animals Listed as Threatened

### Fish

*Acipenser medirostris* -- Green sturgeon (Southern DPS)
*Catostomus warnerensis* - Warner sucker
*Gila bicolor ssp.* - Hutton tui chub
*Oncorhynchus clarki henshawi* - Lahontan cutthroat trout
*Oncorhynchus keta* - Chum salmon (Columbia River ESU)
*Oncorhynchus kisutch* - Coho salmon (Lower Columbia River/SW Washington Coast ESU)
*Oncorhynchus kisutch* - Coho salmon (Southern Oregon/Northern California Coasts ESU)
*Oncorhynchus kisutch* - Coho salmon (Oregon Coast ESU)
*Oncorhynchus mykiss* - Steelhead (Snake River Basin ESU)
*Oncorhynchus mykiss* - Steelhead (Lower Columbia River ESU, summer run)
*Oncorhynchus mykiss* - Steelhead (Lower Columbia River ESU, winter run)
*Oncorhynchus mykiss* - Steelhead (Middle Columbia River ESU, summer run)
*Oncorhynchus mykiss* - Steelhead (Middle Columbia River ESU, winter run)
*Oncorhynchus mykiss* - Steelhead (Upper Willamette River ESU, winter run)
*Oncorhynchus tshawytscha* - Chinook salmon (Snake River ESU, fall run)
*Oncorhynchus tshawytscha* - Chinook salmon (Lower Columbia River ESU, spring run)
*Oncorhynchus tshawytscha* - Chinook salmon (Lower Columbia River ESU, fall run)
*Oncorhynchus tshawytscha* - Chinook salmon (Upper Willamette River ESU, spring run)
*Oncorhynchus tshawytscha* - Chinook salmon (Snake River ESU, spring/summer run)
*Oregonichthys crameri* - Oregon chub
*Rhinichthys osculus ssp.* - Foskett Spring speckled dace
*Salvelinus confluentus* - Bull trout (Klamath River population)
*Salvelinus confluentus* - Bull trout (Columbia River population)
*Salvelinus confluentus* - Bull trout (Deschutes SMU)
*Salvelinus confluentus* - Bull trout (Grande Ronde SMU)
*Salvelinus confluentus* - Bull trout (Hells Canyon SMU)
*Salvelinus confluentus* - Bull trout (Hood River SMU)
*Salvelinus confluentus* - Bull trout (Imnaha SMU)
*Salvelinus confluentus* - Bull trout (John Day SMU)
*Salvelinus confluentus* - Bull trout (Malheur SMU)
*Salvelinus confluentus* - Bull trout (Odell Lake SMU)
*Salvelinus confluentus* - Bull trout (Umatilla SMU)
*Salvelinus confluentus* - Bull trout (Willamette SMU)
*Thaleichthys pacificus* - Eulachon

### Birds

*Brachyramphus marmoratus* - Marbled murrelet
*Charadrius nivosus nivosus* - Western snowy plover (coastal population)
*Strix occidentalis caurina* - Northern spotted owl

### Mammals

*Eumetopias jubatus* - Northern sea lion
*Lynx canadensis* - Canada lynx
*Ursus arctos horribilis* - Grizzly bear (extirpated)

### Invertebrates

*Branchinecta lynchi* - Vernal pool fairy shrimp
*Speyeria zerene hippolyta* - Oregon silverspot butterfly

## Animals Proposed for Listing as Endangered

### Invertebrates

*Euphydryas editha taylori* - Taylor's checkerspot butterfly

## Animals Proposed for Listing as Threatened

### Birds

*Eremophila alpestris strigata* - Streaked horned lark

### Mammals

*Gulo gulo* - Wolverine

## Candidate Animals for Listing

### Amphibians

*Rana luteiventris* - Columbia spotted frog
*Rana pretiosa* - Oregon spotted frog

### Birds

*Centrocercus urophasianus* -- Greater sage-grouse
*Coccyzus americanus* - Yellow-billed cuckoo

### Mammals

*Arborimus longicaudus* -- Red tree vole (North Oregon Coast)
*Pekania (Martes) pennanti* - Fisher
*Urocitellus washingtoni* - Washington ground squirrel

### Invertebrates

*Polites mardon* - Mardon skipper (butterfly

*Does not include sea turtles, whales, or accidental species

## USFWS SPECIES OF CONCERN

### Fish

*Acipenser medirostris* - Green sturgeon (Northern DPS)
*Catostomus occidentalis lacusanserinus* - Goose Lake sucker
*Catostomus rimiculus* - Jenny Creek sucker
*Catostomus snyderi* - Klamath largescale sucker
*Cottus bendirei* - Malheur mottled sculpin
*Cottus marginatus* - Margined sculpin
*Cottus tenuis* - Slender sculpin
*Entosphenus tridentatus*- Pacific lamprey
*Entosphenus tridentatus* ssp. - Goose Lake lamprey
*Gila alvordensis* - Alvord chub
*Gila bicolor eurysoma* - Sheldon tui chub
*Gila bicolor oregonensis* - Oregon Lakes tui chub
*Gila bicolor* ssp. - Summer Basin tui chub
*Gila bicolor* ssp. - Catlow tui chub
*Lampetra ayresi* - River lamprey
*Lavinia symmetricus mitrulus* - Pit roach
*Oncorhynchus clarki* - Coastal cutthroat trout (OR Coast ESU)
*Oncorhynchus clarki* - Coastal cutthroat trout (Upper Willamette River ESU)
*Oncorhynchus clarki* - Coastal cutthroat trout (Southwestern WA/Columbia River ESU)
*Oncorhynchus clarki* - Coastal cutthroat trout (Southern Oregon/California Coasts ESU)
*Oncorhynchus clarki lewisi* - Westslope cutthroat trout
*Oncorhynchus mykiss* - Steelhead (OR Coast ESU, summer run)
*Oncorhynchus mykiss* - Steelhead (OR Coast ESU, winter run)
*Oncorhynchus mykiss gairdneri (= O, m. gibbsi)* - Inland Columbia Basin/Great Basin redband trout
*Oncorhynchus mykiss* - Catlow Valley redband trout
*Oncorhynchus mykiss* - Warner Valley redband trout
*Oncorhynchus mykiss* - Goose Lake redband trout
*Oregonichthys kalawatseti* - Umpqua chub
*Rhinichthys cataractae* ssp. - Millicoma dace

### Amphibians

*Ascaphus montanus* -- Rocky Mountain tailed frog
*Ascaphus truei* - Coastal tailed frog
*Batrachoseps wrighti* - Oregon slender salamander
*Plethodon elongatus* - Del Norte salamander
*Plethodon larselli* - Larch Mountain salamander
*Plethodon stormi* - Siskiyou Mountains salamander
*Rana aurora* - Northern red-legged frog
*Rana boylii* - Foothill yellow-legged frog
*Rana cascadae* - Cascades frog
*Rhyacotriton variegatus* - Southern torrent salamander

### Reptiles

*Actinemys marmorata*– Western pond turtle
*Lampropeltis getula* - Common kingsnake
*Lampropeltis zonata* - California mountain kingsnake
*Sceloporus graciosus graciosus* - Northern sagebrush lizard

### Birds

*Accipiter gentilis* - Northern goshawk
*Agelaius tricolor* - Tricolored blackbird
*Athene cunicularia hypugaea* - Western burrowing owl
*Bartramia longicauda* - Upland sandpiper
*Buteo regalis* - Ferruginous hawk
*Chlidonias niger* - Black tern
*Contopus cooperi* - Olive-sided flycatcher
*Coturnicops noveboracensis* - Yellow rail
*Empidonax traillii adastus* - Willow flycatcher
*Haematopus bachmani* – Black oystercatcher
*Histrionicus histrionicus* - Harlequin duck
*Icteria virens* - Yellow-breasted chat
*Melanerpes formicivorus* - Acorn woodpecker
*Melanerpes lewis* - Lewis's woodpecker
*Oreortyx pictus* - Mountain quail
*Patagioenas fasciata* - Band-tailed pigeon
*Picoides albolarvatus* - White-headed woodpecker
*Plegadis chihi* - White-faced ibis
*Pooecetes gramineus affinis* - Oregon vesper sparrow
*Progne subis* - Purple martin
*Tympanuchus phasianellus columbianus* - Columbian sharp-tailed grouse

### Mammals

*Antrozous pallidus* - Pallid bat
*Arborimus albipes* - White-footed vole
*Brachylagus idahoensis* - Pygmy rabbit
*Corynorhinus townsendii* - Townsend's big-eared bat
*Euderma maculatum* - Spotted bat
*Lasionycteris noctivagans* - Silver-haired bat
*Myotis ciliolabrum* - Western small-footed myotis
*Myotis evotis* - Long-eared myotis
*Myotis thysanodes* - Fringed myotis
*Myotis volans* - Long-legged myotis
*Myotis yumanensis* - Yuma myotis
*Sorex preblei* - Preble's shrew
*Thomomys bottae detumidus* - Pistol River pocket gopher
*Thomomys bulbivorus* - Camas pocket gopher
*Thomomys mazama helleri* - Gold Beach pocket gopher

### Invertebrates

*Acetropis americana* - American grass bug
*Agapetus denningi* - Denning's agapetus caddisfly
*Agonum belleri* - Beller's ground beetle
*Allomyia scotti* - Scott's apatanian caddisfly
*Anodonta californiensis* - California floater (mussel)
*Apatania tavala* - Cascades apatanian caddisfly
*Apochthonius malheuri* - Malheur pseudoscorpion
*Bombus franklini* - Franklin's bumblebee
*Chloealtis aspasma* - Siskiyou short-horned grasshopper
*Cryptochia neosa* -- Blue Mountains cryptochian caddisfly
*Driloleirus macelfreshi* - Oregon giant earthworm
*Eobrachycentrus gelidae* - Mt. Hood brachycentrid caddisfly
*Farula davisi* - Green Springs Mountain farulan caddisfly
*Farula jewetti* - Mt. Hood farulan caddisfly
*Farula reapiri* - Tombstone Prairie farulan caddisfly
*Fluminicola fuscus* - Columbia pebblesnail or spire snail
*Goeracea oregona* - Sagehen Creek goeracean caddisfly
*Gomphus lynnae* - Lynn's clubtail dragonfly
*Homoplectra schuhi* - Schuh's homoplectran caddisfly
*Kenkia rhynchida* - A flatworm (planarian)
*Lepidostoma astaneum* - Goeden's lepidostoman caddisfly
*Littorina subrotundata* - Newcomb's littorine snail
*Monadenia fidelis minor* - Oregon snail (Dalles sideband)
*Nebria gebleri siskiyouensis* - Siskiyou gazelle beetle
*Neothremma andersoni* - Columbia Gorge caddisfly
*Oligophlebodes mostbento* - Tombstone Prairie caddisfly
*Pisidium ultramontanum* - Montane peaclam
*Plebeius saepiolus littoralis* - Insular blue butterfly
*Pterostichus rothi* - Roth's blind ground beetle
*Rhyacophila colonus* - O'Brien rhyacophilan caddisfly
*Rhyacophila haddocki* - Haddock's rhyacophilan caddisfly
*Rhyacophila unipunctata* - One-spot rhyacophilan caddisfly
*Stygobromus hubbsi* - Malheur Cave amphipod
*Zapada wahkeena* - Wahkeena Falls flightless stonefly

## STATE ENDANGERED SPECIES ACT STATUS

### Animals Listed as Endangered

#### Fish

*Chasmistes brevirostris* - Shortnose sucker
*Deltistes luxatus* - Lost River sucker
*Gila boraxobius* - Borax Lake chub
*Oncorhynchus kisutch* - Coho salmon (Lower Columbia River/SW Washington Coast ESU)

#### Birds

*Pelecanus occidentalis californicus* - California brown pelican

#### Mammals

*Canis lupus* - Gray wolf
*Urocitellus washingtoni* - Washington ground squirrel

### Animals Listed as Threatened

#### Fish

*Catostomus warnerensis* - Warner sucker
*Gila bicolor* ssp. - Hutton tui chub
*Oncorhynchus clarki henshawi* - Lahontan cutthroat trout
*Oncorhynchus tshawytscha* - Chinook salmon (Snake River ESU, fall run)
*Oncorhynchus tshawytscha* - Chinook salmon (Snake River ESU, spring/summer run)
*Rhinichthys osculus* ssp. - Foskett Spring speckled dace

#### Birds

*Brachyramphus marmoratus* - Marbled murrelet
*Charadrius nivosus nivosus* - Western snowy plover
*Strix occidentalis caurina* - Northern spotted owl

#### Mammals

*Enhydra lutris* - Sea otter
*Gulo gulo* - Wolverine
*Vulpes macrotis* - Kit fox

## ODFW SENSITIVE SPECIES LIST

#### Fish

*Catostomus microps* - Modoc sucker (C)
*Catostomus occidentalis lacusanserinus* - Goose Lake sucker (V)
*Entosphenus minimus* – Miller Lake lamprey (V)
*Entosphenus tridentatus* - Pacific lamprey (V)
*Gila alvordensis* - Alvord chub (V)
*Gila bicolor* ssp. - Summer Basin tui chub (C)
*Lampetra richardsonii* – Western brook lamprey (V)
*Oncorhynchus clarki* - Coastal cutthroat trout (Southwestern Washington/Columbia River ESU) (V)
*Oncorhynchus clarki lewisi* - Westslope cutthroat trout (C)
*Oncorhynchus keta* - Chum salmon (Columbia River ESU) (C)
*Oncorhynchus keta* - Chum salmon (Pacific Coast ESU) (C)
*Oncorhynchus kisutch* - Coho salmon (Southern Oregon/Northern California Coasts ESU) (V)
*Oncorhynchus kisutch* - Coho salmon (Oregon Coast ESU) (V)
*Oncorhynchus mykiss gairdneri* - Inland Columbia Basin redband trout (V)
*Oncorhynchus mykiss* - Steelhead (Snake River Basin ESU) (V)
*Oncorhynchus mykiss* - Steelhead (Klamath Mountains Province ESU, summer run) (V/C)
*Oncorhynchus mykiss* - Steelhead (Lower Columbia River ESU, summer run) (C)
*Oncorhynchus mykiss* - Steelhead (Lower Columbia River ESU, winter run) (C)
*Oncorhynchus mykiss* - Steelhead (Middle Columbia River ESU, summer run) (C)
*Oncorhynchus mykiss* - Steelhead (Oregon Coast ESU, summer run) (V)
*Oncorhynchus mykiss* - Steelhead (Oregon Coast ESU, winter run) (V)
*Oncorhynchus mykiss* - Steelhead (Upper Willamette River ESU, winter run) (V)
*Oncorhynchus mykiss* - Catlow Valley redband trout (C)
*Oncorhynchus mykiss* - Chewaucan redband trout (V)
*Oncorhynchus mykiss* - Fort Rock redband trout (C)
*Oncorhynchus mykiss* - Goose Lake redband trout (C)
*Oncorhynchus mykiss* - Klamath Basin redband trout (V)
*Oncorhynchus mykiss* - Malheur Lakes redband trout (V)
*Oncorhynchus mykiss* - Warner Valley redband trout (C)
*Oncorhynchus tshawytscha* - Chinook salmon (Lower Columbia River ESU, spring run) (C)
*Oncorhynchus tshawytscha* - Chinook salmon (Lower Columbia River ESU, fall run) (C)
*Oncorhynchus tshawytscha* - Chinook salmon (Middle Columbia River ESU, spring run) (V)
*Oncorhynchus tshawytscha* - Chinook salmon (Middle Columbia River ESU, fall run) (V)
*Oncorhynchus tshawytscha* - Chinook salmon (Oregon Coast ESU, spring run) (C)
*Oncorhynchus tshawytscha* - Chinook salmon (Southern Oregon/Northern California Coast ESU, fall run) (V)
*Oncorhynchus tshawytscha* - Chinook salmon (Southern Oregon/Northern California Coast ESU, spring run) (V)
*Oncorhynchus tshawytscha* - Chinook salmon (Upper Willamette River ESU, spring run) (C)
*Oregonichthys crameri* - Oregon chub (C)
*Oregonichthys kalawatseti* - Umpqua chub (C)
*Rhinichthys cataractae* ssp. - Millicoma dace (V)
*Salvelinus confluentus* - Bull trout (Klamath River population) (C)
*Salvelinus confluentus* - Bull trout (Deschutes SMU) (V)
*Salvelinus confluentus* - Bull trout (Grande Ronde SMU) (C)
*Salvelinus confluentus* - Bull trout (Hells Canyon SMU) (C)
*Salvelinus confluentus* - Bull trout (Hood River SMU) (C)
*Salvelinus confluentus* - Bull trout (Imnaha SMU) (C)
*Salvelinus confluentus* - Bull trout (John Day SMU) (C)
*Salvelinus confluentus* - Bull trout (Malheur SMU) (C)
*Salvelinus confluentus* - Bull trout (Odell Lake SMU) (C)
*Salvelinus confluentus* - Bull trout (Umatilla SMU) (C)
*Salvelinus confluentus* - Bull trout (Willamette SMU) (C)

#### Amphibians

*Anaxyrus boreas* - Western toad (V)
*Aneides ferreus* - Clouded salamander (V)
*Aneides flavipunctatus* - Black salamander (V)
*Ascaphus montanus* - Rocky Mountain tailed frog (V)
*Ascaphus truei* - Coastal tailed frog (V)
*Batrachoseps wrighti* - Oregon slender salamander (V)
*Dicamptodon copei* - Cope's giant salamander (V)
*Lithobates pipiens* - Northern leopard frog (C)
*Plethodon elongatus* - Del Norte salamander (V)
*Plethodon larselli* - Larch Mountain salamander (V)
*Plethodon stormi* - Siskiyou Mountains salamander (V)

*Rana aurora* - Northern red-legged frog (V)
*Rana boylii* - Foothill yellow-legged frog (C/V)
*Rana cascadae* - Cascades frog (V)
*Rana luteiventris* - Columbia spotted frog (C/V)
*Rana pretiosa* - Oregon spotted frog (C)
*Rhyacotriton cascadae* - Cascade torrent salamander (V)
*Rhyacotriton kezeri* - Columbia torrent salamander (V)
*Rhyacotriton variegatus* - Southern torrent salamander (V)

**Reptiles**

*Actinemys marmorata* - Western pond turtle (C)
*Chrysemys picta* - Painted turtle (C)
*Crotalus viridis* - Western rattlesnake (C)
*Lampropeltis getula* - Common kingsnake (V)
*Lampropeltis zonata* - California mountain kingsnake (V)
*Sceloporus graciosus graciosus* - Northern sagebrush lizard (V)

**Birds**

*Accipiter gentilis* - Northern goshawk (V)
*Ammodramus savannarum* - Grasshopper sparrow (V)
*Artemisiospiza belli* - Sage sparrow (C)
*Athene cunicularia hypugaea* - Western burrowing owl (C/V)
*Bartramia longicauda* - Upland sandpiper (C)
*Buteo regalis* - Ferruginous hawk (C/V)
*Buteo swainsoni* - Swainson's hawk (V)
*Centrocercus urophasianus* - Greater sage-grouse (V)
*Cerorhinca monocerata* - Rhinoceros auklet (V)
*Chordeiles minor* - Common nighthawk (C)
*Coccyzus americanus* - Yellow-billed cuckoo (C)
*Contopus cooperi* - Olive-sided flycatcher (V)
*Coturnicops noveboracensis* - Yellow rail (C)
*Dolichonyx oryzivorus* - Bobolink (V)
*Dryocopus pileatus* - Pileated woodpecker (V)
*Egretta thula* - Snowy egret (V)
*Empidonax traillii adastus* - Willow flycatcher (V)
*Empidonax traillii brewsteri* - Little willow flycatcher (V)
*Eremophila alpestris strigata* - Streaked horned lark (C)
*Falcipennis canadensis* - Spruce grouse (V)
*Falco peregrinus anatum* - American peregrine falcon (V)
*Falco peregrinus tundrius* - Arctic peregrine falcon (V)
*Fratercula cirrhata* - Tufted puffin (V)
*Grus canadensis tabida* - Greater sandhill crane (V)
*Haliaeetus leucocephalus* - Bald eagle (V)
*Haematopus bachmani* - Black oystercatcher (V)
*Icteria virens* - Yellow-breasted chat (C)
*Lanius ludovicianus* - Loggerhead shrike (V)
*Larus pipixcan* - Franklin's gull (V)
*Melanerpes formicivorus* - Acorn woodpecker (V)
*Melanerpes lewis* - Lewis's woodpecker (C)
*Numenius americanus* - Long-billed curlew (V)
*Oreortyx pictus* - Mountain quail (V)
*Otus flammeolus* - Flammulated owl (V)
*Pelecanus erythrorhynchos* - American white pelican (V)
*Picoides albolarvatus* - White-headed woodpecker (C)
*Picoides arcticus* - Black-backed woodpecker (V)
*Picoides dorsalis* - American three-toed woodpecker (V)
*Podiceps grisegena* - Red-necked grebe (C)
*Pooecetes gramineus affinis* - Oregon vesper sparrow (C)
*Progne subis* - Purple martin (C)
*Ptychoramphus aleuticus* - Cassin's auklet (V)
*Sialia mexicana* - Western bluebird (V)
*Sitta carolinensis aculeata* - Slender-billed nuthatch (V)
*Strix nebulosa* - Great gray owl (V)
*Sturnella neglecta* - Western meadowlark (C)
*Tympanuchus phasianellus columbianus* - Columbian sharp-tailed grouse (C)

**Mammals**

*Antrozous pallidus* - Pallid bat (V)
*Arborimus longicaudus* - Red tree vole (V)
*Bassariscus astutus* - Ringtail (V)
*Brachylagus idahoensis* - Pygmy rabbit (V)
*Corynorhinus townsendii* - Townsend's big-eared bat (C)
*Euderma maculatum* - Spotted bat (V)
*Lasionycteris noctivagans* - Silver-haired bat (V)
*Lasiurus cinereus* - Hoary bat (V)
*Lepus californicus* - Black-tailed jack rabbit (V)
*Lepus townsendii* - White-tailed jackrabbit (V)
*Martes caurina* - Pacific marten (V)
*Myotis californicus* - California myotis (V)
*Myotis thysanodes* - Fringed myotis (V)
*Myotis volans* - Long-legged myotis (V)
*Odocoileus virginianus leucurus* - Columbian white-tailed deer (V)
*Pekania pennanti* - Fisher (C)
*Sciurus griseus* - Western gray squirrel (V)

C = Critical V = Vulnerable

## DROPS AND NAME CHANGES since October 2010 list

**Fish**

| | |
|---|---|
| *Lampetra lethophaga* (Pit-Klamath brook lamprey) | Name change, now called *Entosphenus lethophagus* |
| *Lampetra minima* (Miller Lake lamprey) | Name change, now called *Entosphenus minimus* |
| *Lampetra tridentata* (Pacific lamprey) | Name change, now called *Entosphenus tridentatus* |
| *Lampetra tridentata* ssp. (Goose Lake lamprey) | Name change, now called *Entosphenus tridentatus* ssp. |

**Reptiles**

| | |
|---|---|
| *Actinemys marmorata* (Pacific pond turtle) | Common name change, now called Western pond turtle |

**Birds**

| | |
|---|---|
| *Amphispiza belli* (Sage sparrow) | Name change, now called *Artemisiospiza belli* |
| *Charadrius alexandrinus nivosus* (Western snowy plover) | Name change, now called *Charadrius nivosus nivosus* |
| *Ixobrychus exilis hesperis* (Western least bittern) | Name change, now called *Ixobrychus exilis* (Least bittern) |

**Mammals**

| | |
|---|---|
| *Martes americana* (American marten) | Name change, now called *Martes caurina* (Pacific marten) |
| *Martes pennanti* (Fisher) | Name change, now called *Pekania pennanti* |

**Invertebrates**

| | |
|---|---|
| *Bembidion nigricoeruleum* (A carabid beetle) | Dropped, too common |
| *Deroceras hesperium* (Evening fieldslug) | Dropped, part of more common *D. laeve* |
| *Euphydryas gillettii* (Gillette's checkerspot) | Common name correction, Gillett's checkerspot |
| *Gliabates sp. nov.* (Cascades axetail slug) | Name change, now called *Carinacauda stormi* |

### Nomenclature

Ongoing research has resulted in a number of recent changes which have been included in this version of the booklet. Whenever possible, for vascular plants we have used names and authorities provided by the Oregon Flora Project at the Oregon State University Herbarium. More information on this project is included on page 41.

### Lists

This plant list is an update of the 2010 edition of this publication. All status changes for specific taxa reflect new information obtained since then.

Species that have been dropped from the list or have had name changes are not included within the main body of the lists. These are listed separately in the "Drops and Name Changes" section on page 106. If you do not see a species name that had been in the 2010 edition of the booklet, please refer to that section.

The lists are arranged alphabetically by scientific name. Descriptions of the categories and lists can be found in the Introduction on page 1. State distribution is included for all vascular plant taxa in this edition. Distribution information for the non-vascular plants and fungi is not complete.

At the end of the main list, taxa are listed again by status. These include: a) the USFWS Federal Listed, Candidate and Species of Concern, b) the ODA State Listed and Candidate taxa, c) List 1, d) List 2, e) List 3, and f) List 4.

**List 1** contains taxa which are endangered or threatened throughout their range or which are presumed extinct. The status of taxa on this list represents its status throughout its range. Species which have been extirpated from Oregon are included with an -ex after the List number (e.g. 1-ex). Taxa known or thought to be extinct throughout their range have an -X following the list number (e.g. 1-X).

**List 2** contains taxa which are threatened, endangered or possibly extirpated from Oregon, but are stable or more common elsewhere. Taxa extirpated from Oregon are included with an -ex after the List number (e.g. 2-ex).

**List 3** contains taxa for which more information is needed before status can be determined, but which may be threatened or endangered in Oregon or throughout their range.

**List 4** contains taxa of concern which are not currently threatened or endangered. This list includes taxa which are very rare but are currently secure, as well as taxa which are declining in numbers or habitat but are still too common to be proposed as threatened or endangered.

### Other Information

ORBIC recognizes that fungi are not plants and should be recognized as a distinct kingdom. However, for this booklet they are included with the plants. As in previous editions, information on the fungi in the lists is not as complete as other groups of species. As a result, most remain on the Review List (List 3).

New information on these species has been summarized from recent work, which included extensive herbaria searches and fieldwork from federal agency biologists as well as from OSU faculty and staff. Most of this work was a result of the efforts by the USFS and BLM in implementing the Survey and Manage program of the Northwest Forest Plan. The heritage ranks are the best determination of a species' status, but due to their limited inventory, heritage ranks for fungi are generally less certain than for other vascular and non-vascular species. We hope their inclusion here will stimulate more research and survey, since many of these taxa may be among Oregon's rarest.

ORBIC is interested in obtaining and databasing information for all locations of taxa on Lists 1 and 2. Manual files are maintained for locations of those on List 3 and 4. It is critical that additional information be obtained for List 3 taxa so accurate status determinations can be made. The submission of additional information on status or occurrences of any species included on these lists would be appreciated. Distribution information is based on historical and current reports and is included to aid in searches and to increase knowledge of these taxa.

## State Endangered Plant Protection

Native Plant Conservation Program
Oregon Department of Agriculture (ODA)
Department of Botany and Plant Pathology
2082 Cordley Hall, Oregon State University
Corvallis, OR 97331-2902

Dr. Robert Meinke, Program Lead (OSU Graduate Faculty, Adjunct)
- (541) 737-2317
Kelly Amsberry, Plant Conservation Research Coordinator (OSU Research Associate)
- (541) 737-4333
Rebecca Currin, Conservation Planning and Regulatory Specialist (OSU Research Associate)
- (541) 737-4135
Jordan Brown, Staff Plant Conservation Biologist
- (541) 737-2346 (OSU Research Associate)
Dr. Stephen Meyers, Consulting Systematist (Oregon Flora Project, OSU)
- (541) 737-4338
Matt Groberg, Graduate Student (Botany Program, OSU)

In 1987, Oregon legislators passed Senate Bill 533 (unofficially the "Oregon Endangered Species Act") at the urging of the Native Plant Society of Oregon and others in the state's botanical community. This bill, and its accompanying statutes (ORS 564.100 through 564.135), directed the state Department of Agriculture (ODA) to conserve and protect those native plant species facing the greatest threats to their survival. The resulting Endangered Species Program (now integrated into the Native Plant Conservation Program in ODA's Plant Division) was initiated in 1988. Currently, there are 60 plant species listed as threatened or endangered in the State of Oregon.

The Native Plant Conservation Program works with governmental agencies, non-governmental organizations, universities, businesses, and individuals to conserve Oregon's rich natural heritage of native plant diversity. This is achieved through two avenues: research and regulation. The research conducted by program staff focuses on taxonomic questions, reproductive biology, disturbance ecology, and population augmentation and creation, providing data in support of listing or delisting species. Such biologically-based projects are critical to the development of accurate status determinations for many rare plants, including formally listed species, candidate taxa, and species of concern.

On the regulatory side, ODA is responsible for setting the guidelines on listing, reclassification, and delisting plant species as threatened or endangered. In addition, the program is charged with developing and administering a permit system which regulates commercial and research actions involving state-listed plant species. Any person or organization planning to study, collect, cultivate, transplant, reintroduce, or otherwise work with or impact a listed species (for commercial or research purposes) must first apply in advance for a written permit from ODA. If the application is approved, the permittee then provides an annual summary describing completed or ongoing activities for each listed species (see OAR 603-073-0100 and -0110). Regular permits are currently issued free of charge, though ODA may request reasonable reimbursement from applicants for any costs incurred by the department during follow-up permit reviews, report evaluations, or for special services. Contact Bob Meinke or Rebecca Currin if you have any questions regarding permits.

With the exception of the state's ability to regulate the import, export, and commercial trafficking of threatened and endangered plants, Oregon's conservation authority regarding state-listed plants presently extends only to non-federal public lands (state, city, county, public schools and utilities, etc.). Although the statutes do not require private or federal land owners to safeguard species protected under state law, ODA is willing to cooperate with the owners or managers of such lands in conservation efforts if they request assistance. Since 1988, ODA has collaborated with federal agencies such as the Forest Service and BLM (as well as with private organizations and individuals) on over 150 plant conservation research and recovery projects.

ODA has also adopted administrative rules (OAR 603-73-001 through 603-73-0090) that describe departmental procedures for the state listing, reclassification, or de-listing of plant species as threatened or endangered; how to go about petitioning ODA for the listing or delisting of a species; and the regulations and programs designed to assist and direct state land management agencies in their important roles involving native plant protection. If you are interested in learning how state agencies are required to protect listed plant species, or wish to review other laws and regulations governing threatened and endangered plant management in Oregon, you may download the complete rules at: *http://arcweb.sos.state.or.us/pages/rules/oars_600/oar_603/603_073.html*

Alternatively, you may write to ODA and ask for a copy of the endangered plant species administrative rules (please cite OAR 603-73-001 through 603-73-0110). Address your request to:
Native Plant Conservation Program
Plant Division
Oregon Department of Agriculture
635 Capitol Street NE
Salem, OR 97301-2532

For more information about the Native Plant Conservation Program, please see the program's website at:
*http://www.oregon.gov/oda/plant/conservation*

## Native Plant Society of Oregon (NPSO)
### Plant Protection and Education Programs

NPSO has had a long history of working to increase the knowledge and protection of rare plants in Oregon. From involvement in the original Oregon Rare and Endangered Plant Project (1972-1982), to writing and passage of the Oregon Endangered Species Act of 1987, NPSO members have been at the forefront of plant conservation in our state.

In addition to sponsoring and supporting endangered species legislation, NPSO carries on its own rare plant protection program. Members in 13 chapters across the state monitor rare plants in each area, and report findings to our state R&E chair. This information is then incorporated into ORBIC's databases. In addition, each chapter has an active schedule of programs, workshops, and field trips. Our monthly *Bulletin,* and annual journal, *Kalmiopsis* feature articles on Oregon R&E species. New members are always welcome. Please visit our website below for more information about NPSO's Rare & Endangered Plant Program. For information contact us at:

Native Plant Society of Oregon
P.O. Box 902
Eugene, OR 97440-0902
*www.npsoregon.org*

## Oregon Flora Project

The goal of the Oregon Flora Project (OFP) is to provide the public with comprehensive information on the vascular plants growing without cultivation in Oregon. The major components of the Oregon Flora Project are a checklist, flora, photo gallery, and atlas of plant distribution. Information is accessible to the public through the OFP website, *http://www.oregonflora.org*. The OFP is housed in the Botany & Plant Pathology Dept. of Oregon State University and is closely associated with the OSU Herbarium. The work is accomplished by scores of participants, many of whom are volunteers.

The **Oregon Vascular Plant Checklist** is a standardized, documented reference for Oregon vascular plants which allows users to effectively communicate taxonomic concepts across diverse datasets. It serves as the foundation of the OFP by providing a nomenclatural framework for use in all aspects of the Project. The Checklist itemizes all native and exotic species, subspecies, and varieties (taxa) confirmed to grow in Oregon without cultivation, either currently or historically. There are currently 4,540 accepted taxa in the most recent version of the Checklist, Version 1.3, which was published online in August 2013. Each taxon entry lists the accepted scientific name, synonyms, common name, plant origin (native or exotic), location of a voucher specimen, and key bibliographic references. Names are also cross-referenced to nine key floras and field guides that cover portions of the state.

The **Oregon Vascular Plant Atlas** is an online, interactive mapping tool that creates distribution maps of any combination of plant taxa. There are >550,000 mappable records derived from herbarium specimens (from 39 herbaria) and unvouchered observations (from images, species lists, research, and survey projects). Details about each plant occurrence (excluding sensitive plant localities) are available and can be downloaded in spreadsheet format. The Atlas can be accessed at
*http://www.oregonflora.org/atlas.php*

The writing of ***The Flora of Oregon*** is in progress. Development is under the direction of Dr. Stephen Meyers, OFP lead taxonomist. As of August 2013, manuscripts for 34% of the flora are complete. Each genus will be represented by a full illustration, and taxa with multiple species will have drawings for every 4(-5) species. The *Flora* will be paper published as a two-volume manual and will include identification keys, illustrations, and detailed species descriptions; the target publication date is 2015. The digital *Flora* will additionally feature a multiple entry key and links to supporting OFP data.

The **Oregon Flora Photo Gallery** is an online resource presenting multiple images of Oregon plants. There are field photographs depicting flowers as well as a plant's habitat, general habit, and details of key characters. An image of a representative herbarium specimen for each taxon is also included. Currently there are more than 26,700 searchable images representing ~99% of the taxa in the flora. The OFP is pleased to accept contributed digital images of plants that are accompanied by an identification and locality data.

Digital presentation of Oregon Flora Project data that is accessible and useful to a broad spectrum of users is a key element of the OFP mission. Information is continuously being updated and curated by OFP staff. A restructured website will be released in late 2013 to add new features and streamline data presentation.

Six staff members (totaling 4.1 FTE), student workers, and volunteers comprise the OFP team. An 11-member advisory board supports the OFP mission, as does a Native Plant Society of Oregon liaison. Collectively, participants' backgrounds encompass plant taxonomy, ecology, horticulture, cartography, GIS, software development, and statistics. To date, thousands of volunteer hours have been donated by hundreds of professionals and amateurs alike.

Since its inception in 1994, approximately 50% of the OFP's funding has come from donations made by individuals, plant-oriented organizations, and the sponsorship of the Native Plant Society of Oregon. Competitive awards cover the balance of expenses, with principal funding from the Bureau of Land Management and the John & Betty Soreng Environmental Fund of the Oregon Community Foundation. Grants from small foundations, societies, and corporations have provided seed money for a number of project activities and have indirectly supported the compilation of primary data. The OFP continues to search for funding opportunities to help accomplish project goals in a timely manner.

To access the resources described, and learn more about the OFP, visit our web site at *http://www.oregonflora.org*. You can also view the online version of the *Oregon Flora Newsletter*, which is published twice yearly.

Contact information:
*ofpflora@oregonflora.org*
Dr. Linda K. Hardison
Director, Oregon Flora Project
Department of Botany and Plant Pathology
Oregon State University
Corvallis, OR 97331-2902

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| **VASCULAR PLANTS** | | | | | |
| *Abronia latifolia* Eschsch.<br>Yellow sandverbena | CR; CA, WA<br>Clat, Coos, Curr, Doug, Lane, Linc, Till | G5<br>S3 | -- | -- | 4 |
| *Abronia turbinata* Torr. ex S. Wats.<br>Trans montane abronia | BR; CA, ID, NV, AZ<br>Harn, Malh | G5<br>S1 | -- | -- | 2 |
| *Abronia umbellata* Lam. ssp. *breviflora* (Standl.) Munz<br>Pink sandverbena | CR; CA, WA, BC<br>Clat, Coos, Curr, Doug, Lane, Linc, Till | G4G5T2<br>S1 | SOC | LE | 1 |
| *Achnatherum hendersonii* (Vasey) Barkworth<br>Henderson ricegrass | BM, CB; WA<br>Croo, Gran, Sher, Wasc | G3<br>S2 | SOC | C | 1 |
| *Achnatherum nevadense* (B.L. Johnson) Barkworth<br>Nevada needlegrass | BM, BR; CA, ID, NV +<br>Bake, Harn, Malh | G4<br>SNR | -- | -- | 3 |
| *Achnatherum pinetorum* (M.E. Jones) Barkworth<br>Pine needlegrass | BR; CA, ID, NV +<br>Harn | G4<br>SNR | -- | -- | 3 |
| *Achnatherum richardsonii* (Link) Barkworth<br>Richardson's needlegrass | BM; WA +<br>Unio | G5<br>SNR | -- | -- | 3 |
| *Achnatherum wallowaense* J.R. Maze & K.A. Robson<br>Wallowa ricegrass | BM<br>Croo, Wall | G2G3<br>S2S3 | SOC | -- | 1 |
| *Achnatherum webberi* (Thurb.) Barkworth<br>Webber needlegrass | BR; CA, ID, NV +<br>Harn, Lake, Malh | G4<br>S3 | -- | -- | 4 |
| *Adiantum jordanii* C. Muell.<br>California maiden-hair | CR, KM; CA<br>Coos, Curr, Doug, Jose | G4G5<br>S2 | -- | -- | 2 |
| *Agastache cusickii* (Greenm.) Heller<br>Cusick's giant-hyssop | BR; ID, MT, NV<br>Harn, Lake, Malh | G3G4<br>S2 | -- | -- | 2 |
| *Agoseris elata* (Nutt.) Greene<br>Tall agoseris | EC, WC; CA,WA<br>Clac, Desc, Hood, Jeff, Wasc | G4<br>S1 | -- | -- | 2 |
| *Agrimonia gryposepala* Wallr.<br>Tall hairy groovebur | KM, WC, WV; CA, WA +<br>Doug, Jack, Jose, Mult | G5<br>SNR | -- | -- | 3 |
| *Agrostis densiflora* Vasey<br>California bentgrass | CR; CA<br>Curr, Lane, Linc, Till | G3G4<br>SNR | -- | -- | 3 |
| *Agrostis hendersonii* A.S. Hitchc.<br>Henderson's bentgrass | KM; CA<br>Jack | G1Q<br>SH | SOC | -- | 1-ex |
| *Agrostis howellii* Scribn.<br>Howell's bentgrass | WC<br>Hood, Mult | G2<br>S2 | SOC | C | 1 |
| *Aliciella triodon* (Eastw.) Brand<br>Coyote gilia | BR; CA, ID, NV +<br>Malh | G5<br>SNR | -- | -- | 3 |
| *Allenrolfea occidentalis* (S. Wats.) Kuntze<br>Iodine bush | BR; CA, ID, NV+<br>Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Allium bisceptrum* S. Wats.<br>Two-stemmed onion | BM, BR; CA, ID+<br>Croo, Desc, Gran, Harn, Klam, Lake, Malh | G4G5<br>S4 | -- | -- | 4 |
| *Allium bolanderi* S. Wats. var. *bolanderi*<br>Bolander onion | KM; CA<br>Curr, Jack?, Jose | G4T3?<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Allium dictuon* St. John<br>Blue Mt. onion | BM; WA<br>Wall | G2<br>S2 | SOC | -- | 1 |
| *Allium geyeri* S. Wats. var. *geyeri*<br>Geyer's onion | BM; ID, NV, WA+<br>Wall | G4G5T4<br>S1 | -- | -- | 2 |
| *Allium nevii* S. Wats.<br>Nevius' onion | CB, EC; WA<br>Hood, Wasc | G3G4<br>S3? | -- | -- | 3 |
| *Allium peninsulare* J.G. Lemmon ex Greene<br>Peninsular onion | KM, WC?; CA<br>Jack | G5<br>S1 | -- | -- | 2 |
| *Allium punctum* Henderson<br>Dotted onion | BR; CA, NV<br>Harn, Lake, Malh | G3?<br>SNR | -- | -- | 3 |
| *Allium robinsonii* Henderson<br>Robinson's onion | CB; WA<br>Gill, Morr, Sher, Umat | G3<br>SH | SOC | -- | 2-ex |
| *Allium sanbornii* Wood var. *sanbornii*<br>Sanborn's onion | KM; CA<br>Jack | G3T3<br>SNR | -- | -- | 3 |
| *Allium unifolium* Kellogg<br>One-leaved onion | WV; CA<br>Polk, Yamh | G4G5<br>S4 | -- | -- | 4 |
| *Ammannia robusta* Heer & Regel<br>An ammannia | BM, CB, WV; CA, ID, NV, WA +<br>Bent, Mult, Sher, Unio, Wasc | G5<br>SNR | -- | -- | 3 |
| *Amsinckia carinata* A. Nels. & J.F. Macbr.<br>Malheur Valley fiddleneck | BR<br>Malh | G2<br>S2 | SOC | LT | 1 |
| *Androsace elongata* L. ssp. *acuta* (Greene) G.T. Robbins<br>Long-stemmed androsace | KM; CA<br>Jack | G5?T3T4<br>SH | -- | -- | 2-ex |
| *Anemone multifida* Poir. var. *tetonensis* (Porter ex Britt.) C.L. Hitchc.<br>Cliff anemone | BM; ID, NV+<br>Unio, Wall | G5T4T5<br>SNR | -- | -- | 3 |
| *Anemone oregana* Gray var. *felix* (M.E. Peck) C.L. Hitchc.<br>Bog anemone | CR, WC; WA<br>Linc, Linn, Polk, Till, Yamh | G4T3<br>S1 | SOC | -- | 2 |
| *Antennaria aromatica* Evert<br>Aromatic antennaria | BM; MT, WY<br>Wall | G4<br>S3 | -- | -- | 4 |
| *Antirrhinum kingii* S. Wats.<br>King snapdragon | BR; CA, NV+<br>Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Antirrhinum vexillo-calyculatum* Kellogg ssp. *breweri* (Gray) D. Thompson<br>Brewer's snapdragon | KM, WC; CA<br>Doug, Jack, Jose | G4G5T4T5<br>SNR | -- | -- | 3 |
| *Arabis furcata* S. Wats.<br>Cascade rockcress | EC, WC; WA<br>Clac?, Hood, Jeff, Mari?, Wasc | G4<br>S3 | -- | -- | 4 |
| *Arabis koehleri* Howell var. *koehleri*<br>Koehler's rockcress | KM<br>Doug | G3T1Q<br>S1 | SOC | C | 1 |
| *Arabis koehleri* Howell var. *stipitata* Rollins<br>Koehler's stipitate rockcress | KM; CA<br>Curr, Jack, Jose | G3T3Q<br>S3 | -- | -- | 4 |
| *Arabis macdonaldiana* Eastw.<br>Red Mountain rockcress | KM; CA<br>Curr, Jose | G2<br>S1 | LE | LE | 1 |
| *Arabis modesta* Rollins<br>Rogue Canyon rockcress | KM; CA<br>Jack, Jose | G3<br>S2 | SOC | -- | 2 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Arctostaphylos hispidula* Howell<br>Gasquet manzanita | CR, KM; CA<br>Curr, Doug, Jose | G3<br>S2 | SOC | -- | 2 |
| *Argemone munita* Dur. & Hilg.<br>Prickly-poppy | BR; NV<br>Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Arnica viscosa* Gray<br>Shasta arnica | WC; CA<br>Desc, Doug, Klam | G4<br>S2 | -- | -- | 2 |
| *Artemisia arbuscula* Nutt. ssp. *longicaulis* Winward & McArthur<br>Lahontan sagebrush | BM?, BR, EC; CA, NV<br>Croo, Harn, Jeff?, Klam, Lake, Malh | G5T3T5<br>S1 | -- | -- | 2 |
| *Artemisia campestris* L. var. *wormskioldii* (Bess. ex Hook.) Cronq.<br>Northern wormwood | CB, WC; WA<br>Mult, Sher, Umat, Wasc | G5T1<br>SX | C | LE | 1-ex |
| *Artemisia ludoviciana* Nutt. ssp. *estesii* Chambers<br>Estes' artemisia | BM, EC<br>Croo, Desc, Jeff | G5T3<br>S3 | SOC | -- | 4 |
| *Artemisia packardiae* J. Grimes & Ertter<br>Packard's artemisia | BR; ID, NV<br>Malh | G3<br>S3 | -- | -- | 4 |
| *Artemisia papposa* Blake & Cronq.<br>Owyhee sagebrush | BR; ID, NV<br>Malh | G4<br>S2 | -- | -- | 2 |
| *Artemisia pycnocephala* (Less.) DC.<br>Coastal sagewort | CR; CA<br>Coos, Curr | G4G5<br>S1 | -- | -- | 2 |
| *Asarum wagneri* Lu & Mesler<br>Green-flowered wild-ginger | EC, WC<br>Doug, Jack, Klam, Lane | G3<br>S3 | -- | C | 4 |
| *Asplenium septentrionale* (L.) Hoffmann<br>Grass-fern | WC; CA<br>Doug, Jack, Klam | G4G5<br>S1 | -- | -- | 2 |
| *Asplenium viride* Huds.<br>Green spleenwort | BM; CA, ID, NV, WA+<br>Bake, Wall | G4<br>S1 | -- | -- | 2 |
| *Astragalus alvordensis* M.E. Jones<br>Alvord milk-vetch | BR; NV<br>Harn, Malh | G4<br>S4 | -- | -- | 4 |
| *Astragalus applegatei* M.E. Peck<br>Applegate's milk-vetch | EC<br>Klam | G1<br>S1 | LE | LE | 1 |
| *Astragalus atratus* S. Wats. var. *owyheensis* (A. Nels. & J.F. Macbr.) M.E. Jones<br>Owyhee milk-vetch | BM, BR; ID, NV<br>Bake, Malh | G4G5T3<br>S3 | -- | -- | 4 |
| *Astragalus californicus* (Gray) Greene<br>California milk-vetch | KM; CA<br>Jack | G3<br>S1 | -- | -- | 2 |
| *Astragalus calycosus* Torr. ex S. Wats.<br>King's rattleweed | BR; CA, ID, NV+<br>Malh | G5<br>S1 | -- | -- | 2 |
| *Astragalus collinus* (Hook.) Dougl. ex G. Don var. *laurentii* (Rydb.) Barneby<br>Laurence's milk-vetch | CB<br>Gill, Morr, Sher, Umat | G5T1<br>S1 | SOC | LT | 1 |
| *Astragalus conjunctus* S. Wats. var. *rickardii* Welsh, K. Beck & F. Caplow<br>Rickard's milk-vetch | CB; WA<br>Gill, Wasc, Whee | G4T3<br>SNR | -- | -- | 3 |
| *Astragalus cusickii* Gray var. *sterilis* (Barneby) Barneby<br>Sterile milk-vetch | BR; ID<br>Malh | G5T2<br>S2 | -- | LT | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Astragalus diaphanus* Dougl. ex Hook. var. *diurnus* (S. Wats.) Barneby ex M.E. Peck<br>South John Day milk-vetch | BM<br>Gran | G3G4T2Q<br>S2 | -- | LT | 1 |
| *Astragalus gambelianus* Sheldon<br>Gambel milk-vetch | KM; CA<br>Jack | G5<br>S1 | -- | -- | 2 |
| *Astragalus geyeri* Gray var. *geyeri*<br>Geyer's milk-vetch | BR, CB; CA, ID, NV, WA +<br>Harn, Malh, Umat | G4T4<br>S2? | -- | -- | 2 |
| *Astragalus hoodianus* Howell<br>Hood River milk-vetch | CB, EC; WA<br>Hood, Wasc | G4<br>S3 | -- | -- | 2 |
| *Astragalus lemmonii* Gray<br>Lemmon's milk-vetch | EC; CA, NV<br>Croo, Desc, Gran, Klam, Lake | G2<br>S1 | -- | -- | 1 |
| *Astragalus misellus* S. Wats. var. *misellus*<br>Pauper milk-vetch | BM, BR?<br>Croo, Desc, Gran, Harn?, Jeff, Whee | G4T2?<br>S2? | -- | -- | 1 |
| *Astragalus mulfordiae* M.E. Jones<br>Mulford's milk-vetch | BR; ID<br>Malh | G2<br>S1 | SOC | LE | 1 |
| *Astragalus peckii* Piper<br>Peck's milk-vetch | BM, EC<br>Desc, Jeff, Klam | G3<br>S3 | -- | LT | 1 |
| *Astragalus platytropis* Gray<br>Broad-keeled milk-vetch | BR; CA, ID, NV, UT<br>Malh | G5<br>S1 | -- | -- | 2 |
| *Astragalus reventiformis* (Rydb.) Barneby<br>Long-leaved milk-vetch | CB; WA<br>Sher | G5<br>SNR | -- | -- | 3 |
| *Astragalus robbinsii* (Oakes) Gray var. *alpiniformis* (Rydb.) Barneby ex C.L. Hitchc.<br>Wallowa milk-vetch | BM<br>Wall | G5T3<br>S3 | -- | -- | 4 |
| *Astragalus sclerocarpus* Gray<br>Stalked-pod milk-vetch | CB; WA, BC<br>Gill, Morr, Sher?, Umat, Wasc | G5<br>SNR | -- | -- | 3 |
| *Astragalus succumbens* Dougl. ex Hook.<br>Columbia milk-vetch | CB; WA<br>Gill, Morr, Umat, Wasc | G4G5<br>S4 | -- | -- | 4 |
| *Astragalus tegetarioides* M.E. Jones<br>Bastard kentrophyta | BM, BR; CA<br>Croo, Harn | G3<br>S3 | SOC | C | 1 |
| *Astragalus tenellus* Pursh<br>Loose flower milk-vetch | BR; ID, NV, WA +<br>Malh | G5<br>S1? | -- | -- | 2 |
| *Astragalus tyghensis* M.E. Peck<br>Tygh Valley milk-vetch | CB<br>Wasc | G2<br>S2 | -- | LT | 1 |
| *Astragalus umbraticus* Sheldon<br>Woodland milk-vetch | CR, KM, WC; CA<br>Curr, Doug, Jose, Lane | G4<br>S3 | -- | -- | 4 |
| *Atriplex gmelinii* C.A. Mey. ex Bong. var. *gmelinii*<br>Gmelin's saltbush | CR, ME; CA, WA, AK<br>Lane, Linc, Till | G5TNR<br>S1 | -- | -- | 2 |
| *Atriplex leucophylla* (Moq.) D. Dietr.<br>Beach saltbush | CR; CA +<br>Coos, Linc | G4G5<br>SNR | -- | -- | 3 |
| *Atriplex powellii* S. Wats.<br>Powell's saltbush | BR; AZ +<br>Malh | G4<br>SNR | -- | -- | 3 |
| *Baccharis douglasii* DC.<br>Marsh baccharis | CR; CA<br>Curr | G5<br>S1? | -- | -- | 2 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Balsamorhiza hookeri* (Hook.) Nutt. var. *idahoensis* (Sharp) Cronq.<br>Hooker's balsamroot | BM; ID<br>Bake | G5T3?<br>SNR | -- | -- | 3 |
| *Balsamorhiza hookeri* (Hook.) Nutt. var. *lanata* Sharp<br>Woolly balsamroot | KM; CA<br>Jack | G5T2?<br>S1 | -- | -- | 1 |
| *Balsamorhiza rosea* A. Nels. & J.F. Macbr.<br>Rosy balsamroot | CB; WA<br>Umat | G4G5<br>S1 | -- | -- | 2 |
| *Balsamorhiza sericea* W.A. Weber<br>Silky balsamroot | KM; CA<br>Jose | G4Q<br>S3 | -- | -- | 4 |
| *Bensoniella oregana* (Abrams & Bacig.) Morton<br>Bensonia | CR, KM; CA<br>Coos, Curr, Doug, Jose | G3<br>S3 | SOC | C | 1 |
| *Bergia texana* (Hook.) Seub. ex Walp.<br>Texas bergia | BR, WV; CA, NV, WA +<br>Colu?, Malh, Mult | G5<br>S3? | -- | -- | 4 |
| *Boechera atrorubens* (Suksdorf ex Greene) Windham & Al-Shehbaz<br>Sickle-pod rockcress | EC, WC; WA<br>Hood, Wasc | G3<br>S2 | -- | -- | 2 |
| *Boechera davidsonii* (Greene) N. H. Holmgren<br>Davidson's rockcress | BM; CA+<br>Bake, Wall | G4?<br>S1 | -- | -- | 2 |
| *Boechera hastatula* (Greene) Al-Shehbaz<br>Hells Canyon rockcress | BM, WC<br>Linn, Wall | G2<br>S2 | SOC | -- | 1 |
| *Boechera horizontalis* (Greene) Windham & Al-Shehbaz<br>Crater Lake rockcress | WC<br>Jack?, Klam | G1<br>S1 | SOC | C | 1 |
| *Boechera paddoensis* (Rollins) Windham & Al-Shehbaz<br>Mt. Adams rockcress | BM; WA<br>Gran, Wall | G4?<br>SNR | -- | -- | 3 |
| *Bolandra oregana* S. Wats.<br>Oregon bolandra | BM, WC, WV; ID, WA<br>Bake, Clac, Hood, Mult, Umat, Unio, Wall | G3<br>S3 | -- | C | 4 |
| *Botrychium ascendens* W.H. Wagner<br>Upward-lobed moonwort | BM; CA, ID, NV, WA +<br>Bake, Gran, Wall, Whee | G3<br>S2 | SOC | C | 1 |
| *Botrychium campestre* W.H. Wagner & Farrar ex W.H. & F. Wagner<br>Prairie moonwort | BM; AB, SK, ND +<br>Wall | G3G4<br>S1 | SOC | -- | 2 |
| *Botrychium crenulatum* W.H. Wagner<br>Crenulate grape-fern | BM, BR; AZ, CA, ID, MT, NV, UT, WA, WY<br>Bake, Croo, Gran, Harn, Lake, Umat, Unio, Wall, Whee | G3<br>S2 | SOC | C | 1 |
| *Botrychium hesperium* (Maxon & Clausen) W.H. Wagner & Lellinger<br>Western moonwort | BM; WA +<br>Umat, Unio, Wall | G4<br>S1 | -- | -- | 2 |
| *Botrychium lanceolatum* (Gmel.) Angstr.<br>Lance-leaved grape-fern | BM, BR, WC; WA, ID +<br>Bake, Gran, Harn, Hood, Klam, Umat, Unio, Wall | G5<br>S3 | -- | -- | 4 |
| *Botrychium lineare* W.H. Wagner<br>Skinny moonwort | BM; CA, CO, ID, MT, NB, QC<br>Wall | G2G3<br>S1 | -- | -- | 1 |
| *Botrychium lunaria* (L.) Sw.<br>Moonwort | BM, BR; NV, WA +<br>Gran?, Harn, Unio, Wall | G5<br>S2 | -- | -- | 2 |
| *Botrychium minganense* Victorin<br>Gray moonwort | BM, BR, EC, WC; CA, ID, WA +<br>Bake, Croo, Doug, Gran, Harn, Hood, Linn, Morr, Umat, Unio, Wall, Wasc, Whee | G4G5<br>S3 | -- | -- | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Botrychium montanum* W.H. Wagner<br>Mountain grape-fern | BM, EC, WC; CA, MT, WA, BC +<br>Bake, Croo, Gran, Hood, Linn, Mari, Unio, Wall, Wasc, Whee | G3<br>S2 | SOC | -- | 2 |
| *Botrychium paradoxum* W.H. Wagner<br>Twin-spike moonwort | BM; MT, UT, WA, AB, BC, SK<br>Bake, Gran, Unio, Wall, Whee | G3G4<br>S1 | SOC | C | 2 |
| *Botrychium pedunculosum* W.H. Wagner<br>Stalked moonwort | BM; MT, WA, AB, BC, SK<br>Bake, Gran, Unio, Wall | G2G3<br>S1 | SOC | C | 1 |
| *Botrychium pinnatum* St. John<br>Pinnate grape-fern | BM, BR, EC; CA, WA, ID +<br>Bake, Gran, Harn, Umat, Unio, Wall, Wasc, Whee | G4?<br>S3 | -- | -- | 4 |
| *Botrychium pumicola* Coville ex Underwood<br>Pumice grape-fern | EC, WC; CA<br>Desc, Klam, Lake | G3<br>S3 | -- | LT | 1 |
| *Brodiaea californica* Lindl.<br>California brodiaea | KM; CA<br>Jack | G4?<br>SNR | -- | -- | 3 |
| *Brodiaea terrestris* Kellogg<br>Dwarf brodiaea | CR; CA<br>Coos, Curr | G4G5<br>S2 | -- | -- | 2 |
| *Bulbostylis capillaris* (L.) Kunth ex C.B. Clarke<br>Densetuft hairsedge | KM; CA +<br>Jose | G5<br>SH | -- | -- | 2-ex |
| *Bupleurum americanum* Coult. & Rose<br>Bupleurum | BM; ID +<br>Bake, Wall | G5<br>S1 | -- | -- | 2 |
| *Calamagrostis breweri* Thurb.<br>Brewer reedgrass | WC; CA<br>Clac, Hood, Jeff, Linn, Mari | G3<br>S2 | -- | -- | 2 |
| *Calamagrostis tweedyi* (Scribn.) Scribn. ex Vasey<br>Tweedy's reedgrass | WC; ID, NV, MT<br>Klam | G3<br>SNR | -- | -- | 3 |
| *Callitriche fassettii* Schotsman<br>Fassett's water-starwort | BR, CB, CR, EC, WV<br>Bent, Clat, Desc, Doug, Harn, Klam, Lake, Malh, Polk, Wasc | G1Q<br>SNR | -- | -- | 3 |
| *Callitriche marginata* Torr.<br>Winged water-starwort | CB, KM; BC, CA<br>Jack, Jose, Wasc | G4<br>S2 | -- | -- | 2 |
| *Callitriche trochlearis* Fassett<br>Wheel fruited water-starwort | EC, KM, WC<br>Bent, Jack, Klam, Linn | G3?<br>SNR | -- | -- | 3 |
| *Calochortus coxii* M. Godfrey & F. Callahan<br>Cox's mariposa-lily | KM<br>Doug | G1<br>S1 | SOC | LE | 1 |
| *Calochortus greenei* S. Wats.<br>Greene's mariposa-lily | EC, KM; CA<br>Jack, Klam | G3<br>S3 | SOC | C | 1 |
| *Calochortus howellii* S. Wats.<br>Howell's mariposa-lily | KM<br>Curr, Jose | G3<br>S3 | SOC | LT | 1 |
| *Calochortus indecorus* Ownbey & M.E. Peck<br>Sexton Mt. mariposa-lily | KM<br>Jose | GX<br>SX | -- | LE | 1-X |
| *Calochortus longebarbatus* S. Wats. var. *longebarbatus*<br>Long-bearded mariposa-lily | BM, EC; CA, WA<br>Klam, Lake, Umat, Unio, Wasc | G4T4<br>S3 | -- | -- | 4 |
| *Calochortus longebarbatus* S. Wats. var. *peckii* Ownbey<br>Peck's mariposa-lily | BM<br>Croo, Gran, Harn, Whee | G4T3<br>S3 | SOC | C | 1 |
| *Calochortus macrocarpus* Dougl. var. *maculosus* (A. Nels. & J.F. Macbr.) A. Nels. & J.F. Macbr.<br>Green-band mariposa-lily | BM; ID, WA<br>Wall | G5T2<br>S2 | SOC | -- | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Calochortus monophyllus* (Lindl.) Lem.<br>One-leaved calochortus | EC, WC; CA<br>Jack, Klam | G3G4<br>S1 | -- | -- | 2 |
| *Calochortus nitidus* Dougl.<br>Broad-fruit mariposa-lily | WC; ID<br>Jack | G3<br>S1 | SOC | -- | 2 |
| *Calochortus nudus* S. Wats.<br>Shasta star-tulip | KM; CA<br>Jack | G3G4<br>S2 | -- | -- | 2 |
| *Calochortus persistens* Ownbey<br>Siskiyou mariposa lily | KM; CA<br>Jack | G2<br>S1 | C | C | 1 |
| *Calochortus umpquaensis* N.A. Fredricks<br>Umpqua mariposa-lily | KM, WC<br>Doug, Jack, Jose | G3<br>S3 | SOC | LE | 1 |
| *Calyptridium roseum* S. Wats.<br>Rosy pussypaws | BM, BR; CA, ID, WA +<br>Harn, Lake, Malh | G5<br>S1 | -- | -- | 2 |
| *Camassia howellii* S. Wats.<br>Howell's camassia | KM<br>Jack, Jose | G2<br>S2 | SOC | C | 1 |
| *Camissonia parvula* (Nutt. ex Torr. & Gray) Raven<br>Lewis' River suncup | BR; CA, ID, NV, WA +<br>Harn, Lake, Malh | G5<br>SNR | -- | -- | 3 |
| *Camissonia pusilla* Raven<br>Washoe suncup | BR; CA, ID, NV, UT<br>Desc, Harn, Lake, Malh | G3G4<br>S2 | -- | -- | 2 |
| *Cardamine nuttallii* Greene var. *gemmata* (Greene) Rollins<br>Purple toothwort | KM; CA<br>Curr, Jose | G5T3<br>S3 | -- | C | 4 |
| *Cardamine pattersonii* Henderson<br>Saddle Mt. bittercress | CR<br>Clat, Till | G2<br>S2 | SOC | C | 1 |
| *Carex abrupta* Mackenzie<br>Abrupt-beaked sedge | BM, BR, KM, WC; CA, ID, NV +<br>Curr, Doug, Harn, Jose, Klam, Lake, Lane, Linn, Wall | G5<br>S3 | -- | -- | 4 |
| *Carex atherodes* Spreng.<br>Awned sedge | BM, BR, EC; CA, ID, NV, WA +<br>Harn, Klam, Lake, Malh, Unio, Wall | G5<br>S2? | -- | -- | 3 |
| *Carex atrosquama* Mackenzie<br>Blackened sedge | BM, BR; ID, WA +<br>Malh, Wall | G5<br>S1 | -- | -- | 2 |
| *Carex barbarae* Dewey<br>Santa Barbara sedge | CR, KM; CA<br>Curr, Doug, Jack, Jose | G4G5Q<br>S3? | -- | -- | 4 |
| *Carex bebbii* Olney ex Fern.<br>Bebb's sedge | BM; WA +<br>Desc, Jeff, Unio, Wall | G5<br>S4 | -- | -- | 4 |
| *Carex brevicaulis* Mackenzie<br>Short-stemmed sedge | CR; WA, CA<br>Clat, Coos, Curr, Doug, Linc, Till | G5<br>S2 | -- | -- | 2 |
| *Carex capillaris* L.<br>Capillary sedge | BM; ID, NV +<br>Wall | G5<br>S2 | -- | -- | 2 |
| *Carex capitata* L.<br>Capitate sedge | BR, EC, WC; ID, NV, WA +<br>Desc, Harn, Jack, Klam, Lake | G5<br>S2 | -- | -- | 2 |
| *Carex comosa* Boott<br>Bristly sedge | EC, KM, WV; CA, ID, WA +<br>Colu?, Jack, Jose, Klam, Mult | G5<br>S1 | -- | -- | 2 |
| *Carex concinna* R. Br.<br>Low northern sedge | BM; ID, WA +<br>Gran, Wall | G5<br>S3 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Carex cordillerana* Saarela & B. A. Ford<br>Cordilleran sedge | BM, BR; AB<br>Bake, Harn, Malh, Morr, Umat, Unio, Wall | G3G4<br>S2 | -- | -- | 2 |
| *Carex crawfordii* Fern.<br>Crawford's sedge | CR, WC; ID, WA +<br>Jack | G5<br>S1 | -- | -- | 2 |
| *Carex davyi* Mackenzie<br>Dry-spike sedge | EC; CA, WA<br>Lake | G2<br>S1 | -- | -- | 1 |
| *Carex diandra* Schrank<br>Lesser panicled sedge | EC, WC; CA, NV, WA +<br>Desc, Jack, Klam, Lake, Lane | G5<br>S1 | -- | -- | 2 |
| *Carex duriuscula* C.A. Mey.<br>Involute-leaved sedge | BM, EC; CA, ID, NV, WA +<br>Bake, Klam | G5<br>SH | -- | -- | 2-ex |
| *Carex gynocrates* Wormsk. ex Drej.<br>Yellow bog sedge | BM; NV +<br>Wall | G5<br>S1 | -- | -- | 2 |
| *Carex gynodynama* Olney<br>Hairy sedge | CR, EC, KM, WC, WV; CA<br>Coos, Curr, Doug, Lane | G4G5<br>S3 | -- | -- | 4 |
| *Carex haydeniana* Olney<br>Hayden's sedge | BM, BR; CA, ID, NV, WA +<br>Bake, Gran, Harn, Wall | G4G5<br>S4 | -- | -- | 4 |
| *Carex heteroneura* W. Boott<br>Different-nerve sedge | BM, BR, WC; CA, ID, NV, WA +<br>Doug, Gran, Harn, Klam, Wall | G5<br>S3 | -- | -- | 4 |
| *Carex idahoa* Bailey<br>Idaho sedge | BM; ID, CA +<br>Gran | G2G3<br>S1 | SOC | -- | 1 |
| *Carex infirminervia* Naczi<br>Weak-veined sedge | BM, WC; CA, ID, NV, WA +<br>Gran, Klam, Lake?, Lane, Morr, Unio, Wall | G5<br>SNR | -- | -- | 3 |
| *Carex klamathensis* B.L. Wilson & L.P. Janeway<br>Klamath sedge | KM; CA<br>Jose | G2<br>S2 | -- | -- | 1 |
| *Carex lasiocarpa* Ehrh. var. *americana* Fern.<br>Slender sedge | BM, EC, WC; CA, ID, WA +<br>Desc, Klam, Lake, Unio, Wall, Wasc | G5T5<br>S2 | -- | -- | 2 |
| *Carex livida* (Wahlenb.) Willd.<br>Pale sedge | CR, WC; CA, ID, WA +<br>Clac, Lane, Linc, Mult | G5<br>S2 | -- | -- | 2 |
| *Carex macrocephala* Willd. ex Spreng.<br>Bighead sedge | CR; WA, AK, BC<br>Clat, Coos, Doug, Lane, Linc, Till | G5<br>S2 | -- | -- | 2 |
| *Carex macrochaeta* C.A. Mey.<br>Alaska long-awned sedge | CR, WC; WA +<br>Clat, Mult | G5<br>S2 | -- | -- | 2 |
| *Carex media* R. Br.<br>Intermediate sedge | BM; WA +<br>Wall | G5?<br>S1 | -- | -- | 2 |
| *Carex micropoda* C.A. Mey.<br>Small-footed sedge | BM; CA, ID, NV, WA +<br>Bake?, Unio?, Wall | G4G5<br>S1 | -- | -- | 2 |
| *Carex nardina* Fries<br>Spikenard sedge | BM, WC; ID, NV, WA +<br>Doug, Gran, Wall | G4G5<br>S2? | -- | -- | 2 |
| *Carex nervina* Bailey<br>Sierra nerved sedge | KM; CA, NV<br>Jack, Jose | G5<br>S1 | -- | -- | 2 |
| *Carex pelocarpa* F.J. Herm.<br>Dusky-seed sedge | BM, BR; ID, NV +<br>Harn, Wall | G4G5<br>S1 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Carex pluriflora* Hulten<br>Many flowered sedge | CR; WA, BC +<br>Clat | G5<br>S1 | -- | -- | 2 |
| *Carex praeceptorum* Mackenzie<br>Teacher's sedge | BM, BR; CA, ID, NV, WA +<br>Bake, Gran, Harn, Unio, Wall | G4G5<br>S3 | -- | -- | 4 |
| *Carex retrorsa* Schwein.<br>Retrorse sedge | BM, CB, WC, WV; ID, WA +<br>Bake, Colu, Lane, Mult, Umat | G5<br>S1 | -- | -- | 2 |
| *Carex saxatilis* L.<br>Russet sedge | BM, BR; ID, NV, WA +<br>Lake, Wall | G5<br>S1 | -- | -- | 2 |
| *Carex scabriuscula* Mackenzie<br>Siskiyou sedge | KM; CA<br>Curr, Jack?, Jose | G3G4<br>S3 | -- | -- | 4 |
| *Carex scirpoidea* Michx. ssp. *stenochlaena* (Holm) A. & D. Love<br>Alaskan single-spiked sedge | BR, WC; ID, WA, MT +<br>Harn, Lane | G5T4T5<br>S1? | -- | -- | 2 |
| *Carex serratodens* W. Boott<br>Saw-tooth sedge | KM, WC; CA<br>Doug, Jack, Jose | G5<br>S3 | -- | -- | 4 |
| *Carex subbracteata* Mackenzie<br>Small-bract sedge | CR, KM; CA<br>Coos, Jose | G5<br>SNR | -- | -- | 3 |
| *Carex subnigricans* Stacey<br>Dark alpine sedge | BM, BR; CA, NV, ID +<br>Harn, Wall | G5<br>S1 | -- | -- | 2 |
| *Carex tahoensis* Smiley<br>Tahoe sedge | BM, BR; CA, ID, WA +<br>Bake, Gran, Harn, Wall | G5<br>SNR | -- | -- | 3 |
| *Carex tiogana* D. Taylor & J. Mastrogiuseppe<br>Tioga Pass sedge | BR; CA<br>Harn | G1<br>S1 | -- | -- | 1 |
| *Carex vernacula* Bailey<br>Native sedge | BM, BR, EC, WC; CA, ID, NV, WA +<br>Bake, Harn, Hood, Lake, Wall | G5<br>S2 | -- | -- | 2 |
| *Castilleja brevilobata* Piper<br>Short-lobed red-paintbrush | KM; CA<br>Curr, Jack, Jose | G3<br>S3 | -- | -- | 4 |
| *Castilleja chambersii* J.M. Egger & R.J. Meinke<br>Chambers' paintbrush | CR<br>Clat | G1<br>S1 | SOC | -- | 1 |
| *Castilleja chlorotica* Piper<br>Green-tinged paintbrush | BM, EC<br>Croo, Desc, Klam, Lake | G3<br>S3 | -- | -- | 1 |
| *Castilleja flava* S. Wats. var. *rustica* (Piper) N. Holmgren<br>Rustic paintbrush | BM; ID, MT<br>Bake, Wall | G4G5T3T4<br>S1 | -- | -- | 2 |
| *Castilleja fraterna* Greenm.<br>Fraternal paintbrush | BM<br>Unio, Wall | G2<br>S2 | SOC | -- | 1 |
| *Castilleja levisecta* Greenm.<br>Golden paintbrush | WV; WA, BC<br>Linn, Mari, Mult | G1<br>SX | LT | LE | 1-ex |
| *Castilleja mendocinensis* (Eastw.) Pennell<br>Mendocino coast paintbrush | CR; CA<br>Curr | G2<br>S1 | SOC | -- | 1 |
| *Castilleja oresbia* Greenm.<br>Pale Wallowa paintbrush | BM<br>Bake, Croo, Gran, Malh, Umat?, Unio, Wall, Whee | G3G4<br>S3? | -- | -- | 3 |
| *Castilleja rubida* Piper<br>Purple alpine paintbrush | BM<br>Wall | G2<br>S2 | SOC | -- | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Castilleja rupicola* Piper ex Fern.<br>Cliff paintbrush | WC; WA, BC<br>Clac?, Desc, Doug, Hood?, Lane, Linn, Mari, Mult | G3G4<br>S3 | SOC | -- | 4 |
| *Castilleja schizotricha* Greenm.<br>Split-hair paintbrush | KM; CA<br>Jack, Jose | G3<br>S2 | -- | -- | 2 |
| *Castilleja thompsonii* Pennell<br>Thompson's paintbrush | EC, WC; WA, BC<br>Wasc | G4<br>S1 | -- | -- | 2 |
| *Castilleja viscidula* Gray<br>Sticky paintbrush | BM, BR; ID, NV<br>Bake, Gran, Harn, Malh, Unio, Wall | G4G5<br>S2 | -- | -- | 2 |
| *Castilleja wightii* Elmer<br>Wight's paintbrush | CR; CA<br>Curr | G2G3Q<br>SH | -- | -- | 3 |
| *Caulanthus crassicaulis* (Torr.) S. Wats. var. *crassicaulis*<br>Thick-stemmed wild cabbage | BR; NV<br>Harn, Lake, Malh | G4G5T3T5<br>S4 | -- | -- | 4 |
| *Caulanthus crassicaulis* (Torr.) S. Wats. var. *glaber* M.E. Jones<br>Smooth wild cabbage | BR; CA, NV, UT<br>Malh | G4G5T3?<br>S1 | -- | -- | 2 |
| *Caulanthus major* (M.E. Jones) Payson var. *nevadensis* Rollins<br>Slender wild cabbage | BR; CA, NV<br>Harn, Malh | G4T3?<br>S1 | SOC | C | 2 |
| *Caulanthus pilosus* S. Wats.<br>Hairy wild cabbage | BM, BR; CA, ID, NV<br>Bake, Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Cerastium beeringianum* Cham. & Schlecht.<br>Alpine chickweed | BR<br>Harn | G5<br>SNR | -- | -- | 3 |
| *Ceratophyllum echinatum* Gray<br>Prickly hornwort | CR; WA +<br>Lane | G4?<br>SH | -- | -- | 2-ex |
| *Chaenactis cusickii* Gray<br>Cusick's chaenactis | BR; ID<br>Malh | G3<br>S3 | -- | -- | 4 |
| *Chaenactis macrantha* D.C. Eat.<br>Large-flowered chaenactis | BR; CA, ID, NV +<br>Harn, Malh | G4<br>S3 | -- | -- | 4 |
| *Chaenactis nevii* Gray<br>Nevius' chaenactis | BM<br>Gill, Gran, Jeff, Wasc, Whee | G4<br>S4 | -- | -- | 4 |
| *Chaenactis suffrutescens* Gray<br>Shasta pincusion | KM; CA<br>Jack | G3<br>SNR | -- | -- | 3 |
| *Chaenactis xantiana* Gray<br>Desert pincushion | BR; CA, NV, AZ<br>Harn, Lake, Malh | G4G5<br>S1? | -- | -- | 2 |
| *Chaetadelpha wheeleri* Gray ex S. Wats.<br>Wheeler's skeleton-weed | BR; CA, NV<br>Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Chamerion latifolium* (L.) Holub<br>Broad-leaved willow-herb | BM, WC; CA, ID, WA +<br>Desc, Gran, Linn, Wall | G5<br>S3 | -- | -- | 4 |
| *Cheilanthes covillei* Maxon<br>Coville's lipfern | WC; CA, NV +<br>Jack | G4?<br>S1 | -- | -- | 2 |
| *Cheilanthes feei* T. Moore<br>Fee's lipfern | BM; CA, ID, NV, WA +<br>Wall | G5<br>S2 | -- | -- | 2 |
| *Cheilanthes intertexta* (Maxon) Maxon<br>Coastal lipfern | KM; CA<br>Doug, Jack | G5<br>S1 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Chlorocrambe hastata* (S. Wats.) Rydb.<br>Spearhead | BM<br>Bake, Wall | G3?<br>S1 | -- | -- | 1 |
| *Chlorogalum angustifolium* Kellogg<br>Narrow-leaved amole | KM; CA<br>Jack, Jose | G4G5<br>S1 | -- | -- | 2 |
| *Chloropyron maritimum* (Nutt. ex Benth.) A. Heller ssp. *palustre* (Behr) Tank & J.M. Egger<br>Pt. Reyes bird's-beak | ME; CA<br>Coos, Linc, Till | G4?T2<br>S2 | SOC | LE | 1 |
| *Cicendia quadrangularis* (Lam.) Griseb.<br>Timwort | CR, KM, WV; CA +<br>Coos, Curr, Doug, Lane, Linn | G4<br>S2 | -- | -- | 2 |
| *Cicuta bulbifera* L.<br>Bulb-bearing water-hemlock | EC; ID, WA +<br>Klam | G5<br>SH | -- | -- | 2-ex |
| *Cimicifuga elata* Nutt. var. *alpestris* Lee & Park<br>Mountain tall bugbane | KM, WC<br>Doug, Jack, Jose | G4T4<br>S4 | -- | C | 4 |
| *Cimicifuga elata* Nutt. var. *elata*<br>Tall bugbane | CR, KM, WC, WV; WA, BC<br>Bent, Clac, Colu, Doug, Lane, Linn, Mari, Mult, Polk, Wash, Yamh | G4T4<br>S4 | -- | C | 4 |
| *Cirsium ciliolatum* (Henderson) J.T. Howell<br>Ashland thistle | KM, WC; CA<br>Jack | G3<br>S3 | -- | -- | 4 |
| *Clarkia heterandra* (Torr.) Lewis & Raven<br>Small-fruit clarkia | KM; CA<br>Doug, Jack, Jose | G4?<br>S3 | -- | -- | 4 |
| *Claytonia nevadensis* S. Wats.<br>Sierra spring-beauty | BR; CA, NV<br>Harn | G4<br>S3 | -- | -- | 4 |
| *Clintonia andrewsiana* Torr.<br>Andrew's bead-lily | CR; CA<br>Curr | G4<br>SH | -- | -- | 2-ex |
| *Cochlearia groenlandica* L.<br>Scurvygrass | CR; CA, WA +<br>Coos, Curr | G4?<br>S1 | -- | -- | 2 |
| *Coleanthus subtilis* (Tratt.) Seidel<br>Moss grass | WV<br>Mult | G3G5<br>SNR | -- | -- | 3 |
| *Collomia larsenii* (Gray) Payson<br>Talus collomia | WC; CA, WA<br>Clac, Desc, Hood, Jeff, Lane | G4<br>S4 | -- | -- | 4 |
| *Collomia mazama* Coville<br>Mt. Mazama collomia | WC<br>Doug, Jack, Klam | G3<br>S3 | -- | -- | 1 |
| *Collomia renacta* E. Joyal<br>Barren Valley collomia | BR; NV<br>Malh | G1<br>S1 | SOC | C | 1 |
| *Coptis trifolia* (L.) Salisb.<br>Three-leaf goldthread | WC; BC +<br>Clac, Wasc | G5<br>S1 | -- | -- | 2 |
| *Corallorhiza wisteriana* Conrad<br>Spring coral-root | KM; ID +<br>Jack | G5<br>SNR | -- | -- | 3 |
| *Corydalis aquae-gelidae* M.E. Peck & Wilson<br>Cold-water corydalis | WC; WA<br>Clac, Lane, Linn, Mari, Mult | G3<br>S3 | SOC | C | 1 |
| *Coryphantha vivipara* (Nutt.) Britt. & Rose var. *vivipara*<br>Cushion coryphantha | BM, BR?, CB; CA, ID, NV +<br>Jeff, Sher, Whee | G5T5<br>S1 | -- | -- | 2 |
| *Crassula solieri* (Gay) Meigen<br>Solieri's pygmyweed | BR; CA, NV +<br>Harn, Lake, Malh | G4G5<br>S1? | -- | -- | 3 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Cryptantha echinella* Greene<br>Prickly cryptantha | BR<br>Harn | G4<br>SNR | -- | -- | 3 |
| *Cryptantha gracilis* Osterhout<br>Narrow-stem cat's-eye | BR; CA, ID, NV, WA +<br>Malh | G5<br>SNR | -- | -- | 3 |
| *Cryptantha grandiflora* Rydb.<br>Clearwater cryptantha | BM; ID, WA<br>Gran, Whee? | GNR<br>S2 | -- | -- | 2 |
| *Cryptantha humilis* (Gray) Payson<br>Low cryptantha | BM, BR; CA, ID, NV +<br>Harn, Malh, Wall | G4?<br>SNR | -- | -- | 3 |
| *Cryptantha leiocarpa* (Fisch. & C.A. Mey.) Greene<br>Seaside cryptantha | CR; CA<br>Curr | G3G4<br>S1 | -- | -- | 2 |
| *Cryptantha leucophaea* (Dougl. ex Lehm.) Payson<br>Gray cryptantha | CB; WA<br>Gill | G2G3<br>SH | -- | -- | 2-ex |
| *Cryptantha milo-bakeri* I.M. Johnston<br>Milo Baker's cryptantha | CR, KM; CA<br>Jack, Jose | G3G4<br>S1 | -- | -- | 2 |
| *Cryptantha simulans* Greene<br>Pine woods cryptantha | BM, BR, EC, KM; CA, ID, NV, WA<br>Bake, Harn, Jack, Klam | G4<br>S2 | -- | -- | 2 |
| *Cryptantha thompsonii* I.M. Johnston<br>Thompson's cryptantha | BM; WA<br>Bake | G3<br>S1 | -- | -- | 3 |
| *Cryptogramma stelleri* (Gmel.) Prantl<br>Steller's rock-brake | BM; NV, WA +<br>Bake?, Wall | G5<br>S1 | -- | -- | 2 |
| *Cymopterus acaulis* (Pursh) Raf. var. *greeleyorum* J. Grimes & Packard<br>Greeley's cymopterus | BR; ID<br>Malh | G5T2<br>S1 | SOC | -- | 1 |
| *Cymopterus longipes* S. Wats. var. *ibapensis* (M.E. Jones) Cronq.<br>Ibapah wavewing | BR; ID, NV +<br>Malh | G4T4<br>S2? | -- | -- | 2 |
| *Cymopterus nivalis* S. Wats.<br>Snowline cymopterus | BM, BR; ID, NV +<br>Gran, Harn, Lake | G5<br>S2 | -- | -- | 2 |
| *Cymopterus purpurascens* (Gray) M.E. Jones<br>Purple cymopterus | BR; CA, ID, NV<br>Harn | G4<br>S2 | -- | -- | 2 |
| *Cyperus acuminatus* Torr. & Hook. ex Torr.<br>Short-pointed cyperus | KM, WV; CA, WA +<br>Jack, Jose, Linn, Mari | G5<br>S1 | -- | -- | 2 |
| *Cyperus bipartitus* Torr.<br>Shining cyperus | BR, CB, CR, KM, WV; CA, ID, WA +<br>Curr, Doug, Jack, Jose, Lane, Malh, Umat, Wasc | G5<br>SNR | -- | -- | 3 |
| *Cyperus lupulinus* (Spreng.) Marcks ssp. *lupulinus*<br>Great Plains flatsedge | BM, WV; ID, WA +<br>Wall | G5T5?<br>S1 | -- | -- | 2 |
| *Cypripedium californicum* Gray<br>California lady's-slipper | CR, KM; CA<br>Coos, Curr, Doug, Jack, Jose | G3<br>S3 | -- | -- | 4 |
| *Cypripedium fasciculatum* Kellogg ex S. Wats.<br>Clustered lady's-slipper | BM, KM, WC; CA, CO, ID, MT, WA, WY<br>Bake, Curr, Doug, Jack, Jose | G4<br>S2 | SOC | C | 2 |
| *Cypripedium montanum* Dougl. ex Lindl.<br>Mountain lady's-slipper | BM, EC, KM, WC, WV; CA, ID, WA +<br>Bake, Bent, Clac, Croo, Desc?, Doug, Gran, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Mari, Morr?, Mult, Umat, Unio, Wall, Wasc, Whee | G4<br>S3S4 | -- | -- | 4 |
| *Danthonia spicata* (L.) Beauv. ex Roemer & J.A. Schultes<br>Poverty oatgrass | WC, WV; ID, WA +<br>Clac, Lane | G5<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Darlingtonia californica* Torr.<br>California pitcher-plant | CR, KM; CA<br>Coos, Curr, Doug, Jose, Lane, Linc, Till | G3G4<br>S3S4 | -- | -- | 4 |
| *Delphinium leucophaeum* Greene<br>White rock larkspur | WV; WA<br>Clac, Mari, Mult, Wash, Yamh | G2<br>S2 | SOC | LE | 1 |
| *Delphinium nudicaule* Torr. & Gray<br>Red larkspur | KM; CA<br>Doug, Jack, Jose | G4<br>S2 | -- | -- | 2 |
| *Delphinium nuttallii* Gray<br>Nuttall's larkspur | EC, KM, WC, WV; WA, BC<br>Clac, Hood, Jack, Mult, Wasc, Yamh | G4<br>S1 | -- | -- | 2 |
| *Delphinium oreganum* Howell<br>Willamette Valley larkspur | CR, WC, WV<br>Clat, Lane, Linn, Mari, Polk, Yamh | G3Q<br>S1 | SOC | C | 1 |
| *Delphinium pavonaceum* Ewan<br>Peacock larkspur | CR?, WC?, WV<br>Bent, Clac, Lane, Mari, Mult, Polk | G1Q<br>S1 | SOC | LE | 1 |
| *Dicentra formosa* (Andr.) Walp. ssp. *oregana* (Eastw.) Munz<br>Oregon bleedingheart | KM; CA<br>Curr, Jose | G5T4<br>S4 | -- | -- | 4 |
| *Dicentra pauciflora* S. Wats.<br>Few-flowered bleedingheart | KM; CA<br>Jose | G3?<br>S1 | SOC | -- | 2 |
| *Dichelostemma ida-maia* (Wood) Greene<br>Firecracker flower | CR, KM, WC; CA<br>Curr, Doug, Jack, Jose | G4<br>S4 | -- | -- | 4 |
| *Dodecatheon austrofrigidum* K.L. Chambers<br>Frigid shootingstar | CR; WA<br>Clat, Till | G2<br>S2 | SOC | -- | 1 |
| *Dodecatheon pulchellum* (Raf.) Merr. var. *shoshonense* (A. Nels.) Reveal<br>Darkthroat shootingstar | BR; CA, ID, NV, UT<br>Malh | G5TNR<br>S2 | -- | -- | 2 |
| *Douglasia laevigata* Gray<br>Smooth-leaved douglasia | CR, WC; WA +<br>Clac, Clat, Desc, Doug, Hood, Lane, Linn, Mari, Mult, Till | G3<br>SNR | -- | -- | 3 |
| *Draba aureola* S. Wats.<br>Golden alpine draba | WC; CA, WA<br>Clac, Desc, Klam, Lane | G4<br>S4 | -- | -- | 4 |
| *Draba cusickii* B.L. Robins. ex O.E. Schulz var. *cusickii*<br>Cusick's draba | BR<br>Harn | G4T3<br>S3 | -- | -- | 4 |
| *Draba cyclomorpha* Payson<br>Wallowa draba | BM<br>Unio, Wall | G3<br>S3 | -- | -- | 4 |
| *Draba howellii* S. Wats.<br>Howell's whitlow-grass | KM; CA<br>Curr, Jose | G4<br>S2 | -- | C | 2 |
| *Dracocephalum parviflorum* Nutt.<br>American dragonhead | BM, BR<br>Harn, Unio | G5<br>SNR | -- | -- | 3 |
| *Dryas drummondii* Richards. ex Hook.<br>Yellow mountain-avens | BM; WA +<br>Wall | G5<br>S4 | -- | -- | 4 |
| *Dryopteris filix-mas* (L.) Schott<br>Male fern | BM, BR, CR, EC, WC; CA, WA, ID +<br>Bake, Colu, Malh, Umat, Unio, Wall, Wasc | G5<br>S3 | -- | -- | 4 |
| *Eatonella nivea* (D.C. Eat.) Gray<br>White eatonella | BR; CA, ID, NV, WA<br>Harn, Lake, Malh | G4G5<br>S3 | -- | -- | 4 |
| *Elatine brachysperma* Gray<br>Short-seeded waterwort | BM, BR; CA, NV, WA +<br>Croo?, Desc, Harn, Lake, Malh | G5<br>S1 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Eleocharis bolanderi* Gray<br>Bolander's spikerush | BM, BR, EC; CA, ID, NV +<br>Bake, Gran, Harn, Klam, Lake, Malh, Morr, Umat, Unio, Wall, Whee | G4<br>S2 | -- | -- | 2 |
| *Elmera racemosa* (S. Wats.) Rydb. var. *racemosa*<br>Yellow coralbells | WC; WA +<br>Desc, Doug, Jeff, Klam, Lane | G4G5T4<br>S4 | -- | -- | 4 |
| *Elodea nuttallii* (Planch.) St. John<br>Nuttall's waterweed | BR, CR, EC, WC, WV; CA, WA, ID +<br>Clat, Colu, Desc, Harn, Lake, Lane, Mult | G5<br>SNR | -- | -- | 3 |
| *Elymus glaucus* Buckl. ssp. *virescens* (Piper) Gould<br>Smooth wildrye | CR; CA, WA, AK, BC<br>Coos, Curr, Linc | G5T4?<br>SNR | -- | -- | 3 |
| *Elymus hirsutus* J. Presl<br>Hairy wildrye | CR<br>Clat, Till | G5<br>SNR | -- | -- | 3 |
| *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould ssp. *psammophilus* (Gillett & Senn) A. Love<br>Sand-dune wild-rye | CB<br>Gill, Morr, Sher | G5T3<br>SNR | -- | -- | 3 |
| *Enemion occidentale* (Hook. & Arn.) Drumm. & Hutchinson<br>Western false rue-anemone | KM<br>Jose | G3?<br>S1? | -- | -- | 2 |
| *Enemion stipitatum* (Gray) Drumm. & Hutchinson<br>Dwarf isopyrum | CR?, EC, KM, WC, WV; CA<br>Bent, Doug, Jack, Jose, Klam, Lane, Polk, Yamh | G4?<br>S3 | -- | -- | 4 |
| *Epilobium canum* (Greene) Raven ssp. *latifolium* (Hook.) Raven<br>California fire chalice | CR, KM, WC; CA, NV +<br>Curr, Jose, Klam | G5T4<br>SNR | -- | -- | 3 |
| *Epilobium luteum* Pursh<br>Yellow willow-herb | BM, WC; CA, WA +<br>Clac, Desc, Doug, Hood, Jack, Lane, Linn | G5<br>S3 | -- | -- | 4 |
| *Epilobium oreganum* Greene<br>Oregon willow-herb | KM; CA<br>Jose | G2<br>S2 | SOC | C | 1 |
| *Epilobium palustre* L.<br>Swamp willow-herb | BM, WC; ID, WA +<br>Doug, Gran?, Hood?, Klam, Unio, Wall, Whee? | G5<br>SNR | -- | -- | 3 |
| *Epilobium rigidum* Hausskn.<br>Rigid willow-herb | KM; CA<br>Curr, Jose | G3G4<br>S3 | -- | -- | 4 |
| *Epilobium siskiyouense* (Munz) Hoch & Raven<br>Siskiyou willow-herb | KM; CA<br>Jack, Jose | G3<br>S2 | SOC | C | 1 |
| *Equisetum pratense* Ehrh.<br>Meadow horsetail | BM; ID, MT, BC +<br>Unio, Wall | G5<br>SNR | -- | -- | 3 |
| *Eragrostis lutescens* Scribn.<br>Yellow lovegrass | BR, WV; CA, ID, NV, WA +<br>Malh, Mult | G4<br>SNR | -- | -- | 3 |
| *Eremothera boothii* (Douglas) W.L. Wagner & Hoch ssp. *boothii*<br>Booth evening-primrose | BM, BR; CA, ID, NV, WA, AZ<br>Bake, Gran, Malh, Wall? | G5T4<br>S3 | -- | -- | 4 |
| *Eremothera pygmaea* (Dougl. ex Lehm.) W.L. Wagner & Hoch<br>Dwarf evening-primrose | BM, BR, CB; WA<br>Gill?, Gran, Harn, Umat?, Wasc, Whee | G3<br>S1 | SOC | C | 1 |
| *Ericameria arborescens* (Gray) Greene<br>Golden fleece | CR, KM; CA, NV<br>Curr | G4<br>S1 | -- | -- | 2 |
| *Ericameria discoidea* (Nutt.) Nesom<br>Discoid goldenweed | BR; CA, ID, NV +<br>Harn, Lake | G4<br>S3? | -- | -- | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Erigeron cascadensis* Heller<br>Cascade daisy | WC<br>Clac?, Desc?, Doug, Klam, Lane, Linn, Mari | G4<br>S4 | -- | -- | 4 |
| *Erigeron cervinus* Greene<br>Siskiyou daisy | KM; CA<br>Curr, Jose | G3<br>S2 | SOC | -- | 2 |
| *Erigeron davisii* (Cronquist) G. L. Nesom<br>Engelmann's daisy | BM; ID<br>Wall | G3<br>S1 | SOC | -- | 2 |
| *Erigeron decumbens* Nutt.<br>Willamette Valley daisy | WV<br>Bent, Clac, Lane, Linn, Mari, Polk, Wash, Yamh | G1<br>S1 | LE | LE | 1 |
| *Erigeron disparipilus* Cronq.<br>White cushion erigeron | BM; WA, CA<br>Wall | G5<br>S2 | -- | -- | 2 |
| *Erigeron howellii* Gray<br>Howell's daisy | WC; WA<br>Clac, Hood, Mult | G2<br>S2 | SOC | C | 1 |
| *Erigeron klamathensis* (Nesom) Nesom<br>Klamath daisy | CR; CA<br>Curr, Jose | G2G4<br>SNR | -- | -- | 3 |
| *Erigeron latus* (A. Nels. & J.F. Macbr.) Cronq.<br>Broad fleabane | BR; ID, NV<br>Malh | G3<br>S1? | -- | -- | 2 |
| *Erigeron oreganus* Gray<br>Oregon daisy | EC, WC; WA<br>Hood, Mult, Wasc? | G3<br>S3 | SOC | C | 1 |
| *Erigeron peregrinus* (Banks ex Pursh) Greene var. *peregrinus*<br>Wandering daisy | CR; WA<br>Clat, Till | G5T4<br>S1 | -- | -- | 2 |
| *Erigeron petrophilus* Greene<br>Cliff daisy | KM; CA<br>Jack, Jose | G4<br>S2 | -- | -- | 2 |
| *Erigeron stanselliae* K.L. Chambers<br>Stansell's daisy | KM<br>Curr | G1?<br>S1? | -- | -- | 3 |
| *Erigeron tener* Gray<br>Tender fleabane | BM, BR; CA, ID, NV +<br>Bake, Harn | G4<br>SNR | -- | -- | 3 |
| *Erigeron vagus* Payson<br>Rambling fleabane | BM; CA, NV +<br>Bake, Wall | G4<br>SNR | -- | -- | 3 |
| *Eriogonum brachyanthum* Coville<br>Short-flowered eriogonum | BR; CA, NV<br>Harn | G5<br>S1 | -- | -- | 2 |
| *Eriogonum chrysops* Rydb.<br>Golden buckwheat | BR<br>Malh | G2<br>S2 | SOC | LT | 1 |
| *Eriogonum crosbyae* Reveal var. *crosbyae*<br>Crosby's buckwheat | BR; NV<br>Harn, Lake | G3T3<br>S2 | SOC | LT | 1 |
| *Eriogonum crosbyae* Reveal var. *mystrium* (Reveal) Grady & Reveal<br>Pueblo Mountains Buckwheat | BR; ID, NV<br>Harn, Malh | G3T2?<br>S2 | SOC | LT | 1 |
| *Eriogonum cusickii* M.E. Jones<br>Cusick's eriogonum | BM, BR<br>Harn, Lake | G2<br>S2 | SOC | C | 1 |
| *Eriogonum diclinum* Reveal<br>Jaynes Canyon buckwheat | KM; CA<br>Jack, Jose | G3<br>S3 | -- | -- | 4 |
| *Eriogonum hookeri* S. Wats.<br>Hooker's wild buckwheat | BR; CA, ID, NV +<br>Malh | G5<br>S1 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Eriogonum lobbii* Torr. & Gray<br>Lobb's buckwheat | KM; CA, NV<br>Curr, Jose | G4<br>S2 | -- | -- | 2 |
| *Eriogonum nudum* Dougl. ex Benth. var. *paralinum* Reveal<br>Del Norte buckwheat | CR; CA<br>Curr | G5T2T4<br>SNR | -- | -- | 3 |
| *Eriogonum nutans* Torr. & Gray<br>Spreading eriogonum | BR; CA, NV<br>Harn | G5<br>SNR | -- | -- | 3 |
| *Eriogonum ochrocephalum* S. Wats. var. *calcareum* (S. Stokes) M.E. Peck<br>Ochre-flowered buckwheat | BR; ID<br>Harn, Malh | G5T3<br>S3 | -- | -- | 4 |
| *Eriogonum pendulum* S. Wats.<br>Waldo buckwheat | KM; CA<br>Curr, Jose | G4<br>S4 | -- | -- | 4 |
| *Eriogonum prociduum* Reveal<br>Prostrate buckwheat | BR, EC; CA, ID, NV<br>Klam, Lake | G2?<br>S1? | SOC | C | 1 |
| *Eriogonum pyrolifolium* Hook. var. *pyrolifolium*<br>Shasta buckwheat | WC; CA, ID, WA<br>Doug, Klam | G4T4<br>SNR | -- | -- | 3 |
| *Eriogonum salicornioides* Gandog.<br>Playa buckwheat | BR; ID, NV<br>Harn, Malh | G3G4<br>S2 | -- | -- | 2 |
| *Eriogonum scopulorum* Reveal<br>Cliff buckwheat | BM<br>Wall | G3<br>S3 | -- | -- | 4 |
| *Eriogonum thymoides* Benth.<br>Thyme-leaved buckwheat | BM, CB; ID, WA<br>Bake, Gill?, Harn, Sher?, Whee | G4<br>SNR | -- | -- | 3 |
| *Eriogonum umbellatum* Torr. var. *glaberrimum* (Gandog.) Reveal<br>Green buckwheat | EC; CA<br>Lake | G5T2?<br>S1? | SOC | -- | 1 |
| *Eriogonum villosissimum* Reveal & D.A. York<br>Acker Rock wild buckwheat | WC<br>Doug | G1<br>S1 | -- | -- | 1 |
| *Eriophorum angustifolium* Honckeny<br>Many-spiked cotton-grass | WC; ID, WA +<br>Clac, Jeff, Linn, Mari | G5<br>S3 | -- | -- | 4 |
| *Eriophorum chamissonis* C.A. Mey.<br>Russet cotton-grass | CR; BC<br>Coos, Lane, Linc, Till | G5<br>S1 | -- | -- | 2 |
| *Eritrichium nanum* (Vill.) Schrad. ex Gaudin var. *elongatum* (Rydb.) Cronq.<br>Pale alpine-forget-me-not | BM; ID, WA +<br>Wall | G5T4<br>S4 | -- | -- | 4 |
| *Erodium macrophyllum* Hook. & Arn.<br>Large-leaved filaree | KM; CA +<br>Jack | G2<br>SH | -- | -- | 1-ex |
| *Eryngium alismifolium* Greene<br>Inland coyote-thistle | BM, BR, EC, WC; CA, ID, NV<br>Croo, Harn, Klam, Lake, Malh, Unio | G4<br>S3 | -- | -- | 4 |
| *Erysimum concinnum* Eastw.<br>Pacific wallflower | CR; CA<br>Curr | G3<br>S1 | SOC | -- | 2 |
| *Erythronium elegans* Hammond & Chambers<br>Coast Range fawn-lily | CR<br>Linc, Polk, Till, Yamh | G2<br>S2 | SOC | LT | 1 |
| *Erythronium howellii* S. Wats.<br>Howell's adder's-tongue | KM; CA<br>Curr, Jack, Jose | G3<br>S3 | -- | -- | 1 |
| *Erythronium revolutum* Sm.<br>Pink fawn-lily | CR, KM; WA, BC<br>Bent, Clat, Coos, Curr, Doug, Lane, Linc, Till | G4<br>S4 | -- | -- | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Eschscholzia caespitosa* Benth.<br>Gold poppy | KM; CA<br>Curr, Doug, Jose | G5<br>S1 | -- | -- | 2 |
| *Eucephalus breweri* (Gray) Nesom<br>Brewer's aster | KM; CA, NV<br>Jack, Jose | G4<br>SNR | -- | -- | 3 |
| *Eucephalus gormanii* Piper<br>Gorman's aster | WC<br>Clac, Jeff, Linn, Mari | G3<br>S3 | -- | -- | 1 |
| *Eucephalus vialis* Bradshaw<br>Wayside aster | KM, WC, WV; CA<br>Doug, Jack, Jose, Lane, Linn | G3<br>S3 | SOC | LT | 1 |
| *Euonymus occidentalis* Nutt. ex Torr.<br>Western wahoo | KM, WC, WV; CA, WA, BC<br>Clac, Colu, Coos, Curr, Doug, Jack, Jose, Lane, Mari, Mult, Polk, Yamh | G5<br>S3 | -- | -- | 4 |
| *Eurybia merita* (A. Nels.) Nesom<br>Arctic aster | BM; CA, ID, WA +<br>Wall, Whee | G5<br>SNR | -- | -- | 3 |
| *Fauria crista-galli* (Menzies ex Hook.) Makino<br>Deer-cabbage | WC; WA, AK, BC<br>Linn | G5<br>SNR | -- | -- | 3 |
| *Festuca brachyphylla* J.A. Schultes ex J.A. & J.H. Schultes<br>Alpine fescue | BM, BR; ID, NV +<br>Harn, Wall | G5<br>SNR | -- | -- | 3 |
| *Festuca elmeri* Scribn. & Merr.<br>Elmer's fescue | KM; CA<br>Doug, Jack, Jose | G5<br>S3 | -- | -- | 4 |
| *Festuca rubra* L. ssp. *mediana* (Pavlick) Pavlick<br>Median red fescue | ME; BC<br>Curr, Lane | G5TNR<br>SNR | -- | -- | 3 |
| *Festuca rubra* L. ssp. *secunda* (J. Presl) Pavlick<br>Leaning red fescue | ME; WA +<br>Till | G5TNR<br>SNR | -- | -- | 3 |
| *Filipendula occidentalis* (S. Wats.) Howell<br>Queen-of-the-forest | CR; WA<br>Clat, Linc, Polk, Till | G2G3<br>S2 | SOC | C | 1 |
| *Frasera fastigiata* (Pursh) Heller<br>Clustered green-gentian | BM; ID, WA<br>Bake? | G4?<br>SNR | -- | -- | 3 |
| *Frasera umpquaensis* Peck & Applegate<br>Umpqua swertia | KM, WC; CA<br>Curr, Doug, Jack, Jose, Lane | G3Q<br>S3 | -- | C | 1 |
| *Fritillaria camschatcensis* (L.) Ker-Gawl.<br>Indian rice | CR, WC; WA +<br>Linc, Mult, Polk? | G5<br>S1 | -- | -- | 2 |
| *Fritillaria eastwoodiae* Macfarlane<br>Butte County fritillaria | KM; CA<br>Jack | G3Q<br>SNR | -- | -- | 3 |
| *Fritillaria gentneri* Gilkey<br>Gentner's fritillaria | KM, WC; CA<br>Jack, Jose | G1<br>S1 | LE | LE | 1 |
| *Fritillaria glauca* Greene<br>Siskiyou fritillaria | KM, WC; CA<br>Curr, Doug, Jack, Jose, Lane | G3G4<br>S3 | -- | -- | 4 |
| *Fritillaria purdyi* Eastw.<br>Purdy's fritillaria | KM; CA<br>Jose | G3<br>S1 | SOC | -- | 2 |
| *Galium californicum* Hook. & Arn. ssp. *californicum*<br>California bedstraw | KM; CA<br>Curr, Jack? | G5T4?<br>SNR | -- | -- | 3 |
| *Galium grayanum* Ehrend. var. *nanum* Dempster & Ehrend.<br>Gray's bedstraw | WC; CA, NV<br>Doug | G4TNR<br>SNR | -- | -- | 3 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Galium serpenticum* Dempster ssp. *warnerense* Dempster & Ehrend. Warner Mountain bedstraw | BR, EC; CA Lake | G4G5T2 S2 | SOC | -- | 1 |
| *Gentiana newberryi* Gray var. *newberryi* Newberry's gentian | EC, WC; CA Desc, Klam, Lane | G4T3T4 S2 | -- | -- | 2 |
| *Gentiana plurisetosa* C.T. Mason Bristly gentian | KM; CA Jose | G2G3 S1 | SOC | -- | 1 |
| *Gentiana prostrata* Haenke Moss gentian | BR; CA, ID, MT, NV Harn | G4G5 S2 | -- | -- | 2 |
| *Gentiana setigera* Gray Waldo gentian | KM; CA Curr, Jose | G2 S2 | SOC | C | 1 |
| *Gentianella propinqua* (Richards.) J. Gillett Four-part gentian | BM; ID + Wall | G5 SNR | -- | -- | 3 |
| *Gentianella tenella* (Rottb.) Boerner ssp. *tenella* Slender gentian | BR; CA, ID, NV, WA + Harn | G4G5T4 S1 | -- | -- | 2 |
| *Geum rossii* (R. Br.) Ser. var. *turbinatum* (Rydb.) C.L. Hitchc. Slender-stemmed avens | BM; ID, NV + Bake | G5T4 S2 | -- | -- | 2 |
| *Geum triflorum* Pursh var. *campanulatum* (Greene) C.L. Hitchc. Western red avens | CR; WA Clat | G5T4 S1 | -- | -- | 2 |
| *Gilia millefoliata* Fisch. & C.A. Mey. Seaside gilia | CR; CA Curr, Linc | G2 S1 | SOC | -- | 1 |
| *Glyptopleura marginata* D.C. Eat. White-margined waxplant | BR; CA, ID, NV + Harn, Lake, Malh | G4G5 S3 | -- | -- | 4 |
| *Gnaphalium californicum* DC. California cudweed | CR, KM, WV; CA, WA Clat, Curr, Doug, Lane, Linc, Till | G5 SNR | -- | -- | 3 |
| *Gnaphalium macounii* Greene Winged cudweed | BM; CA, ID, WA + Bake | G5 SNR | -- | -- | 3 |
| *Gratiola heterosepala* Mason & Bacig. Boggs Lake hedge-hyssop | BR, EC; CA Klam, Lake | G2 S1 | SOC | LT | 1 |
| *Hackelia bella* (J.F. Macbr.) I.M. Johnston Beautiful stickseed | KM, WC; CA Jack | G3? S1 | -- | -- | 2 |
| *Hackelia cronquistii* J.L. Gentry Cronquist's stickseed | BR; ID Bake, Malh | G3 S3 | SOC | LT | 1 |
| *Hackelia diffusa* (Lehm.) I.M. Johnston var. *cottonii* (Piper) R.L. Carr Creamy stickseed | CB, EC; WA Gill, Hood, Jeff, Sher, Wasc | G4T4 S3 | -- | -- | 4 |
| *Hackelia diffusa* (Lehm.) I.M. Johnston var. *diffusa* Diffuse stickseed | BM, CB, WC; WA, BC Hood, Mult, Wall, Wasc | G4T3 S3 | -- | C | 4 |
| *Hackelia mundula* (Jepson) Ferris Pink stickseed | KM; CA Jack | G3G4 SNR | -- | -- | 3 |
| *Hackelia ophiobia* R.L. Carr Three Forks stickseed | BR; ID, NV Malh | G3 S1 | SOC | -- | 2 |
| *Hackelia patens* (Nutt.) I.M. Johnston var. *patens* Spreading stickseed | BR, WC; NV, ID + Harn, Malh, Mult | G5T5 S3 | -- | -- | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Hastingsia bracteosa* S. Wats. var. *atropurpurea* (Becking) F. Lang & P. Zika<br>Purple flowered rush-lily | KM<br>Jose | G2T2<br>S2 | SOC | LT | 1 |
| *Hastingsia bracteosa* S. Wats. var. *bracteosa*<br>Large-flowered rush-lily | KM<br>Jose | G2T2<br>S2 | SOC | LT | 1 |
| *Hazardia whitneyi* (Gray) Greene var. *discoidea* (J.T. Howell) W.D. Clark<br>Whitney's haplopappus | KM, WC; CA<br>Curr, Doug, Jack, Jose, Klam | G4G5T4<br>S3 | -- | -- | 4 |
| *Helianthella californica* Gray var. *nevadensis* (Greene) Jepson<br>California helianthella | CR; CA, NV<br>Doug | G4TNR<br>SNR | -- | -- | 3 |
| *Helianthella quinquenervis* (Hook.) Gray<br>Nodding helianthella | BR; ID, NV +<br>Lake | G5<br>SNR | -- | -- | 3 |
| *Helianthella uniflora* (Nutt.) Torr. & Gray var. *uniflora*<br>Rocky Mountain helianthella | BR; ID, NV, +<br>Harn, Malh | G5T4T5<br>SNR | -- | -- | 3 |
| *Helianthus bolanderi* Gray<br>Bolander's sunflower | EC, KM; CA<br>Jack, Jose, Klam | G4<br>SNR | -- | -- | 3 |
| *Helianthus nuttallii* Torr. & Gray<br>Nuttall's sunflower | BM, BR; CA, ID, NV, WA +<br>Bake, Lake, Malh, Morr?, Umat?, Unio, Whee? | G5<br>SNR | -- | -- | 3 |
| *Heliotropium curassavicum* L.<br>Salt heliotrope | BM, BR, CB, EC, WV; CA, NV, +<br>Bake, Harn, Klam, Lake, Malh, Morr, Mult, Sher, Umat, Unio | G5<br>S2 | -- | -- | 2 |
| *Hesperevax sparsiflora* (Gray) Greene var. *brevifolia* (Gray) Morefield<br>Short-leaved evax | CR; CA<br>Coos, Curr | G4T2T3<br>SNR | -- | -- | 3 |
| *Hesperocyparis bakeri* (Jeps.) Bartel<br>Baker's cypress | KM, WC; CA<br>Jack, Jose | G3<br>S1 | SOC | -- | 2 |
| *Heuchera grossulariifolia* Rydb. var. *tenuifolia* (Wheelock) C.L. Hitchc.<br>Thin-leaved alumroot | EC; WA<br>Hood, Wasc | G4T3T4<br>S3 | -- | -- | 4 |
| *Heuchera merriamii* Eastw.<br>Merriam alumroot | KM, WC; CA<br>Desc, Doug, Jose, Lane, Linn | G3<br>S3 | -- | -- | 4 |
| *Hieracium greenei* Gray<br>Greene's hawkweed | KM, WC; CA<br>Curr, Doug, Jack, Jose, Klam, Lane, Linn | G3G4<br>SNR | -- | -- | 3 |
| *Hieracium horridum* Fries<br>Shaggy hawkweed | KM, WC; CA<br>Curr, Desc, Jack, Jose, Klam, Lane | G4<br>S1 | -- | -- | 2 |
| *Hieracium longiberbe* Howell<br>Long-bearded hawkweed | WC; WA<br>Hood, Mult | G4G5<br>S3 | -- | -- | 4 |
| *Hieracium umbellatum* L.<br>Umbellate hawkweed | WC, WV?; ID, WA +<br>Linn, Mari, Mult? | G5<br>SNR | -- | -- | 3 |
| *Hierochloe odorata* (L.) Beauv.<br>Holy grass | BM, EC, KM, WC, WV; CA +<br>Clac, Croo, Desc, Gran, Harn, Jack, Jose, Klam, Lane, Mult, Unio, Wall | G5<br>S3 | -- | -- | 4 |
| *Horkelia congesta* Dougl. ex Hook. ssp. *congesta*<br>Shaggy horkelia | KM, WC?, WV<br>Bent, Doug, Lane, Linn, Mari, Polk, Wash | G4T2<br>S2 | SOC | C | 1 |
| *Horkelia hendersonii* Howell<br>Henderson's horkelia | KM; CA<br>Jack | G1G2<br>S1S2 | SOC | -- | 1 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Horkelia sericata* S. Wats.<br>Silky horkelia | KM; CA<br>Curr, Jose | G3G4<br>S1? | -- | -- | 3 |
| *Horkelia tridentata* Torr. ssp. *tridentata*<br>Three-toothed horkelia | KM; CA<br>Jack | G4G5T4?<br>S1 | -- | -- | 2 |
| *Howellia aquatilis* Gray<br>Howellia | WV; CA, ID, MT, WA<br>Bent, Clac, Mari, Mult | G3<br>S1 | LT | LT | 1 |
| *Hulsea algida* Gray<br>Alpine hulsea | BM; ID<br>Unio, Wall | G4G5<br>S3 | -- | -- | 4 |
| *Huperzia miyoshiana* (Makino) Ching<br>Pacific fir-moss | CR; WA, BC +<br>Clat | G4<br>S1? | -- | -- | 3 |
| *Huperzia occidentalis* (Clute) Kartesz & Gandhi<br>Fir club-moss | BM, WC; ID +<br>Clac, Hood, Linn, Mari, Mult, Wall, Wasc | G5<br>S3 | -- | -- | 4 |
| *Hydrocotyle verticillata* Thunb.<br>Whorled marsh pennywort | CR, WV; CA +<br>Bent, Coos, Curr, Doug | G5<br>S1 | -- | -- | 2 |
| *Hymenoxys cooperi* (Gray) Cockerell var. *canescens* (D.C. Eat.) Parker<br>Cooper's goldflower | BR; CA, NV<br>Harn, Lake | G4G5T3<br>S1 | SOC | -- | 2 |
| *Iliamna bakeri* (Jepson) Wiggins<br>Baker's globe-mallow | BR, EC, KM, WC; CA<br>Jack, Klam, Lake | G4<br>S4 | -- | -- | 4 |
| *Iliamna latibracteata* Wiggins<br>California globe-mallow | CR, KM, WC; CA<br>Coos, Curr, Doug, Jack, Jose, Linn | G3<br>S2 | -- | -- | 2 |
| *Impatiens ecornuta* Gerry Moore, Zika & Rushworth<br>Spurless jewelweed | CR; ID, WA +<br>Clat, Colu, Till | G3G4<br>S2? | -- | -- | 2 |
| *Iris tenax* Dougl. ex Lindl. var. *gormanii* (Piper) R.C. Foster<br>Gorman's iris | WV<br>Wash | G4G5T1<br>S1 | -- | -- | 1 |
| *Isoetes minima* A.A. Eat.<br>Midget quillwort | BM; WA, BC<br>Wall | G1G2<br>S1? | -- | -- | 3 |
| *Ivesia rhypara* Ertter & Reveal var. *rhypara*<br>Grimy ivesia | BR; NV<br>Lake, Malh | G2T2<br>S1 | SOC | LE | 1 |
| *Ivesia rhypara* Ertter & Reveal var. *shellyi* Ertter<br>Shelly's ivesia | BR; CA<br>Harn, Lake | G2T1T2<br>S1S2 | SOC | -- | 1 |
| *Ivesia shockleyi* S. Wats.<br>Shockley's ivesia | BR, EC; CA, NV<br>Lake, Malh | G3G4<br>S1 | -- | -- | 2 |
| *Juncus bryoides* F.J. Herm.<br>Mosslike dwarf rush | BR; CA, ID, NV +<br>Harn | G4<br>S2? | -- | -- | 2 |
| *Juncus capillaris* F.J. Herm.<br>Hairstemmed rush | BR; CA<br>Harn | G4<br>SNR | -- | -- | 3 |
| *Juncus hemiendytus* F.J. Herm. var. *abjectus* (F.J. Herm.) Ertter<br>Least rush | BR, EC; CA, ID<br>Harn, Lake | G5T4<br>SNR | -- | -- | 3 |
| *Juncus interior* Wieg.<br>Interior rush | CB; CA, ID, WA +<br>Morr | G4<br>SNR | -- | -- | 3 |
| *Juncus kelloggii* Engelm.<br>Kellogg's dwarf rush | EC, KM, WC, WV; CA, WA +<br>Colu, Hood, Jose, Klam, Lake, Linn, Mari | G3?<br>SNR | -- | -- | 3 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Juncus mexicanus* Willd. ex J.A. & J.H. Schultes<br>Mexican rush | CB; CA, NV +<br>Sher | G4G5<br>SNR | -- | -- | 3 |
| *Juncus tiehmii* Ertter<br>Tiehm's rush | BR, EC; CA, ID, NV, WA<br>Harn, Klam | G4<br>S1? | -- | -- | 2 |
| *Juncus triglumis* L. var. *albescens* Lange<br>Three-flowered rush | BM; MT, CO, WY, BC +<br>Wall | G5T5<br>S1 | -- | -- | 2 |
| *Juncus uncialis* Greene<br>Inch-high rush | BR, CB, EC; CA, NV, WA<br>Harn, Klam, Lake, Wasc | G3G4<br>SNR | -- | -- | 3 |
| *Kalmiopsis fragrans* Meinke & Kaye<br>North Umpqua kalmiopsis | WC<br>Doug | G2<br>S2 | SOC | -- | 1 |
| *Kalmiopsis leachiana* (Henderson) Rehd.<br>Kalmiopsis | KM<br>Curr, Jose | G3<br>S3 | -- | -- | 4 |
| *Keckiella lemmonii* (Gray) Straw<br>Bush beardtongue | KM; CA, NV<br>Jack, Jose | G4<br>S1 | -- | -- | 2 |
| *Kobresia bellardii* (All.) K. Koch<br>Bellard's kobresia | BM, BR; CA +<br>Harn, Wall | G5<br>S1 | -- | -- | 2 |
| *Kobresia simpliciuscula* (Wahlenb.) Mackenzie<br>Simple kobresia | BM; ID, BC +<br>Wall | G5<br>S1 | -- | -- | 2 |
| *Langloisia setosissima* (Torr. & Gray ex Torr.) Greene ssp. *punctata* (Gray ex Coville) Timbrook<br>Punctate langloisa | BR; CA, ID NV<br>Malh | G4G5T3T5<br>SNR | -- | -- | 3 |
| *Lasthenia ornduffii* R. Chan<br>Large-flowered goldfields | CR<br>Curr | G2<br>S2 | SOC | C | 1 |
| *Lathyrus holochlorus* (Piper) C.L. Hitchc.<br>Thin-leaved peavine | CR?, WC?, WV; WA<br>Bent, Clac, Doug?, Lane, Linn, Mari, Polk, Wash, Yamh | G2<br>S2 | SOC | -- | 1 |
| *Lathyrus lanszwertii* Kellogg var. *tracyi* (Bradshaw) Isley<br>Tracy's peavine | EC, KM; CA<br>Jack | G4G5T3?<br>S3 | -- | -- | 4 |
| *Lathyrus littoralis* (Nutt.) Endl.<br>Beach peavine | CR; CA, WA, BC<br>Clat, Coos, Curr, Lane, Linc, Till | G5<br>SNR | -- | -- | 3 |
| *Lepidium davisii* Rollins<br>Davis' peppergrass | BR; ID<br>Malh | G3<br>S1 | SOC | LT | 1 |
| *Lepidium dictyotum* Gray<br>Alkali peppergrass | BR; CA, ID, NV, UT, WA<br>Bake?, Harn?, Lake?, Malh, Morr?, Umat?, Wasc? | G3G5<br>SNR | -- | -- | 2 |
| *Lepidium montanum* Nutt. var. *nevadense* Rollins<br>Nevada peppergrass | BR; NV<br>Harn | G5?T1?<br>SNR | -- | -- | 3 |
| *Leucopoa kingii* (S. Wats.) W.A. Weber<br>Spike fescue | BR; CA, ID, NV +<br>Harn | G5<br>SNR | -- | -- | 3 |
| *Leucothoe davisiae* Torr. ex Gray<br>Sierra laurel | KM; CA<br>Curr, Jose | G4<br>S3 | -- | -- | 4 |
| *Lewisia columbiana* (Howell ex Gray) B.L. Robins. var. *columbiana*<br>Columbia lewisia | WC; WA +<br>Doug, Hood, Lane, Mult | G4T4<br>S2 | -- | -- | 2 |
| *Lewisia columbiana* (Howell ex Gray) B.L. Robins. var. *rupicola* (English) C.L. Hitchc.<br>Rosy lewisia | CR; WA<br>Clat, Till | G4T4<br>S2 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Lewisia cotyledon* (S. Wats.) B.L. Robins. var. *howellii* (S. Wats.) Jepson<br>Howell's lewisia | KM; CA<br>Curr, Doug, Jack, Jose | G4T4Q<br>S3 | -- | -- | 4 |
| *Lewisia leeana* (Porter) B.L. Robins.<br>Lee's lewisia | KM; CA<br>Curr, Doug, Jack, Jose | G4<br>S2 | -- | -- | 2 |
| *Lewisia oppositifolia* (S. Wats.) B.L. Robins.<br>Opposite-leaved lewisia | KM; CA<br>Curr, Jack, Jose | G4<br>S4 | -- | -- | 4 |
| *Leymus flavescens* (Scribn. & J.G. Sm.) Pilger<br>Sand wildrye | BR, CB, CR; ID, MT, WA<br>Clat, Malh, Morr, Umat, Wasc | G4<br>SNR | -- | -- | 3 |
| *Lilaea scilloides* (Poir.) Hauman<br>Flowering quillwort | BR, CB?, CR, EC, ME; CA, ID, NV, WA +<br>Clat, Desc, Doug, Harn, Klam, Lake, Lane, Malh, Sher? | G5?<br>S3? | -- | -- | 4 |
| *Lilium kelloggii* Purdy<br>Kellogg's lily | CR, KM; CA<br>Curr, Jose, Klam? | G3<br>SH | SOC | -- | 2-ex |
| *Lilium occidentale* Purdy<br>Western lily | CR; CA<br>Coos, Curr | G1<br>S1 | LE | LE | 1 |
| *Limnanthes alba* Hartw. ex Benth. ssp. *gracilis* (Howell) Morin<br>Slender meadow-foam | KM, WC<br>Doug, Jack, Jose | G4T3<br>S3 | -- | C | 1 |
| *Limnanthes floccosa* Howell ssp. *bellingeriana* (M.E. Peck) Arroyo<br>Bellinger's meadow-foam | EC, KM, WC; CA<br>Jack, Klam | G4T3<br>S2 | SOC | C | 1 |
| *Limnanthes pumila* Howell ssp. *grandiflora* (Arroyo) S.C. Meyers & K.L. Chambers<br>Big-flowered wooly meadow-foam | KM<br>Jack | G1<br>S1 | LE | LE | 1 |
| *Limnanthes pumila* Howell ssp. *pumila*<br>Dwarf wooly meadow-foam | KM<br>Jack | G1<br>S1 | SOC | LT | 1 |
| *Limonium californicum* (Boiss.) Heller<br>Western marsh-rosemary | ME; CA<br>Coos, Linc | G4<br>S1 | -- | -- | 2 |
| *Limosella acaulis* Sesse & Moc.<br>Owyhee mudwort | BR, EC, WC; CA, ID, NV, WA +<br>Desc, Doug, Harn?, Wasc | G5<br>SNR | -- | -- | 3 |
| *Lipocarpha aristulata* (Coville) G. Tucker<br>Aristulate lipocarpha | BM, BR, CB, EC; CA, ID, WA +<br>Malh, Umat, Wall | G5?<br>S1 | -- | -- | 2 |
| *Lipocarpha micrantha* (Vahl) G. Tucker<br>Small-flowered lipocarpha | WV; ID, WA, CA +<br>Bent | G5<br>SH | -- | -- | 2-ex |
| *Listera borealis* Morong<br>Northern twayblade | BM; ID, WA +<br>Bake, Wall | G4<br>S1 | -- | -- | 2 |
| *Lloydia serotina* (L.) Reichenb. ssp. *serotina*<br>Alp lily | BM, BR, CR; NV, WA +<br>Bake?, Clat, Harn, Wall | G5T5<br>SNR | -- | -- | 3 |
| *Lobelia dortmanna* L.<br>Water lobelia | EC, WC; WA +<br>Jeff | G4G5<br>S1 | -- | -- | 2 |
| *Lomatium bentonitum* K. Carlson & D. Mansfield<br>Bentonite biscuitroot | BR<br>Malh | G1<br>S1 | -- | -- | 1 |
| *Lomatium bradshawii* (Rose ex Mathias) Mathias & Constance<br>Bradshaw's lomatium | WV; WA<br>Bent, Lane, Linn, Mari | G2<br>S2 | LE | LE | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Lomatium cookii* J.S. Kagan<br>Agate Desert lomatium | KM<br>Jack, Jose | G1<br>S1 | LE | LE | 1 |
| *Lomatium engelmannii* Mathias<br>Engelmann's desert-parsley | KM; CA<br>Curr?, Jose | G3<br>S1 | -- | -- | 2 |
| *Lomatium erythrocarpum* Meinke & Constance<br>Red-fruited lomatium | BM<br>Bake | G1G2<br>S1S2 | SOC | LE | 1 |
| *Lomatium farinosum* (Hook.) Coult. & Rose var. *hambleniae* (Mathias & Constance) Schlessman<br>Hamblen's lomatium | BM, CB; WA<br>Wasc | G4G5T4<br>S3 | -- | -- | 4 |
| *Lomatium foeniculaceum* (Nutt.) Coult. & Rose var. *fimbriatum* (Theobald) J. Boivin<br>Fringed desert-parsley | BR; CA, NV, UT<br>Malh | G5T2T4<br>S1 | -- | -- | 2 |
| *Lomatium greenmanii* Mathias<br>Greenman's lomatium | BM<br>Wall | G1<br>S1 | SOC | LT | 1 |
| *Lomatium idahoense* Mathias & Constance<br>Idaho lomatium | BR<br>Harn | G4<br>SNR | -- | -- | 3 |
| *Lomatium laevigatum* (Nutt.) Coult. & Rose<br>Smooth desert parsley | CB; WA<br>Sher, Wasc | G3<br>S3 | -- | -- | 4 |
| *Lomatium ochocense* Helliwell & Constance ex Helliwell<br>Ochoco lomatium | BM<br>Croo | G2<br>S2 | SOC | -- | 1 |
| *Lomatium packardiae* Cronq.<br>Packard's lomatium | BR; NV, ID<br>Lake, Malh | G2<br>SNR | -- | -- | 3 |
| *Lomatium pastorale* D.H. Wagner ex M.E. Darrach & D.H. Wagner<br>Meadow lomatium | BM<br>Umat, Unio | G1G2<br>S1 | -- | -- | 1 |
| *Lomatium rollinsii* Mathias & Constance<br>Rollins' lomatium | BM; ID, WA<br>Bake, Wall | G3<br>S3 | -- | -- | 4 |
| *Lomatium roseanum* Cronq.<br>Rose's lomatium | BR; CA, NV<br>Harn, Malh | G2G3<br>S1 | -- | -- | 1 |
| *Lomatium suksdorfii* (S. Wats.) Coult. & Rose<br>Suksdorf's lomatium | EC; WA<br>Hood, Wasc | G3<br>S2 | SOC | C | 1 |
| *Lomatium tamanitchii* M.E. Darrach & K.K. Thie<br>Ribseed lomatium | BM; WA<br>Unio, Whee | G3?<br>SNR | -- | -- | 3 |
| *Lomatium watsonii* (Coult. & Rose) Coult. & Rose<br>Watson's desert-parsley | BM, CB, EC; WA<br>Gill, Hood, Jeff, Wasc | G4<br>S1 | -- | -- | 2 |
| *Lotus stipularis* (Benth.) Greene<br>Stipuled trefoil | KM; CA<br>Jose | G5<br>S2 | -- | -- | 2 |
| *Luina serpentina* Cronq.<br>Colonial luina | BM<br>Gran | G3<br>S3 | SOC | C | 1 |
| *Lupinus andersonii* S. Wats.<br>Anderson's lupine | EC, KM, WC; CA, NV<br>Jack, Klam | G5<br>SNR | -- | -- | 3 |
| *Lupinus biddlei* Henderson ex C.P. Sm.<br>Biddle's lupine | BR<br>Harn, Malh | G3<br>S3 | -- | -- | 4 |
| *Lupinus breweri* Gray var. *breweri*<br>Brewer's lupine | KM; CA, NV<br>Jack | G5T4?<br>S3 | -- | -- | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Lupinus lepidus* Dougl. ex Lindl. var. *ashlandensis* ( B.J.Cox ) Isely<br>Mt. Ashland lupine | KM<br>Jack | G5T1<br>S1 | SOC | C | 1 |
| *Lupinus lepidus* Dougl. ex Lindl. var. *cusickii* (S. Wats.) C.L. Hitchc.<br>Cusick's lupine | BM<br>Bake | G1T1<br>S1 | SOC | LE | 1 |
| *Lupinus nevadensis* Heller<br>Nevada lupine | BR; CA, NV<br>Harn, Malh | G3G4<br>S1? | -- | -- | 2 |
| *Lupinus oreganus* Heller<br>Kincaid's lupine | KM, WC, WV; WA<br>Bent, Doug, Lane, Linn, Mari, Polk, Wash, Yamh | G2<br>S2 | LT | LT | 1 |
| *Lupinus tracyi* Eastw.<br>Tracy's lupine | KM; CA<br>Curr, Jose | G4<br>S2 | -- | -- | 2 |
| *Luzula orestera* C.W. Sharsmith<br>Sierra woodrush | BM; CA<br>Unio, Wall | G2G4<br>SNR | -- | -- | 3 |
| *Lycopodiella inundata* (L.) Holub<br>Northern bog clubmoss | CR, EC, WC; CA, ID, MT<br>Clac, Coos, Doug, Klam, Lane, Linc, Linn, Mult | G5<br>S2 | -- | -- | 2 |
| *Lycopodium annotinum* L.<br>Stiff clubmoss | BM, WC; ID, WA<br>Bake, Clac, Desc, Doug, Gran, Hood, Jeff, Klam, Lane, Mari, Mult, Unio, Wall, Wasc | G5<br>S3 | -- | -- | 4 |
| *Lycopodium complanatum* L.<br>Ground cedar | BM, WC; ID, WA<br>Clac, Jeff, Linn, Mari, Unio | G5<br>S2 | -- | -- | 2 |
| *Lygodesmia juncea* (Pursh) D. Don ex Hook.<br>Rush skeleton plant | BM, CB; WA, ID +<br>Bake, Umat | G5<br>SNR | -- | -- | 3 |
| *Malacothrix glabrata* (D.C. Eat. ex Gray) Gray<br>Smooth malacothrix | BR; CA, ID, NV<br>Harn, Lake, Malh | G5<br>S4 | -- | -- | 4 |
| *Malacothrix sonchoides* (Nutt.) Torr. & Gray<br>Sow-thistle desert-dandelion | BR; CA, ID, NV +<br>Harn, Malh | G5<br>S1 | -- | -- | 2 |
| *Malacothrix stebbinsii* W.S. Davis & Raven<br>Stebbins desert-dandelion | BM; CA, NV<br>Whee | G3?<br>SNR | -- | -- | 3 |
| *Malacothrix torreyi* Gray<br>Torrey's malacothrix | BR; CA, ID, NV, MT<br>Harn, Lake, Malh | G4<br>S4 | -- | -- | 4 |
| *Marsilea vestita* Hook. & Grev.<br>Hairy water-fern | BM, BR, CB, CR, EC, KM, WC, WV; CA, ID, NV, WA +<br>Bake, Clac, Colu?, Curr?, Doug, Harn, Jack, Jeff, Klam, Lake, Lane, Malh, Morr, Mult, Sher, Umat, Unio, Wasc, Whee | G5<br>SNR | -- | -- | 3 |
| *Meconella oregana* Nutt.<br>White meconella | EC, KM, WC; WA, BC<br>Doug, Hood, Jack, Jose, Wasc | G2G3<br>S1 | SOC | C | 1 |
| *Melica smithii* (Porter ex Gray) Vasey<br>Smith's melicgrass | BM; ID, WA +<br>Bake, Gran?, Umat? | G4<br>SNR | -- | -- | 3 |
| *Melica stricta* Boland.<br>Nodding melicgrass | BR, EC; CA, NV<br>Harn, Klam, Lake, Malh | G4<br>S3 | -- | -- | 2 |
| *Mentzelia congesta* Nutt. ex Torr. & Gray<br>United blazingstar | BR; CA, ID, NV<br>Harn, Malh | G5<br>S1 | -- | -- | 2 |
| *Mentzelia mollis* M.E. Peck<br>Smooth mentzelia | BR; ID, NV<br>Malh | G2<br>S2 | SOC | LE | 1 |
| *Mentzelia packardiae* Glad.<br>Packard's mentzelia | BR; NV<br>Malh | G2Q<br>S2 | SOC | LT | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Micranthes hitchcockiana* (Elvander) Brouillet & Gornall<br>Saddle Mt. saxifrage | CR<br>Clat, Till | G1<br>S1 | SOC | C | 1 |
| *Microseris bigelovii* (Gray) Schultz-Bip.<br>Coast microseris | CR; CA, WA +<br>Coos, Curr, Lane, Linc | G4<br>S2 | -- | -- | 2 |
| *Microseris douglasii* (DC.) Schultz-Bip. ssp. *douglasii*<br>Douglas' microseris | KM; CA<br>Jack | G4T4<br>SH | -- | -- | 2-ex |
| *Microseris howellii* Gray<br>Howell's microseris | KM<br>Curr, Jose | G3<br>S3 | -- | LT | 4 |
| *Microseris laciniata* (Hook.) Schultz-Bip. ssp. *detlingii* Chambers<br>Detling's microseris | KM, WC; CA<br>Jack | G4T3<br>S3 | SOC | -- | 4 |
| *Mimulus aurantiacus* W. Curtis<br>Bush monkeyflower | CR; CA<br>Curr | G5<br>SNR | -- | -- | 3 |
| *Mimulus bolanderi* Gray<br>Bolander's monkeyflower | KM; CA<br>Jack | G4<br>S1 | -- | -- | 2 |
| *Mimulus clivicola* Greenm.<br>Bank monkeyflower | BM; ID, WA<br>Bake, Wall | G4<br>S3 | -- | -- | 4 |
| *Mimulus congdonii* B.L. Robins.<br>Congdon's monkeyflower | KM; CA<br>Jack | G4G5<br>S1? | -- | -- | 2 |
| *Mimulus douglasii* (Benth.) Gray<br>Douglas' monkeyflower | KM; CA<br>Curr, Doug, Jack, Jose | G4G5<br>S3 | -- | -- | 4 |
| *Mimulus evanescens* R.J. Meinke<br>Disappearing monkeyflower | BM, BR, CB, EC; CA, ID<br>Croo, Gill, Gran, Harn, Klam, Lake, Malh | G3<br>S2 | SOC | C | 1 |
| *Mimulus hymenophyllus* Meinke<br>Membrane-leaved monkeyflower | BM; ID, MT<br>Wall | G2<br>S1S2 | SOC | C | 1 |
| *Mimulus jepsonii* A.L. Grant<br>Jepson's monkeyflower | EC, KM, WC; CA<br>Desc, Doug, Jack, Jose, Klam, Lake | G4<br>S3 | -- | -- | 4 |
| *Mimulus jungermannioides* Suksdorf<br>Hepatic monkeyflower | BM, CB; WA<br>Gill, Jeff, Sher, Umat, Wasc | G3<br>S3 | -- | C | 4 |
| *Mimulus kelloggii* (Curran ex Greene) Curran ex Gray<br>Kellogg's monkeyflower | KM; CA<br>Doug, Jack, Jose | G4<br>S3 | -- | -- | 4 |
| *Mimulus latidens* (Gray) Greene<br>Broad-toothed monkeyflower | BR; CA, NV<br>Lake | G4<br>S1 | -- | -- | 2 |
| *Mimulus patulus* Pennell<br>Stalked-leaved monkeyflower | BM; ID, WA<br>Bake, Wall | G3?<br>S3? | -- | C | 3 |
| *Mimulus tricolor* Hartw. ex Lindl.<br>Three-colored monkeyflower | BR, EC, WV; CA<br>Bent, Klam, Lake, Linn, Mari | G4<br>S2 | -- | -- | 2 |
| *Minuartia austromontana* S.J. Wolf & Packer<br>Southern mountain sandwort | BM; ID +<br>Wall | G4<br>SNR | -- | -- | 3 |
| *Minuartia californica* (Gray) Mattf.<br>California sandwort | KM; CA<br>Doug, Jack, Jose | G4<br>S4 | -- | -- | 4 |
| *Minuartia pusilla* (S. Wats.) Mattf. var. *pusilla*<br>Dwarf stitchwort | BM, BR, CB, KM, WV; CA, ID, NV, WA +<br>Clac, Gran, Jack, Jose, Malh, Wasc | G5T3T5<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Mirabilis laevis* (Benth.) Curran var. *retrorsa* (Heller) Jepson<br>Bigelow's four-o'clock | BR; CA, NV +<br>Harn, Malh | G4G5T4<br>S3 | -- | -- | 2 |
| *Mirabilis macfarlanei* Constance & Rollins<br>Macfarlane's four-o'clock | BM; ID<br>Wall | G2<br>S1 | LT | LE | 1 |
| *Monardella purpurea* Howell<br>Siskiyou monardella | CR, KM; CA<br>Curr, Jose | G3Q<br>S3 | SOC | -- | 2 |
| *Montia howellii* S. Wats.<br>Howell's montia | CR, KM, WC, WV; CA, WA, BC<br>Bent, Clac, Colu, Doug, Jose, Lane, Linc, Linn, Mari, Mult, Till | G3G4<br>S3S4 | -- | C | 4 |
| *Muhlenbergia minutissima* (Steud.) Swallen<br>Annual dropseed | BR; CA, ID, NV, WA +<br>Malh | G5<br>S2 | -- | -- | 2 |
| *Munroa squarrosa* (Nutt.) Torr.<br>False buffalograss | BR; CA, NV +<br>Malh | G5<br>SNR | -- | -- | 3 |
| *Myosurus sessilis* S. Wats.<br>Sessile mousetail | BM, CB; CA<br>Gill, Jeff, Umat | G2<br>S1 | SOC | C | 1 |
| *Myrica gale* L.<br>Sweet gale | CR, WC; WA +<br>Clat, Curr, Linc, Mult | G5<br>S1? | -- | -- | 3 |
| *Myriophyllum sibiricum* Komarov<br>Common water-milfoil | BM, BR, CR, EC, WC; CA, WA +<br>Croo, Curr, Desc, Harn, Jeff, Klam, Malh, Till, Wall, Whee | G5<br>S3 | -- | -- | 4 |
| *Myriophyllum ussuriense* (Regel) Maxim.<br>Russian water-milfoil | ME; BC +<br>Clat | G3<br>S1? | -- | -- | 3 |
| *Najas guadalupensis* (Spreng.) Magnus<br>Common water-nymph | BR, CR?; CA, WA, ID +<br>Colu?, Malh, Mult? | G5<br>SNR | -- | -- | 3 |
| *Nama densum* J.G. Lemmon var. *parviflorum* (Greenm.) C.L. Hitchc.<br>Compact fiddleleaf | BM, BR; CA, ID, NV, WA +<br>Desc, Harn, Lake, Malh | G5T5<br>SNR | -- | -- | 3 |
| *Nama lobbii* Gray<br>Lobb's nama | EC, WC; CA, NV<br>Doug, Jack, Klam | G4<br>S4 | -- | -- | 4 |
| *Navarretia heterandra* Mason<br>Tehama navarretia | KM; CA<br>Jack | G3<br>S3 | -- | -- | 4 |
| *Navarretia leucocephala* Benth. ssp. *leucocephala*<br>White-flowered navarretia | BM, BR, CB, EC, KM, WV; CA<br>Croo, Desc, Doug, Harn, Jack, Jose, Klam, Lake, Lane, Malh, Sher, Wasc | G4T4?<br>S4 | -- | -- | 4 |
| *Navarretia sinistra* (M.E. Jones) L.A. Johnson ssp. *sinistra*<br>Alva Day's gilia | BM, BR, EC, KM, WC, WV; CA, NV, CO<br>Bake, Croo, Doug, Gran, Harn, Jack, Jose, Klam, Lane, Malh, Unio, Wall | G4G5T4T5<br>S4 | -- | -- | 4 |
| *Navarretia willamettensis* Spencer<br>Willamette navarretia | WV<br>Bent, Lane | G1<br>S1 | -- | -- | 1 |
| *Nemacladus capillaris* Greene<br>Slender nemacladus | KM, WC; CA<br>Jack | G4<br>S1 | -- | -- | 2 |
| *Nicotiana quadrivalvis* Pursh<br>Indian tobacco | CR; CA, NV<br>Doug | G5<br>SNR | -- | -- | 3 |
| *Noccaea fendleri* (A. Gray) Holub ssp. *siskiyouense* (P. Holmgren) Al-Shebaz & M. Koch<br>Siskiyou Mountain pennycress | KM, WC<br>Curr, Doug, Jose | G5T3<br>S3 | -- | -- | 4 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Oenothera wolfii* (Munz) Raven, W. Dietr. & Stubbe<br>Wolf's evening-primrose | CR; CA<br>Curr | G1<br>S1 | SOC | LT | 1 |
| *Ophioglossum pusillum* Raf.<br>Adder's-tongue | BM, CR, WC; CA, ID, WA+<br>Bake, Clac, Coos, Doug, Lane, Linn | G5<br>S1 | -- | -- | 2 |
| *Opuntia fragilis* (Nutt.) Haw. var. *fragilis*<br>Brittle prickly-pear | BM, BR, EC; CA, ID, NV, WA +<br>Bake, Jack, Lake, Whee | G4G5T4T5<br>SNR | -- | -- | 3 |
| *Orobanche californica* Cham. & Schlecht. ssp. *californica*<br>California broom-rape | WV; CA, WA, BC<br>Lane | G4T4<br>SNR | -- | -- | 3 |
| *Orobanche californica* Cham. & Schlecht. ssp. *grayana* (G. Beck) Heckard<br>Gray's broomrape | BM, BR, WV; CA, ID, NV, WA<br>Bake, Croo, Harn, Jeff, Klam, Lake, Lane, Malh | G4T3T4<br>SNR | -- | -- | 3 |
| *Orobanche ludoviciana* Nutt. ssp. *ludoviciana*<br>Louisiana broomrape | BM, BR, CB, CR; CA, ID, NV, WA +<br>Bake, Doug, Lake, Sher?, Umat, Wasc? | G5T5<br>SNR | -- | -- | 3 |
| *Oxytheca dendroidea* Nutt.<br>Tree-lined oxytheca | BR; CA, ID, NV, WA +<br>Harn, Lake, Malh | G4<br>SNR | -- | -- | 3 |
| *Oxytropis sericea* Nutt. var. *sericea*<br>White locoweed | BR; ID, NV+<br>Malh | G5T5<br>S1 | -- | -- | 2 |
| *Packera flettii* (Wieg.) W.A. Weber & A. Love<br>Flett's groundsel | CR; WA<br>Clat, Till, Wash | G4<br>S2 | -- | -- | 2 |
| *Packera hesperia* (Greene) W.A. Weber & A. Love<br>Western senecio | KM; CA<br>Jose | G3<br>S3 | SOC | C | 4 |
| *Packera porteri* Greene (C. Jeffrey)<br>Porter's butterweed | BM; CO, WY<br>Wall | G4<br>SH | -- | -- | 2-ex |
| *Pappostipa speciosa* (Trin. & Rupr.) Romaschenko<br>Desert needlegrass | BR; CA, NV +<br>Harn | G5<br>S2 | -- | -- | 2 |
| *Pedicularis howellii* Gray<br>Howell's lousewort | KM; CA<br>Jose | G4<br>S3 | -- | -- | 4 |
| *Pediocactus nigrispinus* (Hochstätter) Hochstätter<br>Snowball cactus | BM, BR, CB; ID, WA+<br>Croo, Gran, Harn, Jeff, Malh, Sher, Wall, Wasc, Whee | G4<br>S4 | -- | -- | 4 |
| *Pellaea andromedifolia* (Kaulfuss) Fee<br>Coffee fern | CR, KM, WV; CA<br>Coos, Doug, Jack, Jose, Lane | G4<br>S2 | -- | -- | 2 |
| *Pellaea bridgesii* Hook.<br>Bridges' cliff-brake | BM; CA, ID<br>Bake, Gran, Unio | G4<br>S2 | -- | -- | 2 |
| *Pellaea mucronata* (D.C. Eat.) D.C. Eat. ssp. *californica* (Lemmon) Windham<br>California bird-s-foot cliff-brake | KM; CA<br>Jose | G5T5<br>S1 | -- | -- | 2 |
| *Penstemon barrettiae* Gray<br>Barrett's penstemon | EC, WC; WA<br>Hood, Mult, Wasc | G2<br>S2 | SOC | C | 1 |
| *Penstemon davidsonii* Greene var. *praeteritus* Cronq.<br>Davidson's penstemon | BR; NV<br>Harn | G4G5T4<br>S3 | -- | -- | 4 |
| *Penstemon deustus* Dougl. ex Lindl. var. *variabilis* (Suksdorf) Cronq.<br>Hot-rock penstemon | BM, BR, CB; WA<br>Croo, Gran, Harn, Jeff, Malh, Morr, Sher, Umat, Unio, Wall, Wasc, Whee | G5T1T2<br>S1S2 | -- | -- | 1 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Penstemon glaucinus* Pennell<br>Blue-leaved penstemon | EC<br>Klam, Lake | G3<br>S3 | SOC | -- | 1 |
| *Penstemon janishiae* N. Holmgren<br>Janish's penstemon | BR; CA, ID, NV<br>Harn, Malh | G4<br>SNR | -- | -- | 3 |
| *Penstemon kingii* S. Wats.<br>King's beardtongue | BR; NV<br>Malh | G4<br>SNR | -- | -- | 3 |
| *Penstemon miser* Gray<br>Golden-tongue beardtongue | BM, BR; ID<br>Bake, Malh | G3?<br>S3? | -- | -- | 4 |
| *Penstemon peckii* Pennell<br>Peck's penstemon | BM, EC, WC<br>Desc, Jeff | G3<br>S3 | SOC | -- | 1 |
| *Penstemon perpulcher* A. Nels.<br>Beautiful penstemon | BR; ID<br>Malh | G3?<br>S1 | -- | -- | 1 |
| *Penstemon pratensis* Greene<br>White-flowered penstemon | BR; NV, ID<br>Harn, Lake, Malh | G4?<br>SNR | -- | -- | 3 |
| *Penstemon seorsus* (A. Nels.) Keck<br>Short-lobed beardtongue | BM, BR; ID<br>Bake, Croo, Gran, Harn, Jeff, Lake, Malh, Wasc | G4?<br>S3 | -- | -- | 4 |
| *Penstemon spatulatus* Pennell<br>Wallowa penstemon | BM<br>Bake, Gran, Unio, Wall | G4<br>S4 | -- | -- | 4 |
| *Perideridia erythrorhiza* (Piper) Chuang & Constance<br>Red-root yampah | EC, KM, WC<br>Doug, Jack, Jose, Klam | G2<br>S2 | SOC | C | 1 |
| *Perideridia lemmonii* (Coult. & Rose) Chuang & Constance<br>Lemmon's false-caraway | BR; CA, NV<br>Harn, Lake | G4?<br>SNR | -- | -- | 3 |
| *Persicaria punctata* Small<br>Dotted smartweed | BM, CB?, CR, EC, WC, WV; CA, WA+<br>Bake, Clac, Clat, Curr, Klam, Lane, Morr?, Mult, Till | G5<br>SNR | -- | -- | 3 |
| *Phacelia argentea* A. Nels. & J.F. Macbr.<br>Silvery phacelia | CR; CA<br>Coos, Curr | G2<br>S2 | SOC | LT | 1 |
| *Phacelia gymnoclada* Torr. ex S. Wats.<br>Naked-stemmed phacelia | BR; CA, NV<br>Harn, Malh | G4<br>S3 | -- | -- | 4 |
| *Phacelia inundata* J.T. Howell<br>Playa phacelia | BR, EC; CA, NV<br>Harn, Klam, Lake, Malh | G2<br>S2 | SOC | -- | 1 |
| *Phacelia leonis* J.T. Howell<br>Siskiyou phacelia | KM; CA<br>Jose | G2<br>S1 | SOC | -- | 1 |
| *Phacelia lutea* (Hook. & Arn.) J.T. Howell var. *mackenzieorum* J. Grimes & Packard<br>Mackenzie's phacelia | BR<br>Malh | G4T1<br>S1 | SOC | -- | 1 |
| *Phacelia malvifolia* Cham.<br>Mallow-leaved phacelia | CR; CA<br>Curr | G4<br>SH | -- | -- | 2-ex |
| *Phacelia minutissima* Henderson<br>Least phacelia | BM; ID, NV, WA<br>Gran, Harn, Unio, Wall | G3<br>S1 | SOC | C | 1 |
| *Phacelia procera* Gray<br>Tall phacelia | BM, CB, KM; CA, ID, NV, WA<br>Hood, Jack, Jose, Unio, Wasc | G4<br>SNR | -- | -- | 3 |
| *Phacelia tetramera* J.T. Howell<br>Dwarf phacelia | BR, EC; CA, NV, WA +<br>Harn, Lake, Malh | G4<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Phacelia verna* Howell<br>Spring phacelia | CR, KM, WC<br>Coos, Doug, Jose, Lane | G3<br>S3 | -- | -- | 4 |
| *Phalaris angusta* Nees ex Trin.<br>Narrow canarygrass | CR; CA +<br>Curr | G5<br>SNR | -- | -- | 3 |
| *Phalaris californica* Hook. & Arn.<br>California canarygrass | CR; CA<br>Curr | G4G5<br>SNR | -- | -- | 3 |
| *Phemeranthus spinescens* (Torr.) Hershkovitz<br>Spiny flame-flower | BM, BR, CB?; WA<br>Jeff, Malh, Wasc | G4<br>S2 | -- | -- | 2 |
| *Phlox hendersonii* (E. Nels.) Cronq.<br>Henderson phlox | BM, WC; WA<br>Hood, Wall | G4<br>S1 | -- | -- | 2 |
| *Phlox multiflora* A. Nels.<br>Many-flowered phlox | BM; ID<br>Unio | G4<br>S1 | -- | -- | 2 |
| *Physaria chambersii* Rollins<br>Chambers' bladder-pod | BM, BR; CA, NV<br>Bake, Harn, Malh | G4<br>S2 | -- | -- | 2 |
| *Physaria douglasii* (S. Wats.) O'Kane & Al-Shehbaz ssp. *douglasii*<br>Columbia bladderpod | BM, CB; ID, WA +<br>Gill, Gran, Morr, Sher, Wasc | GNRT4?<br>SNR | -- | -- | 3 |
| *Physaria geyeri* (Hook.) Gray var. *geyeri*<br>Geyer's twinpod | BM; WA, MT<br>Gill?, Whee | G4TNR<br>SNR | -- | -- | 3 |
| *Physaria kingii* (S. Wats.) O'Kane & Al-Shehbaz ssp. *cobrensis* (Rollins & Shaw) O'Kane & Al-Shehbaz<br>Cobre bladderpod | BR; ID, NV<br>Malh | G5T3T4<br>SNR | -- | -- | 3 |
| *Physaria kingii* (S. Wats.) O'Kane & Al-Shehbaz ssp. *diversifolia* (Greene) O'Kane & Al-Shehbaz<br>King's bladderpod | BM<br>Bake, Wall | G5T3<br>S3 | -- | -- | 4 |
| *Pilularia americana* A. Braun<br>American pillwort | BM, BR, EC, KM; CA+<br>Croo, Desc, Jack, Klam, Lake | G5<br>S2 | -- | -- | 2 |
| *Pinus albicaulis* Engelm.<br>Whitebark pine | BM, EC, KM, WC; CA, ID, NV, WA +<br>Bake, Desc, Doug, Gran, Hood, Jack, Jeff, Jose, Klam, Lake, Lane, Linn, Mari, Unio, Wall | G3G4<br>S3? | C | -- | 4 |
| *Pinus flexilis* James<br>Limber pine | BM; CA, ID, NV +<br>Bake, Wall | G4<br>S2? | -- | -- | 2 |
| *Pinus sabiniana* Dougl. ex Dougl.<br>Gray pine | KM; CA<br>Jack | G4<br>S1 | -- | -- | 3 |
| *Piperia candida* Morgan & Ackerman<br>White piperia | CR, KM, WC; CA, WA +<br>Coos, Doug, Jack, Jose, Lane | G3?<br>SNR | -- | -- | 3 |
| *Piperia elongata* Rydb.<br>Dense-flower rein orchid | BM, CR, EC, KM, WC; CA, ID, WA +<br>Curr, Doug, Jack, Jeff, Jose, Klam, Lane, Umat | G3G5<br>SNR | -- | -- | 3 |
| *Piptatherum exiguum* (Thurb.) Dorn<br>Little ricegrass | BM; CA, ID, NV, WA +<br>Bake, Wall | G5<br>SNR | -- | -- | 3 |
| *Plagiobothrys austiniae* (Greene) I.M. Johnston<br>Austin's plagiobothrys | KM; CA<br>Jack | G4<br>S2? | -- | -- | 2 |
| *Plagiobothrys figuratus* (Piper) I.M. Johnston ex M.E. Peck ssp. *corallicarpus* (Piper) Chambers<br>Coral seeded allocarya | KM, WC<br>Jack, Jose | G4T1<br>S1 | SOC | C | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Viola langsdorfii* Fisch. ex Gingins<br>Aleutian viola | CR; WA+<br>Coos, Curr, Linc | G4<br>SNR | -- | -- | 3 |
| *Viola praemorsa* Dougl. ex Lindl. ssp. *praemorsa*<br>Upland yellow violet | BM, BR, CR, EC, KM, WC, WV; CA, WA, MT, BC<br>Bent, Clac, Colu, Coos, Croo, Doug, Gran, Harn, Hood, Jack, Jose, Klam, Lake, Lane, Linn, Mari, Polk, Wall, Wash | G5T3T5<br>SNR | -- | -- | 3 |
| *Viola primulifolia* L. ssp. *occidentalis* (Gray) L.E. McKinney & R.J. Little<br>Western bog violet | KM; CA<br>Curr, Jose | G5T2<br>S2 | SOC | C | 1 |
| *Wolffia borealis* (Engelm. ex Hegelm.) Landolt ex Landolt & Wildi<br>Dotted water-meal | WC, WV; WA+<br>Bent?, Jack, Lane, Linn, Polk | G5<br>S1 | -- | -- | 2 |
| *Wolffia columbiana* Karst.<br>Columbia water-meal | KM, WC, WV; CA+<br>Bent, Clac, Clat, Doug, Jack, Lane, Linn, Mult, Yamh | G5<br>S1 | -- | -- | 2 |
| *Zigadenus fontanus* Eastw.<br>Small-flowered death camas | KM; CA<br>Jack | G3<br>S1 | SOC | -- | 2 |
| *Zizia aptera* (Gray) Fern.<br>Golden alexanders | BM, WV; NV, WA+<br>Clac, Colu, Mult, Wall, Wash | G5<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Townsendia montana* M.E. Jones<br>Mountain townsendia | BM; ID+<br>Wall | G4<br>S1 | -- | -- | 2 |
| *Townsendia parryi* D.C. Eat.<br>Parry's townsendia | BM; CA, WA+<br>Wall | G4?<br>S1 | -- | -- | 2 |
| *Townsendia scapigera* D.C. Eat.<br>Tufted Townsend daisy | BR; CA, ID, NV, UT<br>Malh | G4G5<br>S2 | -- | -- | 2 |
| *Trichophorum cespitosum* (L.) Hartman<br>Tufted clubrush | BM, WC; ID, WA +<br>Clac, Gran, Hood, Lane, Linn | G5<br>SNR | -- | -- | 3 |
| *Trifolium douglasii* House<br>Douglas clover | BM; ID, WA<br>Umat, Unio | G2<br>S1 | SOC | -- | 1 |
| *Trifolium leibergii* A. Nels. & J.F. Macbr.<br>Leiberg's clover | BR; NV<br>Harn, Malh | G2<br>S1 | SOC | C | 1 |
| *Trifolium owyheense* Gilkey<br>Owyhee clover | BR; ID<br>Malh | G2<br>S2 | SOC | LE | 1 |
| *Triglochin palustris* L.<br>Slender bog arrowgrass | BM; CA, ID, NV, WA +<br>Bake, Unio | G5<br>S2 | -- | -- | 2 |
| *Triglochin striata* Ruiz & Pavon<br>Three-ribbed arrow-grass | CR; CA +<br>Clat, Coos, Curr, Doug, Lane, Linc, Till | G5<br>SNR | -- | -- | 3 |
| *Trillium kurabayashii* J.D. Freeman<br>Giant purple trillium | CR, KM; CA<br>Curr | G4G5<br>S1 | -- | -- | 2 |
| *Triteleia crocea* (Wood) Greene var. *crocea*<br>Yellow triteleia | KM; CA<br>Jack, Jose | G4T4<br>S4 | -- | -- | 4 |
| *Triteleia hendersonii* Greene var. *leachiae* (M.E. Peck) Hoover<br>Leach's brodiaea | CR, KM<br>Coos, Curr | G4G5T3<br>S3 | SOC | C | 4 |
| *Triteleia ixioides* (Ait. f.) Greene ssp. *anilina* (Greene) Lenz<br>Sierra brodiaea | KM; CA<br>Jack | G5T4<br>SH | -- | -- | 2-ex |
| *Triteleia ixioides* (Ait. f.) Greene ssp. *scabra* (Greene) Lenz<br>Golden triteleia | KM; CA<br>Jack | G5T3?<br>SNR | -- | -- | 3 |
| *Triteleia laxa* Benth.<br>Ithuriel's spear | CR, KM; CA<br>Curr, Jack | G4<br>S1 | -- | -- | 2 |
| *Trollius laxus* Salisb. ssp. *albiflorus* (Gray) A.& D. Love & Kapoor<br>American globeflower | BM; ID, WA+<br>Wall | G5T5<br>S1 | -- | -- | 2 |
| *Utricularia gibba* L.<br>Humped bladderwort | CR, WC, WV; CA, ID, WA+<br>Bent, Coos, Doug, Lane, Linn | G5<br>S1 | -- | -- | 2 |
| *Utricularia minor* L.<br>Lesser bladderwort | BM, BR, CR, EC, KM, WC; CA, ID, NV, WA+<br>Bake?, Clac, Coos, Doug, Gran?, Harn, Jack, Klam, Lane, Linn, Mari, Wall?, Wasc | G5<br>S2 | -- | -- | 2 |
| *Utricularia ochroleuca* R.W. Hartman<br>Northern bladderwort | WC; CA, WA, BC+<br>Clac, Lane | G4?<br>S1 | -- | -- | 2 |
| *Vaccinium oxycoccos* L.<br>Wild bog cranberry | CR, WC; WA, ID+<br>Clac, Clat, Doug, Lane, Linc, Linn, Mari, Mult, Till, Wasc | G5<br>S4 | -- | -- | 4 |
| *Vancouveria chrysantha* Greene<br>Yellow vancouveria | KM; CA<br>Curr, Jose | G4<br>S4 | -- | -- | 4 |

| *Scientific Name*<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Stylocline psilocarphoides* M.E. Peck<br>Malheur stylocline | BR; CA, NV +<br>Malh | G4<br>SH | -- | -- | 2-ex |
| *Suksdorfia violacea* Gray<br>Violet suksdorfia | BM, EC, WC; WA<br>Hood, Wall, Wasc | G4<br>S1 | -- | -- | 2 |
| *Sullivantia oregana* S. Wats.<br>Oregon sullivantia | WC, WV; WA<br>Clac, Colu, Hood, Mult | G2<br>S2 | SOC | C | 1 |
| *Swertia perennis* L.<br>Felwort | BM, BR; CA, ID, NV, WA +<br>Bake, Gran, Harn, Wall | G5<br>S2 | -- | -- | 3 |
| *Symphoricarpos longiflorus* Gray<br>Long-flowered snowberry | BR; CA, NV+<br>Harn, Lake, Malh | G5<br>S2 | -- | -- | 2 |
| *Synthyris missurica* (Raf.) Pennell ssp. *stellata* (Pennell) Kartesz & Gandhi<br>Columbia kittentails | WC; WA<br>Hood, Mult | G4T4<br>S3 | -- | -- | 4 |
| *Synthyris schizantha* Piper<br>Fringed kittentail | CR; WA<br>Clat, Till | G4G5<br>S4 | -- | -- | 4 |
| *Taraxacum ceratophorum* (Ledeb.) DC.<br>Horned dandelion | BM; ID, CA+<br>Wall | G5<br>SNR | -- | -- | 3 |
| *Taraxia ovata* (Nutt.) Small<br>Golden eggs | KM, WV; CA<br>Bent, Doug, Jose | G3G4<br>S1 | -- | -- | 2 |
| *Tauschia howellii* (Coult. & Rose) J.F. Macbr.<br>Howell's tauschia | KM; CA<br>Jack | G2<br>S1 | SOC | C | 1 |
| *Tauschia stricklandii* (Coult. & Rose) Mathias & Constance<br>Strickland's tauschia | WC; WA<br>Mult | G4<br>S1 | -- | -- | 2 |
| *Tetrapteron graciliflorum* (Hook. & Arn.) W.L. Wagner & Hoch<br>Slender-flowered evening-primrose | KM; CA<br>Jack, Jose | G4<br>S2 | -- | -- | 2 |
| *Tetrapteron palmeri* (S. Wats.) W.L. Wagner & Hoch<br>Palmer's evening-primrose | BR; CA, ID, NV<br>Malh | G3G4<br>SNR | -- | -- | 3 |
| *Thalictrum alpinum* L.<br>Alpine meadow-rue | BM; CA, ID, NV+<br>Wall | G5<br>S2 | -- | -- | 2 |
| *Thelypodium brachycarpum* Torr.<br>Short-podded thelypody | BR?, EC; CA<br>Klam, Lake | G3<br>S2 | SOC | -- | 2 |
| *Thelypodium eucosmum* B.L. Robins.<br>Arrow-leaf thelypody | BM<br>Bake, Gran, Whee | G2<br>S2 | SOC | LT | 1 |
| *Thelypodium howellii* S. Wats. ssp. *howellii*<br>Howell's thelypody | BM, BR, EC; CA<br>Croo, Desc, Gran, Harn, Klam, Lake | G2T2<br>S1 | SOC | -- | 1 |
| *Thelypodium howellii* S. Wats. ssp. *spectabilis* (M.E. Peck) Al-Shehbaz<br>Howell's spectacular thelypody | BM<br>Bake, Malh, Unio | G2T1<br>S1 | LT | LE | 1 |
| *Thelypodium sagittatum* (Nutt. ex Torr. & Gray) Endl. ex Walp. ssp. *sagittatum*<br>Slender thelypody | BM, KM; ID, NV, WA +<br>Bake, Jack, Umat | G4T4<br>SNR | -- | -- | 3 |
| *Torreyochloa erecta* (A.S. Hitchc.) Church<br>Narrow mannagrass | BM, KM, WC; CA, NV<br>Gran, Jack, Jose, Klam, Mari | G4G5<br>S3 | -- | -- | 3 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Silene suksdorfii* B.L. Robins.<br>Suksdorf's campion | WC; CA, WA<br>Desc, Doug, Hood, Jeff, Klam, Lane, Mari | G4<br>S4 | -- | -- | 4 |
| *Sisyrinchium hitchcockii* D. Henderson<br>Hitchcock's blue-eyed grass | KM, WV; CA<br>Bent, Doug, Lane, Linn | G2<br>S1 | SOC | -- | 1 |
| *Sisyrinchium sarmentosum* Suksdorf ex Greene<br>Pale blue-eyed grass | WC; WA<br>Clac, Mari | G2<br>S1 | SOC | C | 1 |
| *Smelowskia ovalis* M.E. Jones var. *ovalis*<br>Shortfruited smelowskia | WC; WA+<br>Desc, Hood, Lane | G5T4<br>S4 | -- | -- | 4 |
| *Smilax californica* (A. DC.) Gray<br>California smilax | KM; CA<br>Curr, Jack, Jose | G4<br>S3 | -- | -- | 4 |
| *Solanum parishii* Heller<br>Parish's horse-nettle | KM, WC; CA<br>Curr, Jack, Jose | G4<br>S2 | -- | -- | 2 |
| *Sophora leachiana* M.E. Peck<br>Western necklace | KM<br>Jose | G2<br>S2 | SOC | C | 1 |
| *Sorbus californica* Greene<br>California mountain ash | WC; NV, CA<br>Klam | G5<br>SNR | -- | -- | 3 |
| *Spartina pectinata* Link<br>Prairie cordgrass | BM, BR, CB; ID, WA +<br>Bake, Desc, Harn, Sher, Unio, Wall | G5<br>SNR | -- | -- | 3 |
| *Sphenopholis obtusata* (Michx.) Scribn.<br>Prairie wedgegrass | BM, CB, EC; CA, ID, NV, WA +<br>Desc, Unio, Wall, Wasc | G5<br>SNR | -- | -- | 3 |
| *Sporobolus airoides* (Torr.) Torr.<br>Hairgrass dropseed | BR; CA, ID, NV, WA +<br>Harn, Malh | G5<br>SNR | -- | -- | 3 |
| *Stanleya confertiflora* (B.L. Robins.) T.J. Howell<br>Biennial stanleya | BM, BR; ID<br>Bake, Harn, Malh | G2<br>S2 | SOC | C | 1 |
| *Stellaria humifusa* Rottb.<br>Creeping starwort | ME; WA+<br>Lane, Linc, Till | G5?<br>SH | -- | -- | 2-ex |
| *Stephanomeria malheurensis* Gottlieb<br>Malheur wire-lettuce | BR<br>Harn | G1<br>S1 | LE | LE | 1 |
| *Streptanthus cordatus* Nutt. var. *cordatus*<br>Perennial twistflower | BM, BR, EC, KM; CA, ID, NV +<br>Gran, Harn, Jose, Lake, Malh, Morr | G5T4T5<br>SNR | -- | -- | 3 |
| *Streptanthus glandulosus* Hook.<br>Common jewel flower | KM; CA<br>Jose | G4<br>S1 | -- | -- | 2 |
| *Streptanthus howellii* S. Wats.<br>Howell's streptanthus | KM; CA<br>Curr, Jose | G2<br>S2 | -- | C | 1 |
| *Streptopus streptopoides* (Ledeb.) Frye & Rigg<br>Kruhsea | WC; BC+<br>Clac, Hood, Mult | G5<br>S2 | -- | -- | 2 |
| *Stuckenia filiformis* (Pers) Boerner ssp. *alpina* (Blytt) Haynes, D.H. Les, & M. Kral<br>Northern slender-leaved pondweed | BM, EC; CA, ID, NV, WA +<br>Desc, Wall | G5T5<br>SNR | -- | -- | 3 |
| *Stuckenia filiformis* (Pers) Boerner ssp. *occidentalis* (J.W. Robbins) Haynes, D.H. Les, & M. Kral<br>Western slender-leaved pondweed | Desc, Harn, Klam, Malh | G5T5<br>S3 | -- | -- | 4 |
| *Stuckenia striata* (Ruiz & Pavón) Holub<br>Nevada pondweed | BR; CA, NV +<br>Lake, Malh | G3G4Q<br>S1? | -- | -- | 2 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Senecio ertterae* T.M. Barkl.<br>Ertter's senecio | BR<br>Malh | G2<br>S2 | SOC | C | 1 |
| *Senecio sphaerocephalus* Greene<br>Mountain-marsh butterweed | BM; ID, NV +<br>Gran, Wall | G4G5<br>S1? | -- | -- | 3 |
| *Senecio triangularis* Hook. var. *angustifolius* G.N. Jones<br>Bog groundsel | CR; WA, BC<br>Coos, Curr | G5TNR<br>S1? | -- | -- | 3 |
| *Sericocarpus rigidus* Lindl.<br>White-topped aster | WV; WA, BC<br>Clac, Lane, Linn, Mari, Mult? | G3<br>S2 | SOC | LT | 1 |
| *Sesuvium verrucosum* Raf.<br>Verrucose sea-purslane | BR; ID, NV, CA+<br>Harn, Lake | G5<br>S2 | -- | -- | 2 |
| *Sidalcea campestris* Greene<br>Meadow checker-mallow | CR, WV<br>Bent, Clac, Lane, Linn, Mari, Mult, Polk, Wash, Yamh | G4<br>S4 | -- | C | 4 |
| *Sidalcea cusickii* Piper<br>Cusick's mallow | KM, WC, WV<br>Coos, Doug, Jack?, Jose, Lane, Linn | G4<br>S4 | -- | -- | 4 |
| *Sidalcea hendersonii* S. Wats.<br>Henderson's sidalcea | CR, ME; WA, BC<br>Clat, Doug, Lane, Till | G3<br>S1 | SOC | -- | 1 |
| *Sidalcea hickmanii* Greene ssp. *nov.*<br>Hickman's southern Oregon sidalcea | KM<br>Jack | G3T1<br>S1 | -- | -- | 1 |
| *Sidalcea hirtipes* C.L. Hitchc.<br>Bristly-stemmed sidalcea | CR, WV; WA<br>Clat, Colu, Linc, Till | G2<br>S2 | SOC | C | 1 |
| *Sidalcea malachroides* (Hook. & Arn.) Gray<br>Maple-leaved sidalcea | CR, KM?; CA<br>Curr | G3G4<br>SH | SOC | -- | 2-ex |
| *Sidalcea malviflora* (DC.) Gray ex Benth. ssp. *patula* C.L. Hitchc.<br>Coast checker bloom | CR, KM; CA<br>Coos, Curr | G5T2<br>S1 | SOC | C | 1 |
| *Sidalcea nelsoniana* Piper<br>Nelson's sidalcea | CR, WV; WA<br>Bent, Clac, Clat, Colu, Linn, Mari, Polk, Till, Wash, Yamh | G2G3<br>S2 | LT | LT | 1 |
| *Sidalcea neomexicana* Gray<br>Rocky Mountain sidalcea | BM, BR; CA, ID, NV +<br>Bake, Gran, Malh | G4?<br>SNR | -- | -- | 3 |
| *Silene douglasii* Hook. var. *oraria* (M.E. Peck) C.L. Hitchc. & Maguire<br>Cascade Head catchfly | CR<br>Clat, Till | G4T1<br>S1 | SOC | LT | 1 |
| *Silene hookeri* Nutt. ssp. *bolanderi* (Gray) Abrams<br>Bolander's catchfly | KM; CA<br>Curr, Jose | G4T4?<br>S1 | -- | -- | 2 |
| *Silene hookeri* Nutt. ssp. *serpentinicola* (T.W. Nelson & J.P. Nelson) K.L. Chambers & S.C. Meyers<br>Serpentine catchfly | KM; CA<br>Jose | G4T2<br>S1? | -- | -- | 1 |
| *Silene lemmonii* S. Wats.<br>Lemmon's catchfly | KM; CA<br>Curr, Jack, Jose | G5<br>S3 | -- | -- | 4 |
| *Silene nuda* (S. Wats.) C.L. Hitchc. & Maguire ssp. *insectivora* (Henderson) C.L. Hitchc. & Maguire<br>Fringed campion | EC; CA<br>Klam, Lake | G4G5T4<br>S3 | -- | -- | 4 |
| *Silene spaldingii* S. Wats.<br>Spalding's campion | BM; ID, MT, WA<br>Wall | G2<br>S2 | LT | LE | 1 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Sanicula peckiana* J.F. Macbr.<br>Peck's sanicle | KM; CA<br>Curr, Jose | G4<br>S3 | -- | -- | 4 |
| *Saxifraga adscendens* L. ssp. *oregonensis* (Raf.) Bacig.<br>Wedge-leaf saxifrage | BM, BR; WA, ID+<br>Harn, Wall | G5T4T5<br>S1 | -- | -- | 2 |
| *Saxifragopsis fragarioides* (Greene) Small<br>Strawberry saxifrage | KM; CA, WA<br>Curr, Jose | G3?<br>S1 | -- | -- | 2 |
| *Scheuchzeria palustris* L. ssp. *americana* (Fern.) Hulten<br>Scheuchzeria | EC, WC; CA, ID, WA+<br>Clac, Desc, Doug, Klam, Lane, Linn, Mult | G5T5<br>S2 | -- | -- | 2 |
| *Schoenoplectus heterochaetus* (Chase) Soják<br>Slender bulrush | EC; CA, WA+<br>Klam | G5<br>SH | -- | -- | 3 |
| *Schoenoplectus subterminalis* (Torr.) Sojak<br>Water clubrush | CR, EC, KM, WC; CA, ID, WA+<br>Coos, Curr, Doug, Jose, Klam, Lake, Lane, Linn, Wasc | G4G5<br>S2 | -- | -- | 2 |
| *Scirpus pallidus* (Britt.) Fern.<br>Pale bulrush | BM, BR, WV; WA, ID +<br>Bake, Harn, Lane, Mult, Wall | G5<br>S3 | -- | -- | 3 |
| *Scirpus pendulus* Muhl.<br>Drooping bulrush | EC, KM, WC, WV; CA +<br>Clac, Curr, Jack, Jose, Lane, Linn, Mari | G5<br>S1 | -- | -- | 2 |
| *Sclerolinon digynum* (Gray) Rogers<br>Northwestern yellow flax | EC, KM, WV; CA, ID, WA<br>Bent, Jack, Jose, Klam, Linn, Mari | G5<br>SNR | -- | -- | 3 |
| *Scoliopus bigelovii* Torr.<br>California fetid adder's-tongue | CR; CA<br>Curr | G4?<br>S1 | -- | -- | 2 |
| *Scolochloa festucacea* (Willd.) Link<br>Common rivergrass | BM, BR; ID, WA +<br>Harn, Wall | G5<br>SNR | -- | -- | 3 |
| *Sedella pumila* (Benth.) Britt. & Rose<br>Sierra mock-stonecrop | WV; CA<br>Mult? | G3?<br>SH | -- | -- | 2-ex |
| *Sedum debile* S. Wats.<br>Weak-stemmed stonecrop | BR; CA, ID, NV+<br>Harn, Malh | G4G5<br>S4 | -- | -- | 4 |
| *Sedum lanceolatum* Torr. ssp. *nesioticum* (G.N. Jones) Clausen<br>Lanceleaved stonecrop | WV; BC, WA<br>Colu | G5T4?<br>SNR | -- | -- | 3 |
| *Sedum laxum* (Britt.) Berger ssp. *heckneri* (M.E. Peck) Clausen<br>Heckner's stonecrop | KM; CA<br>Curr?, Doug?, Jack, Jose | G5T3Q<br>S3 | -- | -- | 4 |
| *Sedum moranii* Clausen<br>Rogue River stonecrop | KM<br>Jose | G2<br>S2 | -- | C | 1 |
| *Sedum oblanceolatum* Clausen<br>Applegate stonecrop | KM; CA<br>Jack | G3<br>S3 | -- | C | 4 |
| *Sedum rosea* (L.) Scop. ssp. *integrifolium* (Raf.) Berger<br>Alpine sedum | BM, BR; CA, ID, NV, WA +<br>Bake, Gran, Harn, Umat, Wall | G5T5<br>SNR | -- | -- | 3 |
| *Sedum spathulifolium* Hook. ssp. *purdyi* (Jepson) Clausen<br>Purdy's stonecrop | KM; CA<br>Doug, Jack, Jose | G4G5T4<br>S3 | -- | -- | 4 |
| *Selaginella watsonii* Underwood<br>Watson's spike-moss | BM, BR; CA, NV+<br>Bake, Harn, Unio?, Wall | G4<br>S4 | -- | -- | 4 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Ribes triste* Pallas<br>Western red currant | BM, WC; WA +<br>Clac, Doug, Lane, Unio | G5<br>SNR | -- | -- | 3 |
| *Ribes wolfii* Rothrock<br>Wolf currant | BM; ID, WA+<br>Wall | G4<br>SNR | -- | -- | 3 |
| *Romanzoffia suksdorfii* Greene<br>Suksdorf's mistmaiden | WC; WA<br>Hood, Mult | G3G4<br>S3? | -- | -- | 3 |
| *Romanzoffia thompsonii* Marttala<br>Thompson mistmaiden | CR, KM, WC, WV<br>Doug, Jack, Lane, Linn, Mari | G3<br>S3 | -- | -- | 1 |
| *Rorippa columbiae* Suksdorf ex Howell<br>Columbia cress | BM, BR, CB, EC, WC, WV; CA, WA<br>Bake, Croo, Harn, Klam, Lake, Mult, Umat | G3<br>S3 | -- | C | 1 |
| *Rorippa curvipes* Greene var. *curvipes*<br>Rocky Mt. yellowcress | BR, CB; CA, ID, NV, WA +<br>Harn, Lake, Umat, Unio | G5T5?<br>SNR | -- | -- | 3 |
| *Rosa gymnocarpa* Nutt. var. *serpentina* Ertter & W.H. Lewis<br>Serpentine dwarf rose | KM; CA<br>Curr, Jose | G5T2<br>SNR | -- | -- | 3 |
| *Rotala ramosior* (L.) Koehne<br>Toothcup | BR, EC, WV; CA, WA+<br>Bent, Colu?, Harn, Hood, Lane, Linn, Mari, Mult, Wash? | G5<br>S2 | -- | -- | 2 |
| *Rubus bartonianus* M.E. Peck<br>Bartonberry | BM; ID<br>Wall | G2<br>S2 | SOC | C | 1 |
| *Rumex salicifolius* Weinm. var. *lacustris* (Greene) Hickman<br>Willow dock | BR; CA, NV<br>Harn, Lake, Malh | G5TNR<br>S1? | -- | -- | 3 |
| *Sagittaria montevidensis* Cham. & Schlecht. ssp. *calycina* (Engelm.) Bogin<br>Long-lobe arrowhead | BR, EC; CA +<br>Harn?, Klam, Lake?, Malh? | G5T5?<br>S2? | -- | -- | 3 |
| *Salix brachycarpa* Nutt.<br>Short-fruit willow | BM, BR; CA, ID, WA+<br>Harn, Wall | G5<br>S4 | -- | -- | 4 |
| *Salix delnortensis* Schneid.<br>Del Norte willow | KM; CA<br>Curr, Jose | G4<br>S3 | -- | -- | 4 |
| *Salix drummondiana* Barratt ex Hook.<br>Drummond's willow | BM, BR, WC; CA, ID, NV, WA+<br>Bake, Gran, Harn, Unio, Wall | G4G5<br>S4 | -- | -- | 4 |
| *Salix farriae* Ball<br>Farr's willow | BM; ID +<br>Unio, Wall | G4<br>S2 | -- | -- | 2 |
| *Salix glauca* L. var. *villosa* (D. Don ex Hook.) Anderss.<br>Shaggy leaf willow | BR; ID, NV, WA +<br>Harn | G5T5?<br>SNR | -- | -- | 3 |
| *Salix laevigata* Bebb<br>Polished willow | EC, KM; CA, NV +<br>Jack, Klam | G5<br>S1? | -- | -- | 2 |
| *Salix ligulifolia* (Ball) Ball ex Schneid.<br>Strapleaf willow | BR; CA +<br>Harn | G5<br>SNR | -- | -- | 3 |
| *Salix nivalis* Hook.<br>Snow willow | BM, BR, EC; CA, ID, NV, WA +<br>Gran, Harn, Lake, Wall | G5<br>S2S3 | -- | -- | 3 |
| *Salix wolfii* Bebb<br>Wolf's willow | BM; ID, NV +<br>Wall | G5?<br>S2 | -- | -- | 2 |
| *Samolus parviflorus* Raf.<br>Water-pimpernel | CR, ME; CA, WA+<br>Clat, Coos?, Doug | G5<br>SNR | -- | -- | 3 |

| Scientific Name<br>Common Name | Ecoregion; Adjacent States<br>Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Prosartes parvifolia* S. Wats.<br>Siskiyou fairy bells | KM; CA<br>Curr, Jose | G2?<br>S1 | -- | -- | 1 |
| *Puccinellia nutkaensis* (J. Presl) Fern. & Weatherby<br>Pacific alkaligrass | ME<br>Clat, Coos, Lane, Linc, Till | G4?<br>SNR | -- | -- | 3 |
| *Puccinellia pumila* (Vasey) A.S. Hitchc.<br>Dwarf alkali grass | ME; WA<br>Coos, Doug, Lane, Linc, Till | G4?<br>SNR | -- | -- | 3 |
| *Pyrola dentata* Sm.<br>Toothleaf pyrola | BM, CR, EC, KM, WC; CA, ID, NV, WA +<br>Bake, Coos, Curr, Desc, Doug, Gran, Harn, Jack, Jeff, Jose, Klam, Lane, Linn, Wall | G4<br>S2? | -- | -- | 2 |
| *Pyrola elliptica* Nutt.<br>Shinleaf | BM; ID, WA +<br>Gran, Morr | G5<br>SNR | -- | -- | 3 |
| *Pyrrocoma linearis* (Keck) Kartesz & Gandhi<br>One-flowered goldenweed | BR; NV<br>Harn, Malh | G4?<br>S4 | -- | -- | 4 |
| *Pyrrocoma racemosa* (Nutt.) Torr. & Gray var. *racemosa*<br>Racemose pyrrocoma | WV; CA<br>Bent, Lane, Mari | G5T3T4<br>S1 | -- | -- | 2 |
| *Pyrrocoma radiata* Nutt.<br>Snake River goldenweed | BM, BR; ID<br>Bake, Malh | G3<br>S3 | SOC | LE | 1 |
| *Pyrrocoma scaberula* Greene<br>Rough pyrrocoma | BM; ID, WA<br>Wall | G2<br>S1 | -- | -- | 1 |
| *Rafinesquia californica* Nutt.<br>California chicory | BM?, BR?, KM; CA, NV +<br>Jack, Jose, Malh? | G5<br>S2 | -- | -- | 2 |
| *Ranunculus acriformis* Gray var. *montanensis* (Rydb.) L. Benson<br>Montane sharpleaf buttercup | BM; ID, WA, MT, WY<br>Unio, Wall | G5T5?<br>SNR | -- | -- | 3 |
| *Ranunculus austrooreganus* L. Benson<br>Southern Oregon buttercup | KM, WC<br>Jack | G2<br>S2 | -- | C | 1 |
| *Ranunculus triternatus* Gray<br>Dalles Mt. buttercup | EC; ID, NV, WA<br>Hood, Wasc | G2<br>S1 | SOC | -- | 1 |
| *Rhamnus ilicifolia* Kellogg<br>Redberry | KM; CA+<br>Jack | G5<br>S1 | -- | -- | 2 |
| *Rhinanthus crista-galli* L.<br>Yellow rattle | CR; WA+<br>Clat, Till | G4G5Q<br>S4 | -- | -- | 4 |
| *Rhynchospora alba* (L.) Vahl<br>White beakrush | CR, WC, WV; CA, ID, WA +<br>Clac, Jack, Lane, Linn, Mult? | G5<br>S2 | -- | -- | 2 |
| *Rhynchospora capitellata* (Michx.) Vahl<br>Brownish beakrush | CR; CA+<br>Curr | G5<br>S1 | -- | -- | 2 |
| *Ribes cereum* Dougl. var. *colubrinum* C.L. Hitchc.<br>Wax currant | BM; ID, WA<br>Bake, Wall | G5T3<br>S3 | -- | -- | 4 |
| *Ribes divaricatum* Dougl. var. *pubiflorum* Koehne<br>Straggly gooseberry | CR, KM, WC; CA<br>Curr, Jose, Lane | G4T4?<br>S2 | -- | -- | 2 |
| *Ribes inerme* Rydb. var. *klamathense* (Coville) Jepson<br>Klamath gooseberry | BM, CR, EC; CA<br>Doug, Jack, Jeff, Jose, Klam | G5T3?<br>S3 | -- | -- | 4 |
| *Ribes laxiflorum* Pursh<br>Trailing blackberry | CR, EC, WC; CA, ID, WA +<br>Clat, Coos, Klam, Lake, Lane, Linc, Linn | G5<br>SNR | -- | -- | 3 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Poa unilateralis* Scribn. ssp. *pachypholis* (Piper) D.D. Keck ex Soreng<br>Ocean bluff grass | CR; WA<br>Linc, Till | G4T2<br>S1 | -- | -- | 1 |
| *Poa unilateralis* Scribn. ssp. *unilateralis*<br>San Francisco bluegrass | CR; CA<br>Curr | G4T4<br>S4 | -- | -- | 4 |
| *Pogogyne floribunda* Jokerst<br>Profuse-flowered pogogyne | BR, EC; CA, ID<br>Klam, Lake, Malh | G4<br>S1 | SOC | -- | 2 |
| *Polanisia dodecandra* (L.) DC. ssp. *trachysperma* (Torr. & Gray) Iltis<br>Clammyweed | BR; CA, ID, NV, WA +<br>Malh | G5T5?<br>SNR | -- | -- | 3 |
| *Polemonium viscosum* Nutt.<br>Skunk polemonium | BM, BR; ID, NV, WA+<br>Bake, Harn, Unio, Wall | G5<br>S4 | -- | -- | 4 |
| *Polyctenium fremontii* (S. Wats.) Greene var. *bisulcatum* (Greene) Rollins<br>Silvies Valley desert combleaf | BM<br>Harn | G4TH<br>SH | -- | -- | 3 |
| *Polyctenium williamsiae* Rollins<br>Williams combleaf | BR; CA, NV<br>Harn | G2Q<br>S1 | SOC | -- | 1 |
| *Polygonum gabrielae* Costea & Tardif<br>Gabriela's knotweed | BM<br>Gran | GNR<br>SNR | -- | -- | 3 |
| *Polypodium calirhiza* Whitmore<br>Hotroot polypody | CR; CA+<br>Coos, Curr, Lane, Linc | G4?<br>SNR | -- | -- | 3 |
| *Polystichum californicum* (D.C. Eat.) Diels<br>California sword-fern | CR, KM, WC; CA, WA+<br>Coos, Curr, Doug, Lane, Linn | G4<br>S2 | -- | -- | 2 |
| *Polystichum kruckebergii* W.H. Wagner<br>Kruckeberg's sword-fern | BM, BR, EC; CA, ID, WA+<br>Bake, Desc, Gran, Harn, Klam, Lane, Umat, Wall, Wasc | G4<br>S4 | -- | -- | 4 |
| *Polystichum lemmonii* Underwood<br>Shasta fern | BM, KM; CA, WA+<br>Gran, Jack, Jose | G4<br>S4 | -- | -- | 4 |
| *Potamogeton berchtoldii* Fieber<br>Slender pondweed | BM, BR, CR, EC, WC; CA, ID, NV, WA +<br>Bake, Clac, Coos, Croo, Desc, Doug, Harn, Jack, Klam, Lane, Linc, Linn, Malh, Wall, Wasc, Whee | G5<br>S3? | -- | -- | 4 |
| *Potamogeton diversifolius* Raf.<br>Rafinesque's pondweed | BR, EC; CA, ID, NV, WA+<br>Harn, Klam, Lake, Malh | G5<br>S1 | -- | -- | 2 |
| *Potamogeton fibrillosus* Fernald<br>Fibrous pondweed | BR, EC; CA, ID, NV, WA +<br>Harn, Klam | G2G4<br>SH | -- | -- | 2-ex |
| *Potamogeton praelongus* Wulfen<br>White-stem pondweed | BM, CR, WC; CA, ID, WA +<br>Doug, Lane, Wall | G5<br>SNR | -- | -- | 3 |
| *Potamogeton robbinsii* Oakes<br>Flatleaf pondweed | BM, CR, EC, WC, WV; CA, ID, WA +<br>Bent, Gran, Klam, Lane, Linn, Mari, Umat | G5<br>SNR | -- | -- | 3 |
| *Potentilla jepsonii* Ertter<br>Jepson's cinquefoil | BR; CA, ID, NV, WA +<br>Harn | G4G5<br>SNR | -- | -- | 3 |
| *Potentilla villosa* Pallas ex Pursh<br>Villous cinquefoil | WC; WA+<br>Hood, Lane | G5<br>S1 | -- | -- | 2 |
| *Prenanthella exigua* (Gray) Rydb.<br>Desert prenanthella | BR; CA, NV +<br>Malh | G5?<br>S1 | -- | -- | 2 |
| *Primula cusickiana* (Gray) Gray<br>Wallowa primrose | BM, BR; ID<br>Malh, Wall | G4<br>S3 | -- | -- | 2 |

| *Scientific Name* Common Name | Ecoregion; Adjacent States Oregon Counties | Heritage Rank | Federal Status | ODA Status | ORBIC List |
|---|---|---|---|---|---|
| *Plagiobothrys glyptocarpus* (Piper) I.M. Johnston<br>Sculptured allocarya | KM; CA<br>Jack | G3<br>S3 | -- | -- | 4 |
| *Plagiobothrys greenei* (Gray) I.M. Johnston<br>Greene's popcorn flower | KM, WC; CA<br>Jack, Jose | G4<br>S2? | -- | -- | 2 |
| *Plagiobothrys hirtus* (Greene) I.M. Johnston<br>Rough popcorn flower | KM<br>Doug | G1<br>S1 | LE | LE | 1 |
| *Plagiobothrys lamprocarpus* (Piper) I.M. Johnston<br>Shiny-fruited popcorn flower | KM<br>Jose | GX<br>SX | -- | LE | 1-X |
| *Plagiobothrys salsus* (Brandeg.) I.M. Johnston<br>Desert allocarya | BR, EC; CA, NV, MT<br>Klam, Lake | G2G3<br>S1 | SOC | -- | 2 |
| *Plantago eriopoda* Torr.<br>Hairy-foot plantain | BR, CR; CA, ID, NV+<br>Coos, Linc, Malh | G5<br>SNR | -- | -- | 3 |
| *Plantago macrocarpa* Cham. & Schlecht.<br>North pacific plantain | CR; WA<br>Linc | G4<br>S1 | -- | -- | 2 |
| *Platanthera obtusata* (Banks ex Pursh) Lindl.<br>Small northern bog-orchid | BM; ID, WA+<br>Wall | G5<br>S1 | -- | -- | 2 |
| *Pleuropogon oregonus* Chase<br>Oregon semaphore grass | BM, BR, EC<br>Lake, Unio | G1<br>S1 | SOC | LT | 1 |
| *Poa bolanderi* Vasey<br>Bolander's bluegrass | BM, BR, KM, WC; CA, ID, NV, WA, UT<br>Bake, Croo, Doug, Gran, Harn, Jack, Jose, Klam, Wall | G5<br>S3 | -- | -- | 4 |
| *Poa chambersii* Soreng<br>Chambers' bluegrass | BR, WC<br>Clac, Harn, Klam, Lane, Mari | GNR<br>SNR | -- | -- | 3 |
| *Poa fendleriana* (Steud.) Vasey ssp. *longiligula* (Scribn. & Williams) Soreng<br>Long tongue muttongrass | BR; CA, ID, NV, WA +<br>Harn, Lake | G5TNR<br>SNR | -- | -- | 3 |
| *Poa glauca* Vahl ssp. *rupicola* (Nash ex Rydb.) W.A. Weber<br>Timberline bluegrass | BM, BR; CA, ID, NV, WA +<br>Harn, Wall | G5T5<br>SNR | -- | -- | 3 |
| *Poa laxiflora* Buckl.<br>Loose-flowered bluegrass | CR, WC; WA+<br>Bent, Clac, Coos, Lane, Linc, Linn, Mari, Mult, Polk, Till, Wash, Yamh | G3G4<br>S3 | -- | -- | 4 |
| *Poa lettermanii* Vasey<br>Letterman's bluegrass | WC; CA, ID, NV, WA +<br>Desc, Lane | G4<br>SNR | -- | -- | 3 |
| *Poa marcida* A.S. Hitchc.<br>Weak bluegrass | CR, WC; WA+<br>Clac, Clat, Linc, Mari, Mult, Polk, Till, Yamh | G4G5<br>S4 | -- | -- | 4 |
| *Poa piperi* A.S. Hitchc.<br>Piper's bluegrass | CR, KM; CA<br>Coos, Curr, Jose | G4<br>S3 | -- | -- | 4 |
| *Poa reflexa* Vasey & Scribn. ex Vasey<br>Nodding bluegrass | BM; ID, NV +<br>Wall | G5<br>SNR | -- | -- | 3 |
| *Poa rhizomata* A.S. Hitchc.<br>Timber bluegrass | KM, WC; CA<br>Jack | G3G4<br>S1? | -- | -- | 2 |
| *Poa stenantha* Trin.<br>Narrow-flower bluegrass | BM, CR, WC, WV; ID, WA +<br>Bake, Clac, Clat, Curr, Desc, Doug, Hood, Klam, Lane, Mari, Polk, Till, Wall | G5<br>SNR | -- | -- | 3 |
| *Poa suksdorfii* (Beal) Vasey ex Piper<br>Suksdorf's bluegrass | BM, WC; CA, WA+<br>Desc, Hood, Lane, Unio, Wall | G4<br>SNR | -- | -- | 3 |

# FEDERAL ENDANGERED SPECIES ACT STATUS

**Plants Listed as Endangered**

*Arabis macdonaldiana*
*Astragalus applegatei*
*Erigeron decumbens*
*Fritillaria gentneri*
*Lilium occidentale*
*Limnanthes pumila* ssp. *grandiflora*
*Lomatium bradshawii*
*Lomatium cookii*
*Plagiobothrys hirtus*
*Stephanomeria malheurensis*

**Plants Listed as Threatened**

*Castilleja levisecta*
*Howellia aquatilis*
*Lupinus oreganus*
*Mirabilis macfarlanei*
*Sidalcea nelsoniana*
*Silene spaldingii*
*Thelypodium howellii* ssp. *spectabilis*

**Candidate Plants for Listing**

*Artemisia campestris* var. *wormskioldii*
*Calochortus persistens*
*Pinus albicaulis*

**Species of Concern**

*Abronia umbellata* ssp. *breviflora*
*Achnatherum hendersonii*
*Achnatherum wallowaensis*
*Agrostis hendersonii*
*Agrostis howellii*
*Allium dictuon*
*Allium robinsonii*
*Amsinckia carinata*
*Anemone oregana* var. *felix*
*Arabis hastatula*
*Arabis koehleri* var. *koehleri*
*Arabis modesta*
*Arabis suffrutescens* var. *horizontalis*
*Arctostaphylos hispidula*
*Artemisia ludoviciana* ssp. *estesii*
*Astragalus collinus* var. *laurentii*
*Astragalus mulfordiae*
*Astragalus tegetarioides*
*Bensoniella oregana*
*Botrychium ascendens*
*Botrychium campestre*
*Botrychium crenulatum*
*Botrychium montanum*
*Botrychium paradoxum*
*Botrychium pedunculosum*
*Calochortus coxii*
*Calochortus greenei*
*Calochortus howellii*
*Calochortus longebarbatus* var. *peckii*
*Calochortus macrocarpus* var. *maculosus*
*Calochortus nitidus*
*Calochortus umpquaensis*
*Camissonia pygmaea*
*Cardamine pattersonii*
*Carex idahoa*
*Castilleja chambersii*
*Castilleja fraterna*
*Castilleja mendocinensis*
*Castilleja rubida*
*Castilleja rupicola*
*Caulanthus major* var. *nevadensis*
*Collomia renacta*
*Cordylanthus maritimus* ssp. *palustris*
*Corydalis aquae-gelidae*
*Cupressus bakeri*
*Cymopterus acaulis* var. *greeleyorum*
*Cypripedium fasciculatum*
*Delphinium leucophaeum*
*Delphinium oreganum*
*Delphinium pavonaceum*
*Dicentra pauciflora*
*Dodecatheon austrofrigidum*
*Epilobium oreganum*
*Epilobium siskiyouense*
*Erigeron cervinus*
*Erigeron engelmannii* var. *davisii*
*Erigeron howellii*
*Erigeron oreganus*
*Eriogonum chrysops*
*Eriogonum crosbyae*
*Eriogonum cusickii*
*Eriogonum prociduum*
*Eriogonum umbellatum* var. *glaberrimum*
*Erysimum menziesii* ssp. *concinnum*
*Erythronium elegans*
*Eucephalus vialis*
*Filipendula occidentalis*
*Fritillaria purdyi*
*Galium serpenticum* ssp. *warnerense*
*Gentiana plurisetosa*
*Gentiana setigera*
*Gilia millefoliata*
*Gratiola heterosepala*
*Hackelia cronquistii*
*Hastingsia bracteosa* var. *atropurpurea*
*Hastingsia bracteosa* var. *bracteosa*
*Horkelia congesta* ssp. *congesta*
*Horkelia hendersonii*
*Hymenoxys lemmonii*
*Ivesia rhypara* var. *rhypara*
*Ivesia rhypara* var. *shellyi*
*Kalmiopsis fragrans*
*Lasthenia ornduffii*
*Lathyrus holochlorus*
*Lepidium davisii*
*Leptodactylon pungens* ssp. *hazeliae*
*Lilium kelloggii*
*Limbella fryei* (moss)
*Limnanthes floccosa* ssp. *bellingeriana*
*Limnanthes floccosa* ssp. *pumila*
*Lomatium erythrocarpum*
*Lomatium greenmanii*
*Lomatium ochocense*
*Lomatium suksdorfii*
*Luina serpentina*
*Lupinus lepidus* var. *ashlandensis*
*Lupinus lepidus* var. *cusickii*
*Meconella oregana*
*Mentzelia mollis*
*Mentzelia packardiae*
*Microseris laciniata* ssp. *detlingii*
*Mimulus evanescens*
*Mimulus hymenophyllus*
*Monardella purpurea*
*Myosurus sessilis*
*Oenothera wolfii*
*Packera hesperia*
*Penstemon barrettiae*
*Penstemon glaucinus*
*Penstemon peckii*
*Perideridia erythrorhiza*
*Phacelia argentea*
*Phacelia inundata*
*Phacelia leonis*
*Phacelia lutea* var. *mackenzieorum*
*Phacelia minutissima*
*Plagiobothrys figuratus* ssp. *corallicarpus*
*Plagiobothrys salsus*
*Pleuropogon oregonus*
*Poa unilateralis*
*Pogogyne floribunda*
*Polyctenium williamsiae*
*Pyrrocoma radiata*
*Ranunculus triternatus*
*Rubus bartonianus*
*Saxifraga hitchcockiana*
*Senecio ertterae*
*Sericocarpus rigidus*
*Sidalcea hendersonii*
*Sidalcea hirtipes*
*Sidalcea malachroides*
*Sidalcea malviflora* ssp. *patula*
*Silene douglasii* var. *oraria*
*Sisyrinchium hitchcockii*
*Sisyrinchium sarmentosum*
*Sophora leachiana*
*Stanleya confertiflora*
*Sullivantia oregana*
*Tauschia howellii*
*Texosporium sancti-jacobi* (lichen)
*Thelypodium brachycarpum*
*Thelypodium eucosmum*
*Thelypodium howellii* ssp. *howellii*
*Trifolium douglasii*
*Trifolium leibergii*
*Trifolium owyheense*
*Triteleia hendersonii* var. *leachiae*
*Viola primulifolia* ssp. *occidentalis*
*Zigadenus fontanus*

**Plants Listed as Endangered**

*Abronia umbellata* ssp. *breviflora*
*Arabis macdonaldiana*
*Artemisia campestris* var. *wormskioldii*
*Astragalus applegatei*
*Astragalus mulfordiae*
*Calochortus coxii*
*Calochortus indecorus*
*Calochortus umpquaensis*
*Castilleja levisecta*
*Chloropyron maritimum* ssp. *palustre*
*Delphinium leucophaeum*
*Delphinium pavonaceum*
*Erigeron decumbens*
*Fritillaria gentneri*
*Ivesia rhypara* var. *rhypara*
*Lilium occidentale*
*Limnanthes pumila* ssp. *grandiflora*
*Lomatium bradshawii*
*Lomatium cookii*
*Lomatium erythrocarpum*
*Lupinus lepidus var. cusickii*
*Mentzelia mollis*
*Mirabilis macfarlanei*
*Plagiobothrys hirtus*
*Plagiobothrys lamprocarpus*
*Pyrrocoma radiata*
*Silene spaldingii*
*Stephanomeria malheurensis*
*Thelypodium howellii* ssp. *spectabilis*
*Trifolium owyheense*

**Plants Listed as Threatened**

*Amsinckia carinata*
*Astragalus collinus* var. *laurentii*
*Astragalus cusickii* var. *sterilis*
*Astragalus diaphanus* var. *diurnus*
*Astragalus peckii*
*Astragalus tyghensis*
*Botrychium pumicola*
*Calochortus howellii*
*Eriogonum chrysops*
*Eriogonum crosbyae* var. *crosbyae*
*Eriogonum crosbyae* var. *mystrium*
*Erythronium elegans*
*Eucephalus vialis*
*Gratiola heterosepala*
*Hackelia cronquistii*
*Hastingsia bracteosa* var. *bracteosa*
*Hastingsia bracteosa* var. *atropurpurea*
*Howellia aquatilis*
*Lepidium davisii*
*Limnanthes pumila* ssp. *pumila*
*Lomatium greenmanii*
*Lupinus oreganus*
*Mentzelia packardiae*
*Microseris howellii*
*Oenothera wolfii*
*Phacelia argentea*
*Pleuropogon oregonus*
*Sericocarpus rigidus*
*Sidalcea nelsoniana*
*Silene douglasii* var. *oraria*
*Thelypodium eucosmum*

**State Candidate Taxa**

*Achnatherum hendersonii*
*Agrostis howellii*
*Arabis koehleri* var. *koehleri*
*Asarum wagneri*
*Astragalus tegetarioides*
*Bensoniella oregana*
*Boechera horizontalis*
*Bolandra oregana*
*Botrychium ascendens*
*Botrychium crenulatum*
*Botrychium paradoxum*
*Botrychium pedunculosum*
*Calochortus greenei*
*Calochortus longebarbatus* var. *peckii*
*Calochortus persistens*
*Camassia howellii*
*Cardamine nuttallii* var. *gemmata*
*Cardamine pattersonii*
*Caulanthus major* var. *nevadensis*
*Cimicifuga elata* var. *alpestris*
*Cimicifuga elata* var. *elata*
*Collomia renacta*
*Corydalis aquae-gelidae*
*Cypripedium fasciculatum*
*Delphinium oreganum*
*Draba howellii*
*Epilobium oreganum*
*Epilobium siskiyouense*
*Eremothera pygmaea*
*Erigeron howellii*
*Erigeron oreganus*
*Eriogonum cusickii*
*Eriogonum prociduum*
*Filipendula occidentalis*
*Frasera umpquaensis*
*Gentiana setigera*
*Hackelia diffusa* var. *diffusa*
*Horkelia congesta* ssp. *congesta*
*Lasthenia ornduffii*
*Limbella fryei* (moss)
*Limnanthes alba* var. *gracilis*
*Limnanthes floccosa* ssp. *bellingeriana*
*Lomatium suksdorfii*
*Luina serpentina*
*Lupinus lepidus* var. *ashlandensis*
*Meconella oregano*
*Micranthes hitchcockiana*
*Mimulus evanescens*
*Mimulus hymenophyllus*
*Mimulus jungermannioides*
*Mimulus patulus*
*Montia howellii*
*Myosurus sessilis*
*Packera hesperia*
*Penstemon barrettiae*
*Perideridia erythrorhiza*
*Phacelia minutissima*
*Plagiobothrys figuratus* ssp. *corallicarpus*
*Ranunculus austrooreganus*
*Rorippa columbiae*
*Rubus bartonianus*
*Sedum moranii*
*Sedum oblanceolatum*
*Senecio ertterae*
*Sidalcea campestris*
*Sidalcea hirtipes*
*Sidalcea malviflora* ssp. *patula*
*Sisyrinchium sarmentosum*
*Sophora leachiana*
*Streptanthus howellii*
*Sullivantia oregana*
*Tauschia howellii*
*Trifolium leibergii*
*Triteleia hendersonii* var. *leachiae*
*Viola primulifolia* ssp. *occidentalis*

## DROPS AND NAME CHANGES since October 2010 list

**Vascular Plants**

| | |
|---|---|
| *Achnatherum wallowaensis* | Name change, now called *Achnatherum wallowense* |
| *Arabis davidsonii* | Name change, now called *Boechera davidsonii* |
| *Arabis hastatula* | Name change, now called *Boechera hastatula* |
| *Arabis sparsiflora* var. *atrorubens* | Name change, now called *Boechera atrorubens* |
| *Arabis suffrutescens* var. *horizontalis* | Name change, now called *Boechera horizontalis* |
| *Asplenium trichomanes-ramosum* | Name change, now called *Asplenium viride* |
| *Callitriche hermaphroditica* | Dropped, taxonomic issues, synonym of *Callitriche fassettii* |
| *Camissonia boothii* ssp. *boothii* | Name change, now called *Eremothera boothii* ssp. *boothii* |
| *Camissonia graciliflora* | Name change, now called *Tetrapteron graciliflorum* |
| *Camissonia ovata* | Name change, now called *Taraxia ovata* |
| *Camissonia palmeri* | Name change, now called *Tetrapteron palmeri* |
| *Camissonia pygmaea* | Name change, now called *Eremothera pygmaea* |
| *Cardamine nuttallii* var. covilleana | Dropped, taxonomic issues, synonym of *C. nuttallii* var. *nuttallii* |
| *Cardamine nuttallii* var. dissecta | Dropped, taxonomic issues, synonym of *C. nuttallii* var. *nuttallii* |
| *Cochlearia officinalis* | Dropped, not documented from the state; ours *C. groenlandica* |
| *Cordylanthus maritimus* ssp. *palustre* | Name change, now called *Chloropyron maritimum* ssp. *palustre* |
| *Cupressus bakeri* | Name change, *Hesperocyparis bakeri* |
| *Delphinium bicolor* | Dropped, not documented from the state |
| *Draba lemmonii* var. *cyclomorpha* | Name change, *Draba cyclomorpha* |
| *Epilobium latifolium* | Name change, *Chamerion latifolium* |
| *Ericameria discoidea* var. *discoidea* | Name change, now called *Ericameria discoidea* |
| *Erigeron engelmannii* var. *davisii* | Name change, now called *Erigeron davisii* |
| *Erysimum menziesii* ssp. *concinnum* | Name change, now called *Erysimum concinnum* |
| *Gentianopsis holopetala* | Dropped, not documented from the state |
| *Gilia salticola* | Dropped, not documented from the state |
| *Gilia sinistra* ssp. *sinistra* | Name change, now called *Navarretia sinistra* ssp. *sinistra* |
| *Hymenoxys lemmonii* | Dropped, not documented from the state; ours *H. cooperi* var. *canescens* |
| *Juncus hemiendytus* var. *hemiendytus* | Dropped, too common |
| *Lesquerella douglasii* | Name change, now called *Physaria douglasii* ssp. *douglasii* |
| *Lesquerella kingii* ssp. *diversifolia* | Name change, now called *Physaria kingii* ssp. *diversifolia* |
| *Limnanthes gracilis* ssp. *gracilis* | Name change, now called *Limnanthes alba* ssp. *gracilis* |
| *Limnanthes floccosa* ssp. *grandiflora* | Name change, now called *Limnanthes pumila* ssp. *grandiflora* |
| *Limnanthes floccosa* ssp. *pumila* | Name change, now called *Limnanthes pumila* ssp. *pumila* |
| *Lupinus sulphureus* ssp. *kincaidii* | Name change, now called *Lupinus oreganus* |
| *Luzula arcuata* ssp. *unalaschcensis* | Dropped, not documented from the state |
| *Melica californica* | Dropped, not documented from the state |
| *Pellaea mucronata* ssp. *mucronata* | Dropped, not documented from the state |
| *Poa interior* | Dropped, not documented from the state |
| *Poa unilateralis* | See *P. unilateralis* ssp. *pachypholis* and *P. unilateralis* ssp. *unilateralis* |
| *Populus angustifolia* | Dropped, not documented from the state |
| *Potamogeton filiformis* | Name change, now called *Stuckenia filiformis* ssp. *alpinus* and *Stuckenia filiformis* ssp. *occidentalis* |
| *Potamogeton pusillus* ssp. *tenuissimus* | Name change, now called *Potamogeton berchtoldii* |
| *Potamogeton striatus* | Name change, now called *Stuckenia striata* |
| *Potamogeton vaginatus* | Dropped, not documented from the state |
| *Ranunculus verecundus* | Dropped, taxonomic issues |
| *Salix orestera* | Dropped, not documented from the state |
| *Saxifraga hitchcockiana* | Name change, now called *Micranthes hitchcockiana* |
| *Senecio porteri* | Name change, now called *Packera porteri* |
| *Scirpus heterochaetus* | Name change, now called *Schoenoplectus heterochaetus* |
| *Silene serpentinicola* | Name change, now called *Silene hookeri* ssp. *serpentinicola* |
| *Thlaspi montanum* var. *siskiyouense* | Name change, now called *Noccaea fendleri* ssp. *siskiyouense* |

**Fungi**

| | |
|---|---|
| *Balsamia alba* | Dropped, too common |
| *Cortinarius "barlowensis"* | Being described, *Cortinarius barlowensis* |
| *Gomphus kauffmanii* | Dropped, too common |
| *Hygrophorus caeruleus* | Dropped, too common |
| *Leucogaster citrinus* | Dropped, too common |
| *Ramaria concolor* forma *tsugina* | Name change, now called *Ramaria tsugina* |
| *Ramaria rubella* var. *blanda* | Name change, now called *Ramaria rubella* forma *blanda* |
| *Ramaria spinulosa* var. *diminutiva* | Dropped, not documented from the state |

## DROPS AND NAME CHANGES (continued)

| | |
|---|---|
| **Lichens** | |
| *Bryoria spiralifera* | Dropped, too common |
| *Chaenotheca subroscida* | Dropped, too common |
| *Erioderma sorediatum* | Dropped, too common |
| *Heterodermia leucomela* | Dropped, too common |
| *Hypogymnia duplicata* | Dropped, too common |
| *Lecanora pringlei* | Dropped, too common |
| *Leptogium teretiusculum* | Dropped, too common |
| *Ochrolechia subplicans* var. *subplicans* | Name change, now called *Ochrolechia subplicans* ssp. *subplicans* |
| *Sulcaria badia* | Dropped, too common |
| *Usnea "lambii"* | Officially described, *Usnea lambii* |
| *Usnea subgracilis* | Name change, now called *Usnea schadenbergiana* |
| **Liverworts** | |
| *Chiloscyphus gemmiparus* | Name change, now called *Rivulariella gemmipara* |
| *Diplophyllum plicatum* | Dropped, too common |
| *Herbertus aduncus* | Name change, now called *Herbertus aduncus* ssp. *aduncus* |
| *Tritomaria exsectiformis* | Dropped, too common |
| **Mosses** | |
| *Codriophorus depressus* | Name change, now called *Racomitrium depressum* |
| *Codriophorus ryszardii* | Name change, now called *Racomitrium ryszardii* |
| *Schistostega pennata* | Dropped, too common |

## ACKNOWLEDGMENTS

### ANIMALS

Revisions to the current edition included status changes made by ODFW, USFWS and NOAA Fisheries. Our thanks to these agencies for their continued efforts to protect and study Oregon's fauna. Dana Ross kindly allowed use of his photo for the cover of this book. Our appreciation goes, as always, to the many vertebrate and invertebrate biologists who contributed directly or indirectly and whose comments and criticisms were incorporated into this booklet. In 2013, the following biologists contributed to this effort: Jocelyn Akins, Chris Allen, Bob Altman, Keith Aubry, Barb Bresson, Charlie Bruce, Tom Burke, Bruce Bury, James Capurso, Brett Carre, John Fleckenstein, Sarah Foltz Jordan, Geoff Hammerson, Andrea Hanson, Tyler Hicks, Betsy Howell, Richard Hoyer, Rob Huff, Carol Hughes, Sarina Jepsen, James LaBonte, Christopher Marshall, Kim Nelson, Robert Nichols, Martin Nugent, Deanna Olson, Mark Penninger, Iral Ragenovich, Katherine Ramsey, Jason Reilly, Dana Ross, Randy Scarlett, Nicole Sears, Terry Smith, Robin Snider, Alan St. John, Richard Vacirca, Tom Valente, Steve Valley, Kelli Van Norman, and Tiffany Young.

### PLANTS AND FUNGI

Many of the changes made since the last edition of this booklet in 2010 resulted from the Rare and Endangered Plant Conference held at Oregon State University, Corvallis, Oregon in October 2012. We thank all conference participants and others who have contributed to this project. Many of the improvements in the information included in this booklet are a result of efforts by the professional botanists of the Oregon Department of Agriculture, the U.S. Forest Service and the Bureau of Land Management, and the amateur and professional botanists of the Native Plant Society of Oregon.

Michael Castellano (USFS) compiled the original list of fungi, to which additions have been recommended by agency and university mycologists, and the Oregon Mycological Society. Early contributors included Efren Cazares, Janet Lindgren, Randy Molina, Lorelei Norvell, Judy Roger, James Trappe, and Nancy Weber.

Special thanks go to Stephen Meyers at Oregon State University, who serves as the Taxonomic Director for the Oregon Flora Project and the arbiter for ORBIC and for this publication. We also would like to continue to recognize the years of help and support from Ken and Henny Chambers and from Peter Zika, in providing us with taxonomic guidance and assistance.

Primary sources of expertise for this edition include:

Carex: Carex Working Group – Richard Brainerd, Nick Otting, and Barbara Wilson. Previous Carex Working Group participants and contributors included Manuela Huso, Keli Kuykendall, Danna Lytjen, Bruce Newhouse, and Peter Zika.

Ferns: Ed Alverson, Frank Lang, David Wagner and Peter Zika.

Liverworts: John Christy, Amanda Hardman, Richard Helliwell, Scot Loring, Daphne Stone, Duncan Thomas, Chris Wagner, and David Wagner.

Marine Algae: David and Dianne Bilderback, Gayle Hansen

Mosses: John Christy, Clint Emerson, Ron Exeter, Doug Goldenberg, Amanda Hardman, Judith Harpel, Richard Helliwell, David Kofranek, Jenny Lippert, Scot Loring, Cheshire Mayrsohn, Bruce Newhouse, Wayne Rolle, Daphne Stone, Duncan Thomas, Chris Wagner, David Wagner and Rob Weiss.

Fungi: Johanna Fickenscher, Doug Goldenberg, Clint Emerson, Ron Exeter, Jenny Lippert, Scot Loring, Kelli Van Norman, Darci Rivers-Pankratz, and Darlene Southworth.

Lichens: Clint Emerson, Ron Exeter, Doug Glavich, Doug Goldenberg, Richard Helliwell, Jenny Lippert, Scot Loring, Bruce McCune, Bruce Newhouse, Keith Saylor, Steve Sheehy, Daphne Stone, Rob Taylor, and Rob Weiss.

**FEDERAL STATUS**

| | |
|---|---|
| LE | Listed as an Endangered Species |
| LT | Listed as a Threatened Species |
| PE | Proposed as an Endangered Species |
| PT | Proposed as a Threatened Species |
| C | Candidate for Listing as Threatened or Endangered |
| SOC | Species of Concern - Taxa for which additional information is needed to support a proposal to list under the ESA |

**STATE STATUS – ANIMALS**

| | |
|---|---|
| LE | Listed as an Endangered Species |
| LT | Listed as a Threatened Species |
| PE | Proposed as an Endangered Species |
| PT | Proposed as a Threatened Species |
| SC | Sensitive - Critical |
| SV | Sensitive - Vulnerable |

**STATE STATUS – PLANTS**

| | |
|---|---|
| LE | Listed as an Endangered Species |
| LT | Listed as a Threatened Species |
| PE | Proposed as an Endangered Species |
| PT | Proposed as a Threatened Species |
| C | Candidate for Listing as Threatened or Endangered |

**ECOREGIONS**

| | |
|---|---|
| BM | Blue Mountains (includes High Lava Plains) |
| BR | Northern Basin and Range (includes Owyhee Uplands) |
| CB | Columbia Basin |
| CR | Coast Range |
| EC | East Cascades |
| KM | Klamath Mountains |
| ME | Marine and Estuarine |
| WC | West Cascades and Crest |
| WV | Willamette Valley |

**STATES AND PROVINCES**

| | | | |
|---|---|---|---|
| AB | Alberta | NV | Nevada |
| AK | Alaska | NJ | New Jersey |
| AZ | Arizona | NM | New Mexico |
| AR | Arkansas | NY | New York |
| BC | British Columbia | NC | North Carolina |
| CA | California | NT | NW Territories |
| CO | Colorado | NS | Nova Scotia |
| HI | Hawaii | ON | Ontario |
| ID | Idaho | QC | Quebec |
| KS | Kansas | SK | Saskatchewan |
| LA | Louisiana | TN | Tennessee |
| MB | Manitoba | UT | Utah |
| MA | Massachusetts | WA | Washington |
| MS | Mississippi | WI | Wisconsin |
| MT | Montana | WY | Wyoming |

**NATURAL HERITAGE RANKS**

| | |
|---|---|
| G1 | Critically imperiled throughout its range |
| G2 | Imperiled throughout its range |
| G3 | Rare, threatened or uncommon throughout its range |
| G4 | Not rare, apparently secure throughout its range |
| G5 | Widespread, abundant and secure throughout its range |
| S1 | Critically imperiled in Oregon |
| S2 | Imperiled in Oregon |
| S3 | Rare, threatened or uncommon in Oregon |
| S4 | Not rare, apparently secure in Oregon |
| S5 | Widespread, abundant and secure in Oregon |
| T | Rank for a subspecies, variety, or race |
| Q | Taxonomic questions |
| H | Historic, formerly part of the native biota with the implied expectation that it may be rediscovered |
| X | Presumed extirpated or extinct |
| U | Unknown rank |
| NR | Not yet ranked |
| B | Rank of the breeding population (migratory birds) |
| N | Rank of the wintering population (migratory birds) |

**MISCELLANEOUS**

| | |
|---|---|
| ESA | Endangered Species Act |
| EPA | Environmental Protection Agency |
| FED | Federal |
| NOAA | National Oceanic and Atmospheric Administration |
| ODA | Oregon Department of Agriculture |
| ODFW | Oregon Department of Fish and Wildlife |
| OESA | Oregon Endangered Species Act |
| ORBIC | Oregon Biodiversity Information Center |
| sp. nov. | species novum (new species) - in the process of being described in the literature |
| ssp. | subspecies |
| ssp. nov. | subspecies novum (new subspecies) - in the process of being described in the literature |
| TNC | The Nature Conservancy |
| USFS | United States Forest Service |
| USFWS | United States Fish and Wildlife Service |
| var. | variety |
| + | taxon occurs in additional states |

**ORBIC LISTS**

| | |
|---|---|
| 1 | Threatened or Endangered Throughout Range |
| 2 | Threatened, Endangered or Extirpated from Oregon, but Secure or Abundant Elsewhere |
| 3 | Review |
| 4 | Watch |
| 1-ex | Extirpated in Oregon |
| 2-ex | Extirpated in Oregon |
| 1-X | Presumed extinct |

# APPENDIX Q-4

NMFS 2013 Threatened and Endangered Species List

# Endangered and Threatened Marine Species under NMFS' Jurisdiction

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*****)

## Endangered and Threatened Marine Mammals (29 listed "species")

Manatees and sea otters are also listed under the ESA, but fall under jurisdiction of U.S. Fish and Wildlife Service.

| Species | Year Listed | Status | Critical Habitat* | Recovery Plan* |
|---|---|---|---|---|
| **Cetaceans** | | | | |
| **dolphin, Chinese River / baiji** (*Lipotes vexillifer*) | 1989 | E (F) | n/a | n/a |
| **dolphin, Indus River** (*Platanista minor*) | 1991 | E (F) | n/a | n/a |
| **porpoise, Gulf of California harbor / vaquita** (*Phocoena sinus*) | 1985 | E (F) | n/a | n/a |
| **whale, beluga** (1 listed DPS) *(Delphinapterus leucas)* | | | | |
| o Cook Inlet | 2008 | E | **final** | in process |
| **whale, blue** (*Balaenoptera musculus*) | 1970 | E | n/a | **final** |
| **whale, bowhead** (*Balaena mysticetus*) | 1970 | E | n/a | n/a |
| **whale, false killer** (1 listed DPS) (*Pseudorca crassidens*) | | | | |
| o Main Hawaiian Islands Insular | 2012 | E | no | no |
| **whale, fin** (*Balaenoptera physalus*) | 1970 | E | n/a | **final** |
| **whale, gray** (1 listed DPS) (*Eschrichtius robustus*) | | | | |
| o Western North Pacific | 1970 | E (F) | n/a | n/a |
| **whale, humpback** (*Megaptera novaeangliae*) | 1970 | E | n/a | **final** |
| **whale, killer** (1 listed DPS) (*Orcinus orca*) | | | | |
| o Southern Resident » **under review for delisting** | 2005 | E | **final** | **final** |
| **whale, North Atlantic right** (*Eubalaena glacialis*)<br>*original listing as "northern right whale" -* | 2008<br>1970 | E<br>E | **final** | **final** |
| **whale, North Pacific** | 2008 | E | **final** | no |

| | | | | |
|---|---|---|---|---|
| (*Eubalaena japonica*)<br><br>*original listing as "northern right whale" -* | <br><br>1970 | <br><br>E | | |
| **whale, sei**<br>(*Balaenoptera borealis*) | 1970 | E | n/a | **final** |
| **whale, Southern right whale**<br>(*Eubalaena australis*) | 1970 | E (F) | n/a | n/a |
| **whale, sperm**<br>(*Physeter macrocephalus*) | 1970 | E | n/a | **final** |
| **Pinnipeds** | | | | |
| **sea lion, Steller** (2 listed DPSs)<br>(*Eumetopias jubatus*) | | | | |
| o Eastern<br>***NMFS has proposed to delist this DPS**. | 1990 | T | **final** | **final** |
| o Western<br>*original listing -* | 1997<br>1990 | E<br>T | **final** | **final** |
| **seal, bearded** (2 listed DPSs)<br>*(Erignathus barbatus)* | | | | |
| o Beringia | 2012 | T | no | no |
| o Okhotsk | 2012 | T (F) | no | no |
| **seal, Guadalupe fur**<br>(*Arctocephalus townsendi*) | 1985 | T (F) | n/a | n/a |
| **seal, Hawaiian monk**<br>(*Monachus schauinslandi)* | 1976 | E | **final** | **final** |
| **seal, ringed** (4 listed subspecies)<br>*(Phoca hispida)* | | | | |
| o Arctic<br>(*Phoca hispida hispida*) | 2012 | T | no | no |
| o Baltic<br>(*Phoca hispida botnica*) | 2012 | T (F) | no | no |
| o Okhotsk<br>(*Phoca hispida ochotensis*) | 2012 | T (F) | no | no |
| o Ladoga<br>(*Phoca hispida ladogensis*) | 2012 | E (F) | no | no |
| **seal, Mediterranean monk**<br>(*Monachus monachus)* | 1970 | E (F) | n/a | n/a |
| **seal, Saimaa**<br>(*Phoca hispida saimensis*) | 1993 | E (F) | n/a | n/a |
| **seal, spotted** (1 listed DPS)<br>*(Phoca largha)* | | | | |
| o Southern | 2010 | T (F) | n/a | n/a |

*** NOTE:** Critical habitat and recovery plans are not required for foreign species; critical habitat is also not required for species listed prior to the 1978 ESA amendments that added critical habitat provisions. Bowhead whales are also exempt from recovery planning.

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*****)

## Endangered and Threatened Sea Turtles (16 listed "species")

Recovery plans for marine turtles are developed and implemented by NMFS and USFWS; the plans have been written separately for turtles in the Atlantic and Pacific oceans (and East Pacific for the green turtle) rather than for each listed species.

| Species | Year Listed | Status | Critical Habitat* | Recovery Plan* |
|---|---|---|---|---|
| green turtle (2 listed populations**)<br>(*Chelonia mydas*) | | | | |
| o Florida & Mexico's Pacific coast breeding colonies | 1978 | E | final | final |
| o all other areas<br>» Hawaii population under review to delist | 1978 | T | final | final |
| hawksbill turtle<br>(*Eretmochelys imbricata*) | 1970 | E | final | final |
| Kemp's ridley turtle<br>(*Lepidochelys kempii*) | 1970 | E | n/a | final |
| leatherback turtle<br>(*Dermochelys coriacea*) | 1970 | E | final | final |
| loggerhead turtle (9 listed DPSs)<br>(*Caretta caretta*)<br>*original listing - 1978* | | | no | final |
| o Mediterranean Sea | 2011 | E (F) | n/a | n/a |
| o North Indian Ocean | 2011 | E (F) | n/a | n/a |
| o North Pacific Ocean | 2011 | E | no | final |
| o Northeast Atlantic Ocean | 2011 | E (F) | n/a | n/a |
| o Northwest Atlantic Ocean | 2011 | T | no | final |
| o South Atlantic Ocean | 2011 | T (F) | n/a | n/a |
| o South Pacific Ocean | 2011 | E (F) | n/a | n/a |
| o Southeast Indo-Pacific Ocean | 2011 | T (F) | n/a | n/a |
| o Southwest Indian Ocean | 2011 | T (F) | n/a | n/a |
| olive ridley turtle (2 listed populations**)<br>(*Lepidochelys olivacea*) | | | | |
| o Mexico's Pacific coast breeding colonies | 1978 | E | n/a | final |
| o all other areas | 1978 | T | n/a | final |

*** NOTE:** Critical habitat and recovery plans are not required for foreign species; critical habitat is also not required for species listed prior to the 1978 ESA amendments that added critical habitat provisions.
****** These populations were listed before the 1978 ESA amendments that restricted population listings to "distinct population segments" of vertebrate species.

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*****)

## Endangered and Threatened Marine and Anadromous Fish (44 listed "species")

| Species | Year Listed | Status | Critical Habitat* | Recovery Plan* |
|---|---|---|---|---|
| **bocaccio** (1 listed DPS)<br>(*Sebastes paucispinis*) | | | | |
| o Puget Sound/ Georgia Basin | 2010 | E | no | no |
| **eulachon, Pacific / smelt** (1 listed DPS)<br>(*Thaleichthys pacificus*) | | | | |
| o Southern DPS | 2010 | T | **final** | no |
| **rockfish, canary** (1 listed DPS)<br>(*Sebastes pinniger*) | | | | |
| o Puget Sound/ Georgia Basin | 2010 | T | no | no |
| **rockfish, yelloweye** (1 listed DPS)<br>(*Sebastes ruberrimus*) | | | | |
| o Puget Sound/ Georgia Basin | 2010 | T | no | no |
| **salmon, Atlantic** (1 listed DPS)<br>(*Salmo salar*) | | | | |
| o Gulf of Maine<br><br>*original listing -* | 2009*<br>*expanded<br>2000 | E | **final** | **final** |
| **salmon, Chinook** (9 listed ESUs)<br>(*Oncorhynchus tshawytscha*) | | | | |
| o California coastal | 1999** | T | **final** | **in process** |
| o Central Valley spring-run | 1999** | T | **final** | **draft** |
| o Lower Columbia River | 1999** | T | **final** | **in process** |
| o Upper Columbia River spring-run | 1999** | E | **final** | **final** |
| o Puget Sound | 1999** | T | **final** | **final** |
| o Sacramento River winter-run | 1994** | E | **final** | **draft** |
| o Snake River fall-run | 1992** | T | **final** | **in process** |
| o Snake River spring/ summer-run | 1992** | T | **final** | **in process** |
| o Upper Willamette River | 1999** | T | **final** | **in process** |
| **salmon, chum** (2 listed ESUs) | | | | |

| | | | | |
|---|---|---|---|---|
| (*Oncorhynchus keta*) | | | | |
| o Columbia River | 1999** | T | **final** | **in process** |
| o Hood Canal summer-run | 1999** | T | **final** | **final** |
| **salmon, coho** (4 listed ESUs)<br>(*Oncorhynchus kisutch*) | | | | |
| o Central California coast<br>*original listing* - | 2005**<br>1996** | E<br>T | **final** | **in process** |
| o Lower Columbia River | 2005** | T | not yet proposed | **in process** |
| o Oregon coast | 2008 | T | **final** | no |
| o Southern Oregon & Northern California coasts | 1997** | T | **final** | **in process** |
| **salmon, sockeye** (2 listed ESUs)<br>(*Oncorhynchus nerka*) | | | | |
| o Ozette Lake | 1999** | T | **final** | **final** |
| o Snake River | 1991** | E | **final** | **in process** |
| **sawfish, largetooth**<br>*(Pristis perotteti)* | 2011 | E | no | no |
| **sawfish, smalltooth** (1 listed DPS)<br>(*Pristis pectinata*) | | | | |
| o U.S. portion of range | 2003 | E | **final** | **final** |
| **sturgeon, Atlantic** (5 DPSs)<br>*(Acipenser oxyrinchus oxyrinchus)* | | | | |
| o Gulf of Maine | 2012 | T | no | no |
| o New York Bight | 2012 | E | no | no |
| o Chesapeake Bay | 2012 | E | no | no |
| o Carolina | 2012 | E | no | no |
| o South Atlantic | 2012 | E | no | no |
| **sturgeon, green** (1 listed DPS)<br>*(Acipenser medirostris)* | | | | |
| o Southern DPS | 2006 | T | **final** | in process |
| **sturgeon, Gulf**<br>(*Acipenser oxyrinchus desotoi*) | 1991 | T | **final** | **final** |
| **sturgeon, shortnose**<br>(*Acipenser brevirostrum*) | 1967 | E | n/a | **final** |
| **totoaba**<br>(*Totoaba macdonaldi*) | 1979 | E (F) | n/a | n/a |

| | | | | |
|---|---|---|---|---|
| **trout, steelhead** (11 listed DPSs)<br>*(Oncorhynchus mykiss)* | | | | |
| o Puget Sound | 2007 | T | in process | no |
| o Central California coast | 1997** | T | **final** | **in process** |
| o Snake River Basin | 1997** | T | **final** | **in process** |
| o Upper Columbia River<br><br>*original listing -*<br>*change in status -*<br>*court reinstated status -* | 2009***<br><br>1997**<br>2006**<br>2007*** | T<br><br>E<br>T<br>E | **final** | **final** |
| *** reinstated to endangered status per U.S. District Court decision in June 2007;**reclassified to threatened** [pdf] per U.S. District Court order in June 2009 | | | | |
| o Southern California | 1997** | E | **final** | **draft** |
| o Middle Columbia River | 1999** | T | **final** | **final** |
| o Lower Columbia River | 1998** | T | **final** | **in process** |
| o Upper Willamette River | 1999** | T | **final** | **in process** |
| o Northern California | 2000** | T | **final** | **in process** |
| o South-Central California coast | 1997** | T | **final** | **in process** |
| o California Central Valley | 1998** | T | **final** | **draft** |

*** NOTE:** Critical habitat and recovery plans are not required for foreign species; critical habitat is also not required for species listed prior to the 1978 ESA amendments that added critical habitat provisions.
****** All Pacific salmonid listings were revisited in 2005 and 2006. Only the salmonids whose status changed as a result of the review will show the revised date; for all others, only the original listing date is shown. For more information on the listing history, please click on the link for each ESU/DPS.

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Endangered and Threatened Marine Invertebrates (4 listed "species")

| Species | Year Listed | Status | Critical Habitat* | Recovery Plan* |
|---|---|---|---|---|
| **abalone, black**<br>*(Haliotis cracherodii)* | 2009 | E | **final** | no |
| **abalone, white**<br>(*Haliotis sorenseni*) | 2001 | E | **not prudent** | **final** |
| **coral, elkhorn**<br>*(Acropora palmata)* | 2006 | T* | **final** | in process |
| **coral, staghorn**<br>*(Acropora cervicornis)* | 2006 | T* | **final** | in process |

* These corals are **proposed to be reclassified from threatened to endangered**.

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Endangered and Threatened Marine Plants (1 listed "species")

| Species | Year Listed | Status | Critical Habitat* | Recovery Plan* |
|---|---|---|---|---|
| **Johnson's seagrass** (*Halophila johnsonii*) | 1999 | T | **final** | **final** |

*** NOTE:** Critical habitat and recovery plans are not required for foreign species; critical habitat is also not required for species listed prior to the 1978 ESA amendments that added critical habitat provisions.

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Candidates for Listing (18 candidate "species")

| Species | Year | *Federal Register* notice |
|---|---|---|
| **Fishes** | | |
| **alewife** *(Alosa pseudoharengus)* | 2011 | **76 FR 67652** |
| **cusk** *(Brosme brosme)* | 2007 | **72 FR 10710** |
| **grouper, Nassau** (*Epinephelus striatus*) | 2012 | **77 FR 61559** |
| **herring, blueback** *(Alosa aestivalis)* | 2011 | **76 FR 67652** |
| **herring, Pacific** (1 candidate DPS) *(Clupea pallasi)*<br>o Southeast Alaska | 2008 | **73 FR 19824** |
| **salmon, Chinook** (1 candidate ESU) *(Oncorhynchus tshawytscha)*<br>o Upper Klamath and Trinity Rivers Basin ESU | 2011 | **76 FR 20302** |
| **seahorse, dwarf** *(Hippocampus zosterae)* | 2012 | **77 FR 26478** |
| **shark, dusky** (1 Candidate DPS) (*Carcharhinus obscurus*)<br>o Northwest Atlantic and Gulf of Mexico | 2013 | **78 FR 29100** |
| **shark, great hammerhead** (*Sphyrna mokarran*) | 2013 | **78 FR 24701** |
| **sturgeon** (5 candidate species)<br>o *Acipenser naccarii*<br>o *Acipenser sturio*<br>o *Acipenser sinensis*<br>o *Acipenser mikadoi*<br>o *Huso dauricus* | 2012 | **77 FR 51767** |
| **wrasse, humphead** (*Cheilinus undulatus*) | 2013 | **78 FR 13614** |
| **Marine Mammals** | | |
| **seal, Pacific harbor** (1 candidate DPS) | 2013 | **78 FR 29098** |

| | | |
|---|---|---|
| (*Phoca vitulina richardii*)<br>o Iliamna Lake | | |
| **whale, sperm** (1 candidate DPS)<br>(*Physeter macrocephalus*)<br>o Gulf of Mexico | 2013 | **78 FR 19176** |
| **Marine Invertebrates** | | |
| **conch, queen**<br>*(Strombus gigas)* | 2012 | **77 FR 51763** |

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*****)

## Proposed for Listing (75 proposed "species")

| Species | Year Proposed | Status |
|---|---|---|
| **Fishes** | | |
| sawfish, dwarf<br>(*Pristis clavata*) | 2013 | **proposed endangered** |
| sawfish, green<br>(*Pristis zijsron*) | 2013 | **proposed endangered** |
| sawfish, largetooth<br>(*Pristis pristis**)<br>*includes species and populations formerly considered *P. microdon, P. perotetti*, and *P. pristis* | 2013 | **proposed endangered** |
| sawfish, narrow<br>(*Anoxypristis cuspidata*) | 2013 | **proposed endangered** |
| sawfish, smalltooth<br>(*Pristis pectinata*) | | |
| o population(s) not already listed as threatened or endangered | 2013 | **proposed endangered** |
| **shark, scalloped hammerhead** (4 proposed DPSs)<br>(*Sphyrna lewini*) | | |
| o Eastern Atlantic | 2013 | **proposed endangered** |
| o Eastern Pacific | 2013 | **proposed endangered** |
| o Central & Southwest Atlantic | 2013 | **proposed threatened** |
| o Indo-West Pacific | 2013 | **proposed threatened** |
| **Marine Invertebrates** | | |
| **12 coral species** (includes proposed reclassification from threatened to endangered for already listed elkhorn and staghorn corals) | 2012 | **proposed endangered** |
| **54 coral species** | 2012 | **proposed threatened** |

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Under Review for Delisting (1 "species")

| Species | Year | *Federal Register* notice |
|---|---|---|
| **Marine Turtles** | | |
| **turtle, green**<br>*(Chelonia mydas)*<br>o Hawaiian Population | 2012 | **77 FR 45571** |

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Proposed for Delisting (1 "species")

| Species | Year Delisting Proposed | Year Listed | Status |
|---|---|---|---|
| **Marine Mammals** | | | |
| **sea lion, Steller**<br>*(Eumetopias jubatus)*<br>o Eastern DPS | 2012 | 1990 | **proposed recovered** |

---

(E = **"endangered"**; T = **"threatened"**; F = **"foreign"**; n/a = not applicable*)

## Delisted (2 "species")

| Species | Year Delisted | Year Listed | Status |
|---|---|---|---|
| **Marine Mammals** | | | |
| **seal, Caribbean monk**<br>*(Monachus tropicalis)* | 2008 | 1967 | **extinct** |
| **whale, gray**<br>*(Eschrichtius robustus)*<br>o Eastern North Pacific DPS | 1994 | 1970 | **recovered** |

*Updated: August 21, 2013*

# APPENDIX Q-5

USFWS 2013 Threatened and Endangered Species List

**FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES**
**AND SPECIES OF CONCERN**
**UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE**
**WHICH MAY OCCUR WITHIN COOS COUNTY, OREGON**

# LISTED SPECIES

## Birds

| | | |
|---|---|---|
| Marbled murrelet | *Brachyramphus marmoratus* | CH T |
| Western snowy (coastal) plover | *Charadrius alexandrinus nivosus* | CH T |
| Short-tailed albatross | *Phoebastria albatrus* | E |
| Northern spotted owl | *Strix occidentalis caurina* | CH T |

## Reptiles and Amphibians

***Marine:***

| | | |
|---|---|---|
| Loggerhead sea turtle | *Caretta caretta* | E |
| Green sea turtle | *Chelonia mydas* | T |
| Leatherback sea turtle | *Dermochelys coriacea* | E |
| Olive (=Pacific) ridley sea turtle | *Lepidochelys olivacea* | T |

## Plants

| | | |
|---|---|---|
| Western lily | *Lilium occidentale* | E |

# PROPOSED SPECIES

## None

| | |
|---|---|
| No Proposed Endangered Species | PE |
| No Proposed Threatened Species | PT |

# SPECIES OF CONCERN

## Mammals

| | |
|---|---|
| White-footed vole | *Arborimus albipes* |
| Townsend's western big-eared bat | *Corynorhinus townsendii townsendii* |
| Silver-haired bat | *Lasionycteris noctivagans* |
| Long-eared myotis bat | *Myotis evotis* |
| Fringed myotis bat | *Myotis thysanodes* |
| Long-legged myotis bat | *Myotis volans* |
| Yuma myotis bat | *Myotis yumanensis* |

## Birds

| | |
|---|---|
| Northern goshawk | *Accipiter gentilis* |
| Upland sandpiper | *Bartramia longicauda* |
| Olive-sided flycatcher | *Contopus cooperi* |
| Black oystercatcher | *Haematopus bachmani* |
| Harlequin duck | *Histrionicus histrionicus* |
| Yellow-breasted chat | *Icteria virens* |
| Acorn woodpecker | *Melanerpes formicivorus* |
| Lewis' woodpecker | *Melanerpes lewis* |
| Mountain quail | *Oreortyx pictus* |
| Band-tailed pigeon | *Patagioenas fasciata* |
| Oregon vesper sparrow | *Pooecetes gramineus affinis* |

| | |
|---|---|
| Purple martin | *Progne subis* |

### Reptiles and Amphibians

| | |
|---|---|
| Northern Pacific pond turtle | *Actinemys marmorata marmorata* |
| Coastal tailed frog | *Ascaphus truei* |
| Del Norte salamander | *Plethodon elongatus* |
| Northern red-legged frog | *Rana aurora aurora* |
| Foothill yellow-legged frog | *Rana boylii* |
| Southern torrent (seep) salamander | *Rhyacotriton variegatus* |

### Fish

| | |
|---|---|
| River lamprey | *Lampetra ayresi* |
| Pacific lamprey | *Lampetra tridentata* |
| Coastal cutthroat trout | *Oncorhynchus clarki ssp* |
| Millicoma dace | *Rhinichthys cataractae ssp.* |

### Invertebrates

***Snails:***

| | |
|---|---|
| Newcomb's littorine snail | *Algamorda newcombiana* |

***Clams:***

| | |
|---|---|
| California floater mussel | *Anodonta californiensis* |

### Plants

| | |
|---|---|
| Pink sand-verbena | *Abronia umbellata ssp. breviflora* |
| Bensoniella | *Bensoniella oregona* |
| Pt. Reyes bird's-beak | *Cordylanthus maritimus ssp. palustris* |
| Frye's Limbella | *Limbella fryei* |
| Silvery phacelia | *Phacelia argentea* |
| Coast checkermallow | *Sidalcea malviflora ssp. patula* |
| Leach's brodiaea | *Triteleia hendersonii var. leachiae* |

## DELISTED SPECIES

### Birds

| | |
|---|---|
| Aleutian Canada goose | *Branta canadensis leucopareia* |
| American Peregrine falcon | *Falco peregrinus anatum* |
| Bald eagle | *Haliaeetus leucocephalus* |
| Brown pelican | *Pelecanus occidentalis* |

### Definitions:

Listed Species: An endangered species is one that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered in the foreseeable future.

Proposed Species: Taxa for which the Fish and Wildlife Service or National Marine Fisheries Service has published a proposal to list as endangered or threatened in the Federal Register.

Candidate Species: Taxa for which the Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.

# FEDERALLY LISTED, PROPOSED, CANDIDATE SPECIES AND SPECIES OF CONCERN UNDER THE JURISDICTION OF THE FISH AND WILDLIFE SERVICE WHICH MAY OCCUR WITHIN COOS COUNTY, OREGON

Species of Concern: Taxa whose conservation status is of concern to the U.S. Fish and Wildlife Service (many previously known as Category 2 candidates), but for which further information is still needed. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.

Delisted Species: A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

## Key:

| | |
|---|---|
| E | Endangered |
| T | Threatened |
| CH | Critical Habitat has been designated for this species |
| PE | Proposed Endangered |
| PT | Proposed Threatened |
| PCH | Critical Habitat has been proposed for this species |

## Notes:

**Marine & Anadromous Species:** Please consult the National Marine Fisheries Service (NMFS) (http://www.nmfs.noaa.gov/pr/species/) for marine and anadromous species. The National Marine Fisheries Service (NMFS) manages mostly marine and anadromous species, while the U.S. Fish and Wildlife Service manages the remainder of the listed species, mostly terrestrial and freshwater species.

**Marine Turtle Conservation and Management**: All six species of sea turtles occurring in the U.S. are protected under the Endangered Species Act of 1973. In 1977, NOAA Fisheries and the U.S. Fish and Wildlife Service signed a Memorandum of Understanding to jointly administer the Endangered Species Act with respect to marine turtles. NOAA Fisheries has the lead responsibility for the conservation and recovery of sea turtles in the marine environment and the U.S. Fish and Wildlife Service has the lead for the conservation and recovery of sea turtles on nesting beaches. For more information, see the NOAA Fisheries webpage on sea turtles http://www.nmfs.noaa.gov/pr/species/turtles/.

**Gray Wolf**: In 2008, the Service published a final rule that established a distinct population segment of the gray wolf (*Canis lupis*) in the northern Rocky Mountains (which includes a portion of Eastern Oregon, east of the centerline of Highway 395 and Highway 78 north of Burns Junction and that portion of Oregon east of the centerline of Highway 95 south of Burns Junction). Any wolves found west of this line in Oregon belong to the conterminous USA population [see 73 FR 10514]. On May 5, 2011, the Fish and Wildlife Service published a final rule – as directed by legislative language in the Fiscal Year 2011 appropriations bill – reinstating the Service's 2009 decision to delist biologically recovered gray wolf populations in the Northern Rocky Mountains. Gray wolves in Oregon are State-listed as endangered, regardless of location.

# APPENDIX Q-6

USFWS 2007 Western Snowy Plover Recovery Plan

# Recovery Plan for the

# Pacific Coast Population of the

# Western Snowy Plover

# (*Charadrius alexandrinus nivosus*)

## Volume 1: Recovery Plan

California/Nevada Operations Office
U.S. Fish and Wildlife Service
Sacramento, California

**Approved:** Steve Thompson

Manager, California/Nevada Operations Office,
U.S. Fish and Wildlife Service

**Date:** 8/13/2007

## PRIMARY AUTHORS

This final recovery plan was prepared by Kelly Hornaday, Ina Pisani, and Betty Warne of our Sacramento Fish and Wildlife Office. Ruth Pratt of the Sacramento Fish and Wildlife Office coordinated preparation of the draft recovery plan and acted as Recovery Team Manager.

We gratefully acknowledge the efforts of the Pacific Coast Western Snowy Plover Recovery Team in preparing this recovery plan. Special acknowledgment is also given to Nadav Nur, Point Reyes Bird Observatory, Stinson Beach, California, for his work on the population viability analysis.

## DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and others. Recovery teams serve as independent advisors to the U.S. Fish and Wildlife Service. Objectives of the recovery plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific actions, and may not represent the views or the official positions or approval of any individuals or agencies involved in the recovery plan formulation other than our own. They represent our official position **only** after they have been signed by the Director, Regional Director, or Operations Manager as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

**Literature Citation Should Read As Follows:**
U.S. Fish and Wildlife Service. 2007. Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In 2 volumes. Sacramento, California. xiv + 751 pages.

An electronic version of this recovery plan also will be made available at http://www.fws.gov/cno/es/recoveryplans.html and http://endangered.fws.gov/recovery/index.html#plans

## ACKNOWLEDGMENTS

The following U.S. Fish and Wildlife Service staff provided valuable review and comments on the recovery plan: John Grettenberger and Martha Jensen, Western Washington Office, Lacey, Washington; Carrie Phillips, Elizabeth Kelly, and Fred Seavey, Newport Fish and Wildlife Office, Newport, Oregon; Jim Watkins, Arcata Fish and Wildlife Office, Arcata, California; Kevin Clark and Gjon Hazard, Carlsbad Fish and Wildlife Office, Carlsbad, California; Steve Henry, Steve Kirkland, and David Pereksta, Ventura Fish and Wildlife Office; Diane Elam, California/Nevada Operations Office, Sacramento, California; and Grant Canterbury, Pacific Regional Office, Portland, Oregon. Robert Mesta, Bureau of Land Management Region 2 Office, Tucson, Arizona also provided valuable review and comments on the recovery plan.

Jennifer Bain, Valary Bloom, Don Hankins, Larry Host, Harry McQuillen, Caroline Prose, Caralee Stevens, Glen Tarr, Kim Turner, Betty Warne, and Dan Welsh of the Sacramento Fish and Wildlife Office, Sacramento, California also assisted in preparation of the final recovery plan.

Maps of snowy plover sites in Appendix L were prepared by Brian Cordone, Cheryl Hickam, and Joni Mitchell, Sacramento Fish and Wildlife Office, Sacramento, California.

The cover illustrations for the front cover and Appendix K are used courtesy of Carleton R. Eyster, Santa Cruz, California.

## PACIFIC COAST WESTERN SNOWY PLOVER RECOVERY TEAM

Sarah Allen
National Park Service
Point Reyes, California

Tim Burr
U.S. Department of the Navy
San Diego, California

Jeff Chastain
C & M Stables
Florence, Oregon

Janet Didion
California Dept. of Parks and Recreation
Sacramento, California

David Dixon
California Dept. of Parks and Recreation
Monterey, California

Ivette Loredo
San Francisco Bay National Wildlife Refuge
Newark, California

Richard Griffiths
U.S. Marine Corps
Camp Pendleton, California

Jim Heaney
U.S. Bureau of Land Management
North Bend, Oregon

William Hornbrook
Fish Phone
Eureka, California

Tim Jensen
Monterey Peninsula Regional Park District
Carmel Valley, California

Ron Jurek
California Department of Fish and Game
Sacramento, California

Don Klusman
California Assoc. of 4 Wheel Drive Clubs, Inc.
Yuba City, California

Sean Morton
County of Santa Barbara
Santa Barbara, California

Martin Nugent
Oregon Department of Fish and Wildlife
Portland, Oregon

Gary Page
Point Reyes Bird Observatory
Stinson Beach, California

Kerrie Palermo
U.S. Bureau of Land Management
North Bend, Oregon

Daniel Pearson
Southern California Edison
Rosemead, California

John Phillips (deceased)
Oregon Parks and Recreation Dept.
Coos Bay, Oregon

Abby Powell
U.S.G.S., Biological Resources Division
Fairbanks, Alaska

Jim Raives
California Coastal Commission
San Francisco, California

Nancy R. Francine
U.S. Department of the Air Force
Vandenberg Air Force Base, California

Chris Regan
Washington State Parks and Recreation
Olympia, Washington

Scott Richardson (Max Bahn, alternate)
Washington Department of Fish and Wildlife
Olympia, Washington

Mark Stern
Oregon Natural Heritage Program
Portland, Oregon

# EXECUTIVE SUMMARY

**CURRENT SPECIES STATUS:** The Pacific coast population of the western snowy plover (*Charadrius alexandrinus nivosus*) (western snowy plover) is federally listed as threatened. The current Pacific coast breeding population extends from Damon Point, Washington, south to Bahia Magdalena, Baja California, Mexico (including both Pacific and Gulf of California coasts). The western snowy plover winters mainly in coastal areas from southern Washington to Central America.

**HABITAT REQUIREMENTS AND LIMITING FACTORS:** The Pacific coast population of the western snowy plover breeds primarily above the high tide line on coastal beaches, sand spits, dune-backed beaches, sparsely-vegetated dunes, beaches at creek and river mouths, and salt pans at lagoons and estuaries. Less common nesting habitats include bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars. In winter, western snowy plovers are found on many of the beaches used for nesting as well as on beaches where they do not nest, in man-made salt ponds, and on estuarine sand and mud flats.

Habitat degradation caused by human disturbance, urban development, introduced beachgrass (*Ammophila* spp.), and expanding predator populations have resulted in a decline in active nesting areas and in the size of the breeding and wintering populations.

**RECOVERY OBJECTIVE**: The primary objective of this recovery plan is to remove the Pacific coast population of the western snowy plover from the *List of Endangered and Threatened Wildlife and Plants* by: (1) increasing population numbers distributed across the range of the Pacific coast population of the western snowy plover; (2) conducting intensive ongoing management for the species and its habitat and developing mechanisms to ensure management in perpetuity; and (3) monitoring western snowy plover populations and threats to determine success of recovery actions and refine management actions.

**RECOVERY PRIORITY**: 3C, per criteria published by Federal Register Notice (U.S. Fish and Wildlife Service 1983).

**RECOVERY CRITERIA**: The Pacific coast population of the western snowy plover will be considered for delisting when the following criteria have been met:

1. An average of 3,000 breeding adults has been maintained for 10 years, distributed among 6 recovery units as follows: Washington and Oregon, 250 breeding adults; Del Norte to Mendocino Counties, California, 150 breeding adults; San Francisco Bay, California, 500 breeding adults; Sonoma to Monterey Counties, California, 400 breeding adults; San Luis Obispo to Ventura Counties, California, 1,200 breeding adults; and Los Angeles to San Diego Counties, California, 500 breeding adults. This criterion also includes implementing monitoring of site-specific threats, incorporation of management activities into management plans to ameliorate or eliminate those threats, completion of research necessary to modify management and monitoring actions, and development of a post-delisting monitoring plan.

2. A yearly average productivity of at least one (1.0) fledged chick per male has been maintained in each recovery unit in the last 5 years prior to delisting.

3. Mechanisms have been developed and implemented to assure long-term protection and management of breeding, wintering, and migration areas to maintain the subpopulation sizes and average productivity specified in Criteria 1 and 2. These mechanisms include establishment of recovery unit working groups, development and implementation of participation plans, development and implementation of management plans for Federal and State lands, protection and management of private lands, and public outreach and education.

**ACTIONS NEEDED:**

1. Monitor breeding and wintering populations and habitats of the Pacific coast population of the western snowy plover to determine progress of recovery actions to maximize survival and productivity.

2. Manage breeding and wintering habitat of the Pacific coast population of the western snowy plover to ameliorate or eliminate threats and maximize survival and productivity.

3. Develop mechanisms for long-term management and protection of western snowy plovers and their breeding and wintering habitat.

4. Conduct scientific investigations that facilitate the recovery of the western snowy plover.

5. Conduct public information and education programs about the western snowy plover.

6. Review progress towards recovery of the western snowy plover and revise recovery efforts, as appropriate.

7. Dedicate U.S. Fish and Wildlife Service staff to allow the Arcata Fish and Wildlife Office to coordinate western snowy plover recovery implementation.

8. Establish an international conservation program with the government of Mexico to protect western snowy plovers and their breeding and wintering locations in Mexico.

Appendices B and C address Actions 1 and 2, providing site-specific recommendations for breeding numbers and management actions. Appendix J addresses Action 1, providing guidelines for monitoring western snowy plovers during the breeding and wintering seasons. Appendix K addresses Action 5, providing a public information and education plan.

**ESTIMATED COST OF RECOVERY:** $149,946,000 plus additional costs that cannot be estimated at this time.

**DATE OF RECOVERY:** Delisting could occur by 2047 if the recovery criteria above have been met.

## TABLE OF CONTENTS

## LIST OF APPENDICES
**(See Volume 2)**

## LIST OF TABLES

## LIST OF FIGURES

# I. INTRODUCTION

On March 5, 1993, the Pacific coast population of the western snowy plover (*Charadrius alexandrinus nivosus*) (western snowy plover) was listed as threatened under provisions of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*). The Pacific coast population is defined as those individuals that nest within 50 miles of the Pacific Ocean on the mainland coast, peninsulas, offshore islands, bays, estuaries, or rivers of the United States and Baja California, Mexico (U.S. Fish and Wildlife Service 1993*a*) (Figure 1). General locations of the western snowy plover's breeding and wintering locations in the United States are shown in Appendix A. Surveys, status reviews, and literature searches have identified 159 current or historical western snowy plover breeding or wintering locations on the U.S. Pacific coast. These localities include 6 in Washington, 19 in Oregon, and 134 in California (Appendix B). In Baja California, breeding western snowy plovers concentrate at coastal wetland complexes as far south as Bahia Magdalena, Mexico (Palacios *et al.* 1994). The locations listed in Appendix B are important for the recovery of the United States Pacific coast population of the western snowy plover because they represent important breeding, feeding, and sheltering habitat for the species.

In Washington, the western snowy plover was listed as endangered under Washington Department of Fish and Wildlife Policy #402 in 1981. In 1990 the Washington Fish and Wildlife Commission (Washington Administrative Code 232-12-014) reaffirmed the endangered status. In 1975, the Oregon Fish and Wildlife Commission listed the western snowy plover as threatened. Its threatened status was reaffirmed in 1989 under the Oregon Endangered Species Act and again in 1993 and 1998 by the Oregon Fish and Wildlife Commission as part of its periodic review process. Since 1978, the California Department of Fish and Game has classified both the inland and coastal population of western snowy plover as a "species of special concern." (Remsen 1978, California Natural Diversity Database 2001).

In August 2002, we received a petition from the Surf Ocean Beach Commission of Lompoc, California to delist the Pacific Coast population of the western snowy

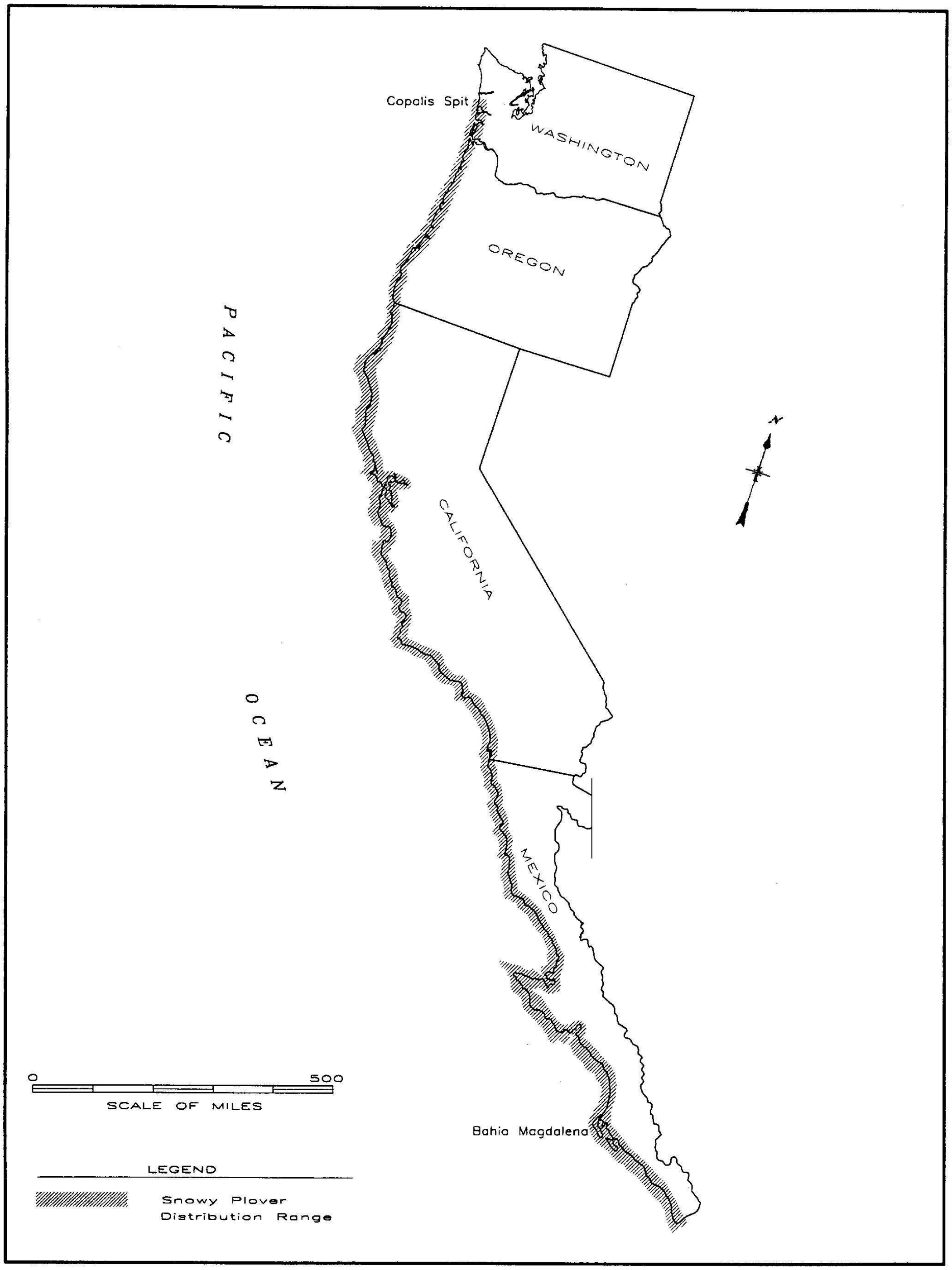



**Figure 1.** Map of known breeding and wintering distribution of the Pacific coast population of the western snowy plover.

plover. The City of Morro Bay, California submitted substantially the same petition dated May 30, 2003. On March 22, 2004, we published a notice that the petition presented substantial information to indicate that the delisting may be warranted (U.S. Fish and Wildlife Service 2004*a*). This notice also announced our initiation of a 5-year status review for the Pacific coast population of western snowy plover.

Under sections 4(b)(3)(B) and 4(c)(2) of the Endangered Species Act, we conducted a 5-year status review and evaluated whether the petitioned action was warranted. On April 21, 2006, we published a 12-month finding that concluded the petitioned action was not warranted (U.S. Fish and Wildlife Service 2006*a*). We also proposed a special rule pursuant to section 4(d) of the Endangered Species Act (U.S. Fish and Wildlife Service 2006*b*), which would exempt counties that have met western snowy plover recovery goals from most prohibitions on take as long as populations remain above recovery goals. The 5-year status review was completed on June 8, 2006.

Section 4 of the Endangered Species Act of 1973, as amended, requires us to develop a recovery plan for the conservation and survival of a species after it is federally listed as threatened or endangered, unless it is determined that such a plan will not promote the conservation of the species. Recovery is the process of reversing the decline of a listed species, eliminating threats, and ensuring the species' long-term survival. This recovery plan recommends actions necessary to satisfy the biological needs and assure recovery of the Pacific coast population of the western snowy plover. These actions include protection, enhancement, and restoration of all habitats deemed important for recovery; monitoring; research; and public outreach.

This recovery plan will serve as a guidance document for interested parties including Federal, State, and local agencies; private landowners; and the general public. It includes recommendations for western snowy plover management measures for all known breeding and wintering locations (Appendix C). These locations have been divided into six recovery units, as follows: (1) Oregon and Washington; (2) northern California (Del Norte, Humboldt, and Mendocino Counties); (3) San Francisco Bay (locations within Napa, Alameda, Santa Clara, and San Mateo Counties); (4) Monterey Bay (including coastal areas along Monterey, Santa Cruz, San Mateo, San Francisco, Marin, and Sonoma Counties); (5) San Luis Obispo, Santa Barbara, and Ventura Counties; and (6) Los Angeles, Orange, and San Diego Counties. Designation of these locations and recovery units assists in identifying priority areas for conservation planning across the western snowy plover's breeding and wintering range.

This recovery plan emphasizes management on Federal and State lands, including opportunities to improve or expand upon current efforts. Because of this emphasis on public lands, the cost associated with this emphasis, and potential restrictions of public use on these lands, public support and involvement will be crucial to the recovery of the western snowy plover. Opportunities for public participation in recovery efforts are emphasized in Appendix K (Information and Education Plan).

## A. DESCRIPTION AND TAXONOMY

The western snowy plover, a small shorebird in the family Charadriidae, weighs from 34 to 58 grams (1.2 to 2 ounces) and ranges in length from 15 to 17 centimeters (5.9 to 6.6 inches) (Page *et al.* 1995*a*). It is pale gray-brown above and white below, with a white hindneck collar and dark lateral breast patches, forehead bar, and eye patches (Figure 2). The bill and legs are blackish. In breeding plumage, males usually have black markings on the head and breast; in females, usually one or more of these markings are dark brown. Early in the breeding season a rufous crown may be evident on breeding males, but it is not typically seen on females. In non-breeding plumage, sexes cannot be distinguished because the breeding markings disappear. Fledged juveniles have buffy edges on their upper parts and can be distinguished from adults until approximately July through October, depending on when in the nesting season they hatched. After this period, molt and feather wear makes fledged juveniles indistinguishable from adults. Individual birds 1 year or older are considered to be breeding adults. The mean annual life span of western snowy plovers is estimated at about 3 years, but at least one individual was at least 15 years old when last seen (Page *et al.* 1995*a*).

**Figure 2.** Adult male western snowy plover (photo by Peter Knapp, with permission).

The species was first described in 1758 by Linnaeus (American Ornithologists' Union 1957). Two subspecies of the snowy plover have been recognized in North America (American Ornithologists' Union 1957): the western snowy plover (*Charadrius alexandrinus nivosus*) and the Cuban snowy plover (*C. a. tenuirostris*). The Pacific coast population of the western snowy plover breeds on the Pacific coast from southern Washington to southern Baja California, Mexico. Wintering birds may remain at their breeding sites or move north or south to other wintering sites along the Pacific coast. The interior population of the western snowy plover breeds in interior areas of Oregon, California, Nevada, Utah, New Mexico, Colorado, Kansas, Oklahoma, and north-central Texas, as well as coastal areas of extreme southern Texas, and possibly extreme northeastern Mexico (American Ornithologists' Union 1957). Although previously observed only as a migrant in Arizona, small numbers have bred there in recent years (Monson and Phillips 1981, Davis and Russell 1984). Interior population birds breeding east of the Rockies generally winter along the Gulf coast, while most interior population birds breeding west of the Rockies winter in coastal California and Baja

California, often intermingling with birds from the Pacific coast breeding population. The Cuban snowy plover breeds along the Gulf coast from Louisiana to western Florida and south through the Caribbean (American Ornithologists' Union 1957). More recent works recognize only subspecies *C. a. nivosus* for North America (Hayman *et al.* 1986, Binford 1989, Sibley and Monroe 1990).

A large amount of breeding data indicates that the Pacific coast population of the western snowy plover is distinct from western snowy plovers breeding in the interior (U.S. Fish and Wildlife Service 1993*a*, 2006*a*). A study conducted between 1977 and 1982 reported that western snowy plovers tend to exhibit breeding site fidelity (Warriner *et. al.* 1986). Banding and resighting data show that the Pacific Coast breeding populations and the western interior breeding populations experience limited or rare reproductive interchange (G. Page *in litt.* 2004*a*). Between 1984 and 1995, the period with the most extensive banding studies and search efforts, 907 plovers color-banded in coastal and interior populations were subsequently resighted (excluding birds banded on the coast during winter and birds resighted in their original region without evidence of nesting). Of these, 894 birds (98.6 percent) were observed during the breeding season using the same breeding range in which they were originally banded. Twelve birds (1.3 percent) were banded on the coast and later observed in the interior, only one of which was known to nest in the interior. Only one male (0.1 percent) was banded in the interior (without evidence of nesting) and later found nesting on the coast. Moreover, data from a period of less intensive surveys and banding from 1977 to 1983 corroborate this pattern (G. Page *in litt.* 2004*a*, U.S. Fish and Wildlife Service 2006*a*). During this period, of 400 birds banded in the interior, none were observed on the coast during breeding season, and of 599 birds banded on the coast only one was found nesting in the interior. Finally, 304 retrievals of numbered metal bands reported between 1969 and 2002 show no evidence of movement from interior to coast and only one bird (G. Goldsmith *in litt.* 2004, U.S. Fish and Wildlife Service 2006*a*) that moved from coast to interior (the dates being consistent with a bird from the interior population having been banded on the coast during the non-breeding season).

Thus, intensive banding and monitoring studies have documented only two clear instances of interbreeding between coastal and interior populations, and a few cases of inter-population movement without confirmed breeding, among thousands of birds observed. These results illustrate that the amount of interchange between coastal and interior populations is likely to be extremely low, though not zero. Movement of birds from coastal to interior populations has been documented more often than the reverse (see also U.S. Fish and Wildlife Service 2006a).

Genetic studies using mitochondrial DNA and microsatellite DNA markers (Gorman 2000, Funk *et al.* 2006) have found no significant genetic differentiation between the Pacific coast and interior populations of the western snowy plover. However, because a small number of dispersing individuals per generation is sufficient to prevent genetic differentiation between two semi-isolated populations (Mills and Allendorf 1996, Funk *et al.* 2006), this result is consistent with the banding data reported above. Because the small number of dispersing individuals indicated by banding data appear insufficient to substantially affect rates of population growth or decline in either population, the two populations evidently function demographically as largely independent of one another. Moreover, the infrequency of observed dispersal from coast to interior further indicates that any declines in the coastal population are not likely to be effectively offset by immigration of interior birds to the coast. Consequently there is no evidence that existing unoccupied habitat along the Pacific coast is currently being or in future would be naturally colonized by birds from the interior population (Funk et al. 2006).

## B. LIFE HISTORY AND ECOLOGY

### 1. Breeding

The Pacific coast population of the western snowy plover breeds primarily on coastal beaches from southern Washington to southern Baja California, Mexico (*e.g.*, Figure 3). Sand spits, dune-backed beaches, beaches at creek and river mouths, and salt pans at lagoons and estuaries are the main coastal habitats for nesting (Stenzel *et al.* 1981, Wilson 1980). This habitat is unstable because of

**Figure 3.** Coastal beach in Oregon Dunes National Recreational Area (photo by Ruth Pratt, with permission)

unconsolidated soils, high winds, storms, wave action, and colonization by plants. Less common nesting habitats include bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars (Wilson 1980, Page and Stenzel 1981, Powell *et al.* 1996, Tuttle *et al.* 1997).

***a. Population Size and Distribution***

Population estimates referenced below are based on window surveys as well as on more intensive studies involving repeated surveys of populations with individually identifiable color-banded birds. Window surveys are a one-time pass of a surveyor, or team of surveyors, through potential western snowy plover nesting habitat during May or June (see survey protocol in Appendix J). The surveyor counts all adult western snowy plovers in the habitat and identifies the adults as male or female, when possible. Because window surveys may not detect all birds, they are not directly comparable to more intensive studies. A correction factor can be estimated by comparing window survey data with concurrent population estimates from detailed studies of color-banded populations; currently the best rangewide estimate of the correction factor is 1.3 (U.S. Fish and Wildlife Service 2006*a*), but it is preferable to determine corrections on a more specific regional or site basis if possible due to differences in survey efficiency in different habitats (see action 4.3.1).

Western snowy plovers concentrate in suitable habitat, with the number of adults at coastal breeding locations ranging from 1 to 315, depending in part, on the size of the area (Appendix B). The largest number of breeding birds occurs from south San Francisco Bay to southern Baja California (Page and Stenzel 1981, Palacios *et al.* 1994).

The locations of the following parenthetical references to western snowy plover breeding and wintering locations in Washington, Oregon, and California are shown in Figures A-1 through A-7 of Appendix A, and mapped in greater detail in Appendix L. Information on the numbers of breeding and wintering western snowy plovers at these locations is described in Appendix B.

Four breeding areas currently exist in southern Washington: Damon Point (Washington location 2 [WA-2]) in Grays Harbor; Midway Beach (WA-4); and Leadbetter Point (WA-5) and Graveyard Spit (discovered in 2006) in Willapa Bay. Prior to the 1998 breeding season, fewer than 25 western snowy plovers and 12 nests were found in Washington during regular, standardized surveys. However, surveys from 1998 through 2006 (Sundstrom 2003, 2005; Brennan and Fernandez 2004*a*, 2006; Pearson *et al.* 2006; Washington Department of Fish and Wildlife unpub. data) indicate greater numbers of western snowy plovers are nesting at Leadbetter Point (WA-5) and Midway Beach (WA-4), with a maximum estimated population of 70 western snowy plovers statewide in 2006.

In Oregon, nesting birds have been recorded at 14 sites since 1990 (Castelein *et al.* 2002, Lauten *et al.* 2006*a*, 2006*b*). Nesting has occurred most frequently at 9 sites, including Sutton (OR-8), Siltcoos (OR-10), Dunes Overlook (OR-10), Tahkenitch (OR-10), Tenmile Spits (OR-12), Coos Bay North Spit (OR-13), Bandon (OR-15), New River (OR-15), and Floras Lake (OR-15). An estimated 177-179 adult western snowy plovers were observed at Oregon sites during the 2006 breeding season. A total of 135 individuals were known to have nested in

2006, with 147 nests located. Individual nests have also been found between 1990 and 2002 at several other Oregon sites, including Necanicum (OR-1); Bayocean Spit (OR-3); North Siuslaw (OR-8); Threemile-Umpqua River (OR-11); and Menasha Spoils, North Bend.

Western snowy plover populations in California have fluctuated between roughly one thousand and two thousand birds over the past 30 years, as detailed in section I.C.1.c below. Eight geographic areas support over three-quarters of the California coastal breeding population: San Francisco Bay (CA-27 to CA-47), Monterey Bay (CA-63 to CA-65), Morro Bay (CA-79 to CA-81), the Callendar-Mussel Rock Dunes area (CA-83), the Point Sal to Point Conception area (CA-84 to CA-88), the Oxnard lowland (CA-96 to CA-99), Santa Rosa Island (CA-93), and San Nicolas Island (CA-100) (Page *et al.* 1991, G. Page *in litt.* 2005*a*).

A survey of breeding western snowy plovers along the Pacific coast of Baja California, Mexico between 1991 to 1992 found 1,344 adults, mostly at four coastal wetland complexes: Bahia San Quintin, Lagunas Ojo de Liebre and Guerrero Negro, Laguna San Ignacio, and Bahia Magdalena (Palacios *et al.* 1994).

***b. Arrival and Courtship***

Nesting western snowy plovers at coastal locations consist of both year-round residents and migrants (Warriner *et al.* 1986). Migrants begin arriving at breeding areas in southern Washington in early March (Widrig 1980) and in central California as early as January, although the main arrival is from early March to late April (Page *et al.* 1995*a*). Since some individuals nest at multiple locations during the same year, birds may continue arriving through June (Stenzel *et al.* 1994).

Mated birds from the previous breeding season frequently reunite. Pair bonds are associated with territorial defense by males and nest scraping behavior, but early in the season birds begin to associate with one another in pairs within and apart from roosting flocks before nest scraping activity is observed, suggesting that pair bonds can be established prior to overt displays (Warriner *et al.* 1986). A scrape is a depression in the sand or substrate that a male constructs by leaning forward on his breast and scratching his feet while rotating his body axis (Page *et al.* 1995*a*). Copulations are associated with scraping behavior (Warriner *et al.* 1986). Females choose which scrape becomes the nest site by laying eggs in one of them. In California, pre-nesting bonds and courtship activities are observed as early as mid-February. Similar activities begin by March in Oregon. During courtship, males defend territories and usually make multiple scrapes.

***c. Duration of Breeding Season***

Along the west coast of the United States, the nesting season of the western snowy plover extends from early March through late September. Generally, the breeding season may be 2 to 4 weeks earlier in southern California than in Oregon and Washington. Fledging (reaching flying age) of late-season broods may extend into the third week of September throughout the breeding range.

The earliest nests on the California coast occur during the first week of March in some years and by the third week of March in most years (Page *et al.* 1995*a*). Peak initiation of nesting is from mid-April to mid-June (Warriner *et al.* 1986; Powell *et al.* 1997). Hatching lasts from early April through mid-August, with chicks reaching fledging age approximately 1 month after hatching (Powell *et al.* 1997). On the Oregon coast nesting may begin as early as mid-March, but most nests are initiated from mid-April through mid-July (Wilson-Jacobs and Meslow 1984); peak nest initiation occurs from mid-May to early July (Stern *et al.* 1990). In Oregon, hatching occurs from mid-April through mid-August, with chicks reaching fledging age as early as mid- to late May. Peak hatching occurs from May through July, and most fledging occurs from June through August. On the Washington coast, most adults arrive during late April, with maximum numbers present from mid-May to late June. Fledging occurs from late June through August (Washington Department of Fish and Wildlife 1995).

***d. Nests and Nest Sites***

Nests typically occur in flat, open areas with sandy or saline substrates; vegetation and driftwood are usually sparse or absent (Widrig 1980, Wilson 1980, Stenzel *et al.* 1981). Western snowy plovers also regularly nest on the gravel bars along the

Eel River in northern California. In southern California, western snowy plovers nest in areas with 6 to 18 percent vegetative cover and 1 to 14 percent inorganic cover; vegetation height is usually less than six centimeters (2.3 inches) (Powell *et al.* 1995, 1996). Nests consist of a shallow scrape or depression, sometimes lined with beach debris (*e.g.*, small pebbles, shell fragments, plant debris, and mud chips); nest lining increases as incubation progresses. Driftwood, kelp, and dune plants provide cover for chicks that crouch near objects to hide from predators. Invertebrates are often found near debris, so driftwood and kelp are also important for harboring western snowy plover food sources (Page *et al.* 1995*a*). Page and Stenzel (1981) found that nests were usually within 100 meters (328 feet) of water, but could be several hundred meters away when there was no vegetative barrier between the nest and water. They believed the absence of such a barrier is probably important for newly-hatched chicks to have access to the shore. Powell *et al.* (1995, 1996) also reported that nests from southern California were usually located within 100 meters (328 feet) of water, which could be either ocean, lagoon, or river mouth. Although the majority of western snowy plovers are site-faithful, returning to the same breeding area in subsequent breeding seasons, some also disperse within and between years (Warriner *et al.* 1986, Stenzel *et al.* 1994). Western snowy plovers occasionally nest in exactly the same location as the previous year (Warriner *et al.* 1986).

### *e. Egg Laying, Clutch Size, and Incubation*

Initiation (eggs and laying) occurs from mid-February/early March through the third week of July (Wilson 1980, Warriner *et al.* 1986). The approximate periods required for nesting events are: scrape construction (in conjunction with courtship and mating), 3 days to more than a month; egg laying, usually 4 to 5 days; and incubation, 26 to 31 days (mean 27 days) (Warriner *et al.* 1986). The usual clutch size (*e.g.*, number of eggs in one nest) is three (Figure 4) with a range from two to six. (Warriner *et al.* 1986, Page *et al.* 1995*a*). Both sexes incubate the eggs, with the female tending to incubate during the day and the male at night (Warriner *et al.* 1986). Adult western snowy plovers frequently will attempt to lure people and predators from hatching eggs with alarm calls and distraction displays. Occasionally, adults behave similarly during the egg-laying period or

**Figure 4.** Western snowy plover clutch (photo by Bruce Casler, with permission).

incubation of completed clutches. More typical, however, is for the incubating adult to run away from the eggs without being seen. Incomplete clutches are those in which all eggs have not been laid. Partly-incubated clutches are those clutches having some degree (in days) of incubation.

Western snowy plovers will re-nest after loss of their eggs (Wilson 1980, Warriner *et al.* 1986). Re-nesting occurs 2 to 14 days after failure of a clutch, and up to five re-nesting attempts have been observed for a pair (Warriner *et al.* 1986).

Double brooding with polyandry (meaning the female successfully hatches more than one brood [*i.e.* sibling chicks of a hatched nest] in a nesting season with different mates) is common in coastal California (Warriner *et al.* 1986) and Oregon (Wilson-Jacobs and Meslow 1984). On the California coast, the breeding season is long enough for some females to triple brood and for some males to double brood (Page *et al.* 1995*a*). Triple brooding in a male has, on rare occasion, been recorded; a male triple brooded at Moss Landing salt ponds in 2001 (D. George *in litt.* 2001). After losing a clutch or brood or successfully hatching a nest, western snowy plovers may re-nest at the same site or move up to several hundred kilometers to nest at other sites (Stenzel *et al.* 1994, Powell *et al.* 1997 ).

### *f. Clutch Hatching Success*

Widely varying clutch hatching success (percent of clutches hatching at least one egg) is reported in the literature. Clutch hatching success ranging from 0 to 90 percent has been recorded for coastal western snowy plovers (Widrig 1980, Wilson 1980, Saul 1982, Wilson-Jacobs and Dorsey 1985, Warriner *et al.* 1986, Wickham unpubl. data *in* Jacobs 1986). Low clutch hatching success has been attributed to a variety of factors, including predation, human disturbance, high tides, and inclement weather. Heavy recreational beach use coincides with the peak hatching period for western snowy plover eggs (Powell 2001), adding additional pressures to western snowy plover adults and chicks that are more exposed to human disturbance. Observed clutch hatching success ranged from 12.5 to 86.8 percent and averaged 50.6 percent in eight studies of coastal breeding western snowy plovers (Page *et al*. 1995*a*). In San Diego County, estimated nesting success ranged from 43 to 68 percent between 1994 and 1998, averaging 54 percent (Powell *et al.* 2002); nesting western snowy plovers in San Diego County likely benefitted from predator management efforts for snowy plovers and California least terns (*Sternula antillarum browni*) (A. Powell, U.S. Geological Survey, pers. comm. 1998). In Monterey Bay, hatching rate was significantly increased from 43 percent (during 1984-1990) to 68 percent (during 1991-1999) by intensive control of mammalian predators and use of nest exclosures (Neuman *et al.* 2004).

### *g. Brood-rearing*

The first chick hatched remains in or near the nest until other eggs (or at least the second egg) hatch. The adult western snowy plover, while incubating the eggs, also broods the first chick. The non-incubating adult also may brood the first-born chick a short distance from the nest. If the third egg of a clutch is 24 to 48 hours behind the others in hatching, it may be deserted. Western snowy plover chicks are precocial, leaving the nest within hours after hatching to search for food. They are not able to fly (fledge) for approximately 1 month after hatching;

fledging requires 28 to 33 days (Warriner *et al.* 1986). Broods rarely remain in the nesting area until fledging (Warriner *et al.* 1986, Stern *et al.* 1990). Western snowy plover broods may travel along the beach as far as 6.4 kilometers (4 miles) from their natal area (Casler *et al.* 1993).

Adult western snowy plovers do not feed their chicks, but lead them to suitable feeding areas. Adults use distraction displays to lure predators and people away from chicks. With vocalizations, adult western snowy plovers signal the chicks to crouch as another way to protect them (Page *et al.* 1995*a*). They also may lead chicks, especially larger ones, away from predators. Warriner *et al.* (1986) reported that most chick mortality occurs within 6 days after hatching.

Females generally desert mates and broods by the sixth day after hatching and thereafter the chicks are typically accompanied by only the male. While males rear broods, females obtain new mates and initiate new nests (Page *et al.* 1995*a*). Females typically help rear the last brood of the season.

***h. Fledging success***

The fledging success of western snowy plovers (percentage of hatched young that reach flying age) varies greatly by location and year. Even western snowy plovers nesting on neighboring beach segments may exhibit quite different success in the same year. For example, the percentage of chicks fledged on different beach segments of Monterey Bay in 1997 varied from 11 to 59 percent (average 24 percent) (Page *et al.* 1997). During the prior 13 years, fledging success on Monterey Bay beaches averaged 39 percent (Page *et al.* 1997). From the former Moss Landing salt ponds (now known as the Moss Landing Wildlife Area) in Monterey Bay (CA-64), fledging success ranged from 13.2 percent to 57.1 percent from 1988 to 1997. In San Diego County, fledging success ranged from 32.6 to 51.4 percent (Powell *et al.* 1997). In Oregon, annual fledging success for 1992 to 2006, for all coastal sites combined, ranged from 26 to 55 percent (Lauten *et al.* 2006*a*, 2006*b*). As in California, there is considerable variation among sites within years. For example, in 2005, the fledging success ranged from 24 percent at New River (OR-15) to 70 percent at Coos Bay South Beach (OR-13). There also is variation at individual sites among years. At the Coos Bay North Spit

(OR-13), one of the larger nesting areas in coastal Oregon, annual fledging success for 1992 to 2006 ranged from 38 to 74 percent.

### *i. Productivity*

The productivity information most useful for this recovery plan is reproductive success (the annual number of young fledged per adult male). For the population viability analysis (Appendix D), males were used in the model because their population parameters can be estimated with greater certainty than for females. In addition, it is reasonable to consider that the availability of males is limiting reproductive success because they are responsible for post-hatching parental care, and females can lay clutches for more than one male (Warriner *et al.* 1986).

Chicks are considered fledged at 28 to 33 days after hatching. Estimates of the number of young fledged per adult male are available for Oregon; northern California from Mendocino to Del Norte Counties; Monterey Bay, California; and San Diego County, California. Along the Oregon coast, the average number of young annually fledged per male during the period between 1992 and the initiation of predator management (2002 to 2004 depending on site) was estimated as 0.87 (Lauten *et al.* 2006*b*); this fledging success significantly increased to 1.44 since implementation of predator management. Male fledging success in Oregon has annually ranged between 0.70 and 1.64 (Lauten *et al.* 2006*a*). In northern California, fledging success ranged from 0.8 to 1.7 fledglings per male between 2001-2005, with birds nesting on river gravel bars consistently achieving greater success than those nesting on beaches (Colwell *et al.* 2005). At Monterey Bay, California, from 1984 to 1990, when little effort was made to protect chicks from predators and people, males averaged 0.86 fledglings annually. When intensive efforts were undertaken to control mammalian predators from 1993 to 1999, the number of young fledged per adult male initially increased above 1.1, then declined sharply as avian predation on chicks became increasingly significant (Neuman *et al.* 2004). After live trapping and removal of avian predators was initiated, fledging success again increased in target areas (G. Page *in litt.* 2004b). Over 16 years of study at Monterey Bay, the annual number of young fledged ranged from 0.32 to 1.23 per male (Neuman *et al.* 2004). In San Diego County from 1994 to 1998, an average of 0.15 to 0.44 young were fledged per male

(Powell et al. 2002). Fledging success in Washington cannot be accurately estimated due to lack of banded chicks and adults and variable monitoring effort prior to 2006 (S. Pearson *in litt.* 2006); however it was roughly estimated at between 0.76 and 1.45 young fledged per male in 2006, excluding Leadbetter Point which was insufficiently surveyed but may have had poorer fledging success (Pearson *et al.* 2006).

### *j. Survival*

Annual survival rates for adult and juvenile western snowy plovers have been calculated from studies of color banded birds from the coast of Oregon (M. Stern unpubl. data), the shoreline of Monterey Bay, California (Point Reyes Bird Observatory unpublished data), and the coast of San Diego County, California (A. Powell and J. Terp unpublished data) using the program SURGE (Lebreton *et al.* 1992, Cooch *et al.* 1996). Annual juvenile survival rates for fledged young average 48.5 percent (1992-2002) from the Oregon coast, 45 percent from Monterey Bay, and 45 percent from the San Diego coast. Annual survival rates for adult females and males, respectively, averaged 75 and 75 percent from the Oregon coast, 69 and 75 percent from Monterey Bay, and 72 and 71 percent from the San Diego coast. Differences between males and females were statistically significant only for the Monterey Bay area. Appendix D explains how these survival rates were incorporated into the population viability analysis.

## 2. Feeding Habitat and Habits

Western snowy plovers are primarily visual foragers, using the run-stop-peck method of feeding typical of *Charadrius* species. They forage on invertebrates in the wet sand and amongst surf-cast kelp within the intertidal zone, in dry sand areas above the high tide, on salt pans, on spoil sites, and along the edges of salt marshes, salt ponds, and lagoons. They sometimes probe for prey in the sand and pick insects from low-growing plants. At the Bolsa Chica wetlands in California, western snowy plovers have been observed pecking small, flying insects from mid-air and shaking one foot in very shallow water to agitate potential prey (Fancher *et al.* 1998). Western snowy plover food consists of immature and adult forms of aquatic and terrestrial invertebrates. Little quantitative information is available on food habits. In San Diego, California, invertebrates found in western snowy plover feces during the breeding season included rove beetles (Staphylinidae), long-legged flies (Dolichopodidae), shore flies (Ephydridae), water bugs (Saldidae), hymenopterans (Braconidae), and unidentified insect larvae (Tucker and Powell 1999). During the breeding season, Jacobs (1986) observed adult western snowy plovers feeding on sand hoppers (Orchestoidea) and small fish on the Oregon coast. Other food items reported for coastal western snowy plovers include Pacific mole crabs (*Emerita analoga*), striped shore crabs (*Pachygrapsus crassipes*), polychaetes (Neridae, *Lumbrineris zonata, Polydora socialis, Scoloplos acmaceps),* amphipods (*Corophium* ssp., *Ampithoe* spp., *Allorchestes angustus*), tanadacians (*Leptochelia dubia*), shore flies (Ephydridae), beetles (Carabidae, Buprestidae, Tenebrionidae), clams (*Transenella* sp.), and ostracods (Page *et al.* 1995*a*). In salt evaporation ponds in San Francisco Bay, California, the following prey have been recorded: brine flies (*Ephydra cinerea*), beetles (*Tanarthrus occidentalis, Bembidion* sp.), moths (*Perizoma custodiata*), and lepidopteran caterpillars (Feeney and Maffei 1991). Opportunities for foraging are directly dependent on salinity levels. Specifically, salt ponds of medium salinity seem to provide the best quality foraging habitat (M. Kolar, San Francisco Bay National Wildlife Refuge, pers. comm. 2004).

**3. Migration**

While some western snowy plovers remain in their coastal breeding areas year-round, others migrate south or north for winter (Warriner *et al.* 1986, Page *et al.* 1995*a,* Powell *et al.* 1997). In Monterey Bay, California, 41 percent of nesting males and 24 percent of the females were consistent year-round residents (Warriner *et al.* 1986). At Marine Corps Base Camp Pendleton in San Diego County, California, about 30 percent of nesting birds stayed during winter (Powell *et al.* 1995, 1996, 1997). The migrants vacate California coastal nesting areas primarily from late June to late October (Page *et al.* 1995*a*). There is evidence of a late-summer (August/September) influx of western snowy plovers into Washington; it is suspected that these wandering birds are migrants (S. Richardson, Washington Department of Fish and Wildlife, pers. comm. 1998).

Most western snowy plovers that nest inland migrate to the coast for the winter (Page *et al.* 1986, 1995*b*). Thus, the flocks of non-breeding birds that begin forming along the U.S. Pacific coast in early July are a mixture of adult and hatching-year birds from both coastal and interior nesting areas. During migration and winter, these flocks range in size from a few individuals to up to 300 birds (Appendix B).

## 4. Wintering

### *a. Distribution and Abundance*

In western North America, the western snowy plover winters (here defined as late October to mid-February) mainly in coastal areas from southern Washington to Central America (Page *et al.* 1995*a*). Both coastal and interior populations use coastal locations in winter. Small numbers of western snowy plovers occur at two locations on the Washington coast: Midway Beach (WA-4) (S. Richardson, pers. comm. 1998, J. Grettenberger, U.S. Fish and Wildlife Service, pers. comm. 2004), and Leadbetter Point (WA-5), Willapa Bay (Washington Department of Fish and Wildlife 1995), both in Pacific County. Increasing numbers of wintering western snowy plovers are being documented along the Washington coast, with 32 counted in 2005 (L. Kelly *in litt.* 2005). As many as 97 western snowy plovers were observed wintering on the Oregon coast in 2005 (L. Kelly *in litt.* 2005). During the survey period between 1990 and 2005, at least 9 Oregon locations (Appendix B) have been used by wintering plovers. Probably as many as 2,500 plovers overwinter along the mainland California coast, and hundreds more at San Francisco Bay and in the Channel Islands (Appendix B, Page *et al.* 1986). The majority of wintering western snowy plovers on the California coast are found from Bodega Bay, Sonoma County, southward (Page *et al.* 1986). Appendix B gives the range of years over which each state's data was collected as well as the minimum and maximum number of western snowy plovers inventoried.

Nesting western snowy plovers from the Oregon coast have wintered as far south as Monterey Bay, California; those from Monterey Bay in central California have wintered north to Bandon, Oregon, and south to Laguna Ojo de Liebre, Baja California, Mexico (Page *et al.* 1995*a*); and those from San Diego in southern

California have wintered north to Vandenberg Air Force Base in Santa Barbara County and south to Laguna Ojo de Liebre, Baja California, Mexico (Powell *et al.* 1995, 1996, 1997).

In winter, western snowy plovers are found on many of the beaches used for nesting, as well as some beaches where they do not nest (Appendix B). They also occur in man-made salt ponds and on estuarine sand and mud flats. In California, the majority of wintering western snowy plovers concentrate on sand spits and dune-backed beaches. Some also occur on urban and bluff-backed beaches, which are rarely used for nesting (Page *et al.* 1986). Pocket beaches at the mouths of creeks and rivers on otherwise rocky shorelines are used by wintering western snowy plovers south, but not north, of San Mateo County, California.

***b. Site Fidelity***

Western snowy plovers that breed on the coast and inland are very site faithful in winter (Point Reyes Bird Observatory unpublished data). For example, after 166 adults and 204 chicks were banded at Lake Abert, Oregon during summer, many were subsequently found along the California and Baja California, Mexico coasts. Of those for which a wintering location was identified, 67 percent of the adult males, 73 percent of the adult females, and 60 percent of the birds banded as chicks (immatures) were found at the same winter location in at least 2 consecutive years; and 33 percent of the males, 32 percent of the females, and 35 percent of the immatures for at least 3 years (Page *et al.* 1995***b***).

***c. Behavior***

Western snowy plovers are typically gregarious in winter. Although some individuals defend territories on beaches, most usually roost in loose flocks; frequently western snowy plovers also are observed foraging in loose flocks (Page *et al.* 1995***a***). Roosting western snowy plovers usually sit in small depressions in the sand, or in the lee of kelp, other debris, or small dunes (Page *et al.* 1995***a***). Sitting behind debris or in depressions provides some shelter from the wind and probably makes the birds more difficult for predators to detect. When roosting western snowy plovers are disturbed, they frequently run a few meters to a new spot where they sometimes displace other individuals. Alternatively, the whole flock may fly to a new location.

## C. POPULATION STATUS AND TRENDS

### 1. Historical Trends

Historical records indicate that nesting western snowy plovers were once more widely distributed and abundant in coastal Washington, Oregon, and California.

#### *a. Washington Coast*

In Washington, western snowy plovers formerly nested at five coastal locations (Washington Department of Fish and Wildlife 1995). Three of these sites have had active nesting in recent years, as summarized in Table 1. One new site was also recently discovered in 2006. Populations appear to have increased overall since the early 1990s, although consistent, intensive surveys have been conducted only since the mid-1990s. Quantitative comparisons prior to that are not possible because of the inconsistency in surveys. Estimated numbers of breeding adults (Table 1) substantially exceed window survey data (M. Jensen *in litt.* 2006), partially because of adverse weather during window survey periods in recent years.

#### i. Grays Harbor County

Copalis Spit (WA-1) held 6 to 12 western snowy plover pairs in the late 1950s or early 1960s (Washington Department of Fish and Wildlife 1995). No other information on breeding at Copalis Spit is available. Suitable habitat was judged capable of supporting four pairs in 1984 (Washington Department of Fish and Wildlife 1995). Periodic surveys since 1983 have revealed just a single western snowy plover (Washington Department of Fish and Wildlife unpubl. data). Two post season juvenile western snowy plovers were observed at Copalis Spit in 2001 (Sundstrom 2002*a*). There is no longer vehicle access to the site since the road washed out several years ago, which has reduced the potential for disturbance from recreational activities. Erosion caused by the northward shift of Connor

Creek has reduced the amount of habitat, but some suitable habitat remains at the end of the spit and the area has potential as a nesting site with habitat restoration and public education (U.S. Fish and Wildlife Service 2005, M. Jensen *in litt.* 2006).

Damon Point and Oyhut Wildlife Area (WA-2) lack western snowy plover records prior to 1971, but this is likely due to limited visitation rather than western snowy plover absence. Between 1971 and 1983, birders reported up to six western snowy plovers during infrequent visits-to Damon Point (Washington Department of Fish and Wildlife 1995). Western snowy plover research in 1985 and 1986 revealed up to 20 western snowy plovers and 8 nests at Damon Point (Anthony 1987). Although most of the locality is suitable habitat, increasing levels of public use have reduced the secure nesting areas to a small portion of the site that is difficult to access, and the breeding population has declined over the last two decades (M. Jensen *in litt.* 2006). From 1993 to 2006 the number of adults at Damon Point has ranged from 2 to 10 (Table 1). Only one nest was found in 2006 (Pearson *et al.* 2006).

Westport Spit (WA-3) held low numbers of western snowy plovers from before 1915 until at least 1968, and scientific collecting was concentrated there through 1934 (Washington Department of Fish and Wildlife 1995). A single nest, poorly documented, was reported in 1983 (Washington Department of Fish and Wildlife unpublished data). No other quantitative information on abundance or nesting is available for this site. Erosion of the site has rendered the beach too narrow to support successful nesting, and there is little opportunity for habitat restoration through beachgrass removal due to private ownership of upland dune habitat (M. Jensen *in litt.* 2006). Recreational use is also substantial. This location is no longer being surveyed due to lack of suitable habitat.

**ii. Pacific County**

Midway Beach (WA-4) and Cape Shoalwater once contained several hundred acres of suitable western snowy plover habitat, but the area lacks historical records of these birds except for specimens collected in 1914 and 1960 and labeled "Tokeland" (Washington Department of Fish and Wildlife 1995). In recent years, Midway Beach has been accreting sand and creating high quality habitat. Recent nesting was first documented in 1998 (Richardson *et al.* 2000). Numbers of breeding adults have increased since 1998, and during 2003-2006 the numbers of adults during the breeding season have ranged from 23-33, with a peak number of 30 nests (M. Jensen *in litt.* 2006; Pearson *et al.* 2006). Approximately one third of the habitat is on State Park land with controlled access; on the privately owned land recreational disturbance is fairly high and contributes to high rates of nest failure.

In 2006, western snowy plovers were discovered nesting on Graveyard Spit in northern Willapa Bay, which is primarily on the Shoalwater Indian Reservation and State lands (M. Jensen *in litt.* 2006; Pearson *et al.* 2006). Three pairs of plovers used the spit in 2006 and produced three fledglings.

Leadbetter Point (WA-5) was rarely visited by western snowy plover observers prior to 1964. In the 1960s and 1970s, birders reported up to 35 western snowy plovers, with nesting confirmed in 1967 by the sighting of two chicks (Washington Department of Fish and Wildlife 1995). Western snowy plover numbers were estimated at up to 24 individuals and between 7 and 11 nests during surveys done between 1978 to 1997 (Widrig 1980, 1981; Willapa National Wildlife Refuge unpublished data; Williamson 1995, 1996, 1997). Numbers increased slightly from 1998-2006, with numbers ranging from 24 to 45 adults present (Table 1). The distribution of nesting by western snowy plovers has changed, however, with recent habitat loss from erosion on the tip of Leadbetter Point and shifting of nesting southwards. Since 2002 the refuge has cleared 25 hectares (63 acres) of non-native beachgrass and the habitat restoration site has been consistently used by nesting plovers. Western snowy plovers are also nesting in Leadbetter State Park and State-owned lands south of the Park. Use of predator exclosures at the refuge since 2004 has greatly improved hatching success in the habitat restoration area and outer beach. Gunpowder Sands Island became intertidal in 2001 and no longer is suitable for nesting western snowy plovers (K. Brennan *in litt.* 2006).

**Table 1.** Status of western snowy plovers at four nesting sites in Washington (Sundstrom-Bagley *et. al.* 2000; Jaques 2001; Sundstrom 2001, 2002*a*, 2002*b*, 2003, 2004, 2005; Brennan and Jaques 2002; Brennan 2003; Brennan and Fernandez 2004*a*, 2004*b*, 2006; Pearson *et al.* 2006).

| Year | Estimated Number of Adults Present | | | | |
|---|---|---|---|---|---|
| | Leadbetter Point | Midway Beach | Damon Point | Graveyard Spit | Total |
| 1993 | 16 | - | 7 | - | 23 |
| 1994 | 13 | - | 6 | - | 19 |
| 1995 | 25 | 0 | 9 | - | 34 |
| 1996 | 19 | 0 | 4 | - | 23 |
| 1997 | 21 | 0 | 3 | - | 24 |
| 1998 | 45 | 6 | 5 | - | 56 |
| 1999 | 26 | 12 | 5 | - | 43 |
| 2000 | 25 | 21 | 4 | - | 50 |
| 2001 | 27 | 14 | 4 | - | 45 |
| 2002 | 32 | 23 | 4 | - | 59 |
| 2003 | 30 | 33 | 5 | - | 68 |
| 2004 | 24 | 19 | 10 | - | 53 |
| 2005 | 38 | 25 | 5 | - | 68 |
| 2006 | 39 | 23 | 2 | 6 | 70 |

### *b. Oregon Coast*

In Oregon, western snowy plovers historically nested at over 20 sites on the coast. At present only seven core nesting sites are consistently used, with a few additional areas occupied during some years (Lauten *et al*. 2006*a*, 2006*b*). Annual window surveys of western snowy plovers in Oregon (Table 2), including both adults and young of the year, began in 1978, with counts ranging from a high of 139 at 13 sites (1981) to a low of 30 observed at 9 sites (1992). Populations reached a low from 1991 to 1993 with a mean of 33 individuals recorded annually. From 1994 to 2006 western snowy plover numbers have generally

**Table 2.** Number of adult western snowy plovers observed on window surveys of the Oregon coast during the breeding season (1978-2006). Window surveys record the number of birds seen during 1-day censuses in May to June (Lauten *et al.* 2006*a*, 2006*b*).

| Year | Number | Year | Number |
|---|---|---|---|
| 1978 | 93 | 1993 | 45 |
| 1979 | 100 | 1994 | 51 |
| 1980 | 80 | 1995 | 64 |
| 1981 | 139 | 1996 | 85 |
| 1982 | 78 | 1997 | 73 |
| 1983 | 52 | 1998 | 57 |
| 1984 | 46 | 1999 | 49 |
| 1985 | 48 | 2000 | no surveys conducted |
| 1986 | 73 | 2001 | 71 |
| 1987 | 61 | 2002 | 71 |
| 1988 | 53 | 2003 | 63 |
| 1989 | 58 | 2004 | 82 |
| 1990 | 59 | 2005 | 100 |
| 1991 | 35 | 2006 | 91 |
| 1992 | 30 | | |

increased, with an average of 71 plovers observed. The increase in the numbers of plovers observed in recent years is believed to be related to intensive management that began at the time of Federal listing.

Since 1993, the population on the Oregon coast has been intensively monitored, with many of the adults and chicks being uniquely color-banded. The presence of marked birds has allowed for the development of two other means of estimating the population (Table 3, Lauten *et al.* 2006b). The number of western snowy plovers, as indicated by the three indices in Table 3, has increased between 1993 and 1997, declined in 1998/1999, then increased again through 2006. The trends

**Table 3.** Comparison of population estimates of adult western snowy plovers on the Oregon coast during the breeding season (1993 to 2005) based on three different measures of abundance (Lauten *et al.* 2006*a*, 2006*b*).

| **Year** | **Estimates** | | |
|---|---|---|---|
| | **A** | B | C |
| 1993 | 45 | 55 to 61 | 72 |
| 1994 | 51 | 67 | 83 |
| 1995 | 64 | 94 | 120 |
| 1996 | 85 | 110 to 113 | 134 to 137 |
| 1997 | 73 | 106 to 110 | 141 |
| 1998 | 57 | 75 | 97 |
| 1999 | 45 | 77 | 95 to 96 |
| 2000 | no survey | 89 | 109 |
| 2001 | 71 | 79 to 80 | 111 to 113 |
| 2002 | 71 | 80 | 99 to 102 |
| 2003 | 63 | 93 | 102 to 107 |
| 2004 | 82 | 120 | 136 to 142 |
| 2005 | 100 | 104 | 153 to 158 |
| 2006 | 91 | 135 | 177 to 179 |

A = Window census.

B = Estimated number of breeding adults. This number is lower than those in column C because it is an estimate of the number of individual birds thought to be breeding birds.

C = Total number of individual adults present during breeding season (includes depredated adults).

for all three indices remained relatively consistent throughout that measurement period.

Management measures (Lauten *et al.* 2006a, 2006b) have included the use of exclosures to reduce predation, predator control measures, restoration of breeding habitat by removing European beachgrass (*Ammophila arenaria*), increased presence of law enforcement personnel, additional and improved signs, additional symbolic fencing (consisting of one or two strands of light-weight string or cable tied between posts to delineate areas where pedestrians and vehicles should not enter), and increased efforts on public information and education.

### *c. California Coast*

#### i. Coastwide Perspective

In California, there also has been a significant decline in breeding locations, especially in southern California. By the late 1970s, nesting western snowy plovers were absent from 33 of 53 locations with breeding records prior to 1970 (Page and Stenzel 1981). The first quantitative data on the abundance of western snowy plovers along the California coast came from window surveys conducted during the 1977 to 1980 breeding seasons by Point Reyes Bird Observatory (Page and Stenzel 1981). An estimated 1,593 adult western snowy plovers were seen on these pioneer surveys (Table 4). The surveys suggested that the western snowy plover had disappeared from significant parts of its coastal California breeding range by 1980. It no longer bred along the beach at Mission Bay or at Buena Vista Lagoon in San Diego County. In Orange County, the only remaining breeding location was the Bolsa Chica wetlands; historically, the western snowy plover was known to breed along the beach from Upper Newport Bay to Anaheim Bay. It was absent from Los Angeles County where it formerly nested along the shores of Santa Monica Bay. In Ventura County, it had ceased breeding on Ventura Beach (San Buenaventura Beach), and in Santa Barbara County on Carpinteria, Santa Barbara (East Beach), and Goleta Beaches. Nesting no longer occurred along the northernmost portion of Monterey Bay in Santa Cruz County or on Doran Beach at Bodega Harbor in Sonoma County.

Subsequent coast-wide surveys by Point Reyes Bird Observatory in 1989 and 1991 indicated a further decline in numbers of breeding adult western snowy plovers during the decade after the 1977 to 1980 survey. Along the mainland coast, including the shores of the Channel Islands, western snowy plover populations had declined by about 5 percent, and in San Francisco Bay by about 44 percent (Table 4).

**Table 4.** Number of adult western snowy plovers observed during breeding season window surveys of the California coast.

| Location | 1977/80 | 1989 | 1991 | 1995 | 2000 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|
| Del Norte County | 11 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Humboldt County | 54 | 32 | 30 | 19 | 39 | 49 | 38 | 37 | 32 | 49 |
| Mendocino County | 15 | 2 | 0 | - | 1 | 0 | 1 | 3 | 9 | 3 |
| Sonoma County | 0 | 10 | 9 | 3 | 0 | 0 | 0 | 0 | 5 | 0 |
| Marin County | 40 | 24 | 25 | 8 | 21 | 25 | 17 | 26 | 22 | 16 |
| San Mateo County (incl. SF beaches) | 4 | 8 | 1 | - | 4 | 3 | 4 | 17 | 3 | 7 |
| Northern Santa Cruz County | 25 | 19 | 22 | 26 | 19 | 9 | 2 | 2 | 3 | 4 |
| Monterey Bay | 146 | 146 | 119 | 125 | 120 | 270 | 279 | 331 | 297 | 317 |
| Point Sur | 3 | 4 | - | - | 8 | 5 | 6 | 5 | 7 | 13 |
| Northern San Luis Obispo County | | | 9 | - | 1 | 3 | 0 | 3 | 12 | 15 |
| Morro Bay Area | 80 | 126 | 87 | 85 | 113 | 150 | 172 | 268 | 259 | 167 |
| Pismo Beach/Santa Maria River | 45 | 123 | 246 | 124 | 81 | 170 | 137 | 167 | 200 | 211 |
| Vandenberg AFB | 119 | 115 | 242 | 213 | 106 | 179 | 256 | 420 | 259 | 245 |
| Jalama Beach | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hollister Ranch | | | 8 | - | - | - | - | - | - | - |
| Coal Oil Point (Devereaux) vicinity | | | - | - | - | 8 | 26 | 30 | 30 | 39 |
| Oxnard Lowland | 136 | 175 | 105 | 69 | 107 | 164 | 80 | 119 | 110 | 125 |
| Channel Islands | (288)[1] | 217 | 200 | 196 | 89 | 79 | 90 | 82 | 99 | 115 |
| Orange County | 19 | 21 | 5 | 9 | 27 | 38 | 31 | 31 | 66 | 62 |
| Northern San Diego County | 160 | 72 | 48 | 49 | 63 | 80 | 145 | 159 | 107 | 141 |
| Mission Beach | | | - | - | - | - | - | 1 | 0 | - |
| San Diego Bay | 60 | 36 | 31 | 33 | 73 | 61 | 76 | 76 | 30 | 81 |
| Tijuana Estuary | 37 | 21 | 4 | 10 | 8 | 16 | 12 | 14 | 6 | 14 |
| **Subtotal** | **1,242** | **1,160** | **1,195** | **969** | **880** | **1,309** | **1,372** | **1,791** | **1,556** | **1,624** |
| S San Francisco Bay | 351 | 216 | 176 | - | 96 | 78 | 72 | 113 | 124 | 99 |
| **Total** | **1,593** | **1,376** | **1,371** | **-** | **976** | **1,387** | **1,444** | **1,904** | **1,680** | **1,723** |

[1] 260 adults during the survey; 28 additional adults extrapolated for unsurveyed portions of Santa Rosa Island.

The more recent coast-wide surveys, during the summers of 1995, 2000, and 2002-2006, were accomplished through the collaboration of researchers studying western snowy plovers along the California coast. Between the 1977 to 1980 surveys and the 1995 survey, western snowy plovers apparently ceased nesting at Los Penasquitos, and Agua Hedionda Lagoons in northern San Diego County (A. Powell, pers. comm. 1998). Nesting has been absent or sporadic at San Elijo Lagoon; Año Nuevo State Beach and Pescadero State Beach in San Mateo County; Bolinas Lagoon in Marin County; the south and north spits of Humboldt Bay and Big Lagoon in Humboldt County; and the Lake Talawa region of Del Norte County (Point Reyes Bird Observatory, unpublished data).

By 2000 populations had declined further to 71 percent of the 1977-1980 levels along the California coast and 27 percent of the 1977-1980 levels in San Francisco Bay. However, since then populations have grown substantially, roughly doubling along the coast while fluctuating irregularly in San Francisco Bay (Table 4). Recent population increases along the coast have been associated with implementation of management actions for the benefit of western snowy plovers and California least terns, including predator management and protection and restoration of habitat.

**ii. Regional Perspective**

**Del Norte, Humboldt, and Mendocino Counties -** Numbers of western snowy plover breeding adults declined and then somewhat rebounded in this northern California region since the initial Point Reyes Bird Observatory survey in 1977. In this region where there were 80 adults counted in 1977, a low of 19 were found in 1995 and 52 in 2006. In 1996, breeding was documented on the gravel bars of the Eel River, Humboldt County, and this area has continued to be a successful nesting site for western snowy plover breeding (Colwell *et al.* 2002, 2005). Even with the nest success at the gravel bars there is still a reduction in western snowy plovers from 1977; Del Norte County has no breeding birds, and Mendocino County has very few.

**San Francisco Bay -** As indicated in Table 4, western snowy plover numbers in San Francisco Bay declined markedly between the initial survey in 1978 and follow-up surveys. Western snowy plover numbers steadily declined over 26 years, reaching a low of 72 in 2003, followed by a moderate but irregular increase (124 in 2005 surveys; 99 in 2006).

Recent surveys in South San Francisco Bay (Strong and Dakin 2004, Strong *et al.* 2004, Tucci *et al.* 2006) indicate that the largest breeding populations are concentrated at Eden Landing Ecological Reserve/Baumberg North (CA-33), managed by California Department of Fish and Game. Other population centers occur at Oliver Salt Ponds (CA-31), managed by Hayward Area Recreation District and East Bay Regional Parks District; and at Dumbarton (CA-36), Warm Springs (CA-39), Alviso (CA-41), and Ravenswood (CA-44), managed by Don Edwards San Francisco Bay National Wildlife Refuge. Foraging and nesting activities are concentrated in specific salt ponds within these areas. Small numbers of western snowy plovers have been observed at Ponds 7 and 7A in Napa County (CA-25 and vicinity), the only currently known nesting site in the North Bay.

**Sonoma, Marin, San Francisco, San Mateo, Santa Cruz, and Monterey Counties -** Along the segment of coastline from Sonoma County to Monterey Bay, numbers of western snowy plover adults during window surveys declined from 215 in 1977 to 162 in 1995, and subsequently increased to a maximum of 376 in 2004. The numbers of adults breeding on the beaches and salt ponds of Monterey Bay, and the beaches of northern Santa Cruz County, has increased dramatically since management actions have been undertaken to increase nesting success (Neuman *et al.* 2004; G. Page *in litt.* 2004*b*)

**San Luis Obispo, Santa Barbara, and Ventura Counties, including Channel Islands -** There is no clear evidence of an overall decline in the number of breeding western snowy plovers for this region from 1978/1980 to the present. Numbers of adults fluctuated between a high of 1089 and a low of 497 between 1978 and 2006. While numbers for the region may not have changed overall, there have been definite changes at specific locations (Table 5). Most notable are the decline and loss of the population on San Miguel Island from 1978 /1980 to 2000, the decline at Santa Rosa Island from 1991 to 2006, and the sudden increase in numbers at Vandenberg Air Force Base between 2000 and 2004 and at Coal Oil Point Reserve between 2002 and 2006 (Table 4).

**Table 5.** Breeding season window surveys of western snowy plover adults at selected sites along the coast of San Luis Obispo, Santa Barbara, and Ventura Counties.

| Location | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1978-80** | **1989** | **1991** | **1995** | **1996** | **1997** | **1998** | **2000** | **2002** | **2003** | **2004** | **2005** | **2006** |
| Atascadero Beach | 0 | 17 | 2 | 38 | 28 | 23 | 26 | 5 | 19 | 23 | 21 | 21 | 24 |
| Morro Bay Spit | 80 | 94 | 69 | 34 | 40 | 39 | 55 | 87 | 93 | 114 | 203 | 205 | 120 |
| Vandenberg AFB [1] | 119 | 115 | 242 | 213 | 230 | 238 | 130 | 106 | 179 | 256 | 420 | 259 | 245 |
| Ormond Beach | 25 | 24 | 34 | 20 | 19 | 34 | 19 | 10 | 35 | 19 | 28 | 21 | 22 |
| Naval Base Ventura County (Pt. Mugu) | 82 | 81 | 59 | 40 | 49 | 26 | 47 | 81 | 85 | 51 | 75 | 83 | 79 |
| Santa Rosa Island [2] | 84 | 91 | 103 | 71 | 78 | 79 | 76 | 17 | 10 | --- | --- | 37 | 19 |
| San Miguel Island [2] | 133 | 36 | 19 | 9 | 3 | 5 | 1 | 0 | 0 | 0 | 0 | --- | 0 |
| San Nicolas Island [3] | 71 | 90 | 78 | 116 | 104 | 91 | 90 | 72 | 69 | 90 | 79 | 62 | 96 |
| **Total** | 594 | 548 | 606 | 541 | 551 | 535 | 444 | 378 | 490 | 553 | 826 | 688 | 605 |

Unless footnoted, the source of all data is Point Reyes Bird Observatory.

1 The source of this data is the U.S. Air Force (Phil Persons)

2 The source of this data is the National Park Service

3 The source of this data is the U.S. Navy

**Los Angeles, Orange, and San Diego Counties -** Western snowy plover numbers detected during window surveys declined from the 276 adults tallied during the 1978 Point Reyes Bird Observatory survey to 88 during the 1991 survey. Subsequently the population has increased to 298 in 2006.

### 2. Current Breeding Distribution

The current Pacific coast breeding range of the western snowy plover extends from Damon Point, Washington, to Bahia Magdelena, Baja California, Mexico. The population is sparse in Washington, Oregon, and northern California. In 2006, estimated populations were 70 adults along the Washington coast (Pearson *et al*. 2006), 177-179 adults along coastal Oregon (Lauten *et al.* 2006*b*), and 2,231 adults in coastal California and San Francisco Bay (window survey including correction factor: G. Page *in litt.* 2006, U.S. Fish and Wildlife Service 2006*a*). Approximately 7 percent of the California population was observed in San Francisco Bay, and 4 percent in northern California north of the Golden Gate bridge. Along the coast of Baja California, Mexico, most nesting western snowy plovers are associated with the largest wetlands, especially Bahia San Quintin, Laguna Ojo de Liebre, and Bahia Magdelena (Palacios *et al.* 1994). No recent quantitative data exist on the western snowy plover population in Baja California, but it is probably roughly similar in size to the U.S. Pacific coast population.

### 3. Habitat Carrying Capacity

There is no quantitative information on carrying capacity of beaches for western snowy plovers. Determining carrying capacity of beaches is confounded by human use that affects the numbers of snowy plovers using the beaches. Beaches vary substantially in their structure, width, vegetation, and level of human use, complicating such a measurement.

The maximum reported breeding density of western snowy plovers is associated with the Moss Landing Wildlife Area, where since 1995 Point Reyes Bird Observatory staff have conducted intensive management specifically for western snowy plovers. These measures include predator control, removal of excessive vegetation, and operation of water control structures to maintain desired water levels. With extensive management of approximately 55 hectares (138 acres) of mostly dried ponds in the Moss Landing Wildlife Area, 25 active nests, 3 pairs within 5 days of initiating nests, and 10 broods have been documented simultaneously; thus a peak of 76 nesting adults was accommodated simultaneously by 55 hectares (138 acres) of playa, or 1.4 hectares (3.6 acres) per functional pair (some of the broods were only being cared for by males) (D. George, Point Reyes Bird Observatory, pers. comm.). However, the numbers of nesting western snowy plovers at the Moss Landing Wildlife Area cannot be applied to beach areas because of the physical differences between salt pond and beach habitats and because beach habitats are typically subject to much more human disturbance. Neither can these numbers necessarily be applied to other salt ponds (***e.g.***, San Francisco Bay) because habitat and management opportunities differ.

## D. REASONS FOR DECLINE AND CONTINUING THREATS

Overall, western snowy plover numbers have declined on the U.S. Pacific coast over the past century (see Population Status and Trends section). The subspecies faces multiple threats throughout its Pacific coast range. The reasons for decline and degree of threats vary by geographic location; however, the primary threat is habitat destruction and degradation. Habitat loss and degradation can be primarily attributed to human disturbance, urban development, introduced beachgrass (*Ammophila* spp.), and expanding predator populations. Natural factors, such as inclement weather, have also affected the quality and quantity of western snowy plover habitat (U.S. Fish and Wildlife Service 1993***a***). The following discussion is organized according to the five listing criteria under section 4(a)(1) of the Endangered Species Act.

### 1. The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

#### *a. Shoreline Stabilization and Development*

The wide, flat, sparsely-vegetated beach strands preferred by western snowy plovers are an unstable habitat, subject to the dynamic processes of accretion and erosion of sand, and dependent on natural forces for replenishment and renewal. These habitats are highly susceptible to degradation by construction of seawalls, breakwaters, jetties, piers, homes, hotels, parking lots, access roads, trails, bike paths, day-use parks, marinas, ferry terminals, recreational facilities, and support services that may cause direct and indirect losses of breeding and wintering habitat for the western snowy plover.

Beach stabilization efforts may interfere with coastal dune formation and cause beach erosion and loss of western snowy plover nesting and wintering habitat. Shoreline stabilization features such as jetties and groins may cause significant habitat degradation by robbing sand from the downdrift shoreline (U.S. Fish and Wildlife Service 1996*a*). However, jetties also can redirect sand deposition, causing an increase in available habitat. Construction of homes, resorts, and parking lots on coastal sand dunes constitutes irrevocable loss of habitat for western snowy plovers. Urban development has permanently eliminated valuable nesting habitat on beaches in southern Washington (Brittell *et al.* 1976), Oregon (Oregon Department of Fish and Wildlife 1994), and California (Page and Stenzel 1981). In addition to causing direct loss of habitat, there are additional potential adverse impacts to western snowy plovers from urban development (Figure 5). Increased development increases human use of the beach, thereby increasing disturbance to nesting plovers. When urban areas interface with natural habitat areas, the value of breeding and wintering habitat to native species may be diminished by increased levels of illumination at night (***e.g.***, building and parking lot lights); increased sound and vibration levels; and pollution drift (***e.g.***, pesticides) (Kelly and Rotenberry 1996/1997). Beach raking removes habitat features for both plovers and their prey, and precludes nests from being established. Also, construction of residential development in or near western snowy plover habitat attracts predators, including domestic cats.

***b. Resource Extraction***

**i. Sand Removal and Beach Nourishment**

Sand is mined in coastal areas such as Monterey Bay. Mining sand from the coastal mid-dunes and surf zone can cause erosion and loss of western snowy plover breeding and wintering habitat. Sand removal by heavy machinery can disturb

**Figure 5.** New housing development next to beach at Monterey Bay, California (photo by Peter Baye, with permission).

incubating western snowy plovers, destroy their nests or chicks, and result in the loss of invertebrates and natural wave-cast kelp and other debris that western snowy plovers use for foraging. Mining of surface sand from the 1930s through the 1970s at Spanish Bay in Monterey County degraded a network of dunes by lowering the surface elevations, removing sand to granite bedrock in many locations, and creating impervious surfaces that supported little to no native vegetation (Guinon 1988).

Beach nourishment with sand can be beneficial for the western snowy plover if it results in an increase in habitat. However, unless beach nourishment projects are properly designed, they can result in changes to beach slope from redeposition of sediments by storm waves, and result in the loss of western snowy plover breeding and wintering habitat. For example, if an inappropriate size class of sand (*e.g.*, coarser-grained sand) and range of minerals are introduced that are different from the current composition of native sand on a beach, it can alter dune slope (making it steeper or narrower), affect mobility and color of sand, decrease the abundance of beach invertebrates, and facilitate establishment of invasive exotic plants that may have a competitive advantage over native plants. Feeney and Maffei (1991) investigated the color hues of the ground surface within San Francisco Bay salt ponds used as western snowy plover nesting habitat. Predominant soils were silty clay with varying amounts of humus, salt crystals, and shell fragments. They found a strong similarity between the color of the substrate in habitat preferred by western snowy plovers and the color of western snowy plover mantles (upper parts).

**ii. Dredging and Disposal of Dredged Materials**

Dredging is detrimental to western snowy plovers when it eliminates habitat or alters natural patterns of beach erosion and deposition that maintain habitat. Disturbances associated with dredging, such as placement of pipes, disposal of dredged materials, or noise, also may negatively affect breeding and wintering western snowy plovers. Dredging also is detrimental when it promotes water-oriented developments that increase recreational access to western snowy plover habitat (*e.g.*, marinas, boat ramps, or other facilities to support water-based recreation). In some cases, however, dredged materials may provide important nesting habitat for western snowy plovers such as those at Coos Bay, Oregon (Wilson-Jacobs and Dorsey 1985). Western snowy plovers also have been observed using dredged material during the winter; however, these areas are not used nearly as often as the adjacent ocean beach (E.Y. Zielinski and R.W. Williams *in litt.* 1999).

**iii. Driftwood Removal**

Driftwood can be an important component of western snowy plover breeding and wintering habitat. Driftwood contributes to dune-building and adds organic matter to the sand as it decays (Washington Department of Fish and Wildlife 1995). Additionally, driftwood provides western snowy plovers with year-round protection from wind and blowing sand. Often, western snowy plovers build nests beside driftwood, so its removal may reduce the number of suitable nesting sites.

Driftwood removed for firewood or decorative items can result in destruction of nests and newly-hatched chicks that frequently crouch by driftwood to hide from predators and people. Chainsaw noise may disrupt nesting, and vehicles used to haul wood may crush nests and chicks. Removal of driftwood has been documented as a source of nest destruction at Vandenberg Air Force Base where two nests were crushed beneath driftwood dragged to beach fire sites (Persons 1994). Also, driftwood beach structures built by visitors are used by avian predators of western snowy plover chicks such as loggerhead shrikes (*Lanius ludovicianus*) and American kestrels (*Falco sparverius*), and predators of adults such as merlins (*Falco columbarius*) and peregrine falcons (*Falco peregrinus*).

Although driftwood is an important component of western snowy plover habitat, too much driftwood on a beach, which may occur after frequent and prolonged storm events, can be detrimental if there is not sufficient open habitat to induce the birds to nest.

### iv. Beach Fires and Camping

Beach fires and camping may be harmful to nesting western snowy plovers when valuable driftwood is destroyed, as described above. Camping near breeding locations can cause greater impacts due to the prolonged disturbance and increased chance for possible direct mortality from associated dogs and children (S. Richardson *in litt*. 2001). Nighttime collecting of wood increases the risk of stepping on nests and chicks, which are difficult to see even during daylight hours. Fires near a western snowy plover nest could cause nest abandonment due to disturbance from human activities, light, and smoke. Fires have the potential to attract large groups of people and result in an increase of garbage, which attracts scavengers such as gulls (*Larus* spp.) and predators such as coyotes (*Canis latrans*), American crows (*Corvus brachyrhynchos*), and common ravens (*Corvus corax*). Also, after fires are abandoned, predators such as coyotes may be attracted into the area by odors lingering from the fire, particularly if it was used for cooking. Occasionally fires escape into nearby driftwood; fire suppression activities may disturb and threaten western snowy plover nests and chicks.

### v. Watercourse Diversion, Impoundment, or Stabilization

Water diversion and impoundment of creeks and rivers may negatively affect western snowy plover habitat by reducing sand delivery to beaches and degrading water quality. Water diversions are a major threat to western snowy plovers when they impair hydrologic processes (such as migration of creek and river mouths) that maintain open habitat at river and creek mouths by retarding the spread of introduced beachgrass (*Ammophila* spp.) and other vegetation. Water diversion, impoundment, or stabilization activities could include construction of dams and irrigation, flood control, and municipal water development projects (Powell *et al.* 2002).

#### vi. Operation of Salt Ponds

Salt ponds of San Francisco Bay and San Diego Bay, which are filled and drained as part of the salt production process, provide breeding and wintering habitat for western snowy plovers. Dry salt ponds and unvegetated salt pond levees are used as western snowy plover nesting habitat. Ponds with shallow water provide important foraging habitat for western snowy plovers, with ponds of low and medium salinity providing the highest invertebrate densities. Ponds of high salinity have reduced invertebrate densities and therefore provide lower quality foraging habitat. Nesting western snowy plovers can be attracted to an area when ponds are drained during the breeding season, but flooding can then destroy the nests when the ponds are refilled. Also, human disturbance resulting from maintenance activities associated with the operation of commercial salt ponds can result in the loss of western snowy plovers and disturbance of their habitat. If conducted during the western snowy plover breeding season, reconstruction of salt pond levees could destroy western snowy plover nests. Maintenance activities that are conducted by vehicles, on foot, or through the use of dredging equipment could result in direct mortality or harassment of western snowy plovers (See Dredging, Pedestrian, and Motorized Vehicle sections).

### *c. Encroachment of Introduced Beachgrass and Other Nonnative Vegetation*

One of the most significant causes of habitat loss for coastal breeding western snowy plovers has been the encroachment of introduced European beachgrass (*Ammophila arenaria*) and American beachgrass (*Ammophila breviligulata*). Foredunes dominated by introduced beachgrass have replaced the original low, rounded, open mounds formed by the native American dunegrass (*Leymus mollis*) and other beach plants. Native dune plants do not bind sand like *Ammophila* spp., and thus allow for sand movement and regenerating open expanses of sand. However, *Ammophila* spp. forms a dense cover that excludes many native taxa. On beaches dominated by this invasive grass, species richness of vegetation is halved, in comparison with foredunes dominated by native dune grass (Barbour and Major 1990). Similarly, American beachgrass greatly depresses the diversity of native dune plant species (Seabloom and Wiedemann 1994).

European beachgrass was introduced to the west coast around 1898 to stabilize dunes (Wiedemann 1987). Since then, it has spread up and down the coast and now is found from British Columbia to Ventura County in southern California. This invasive species is a rhizomatous grass that sprouts from root segments, with a natural ability to spread rapidly. Its most vigorous growth occurs in areas of wind-blown sand, primarily just above the high-tide line, and it thrives on burial under shifting sand. In 1988, European beachgrass was considered a major dune plant at about 50 percent of western snowy plover breeding areas in California and all of those in Oregon and Washington (J. Myers *in litt.* 1988).

American beachgrass is native to the East coast and Great Lakes region of North America. The densest populations of American beachgrass on the Pacific coast are currently located between the mouth of the Columbia River and Westport, Washington. Like European beachgrass, American beachgrass is dominant on the mobile sands of the foredune and rapidly spreads through rhizome fragments. American beachgrass occurs along the entire coast of Washington, ranging from Shi Shi Beach, Washington, in the north, to Sand Lake, Oregon, in the south, although its frequency decreases markedly at the northern and southern limits of this range. Currently, American beachgrass is the dominant introduced beachgrass species in much of the western snowy plover range in the State of Washington (Seabloom and Wiedemann 1994).

Stabilizing sand dunes with introduced beachgrass has reduced the amount of unvegetated area above the tideline, decreased the width of the beach, and increased its slope (Wiedemann 1987). These changes have reduced the amount of potential western snowy plover nesting habitat on many beaches and may hamper brood movements. In Oregon, the beachgrass community may provide habitat for western snowy plover predators (*e.g.*, skunks [*Mephitis* spp.], weasels [*Mustela* spp.], coyotes [*Canis latrans*], foxes [*Urocyon cinereoargenteus* and *Vulpes vulpes*.], raccoons [*Procyon lotor*], and feral cats [*Felis domesticus*]) that historically would have been largely precluded by the lack of cover in the dune community (Stern *et al.* 1991; K. Palermo, U.S. Forest Service, pers. comm. 1998).

In areas with European beachgrass, it has caused the development of a vegetated foredune that effectively blocks movement of sand inland and creates conditions favorable to the establishment of dense vegetation in the deflation plain, which occurs behind the foredunes (Wiedemann *et al.* 1969). In natural sand dunes, deflation plains consist of open sand ridges and flat plains at or near the water table. Thus, in areas with European beachgrass, the open features that characterize western snowy plover breeding habitat are destroyed. The establishment of European beachgrass has also caused sand spits at the mouths of small creeks and rivers to become more stable than those without vegetation because of the creation of an elevated beach profile. This elevated profile, in effect, reduces the scouring of spits during periods of high run-off and storms. A secondary effect of dune stabilization has been human development of beaches and surrounding areas (Oregon Department of Fish and Wildlife 1994). This development, in turn, has reduced available beach habitat and focused human activities on a smaller area that must be shared with western snowy plovers and other shorebirds.

On the Oregon coast, the establishment of European beachgrass has produced dramatic changes in the landscape (Oregon Department of Fish and Wildlife 1994). The spread of this nonnative species was greatly enhanced by aggressive stabilization programs in Oregon in the 1930s and 1940s (Wiedemann 1987). European beachgrass spread profusely along the Washington coast, and was well established by the 1950s (Washington Department of Fish and Wildlife 1995). In 1988, the spread of beachgrass was termed an "increasing threat" to traditional western snowy plover nesting areas at Leadbetter Point, Washington, having become established where absent only 4 years earlier (Willapa National Wildlife Refuge 1988).

In California, there are many beaches where European beachgrass has established a foothold. These beaches include the dunes at Lake Earl, Humboldt Bay (from

Trinidad to Centerville Beach), MacKerricher State Beach/Ten Mile Dunes Preserve, Manchester State Beach, Bodega Bay, Point Reyes National Seashore, Golden Gate National Recreation Area, Monterey Bay, Morro Bay Beach, Guadalupe-Nipomo Dunes, and Vandenberg Air Force Base (A. Pickart *in litt.* 1996). Chestnut (1997) studied the spread of European beachgrass at the Guadalupe-Nipomo Dunes in San Luis Obispo County. He documented an increase in beachgrass from approximately 8 to 109 hectares (20 to 270 acres) between 1969 and 1997, and found that its rapid spread through native vegetation posed a serious threat to nesting western snowy plovers and rare plants.

In addition to the loss of nesting habitat, introduced beachgrass also may adversely affect western snowy plover food sources. Slobodchikoff and Doyen (1977) found that beachgrass markedly depressed the diversity and abundance of sand-burrowing arthropods at coastal dune sites in central California. Because western snowy plovers often feed on insects well above the high-tide line, the presence of this invasive grass may also result in loss of food supplies for plovers (Stenzel *et al.* 1981).

In some areas of California, such as the Santa Margarita River in San Diego County, and the Santa Clara and Ventura Rivers in Ventura County, giant reed (*Arundo donax*) has become a problem along riparian zones. During winter storms, giant reed is washed downstream and deposited at the river mouths where western snowy plovers nest (Powell *et al.* 1997). Large piles of dead and sprouting giant reed eliminate nesting sites and increase the presence of predators, which use it as perches and prey on rodents in the piles of vegetation.

Other nonnative vegetation that has invaded coastal dunes, thereby reducing western snowy plover breeding habitat, includes Scotch broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), South African iceplant (*Carpobrotus edulis*), pampas grass (*Cortaderia jubata* and *Cortaderia selloana*) and iceplant (*Mesembryanthemum* sp.); shore pine (*Pinus contorta*) is a native plant species that has invaded coastal dunes and resulted in similar impacts to western snowy plovers (Schwendiman 1975, California Native Plant Society 1996, Powell 1996). Many nonnative weed species also occur on and along San Francisco Bay salt pond levees, resulting in unsuitable nesting habitat for western snowy plovers (J. Albertson *in litt.* 1999).

***d. Habitat Conversion for Other Special Status Species***

It is not known whether western snowy plovers historically nested in San Francisco Bay prior to the construction of salt evaporator ponds beginning in 1860 (Ryan and Parkin 1998). However, western snowy plovers have wintered on the San Francisco Bay since at least the late 1800's, as indicated by a specimen dated November 8, 1889, in the California Museum of Vertebrate Zoology (Grinnell *et al.* 1918). It is possible that natural salt ponds in the vicinity of San Lorenzo once supported nesting birds, but insufficient data exist to assess this possibility (U.S. Fish and Wildlife Service 1992). Today, however, the San Francisco Bay recovery unit supports an important western snowy plover source population, representing approximately 5 to 10 percent of the total breeding population. Feeney and Maffei (1991) observed a sizable population of western snowy plovers at the Baumberg and Oliver salt ponds during the breeding and nonbreeding seasons, suggesting that these ponds are important to western snowy plovers throughout the year. They suspected that these ponds are used by western snowy plovers as both a pre-breeding and post-breeding staging area, based on the high numbers of plovers in mid-February and in late August/September, respectively.

As part of the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (U.S. Fish and Wildlife Service, in preparation), extensive tidal marsh restoration is identified as a recovery action for listed and other sensitive species of tidal salt marshes including the California clapper rail (*Rallus longirostris obsoletus*) and salt marsh harvest mouse (*Reithrodontomys raviventris*). A large area of San Francisco Bay salt ponds, especially within the South Bay, are proposed for tidal marsh restoration for the benefit of federally listed tidal marsh species. Salt ponds are large, persistent hypersaline ponds that are intermittently flooded with South Bay water. Some of these ponds currently provide valuable breeding and wintering habitat for western snowy plovers. However, they occur within the historical areas of tidal salt marsh, which once dominated San Francisco Bay. Endangered tidal marsh species would benefit from conversion of these ponds back to salt marsh; however, western snowy plovers would lose suitable nesting and wintering areas.

The Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California will focus primarily on management of tidal marsh species, but will also provide for some areas to be maintained as managed ponds that would provide habitat for western snowy plovers and California least terns (*Sternula antillarum browni*). The South Bay Salt Pond Restoration Project (Philip Williams & Associates *et al.* 2006) has identified sites on National Wildlife Refuge and California Department of Fish and Game lands with potential for salt marsh restoration and managed ponds under a range of alternatives; the projected area of managed ponds ranges from 647 to 3,035 hectares (1,600 to 7,500 acres). Six of the plover locations identified in Appendices B and L (CA-33, CA-34, CA-39, CA-40, CA-41, CA-44) occur within the South Bay Salt Pond Restoration Project area. These six locations comprise about 60 percent of the western snowy plover locations in San Francisco Bay by area, and currently support over 90 percent of the western snowy plover population in San Francisco Bay (Strong *et al.* 2004, Tucci *et al.* 2006). In particular, several salt ponds at Eden Landing (location CA-33 and vicinity) currently support the largest population of western snowy plovers in San Francisco Bay. Distribution of plover populations and nesting sites within San Francisco Bay can fluctuate with salt pond management and availability of appropriate habitat, such that some locations identified in Appendix L are not currently occupied and other locations not mapped in Appendix L may nonetheless support breeding birds as management practices change. Thus the boundaries of San Francisco Bay locations as mapped in Appendix L reflect current and historical conditions and should be considered as flexible in the context of planning for future tidal marsh restoration. Specific localities to be managed for plovers should be coordinated with tidal marsh restoration in an integrated fashion, and thus may not be identical with the current or historical localities identified in this recovery plan.

Thus intensive management of designated ponds within the South Bay Salt Pond Restoration Project area will be crucial to achieving success in meeting western snowy plover recovery goals in San Francisco Bay. However, establishing western snowy plover populations at a variety of sites in San Francisco Bay, both within and outside the South Bay Salt Pond Restoration Project area, is advisable to minimize their vulnerability to loss (L. Trulio *in litt.* 2007). Potential western snowy plover habitat in San Francisco Bay outside of the South Bay Salt Pond Restoration Project area includes several sites around Alameda, Napa County, Hayward Shoreline, and

Crissy Field. In addition, large salt pond tracts in the South Bay remain under the ownership of Cargill; certain areas are still managed for salt production and could incidentally provide habitat for western snowy plovers, while approximately 600 hectares (1,400 acres) of ponds near Redwood City are no longer in salt production and provide an opportunity for significantly increasing western snowy plover habitat through active management. If these locations can be managed to encourage western snowy plover nesting, they may contribute substantially to meeting the overall goal of 500 breeding birds in San Francisco Bay. Western snowy plover management targets for the South Bay Salt Pond Restoration Project should take into account the habitat quality and management potential of plover habitat elsewhere in San Francisco Bay to meet overall goals for the recovery unit.

Don Edwards San Francisco Bay National Wildlife Refuge is currently planning pilot studies to assess how best to manage salt ponds for high densities of breeding western snowy plovers. Special management for western snowy plover may include intensive control of avian predators (*e.g.*, California gull colonies, ravens); active management of water levels to control vegetation, maintain optimal salinity, and produce brine flies; timing of inundation to avoid flooding nests; and reconfiguration of shallow salt ponds with isolated islands and furrowed areas. Locations of managed salt ponds should be planned to minimize the proximity of western snowy plover populations to landfills, gull colonies, and areas with high predator densities. Intensive management of salt ponds for western snowy plovers generally appears feasible, and plovers have been observed to opportunistically disperse among sites and use habitat that becomes suitable (V. Bloom *in litt.* 2005), so we expect relocation of plover nesting concentrations away from tidal marsh restoration areas to be possible, but management success should be carefully evaluated. Those alternatives with greater acreages of tidal marsh restoration (e.g., Alternative C at 90 percent tidal habitat) would require correspondingly more intensive management and reconfiguration of the remaining salt ponds (Philip Williams & Associates *et al.* 2006), and should be implemented gradually in conjunction with evaluation of management effectiveness for western snowy plovers.

Thus, we believe tidal marsh restoration can be compatible with the recovery of western snowy plovers and should not preclude meeting a goal of 500 breeding birds in San Francisco Bay. As described below under Recovery Action 2.6, occupied salt ponds should initially be conserved. Salt marsh restoration in occupied plover habitat, particularly at densely populated sites, should be phased in after intensive adaptive management of other compensating salt pond habitat has demonstrated success in increasing plover populations. Thus habitat quality should be continually assessed so that overall western snowy plover populations in San Francisco Bay are not adversely affected by the restoration project and can increase to meet the management goal for this recovery unit.

In southern California, unless carefully planned, conversion of western snowy plover habitat to tidal salt marsh may result in loss of western snowy plover habitat. The light-footed clapper rail (*Rallus longirostris levipes*) inhabits coastal tidal marshes from Santa Barbara County south to Baja California, Mexico. Several locations in Ventura, Orange, and San Diego Counties provide nesting and/or wintering habitat for western snowy plovers, but also provide high quality light-footed clapper rail habitat or represent high priority tidal marsh restoration sites in the recovery plan for the light-footed clapper rail (U.S. Fish and Wildlife Service 1985). These sites include Bolsa Chica, Agua Hedionda Lagoon, San Elijo Lagoon, San Dieguito Lagoon, and Los Penasquitos Lagoon. The Bolsa Chica wetlands were opened to tidal action in 2006, in a project combining tidal restoration work with construction of islands and sand flats for nesting of shorebirds and California least terns.

**2. Overutilization for Commercial, Recreational, Scientific, or Education Purposes**

Biologists and agency personnel monitor western snowy plovers to assess population status and evaluate management techniques. Additionally, nest searches at some sites allow for placement of predator exclosures that aid in hatching success. Measures to minimize disturbance from these activities include: time limits for surveys, exclosure construction and sign/rope maintenance; conducting walking surveys where feasible; and limited entries.

Egg collecting has been observed at several California nesting colonies (Stenzel *et al.* 1981, Warriner *et al.* 1986). Occasionally recreational birdwatchers also may harass western snowy plovers. The significance of these factors to nesting success is uncertain but probably relatively minor.

Qualified individuals may obtain permits to conduct scientific research and population census activities on western snowy plovers under section 10(a)(1)(A) of the Endangered Species Act. Specific activities that may be authorized include: population censuses and presence/absence surveys; monitoring of nesting activity; capturing, handling, weighing, measuring, banding, and color-marking of young and adults on breeding and wintering grounds; radio-telemetry studies; translocation studies; genetic studies; contaminant studies; behavioral, ecological, and life history studies; and placing predator exclosures around active nests. Short-term impacts of these activities may include harassment and possible accidental injury or death of a limited number of individual western snowy plovers. The long-term impacts will be to contribute to recovery of the species by facilitating development of more precise scientific information on status, life history, and ecology (U.S. Fish and Wildlife Service 1993*b*).

Banding birds with metal and plastic bands to identify individuals and to monitor bird populations is a common practice. However, a number of leg injuries to western snowy plovers, possibly resulting from banding, have been reported (G. Page *in litt.* 2005*b*). These injuries include swelling and abrasion of legs possibly from sand or other particles becoming lodged between the bands and the leg. Some banding injuries appear to have resulted in foot loss and in a few instances, death of the bird. Similar injuries have been observed in piping plovers (*Charadrius melodus*) banded on the Atlantic coast and interior U.S., and resulted in a moratorium on banding of that species (Lingle *et. al.* 1999, U.S. Fish and Wildlife Service 1996*a*, U.S. Fish and Wildlife Service 2002). Despite leg injuries, several piping plovers were observed to successfully breed and fledge young (Lingle *et. al.* 1999). However, these injuries may contribute directly or indirectly to mortalities or reduce breeding performance. It should be noted that incidents of foot loss in Pacific coast western snowy plovers usually appear to result from fine fibers wrapping around the bird's ankle, and have occurred in unbanded as well as banded individuals (J. Watkins, pers. comm. 2006). Despite risk of injuries, banding remains the best technique to study population traits such as survival, recruitment, and dispersal, and may be the most effective way to monitor populations of the western snowy plover to determine effectiveness of management strategies. Currently the percentage of banded birds range-wide that become injured from banding and the impacts of banding injuries on populations of the western snowy plover are unknown; a study was initiated in 2005 by Point Reyes Bird Observatory to assess the effectiveness of alternative banding techniques in reducing injuries and band loss (G. Page *in litt.* 2005*b*).

Concerns that color bands increase the vulnerability of western snowy plovers to predation by reducing effectiveness of camouflage do not appear to be supported by existing evidence. Because western snowy plovers crouch and flatten to the sand at the approach of avian predators, color bands are typically hidden from sight; terrestrial predators are evaded by running or taking flight at their approach (J. Watkins, pers. comm. 2006).

**3. Disease or Predation**

West Nile virus, a mosquito-borne disease which can infect birds, reptiles, and mammals, has spread rapidly across the United States from the initial introduction in New England (National Audubon Society 2006). The disease has killed birds of various species in all coastal California counties since its arrival in the state in 2003 (U.S. Geological Survey 2006). In 2004 to 2006 the disease was reported from two coastal counties (Lane and Lincoln) in Oregon but has not been reported from any coastal counties in Washington (U.S. Geological Survey 2006). The deadliness of the disease varies by species; however, the virus has been identified in dead piping plovers (*Charadrius melodus*) and killdeer (*C. vociferus*), both closely related to the western snowy plover (Center for Disease Control 2004).

Since 2004 numerous western snowy plovers in southern California have been found dead or exhibited neurological signs consistent with avian botulism (M. Long *in litt.* 2006). Confirmation of disease diagnosis is currently pending availability of specimens for autopsy. We are currently coordinating with the USGS National Wildlife Health Center to better understand the causes of these mortalities and to develop a program for treatment of ill birds diagnosed with botulism. Additionally, 32 western snowy plovers died in 2006 from unknown causes in San Diego County (U.S. Navy *in litt.* 2007).

Predator density is a significant factor affecting the quality of western snowy plover nesting habitat (Stenzel *et al.* 1994). Predation can result in the loss of adults, chicks, or eggs; separation of chicks from adults is also caused by the presence of predators. Powell *et al.* (2002) found that predation accounted for most nest failures in 1994, 1996, and 1997, in San Diego County, California. Western snowy plovers generally cannot defend themselves or their nests against predation but must rely on antipredator adaptation, including (1) pale coloration of adults, eggs, and young, which acts as camouflage against detection by predators; (2) a skulking retreat from the nest at a predator's approach; (3) extreme mobility and elusiveness of precocial young and; (4) maintenance of low nesting density (Page *et al.* 1983). In natural ecosystems, there is a co-evolution of the predator-prey relationship, where prey species slowly evolve with evading behavior as predator species slowly evolve effective prey-capturing behavior. However, when exotic predators are introduced into the ecosystem and thrive there, they frequently occur in much higher densities and possess more effective strategies than native predators and, hence, usually have a more severe effect.

Predation, by both native and nonnative species, has been identified as a major factor limiting western snowy plover reproductive success at many Pacific coast sites. Known mammalian and avian predators of western snowy plover eggs, chicks, or adults include the following native species: gray foxes (*Urocyon cinereoargenteus*), Santa Rosa Island foxes (*Urocyon littoralis santarosae*), coyotes, striped skunks (*Mephitis mephitis*), spotted skunks (*Spilogale putorius*), raccoons, California ground squirrels (*Citellus beecheyi*), long-tailed weasels (*Mustela frenata*), American crows, common ravens (*Corvus corax*), ring-billed gulls (*Larus delawarensis*), California gulls (*Larus californicus*), western gulls (*Larus occidentalis*), glaucous-winged gulls (*Larus glaucescens*), gull-billed tern (*Gelochelidon nilotica*), American kestrels (*Falco sparverius*), peregrine falcons (*Falco peregrinus*), northern harriers (*Circus cyaneus*), loggerhead shrikes, merlins (*Falco columbarius*), great horned owls (*Bubo virginianus*), burrowing owls (*Speotyto cunicularia*), great blue herons (*Ardea herodias*); and the following nonnative species: eastern red foxes (*Vulpes vulpes regalis*), Norway rats (*Rattus norvegicus*), Virginia opossums (*Didelphis marsupialis*), domestic and feral dogs (*Canis familiaris*), and cats (*Felis domesticus*). Loss or abandonment of eggs due to predation by fire ants and Argentine ants (*Iridomyrmex humilis*) has also been observed (Fancher *et al.* 2002, Powell *et al.* 2002).

In Oregon, nest predation by corvids (common ravens and American crows) is the major cause of nest failures. Of 63 unexclosed nests in 2005, corvid predation accounted for 22 nest failures, by comparison with 14 failures due to mammalian or unknown predators and 10 due to abandonment (Lauten *et al.* 2006*a*). Exclosures were effective in protecting nests against this threat (0 of 83 exclosed nests failed due to nest predation).

American crows have been consistently documented as a major predator on western snowy plover nests along the California and Oregon coasts (Page 1990; Persons and Applegate 1997; T. Applegate, Bioresources, pers. comm. 1999; M. Stern, The Nature Conservancy, pers. comm. 1999). At Coal Oil Point, American crows were the most frequent predator on western snowy plover nests and experimentally placed quail eggs (Lafferty *et al.* 2006). Populations of American crows have increased in the San Francisco Bay and central California coast over the past several decades, and are positively associated with human population density (Leibezet and George 2002).

Common ravens are known predators of western snowy plover eggs (Wilson-Jacobs and Dorsey 1985, Point Reyes Bird Observatory unpublished data, George 1997, Stein 1993, Point Reyes Bird Observatory unpublished data, J. Albertson *in litt.* 1999, Point Reyes Bird Observatory unpubl. data, Stern *et al.* 1991). Ravens have consistently been the most significant nest predator at Point Reyes, accounting for 69 percent of all predation events over 5 years and destroying approximately 50 percent of nests (Hickey *et al.* 1995). Hatching success at Point Reyes National Seashore increased after exclosures were used to protect western snowy plover nests from ravens in 1996. Approximately 12 percent of nests in San Diego County were destroyed by ravens (Powell *et al.* 1996, Powell *et al.* 1997). Raven populations in coastal California have significantly increased in recent decades (Leibezet and George 2002), and as their range expands they are becoming increasingly significant as a nest predator on western snowy plovers; ravens were observed to destroy nests in Monterey Bay for the first time in 2002 and 2003 (G. Page *in litt.* 2004*b*). In northern California ravens are the single most limiting factor on western snowy plover reproduction (Colwell *et al.* 2006). Ravens also prey on western snowy plover chicks, but not nearly to the extent that they do on eggs. However, at Point Reyes raven predation primarily affected chicks after exclosures were erected to protect snowy plover eggs (S. Allen *in litt.* 2004).

Gulls pose a special threat to breeding western snowy plovers because they not only depredate nests and chicks, but also usurp and trample western snowy plover nesting habitat and crush eggs (Persons and Applegate 1997, Point Reyes Bird Observatory unpublished data, Widrig 1980, J. Albertson *in litt.* 1999, Page *et al.* 1983).

The first time a gull-billed tern was found in San Diego County, California, was in 1985. Two years later they were nesting in south San Diego Bay (Unitt 2004). Since then, the nest colony has steadily increased with an estimated 52 pairs in 2006 (Patton 2006a). Gull-billed terns have become a concern to managers of beach-nesting birds in the region. Gull-billed terns were first documented taking California least terns (presumably chicks) in south San Diego Bay in 1992 (Caffrey 1993). Patton (2006a) summarizes recent incidents of gull-billed tern predation on both terns and western snowy plovers. He notes roughly 20 to 60 California least terns and 1 to 4 western snowy plover depredations by gull-billed terns and a greater number was suspected. Although the documented number of gull-billed tern depredations on western snow plovers is considerably lower than on California least terns, it is difficult to know the full extent of gull-billed tern impacts (Patton 2006b), especially for the plovers whose nests are more dispersed and less easily monitored.

Unlike management of other avian predators, management of gull-billed terns is problematic. The local subspecies of gull-billed tern, *G. n. vanrossemi*, is limited to western North America (Molina and Erwin 2006, but see Unitt 2004). The subspecies nests in scattered, localized colonies and "[i]n 2003 and 2005, the entire North American population of *vanrossemi* gull-billed terns ranged from about 533 to 810 pairs" (Molina and Erwin 2006). This means that this predator is considerably rarer than the listed bird species upon which it preys (California least terns and western snowy plovers), which poses a conundrum for managers of western snowy plovers and California least terns (Unitt 2004). Because of the gull-billed tern's status, lethal predator control has not been used on this species since 1999 (Unitt 2004). Gull-billed terns will likely become a greater source of management concern as the local population of this species grows. Gull-billed terns have been observed at other locations of beach-nesting birds farther north from San Diego Bay, including Camp Pendleton, San Diego County (Foster 2005); Bolsa Chica, Orange County (Hamilton and Willick 1996), and Venice Beach, Los Angeles County (McCaskie and Garrett 2005).

Loggerhead shrikes are not known to take western snowy plover eggs, but do prey upon chicks and locally can have substantial effects on fledging success (Warriner *et al.* 1986, D. George *in litt.* 2001, Page *et al.* 1997, George 1997, Page 1988, Feeney and Maffei 1991).

Although not known to be predators of western snowy plover eggs, American kestrels are predators of chicks and possibly adults (D. George, pers. comm. 1998). Fledging success increased from 9 to 64 percent after a kestrel unexpectedly disappeared from a western snowy plover nest site in Moss Landing Wildlife Area (Page *et al.* 1998). In 1997, a merlin was suspected of taking 13 banded adults within the period of a few days at Salinas River National Wildlife Refuge. Also, western snowy plover chicks and adults are among the avian prey of the peregrine falcon (B. Walton, University of California Santa Cruz, pers. comm. 1998; D. George, pers. comm. 1998; Feeney and Maffei 1991). Northern harriers are effective predators of western snowy plover chicks and adults. In 1987, a harrier was observed hunting on the islands in the Salinas River where only approximately one third of the hatched chicks reached fledging age (Point Reyes Bird Observatory unpubl. data). At the Moss Landing Wildlife Area, fledging success dropped from 61 to 23 percent after a harrier began foraging there (Page *et al.* 1997). A northern harrier was seen capturing 2 to 4 western snowy plover chicks at Moss Landing salt ponds in 2000 (D. George *in litt.* 2001).

In recent decades, alien eastern red foxes have become a serious new predator of endangered and threatened animals in coastal habitats (Jurek 1992, Golightly *et al.* 1994, Lewis *et al.* 1993). Nonnative red foxes were imported into the southern Sacramento Valley, primarily for hunting and fur farming purposes, as early as the 1870s and experienced explosive spread in the 1970s and 1980s (Jurek 1992, Lewis *et al.* 1993, 1995). The red fox now occurs throughout a significant portion of coastal California, including Marin, San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Ventura, Orange, and Los Angeles Counties (California Department of Fish and Game 1994). It also occurs at Monterey Bay (G. Page *in litt.* 1988) and San Francisco Bay (Harding *et al.* 1998), including the additional San Francisco Bay area counties of Napa, Solano, Contra Costa, Alameda, and Santa Clara (California Department of Fish and Game 1994). Red foxes also are present in some areas of coastal Oregon where western snowy plovers breed (D. George *in litt.* 2001, Lauten *et al.* 2006*b*).

Red foxes have been identified as a significant predator of western snowy plover eggs in the Monterey Bay area, where they are suspected of also preying on adults and chicks. On Monterey Bay beaches, red fox depredation of western snowy plover eggs resulted in a decline in clutch hatching rate of 30 percent from 1984 to 1990. After exclosures and mammalian predator control came into use to protect nests around Monterey Bay, annual clutch hatching rates have climbed from 43 to 68 percent (Neuman *et al.* 2004).

Predation of western snowy plover nests and chicks by red fox have been documented at Bandon Beach, New River and other portions of OR-15 on the Oregon coast. Biologists have documented red fox tracks around western snowy plover nest exclosures and have followed fox tracks back to dens located within western snowy plover nest areas. As part of the emergency response to the New Carissa oil spill in February 1999, a predator program was implemented. Animal and Plant Health Inspection Service (APHIS) Wildlife Services Division personnel removed 17 red fox from the New River area over a 3 month period (S. Richardson *in litt.* 2001). Ongoing predator management since 2002 has removed an average of 15 foxes per year from Bandon Beach/New River (Lauten *et al.* 2006*b*).

The U.S. Department of Agriculture, Wildlife Services Branch, has been involved in predator damage management for protection of threatened and endangered species for over 10 years in California. The management of nonnative red foxes has become a controversial issue in many areas of California, particularly in coastal habitats near urban areas (California Department of Fish and Game 1994). In November 1998, California voters approved Proposition 4, which banned the use of leghold traps in California. In February 1999, the U.S. District Court issued a Preliminary Declaratory Relief Order, which allows the use of padded leghold traps on Federal and non-Federal lands for the purpose of protecting threatened or endangered species. Trapping of nonnative and native predators of western snowy plovers will therefore not be affected by Proposition 4 (J. Albertson *in litt.* 1999).

Coyotes are known predators of western snowy plover eggs in the Pismo Beach/Santa Maria River area of San Luis Obispo County (T. Applegate, pers. comm. 1996). They are the main nest predator of eggs on Vandenberg Air Force Base where they were the cause of 43 percent of all clutch losses attributed to predators from 1994 to 1997 (Persons and Applegate 1997). At Vandenberg Air Force Base, coyotes may be attracted to marine mammal carcasses on the beach early in the western snowy plover nesting season (Page and Persons 1995). Coyotes also have been identified as predators of western snowy plover nests at Mono Lake, California (Page *et al.* 1983).

Striped skunks have been recorded as predators of western snowy plover eggs (Hickey *et al.* 1995, George 1997, Page *et al.* 1997, Hutchinson *et al.* 1987, Stein 1993, Stern *et al.* 1991). Skunks were believed to be the main cause of nest loss on Morro Bay Spit in 1987, the only year that the reproductive success of western snowy plovers has been monitored at that location (Hutchinson *et al.* 1987). Persons and Ellison (2001) reported that the striped skunk was the predominant predator of nests at Morro spit, destroying 87 percent of depredated nests in 2000.

Domestic and feral cats are widespread predators. The threat of predation of western snowy plovers by cats increases when housing is constructed near western snowy plover breeding habitat. As natural-appearing beaches continue to be surrounded by urban areas, western snowy plovers will increasingly be subjected to this predator in the future. Predation by cats is difficult to measure because of the difficulty in finding evidence of bird remains, but they are known to take western snowy plover adults and eggs (B. Farner, pers. comm. *in* Powell and Collier 1994; Page 1988; D. George *in litt.* 2001).

Predation, while predominantly a natural phenomenon, is exacerbated through the introduction of nonnative predators and unintentional human encouragement of larger populations of native predators. Elevated predation pressures result from landscape-level alterations in coastal dune habitats which, in turn, now support increased predator populations within the immediate vicinity of nesting habitat for western snowy plovers. Urbanization benefits red fox population growth by eliminating coyotes, which are the red fox's most common native predator and competitor; by providing ready sources of food, water and denning sites; and by aiding dispersion of foxes into new areas. Red foxes disperse readily in urban areas because there are no predators besides the domestic dog. Red foxes traverse most urban habitats, and readily cross busy highways and travel long distances underground through culverts (Lewis *et al.* 1993). Other predators, such as corvids, attracted by the presence of human activities (*e.g.*, improper disposal of trash), may frequent beaches in increasing numbers. Gulls have greatly expanded their range and numbers, especially along the United States portion of the Pacific coast, as a result of human-supplied food sources (trash, fish offal, and dumps). Thousands of California gulls now breed in the southern part of San Francisco Bay, where only a few were present in the early 1980s (J. Albertson *in litt.* 1999). This population growth is attributed largely to the increase in landfills along the Bay within the last 20 years. Also, crows and ravens forage at landfills. Buick and Paton (1989) found that losses of hooded plover (*Charadrius rubricollis*) nests with human footprints around them were higher than at those without footprints, suggesting "that scavenging predators may use human footprints as a visual cue in locating food." Beach litter and garbage also attract predators such as skunks and coyotes (*e.g.*, N. Read *in litt.* 1998). Unnatural habitat features such as landscaped vegetation (*e.g.*, palm trees), telephone poles, transmission towers, fences, buildings, and landfills near western snowy plover nesting areas attract predators and provide them with breeding areas (*e.g.*, J. Buffa *in litt.* 2004). These alterations all combine to make the coastal environment more conducive to various native and nonnative predators that adversely affect western snowy plovers.

Substantial evidence exists that human activities are affecting numbers and activity patterns of predators on western snowy plovers. For example, increased depredation of western snowy plover nests by ravens at the Oliver Brothers salt pond, California, may be an indirect adverse impact of nearby installation of light structures by the California Department of Transportation and high-tension power lines by the Pacific Gas and Electric Company, thereby creating corvid nesting sites

(G. Page, Point Reyes Bird Observatory, pers. comm. 1997). Raven nests have also been discovered by National Wildlife Refuge biologists in transmission towers near other snowy plover nesting areas managed by the Don Edwards San Francisco Bay National Wildlife Refuge in Warm Springs, Alviso, and Mountain View (J. Buffa *in litt.* 2004). On the Oregon coast, predation risk by mammals has increased as a result of the spread of European beachgrass, Scotch broom, and shore pine, which has transformed vast areas of open sand into dense grass-shrub habitat, providing excellent habitat for native and nonnative mammalian predators, such as skunks, raccoons, foxes, and feral cats (Stern *et al.* 1991). At Vandenberg Air Force Base, coyote predation can be exacerbated by human presence when trash or debris is left behind (N. Read *in litt.* 1998).

Signing and fencing of restricted areas on the beach may provide perches for avian predators of western snowy plover adults or chicks (Hallett *et al.* 1995). Although signs and fences are important conservation tools in many areas, land managers need to be aware that modifications to them may be necessary to deter predators in some circumstances.

**4. The Inadequacy of Existing Regulatory Mechanisms**

The western snowy plover is protected by the Federal Migratory Bird Treaty Act (16 U.S.C. 703 *et seq.*) and, in each state, by State law as a nongame species. The western snowy plover's breeding habitat, however, receives only limited protection from these laws (*e.g.*, the Migratory Bird Treaty Act prohibition against taking "nests"). Listing of the western snowy plover under State endangered species laws generally provides some protection against direct take of birds, and may require State agencies to consult on their actions, but may not adequately protect habitat. State regulations, policies, and goals include mandates both for protection of beach and dune habitat and for public recreational uses of coastal areas; consequently they may conflict with protection of western snowy plovers in some cases. Section 404 of the Clean Water Act (33 U.S.C. 1251 et seq.) and section 10 of the Rivers and Harbors Act (33 U.S.C. 403) are the primary Federal laws that could provide some protection of nesting and wintering habitat of the western snowy plover that is determined by the U.S. Army Corps of Engineers (Corps) to be wetlands or historic navigable waters of the United States. These laws, however, would apply to only a small fraction of the nesting and wintering areas of the western snowy plover on the Pacific coast. Aside from the Migratory Bird Treaty Act, western snowy plovers have no protection status in Mexico.

To effectively recover the western snowy plover, it is necessary to develop participation plans among cooperating agencies, landowners, and conservation organizations to assure protection and appropriate management of breeding, wintering, and migration areas. Since listing of the western snowy plover in 1993, several local working groups have been developed and local governments and State and Federal agencies have cooperated extensively to implement a wide variety of western snowy plover conservation actions. These partners continue to work to implement appropriate management of coastal areas for recovery of the western snowy plover. These conservation efforts and the environmental policies of State and Federal agencies are described in greater detail in the Conservation Efforts section, below.

For additional discussion of regulatory mechanisms and management actions taken by California State Parks and other entities, see U.S. Fish and Wildlife Service (2006a).

### 5. Other Natural or Manmade Factors Affecting Their Continued Existence

#### *a. Natural Events*

Western snowy plover breeding and wintering habitat is subject to constant change from weather conditions. Stenzel *et al.* (1994) reported that the quality and extent of western snowy plover nesting habitat is variable in both the short- and long-term. Coastal beaches increase in width and elevation during the summer through sand deposition, making marginal beaches more suitable for nesting later in the season. Over the longer term, an increase or decrease in habitat quality may occur after several years of winter storms. Based on the amount of flooding, the availability of dry flats at the edges of coastal ponds, lagoons, and man-made salt evaporators also varies within and between seasons. Therefore, the number of western snowy plovers breeding in some areas may change annually or even over one breeding season in response to natural alterations in habitat availability (Stenzel *et al.* 1981).

Because most western snowy plover nesting areas occur on unstable sandy substrates, nest losses caused by weather-related natural phenomena commonly occur. High tides and strong winds cause many nest losses. Events such as extreme high tides (Wilson 1980, Stenzel *et al.* 1981), river flooding (Stenzel *et al.* 1981), and heavy rain (Wilson 1980, Warriner *et al.* 1986, Page 1988) have been reported to destroy or wash away nests. The annual percentage of total nest losses attributed to weather-related phenomenon has reached 15 to 38 percent at some locations (Wilson 1980, Warriner *et al.* 1986, Page 1988).

Stormy winters can adversely affect the western snowy plover. It is suspected that the severe storms occurring during the El Niño atmospheric and oceanic phenomenon of the winter of 1997/1998 caused a 10 to 30 percent decline in the 1998 western snowy plover breeding population, depending on the coastal region. In all monitored recovery units, the number of breeding birds in 1998 was lower than in the 1997 nesting season. Additionally, a very wet spring resulted in a later than normal breeding initiation and fewer nesting attempts.

The western snowy plover population naturally varies, both spatially and temporally, because of natural changes in weather and habitat conditions from year to year. However, as described above, human influences over the past century (*e.g.*, habitat destruction, invasion of introduced beachgrass, and elevated predation levels) have reduced the western snowy plover's ability to respond to these natural perturbations.

***b. Disturbance of Breeding Plovers by Humans and Domestic Animals***

The coastal zone of the United States, including both open coastal areas and inland portions of coastal watersheds, is home to over one-third of the U.S. human population, and that proportion is increasing (U.S. Fish and Wildlife Service 1995*a*). The southern California coastal area, which constitutes the central portion of the western snowy plover's coastal breeding range, attracts large crowds on a regular basis (Figure 6). The increasing level of human recreation was cited as a major threat to the breeding success of the Pacific coast population of the western snowy plover at the time of listing (U.S. Fish and Wildlife Service 1993*a*).


**Figure 6.** Recreationists at Salt Creek Beach, California (photo by Ruth Pratt, with permission).

**i. Pedestrians**

Pedestrians (*e.g.*, beach walkers and joggers) can cause both direct mortality and harassment of western snowy plovers. Pedestrians on beaches may crush eggs or chicks and chase western snowy plovers off their nests. Separation of western snowy plover adults from their nests and broods can cause mortality through exposure of vulnerable eggs or chicks to heat, cold, blowing sand, and/or predators. Pedestrians have been known to inadvertently step on eggs and chicks, deliberately take eggs from nests, and remove chicks from beaches, erroneously thinking they have been abandoned. People also may cause broods of western snowy plovers to run away from favored feeding areas. These effects are described in more detail below. Trash left on the beach by pedestrians also attracts predators. In addition to public pedestrians, military personnel using the beach for maneuvers, boat launches, and landings have the potential to similarly cause adverse impacts to western snowy plovers.

Beach-related recreational activities that are concentrated in one location (*e.g.*, sunbathing, picnicking, sandcastle building, birding, and photography) can negatively affect incubating adult western snowy plovers when these activities occur too close to their nests. Recreational activities that occur in the wet sand area (*e.g.*, sand sailing) can adversely affect western snowy plovers when they disturb plover adults or broods, which feed at the edge of the surf along the wrack line. Recreational activities that occur in or over deep water (such as the beach- and water-oriented activities of surfing, kayaking, wind surfing, jet skiing, and boating, and the coastal-related recreational activity of hang gliding) may not directly affect western snowy plovers; however, they can potentially be detrimental to western snowy plovers when recreationists use the beach to take a break from these activities, or as access, exit, or landing points.

Concentrations of people may deter western snowy plovers and other shorebirds from using otherwise suitable habitats. Anthony (1985) found that intensive human activity at Damon Point had a "bracketing effect" on the distribution of nesting western snowy plovers, confining their breeding activity to a section of the spit and precluding their regular use of otherwise suitable habitat. Fox (1990) also found that western snowy plovers avoided humans at Damon Point, and the presence of fishermen and beachcombers kept them hundreds of yards away from potential habitat. Because early-nesting western snowy plovers have narrower beaches from which to select nest locations, recreational use may be more concentrated in the limited habitat available. Also, repeated intrusions by people into western snowy plover nesting areas also may cause birds to move into marginal habitats where their chances of reproductive success are reduced. Studies of the Atlantic coast population of the piping plover (*Charadrius melodus*), an eastern species with habitat requirements very similar to the snowy plover, indicate that some piping plovers that nest early in the season are forced to move elsewhere when human use becomes too intense (Cairns and McLaren 1980). These authors concluded that piping plovers that nest early, before beaches become heavily used for recreation, "cannot predict and avoid reproductive failure in habitats that otherwise appear suitable to them." Burger (1993) observed that piping plovers, in response to human disturbance, spent more energy on vigilance and avoidance behavior at the expense of foraging activity, and sometimes abandoned preferred foraging habitat.

Page *et al.* (1977) observed western snowy plovers' response to human disturbance at two coastal beaches where normal beach use ranged from light to heavy. The study included 156 hours of observation at 15 western snowy plover nests. At Point Reyes, they found that pedestrians disrupt incubation of nests. When humans approached western snowy plovers, adults left their nests 78 percent of the time when people were within 50 meters (164 feet) and 34 percent of the time when people were over 100 meters (328 feet). They also found that western snowy plovers' reaction to disturbance by humans varied, ranging from one bird remaining off the nest for less than 1 minute when a person walked within 1 meter (3 feet) of the nest on a heavily-used beach to another western snowy plover leaving the nest when three people were 200 meters (656 feet) away on a less-used beach. They noted that "birds exposed to prolonged human activity near the nest seemed to become accustomed to it." It has been speculated that predators of western snowy plovers may benefit from a decline in wariness by western snowy plovers nesting on beaches that are subject to ongoing high levels of human disturbance (Persons and Applegate 1997).

Lafferty (2001) observed western snowy plovers' response to people, pet dogs, equestrians, crows and other birds. Observations were made at Devereux Slough in Santa Barbara County, Santa Rosa Island, San Nicolas Island, and Naval Base Ventura County (Point Mugu). This study found that western snowy plover are most frequently disturbed when approached closely (within 30 meters) by people and animals. The most intense disturbance (causing the western snowy plover to fly away) were in response to crows, followed by horses, dogs, humans, and other birds. Lafferty (2001) created a management model based on his findings and estimated flight response disturbances under different scenarios. The model predicted a reduced disturbance response for buffer zones of 20 to 30 meters.

Fahy and Woodhouse (1995) quantified the levels of recreational disturbance, their effect on western snowy plovers, and the effectiveness of the Linear Restriction Program at Ocean Beach, Vandenberg Air Force Base in 1995. Under this program signs directed visitors not to cross from the outer beach into the Linear Restriction area (inland of mean high tide mark, in dune habitat used by western snowy plovers). Seventy percent of all disturbances were in compliance with restriction warning signs. The disturbance types that were most and least frequently in compliance with the boundary were joggers or walkers and stationary visitors, respectively. The closer the disturbance occurred to the plover, the more severe the plover response. All-terrain vehicles caused the most significant alert and flight behaviors by western snowy plovers, even though they were in compliance with the Linear Restriction. The disturbance types that caused incubating western snowy plovers to flush from their nests most frequently were joggers and walkers, followed by joggers or walkers with dogs off leash, and stationary visitors. The disturbance types that kept incubating western snowy plovers off their nests for the longest period of time were stationary visitors and surf fishermen, probably because of the duration of these stationary disturbances that occurred close to nests. Weekends accounted for 60 percent of all disturbances. The enforcement personnel appeared to have a limited presence; their presence was documented during only 14 percent of all identified disturbances.

Hoopes *et al.* (1992) quantified human use and disturbance to piping plovers in Massachusetts during the 1988 and 1989 nesting seasons. They found pedestrians caused piping plovers to flush or move at an average distance of 23 meters (75 feet). Pedestrians within 50 meters (164 feet) of the birds caused piping plovers to stop feeding 31 percent of the time.

Point Reyes Bird Observatory found that management actions that included exclusion zones around nesting areas, seasonal closure to dogs, and active weekend docent programs reduced mortality of chicks and eggs during the weekend such that the weekend and weekday mortality was the same (Peterlein and Roth 2003).

At the Pajaro River mouth in California, at least 14 percent of western snowy plover clutches were destroyed by being driven over, stepped on, or deliberately taken by people (Warriner *et al.* 1986). Since exclosures have been used to protect nests at the Pajaro River mouth and other locations at Monterey Bay, a few nests have still been deliberately destroyed by vandals in most years (Point Reyes Bird Observatory unpublished data). At South Beach, Oregon, the number of western snowy plovers declined from 25 in 1969 to 0 in 1981 when a new park was constructed next to the beach and the adjacent habitat became more accessible to vehicles and people (Hoffman 1972 *in* Oregon Department of Fish and Wildlife 1994).

At Vandenberg Air Force Base, western snowy plover monitoring during 1993 at South Beach (where recreational use was high) and North Beach (where recreational use was low) found the rate of nest loss caused by humans differed markedly: 24.3 percent of South Beach nests were lost compared to only 3.0 percent of North Beach nests (Persons 1994). Persons and Applegate (1997) reported that "rates of reproductive success, combined for 1994 through 1997, were substantially higher on North Beach than on South Beach." This difference occurred despite the fact that nesting habitat was posted as off-limits during the nesting season in 1994. However, at that time restrictions were new and not strictly enforced (R. Dyste *in litt.* 2004). Since 2000, public access has been restricted and fully enforced by Vandenberg Air Force Base personnel. Additionally, Santa Barbara County-supported volunteer docents were present at Surf Station (within Vandenberg Air Force Base) during the 2001-2003 plover breeding seasons when the beach was open for public access. In 2003, plover monitors did not document the loss of any nests within Surf Station Beach as a result of trampling by humans (R. Dyste *in litt.* 2004).

Loss of western snowy plover chicks also may occur because of human activities. The number of young produced per nesting attempt increased from 0.75 in disturbed habitat to 2.0 for nests free of disturbance at Willapa National Wildlife Refuge, Washington (Saul 1982). At Vandenberg Air Force Base, the 1997 fledging success of western snowy plovers was 33 to 34 percent on North Beach where recreational activity is restricted and only 12 percent on South Beach where recreational use is high (Persons and Applegate 1997). In 1999 and 2000, Ruhlen *et al.* (2003) found that increased human activities on Point Reyes beaches had a negative effect on western snowy plover chick survival. In both 1999 and 2000, western snowy plover chick loss was about three times greater on weekends and holidays than on weekdays. In most coastal areas, beach visitation in summer months is much higher on weekends and holidays than on weekdays.

Flemming *et al.* (1988) measured the effects of human disturbance on reproductive success and behavior of piping plovers in Nova Scotia. To assess human disturbance, they recorded positions of people, pedestrian tracks, and vehicle tracks, then defined classes based on visits per week. They found significantly fewer young survived in areas of high versus low disturbance; humans elicited a significantly higher response level from adult piping plovers than did predators or nonpredatory species; chicks fed less and were brooded less when humans were within 160 meters (525 feet); and chick peck rate during feeding was lower when humans were present. They speculated that because chicks shifted from feeding and energy conservation activities to vigilance and cryptic predator avoidance behaviors, their energy reserves would be depleted, making them more susceptible to predators and inclement weather. They postulated that a decline in piping plover abundance in Nova Scotia could be caused by human disturbance altering chick behavior. Fewer chicks survived to 17 days in areas heavily disturbed by humans.

Schultz and Stock (1993) studied the effects of tourism on colonization, distribution, and hatching success of Kentish plovers (*Charadrius alexandrinus alexandrinus*), a Eurasian subspecies of the snowy plover, at the Wadden Sea in Germany. They measured disturbance intensity by counting and mapping tourists on 50 days from April to July, during times of peak human activity (1500 to 1600 hours) and in intervals of 30 minutes throughout other days. An index of person-hours per area per day was calculated. They found that Kentish plovers did not colonize heavily-disturbed areas and that resting and sunbathing people were apparently more disruptive than walking people because the latter generally followed the high-tide line. Clutch losses were lowest in areas with little disturbance and highest in areas with heavy disturbance. They indicated that hatching success in highly disturbed areas, even with optimal habitat, is as low as in poor habitat with a low level of disturbance.

**ii. Dogs**

Dogs on beaches can pose a serious threat to western snowy plovers during both the breeding and nonbreeding seasons. Unleashed pets, primarily dogs, sometimes chase western snowy plovers and destroy nests. Repeated disturbances by dogs can interrupt brooding, incubating, and foraging behavior of adult western snowy plovers and cause chicks to become separated from their parents. Pet owners frequently allow their dogs to run off-leash even on beaches where it is clearly signed that dogs are not permitted or are only permitted if on a leash. Enforcement of pet regulations on beaches by the managing agencies is often lax or nonexistent.

A number of examples of disruptive ways that dogs affect western snowy plovers have been noted at beaches in Monterey County (Marina State Beach), Santa Cruz County (Laguna, Scott Creek, and Seabright Beaches) and San Mateo County (Half Moon Bay and Pacifica Beaches) (D. George, pers. comm. 1997). Incubating birds have been flushed from nests by dogs, including nests located inside areas protected by symbolic fencing. Dogs also have displaced adults from nests with newly-hatched chicks. Roosting and feeding flocks, as well as individual birds, have been deliberately and persistently pursued by dogs. At Laguna Creek Beach, Zmudowski State Beach, and Salinas River State Beach, dogs partially or entirely destroyed western snowy plover nests which were in several cases, protected with symbolic fencing (D. George, pers. comm. 1997; Point Reyes Bird Observatory unpublished data; G. Page, pers. comm. 1998). Feral dogs are suspected to have disturbed western snowy plover nests and chicks on San Francisco Bay salt ponds (J. Albertson *in litt.* 1999).

Even when not deliberately chasing birds, dogs on a beach may disturb western snowy plovers and other shorebirds that are roosting or feeding. Page *et al.* (1977) found that western snowy plovers flushed more frequently and remained off their nests longer when a person was accompanied by a dog than when alone. They collected data during 156 hours of observation at 15 nests at Point Reyes, California, and found the following distances at which western snowy plovers flushed from their nests as a result of disturbance by people with dogs. Within 50 meters (164 feet), people with dogs caused flushing 100 percent of the time. At a distance of over 100 meters (328 feet), people with dogs caused flushing 52 percent of the time (Page *et al*. 1977). Fahy and Woodhouse (1995) found that joggers or walkers with off-leash dogs caused a significantly greater number of avoidance responses from western snowy plovers than other types of disturbances at Ocean Beach, Vandenberg Air Force Base, California. Lafferty's (2001) management model predicted that intense disturbances could be dramatically reduced by removing dogs.

At wintering sites such as Ocean Beach in San Francisco, California, off-leash dogs have caused frequent disturbance and flushing of western snowy plovers and other shorebirds. Off-leash dogs chase wintering western snowy plovers at this beach and have been observed to regularly disturb and harass birds (P. Baye, U.S. Fish and

Wildlife Service, pers. comm. 1997). Observations by National Park Service volunteers suggest that unleashed pets represent the most significant recreational threat to wintering western snowy plovers and migratory shorebirds at Ocean Beach, because of the prolonged and repeated disturbance created when they chase birds (Hatch 1997). In 1995 and 1996, during 45 hour-long observations of wintering flocks of western snowy plovers at Ocean Beach, western snowy plovers responded by moving in 73 percent of 74 instances when dogs with or without people approached to within 15 meters (50 feet) (Golden Gate National Recreation Area unpublished data). When shorebirds are flushed, they must spend more energy on vigilance and avoidance behaviors at the expense of foraging and resting activity (Burger 1993, Hatch 1997). Disruption of foraging and roosting may result in decreased accumulation of energy reserves necessary for shorebirds to complete the migration cycle and successfully breed (Burger 1986, Pfister *et al.* 1992). Dog disturbance at wintering and staging sites, therefore, may adversely affect individual survivorship and fecundity, thereby affecting the species at the population level.

**iii. Motorized Vehicles**

Unrestricted use of motorized vehicles on beaches is a threat to western snowy plovers and their habitat. Motorized vehicles may affect remote stretches of beach where human disturbance would be slight if access were limited to pedestrians. The magnitude of this threat is variable, depending on level of use and type of terrain covered. Use of motor vehicles on coastal dunes may also be destructive to dune vegetation, especially sensitive native dune plants.

Driving vehicles in breeding habitat may cause destruction of eggs, chicks, and adults, abandonment of nests, and considerable stress and harassment to western snowy plover family groups (G. Page, pers. comm. 1997; J. Myers *in litt.* 1988; J. Price *in litt.* 1992; Stern *et al.* 1990; Casler *et al.* 1993; S. Richardson, pers. comm. 1998; Widrig 1980). In addition to recreational vehicles, vehicles used for military activities have also caused western snowy plover mortality (Powell *et al.* 1995, 1997; Persons 1994).

Driving motor vehicles at night seems to be particularly hazardous to western snowy plovers. Drivers of all-terrain vehicles at night have run over and killed western snowy plover adults at Vandenberg Air Force Base, and State park ranger patrol vehicles have crushed western snowy plover chicks at Oceano Dunes State Vehicular Recreation Area during night patrols (R. Mesta *in litt.* 1998).

On the Eel River gravel bars, vehicle use (including motorcycles, ATVs, and full-size 4x4s) has resulted in the crushing of nests and disturbance to nesting plovers (Colwell *et al.* 2006).

Western snowy plover adults and chicks have been observed using tire tracks and human footprints for loafing at Camp Pendleton and Naval Amphibious Base Coronado (Powell and Collier 1994). This behavior increases their chances of being run over. Western snowy plover chicks also may have difficulty getting out of tire ruts, thereby increasing their likelihood of being run over. Their cryptic coloring and habit of crouching in depressions like tire tracks makes western snowy plover chicks especially vulnerable to vehicular traffic. In Massachusetts, between 1989 and 1997, a total of 25 piping plover chicks and 2 adults were found dead in off-road vehicle tire ruts on the upper beach between the mean high tide line and the foredune (U.S. District Court of Massachusetts 1998).

Hoopes *et al.* (1992) found off-road vehicles caused piping plovers to flush or move at an average distance of 40 meters (131 feet). Off-road vehicles within 50 meters (164 feet) of the birds caused piping plovers to stop feeding 77 percent of the time. While most responses by piping plovers to off-road vehicles resulted in movement by the birds, they observed three instances where the plovers “froze” in response to the off-road vehicles. Both types of responses have a negative impact on plovers through either disturbance, interruption of feeding behavior, or increasing the risk that piping plovers will be hit or crushed by vehicles.

At wintering sites, disturbance from motorized vehicles may harass western snowy plovers and disrupt their foraging and roosting activities, thereby decreasing energy reserves needed for migration and reproduction. When motorcycles, most of which were in the wet sand zone, were driven at high speed along Ocean Beach in San Francisco, Hatch (1997) observed that western snowy plovers and other shorebirds were continually disturbed and often took flight.

### iv. Beach Cleaning

Removal of human-created trash on the beach is desirable to reduce predation threats by eliminating food for predators of western snowy plovers; however, the indiscriminate nature of mechanized beach-cleaning adversely affects western snowy plovers and their habitat. Mechanized beach cleaning can be dangerous to western snowy plovers by crushing their clutches and chicks or causing prolonged disturbance from the machine's noise. Also, this method of beach cleaning removes the birds' natural wrackline (area of beach containing seaweed and other natural wave-cast organic debris) feeding habitat, reducing the availability of food. Kelp and driftwood, with their associated invertebrates, are regularly removed and the upper layer of sand is disturbed. Beach grooming also alters beach topography, removes objects associated with western snowy plover nesting, and prevents the establishment of native beach vegetation (J. Watkins *in litt.* 1999). In all of Los Angeles County and parts of Ventura, Santa Barbara, and Orange Counties, California, entire beaches are raked on a daily to weekly basis. Large rakes, with tines 5 to 15 centimeters (2 to 6 inches) apart, are dragged behind motorized vehicles from the waterline to pavement or to the low retaining wall bordering the beaches (Stenzel *et al.* 1981). Even if human activity was low on these beaches, grooming activities completely preclude the possibility of successful western snowy plover nesting (Powell 1996).

### v. Equestrian Traffic

Most equestrian use on beaches is directed to wet-sand areas. However, during high tide periods, horseback riders on the beach sometimes enter coastal dunes or upper beach areas (Figure 7), where they may crush clutches or disturb western snowy plovers (Point Reyes Bird Observatory unpublished data, Page 1988, Persons 1995, Craig *et al.* 1992, Woolington 1985).

**Figure 7.** Equestrians on beach (photo by U.S. Forest Service, with permission).

### vi. Fishing

Impacts on western snowy plover nesting may be associated with surf fishing and shellfish harvesting in and near western snowy plover habitat. The improper disposal of offal (waste parts of fish), bait, and other litter attracts crows, ravens, and gulls, which are predators of western snowy plover eggs and chicks. Also, western snowy plovers may become entangled in discarded fishing lines (G. Page, pers. comm. 1998).

Surf fishing is a commercial enterprise in many coastal locations, including the ocean smelt fishery in northern California (C. Moulton *in litt.* 1997). Recreational surf fishing occurs throughout the California coast. In Humboldt County, California, Redwood National and State Parks have proposed allowing beach vehicle use, by annual permit, for commercial fishing and tribal fishing/gathering on Gold Bluffs Beach, Freshwater Spit, and Crescent Beach (J. Watkins *in litt.* 1999). In the State of Washington, the most popular season for surf fishing is April through July (Washington Department of Fish and Wildlife 1995). At present, demand for surf perch fishing is relatively low in Oregon. However, the Oregon Department of Fish and Wildlife is promoting a surf perch fishery to lessen the demand for anadromous fishing. This fishery would increase vehicle driving to remote and relatively undisturbed sites used by western snowy plovers (K. Palermo *in litt.* 1998*a*).

Because the earliest western snowy plover clutches in Washington are laid between mid-April and mid-May, harvesting of razor clams during the mid-March to mid-May clamming season may have adverse impacts on prospecting or nesting western snowy plovers. Clammers near nesting areas may disturb adults and chicks; human activity in feeding areas may restrict western snowy plover foraging activity, and increased motorized traffic may increase the risk of nest and chick loss (Washington Department of Fish and Wildlife 1995). However, observations of western snowy plover and human activities during the spring 1995 razor clam season showed clamming had no visible impact on western snowy plovers where clamming intensity was low (Kloempken and Richardson 1995). Instances of trespassing into the western snowy plover protection area were noted; however, movement of the western snowy plover protection area boundary about 327 meters (1,073 feet) west of its previous location seemed to benefit the birds by providing more space between them and pedestrian and vehicular disturbances.

**vii. Fireworks**

Fireworks are highly disturbing to western snowy plovers. All western snowy plovers flushed from Coal Oil Point Reserve during a nearby July 4, 2005, fireworks display (C. Sandoval, University of California Santa Barbara, pers. comm. 2005). At Del Monte Beach, California, a western snowy plover chick hatched on July 4, 1996, within an area demarcated by symbolic fencing, and was abandoned by its parents after a fireworks display. Disturbance from the noise of the pyrotechnics is exacerbated by disturbance caused by large crowds attracted to fireworks events. California Department of Parks and Recreation staff estimated that 6,000 people visited Del Monte Beach on that day. Because of the extensive disturbance, the adult western snowy plovers left the nest site with two chicks, abandoned the third chick, and were not seen again (K. Neuman, California Department of Parks and Recreation, pers. comm. 1997). During July 4, 1992, observations of piping plovers that nest on the Breezy Point Cooperative and adjacent beaches of Gateway National Recreation Area in Queens, New York, the birds were disturbed by fireworks displays (Howard *et al.* 1993). Management recommendations for this area included prohibition of fireworks in or near the fenced and posted nesting and brood-rearing areas.

### viii. Kite Flying and Model Airplanes

Biologists believe plovers perceive kites as potential avian predators (Hoopes *et al.* 1992, Hatch 1997). The reaction of western snowy plovers to kites at Ocean Beach in San Francisco, California, "ranged from increased vigilance while roosting in close proximity to the kite flying, to walking or running approximately 10 to 25 meters (33 to 82 feet) away and resting again while remaining alert" (Hatch 1997). It is expected that stunt-kites would cause a greater response from western snowy plovers than traditional, more stationary kites. Stunt kites include soaring-type, two-string kites with noisy, fluttering tails, which often exhibit rapid, erratic movements.

Hoopes *et al.* (1992) found that piping plovers are intolerant of kites. Compared to other human disturbances (i.e., pedestrian, off-road vehicle, and dog/pet), kites caused piping plovers to flush or move at a greater distance from the disturbance, to move the longest distance away from the disturbance, and to move for the longest duration. Piping plovers responded to kites at an average distance of 85 meters (279 feet); moved an average distance of over 100 meters (328 feet); and the average duration of the response was 70 seconds.

It is expected that model airplanes may also have a detrimental impact to western snowy plovers because western snowy plovers may perceive them as potential predators (Hatch 1997).

### ix. Aircraft Overflights

Low-flying aircraft (*e.g.*, within 152 meters (500 feet) of the ground) can cause disturbances to breeding and wintering western snowy plovers. Hatch (1997) found that all types of low-flying aircraft potentially may be perceived by western snowy plovers as predators. She also found that the general response of roosting western snowy plovers to low-flying aircraft at Ocean Beach, San Francisco, California, was to increase vigilance and crouch in depressions on the beach, whereas foraging western snowy plovers frequently took flight. Plovers may, however, become acclimated to aircraft overflights in some instances, since at Naval Air Station North Island they chose to nest repeatedly within military airfield boundaries on runway ovals next to busy military runways (S. Vissman, U.S. Fish and Wildlife Service, pers. comm. 1997). Federal Aviation Regulations, Part 91, General Operating and Flight Rules, require that over open water, aircraft may not be operated closer than 152 meters (500 feet) to any person, vessel, vehicle, or structure. Emergency operations, including those by Coast Guard helicopters, are exempted from these rules. However, helicopters may be operated at less than 152 meters (500 feet) if the operation is conducted without hazard to people or property on the surface (U.S. Federal Aviation Administration 1997). Helicopters can cause excessive noise, which can also disturb western snowy plovers, even at an altitude of 152 meters (500 feet) (Howard *et al.* 1993; J. Watkins *in litt.* 1999; D. Stadtlander, pers. comm. 1999). At Marine Corps Base Camp Pendleton, California, where military training can require aircraft (especially helicopters) to fly at very low elevations, the Marine Corps minimizes impacts to western snowy plovers and California least terns by requiring aircraft to stay at least 91 meters (300 feet) above the ground over tern and plover nesting areas during the nesting season (U.S. Marine Corps 2006).

**x. Special Events**

Special events which attract large crowds, such as media events, sporting events, and beach clean-ups, have a potential for significant adverse impacts when held in or near western snowy plover habitat. An example is the National Marine Debris Monitoring Program, implemented by the U.S. Environmental Protection Agency in conjunction with the National Oceanic and Atmospheric Administration, National Park Service, and the U.S. Coast Guard. This year-round program uses volunteers (including high school students) to document and collect trash and marine debris on coastal transects within western snowy plover nesting and wintering habitat. Potential threats from crowds of people attracted to special events are similar to those previously identified for pedestrians, including direct mortality and harassment of western snowy plovers.

### xi. Coastal Access

Expanding public access to the coast (*e.g.*, State Coastal Trails) for recreation (*e.g.*, walking, hiking, biking) may adversely affect western snowy plovers and their breeding or wintering habitat. Expanded coastal access brings significantly greater numbers of people to the beach and other coastal habitats, exacerbating potential conflicts between human recreational activities and western snowy plover habitat needs (see Pedestrian section). Expanded coastal access may exceed the threshold of beach visitors that public resource agencies (*e.g.*, State Parks and National Park Service) can effectively manage while also meeting their responsibilities to protect natural resources.

Bicycles are known to adversely affect western snowy plovers nesting on levees and roads near San Francisco Bay salt ponds within the Don Edwards San Francisco Bay National Wildlife Refuge. Many of these levees are closed to human access, but some bicyclists trespass onto closed levees. In 1998, one western snowy plover nest, located on the main access road to the Refuge, was run over by a bicycle as biologists were putting up a barrier to protect it (J. Albertson *in litt.* 1999).

### xii. Livestock Grazing

Western snowy plover nests have been trampled by cattle, causing both direct mortality of eggs and flushing of adults from the nests (U.S. Fish and Wildlife Service *in litt.* 1995). Additionally, feral pigs (*Sus scrofa*) may trample western snowy plover habitat and disturb nesting western snowy plovers (R. Klinger, The Nature Conservancy, pers comm. 1998, D. George *in litt.* 2001). Cow and horse manure can introduce seeds of non-native plants into the dunes.

### *c. Oil Spills*

The Pacific Coast population of the western snowy plover is vulnerable to oil spills. Western snowy plovers forage along the shoreline and in sea wrack (seaweed and other natural wave-cast organic debris) at the high-tide line and are thus at risk of direct exposure to oil during spills. The loss of thermal insulation is considered to be the primary cause of mortality in oiled birds (National Research Council 1985, Leighton 1991). Oiled feathers lose their ability to keep body heat in and cold water out, causing reduced insulation, increased metabolic rate, and hypothermia. Ingestion of oil may lead to physiological changes in birds, including pathological effects on the alimentary tract, blood, adrenal glands, kidneys, liver, and other organs (Fry and Lowenstine 1985, Khan and Ryan 1991, Burger and Fry 1993). Exposure of adult birds to oil also may impair reproduction, including reductions in egg laying and hatchability (Ainley *et al.* 1981, Fry *et al.* 1986) and reductions in survival and growth of chicks (Trivelpiece *et al.* 1984). Oil transferred to eggs from plumage or feet of incubating birds can kill embryos (Albers 1977, Albers and Szaro 1978, King and Lefever 1979). Oiled shorebirds may spend more time preening and less time feeding than unoiled birds, such that their body condition and ability to migrate to breeding grounds and reproduce may be impaired (Evans and Keijl 1993, Burger 1997).

Oil spills may result in contamination or depletion of western snowy plover food sources. Elevated concentrations of total petroleum hydrocarbons have been found in the sand crab (*Emerita analoga*), a potential western snowy plover food item, following a southern California oil spill (J.E. Dugan, unpublished data). Oil or other chemicals washed onto mudflats or sand beaches may result in reduction in the availability of invertebrate prey (Kindinger 1981). Elimination of shorebird food resources on intertidal flats of the Saudi Arabian Gulf coast as a result of the large oil spills associated with the 1991 Gulf War led to drastic reductions in the number of shorebirds supported by this habitat (Evans *et al.* 1993). Disturbance and other adverse impacts to western snowy plovers also may occur during oil clean-up activities if response teams are not careful when driving heavy equipment and vehicles or traversing on foot through western snowy plover habitat.

During the 1990s, at least six oil spill incidents in California and one in Oregon resulted in adverse impacts to western snowy plovers. The U.S. Coast Guard and various other State and Federal agencies and the responsible parties responded to these spills. One of these incidents occurred between 1984 and 1998 at Unocal's Guadalupe Oil Field in San Luis Obispo, California contaminated western snowy plover habitat with toxic hydrocarbons. In 1993, oil spilled from a ruptured oil transfer line into McGrath Lake, Ventura County, California and then flowed into the Pacific Ocean. Western snowy plover habitat and prey were contaminated with oil and wintering western snowy plovers were displaced during the cleanup activities (S. Henry *in litt.* 1998, McGrath Oil Spill Restoration Scoping Document 1995). In 1996, the SS Cape Mohican discharged fuel oil into the San Francisco Drydock Shipyard, California, where it spread throughout the central bay and into the Pacific Ocean, oiling western snowy plovers and their beach habitat (Cape Mohican Trustee Council 2002, Point Reyes Bird Observatory unpublished data). In 1997, a pipeline extending between an offshore oil platform (Platform Irene) and the mainland ruptured near Pedernales Point, Santa Barbara County, California, oiling western snowy plovers and wrack where western snowy plovers were seen feeding (Applegate 1998, Ford 1998, Lockyer *et al.* 2002). In 1997 and 1998, large numbers of tarballs became stranded on beaches at Point Reyes National Seashore and resulted in oiling of snowy plovers and their habitat. Subsequent tarball incidents in 2001 and 2002 resulted in identification of the source of the tarballs as the SS Jacob Luckenbach, an oil tanker that sank in 1953 (Carter and Golightly 2003, Point Reyes Bird Observatory unpublished data, Hughes 2003). In 1999, the dredge M/V Stuyvesant spilled fuel oil into the Pacific Ocean off Humboldt Bay, California (U.S. Coast Guard 2001), resulting in oiling of western snowy plovers and their habitat (LeValley *et al.* 2001).

In February 1999, the freighter New Carissa went aground near the North Jetty of Coos Bay, Oregon, breaking apart and spilling 25,000 to 70,000 or more gallons of oil into coastal water. (U.S. Bureau of Land Management 2001). The incident oiled approximately 52 snowy plovers, representing at least 60 percent of the Oregon wintering population of western snowy plover (Stern *et al.* 2000). In Washington, the 1988 Nestucca oil spill and the 1991 Tenyo Maru oil spill may also have affected western snowy plovers or their habitats, although impacts are not as well documented as in the above cases (Larsen and Richardson 1990).

In addition to catastrophic spills like those described above, chronic oil pollution may affect western snowy plovers. Surveys of beached birds have shown that small-volume, chronic oil pollution is an ongoing source of avian mortality in coastal regions (Burger and Fry 1993). Dead oiled birds and tarballs are found regularly on Pacific coast beaches in the absence of reported oil spills (Roletto *et al.* 2000). Potential sources of chronic oiling include natural seeps, bilge water pumping, sunken vessels, urban runoff, and small or unreported spills from vessels, tankers, pipelines, and offshore oil platforms. Elevated concentrations of total petroleum hydrocarbons have been found in the sand crab *(Emerita analoga*), a potential western snowy plover food item, in the vicinity of natural oil seeps (Dugan *et al.* 1997).

Intensive oil spill cleanup operations, including use of vehicles to deploy beach booms, move personnel, and remove debris, cause disturbance to nesting and foraging activities of western snowy plovers. These temporary impacts are offset by restoration of habitat and cleaning affected birds.

***d. Contaminants***

The most likely route of exposure of western snowy plovers to contaminants other than spilled oil is through the diet. Western snowy plovers feed on aquatic and terrestrial insects, and the bioaccumulation of environmental contaminants on western snowy plover nesting and wintering grounds may adversely affect their health and reproduction. Organochlorines are known to have caused reduced avian egg production, aberrant incubation behavior, delayed ovulation, embryotoxicosis, and mortality of chicks and adults (Blus 1982). Selenium has caused decreased hatchability of avian eggs, developmental abnormalities, altered nesting behavior, and embryotoxicosis in birds in field and laboratory studies (Ohlendorf *et al.* 1986, Heintz *et al.* 1987). Mercury can cause decreased hatchability of avian eggs (Connors *et al.* 1975), boron has been shown to reduce hatchability of waterfowl eggs in laboratory experiments (Smith and Anders 1989), and arsenic may also adversely affect avian reproduction (Stanley *et al.* 1994).

Hothem and Powell (2000) analyzed 23 western snowy plover eggs collected from 5 sites (Camp Pendleton Marine Corps Base, Batiquitos Lagoon, Naval Amphibious Base Coronado, Sweetwater Marsh National Wildlife Refuge, and Tijuana Estuary) in southern California from 1994 to 1996 for metals and trace elements, and 20 eggs for organochlorine pesticides and metabolites. All eggs were either abandoned or failed to hatch. Organochlorines, including dieldrin, o,p’-DDD, o,p’-DDE, o,p’-DDT, p,p’-DDD, p,p’-DDE, p,p’-DDT, oxychlordane, and trans-nonachlor were found above the detection limits in western snowy plover eggs. Median DDE and PCB concentrations were less than those normally associated with eggshell thinning. deformities, or other detrimental effects on birds. Twelve metals and trace elements (arsenic, boron, chromium, copper, iron, magnesium, manganese, mercury, nickel, selenium, strontium and zinc) were detected in at least 90 percent of the samples, but generally at background levels. Mean concentrations of all contaminants were below those that would adversely affect reproduction.

Concentrations of mercury in western snowy plover eggs that failed to hatch at Point Reyes National Seashore were five to ten times higher than the mercury concentrations in the five Southern California locations studied by Hothem and Powell (Schwarzbach *et al.* 2003). The mean mercury concentration of 1.07 micrograms/gram (1.07 parts per million), wet weight, in western snowy plover eggs from Point Reyes National Seashore is probably high enough to account for egg failure through direct toxic effects to western snowy plover embryos (Schwarzbach *et al.* 2003). Because only failed and abandoned eggs were taken rather than randomly collected eggs, the extent of mercury contamination of the entire breeding western snowy plover population at Point Reyes can not be reliably assessed from these data; however, the data from the 2000 field season would suggest that about one fifth of the nests appeared to be at risk from adverse effects of mercury (Schwarzbach *et al.* 2003).

***e. Litter, Garbage, and Debris***

Placement of litter, garbage, and debris in the coastal ecosystem can result in direct harm to western snowy plovers and degradation of their habitats. Litter and garbage feed predators and encourage their habitation at higher levels than would otherwise occur along the coast, making predators a greater threat to western snowy plovers. For example, as noted previously, the California gull (*Larus californicus*) has become far more prevalent in the South San Francisco Bay area. Currently, the estimated 25,000 California gulls in this area feed in landfills and forage in salt marshes using habitat that once supported the western snowy plover (J. Albertson, pers. comm. 2005).

Marine debris and contaminated materials on the beach also adversely affect western snowy plovers. Marine debris is attributed to both ocean and shoreline sources. Ocean sources of marine debris and contamination include fishing boats, ships, and cruise lines. Cruise line debris may include small plastic shampoo, conditioner, hand lotion, and shoe polish containers, plastic cups, and balloons (Center for Marine Conservation 1995). Shoreline debris is usually from land sources. Western snowy plovers may become entangled in discarded fishing line, fishing nets, plastic rings that hold together six-packs of canned drinks, and other materials on the beach. Containers of contaminated materials (***e.g.***, motor oil, cleaning fluid, and syringes) can introduce toxic chemicals to the beach. The National Marine Debris Monitoring Program, headed by the U.S. Environmental Protection Agency, was established to clean and track sources of marine debris in coastal areas. This monitoring program, while beneficial to western snowy plovers in the long-term, could potentially adversely affect nesting western snowy plovers since the program is conducted year-round. Similarly, the annual spring SOLV beach cleanup held on the Oregon Coast in late March and the annual Coastal Cleanup Day held on the California coast in September are two organized beach events that are poorly timed with respect to prospecting and nesting western snowy plovers. These programs could greatly improve western snowy plover habitat if timed appropriately.

***f. Water Quality and Urban Run-off***

Many coastal beaches used as habitat by western snowy plovers contain channelized streams or outfalls receiving run-off from urban, industrial, and agricultural areas. Nonpoint sources of water pollution (including hydrocarbons, heavy metals, and household chemicals) could end up at coastal beaches used as western snowy plover foraging areas. In 1995, three dead male western snowy plovers (all banded and local breeders) were found in an area containing local outfalls, including an outfall connected to a sewage treatment plant at Monterey Bay. By the beginning of the next breeding season, it was discovered that another male western snowy plover from this area disappeared and possibly died. Factors unrelated to the outfall have not been ruled out in the disappearance of this bird. One of the birds was analyzed through necropsy and found to have an enlarged liver, but it could not be determined whether there was a relationship between the mortality and the outfall (Point Reyes Bird Observatory unpublished data).

### *g. Management for Other Special Status Species*

In several instances fencing used to enclose California least tern colonies has caused mortality of western snowy plover chicks that have become entangled within the fence mesh (Powell and Collier 1995, Powell *et al.* 1995), or prevented western snowy plover chicks from following their parents to feeding areas by blocking their movement (Powell *et al.* 1996). These issues have largely been resolved by utilizing fencing with a mesh size of less than 0.64 centimeter (0.25 inch), tightening gaps in fencing seams, and installing "gates" in tern fencing (Foster 2005). Monitoring and minimization measures to avoid these impacts continue to be implemented in coordination with the appropriate Fish and Wildlife Offices. Increasing density and abundance of California least terns within colonies may also result in western snowy plovers being displaced a short distance, but the benefits of tern management for western snowy plovers appear to outweigh such conflicts.

At the Channel Islands and other lands managed by the National Park Service and the Department of the Navy, a decline of western snowy plovers may be caused by disturbance and habitat loss resulting from the large increase in numbers of marine mammals on beaches (U.S. Fish and Wildlife Service *in litt.* 1995, U.S. Department of the Navy *in litt.* 2001). Breeding pinnipeds, including northern elephant seals (*Mirounga angustirostris*), northern fur seals (*Callorhinus ursinus*) and California sea lions (*Zalophus californianus*) at San Miguel Island and San Nicolas Island, have occupied western snowy plover nesting habitat. Beach-cast dead whales have, on occasion, posed threats to nesting western snowy plovers. At Point Reyes beaches, large, whole carcasses have washed ashore and other agencies such as the National Marine Fisheries Service have sought to collect them for scientific purposes. They also attract people who are curious about whales. These activities could potentially cause direct mortality and disturbance to western snowy plovers. In addition, mammal carcasses attract scavengers such as gulls, ravens, crows, and coyotes that are potential predators to western snowy plovers.

## E. IMPLICATIONS FOR THE COASTAL BEACH-DUNE ECOSYSTEM

The western snowy plover lives in an ecosystem that has been significantly degraded. Environmental stressors (*i.e.*, development, human recreation, degraded water quality, etc.) have adversely affected the biological diversity of the coastal dune ecosystem. Many of the characteristics that attract people to coastal areas make these areas prime habitat for fish and wildlife resources. Although they comprise less than 10 percent of the Nation, coastal ecosystems are home to over one-third of the United States human population, nearly two-thirds of the Nation's fisheries, half of the migratory songbirds, and one-third of our wetlands and wintering waterfowl (U.S. Fish and Wildlife Service 1995*a*). The coasts also provide habitat for 45 percent of all threatened and endangered species, including three-fourths of the federally-listed birds and mammals (U.S. Fish and Wildlife Service 1995*a*). Proper stewardship of this unique ecosystem is needed to maintain its ecological integrity while meeting its human demands.

**1. Description of Coastal Beach-Dune Ecosystem**

The coastal beach-dune ecosystem may include several features such as beaches, foredunes, deflation plains, blow-outs, and reardunes. The beach includes the expanse of sandy substrate between the tide line and the foredune or, in the absence of a foredune, to the furthest inland reach of storm waves. Beach steepness, height, and width are affected by wave height, tidal range, sand grain size, and sand supply. The beach has high exposure to salt spray and sand blast and contains a shifting, sandy substrate with low water-holding capacity and low organic matter content. Dunes include sandy, open habitat, extending from the foredune to typically inland vegetation on stabilized substrate. Major differences occur between beach and dune in salt spray, soil salinity, and air and soil temperatures (Barbour and Major 1990).

Coastal dunes generally consist of three primary zones (Powell 1981). The foredunes are the line of dunes paralleling the beach behind the high tide line. Foredunes are characterized by unstabilized sand and a simple community of low-growing native dune plant species, such as American dunegrass (*Leymus mollis*). Foredunes also support a rich community of sand-burrowing insects (Powell 1981). Behind the foredunes is the deflation plain, which is at or near the water table and is characterized by a mixture of water tolerant plants and dune species. Deflation plains are also called dune hollows and can be invaded by hydrophilic (having a strong affinity for water) trees, shrubs, or herbs (*e.g.*, species of *Carex, Juncus, Salix, Scirpus*) (Barbour and Major 1990). The inner zone of coastal dunes consists of stabilized dunes, which are dominated by woody perennial plants (Powell 1981). Beach flora can also colonize inland dune areas, where the sand is actively moving (Barbour and Major 1990).

Barren dunes, receiving sand from the beach and losing it to wind erosion, are mobile. Older, more inland dunes are stabilized by a nearly continuous plant cover; these dunes are referred to as stable dunes or fixed dunes. Localized openings in the plant cover, which permit wind erosion, are called blowouts, but they are not deep enough to allow invasion by mesophytes (plants growing in moderately moist environments). The innermost ridge of sand is generally high and is called a precipitation ridge; sand is blown over the ridge and down the slipface, continuing the process of dune advance (Barbour and Major 1990). The conditions necessary for dune growth at the coast are partly climatic, but more important is the occurrence of strong onshore winds, abundant sand supply, and vegetation that traps sand. Low, near-shore slopes with a large tidal range providing wide expanses of sand that dries at low tide are ideal for dune growth (Pethick 1984).

Very few coastal dunes are “natural,” because they have been extensively altered over time by humans for agriculture, mineral extraction, military training, and recreation (Carter 1988). Before the introduction of European beachgrass, foredunes were low and rose gradually, and a large number of native species shared this habitat. They were composed of a series of dunes alternating with swales oriented perpendicular to the coast and aligned with prevailing onshore winds. Since the introduction of European beachgrass, most systems have been replaced by a steep foredune that gives way inland to a series of dunes and swales oriented parallel to the coast (Barbour and Major 1990).

Western snowy plovers use the beach and mobile dunes as nesting habitat. Other habitat features that occur within or adjacent to the coastal beach-dune ecosystem, and serve as important foraging habitat for the western snowy plover, include river, stream, and creek mouths, river bars, lagoons, and tidal and brackish-water wetlands.

## 2. Sensitive Species of the Coastal Beach-Dune Ecosystem

Along with the western snowy plover, many other sensitive species inhabit the coastal beach-dune ecosystem and adjacent habitats. Appendix E contains a list of, and brief species accounts for, sensitive species associated with this ecosystem and adjacent habitats. We recognize these fish and wildlife species as endangered, threatened, candidate species, or species of concern. This list includes a number of sensitive species recognized by the states of California, Oregon, and Washington. This appendix also describes several marine mammals associated with the coastal beach-dune ecosystem and protected under the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361 *et. seq.*), as amended.

Some of these sensitive species have many threats in common with the western snowy plover. Habitat loss and degradation from shoreline development and beach stabilization, invasion of exotic species, and crushing by off-road vehicles are cited as major factors contributing to the status and listing of these species. European beachgrass is a current or potential threat to six federally-listed endangered plants that occur in coastal dunes of California: beach layia (*Layia carnosa*), Howell's spineflower (*Chorizanthe howellii*), Monterey spineflower (*Chorizanthe pungens* var. *pungens*), Menzies' wallflower (*Erysimum menziesii*), Monterey gilia *(Gilia tenuiflora* ssp. *arenaria*), and Tidestrom's lupine (*Lupinus tidestromii*) (Pickart 1997). European beachgrass is also a current and potential threat to native and sensitive plants in Washington and Oregon, including the pink sand-verbena (*Abronia umbellata* ssp. *breviflora*), which is classified as endangered in the State of Oregon. Equestrian use has also been identified as a threat to several endangered plant species, including the endangered Howell's spineflower, Menzies' wallflower, Monterey gilia, and the coastal dunes milk vetch (*Astragalus tener* var. *titi*). Off-road vehicles are cited as threats to several sensitive plant and animal species, including the endangered beach layia, Menzies' wallflower, Monterey gilia, Tidestrom's lupine, Hoffman's slender-flowered gilia (*Gilia tenuiflora* var. *hoffmanii*), and Smith's blue butterfly (*Euphilotes enoptes smithi*); the federally endangered La Graciosa thistle (*Cirsium longholepis*), and the following species considered to be of Federal concern: beach spectacle pod (*Dithyrea maritima*) and Morro blue butterfly (*Icaricia icarioides morroensis*).

The precarious status of these species is a symptom of a highly stressed ecosystem. Remedial efforts aimed at restoration of the natural processes that maintain this ecosystem, rather than single-species “fixes,” are likely to have the greatest and most successful long-term benefits. Important components of ecologically-sound coastal beach-dune ecosystem management include (1) removal of exotic, invasive vegetation; (2) management of human recreation to prevent or minimize adverse impacts on dune formation, vegetation, invertebrate and vertebrate fauna; and (3) efforts to counter the effects of human-induced changes in the types, distribution, numbers, and activity patterns of predators. Implementation of more ecosystem-oriented approaches to western snowy plover protection would provide important benefits to other sensitive species within the coastal dune ecosystem and merits serious consideration.

Some western snowy plover recovery efforts implemented to date (*e.g.*, removal of European beachgrass) support the natural functions of the coastal dune ecosystem. Furthermore, many protection efforts for western snowy plovers should benefit other sensitive beach species, such as California least terns, and vice versa. Many of the same predators that take western snowy plover eggs also prey on California least tern eggs. The relatively low rate of predation of western snowy plover nests in San Diego County has been attributed to predator control programs to benefit California least terns and other species, funded primarily by the Department of Defense and National Wildlife Refuge System (Powell *et al.* 1995). These programs are implemented under contract with the U.S. Department of Agriculture, Wildlife Services branch. Control of ants at California least tern colonies probably also benefits western snowy plovers nesting nearby. Opportunities also may exist for reestablishment of special status plant species that occur in coastal dunes, including Menzies’ wallflower, beach spectacle pod, Tidestrom’s lupine, beach layia, and pink sand verbena.

Some conflicts have occurred in management of western snowy plovers and California least terns in southern California, including harm to western snowy plover chicks due to entanglement in the mesh of California least tern fencing as described above. These problems have now largely been minimized with the use of new methods and materials, however such management measures should continue to be coordinated to meet the habitat needs of both western snowy plovers and California least terns.

Potential conflicts also exist between native dune restoration and western snowy plover habitat. Revegetation efforts could result in too much cover, thereby reducing the amount of suitable breeding habitat available for western snowy plovers.

Conflicting habitat requirements for western snowy plovers and pinnipeds have also occurred on lands where marine mammals haul out or breed on beaches that would otherwise be suitable for nesting western snowy plovers (U.S. Fish and Wildlife Service *in litt.* 1995, U.S. Department of the Navy *in litt.* 2001). Where this conflict continues to occur, coordination with land management agencies and NOAA's National Marine Fisheries (NMFS) may be helpful to identify methods for modifying or discouraging use by breeding pinnipeds during the western snowy plover nesting season.

Although some management measures may benefit a broad array of sensitive species within the coastal dune ecosystem (*i.e.*, control of *Ammophila,* access restrictions, and integrated predator management programs), some single-species protection measures for the western snowy plover, such as exclosures, are needed. Although exclosures can be risky to nesting western snowy plovers in some situations (see Lauten *et al.* 2006), they can be an effective way to protect nests against heavy recreational use and predation, especially where reductions in predator numbers would otherwise be temporary and difficult to achieve or would have adverse ecological effects.

## F. CONSERVATION EFFORTS

Western snowy plover recovery efforts have accelerated since this population was federally listed as a threatened species in 1993. Current breeding and wintering site protection efforts are documented in Appendix C (Summary of Current and Additional Needed Management Activities). The most common management strategies include protection of nests with predator exclosures; signing and symbolic fencing of nesting areas; restrictions on motorized vehicles in the vicinity of western snowy plover nests and broods; restrictions on dogs (even though enforcement of dogs on-leash has been problematic); and public information and outreach. These strategies are effective means of improving western snowy plover reproductive success.

**1. Conservation Planning on Federal and State Lands**

The direction of land management on Federal lands is often outlined in management plans or agency regulations that provide objectives and guidelines for western snowy plovers. These plans include the Naval Base Coronado Integrated Natural Resources Management Plan (U.S. Navy 2001), Camp Pendleton Integrated Natural Resources Management Plan (U.S. Marine Corps 2006), San Diego Bay National Wildlife Refuge Comprehensive Conservation Plan (U.S. Fish and Wildlife Service 2006*c*), Oregon Dunes National Recreation Area Management Plan (U.S. Forest Service 1994), the Coos Bay Shorelands Final Management Plan (U.S. Bureau of Land Management 1995*a*), the New River Area of Critical Concern Management Plan (U.S. Bureau of Land Management 1995*b*), the Draft Snowy Plover Management Plan for Ocean Beach, Golden Gate National Recreation Area (Hatch 1997), and the Western Snowy Plover Management Plan for the Point Reyes National Seashore (White and Allen 1999).

Wildlife protection, especially the preservation, restoration, and enhancement of threatened and endangered species and migratory birds, is the primary goal of national wildlife refuges, as stated in the National Wildlife Refuge System Administration Act of 1997 (16 U.S.C. 668dd *et. seq.*). Western snowy plover habitat on national wildlife refuges has been accorded intensive protection, including (1) integrated predator management and (2) closures during the nesting season where appropriate, to minimize adverse effects of disturbance. Consistent with requirements of the National Wildlife Refuge System Administration Act and the Refuge Recreation Act of 1962, as amended (16 U.S.C. 460k *et. seq.*) regarding compatibility of refuge activities, western snowy plover nesting areas within some national wildlife refuges are closed to public use during the breeding season. Western snowy plover use areas within some national wildlife refuges (such as Salinas River National Wildlife Refuge) are closed to public use year-round.

Additionally, the Department of Defense manages for western snowy plovers on military installations through actions associated with section 7 of the Endangered Species Act and through conservation planning efforts (*e.g.*, Programmatic Activities and Conservation Plans in Riparian and Estuarine/Beach Ecosystems on Marine Corps Base Camp Pendleton, 1995; see also Federal Regulatory Program, below). This includes avoidance and minimization measures, which have resulted in individual military installations placing limits on or otherwise restricting military activities and implementing management actions to specifically benefit western snowy plovers, such as monitoring, predator control, habitat improvement, and research. This management, in conjunction with other factors such as habitat availability and restricted public access, has allowed certain Department of Defense lands to significantly contribute to regional western snowy plover populations.

The *Washington State Recovery Plan for the Western Snowy Plover* recommends strategies to recover this species, including protection of the population, evaluation, and management of habitat, and initiation of research and education programs (Washington Department of Fish and Wildlife 1995).

The State of Oregon's *Conservation Program for the Coastal Population of the Western Snowy Plover*, required by the Oregon Endangered Species Act and adopted by the Oregon Fish and Wildlife Commission (Oregon Revised Statutes 496.171 through 496.192), requires a variety of actions to protect this subspecies. These actions include: (a) protecting all existing western snowy plover sites from negative impacts; (b) monitoring impacts and responding to damaging activities (*e.g.*, urban development and recreation disturbance) to minimize or eliminate their effects to western snowy plovers; (c) maintaining a long-term monitoring program to track numbers, distribution, and nesting success; (d) habitat management, such as local control of European beachgrass and maintaining predator protection measures to maximize breeding success for as long as deemed necessary; (e) conducting additional research to maintain and recover western snowy plovers; and (f) enhancing information availability, education, and awareness of western snowy plovers and their requirements for survival and recovery (Oregon Department of Fish and Wildlife 1994).

The California Public Resources Code (Section 5019.71) allows designation of natural preserves, the most protective designation given to a part of any California State Park system unit. The purpose of natural preserves is to preserve such features as rare or endangered plant and animal species and their supporting ecosystems, and representative examples of plant or animal communities existing in California prior to the impact of civilization. The Pajaro Rivermouth Natural Preserve, Wilder Creek Natural Preserve, and Salinas Rivermouth Natural Preserve were designated by the California State Park and Recreation Commission in recognition of the need to protect western snowy plovers. In addition, Section 5019.62 of the California Resources Code allows the designation of State seashores to preserve the outstanding values of the California coastline and provide for public enjoyment of those values. Within the state of California, the following California State seashores containing western snowy plover habitats have been established: Del Norte State Seashore; Clem Miller State Seashore; Sonoma Coast State Seashore; Año Nuevo State Seashore; Monterey Bay State Seashore; San Luis Obispo State Seashore; Point Mugu State Seashore; Capistrano Coast State Seashore; and San Diego Coast State Seashore. Under the California Public Resources Code, the California Department of Parks and Recreation has the authority to identify additional lands appropriate for inclusion in California State seashores and recommend land acquisition for these purposes.

Special management actions for western snowy plovers are conducted within the portions of California State Seashores that are owned by the California Department of Parks and Recreation. An example is the Monterey State Seashore, where the California Department of Parks and Recreation has conducted intensive management activities for western snowy plovers since 1991. Strategies include resource management, interpretation, law enforcement, and park operations. Resource management actions include monitoring, predator trapping, and use of exclosures, symbolic fences, and signage, and consideration of snowy plovers during planning recreational access and trails in San Francisco Bay. Interpretative efforts include informational signage at nesting areas, information brochures, small handout cards with photographs and information on western snowy plovers, several annual public outreach programs (***e.g.***, slide programs and field trips), and actions to engage community support for the western snowy plover guardian program (***i.e.***, recruitment, training, and scheduling for volunteer presence in sensitive habitat).

Enforcement actions include verbal warnings, written warnings, citations, and arrests as necessary. Key enforcement concerns include dogs off-leash and off-road vehicles, which are prohibited on all beaches. Operational management includes a permit process that screens special events to avoid the nesting season in sensitive areas, and regulation of recreational use of beaches to avoid sensitive areas (*i.e.*, kite flying, hang gliding, fishing, etc.). Other management actions on California Department of Parks and Recreation property within some other State seashores are shown in Appendix C.

**2. Conservation Efforts on Federal and State Lands**

***a. Exclosures, Symbolic Fencing, and Signs***

Since 1991, one of the primary techniques to protect nesting western snowy plovers has been the use of exclosures (Appendix F). Exclosures are small, circular, square, or triangular metal fences that can be quickly assembled and are designed to keep predators out of nests and/or prevent people from trampling nests (Figure 8). Exclosure designs are described in Appendix F; modifications to exclosure design in response to site specific predator conditions may be appropriate on a case by case basis but should be coordinated in advance with the Fish and Wildlife Service.

Nests protected from predators by exclosures have consistently had increased nest success (White and Hickey 1997, Stern *et al.* 1991, Craig *et al.* 1992, Mabee and Estelle 2000, U.S. Fish and Wildlife Service 2002, Lauten *et al.* 2006). At some locations in Oregon and California, exclosures are designed with tops consisting of parallel lengths of nylon seine lines spaced approximately 15 centimeters (6 inches) apart -or- mesh netting with a minimum spacing of approximately 10 centimeters (4 inches), designed to discourage entry by avian predators. At Eden Landing State Ecological Reserve in San Francisco Bay, nest predation decreased from 32 percent in 2000 to 3 percent in 2001, largely due to a switch from string tops to net tops on exclosures (Marriott 2001).

**Figure 8.** Erecting western snowy plover exclosure (photo by Sue Powell, with permission).

Although exclosures are contributing to improved productivity and population increases in some portions of the western snowy plover's Pacific coast range, problems have been noted in some localities. Potential risks associated with exclosures include vandalism, disturbance of the birds by curiosity seekers, and use of exclosures as predator perches. Over time, exclosures may provide a visual cue to predators, making it easier for them to target adults, chicks, and eggs, and requiring predator management. On several occasions depredations of adult western snowy plovers have been documented in or near exclosures, and efforts have been made to establish exclosures later in the season after the peak migration of raptors (Brennan and Fernandez 2004, Lauten *et al.* 2006). Also, predator exclosures may be impractical where western snowy plovers nest within California least tern colonies or other instances where such exclosures may conflict with the needs of other threatened or endangered species.

Symbolic fencing also is used to passively protect western snowy plover nests, eggs, and chicks during nesting season. This fencing consists of one or two strands of light-weight cord or cable strung between posts to delineate areas where humans (*e.g.*, pedestrians and vehicles) should not enter (Figure 9). It is placed around areas where there are nests or unfledged chicks, and is intended to prevent accidental crushing of eggs, flushing of incubating adults, and, if large enough, to provide an area where chicks can rest and seek shelter when large numbers of people are on the beach. Directional signs (regarding closed areas, nesting sites, etc.) also are used within western snowy plover habitats and near protective fencing to alert the public and other beach users of the sensitivity of western snowy plover nesting and wintering areas. Installation of symbolic fencing at Coal Oil Point Reserve (CA-88) in conjunction with a docent program has allowed management of

**Figure 9.** Symbolic fencing on beach at Monterey Bay, California (photo by Ruth Pratt, with permission).

recreational use and resulted in successful re-establishment of a breeding population of western snowy plovers at the site (Lafferty *et al.* 2006).

Additionally, land managers may prevent or restrict access to areas used by nesting western snowy plovers. For example, military installations often curtail or redirect training activities near western snowy plover nesting areas and some State parklands and recreation areas restrict public access in certain areas during the breeding season.

### *b. Law Enforcement*

Management agencies recognize that law enforcement is needed for protection measures to be effective. Though a majority of beach visitors respect restrictions to protect western snowy plovers, there will always be a certain percentage who do not. Enforcement of western snowy plover area restrictions shows that managers are serious about compliance. In Oregon, biologists have established a working relationship with a variety of law enforcement agencies who have jurisdiction in western snowy plover habitat. Their goal is to increase awareness, gain advice, increase communication and coordination to alleviate jurisdictional conflicts, and train officers on how to minimize disturbance while patrolling western snowy plover habitat. Conflicting priorities and personnel turnover require perseverance to maintain effective working relationships across law enforcement jurisdictions.

### *c. Predator Control*

Lethal and nonlethal means of predator control have been used with mixed success to protect western snowy plovers on Pacific beaches. Nonlethal methods include litter control at campgrounds (to reduce available food sources), exclosures and fencing, and trapping and relocation. Lethal methods include reducing local populations of avian predators by addling (*i.e.* killing the developing chick within the egg) of raptor and corvid eggs, trapping and euthanizing nonnative mammalian predators, and killing individual predators upon which nonlethal methods have proven ineffective.

On the Oregon Coast, snowy plover predator control has historically been in the form of nest exclosures and site specific lethal control. The use of nest exclosures, adaptively modified in response to predator behavior, has been very successful in increasing hatching success. However, because in some cases predation on adults has been linked to the presence of exclosures, their use is presently targeted to specific instances where it appears most beneficial, and the program is working toward elimination of exclosure use (Lauten *et al.* 2006a, 2006b).

In 2002, Federal and State agencies approved an integrated predator management program to improve western snowy plover nesting and fledging success in Oregon. The decision followed public review and comment on an analysis of the effects of the proposed predator control methods and alternatives to protect the western snowy plover in Oregon (U.S. Department of Agriculture 2002). To date lethal predator control has been implemented at selected plover breeding sites along the Oregon Coast at Coos Bay North Spit, Bandon Beach, New River, Siltcoos, Overlook, Tahkenitch, and Tenmile, resulting in an overall positive effect on western snowy plover productivity (Lauten *et al.* 2006*a*, 2006*b*).

Another form of predator control is fencing, which is used on the south spoils area of Coos Bay, North Spit, where the U.S. Bureau of Land Management, U.S. Army Corps of Engineers, and Oregon Department of Fish and Wildlife have fenced 8 hectares (20 acres) of western snowy plover nesting habitat. This wire mesh fence was installed to exclude mammalian predators, especially skunks, and to discourage human disturbance from off-highway vehicle use. The original fence, constructed in 1991, suffered from the effects of weathering and although it continued to deter vehicles, it was no longer an effective barrier to predators. In 1998, the U.S. Army Corps of Engineers and U.S. Bureau of Land Management jointly constructed a new fence and removed the old fence. The new fence matched the design of the 1991 fence (5-centimeter by 5-centimeter (2-inch by 2-inch) mesh fence material with an effective fence height of about 1.2 meters (4 feet) after burial of the bottom). However, the new fence has increased the protected area from 8 hectares (20 acres) to 28 hectares (71 acres), and includes both the south spoils area and the 1994 Habitat Restoration Area (E.Y. Zielinski and R.W. Williams *in litt.* 1999).

At the Don Edwards San Francisco Bay National Wildlife Refuge, fences are sometimes constructed across salt pond levees to block access by terrestrial predators (J. Albertson *in litt.* 1999). However, fences are not feasible in many areas, and do not restrict aerial predators.

Exclosures are much more effective when used in conjunction with an integrated predator management program that includes selective removal of non-native predators and other individual problem predators. Otherwise, exclosures may promote better hatching success, but not fledging success if predators such as red fox

(*Vulpes vulpes*) focus on adults protecting the nest or newly-hatched chicks that leave the exclosure to feed. These measures are also much more effective where combined with other access restrictions to increase survival of clutches and broods. Trapping the nonnative red fox has been credited with substantially increased western snowy plover abundance and productivity at Salinas River National Wildlife Refuge (E. Fernandez, U.S. Fish and Wildlife Service, pers. comm. 1998). At the Don Edwards San Francisco Bay National Wildlife Refuge, predation on western snowy plovers and California clapper rails by red foxes prompted the initiation of a predator management program targeting red foxes, feral cats, skunks, and raccoons, in conjunction with use of western snowy plover nest exclosures (J. Albertson *in litt.* 1999, Strong *et al.* 2004). This ongoing program has resulted in improved nest success. Use of exclosures has subsequently been discontinued due to the success of the trapping program and incidents of nest abandonment at exclosures. At Eden Landing Ecological Reserve selective removal of problem corvids and their nests has also been practiced by USDA Wildlife Services since 2004 (Tucci *et al.* 2006).

The U.S. Air Force has used electric fencing around the California least tern colony at Purisima Point, Vandenberg Air Force Base, California, where western snowy plovers also nest and winter. The electrified portion of this fence is approximately 273 meters (300 yards) long and 1.2 meters (4 feet) high. The electric fence contains six strands of electrified wire placed approximately 10.2 centimeters (4 inches) apart. This fence is generally effective at keeping out mammalian predators of California least terns. It has also incidentally protected a small population of western snowy plovers by deterring western snowy plover predators.

Proposals have been developed to test a conditioned taste aversion technique on predators of piping plovers (*i.e.*, red fox) by using quail eggs treated with the chemical emetine (McIvor 1991). The purpose of this technique is to condition foxes to avoid eating plover eggs, expecting that if foxes eat treated quail eggs prior to the nesting season and become sick, they might develop a conditioned aversion to eating plover eggs. This technique requires that the predator consumes the needed dose that will produce short-term illness but no mortality. Due to uncertainty in effectiveness, at this point in time we do not advocate this taste aversion technique. Proposals to test conditioned taste aversion techniques on predators of piping plovers on the east coast have not been implemented due to difficulties obtaining permission to field test emetine (A. Hecht, U.S. Fish and Wildlife Service, pers. comm. 1996). Avery *et al.* (1995) found that deployment of quail eggs treated with the chemical methiocarb might be a useful means of reducing predation of California least terns by ravens and crows. However, subsequent tests of aversion methods have proven to be unsuccessful (E. Copper and B. Foster *in litt.* 2001).

With proper research, techniques that have been used to deter predators of other wildlife species may prove beneficial to western snowy plovers. Strategic placement of crow and gull carcasses around the perimeter of a California least tern colony has been used at Vandenberg Air Force Base (Persons and Applegate 1996), however, this method may not be effective for more loosely colonial species such as snowy plover (J. Buffa *in litt.* 2004). Moreover, the presence of gull carcasses could prove counterproductive by attracting mammalian predators (N. Read, U.S. Air Force, pers. comm. 1998).

In 1999 Vandenberg Air Force Base initiated studies of coyote ecology and movements, with the goal of developing non-lethal alternatives for reducing coyote predation on western snowy plover. Although results are preliminary, in 2001 beach access restrictions and regular pick-up of trash, in combination with availability of alternative prey such as rabbits, may have contributed to the lowest incidence of coyote predation ever recorded at Vandenberg Air Force Base, even though evidence of coyote presence continued to be observed on a daily basis.

For top-level predators such as coyotes, western snowy plover nests are not a primary food source. Vandenberg Air Force Base has avoided large-scale coyote removal to prevent exacerbated predation on listed species from mesopredators such as racoons, and to prevent expansion of non-native predators such as feral cats and red foxes into western snowy plover nesting areas (N. Read Francine *in litt.* 2001).

***d. European Beachgrass Control***

Experiments to find cost-effective methods to control or eradicate European beachgrass are ongoing. Control methods employed in various situations have included foredune grading and foredune breaching with front-end loaders and bulldozers, subsoiling with a winged subsoiler (essentially a heavy duty three-point plow), discing with a standard farm tractor and disk, burning, saltwater irrigation, spraying of herbicide, and hand-pulling. Herbicide treatment is not always possible, however, when rare or federally-listed plants are present. In these cases hand-pulling or other mechanical removal may need to be employed. At Point Reyes National Seashore mechanical and hand-removal were used to remove non-native beach grass on 12 hectares (30 acres) with immediate beneficial response by nesting snowy plovers (Peterlein and Roth 2003). Some control methods are only suitable for the inland sites. Areas containing heavy growth of European beachgrass and woody vegetation are prescribed-burned prior to using heavy equipment. Areas are leveled to allow discing for maintenance. In some areas, oyster shell hash provided by a local oyster grower has been distributed after vegetation has been removed. Effectiveness of the various control methods varies, though some form of maintenance may always be required. Maintenance is critical and achieved through multiple treatments over a succession of years. Discing requires maintenance twice per year to keep beachgrass from reestablishing. Comparatively, yearly maintenance in portions of some restoration sites may not be needed after employing several years of bull-dozing, herbicides, or hand-pulling following initial mechanical removal.

Since 1994, multiple projects have been conducted in Oregon to control beachgrass on existing nest sites and to clear and maintain additional areas. These Habitat Restoration Areas (HRAs) are essential for the recovery of the western snowy plover. Three significant HRAs established on the Oregon Coast between 1994 and 2002 include the Dunes Overlook (Oregon Dunes National Recreation Area), Coos Bay North Spit, and New River. Other habitat restoration areas have recently been established or are planned at Baker Beach (140 acres), Tenmile Creek (200 acres) and Bandon Beach State Natural Area (30 acres). HRAs accounted for 34 percent of nests (Table 6) and 43 percent of fledglings (Table 7) found on the Oregon Coast between 1999 and 2004.

The Oregon Dunes National Recreation Area contains about 2,428 hectares (6,000 acres) of European beach grass and now has few remaining examples of intact native plant communities (Pickart 1997). Habitat restoration was initiated in the summer of 1998 and by 2002, the U.S. Forest Service had treated 24 hectares (60 acres) of the 208 hectares (516 acres) of habitat planned for restoration. Prior to 1999, no western snowy plovers were found at the Overlook site, but after habitat was restored, western snowy plovers began nesting there successfully (Table 6, Table 7).

The U.S. Forest Service employs a combination of mechanical, manual, and herbicide treatments to control European beachgrass. Mechanical treatment consists of scalping off the top 1 meter (3 feet) of beachgrass and then burying it in an adjacent trench with a minimum covering of l meter (3 feet) of sand. Moderate to heavy resprouting occurs with this method, requiring manual or chemical follow-up treatment. Other mechanical treatments have consisted of placement of dredged material on the beachgrass and scalping the top half of foredunes to remove beachgrass and allow for inland sand movement and tidal action to maintain open dunes (K. Palermo *in litt.* 1998*b*).

Herbicide treatments have been conducted as a primary control method and as follow-up to mechanical control. In recent years, from 2 to 26 hectares (5 to 65 acres) of beachgrass were sprayed with an herbicide treatment of 8 percent Rodeo and nonionic surfactant (spray-to-wet) at three locations. Employees found that a follow-up application within 2 weeks of the first application was critical to obtain optimum coverage and initial die-off rates (90 percent). Additionally, herbicide treatments were most effective when conducted consecutively over 2 to 3 years depending on density. Beachgrass control at the Oregon Dunes is still considered experimental. Preliminary results suggest that maintenance will always be necessary (K. Palermo *in litt.* 1998*b*).

**Table 6.** Total number of nests at habitat restoration areas on the Oregon Coast 1994-2004 (J. Heaney, pers. comm. 2003; C. Burns, pers. comm.; M. VanderHeyden, pers. comm.; Castelein *et. al.* 2002; Lauten *et al.* 2006).

| **Site Name** | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Total Nests** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baker Beach | | | | | | | | | 0 | 1 | 0 | 1 |
| Dunes Overlook | | | | | | 2 | 8 | 15 | 8 | 9 | 14 | 56 |
| Coos Bay North Spit | 4 | 3 | 2 | 3 | 7 | 12 | 22 | 13 | 15 | 11 | 16 | 108 |
| Bandon State NRA | | | | | | | | | | 4 | 17 | 21 |
| New River | | | | | | 2 | 4 | 10 | 7 | 5 | 6 | 34 |

**Table 7.** Total number of fledged young at habitat restoration areas on the Oregon Coast 1994-2004. Includes fledglings from broods from undiscovered nests (J. Heaney, pers. comm. 2003; C. Burns, pers. comm; M. VanderHeyden pers. comm.; Castelein *et. al.* 2002; Lauten *et al.* 2006).

| **Site Name** | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | **Total Nests** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baker Beach | | | | | | | | | 0 | 0 | 0 | 0 |
| Dunes Overlook | | | | | | 3 | 5 | 2 | 2 | 3 | 6 | 21 |
| Coos Bay North Spit | 7 | 2 | 1 | 1 | 1 | 23 | 6 | 6 | 8 | 14 | 22 | 91 |
| Bandon State NRA | | | | | | | | | | 4 | 15 | 19 |
| New River | | | | | | 2 | 1 | 3 | 3 | 7 | 5 | 21 |

On Coos Bay North Spit, the Bureau of Land Management has cleared and maintained approximately 67 hectares (166 acres) of vegetation dominated by European beachgrass, shore pine, Sitka spruce, and Scotch broom. The objective is to remove predator cover, remove encroaching beachgrass, and expand the existing habitat. The goal is to create an area for western snowy plovers to nest that is large enough to lessen possible detection of nests and chicks by predators. Nest sites used by western snowy plovers on the North Spit include both beach habitat and inland areas of previous dredged material deposition. Many of the cleared areas were used almost immediately by nesting western snowy plovers or for brood rearing activities. Prior to 1994, western snowy plovers were not nesting in these areas, but after 1994, the Coos Bay North Spit became the most productive western snowy plover nesting sites on the Oregon Coast (Table 6, Table 7) (M. VanderHeyden, Bureau of Land Management, pers. comm.).

At the Coos Bay North Spit, an inmate crew from the Shutter Correctional Facility, hired by the U.S. Bureau of Land Management, hand pulled European beachgrass on approximately 6 hectares (15 acres) of the south spoil area. The 4-month project cost $11,500; most of these costs covered the crew supervisor’s salary and transport vehicle charges. Another European beachgrass removal project around the south spoil areas of the Coos Bay North Spit, included burning European beachgrass, followed by scarification using a bulldozer in March 1994. By August, most of the area had resprouted (Oregon Department of Fish and Wildlife 1996). New beachgrass sprouts are relatively easy to remove. However, initial and maintenance work can be costly and labor intensive. At the Coos Bay North Spit, eradication of European beachgrass using 91.4 centimeters (36 inches) of sprayed seawater was attempted in 1996. The saltwater application was not effective because desiccated sand layers did not allow seawater penetration to the grass’s root zone. Future experimentation using wetting agents to achieve water penetration on small-scale applications could demonstrate potential applicability of this technique (G. Dorsey, U.S. Army Corps of Engineers, pers. comm. 1997).

The New River Spit is another key nesting area for the western snowy plover that is managed by the Coos Bay U.S. Bureau of Land Management. Each year since 1998, the U.S. Bureau of Land Management has used heavy equipment (i.e., front-end loader, bulldozer) to remove European beachgrass from in and around a target restoration site. Typically, the bulldozer is used to push the beachgrass into depressions and bury it under several feet of sand, or to push sand and beachgrass out into the surf zone. Just over two miles of foredune have been lowered and select areas along the foredune have been removed to allow ocean surf to overwash into interior portions of the spit. The overwashing aids in scouring vegetation and appears to self-maintain portions of the overwashes throughout the restoration area. By 2002, approximately 48 hectares (120 acres) of foredune and overwash were cleared of beachgrass (Jim Heaney, Bureau of Land Management, pers. comm. 2003).

Work at Lanphere-Christensen Dune Preserve in Humboldt County, California, showed that hand pulling can eliminate European beachgrass, but 3 years of multiple maintenance treatments were required (Pickart and Sawyer 1998). Use of heavy equipment (*e.g.*, "V" ripper) and herbicides may be more cost-effective; however, resprouting of the grass occurs, necessitating follow-up, manual pulling for long-term beachgrass removal (A. Pickart, The Nature Conservancy, pers. comm. 1997).

The effective strategy used by the California Department of Parks and Recreation to remove beachgrass at Marina Dunes and Salinas River State Beaches, Monterey Bay, included multiple herbicide applications of 10 percent Round-Up. Approximately 25 patches of beachgrass covering a total of approximately 0.5 hectare (1.3 acres) have been treated along a 6.4-kilometer (4-mile) section of beach. Each patch of beachgrass was sprayed every 3 months over a 3-year period. All treated sites were marked so that they could be easily located and monitored for regrowth and spread. Current plans include beachgrass removal on approximately 30 hectares (75 acres) at Zmudowski State Beach at the Pajaro River mouth (D. Dixon *in litt.* 1998).

Western snowy plover habitat restoration efforts at the Leadbetter Point Unit of the Willapa National Wildlife Refuge began in 2002 and continue. American beachgrass and some European beachgrass have been mechanically removed, clearing approximately 25 hectares (63 acres) as of 2006. In addition, cuts have been made through the foredune and oystershell placed to cover 11 hectares (28 acres) within the restored area (K. Brennan *in litt.* 2006).

Pickart (1997) suggested that chemical treatment of European beachgrass is likely to be the most cost-effective method used to date. Herbicides that have been used for this purpose are glyphosates (trade names Rodeo and Round-Up). The most effective period for herbicide treatment of beachgrass is during its flowering stage (Wiedemann 1987); plants should be treated during periods of active growth (Pickart 1997). However, potential adverse biological impacts to other native plants and animals must be considered when using herbicides, and selective spraying may be difficult in some areas. Chemical treatment in active western snowy plover nesting areas may need to be limited to the period outside the breeding season in certain areas to avoid disturbing nesting western snowy plovers.

Additional management options for beach and dune erosion control are needed. Beachgrass continues to be used because it has been tried successfully in the past, nursery stock is available, and field planting technology is well known. However, negative aspects of its monoculture are recognized. Proper planting and management of a mixture of native vegetation, together with the provision of walkways for pedestrian traffic and the elimination of horse traffic, cattle grazing, and off-road vehicles, may result in stabilization as effective as beachgrass, yet there has been minimal experimentation with this technique (Barbour and Major 1990).

***e. Off-Road Vehicle Restrictions and Management***

Management strategies to reduce off-road and other vehicle impacts have been implemented at some western snowy plover breeding areas. At Pismo/Oceano Dunes State Vehicular Recreation Area, California, management strategies include fenced-off nesting areas; placement of exclosures around nests; restrictions on vehicle speed and access areas; and requirements that car campers remove all trash. At Pismo/Oceano Dunes State Vehicle Recreation Area, the California Department of Parks and Recreation, Off-Road Vehicle Division, has developed an interim management plan, which is adapted annually in coordination with us to address what effects current management measures have on hatching rates and fledging success, as well as recruitment into the western snowy plover population (California Department of Parks and Recreation 2005). The Off-Road Vehicle Division of the California Department of Parks and Recreation is now funding the development of a habitat conservation plan (in anticipation of applying for a section 10(a)(1)(B) permit under the Endangered Species Act) for the Pismo/Oceano Dunes State Vehicular Recreation

Area and other State parks within the San Luis Obispo Coast District of the California Department of Parks and Recreation.

The conservation issues for western snowy plovers and California least terns at the Pismo/Oceano Dunes State Vehicular Recreation Area are directing the development of the habitat conservation plan, but other species also will be covered. This plan will evaluate the effects that recreation and park management activities are having on the covered species.

On Camp Pendleton, the Marine Corps conducts its vehicle operations in and near nesting areas in ways that minimize impacts to western snowy plovers. Under the Marine Corps' Base Regulations all training activities, including vehicle training, are prohibited within 300 meters of fenced nesting areas during the breeding season (1 March to 15 September). Further, amphibious vehicles are directed to transit adjacent to nesting areas with tracks in the ocean whenever possible (U.S. Marine Corps 2006).

On the Don Edwards San Francisco Bay National Wildlife Refuge, part of the main access road (Marshlands Road) is closed to motorized vehicles from April 1 to August 31, to protect western snowy plovers nesting near the roadway. Highway traffic cones and ribbons are installed to discourage vehicle access to nesting areas on roads and levees (J. Albertson *in litt.* 1999).

In 1995, after the Oregon Dunes National Recreation Area completed its management plan, the U.S. Forest Service petitioned the Oregon Parks and Recreation Department to close several kilometers of beach that had been open to vehicles. Resulting closures reduced conflicts between off-highway vehicles and nonmotorized recreationists, western snowy plovers, and other wildlife (E.Y. Zielinski and R.W. Williams *in litt.* 1999).

Leadbetter State Park (immediately to the south of Willapa National Wildlife Refuge) is closed to beach driving from April 15 to the day after Labor Day. The entire beach along Willapa National Wildlife Refuge is closed to driving year round, except during razor clam openers (K. Brennan *in litt.* 2006). Diligent surveillance and enforcement by applicable agencies is extremely important due to the potential for violations.

### *f. Population Monitoring*

Western snowy plover researchers in Washington, Oregon and California conduct intensive population monitoring programs. Tasks include some or all of the following: (1) conducting winter and breeding season window surveys; (2) banding adults and chicks; (3) determining nest success; (4) determining fledging success, (5) monitoring and documenting brood movements; and (6) collecting general observational data on predators.

The Point Reyes Bird Observatory has been monitoring the distribution and breeding success of western snowy plovers since 1977. Monitoring at Vandenberg Air Force Base has been conducted by Point Reyes Bird Observatory and SRS Technologies. Additionally, Santa Barbara County-supported volunteer docents stationed at Surf Station, within Vandenberg Air Force Base, keep tallies of numbers of visitors, violations prevented, and predators seen (R. Dyste *in litt.* 2004). The U.S. Geological Survey Biological Resources Division monitored western snowy plovers in San Diego County from 1994 to 1998. Teams led by Elizabeth Copper, Robert Patton, Shauna Wolf, and Brian Foster have monitored western snowy plovers in San Diego County since 1999 for military installations. The Oregon Natural Heritage Program and The Nature Conservancy have conducted western snowy plover monitoring since 1990 in Oregon. The Point Reyes Bird Observatory, Oregon Natural Heritage Program, and U.S. Geological Survey, Biological Resources Division, also band western snowy plovers at some locations (Figure 10). The California Department of Parks and Recreation conducts annual monitoring throughout the state and at the Pismo/Oceano Dunes State Vehicular Recreation Area (J. Didion *in litt.* 1999). Mad River Biologists and Humboldt State University are currently conducting intensive population monitoring in northern California. Department of Defense installations continue to maintain long-term programs for monitoring and management of western snowy plover populations and predators in San Diego and Ventura Counties, including programs at Camp Pendleton, Naval Amphibious Base Coronado, Naval Radio Receiving Facility Imperial Beach, North Island, and San Clemente Island.

**Figure 10.** Banding a western snowy plover chick (photo by Bonnie Peterson with permission)

***g. Salt Pond Management***

Intensive management at the Moss Landing Wildlife Area has made a major contribution to western snowy plover breeding success in the Monterey Bay area. Management by Point Reyes Bird Observatory staff, in coordination with the California Department of Fish and Game, has been ongoing since 1995. Management activities include draw-down of water levels in part of the salt ponds at the beginning of the nesting season to provide dry sites for nests, and flooding of remnant wet areas twice per month through the nesting season to maintain foraging habitat for adults and their young. Predator control is conducted by the U.S. Department of Agriculture, Wildlife Services Branch.

The Don Edwards San Francisco Bay National Wildlife Refuge manages a former salt pond called the “Crescent Pond” (within location CA-36, mapped in Appendix L) for western snowy plovers by reducing the water levels prior to the breeding season. In the early 1990s, this pond was mostly unvegetated salt flat, but since then native pickleweed (*Salicornia virginica*) has slowly increased on the site, making the areas less valuable for western snowy plover nesting habitat. The Refuge has begun to conduct winter flooding in the Crescent Pond to reduce vegetative cover and improve western snowy plover nesting habitat.

The 2003 acquisition of Cargill's West Bay, Alviso, and Baumberg Salt Ponds in the South Bay by California Department of Fish and Game and Don Edwards San Francisco Bay National Wildlife Refuge will greatly further the goal of achieving 810 hectares (2,000 acres) of ponds managed for western snowy plover habitat (see Recovery Action 2.6). The Refuge's long-term management plans for these areas will include management that is compatible with western snowy plover and will coordinate with the recovery goals of this Recovery Plan (J. Albertson, pers. comm. 2005). Many of the salt ponds are currently used for breeding and wintering by western snowy plovers. San Francisco Bay Bird Observatory is assisting the Refuge with salt marsh management and western snowy plover monitoring.

### *h. Habitat Acquisition*

Acquisition and management of key sites is an important conservation effort. In October 1998, The Nature Conservancy transferred the approximately 193-hectare (483-acre) Lanphere-Christensen Dunes Preserve (part of Mad River Mouth and Beach, California, CA-7) to us for conservation purposes. The area will be managed by the Humboldt Bay National Wildlife Refuge for natural resources, including the western snowy plover. In October 1998, the Port of San Diego announced an agreement enabling approximately 560 hectares (1,400 acres) of Western Salt Company land (CA-131) to be managed by the San Diego National Wildlife Refuge. The salt ponds are a western snowy plover nesting and wintering area. As noted above, Cargill's transfer of the West Bay, Alviso, and Baumberg salt ponds, including 6,110 hectares (15,100 acres), to California Department of Fish and Game and Don Edwards San Francisco Bay National Wildlife Refuge was completed in 2003; portions of this area will be managed as western snowy plover habitat.

### *i. Use of Volunteers*

Volunteers contribute to the conservation of western snowy plovers and their habitat at many beach locations, including Morro Bay and Oceano Dunes State Vehicular

Recreation Area, Point Reyes National Seashore, and Golden Gate National Recreation Area. Volunteers and docents assist public land managers in many ways (Appendix K), including informing park visitors about threats to the western snowy plover, reducing human and pet disturbances, and assisting with direct habitat enhancement (*e.g.*, manual removal of European beachgrass; Figure 11). In 1998, the Western Snowy Plover Guardian Program was developed to assist the conservation and recovery of western snowy plovers in Monterey Bay. This program is mainly a volunteer effort by local citizens who assist in protecting western snowy plovers through monitoring, reporting, and educational activities (D. Dixon *in litt.* 1998).

**Figure 11.** High school students removing European beachgrass (photo by Kerrie Palermo, with permission).

### *j. Public Outreach and Education*

Public land managers and private conservation organizations have produced public educational materials, including brochures, posters, flyers, and informational/interpretative signs regarding western snowy plovers (Appendix K). Environmental education/interpretation is recognized by land management agencies as an important tool that supports their mission of resource stewardship. Increased understanding and appreciation of natural resources (specifically threatened and endangered species) often results in increased public support. This support is not easily measured and when the audience is children, results may not be seen until they reach adulthood. However, those agencies conducting western snowy plover education to date have found a positive response by individuals. In Oregon, on-site monitors of the U.S. Forest Service (Oregon Dunes National Recreation Area) and U.S. Bureau of Land Management report a willingness of the majority of contacted individuals to comply with restrictions after better understanding the reasons for them.

The La Purisima Audubon Society, Santa Barbara County, produced an educational video about the western snowy plover and the California least tern in 1999. It was distributed to public schools and museums within Santa Barbara County in 2000.

***k. Section 6 Cooperative Agreements***

Section 6 of the Endangered Species Act allows us to enter into cooperative agreements with states that establish and maintain active programs for the conservation of listed species. Through funding under section 6, those states assist the recovery of endangered and threatened species and monitor their status. Between 2000 and 2006, traditional section 6 funds have been used for creation of a docent program at Silver Strand State Beach in California ($8,300); development of a water management plan at Moss Landing Wildlife Area, California ($4,886); surveillance and protection of snowy plover nests on California beaches ($92,000); and surveys, nest monitoring, protecting nests with exclosures, collecting data on human uses of beaches, and encouraging beach uses compatible with snowy plovers in Oregon ($64,386) and Washington ($48,677). HCP Planning grants were used for development of a habitat conservation plan to address management of beach use by the Oregon Parks and Recreation Department ($103,950) and development of an Environmental Impact Statement for this Habitat Conservation Plan ($200,000). A Recovery Land Acquisition grant ($307,000) supported purchase of a conservation easement on 89 hectares (220 acres) of western snowy plover habitat along 3.7 kilometers (2.3 miles) of the Elk River Spit.

### 3. Conservation Efforts on Private Lands

Private landowners interested in conservation efforts for western snowy plovers and coastal dune habitats have made important contributions to recovery efforts for coastal dune species. At Ormond Beach, California, Southern California Edison has enhanced approximately 60 hectares (150 acres) of degraded wetlands and coastal dune habitat for several special status species, including the western snowy plover and California least tern (D. Pearson, Southern California Edison, pers. comm. 1996).

### 4. Federal Regulatory Program

#### *a. Critical Habitat*

On March 2, 1995, we published a proposed rule to designate critical habitat for western snowy plover at 28 areas along the coast of California, Oregon, and Washington (U.S. Fish and Wildlife Service 1995*b*). At that time, critical habitat was proposed to fulfill an outstanding requirement under section 4 of the Endangered Species Act to highlight important habitat areas on which activities that require Federal actions need to be evaluated under section 7 of the Endangered Species Act. A funding moratorium by the U.S. Department of the Interior for listing actions was in place during the period April 1995 to April 1996. We subsequently acknowledged a serious backlog of listing actions and the need to prioritize them (U.S. Fish and Wildlife Service 1996*b*). Hence, we developed guidance for assigning relative priorities to listing actions conducted under section 4 of the Endangered Species Act during fiscal years 1998 and 1999 (U.S. Fish and Wildlife Service 1998). Designation of critical habitat was placed in the lowest priority (Tier 3). Under this guidance, we placed higher priority on listing imperiled species that currently have limited or no protection under the Endangered Species Act than on devoting limited resources to the process of designating critical habitat for currently-listed species. In addition, we found that because the protection afforded by critical habitat designation applies only to Federal actions, such designation provides little or no additional protection beyond the "jeopardy" prohibition of section 7 of the Endangered Species Act, which also applies only to Federal actions (U.S. Fish and Wildlife Service 1998).

In December 1995, legal challenges by the Environmental Defense Center, Santa Barbara, California, against the U.S. Department of the Interior to finalize designation of critical habitat for the western snowy plover were overruled by the California District Court (U.S. District Court, Central District of California 1995). At that time, the Court's order was based on its decision that lack of funding prevented the Secretary of the Interior from taking final action on proposals for designating critical habitat. However, on November 10, 1998, the U.S. District Court for the Central District of California ruled that the Secretary of the Interior must publish a final designation of critical habitat for the western snowy plover before December 1, 1999 (U.S. District Court, Central District of California 1998).

A final rule designating critical habitat was published on December 7, 1999 (U.S. Fish and Wildlife Service 1999). In May of 2002 the Coos County Board of County Commissioners, Friends of Oceano Dunes, and Concerned Citizens for western Lane County filed a complaint asking for invalidation of the rule. The United States moved for voluntary remand to reconsider the economic analysis and for partial vacatur of the existing designation. On July 19, 2003, the District Court for the District of Oregon granted the United States' motion, ordering the Service on remand to consider the economic impact analysis and ensure that the new rule is based on the best scientific evidence available. This Order was converted to Judgment on July 2, 2003. Based on the potential for harm to the population, at the Service's request the court left most of the established units in place during the redesignation process, but vacated two units in southern California and two units in Washington.

On December 17, 2004, we published a new proposal to designate critical habitat for the Pacific coast distinct population segment of the western snowy plover (U.S. Fish and Wildlife Service 2004*b*). The final rule to designate critical habitat was published on September 29, 2005 (U.S. Fish and Wildlife Service 2005). This rule designated critical habitat in 32 units, compared to 28 units in the 1999 critical habitat final rule, but covers only 4,921 hectares (12,145 acres) compared to 7,881 hectares (19,474 acres) in the 1999 rule. Of the 32 units, 23 are in California, 5 are in Oregon, and 3 are in Washington. Of the total acreage, 1,002 hectares (2,478.5 acres), or 20 percent, are on Federal lands; 2620.5 hectares (6,474 acres), or 53 percent, are on land owned by States or local agencies; and 1294.5 hectares (3,191 acres), or 26 percent, are privately-owned.

It is important to understand what critical habitat means and how it differs from this recovery plan. Section 3 of the Endangered Species Act defines critical habitat to mean: (i) the specific areas within the geographical area occupied by the species at the time it is listed on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed, upon determination that such areas are essential for the conservation of the species. The term "conservation" is defined in section 3 as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary." Therefore, critical habitat is to include biologically suitable areas necessary to recovery of the species.

Section 7 of the Endangered Species Act requires Federal agencies to consult with us to evaluate the effects that any activities they fund, authorize, or carry out may have on designated critical habitat. Agencies are required to ensure that such activities are not likely to adversely modify (*e.g.*, damage or destroy) critical habitat. Because the issuance of permits under section 10(a)(1)(B) of the Endangered Species Act constitutes a Federal action or connection and is subject to an internal section 7 consultation, habitat conservation plans developed for actions on private lands must also analyze the potential for adverse modification of critical habitat. Accordingly, where Federal activities may affect western snowy plover critical habitat, we will consult with Federal agencies under section 7 to ensure that these actions do not adversely modify critical habitat.

Critical habitat designation does not create a wilderness area, preserve, or wildlife refuge, nor does it close an area to human access or use. It applies only to activities sponsored at least in part by Federal agencies. Such federally-permitted land uses as grazing and recreation may take place if they do not adversely modify critical habitat. Designation of critical habitat does not constitute a land management plan, nor does it signal any intent of the government to acquire or control the land. Therefore, if there is no Federal involvement (*e.g.*, Federal permit, funding, or license), activities of a private landowner, such as farming, grazing, or constructing a home, generally are not affected by a critical habitat designation, even if the landowner's property is within the geographical boundaries of critical habitat (U.S. Fish and Wildlife Service 1993*c*). Without a Federal connection to a proposed action, designation of critical habitat does not require that landowners of State or other non-Federal lands do anything more than they would otherwise do to avoid take of listed species under provisions of section 9 of the Endangered Species Act.

By comparison, a recovery plan delineates site-specific management actions that we believe are required to recover and/or protect listed species, establishes objective, measurable criteria for downlisting or delisting the species, and estimates time and cost required to carry out these actions. A recovery plan is not a regulatory document and does not obligate cooperating or other parties to undertake specific tasks or expend funds.

Critical habitat designation is not necessarily intended to encompass a species' entire current range. Recovery plans, however, address all areas determined to be important for recovery of listed species and identify needed management measures to achieve recovery. Because critical habitat designations may exclude areas based on factors such as economic cost, approved or pending management plans, or encouragement of cooperative conservation partnerships with landowners, the areas identified in recovery plans as important for recovery of the species may not be identical to designated critical habitat. The recovery units described in this recovery plan include but are not restricted to the 32 areas designated as critical habitat: Damon Point, Midway Beach, Leadbetter Point, Bayocean Spit, Baker/Sutton Beaches, Siltcoos to Tenmile, Coos Bay North Spit, and Bandon to Floras Creek in Recovery Unit 1; Lake Earl, Big Lagoon, McKinleyville area, Eel River area, MacKerricher Beach, and Manchester Beach in Recovery Unit 2; Point Reyes Beach, Limantour Spit, Half Moon Bay, Santa Cruz Coast, Monterey Bay Beaches, and Point Sur Beach in Recovery Unit 4; San Simeon Beach, Estero Bay, Devereaux Beach, Oxnard Lowlands in Recovery Unit 5; and Zuma Beach, Santa Monica Bay, Bolsa Chica area, Santa Ana River Mouth, San Onofre Beach, Batiquitos Lagoon, Los Penasquitos, and South San Diego in Recovery Unit 6. Implementation of the recovery actions in this recovery plan (*e.g.*, monitoring, habitat improvement, nest protection, recreation management) may not be limited to designated critical habitat areas.

### *b. Section 9 Take Prohibitions*

Section 9 of the Endangered Species Act of 1973, as amended, prohibits any person subject to the jurisdiction of the United States from taking (i.e., harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting) listed wildlife species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the Endangered Species Act (50 CFR 17.3) further define "harm" to include significant habitat modification or degradation that results in the killing or injury of wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns, which include, but are not limited to, breeding, feeding, or sheltering.

As an example under the authority of section 9 of the Endangered Species Act, on May 15, 1998, we received preliminary injunctive relief against the Town of Plymouth, Massachusetts, because their beach management failed to prevent take (killing) of a piping plover chick by an off-road vehicle (U.S. District Court for Massachusetts 1998). The judge's order prohibited off-road vehicle traffic through the piping plover's nesting season unless the town implemented specific management measures to preclude take, including twice-daily monitoring of nests and a 400-meter (1,148-foot) buffer of protected habitat for newly-hatched chicks.

The proposed special rule under section 4(d) of the Endangered Species Act (U.S. Fish and Wildlife Service 2006b) would exempt most recreational and commercial activities within a county from section 9 prohibitions on take of western snowy plovers, if documentation of conservation actions was provided and populations within the county met targets based on the Management Goal Breeding Numbers in Appendix B of the recovery plan. Research and monitoring actions would continue to require recovery permits under section 10(a)(1)(A) of the Endangered Species Act.

### *c. Section 10 Permits*

Section 10 of the Endangered Species Act and related regulations provide for permits that may be granted to authorize activities otherwise prohibited under section 9, for scientific purposes or to enhance the propagation or survival of a listed species (i.e., section 10(a)(1)(A) permits). These permits have been granted to certain biologists of conservation organizations (***e.g.***, Point Reyes Bird Observatory and Oregon Natural Heritage Program) and Federal and State agencies to conduct western snowy plover population monitoring and banding studies and construct predator exclosures. It is also legal for employees or designated agents of certain Federal or State agencies to take listed species without a permit if the action is necessary to aid sick, injured, or orphaned animals or to salvage or dispose of a dead specimen.

Section 10(a)(1)(B) of the Endangered Species Act also allows permits to be issued for take of endangered and threatened species that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity" if we determine that certain conditions have been met. An applicant for an incidental take permit must prepare a habitat conservation plan that specifies the impacts of the take, the steps the applicant will take to minimize and mitigate the impacts, funding that will be available to implement these steps, alternative actions to the take that the applicant considered, and the reasons why such alternatives are not being utilized. Conditions that we must meet include a determination: (1) whether the taking will be incidental, (2) whether the applicant will minimize and mitigate the impacts of such taking to the maximum extent possible, (3) that adequate funding for the recovery will be provided, (4) that the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild, and (5) of any other measures that we may require as being necessary or appropriate for the recovery plan. Section 10(a)(1)(B) of the Endangered Species Act provides for permits that have the potential to contribute to conservation of listed species. Such permits are intended to reduce conflicts between the conservation of listed species and economic activities, and to develop partnerships between the public and private sectors.

### *d. Section 7 Requirements and Consultations*

Section 7(a)(1) of the Endangered Species Act requires all Federal agencies to "utilize their authorities in furtherance of the purposes of [the] Act by carrying out programs for the conservation of endangered species and threatened species". Hence, Federal agencies have a greater obligation than do other parties, and are required to be pro-active in the conservation of listed species regardless of their requirements under section 7(a)(2) of the Act. Section 7(a)(2) of the Endangered Species Act requires Federal agencies to consult with us prior to authorizing, funding, or carrying out activities that may affect listed species. Section 7 obligations have caused Federal land management agencies to implement western snowy plover protection measures that go beyond those required to avoid take; for example, eradicating European beachgrass and conducting research on threats to western snowy plovers. Other examples of Federal activities that may affect western snowy plovers along the Pacific coast, thereby triggering a section 7 consultation, include permits for sand management activities or major restoration projects that affect coastal processes or that are targeted to protect other species on Federal lands such as dune plants (National Park Service, U.S. Department of the Interior); disposal of dredged materials (U.S. Army Corps of Engineers); military training (U.S. Department of Defense); and funding to public agencies for projects to repair beach facilities, such as public access paths (Federal Emergency Management Agency).

### *e. Other Federal Regulations, Executive Orders, and Agreements*

Section 404 of the Clean Water Act, as amended, and section 10 of the Rivers and Harbors Act of 1899 are the primary Federal laws that could provide some protection of nesting and wintering habitat of the western snowy plover that is determined by the U.S. Army Corps of Engineers (Corps) to be wetlands or historic navigable waters of the United States. Excavation or placement of any fill material (including sand) below the high tide line, as defined under 33 CFR, Section 328.3(d), Definition of Waters of the United States, also requires a permit from the U.S. Army Corps of Engineers.

Executive Order 11644, Use of Off-Road Vehicles on Public Lands, and Executive Order 11989, Off-Road Vehicles on Public Lands, pertain to lands under custody of the Secretaries of Agriculture, Defense, and Interior (except for Native American Tribal lands). Executive Order 11644 requires administrative designation of areas and trails where off-road vehicles may be permitted. Executive Order 11989 states that "... the respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, wildlife, wildlife habitat ... immediately close such areas or trails to the type of off-road vehicles causing such effects, until such time as he determines that such effects have been eliminated and that measures have been implemented to prevent future recurrence". Compliance with this executive order would promote prohibitions or restrictions on off-road vehicles so that they are not allowed to adversely affect sensitive habitats used by western snowy plovers.

Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands, provide protective policies that apply to western snowy plover habitats. Executive Order 11988 mandates that all Federal agencies avoid direct or indirect support of floodplain development wherever there is a practicable alternative. Executive Order 11990 mandates that all Federal agencies shall "provide leadership and shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands..." Compliance with Executive Order 11988 would promote protection of beach and dune habitats through restrictions on development within floodplains. Application of Executive Order 11990 would promote protection of wetland habitats used by western snowy plovers.

Executive Order 13112, Invasive Species, directs Federal agencies to prevent the introduction of invasive species; control their populations in a cost-effective and environmentally sound manner; monitor invasive species; restore native species and habitat conditions in ecosystems that have been invaded; conduct research and develop technologies to prevent their introduction; and promote public education on invasive species and the means to address them. This executive order also requires that a Federal agency "not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species..." Compliance with this executive order would enhance western snowy plover habitats through (1) avoidance of use, approval, or funding the planting of invasive species like European beachgrass; and (2) active programs to remove this invasive species and restore coastal dune habitats with native plant species.

The Fish and Wildlife Coordination Act (16 U.S.C. 661-667e), as amended, requires that whenever a proposed public or private water development project is subject to Federal permit, funding, or license, the conservation of fish and wildlife resources shall be given equal consideration. This Act also requires that project proponents shall consult with us and the State agency responsible for fish and wildlife resources. Compliance with the Fish and Wildlife Coordination Act highlights the importance of considering and providing for the habitat needs of fish and wildlife resources when reviewing projects that would adversely affect these resources.

The National Environmental Policy Act of 1969, (42 U.S.C. 4321-4347), as amended, requires that each Federal agency prepare an environmental impact statement on the potential environmental consequences of major actions under their jurisdiction. Environmental impact statements must include the impacts on ecological systems, any direct or indirect consequences that may result from the action, less environmentally damaging alternatives, cumulative long-term effects of the proposed action, and any irreversible or irretrievable commitment of resources that might result from the action. Compliance with the National Environmental Policy Act highlights the need to disclose, minimize, and mitigate impacts to biological resources, including western snowy plovers.

The Coastal Zone Management Act of 1972 (16 U.S.C. 1451-1464), as amended, established a program for states to voluntarily develop comprehensive programs to protect and manage coastal resources. To receive Federal approval and funding under this Act, states must demonstrate that they have programs and enforceable policies that are sufficiently comprehensive and specific to regulate land uses, water uses, and coastal development, and must have authorities to implement enforceable policies. Local coastal plans, local comprehensive plans, and implementing measures by coastal planning jurisdictions pursuant to the Coastal Zone Management Act should be developed, updated, and implemented with protective measures for western snowy plovers.

Western snowy plovers are protected under the Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712), as amended. Under the Migratory Bird Treaty Act, prohibited acts include pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting any migratory bird, nest, or eggs without a permit from the U.S. Fish and Wildlife Service.

**5. State Regulatory Protection, Policies, and Agreements**

In Washington, Oregon, and California, each state holds title to, and has regulatory jurisdiction over, the coastal intertidal zone. In Washington, the area between mean high tide to extreme low tide is the seashore conservation area under the authority of the Washington State Parks and Recreation Commission. In California, the California State Lands Commission has regulatory authority to the mean high tide line along the California coast.

In Oregon, the Oregon Parks and Recreation Department administers the State beach for the ocean shore recreation area, which is defined as the area between the line of extreme low water and the statutory vegetation line, which is a line surveyed to the approximate line of vegetation that existed in 1969 (Oregon Revised Statutes 390.770). The Oregon Division of State Lands also has jurisdiction over waters of the state along the Pacific coast to the line of highest tide or the line of established vegetation, whichever is higher. Therefore, the Oregon Parks and Recreation Department has direct jurisdiction, authority, and responsibility for management of western snowy plover habitats in the State of Oregon, which owns not only to the mean high tide line, which is western snowy plover foraging habitat, but also into the vegetation line, which is essentially the dry sand area used by western snowy plovers for nesting.

State coastal planning and regulatory agencies, such as the California Coastal Commission, require preparation of local coastal zone management plans by local coastal municipalities. These local coastal zone management plans must comply with the Coastal Zone Management Act of 1972 regarding protection of coastal resources, including natural resources. Under the California Coastal Management Program, coastal resources are managed and cumulative impacts addressed through: (1) coastal permits and appeals; (2) planning and implementation of local coastal programs; and

(3) Federal consistency review. However, effective management of cumulative impacts is difficult under the existing management framework because multiple jurisdictions have varying policies and standards in different geographic areas (California Coastal Commission 1995). Through the Coastal Commission's regional cumulative assessment program, cumulative impacts to coastal resources can be addressed through the periodic review of local coastal programs. In California, most local coastal programs and general plans were completed prior to 1993 (when we listed the western snowy plover as a threatened species); therefore, many do not reflect protective measures specifically for the western snowy plover.

The Oregon Department of Land Conservation and Development is the designated coastal zone management agency for the State of Oregon. The State of Oregon's land use planning system has several elements that are related to conservation of western snowy plovers and their habitats. In Oregon, local jurisdictions (cities and counties), service districts, and State agencies are required to develop Local Comprehensive Plans and Implementing Measures, such as zoning and land division ordinances, to effect these plans. Each plan must satisfy a set of 19 goals established through Oregon land use law and policy. Plans must be reviewed by the Land Conservation and Development Commission for consistency with these goals before they can be put into effect. Several of the planning goals have application to, or should be considered during, planning for western snowy plover conservation and recovery. These goals include: Goal 5 - Open Spaces, Scenic and Historic Areas, and Natural Resources; Goal 7 - Areas Subject to Natural Disasters and Hazards; Goal 8 - Recreational Needs; Goal 16 - Estuarine Resources; Goal 17 - Coastal Shorelands; and Goal 18 - Beaches and Dunes.

Taken in aggregate, the elements of these goals that can contribute to western snowy plover recovery include:

- several requirements for protection of wildlife habitat;
- requiring protection of estuarine ecosystems including habitats, diversity, and other natural values;
- establishing that uses of beaches and dunes shall be based on factors including the need to protect areas of critical environmental concern and significant wildlife habitat;

- requiring that coastal plans provide for uses of beaches and dunes that are consistent with their ecological values and natural limitations;
- requiring an evaluation of the beneficial effects to natural resources from allowing continuation of natural events that are hazardous to human developments (such as erosion and ocean flooding);
- establishing a preference for nonstructural solutions to erosion and flooding of coastal shorelands over structural approaches (such as seawalls and rip-rap);
- requiring that development of destination resorts be compatible with adjacent land uses and maintain important natural features such as threatened and endangered species habitats;
- encouraging coordination among State, Federal, and local governmental agencies while developing recreation plans, and discouraging development of recreation plans that exceed the carrying capacity of the landscape;
- encouraging planning for Open Space, Scenic and Historic Areas, and Natural Resources (Goal 5), Recreational Needs (Goal 8), and Coastal Shorelands (Goal 17) in close coordination; and
- allowing dune stabilization programs only when in conformance with the overall comprehensive plan and after assessment of the potential impacts.

Some aspects of these planning goals could be interpreted to be contrary to western snowy plover conservation and recovery when viewed in isolation. However, when viewed in the context of the entire goal or all the planning goals, these elements should be compatible with western snowy plover conservation and carefully-planned habitat restoration activities. Two such elements are the directive to increase recreational access to coastal shorelands and the restrictions placed on dune grading and removal of vegetation. Goal 17 - Coastal Shorelands directs local governments and the Oregon Parks and Recreation Department to develop a program to increase public access. In many areas, recreational use of western snowy plover habitat during the nesting season is detrimental to or incompatible with western snowy plover conservation. However, this goal also recognizes that many shorelands have unique or exceptional natural area values, includes the objective of reducing adverse impacts to fish and wildlife habitat associated with use of coastal shorelands, clearly establishes that significant wildlife habitat shall be protected, establishes that uses of such habitat areas shall be consistent with protection of natural values, and directs recreation plans to provide for "appropriate" public access and recreational use. Goal

18 - Beaches and Dunes directs local governments and State and Federal agencies to regulate actions in beach and dune areas to minimize any resulting erosion and only allows foredune breaching to replenish interdune areas or in the case of an emergency. Western snowy plover habitat restoration efforts in areas that have been overtaken by European beachgrass (*Ammophila arenaria*) may involve foredune breaching, vegetation removal, dune grading, and other actions that will remove the European beachgrass and restore the natural beach and dune processes of sand movement, including erosion and deposition. However, this goal also recognizes the need to protect areas of critical environmental concern, areas of biological importance, and areas with significant habitat value, specifically identifies removal of "desirable" vegetation as an action requiring minimization of erosion, and requires that any foredune breaching be consistent with sound principles of conservation.

The Washington State Parks and Recreation Commission administers the Seashore Conservation Act of 1988 in accordance with the Revised Code of Washington and the Washington Administrative Code. The Seashore Conservation Area (Revised Code of Washington 43.51) emphasizes the importance of beaches to the public for recreational activities. In designating beach areas to be reserved for pedestrian use, it considers natural resources, including protection of shorebird and marine mammal habitats, preservation of native beach vegetation, and protection of sand dune topography. Chapter 352-37 (Ocean Beaches) of the Washington Administrative Code requires local governments within the Seashore Conservation Area to prepare recreation management plans that designate at least 40 percent of the ocean beach for use by pedestrians and nonmotorized vehicles from April 15 to the day after Labor Day. These regulations also identify restrictions on certain uses within ocean beaches, including motor vehicles, equestrian traffic, speed limits, aircraft, wind/sand sailers, parasails, hovercraft, group recreation events, and beach parking and camping. In 1989, an interagency agreement was signed by the Washington Department of Natural Resources, Washington State Parks and Recreation Commission, Washington Department of Wildlife, and City of Ocean Shores regarding management of mixed uses at Damon Point. The intent of the agreement was to protect western snowy plovers while allowing recreation.

State regulations, policies, and goals for the States of California, Oregon, and Washington provide many protective measures for western snowy plovers. However, because they frequently emphasize public uses of beach habitat, there is potential for conflicts between human uses of the coastal zone and needed management measures for recovery of the western snowy plover.

The California Department of Parks and Recreation has written management guidelines for the western snowy plover which are meant to be used in conjunction with the recovery plan. Management actions will be implemented from the guidelines and may result in changes in how coastal units are operated. Increased emphasis will be required for monitoring, nest area protection, prohibition of certain activities in important nesting areas, and public education.

**6. Consultations, Habitat Conservation Plans, and Other Regulatory Actions**

Through consultations with Federal agencies under section 7 of the Endangered Species Act and through the development of habitat conservation plans with non-Federal agencies developed under section 10 of the Endangered Species Act, we provide nondiscretionary terms and conditions that minimize (sections 7 and 10) and mitigate (section 10) the impacts of covered activities on listed species and their habitat. Several major consultations and habitat conservation planning efforts to benefit the western snowy plover have been completed or are currently under way.

In 1995 our Sacramento Fish and Wildlife Office completed formal consultation with the National Park Service, Golden Gate National Recreation Area, on the effects of their management of Ocean Beach, San Francisco on the western snowy plover. Ocean Beach experiences tremendous visitor use year-round because of its proximity to San Francisco, yet it supports high numbers of nonbreeding western snowy plovers, which may be present from May through July. The consultation covered actions and policies the National Park Service had taken that resulted in unnecessary harassment of nonbreeding western snowy plovers. Most significant of these measures was their policy not to enforce regulations requiring pets to be leashed and under control by their owners on all National Park Service lands. Data collected by the National Park Service clearly identified that unleashed dogs were the most significant disturbance factor of the many sources of disturbance to western snowy plovers on Ocean Beach. As a result of the consultation, the National Park Service began to enforce their "leash law" along 3.2 kilometers (2 miles) of beach utilized by western snowy plovers. The

National Park Service implemented this policy despite vocal and persistent opposition by the San Francisco Society for the Prevention of Cruelty to Animals and other local advocacy groups, including the "Rovers for Plovers", which organized themselves to challenge the National Park Service's leash law. These groups were successful in advocating their position in numerous television news stories and articles in local newspapers. At the height of this discourse, the local public radio station held a round-table discussion between the National Park Service, U.S. Fish and Wildlife Service, and Society for the Prevention of Cruelty to Animals, and solicited audience members to call in and identify their viewpoint. The overwhelming majority of callers supported leash law restrictions that would minimize harassment of western snowy plovers.

Our Arcata Fish and Wildlife Office has formally consulted with the U.S. Army Corps of Engineers regarding gravel extraction on the Eel River, California. Gravel mining operations are subject to permits from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. The western snowy plover breeds on the Eel River gravel bars. Impacts to the western snowy plover and its designated critical habitat associated with gravel mining operations have been assessed based on nesting surveys and changes to habitat resulting from gravel extraction. The Arcata Fish and Wildlife Office has also worked with Humboldt County, the California Department of Fish and Game, and the California Department of Parks and Recreation to implement additional protections for nesting western snowy plovers at MacKerricher, Manchester, Little River, Humboldt Lagoons, and Prairie Creek State Parks; Clam Beach County Park, and the Eel River Wildlife Area. These measures include installation of nest exclosures, signing, and development of educational material for kiosks. Technical assistance has also been provided to Prairie Creek State Park and MacKerricher State Park on exotic vegetation management programs (J. Watkins *in litt.* 1999, pers. comm. 2001). A section 7 consultation with the Bureau of Land Management on finalization of a management plan for Humboldt Bay South Spit is expected to be initiated soon (J. Watkins, pers. comm. 2006).

Our Ventura Fish and Wildlife Office is attempting to initiate a regional approach to habitat conservation planning for western snowy plovers and other listed species along Monterey Bay in Monterey County, California. Currently, there are several proposed development projects within the city of Sand City and a "city wide" habitat conservation plan has been prepared for these projects. The City of Sand City has yet to present a complete draft of their habitat conservation plan to the Ventura Fish and Wildlife Office for review. Formerly, the City of Marina was also proposing several coastal developments that were expected to have adverse effects on western snowy plovers, but these projects are no longer planned due to changes in land ownership and other factors. The City of Marina has halted the drafting of a habitat conservation plan for lands within their jurisdiction. We have expressed concerns about projects being presented in a piecemeal fashion, which does not allow an adequate assessment of their cumulative effects, and have recommended a regional approach through preparation of a regional habitat conservation plan. This plan would provide greater conservation benefits to the western snowy plover. In addition to the adverse effects of development on western snowy plovers and their habitat, recreation on the extensive public lands along Monterey Bay is also adversely affecting western snowy plovers. Therefore, public land managers, including our Refuges Division, the California Department of Parks and Recreation, the California Department of Fish and Game, and the Monterey Peninsula Regional Park District, need to be involved in planning efforts along Monterey Bay.

Through the consultation process, our Ventura Fish and Wildlife Office determined that a draft biological opinion on Vandenberg Air Force Base’s initial proposed beach management plan for the western snowy plover, concluding that the plan would "likely jeopardize the continued existence of the western snowy plover and adversely modify its critical habitat." Our draft biological opinion of January 2001 pointed out that the Air Force's beach plan would have allowed twice as much nesting habitat to be open to public recreation as was allowed during the 2000 breeding season, and it would have reduced the time the Air Force spends patrolling the beaches by about 80 percent. Based on this feedback, the Air Force subsequently reinitiated consultation on a modified version of the beach management plan, including commitments to signage, information kiosk, and enforcement patrols. The Ventura Fish and Wildlife Office issued a non-jeopardy biological opinion on the modified action in March 2001. Beach opening and full implementation of conservation measures was implemented on May 25, 2001, with hours and days of open beach limited due to limited availability of enforcement personnel. For the next three breeding seasons (2002, 2003, 2004), the Service issued biological opinions on annual beach management plans proposed by the Air Force. In 2004, we had a series of meetings with the Air Force to discuss their beach management strategy and its effects on the western snowy plover. Through a cooperative effort, the Service and the Air Force came to agreement on a 5-year beach management plan that includes many of the same protective measures that had been in place the last several years, yet allows the Air Force to provide recreational access seven days a week. On March 1, 2005, the Ventura Fish and Wildlife Office issued a new non-jeopardy biological opinion on the Air Force's proposed 5-year beach management plan (2005-2009).

Our Ventura Fish and Wildlife Office is also involved with the development of a habitat conservation plan being funded by the Off-Road Vehicle Division of the California Department of Parks and Recreation for the Pismo/Oceano Dunes State Vehicular Recreation Area and other State parks within the San Luis Obispo District of the California Department of Parks and Recreation. The Ventura Fish and Wildlife Office is also involved in the development of a HCP for the Rancho Guadalupe County Park, Santa Barbara, California. These habitat conservation plans will evaluate and mitigate for effects that recreation and park management activities are having on the covered species, including the western snowy plover.

Recent consultations handled by our Newport Field Office include those in response to the New Carissa Oil Spill, a consultation on BLM management actions at the New River Area of Critical Environmental Concern (ACEC), and a consultation on the Integrated Predator Damage Management Program 2002 to 2007. The Oregon Parks and Recreation Department is currently developing a Habitat Conservation Plan that proposes restrictions on some Oregon beaches to help the plover population recover.

The New Carissa oil spill was a long and complicated incident involving a variety of Federal, State, local and private participants. On February 4, 1999, the *New Carissa*, carrying 359,000 gallons of bunker oil and 37,400 gallons of diesel, grounded on the north spit of Coos Bay and began leaking oil shortly thereafter. Subsequently, oil and oiled wildlife were observed on the beach. Attempts were made to burn off the oil. The vessel broke into two pieces during the second attempt. There were three formal consultations associated with the *New Carissa* between 1999 and 2000. The first consultation addressed the effects of issuing permits for salvage of the *New Carissa* stern section, the second the effects of restoring recreational access to the Coos Bay north spit, and the third the response efforts led by the Coast Guard. In all three consultations, it was concluded that the proposed actions would not jeopardize the western snowy plover if protective measures required to limit take were implemented.

A consultation on the New River ACEC was completed in 2005. The purpose of the biological opinion was to address a variety of issues: recreation management at Floras Lake where measures were not adequately protecting nesting plovers; the periodic construction of a breach on the New River spit to improve fish and wildlife habitat and alleviate flooding; increased habitat restoration; and the development of a primitive beach camping area.

A consultation on Oregon’s Integrated Predator Damage Management Program was completed in 2001. The objective of this program is to assist in recovery of the western snowy plover in Oregon by improving western snowy plover nesting and fledging success, through 1) expanding assessment efforts to all western snowy plover breeding and nesting locations to determine predator species responsible for nest, chick and adult predation; and 2) reducing the local predator populations where feasible and where the predator species or individual is known. The consultation calls for a variety of lethal and non-lethal methods to be used by APHIS-WS personnel to control the predator population.

The Oregon Parks and Recreation Department has been working with various cooperating agencies to develop a Habitat Conservation Plan for Oregon beaches. The Oregon Parks and Recreation Department is responsible for various management activities for most of Oregon's coast, including recreation management, general beach management, and the management of natural resources. In addition, the Oregon Parks and Recreation Department is responsible for issuing various permits along the Oregon coast. Some of these activities may result in "take" of or harm to the snowy plover. A draft version of the Habitat Conservation Plan was distributed to the public in January 2004. The Oregon Parks and Recreation Department conducted public meetings in seven coastal communities to solicit public comment. The area covered under the HCP includes the portions of the ocean shore along the Oregon coast that extend between the mouth of the Columbia River South Jetty on the north and the California/Oregon border on the south (approximately 230 miles of beach). In addition, specific portions of six key state parks, state natural areas, and state recreation areas are included in the covered lands to be managed for snowy plover recovery. Implementation of the plan will begin after approval and completion of the Habitat Conservation Plan and its associated documents.

In southern California, we, through our Carlsbad Fish and Wildlife Office, have worked with local jurisdictions to develop regional habitat conservation plans under section 10 of the Endangered Species Act. The Multiple Species Conservation Program addresses southwestern San Diego County, including, for example, western snowy plover breeding habitat in south San Diego Bay through the City of San Diego. The Multiple Habitat Conservation Program addresses northwestern San Diego County. This plan provides for the conservation of western snowy plover breeding habitat and will potentially result in more management in association with a proposed preserve.

Also in San Diego County, we have been working with the Navy and the Marine Corps to avoid and minimize impacts to western snowy plovers. For example, with the assistance of our programmatic biological opinion in 1995, the Marine Corps has addressed training-related impacts on western snowy plovers and other species on approximately 17 miles of coastline on Camp Pendleton. We have likewise worked with the Navy at Naval Base Coronado to develop a program to conserve western snowy plover nesting and breeding habitat and allow necessary military training. As a result of successful management on these San Diego County military installations, they support a majority of the western snowy plover population in Recovery Unit 6 (*e.g.*, roughly 65 percent in 2006 from window survey data) while the military installations accomplish their respective training missions.

In the past, several instances were documented of western snowy plover nests being trampled by cattle belonging to the Vail and Vickers Company on Santa Rosa Island within the Channel Islands National Park, owned and managed by the National Park Service. In 1996, a lawsuit to remove cattle from Santa Rosa Island was initiated by the Environmental Defense Center, Santa Barbara, on behalf of the National Park Conservation Association. It was initiated under the authority of the Clean Water Act and the Endangered Species Act, based on concerns about management of livestock by the National Park Service and associated impacts to water quality and sensitive plant and animal species. As a result of a lawsuit settlement, all cattle were removed from Santa Rosa Island in early 1998.

**7. Regulatory Protection and Policies of Local Governments**

Local governments regulate municipal land uses through development of local land use plans, general plans, comprehensive plans, and zoning policies. On April 21, 1998, we requested that county and coastal city planners within the states of Washington, Oregon, and California complete land-use management surveys regarding the western snowy plover. We sent surveys to 91 State, county, or coastal city planners and received responses from 37 percent of the recipients. Approximately 50 percent of the respondents were aware that western snowy plover habitats occur within their jurisdictions. However, only about one-third knew whether sandy beach and other habitats within their jurisdictions provided breeding and/or wintering habitat for western snowy plovers. Many general plans, coastal zone programs, and comprehensive plans prepared by local governments contain land use designations that are protective of western snowy plover habitats (*e.g.*, parkland, open space, and conservation designations for sandy beach). However, allowable uses in or adjacent to these zones, such as development (*e.g.*, seawalls, recreational facilities, single-family homes), recreation and public access, could cause direct or indirect threats to breeding or wintering western snowy plovers.

Whereas 43 percent of the respondents include regulatory policies that protect western snowy plover habitat (*e.g.*, sandy beach) in their general plans, local coastal programs or comprehensive plans, only 8 percent have developed regulatory policies specifically to protect the western snowy plover. These respondents included the City of Half Moon Bay, California, and Coos and Curry Counties, Oregon. Only 23 percent of the respondents specifically explain the threatened status of the western snowy plover, identify western snowy plover breeding/wintering locations, or specify shorebird nesting/roosting habitats as environmentally sensitive habitat areas in their jurisdictions. About 50 percent of the respondents indicated they either (1) have approved development within or adjacent to sandy beach or other habitats used by the western snowy plover, or (2) did not know whether such development had been approved by their agency. About half of these same respondents could provide some information on the number of permits authorized, area or linear distance affected, percentage of development types (*e.g.*, housing, recreational) permitted, and permit conditions.

Based on these responses, it seems that specific locations of, and protective measures for, western snowy plover breeding and/or wintering locations are not included in most of the existing general plans, comprehensive plans, local coastal programs, or their implementing ordinances. Also, to better assess cumulative impacts, these responses indicate a need for a better tracking method regarding development projects approved within and adjacent to western snowy plover habitat.

**8. Interagency Coordination**

Each of the six recovery units for the western snowy plover is represented by a working group which meets at least once a year to coordinate western snowy plover recovery efforts. The working groups have provided a forum for the participation of affected Federal and State agencies and others in discussion, implementation, and adjustment of recovery efforts. Items addressed include research and monitoring needs, predator control, recreation management, habitat restoration, public outreach and law enforcement. In addition, a joint meeting of all six working groups is held annually. This group, consisting of beach managers, researchers, and outreach staff, meet to discuss range-wide issues (within the United States), to coordinate recovery actions, to learn from the experience of others, and to share information and research. Attendees have included local, State, and Federal agency staff, non-governmental organizations, consulting firms, private citizens, and volunteers.

The recovery unit working groups vary somewhat in organizational structure depending on major local issues, patterns of land ownership within the area, and specific agencies responsible for management. For example, the Oregon/Washington working group is composed of several subcommittees, including Outreach, Media, Predator Control, Research, Law Enforcement, and Recovery Plan Implementation. They facilitate funding partnerships for monitoring and management programs, thus promoting the best use and leveraging of limited funds. They also act as the main forum for discussing and tracking the status and trends of the snowy plover population. The subcommittees have worked on or supported a variety of cooperative projects, such as monitoring of yearly reproductive success, predator control, and outreach materials. Products developed by the Outreach subcommittee include an outreach plan for Oregon/Washington and “Share the Beach” bookmarks, table tents, dog leashes, brochures, interpretive signs, and coloring books. The Media subcommittee is producing a media outreach CD for distribution to various media outlets and inter-agency press releases. The Predator Control subcommittee approved a predator management plan for Oregon, which first went into effect in 2002. The purpose of the Research subcommittee is to identify research and monitoring priorities, establish criteria for setting priorities, review proposed projects, and address funding mechanisms. The Law Enforcement subcommittee focuses on improving compliance with rules and regulations in plover nesting areas and the Recovery Plan Implementation subcommittee is working on guidance that would assist in “stepping down” the recovery plan for Oregon and eventually Washington.

In 1998, an interagency effort in Oregon produced a slide show and portable display to educate beach visitors about western snowy plover conservation. Outdoor education specialists and/or western snowy plover biologists from the U.S. Bureau of Land Management, U.S. Forest Service, Oregon Department of Fish and Wildlife, Oregon Parks and Recreation Department, and U.S. Fish and Wildlife Service participated in this effort. The show provides basic information about the western snowy plover, the reasons for its decline, and actions needed for its recovery, emphasizing the contribution that beach visitors can make.

# II. RECOVERY

## A. RECOVERY STRATEGY

The recovery strategy for the Pacific coast population of the western snowy plover (western snowy plover) includes three major components: 1) increase population numbers distributed across the range of the Pacific coast population of the western snowy plover; 2) ameliorate or eliminate threats by conducting intensive ongoing management for the species and its habitat, and developing mechanisms to ensure management in perpetuity; and 3) monitor western snowy plover populations and threats to determine success of recovery actions and to refine management actions. Developing and implementing intensive adaptive management actions, ensuring that management will continue in perpetuity, and monitoring to refine management actions, are all necessary to achieve the targeted population increases across the range. These three major components of the recovery strategy each include many actions and multiple partners that are described in further detail below.

### 1. Recovery Strategy Components

The following recovery strategy components will guide future recovery efforts for the U.S. Pacific coast population of the western snowy plover.

a. Population increases should be distributed across the western snowy plover's Pacific coast range.

A key component of recovering western snowy plovers is to ensure that population increases are distributed throughout the species' Pacific coast range. In order to achieve this, management goals (Appendix B) and needed management actions (Appendix C) have been determined for 155 sites distributed along the coasts of southern Washington, Oregon, and California. Additionally, the population's range has been divided into six recovery units (see discussion below) with population goals established for each recovery unit. The six recovery units correspond to regions of the U.S. Pacific coast and to the six subpopulations used in the Population Viability Analysis for the Pacific coast Snowy Plovers (Appendix D). In the population viability analysis, the Pacific coast population of the western snowy plover is treated as a metapopulation, defined as a set of subpopulations among which there is limited dispersal.

The population viability analysis assumes dispersal among subpopulations is limited; however, even limited dispersal among subpopulations is important to species survival and recovery. Dispersal of the population across its breeding range helps to counterbalance catastrophes, such as extreme climatic events, oil spills, or disease that might depress regional survival and/or productivity. Maintaining robust, well-distributed subpopulations should reduce variance in survival and productivity of the Pacific coast population of the western snowy plover as a whole, facilitate interchange of genetic material between subpopulations, and promote recolonization of any sites that experience declines or local extirpations due to low productivity and/or temporary habitat loss.

This recovery plan and the population viability analysis (Appendix D) consider the U.S. Pacific coast population of the western snowy plover to be a single management entity, and population goals and objectives are based on that premise. No portion of the Pacific coast population of the western snowy plover appears to function as a distinct population segment. The Recovery Team therefore recommends that no State, geographic region, or subpopulation of the Pacific coast population of the western snowy plover be considered for delisting separately from the others.

b. Remove or reduce threats by conducting intensive ongoing management for the species and its habitat, and develop mechanisms to ensure management in perpetuity to prevent a reversal of population increases following delisting under the Endangered Species Act.

Management consists of multiple components, including identifying actions to ameliorate or eliminate threats, developing mechanisms to ensure management in perpetuity, continuing outreach and education to provide information to the public, partners, and stakeholders on recovery needs and opportunities, and developing of partnerships among Federal, State, and local agencies and groups to develop and implement effective management. Management actions for the western snowy plover are described in the recovery action outline and in Appendix C. These management actions are necessary to eliminate or ameliorate threats to the western snowy plover, including loss, degradation, and alteration of habitat; disease, predation; and other manmade factors including disturbance of breeding and wintering birds, contaminants, and oil spills.

In addition to specific management recommendations to ameliorate or eliminate threats, the recovery action outline and recovery strategy for the western snowy plover include several recovery actions to develop mechanisms to ensure that management actions continue in perpetuity to ensure that threats remain neutralized. These include establishing working groups and developing participation plans for each recovery unit; ensuring sufficient U.S. Fish and Wildlife Service staff to coordinate recovery of the Pacific coast population of the western snowy plover; developing and implementing management plans for publicly owned lands; assisting local governments and private land owners in developing habitat conservation plans, developing land use protection measures, and developing landowner agreements; and acquiring habitat where necessary. A key component of these efforts includes education and outreach to inform partners and the public about recovery needs and opportunities for the western snowy plover. Actions for outreach are included in the recovery action outline, and the Information and Education Plan (Appendix K) provides greater detail on implementing these outreach and education actions.

Participation of many different groups will be essential to achieve both short-term and long-term management for the western snowy plover and its habitat. The roles of various groups, potential conservation tools and funding available, and the Recovery Team's vision for participation and coordination of partners are further described below.

c. Annual monitoring of western snowy plover subpopulations and reproductive success, and monitoring of threats and effects of management actions in reducing threats, is essential for adaptive management and to determine the success of recovery efforts.

The recovery action outline describes monitoring for breeding, wintering, and migration areas both to determine whether population numbers and survival of western snowy plovers is increasing and whether threats continue to limit population increases. Additional research actions are also recommended to study certain threats and develop management techniques and monitoring methods. Results from research and monitoring efforts will be used to develop, refine, and improve management of western snowy plovers and their habitat. Monitoring of demographic characteristics will be necessary to demonstrate that population goals in the recovery criteria are being achieved. Monitoring of threats and effects of management actions in reducing those threats also is essential in demonstrating progress toward recovery and ultimately will assist in threats analyses necessary to make a delisting determination.

## 2. Roles of Federal, State, Local, and Private Sectors

### *a. Role of Federal Lands*

Federal lands administered by the U.S. Fish and Wildlife Service, National Park Service, U.S. Forest Service, U.S. Bureau of Land Management, the National Marine Sanctuary Program, U.S. Marine Corps, and the U.S. Departments of the Army (including Corps of Engineers), Navy, and Air Force are extremely important to the conservation of the western snowy plover. In California, breeding occurs on National Wildlife Refuge lands, Department of Defense lands, Bureau of Land Management lands, and National Park Service lands. In Oregon, the major Federal landowners are the U.S. Forest Service and Bureau of Land Management, although the State also has jurisdiction over much of the Federally owned area (from mean high tide to the vegetation line) through a recreational easement (E.Y. Zielinski and R.W. Williams *in litt.* 1999). In Washington, the breeding area at Leadbetter Point is within a National Wildlife Refuge.

Under section 7(a)(1) of the Endangered Species Act, Federal agencies are required to actively promote the conservation of listed species. The western snowy plover cannot be recovered simply through general habitat protection or complying with required section 7(a)(2) consultations. The western snowy plover must be actively monitored and managed for the purpose of recovery or its population size will decline. Federal agencies alone cannot assure recovery of the western snowy plover, but should have a leading role in monitoring and management efforts to assure survival and recovery of this species. Some Federal lands contain large areas of contiguous habitat, including adjacent inland areas that are easier to manage for conservation of natural resources than fragmented, linear strips of land that may be owned by states, counties, cities, and private landowners. Protection of western snowy plovers and their habitat on Federal lands is important not only because of the direct benefits to plovers that use these areas, but also because plover protection programs on Federal lands frequently utilize state-of-the art management measures and therefore serve as examples to non-Federal landowners. The Federal Government also should take the lead in addressing the sensitive issue of predator control.

***b. Role of State Lands***

State lands administered by the California Department of Parks and Recreation, California Department of Fish and Game, Oregon Department of Fish and Wildlife, Oregon Parks and Recreation Department, Washington Department of Fish and Wildlife, Washington State Parks and Recreation Commission, and Washington Department of Natural Resources play an important role in conservation of western snowy plovers and their habitats. Intensive management for western snowy plovers occurs at a number of State-owned plover habitat areas. The western snowy plover cannot be preserved simply through general habitat protection. Western snowy plovers must be actively monitored and managed to achieve recovery goals on State lands or their population size will decline.

***c. Roles of State and Local Governments***

State and local government agencies, including state planning agencies and city and county planning and community resources departments, have the primary responsibility for overseeing land uses within their jurisdictions. Therefore, their involvement in future recovery planning and implementing processes is critical. All Appendix B locations should be identified as environmentally sensitive habitat areas requiring protective measures for the western snowy plover in state and local planning documents and zoning designations. Local coastal programs should be amended to include these areas. To facilitate this effort, Federal and State agencies managing western snowy plover habitat should provide technical assistance and information to local governments (see Actions 3.1.6, 3.1.7 and 5.2). We can provide detailed maps of current western snowy plover breeding and/or wintering locations; these maps will be updated periodically as needed.

### *d. Role of Municipal Lands*

Regional, county, and city lands, including regional and municipal park districts, also serve a role in conserving breeding and wintering habitats for western snowy plovers. Because these areas frequently receive heavy pedestrian and recreational use, local jurisdictions with active public outreach programs can reach a large segment of the coastal community regarding the plover's status and habitat needs.

### *e. Role of Private Lands*

Conservation efforts on private lands are needed for the survival and recovery of many listed and other sensitive species. Private landowners can also make important contributions to western snowy plover conservation through facilitating or allowing the monitoring of western snowy plover populations on their land and implementing protective measures.

## 3. Conservation Tools and Strategies

There are numerous conservation tools and strategies available to Federal, State, municipal, and private landowners interested in western snowy plover protection and recovery. Appendix H includes a summary of conservation tools and strategies that may be adopted by landowners, nonprofit organizations, and regulatory agencies to protect western snowy plover habitat.

## 4. Funding Sources

Appendix I includes a summary of some potential sources of funds for implementation of recovery actions for the western snowy plover. This list is not intended to be exhaustive, however, and other funding opportunities may also be available.

An essential mechanism for recovery of the western snowy plover is the development and implementation of participation plans for each of the six recovery units (see Action 3.1.2). A key element of these participation plans is the long-term commitment by participating agencies to seek annual, ongoing funding for western snowy plover management and monitoring activities so that funding within agency budgets can be secured.

In many areas a significant portion of western snowy plover conservation resources are expended in efforts to minimize the adverse impacts of recreation. Often, the primary objective of signs, ropes, on-site interpretation, and enforcement is to manage the behavior of beach-goers such that impacts to western snowy plovers are reduced as much as possible. In areas that have suffered extensive habitat loss or degradation, such recreation management activities are an extremely high priority in order to protect the western snowy plovers using the limited habitat that remains. For some beach managers, much of the funding and staff time expended on recreation management in and near western snowy plover habitat comes from resources targeted for threatened and endangered species recovery. In absence of the need to coordinate and pay for recreation management activities, more of these limited conservation dollars and staff resources could be directed toward western snowy plover management actions such as biological monitoring, habitat restoration, and predation control.

This situation is unique in the experience of many resource biologists. More typically, avoidance, minimization, and mitigation measures are integral components of projects or programs that entail adverse impacts to sensitive resources, and the costs of these activities are regarded as part of the overall cost of the project or program. Applying this traditional construct to recreation projects and programs could significantly promote western snowy plover recovery in several ways. First, it would require impacts to western snowy plovers to be considered up front when planning beach access or other recreation projects. Second, it would encourage impact avoidance and minimization since such measures are often less expensive than mitigation. Third, it would promote involvement of recreation professionals in designing and implementing recreation management measures. And fourth, it would eliminate or reduce the diversion of biological resource management funds toward recreation management activities, thus enabling more of those dollars to be spent on western snowy plover recovery actions.

## 5. Coordination, Participation, and Working Groups

We strongly believe that a collaborative stewardship approach to the proactive management of listed species involving government agencies (Federal, State, and local) and the private sector is critical to achieving the ultimate goal of recovery of listed species under the Endangered Species Act. An essential mechanism to achieve recovery of the western snowy plover is the formation and maintenance of working groups for each of the six recovery units (Appendix A), (see Action 3.1.1). Representation from the full range of Federal, State, local, and private landowners and other parties who have a stake in western snowy plover conservation within each of these six recovery units is needed to advance the recovery actions recommended in this recovery plan. Working group membership should include land managers, environmental groups, user groups, and groups involved in conservation projects (including local chapters such as the National Audubon Society, Sierra Club, Native Plant Society, Americorps, California Conservation Corps, Boy Scouts, Surfrider Foundation, and other recreational use groups). These groups can provide large networks of volunteers who can be mobilized to assist public resource agencies in the implementation of management measures for protection and recovery of the western snowy plover.

Working groups for each of the six recovery units currently exist and convene annually for regional and rangewide meetings. Through evaluation, communication, and coordination, members of each of the six working groups should manage the western snowy plover population and monitor progress towards recovery. They should produce annual reports on population monitoring and the effectiveness of management activities for the working group and our Arcata Fish and Wildlife Office. Each of the six working groups should prepare a participation plan, thereby formalizing recovery implementation efforts and the intentions of responsible agencies to seek ongoing, annual funding for recovery implementation. The Recovery Coordinator should coordinate and communicate with each recovery unit to support recovery efforts and assure implementation of the recovery plan (see Actions 3.1 through 3.4, 6, and 7). The Recovery Coordinator also should coordinate with other western snowy plover survey efforts and assessments throughout the west and throughout North America. Coordination with these other efforts may provide valuable information on the status and distribution of the western snowy plover, as well as valuable information on management actions that may benefit the Pacific coast population of the western snowy plover. A coordinated international conservation program with Mexico also should be established to protect western snowy plover populations and their habitat in that country (see Action 8).

## B. RECOVERY UNITS

The Pacific coast population of the western snowy plover has been divided into six recovery units (Appendix A, Figures A-1 through A-7). Establishing recovery units with specific recovery goals for each recovery unit will assist in meeting the objective of ensuring that population increases are distributed throughout the western snowy plover's Pacific coast range. A recovery unit is a special unit of a listed species that is geographically or otherwise identifiable and is necessary to the survival and recovery of the entire listed entity. Recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or other features for long-term sustainability of the entire listed species. However, recovery units are not listed as separate entities and cannot be delisted individually. Each recovery unit must be recovered before the species can be delisted.

The resilience to extinction of a widespread species can be negated if the species is subjected to a new stress over a large area (Raup 1991:122, 182). For the western snowy plover the primary stresses that led to the listing of the species were the loss of habitat due to encroachment of European beachgrass and urban development. As a consequence of such widespread habitat loss and the subsequent reduction in the range and vigor of the species, the western snowy plover is now more vulnerable to environmental fluctuations and catastrophes that the species would otherwise be able to tolerate. Chance events such as oil and contaminant spills, windstorms, and continued habitat loss from European beachgrass expansion, described earlier in this plan, could now cause or facilitate the extirpation of the entire listed species or one or more of the breeding populations.

The recovery unit approach in this recovery plan addresses this risk to the long-term survival and recovery of the western snowy plover by employing two widely recognized and scientifically accepted goals for promoting viable populations of listed species: (1) creation or maintenance of multiple populations so that a single or series of catastrophic events cannot destroy the whole listed species; and (2) increasing the size of each population in the respective recovery unit to a level where the threats of genetic, demographic, and normal environmental uncertainties are diminished (Mangel and Tier 1994; National Research Council 1995:91; Tear *et al.* 1993; Meffe and Carroll 1994:192).

In general, the larger the number of populations and the larger the size of each population, the lower the probability of extinction (Raup 1991:182; Meffe and Carroll 1994:190). This basic principle of redundancy applies to the western snowy plover. By maintaining viable populations at the breeding locations within multiple recovery units, the threats represented by a fluctuating environment are alleviated and the species has a greater likelihood of achieving long-term survival and recovery. Conversely, loss of one or more important breeding locations within a recovery unit could result in an appreciable increase in the risk that the entire listed species may not survive and recover. Because western snowy plovers tend to exhibit site fidelity, migration to new nesting sites could increase stress to breeding birds and reduce nesting success.

Therefore, when evaluating the potential impact of land management actions that may affect the western snowy plover, we will consider whether a significant loss of western snowy plover breeding or wintering habitat in one recovery unit --without adequate compensation alleviating the impacts of that loss-- would adversely affect the viability of the population in that recovery unit as well as the long-term viability of populations in other recovery units.

Several aspects of the biology and life history of the western snowy plover indicate that designation of recovery units is necessary to ensure the long term health and sustainability of the western snowy plover. A portion of the Pacific coast population of western snowy plovers do not migrate up or down the coast and are year round residents. Additionally, the majority of western snowy plovers that do migrate are site-faithful, returning to the same breeding areas in subsequent breeding seasons (Warriner *et al.* 1986, Stenzel *et al.* 1994). Western snowy plovers occasionally nest in exactly the same location as the previous year (Warriner *et al.* 1986). These two features indicate that the Pacific coast population of western snowy plover likely exhibits subpopulation and metapopulation structure (see also Appendix D).

Designation of separate recovery units across the range will ensure that metapopulation dynamics can be maintained for the species.

The area covered by the six recovery units encompasses all the known breeding and wintering sites for the Pacific coast population of the western snowy plover. In addition to exhibiting site fidelity to breeding locations, western snowy plovers also exhibit fidelity to wintering locations. In contrast to many migratory birds, winter migration of the Pacific coast population of western snowy plovers is not uni-directional. Western snowy plovers may move both north and south along the coast from breeding locations. Nesting birds from Oregon have wintered as far south as Monterey Bay, California, while birds from Monterey Bay in central California have wintered north to Bandon, Oregon and south to Laguna Ojo de Liebre in Baja California, Mexico (Page *et al*. 1995*a*). Nesting birds from San Diego County in southern California have wintered north to Vandenberg Air Force Base in Santa Barbara County and south to Baja California (Powell *et al*. 1995, 1996, 1997). Designation of separate recovery units, each essential to the recovery of the western snowy plover, will ensure that wintering and migratory habitat is distributed across the western snowy plover's Pacific coast range and is protected and managed to maximize western snowy plover population survival.

The six recovery units for the Pacific coast population of the western snowy plover are: (1)Washington and Oregon; (2) Del Norte to Mendocino Counties, California; (3) San Francisco Bay, California; (4) Sonoma to Monterey Counties, California; (5) San Luis Obispo to Ventura Counties, California; and (6) Los Angeles to San Diego Counties, California. These recovery units were designated partly based on gaps in distribution of western snowy plover breeding and wintering locations, and on gaps in available habitat along the coast. For example, a significant portion of the coast of Sonoma County and southern Mendocino County is rocky and composed of steep bluffs lacking beach, dune, or estuary habitat suitable for the western snowy plover. This area constitutes a gap in the distribution of breeding and wintering locations between recovery units 2 and 4. This situation is repeated along the coast of Monterey County, where a gap in western snowy plover locations and suitable habitat occurs between recovery units 4 and 5. Smaller gaps also occur between recovery units 1 and 2, and between recovery units 5 and 6. Recovery unit 3 is unique and has been designated as a separate recovery unit because much of the habitat in the San Francisco Bay area consists of salt ponds and salt pond levees.

The six recovery units designated for the western snowy plover also vary significantly in numbers of breeding western snowy plovers. Recovery unit 5 supports the greatest number of western snowy plovers, approximately half of the U.S. population, and has the greatest amount of available suitable habitat. Recovery units 4 and 6 support, or have the potential to support, a lesser number of western snowy plovers, collectively about a third of the population. The population in Recovery Unit 3 is relatively lower but has potential to increase with intensive management of salt pond habitat. Recovery units 1 and 2 also support relatively low numbers of western snowy plovers, probably due to suitable habitat being lesser in extent and more widely separated, but represent about half of the geographic range of the Pacific coast population of western snowy plovers within the United States and provide essential wintering, migratory, and breeding habitats.

Collectively, recovery of western snowy plovers within each of the six recovery units is necessary to maintain metapopulation dynamics, ensure protection and appropriate management of wintering and migratory habitat, and ensure the long term health and sustainability of the Pacific Coast population of western snowy plovers across its current range.

## C. RECOVERY GOALS AND OBJECTIVES

The goal of this recovery plan is to ensure the long-term viability of the Pacific coast western snowy plover population so that this population can be removed from the Federal list of endangered and threatened species. The specific objectives to achieve this goal are the major components of the recovery strategy described above:

1) Increase population numbers distributed across the range of the Pacific coast population of the western snowy plover;

2) Conduct intensive ongoing management for the species and its habitat and develop mechanisms to ensure management in perpetuity; and

3) Monitor western snowy plover populations and threats to determine success of recovery actions and refine management actions.

## D. RECOVERY CRITERIA

Recovery criteria for the Pacific coast population of the western snowy plover include numeric subpopulation targets, reproductive productivity targets, and establishment of management actions. Under each of these three major recovery criteria are additional subcriteria that must be achieved in order to progress toward the major criteria or that must be achieved in order to determine whether the major criteria are being met. Subcriteria include completing development and implementation of population, demographic and threat monitoring programs, incorporating specific management actions into participation and management plans, and completing research actions necessary to refine management actions.

Recovery criteria in this recovery plan are necessarily preliminary and will need periodic reassessment because additional data upon which to base decisions about western snowy plover recovery are needed (***i.e.***, effective predator management techniques, effective restoration techniques, improved monitoring techniques, additional demographic information for some subpopulations). Research actions, monitoring programs, and periodic recovery implementation review are included as recovery actions in order to obtain this information. The completion of many of these actions have been incorporated into recovery criteria in order to ensure that new information is incorporated into recovery implementation decisions.

The recovery criteria recommend that the Pacific Coast population of the western snowy plover be maintained at 3,000 breeding birds. This population increase to 3,000 breeding individuals could occur within 25 years with intensive management of breeding and wintering sites (see Appendix D. Population Viability Analysis for Pacific Coast Snowy Plovers). This population level must be maintained for at least ten years. In addition, average annual productivity of at least one (1.0) fledged chick per male in each recovery unit must be maintained in the last 5 years prior to delisting. Forty years may be required to achieve these demographic components of the recovery criteria, assuming that mechanisms to assure long-term protection and management of breeding, wintering, and migration areas necessary to maintain the subpopulation sizes and average productivity have been developed and are in place.

The Pacific coast population of the western snowy plover will be considered for delisting when the following criteria have been met:

**Criterion 1. Monitoring shows that an average of 3,000 breeding adults distributed among 6 recovery units as specified below have been maintained for a minimum of 10 years:**

| *Recovery Unit* | *Subpopulation Size* |
|---|---|
| 1. Washington and Oregon | 250 breeding adults |
| 2. Del Norte to Mendocino Counties, California | 150 breeding adults |
| 3. San Francisco Bay, California | 500 breeding adults |
| 4. Sonoma to Monterey Counties, California | 400 breeding adults |
| 5. San Luis Obispo to Ventura Counties, California | 1,200 breeding adults |
| 6. Los Angeles to San Diego Counties, California | 500 breeding adults |

Subpopulation sizes represent the best professional judgment of the Western Snowy Plover Recovery Team's technical subteam. Numbers are based on a site-by-site evaluation of historical records, recent surveys, and future potential (assuming dedicated, proactive management at breeding and wintering locations). Collectively, these numbers represent an approximately 70 percent increase in the Pacific coast population size from the time of listing. On a cumulative range-wide basis the recovery criteria are approximately 83 percent of the total of the "Management Goal Breeding Numbers" identified in Appendices B and C, which represent site-specific target populations under an intensive management scheme. The recovery criteria for population size and distribution for the Pacific coast population of the western snowy plover represent only a portion of its historical abundance and distribution.

To reach these subpopulation sizes will require proactive management to attain a level of productivity that will allow the population to grow. The population viability analysis (Appendix D) suggests that reproductive success between 1.2 to 1.3 fledglings per male per year, with adult survival of 76 percent and juvenile survival of 50 percent, provides a 57 to 82 percent probability of reaching a population of 3,000 western snowy plovers within 25 years. Enhancing productivity is critical to population growth. Once the population size criterion is met, a lower rate of productivity can sustain the population.

**1a. A program is developed and implemented to monitor the western snowy plover breeding population and wintering locations (see Actions 1.1 and 1.2) to determine whether recovery unit subpopulation criteria are being achieved.**

The monitoring program must include monitoring of population size and distribution, survival, and productivity. Monitoring population size and distribution are necessary as a means of measuring whether the recovery criterion is being met. Monitoring demographic characteristics such as survival and productivity also will be necessary to determine population trends and progress toward achieving the recovery criterion. The monitoring program should also assess whether management goals for breeding and wintering sites listed in Appendix B are being achieved. Collectively, the breeding management goal numbers are about 20 percent higher than the recovery criteria subpopulation sizes. Monitoring of individual sites will assist in determining the effectiveness of management actions and whether any refinements are necessary. Monitoring of wintering sites will assist in indicating whether survival of western snowy plovers is sufficient to make progress toward meeting breeding population size criteria.

When the species has recovered sufficiently to be delisted, the ongoing program of monitoring actions should be integrated into a post-delisting monitoring plan to cover a minimum of 5 years after delisting and ensure ongoing recovery and effectiveness of management actions. This monitoring plan should be developed and ready for implementation before delisting.

**1b. A program is developed and implemented to monitor the site-specific threats identified in Appendix C (Action 1.3) and monitoring results are used to refine site-specific management actions identified in Appendix C.**

In conjunction with monitoring of breeding subpopulation sizes and distribution and demographic characteristics, threats at each breeding and wintering site must be monitored in order to determine whether management actions are effective in increasing western snowy plover survival and reproduction. If threats continue limiting population increases, or additional threats are identified, management actions recommended in Appendix C may require modification.

**1c. Management activities identified in Appendix C that are necessary to ameliorate threats and achieve increases in reproductive success, survival, and overall population size are incorporated into participation and management plans developed and implemented under Criterion 3.**

Appendix C provides location-specific summaries of current management activities at western snowy plover breeding and wintering sites based on: 1) responses by public land managers and private conservation organizations to a survey prepared by the Recovery Team on western snowy plover management and beach use; and 2) supplemental information from the Recovery Team and from our field office staff. Appendix C also identifies additional management activities needed at each site to ameliorate threats and achieve management goals. These management recommendations are intended to provide preliminary guidance but additional management needs likely will be identified through monitoring, research, and site-specific experience.

**1d. Research actions (Action 4) are completed and incorporated into management and participation plans and into monitoring plans.**

Several research needs identified under Action 4 are necessary to refine and improve management activities for the western snowy plover and also to improve monitoring of western snowy plover population sizes, demographics, and threats. Improving and refining management actions will increase the effectiveness of management actions in increasing population numbers, survivorship, and productivity. Improved monitoring techniques are needed to ensure that monitoring efforts are adequate to determine whether recovery actions are successful and recovery criteria are being met.

**Criterion 2. A yearly average productivity of at least one fledged chick per male has been maintained in each recovery unit in the last 5 years prior to delisting.**

From currently available data, it is estimated that males must average one fledged young annually for population equilibrium (see Appendix D). Higher rates of productivity will be necessary to reach the target population size of 3,000 breeding adults. After this population size is achieved and maintained for a minimum of 10 years, a lower rate of productivity of one fledged chick per male will be necessary to maintain the population size at an average of 3,000 breeding adults. Monitoring programs developed and implemented under criteria 1a and 1b should continue throughout this period. We also assume that management designed to ameliorate threats (criteria 1c and 3) will continue through this period and after delisting.

**Criterion 3. Mechanisms have been developed and are in place to assure long-term protection and management of breeding, wintering, and migration areas listed in Appendix B to maintain the subpopulation sizes and average productivity specified in Criteria 1 and 2.**

Development of mechanisms to ensure long-term management and protection of western snowy plovers and their habitat are listed under Action 3, which outlines the recovery actions recommended to meet these recovery criteria. The recovery action outline section describes each action in detail. The recovery action outline lists all subactions necessary to fulfill the main recovery action. It also represents a prioritization of measures to be implemented. Completion of these actions will ensure that threats to western snowy plovers and their habitat are ameliorated and that management will continue after delisting to prevent a reversal of population increases.

**3a. Working groups for each of the six recovery units are established.**

Action 3.1 recommends the establishment of working groups for each recovery unit. Working groups should be diverse and include representatives from Federal, State, local, and private sectors. At present working groups are in existence for all recovery units, and should continue to be maintained and meet regularly. The roles of the working groups are to coordinate and facilitate recovery efforts within each recovery unit, assess population trends, and carry out outreach activities.

**3b. A participation plan for each recovery unit working group has been developed and implemented.**

Each working group is tasked with developing a participation plan that delineates and prioritizes recovery activities within each recovery unit and for each location identified in Appendix B. These plans should identify the roles and responsibilities of each member of the working group and their commitments to carry out identified recovery actions.

**3c. Management plans for all Federal and State lands identified in Appendix C have been developed and implemented.**

Appendix C identifies the landowners of western snowy plover wintering and breeding sites. Many of the sites are owned or managed by Federal or State agencies. Development and implementation of management plans that incorporate the management goals and recommendations in Appendix C for all these sites are necessary to ensure that population goals are reached, threats ameliorated, and long-term protection and management of western snowy plovers and their habitat are in place.

**3d. Mechanisms to protect and manage western snowy plover breeding and wintering sites identified in Appendices B and C are in place for all areas owned or managed by local governments or private landowners.**

Appendix C also identifies many western snowy plover breeding and wintering locations that are owned or managed by local governments, private conservation organizations, or private landowners. These lands also require protection and management to ensure that population goals are reached, threats ameliorated, and long-term protection and management of western snowy plovers and their habitat are in place. Because of the diverse ownership and management of these lands, many different mechanisms may be used to ensure protection and management of these locations. These mechanisms are further described in the recovery action outline and Appendices H and I.

**3e. Public information and education programs are developed and implemented.**

Outreach is a major component of developing and putting in place mechanisms to assure long-term protection and management of breeding, wintering, and migration areas listed in Appendix B. Outreach efforts will be needed to solicit participation of the many Federal, State, local, and private groups in recovery efforts and notify groups and individuals of recovery opportunities and incentives for the western snowy plover. Outreach efforts also must be used as a component of management of western snowy plovers and their habitats. These efforts will include informing the public and gaining their support for measures intended to protect western snowy plovers.

## E. RELATIONSHIP OF RECOVERY ACTIONS AND CRITERIA TO THREATS

The goal of this recovery plan is to ensure the long-term viability of the Pacific coast population of western snowy plovers so that they can be removed from the Federal list of endangered and threatened species. The delisting process requires demonstrating that threats to the western snowy plover have been reduced or eliminated such that the species survival in the wild is assured. Table 8 lists the threats to the western snowy plover that have been identified during and since the listing process and indicates the actions and recovery criteria in the recovery plan that address each threat.

The western snowy plover faces multiple threats throughout its Pacific coast range. Major threats to the western snowy plover include habitat destruction and modification and lack of habitat protection mechanisms (listing factors A and D), disease or predation (listing factor C), and manmade factors that primarily result in disturbance or mortality of breeding birds (listing factor E). Effects of research on western snowy plovers (listing factor B) is also a threat but is comparatively minor and easily addressed through permitting processes. Many of the threats to western snowy plovers are interrelated or have complex interactions with each other. For example, coastal development that destroys or modifies habitat (listing factor A) also results in increased disturbance from recreational activities (listing factor E) and in increased predator populations (listing factor C). Recovery actions and criteria therefore may address multiple threats.

The majority of threats to the western snowy plover, other than habitat destruction or modification, affect the western snowy plover's productivity (breeding success) and survival within otherwise suitable habitat. Criteria 1 and 2 are directed at determining whether the effects of threats on productivity and survival have been removed and expected population and productivity increases are being achieved. Threats addressed by these recovery criteria primarily fall under listing factors B, C, and E. Reduction and elimination of these threats, and the expected increases in productivity and survival, rely primarily on developing intensive management and monitoring programs for the western snowy plover. Criterion 3 is directed at achieving the management and habitat protections necessary to reduce and eliminate threats that fall primarily under listing factors A and D, but also address threats under listing factors B, C, and E that can be eliminated or ameliorated by ensuring long-term management.

**Table 8.** Threats to the Pacific coast population of the western snowy plover and steps within the recovery plan to reduce or eliminate threats.

| Factor* | Threat | Action | Criterion |
|---|---|---|---|
| **A** | **The present of threatened destruction, modification, or curtailment of its habitat or range.** | | |
| A* | Encroachment of introduced beachgrass and nonnative vegetation. | 1.1-1.3, 2.2.1, 3.1-3.10, 4.1.1, 5.1-5.7 | 1b-d,<br>2,<br>3a-e |
| A* | Shoreline stabilization | 1.1-1.3, 2.1, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |
| A* | Urban development and construction | 1.1-1.3, 2.1, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |
| A | Dredging disturbance and tailings deposit | 1.1-1.3, 2.1, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |
| A* | Sand mining | 1.1-1.3, 2.1, 2.2.2, 3.1-3.10, 5.1-5.7 | 3a-e |
| A | Beach nourishment with inappropriate design and/or sand type | 1.1-1.3, 2.2.3, 3.1-3.10, 5.1-5.7 | 3a-e |
| A | Driftwood removal | 1.1-1.3, 2.3.4, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| A | Beach fires and camping | 1.1-1.3, 2.3.3, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |

| Factor* | Threat | Action | Criterion |
|---|---|---|---|
| A | Water course diversion, impoundment, or stabilization | 1.1-1.3, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |
| A | Habitat conversion for other species | 1.1-1.3, 3.1-3.10, 5.1-5.7 | 1d,<br>3a-e |
| A | Operation of salt ponds | 1.1-1.3, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |
| **B** | **Overutilization for commercial, recreational, scientific or educational purposes.** | | |
| B* | Egg collecting | 1.1-1.3, 2.3.8 | none, 1c |
| B | Studying and monitoring plovers | 1.4, 1.5, 3.1-3.2, 4.3 | 1a-d<br>2 |
| B | Banding | 4.6 | 1a-d |
| **C** | **Disease or predation.** | | |
| C* | Introduced nonnative predators | 1.1-1.3, 2.4, 4.2, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| C | Increased populations of native predators due to human influences | 1.1-1.3, 2.4, 4.2,3.1-3.10, 5.1-5.7 | 1b, 1c, 1d,<br>2,<br>3a-e |
| C* | Predator attractants | 1.1-1.3, 2.4, 4.2, 3.1-3.10, 5.1-5.7 | 1b, 1c, 1d,<br>2,<br>3a-e |
| C | Predation by domestic and feral cats | 1.1-1.3, 2.4, 4.2, 3.1-3.10, 5.1-5.7 | 1a-d,<br>2,<br>3a-e |
| **D** | **The inadequacy of existing regulatory mechanisms.** | | |

| Factor* | Threat | Action | Criterion |
|---|---|---|---|
| D* | Limited habitat protection under the Migratory Bird Treaty Act and State laws | 2.3.8, 3.1-3.10, 5.1-5.7 | 3a-e |
| D | Conflicting beach management methods and mandates | 1.1-1.3, 2.3.8, 3.1-3.10, 5.1-5.7 | 1b, 1c, 3a-e |
| D* | Sections 404 of Clean Water Act and 10 of Rivers and Harbors Act apply to limited amount of habitat | 2.3.8, 3.1-3.10, 5.1-5.7 | 1b-d 3a-e |
| D* | Lack of protection in Baja California, Mexico | 8 | |
| **E** | **Other natural or manmade factors affecting its continued existence.** | | |
| E* | Loss of nests and habitat due to natural events | 1.1-1.3, 1.6, 2.1, 2.2, 2.3.8, 3.1-3.10, 4.4, 4.5, 4.10 | 1b, 1c, 3a-e |
| E* | Disturbance by pedestrians | 1.1-1.3, 2.3.1, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c, 2, 3a-e |
| E* | Disturbance by dogs | 1.1-1.3, 2.3.1, 2.3.2, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c, 2, 3a-e |
| E* | Disturbance by motorized vehicles | 1.1-1.3, 2.3.5, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c, 2, 3a-e |

| Factor* | Threat | Action | Criterion |
|---|---|---|---|
| E* | Disturbance by beach cleaning | 1.1-1.3, 2.3.5, 2.4.1, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2,<br>3a-e |
| E* | Disturbance from equestrian traffic | 1.1-1.3, 2.3.6, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2,<br>3a-e |
| E | Disturbance from fishing activities | 1.1-1.3, 2.3.3, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| E | Disturbance by fireworks | 1.1-1.3, 2.3.3, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2,<br>3a-e |
| E | Disturbance by kites and model airplanes | 1.1-1.3, 2.3.3, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2,<br>3a-e |
| E* | Military exercises and aircraft overflights | 1.1-1.3, 2.3.8, 2.3.9, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| E | Large crowds associated with special events | 1.1-1.3, 2.3.3, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| E | Increased coastal access to beaches | 1.1-1.3, 2.3.1.2, 2.3.8, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| E | Livestock grazing | 1.1-1.3, 2.3.7, 2.3.8, 3.1-3.10, 5.1-5.7 | 1b, 1c,<br>3a-e |

| Factor* | Threat | Action | Criterion |
|---|---|---|---|
| E | Oil spills and disturbance from oil spill clean-ups | 1.1-1.3, 2.5, 4.7, 5.6 | 1b-d<br>3a-e<br>1b, 1c,<br>2<br>3a-e |
| E | Environmental contaminants | 1.1-1.3, 4.8, 5.6 | 1b-d,<br>3a-e |
| E | Litter, garbage, & debris | 1.1-1.3, 2.3.8, 2.4.1, 3.1-3.10, 4.9, 5.1-5.7 | 1b, 1c,<br>2<br>3a-e |
| E | Urban runoff and impaired water quality | 1.1-1.3, 2.1, 2.3.8, 3.1-3.10, 5.1-5.7 | 3a-e |
| E | Management for other special status species | 1.1-1.3, 1.7, 2.6, 2.7, 2.3.3, 3.1-3.10, 4.2.2, 5.1-5.7 | 3a-e |

* Indicates threats originally identified during the listing process.

## III. NARRATIVE OUTLINE OF RECOVERY ACTIONS

1 **Monitor breeding and wintering population and habitats of the Pacific coast population of the western snowy plover to determine effects of recovery actions to maximize survival and productivity.** To assure the long-term viability of western snowy plover populations, their populations and breeding and wintering habitat should be monitored and managed in a systematic, ongoing fashion. Systematic, ongoing monitoring of breeding birds and wintering birds should be undertaken at the recovery-unit level to measure progress towards recovery and identify management and protection efforts that are needed. In addition to the known breeding sites, all known wintering locations (Appendix B) are considered currently important to western snowy plover conservation. These sites include both wintering locations that currently support breeding birds and locations that may potentially support nesting birds in the future. These locations also may support migrating western snowy plovers. There is a need for better information about wintering and migration sites, including spatial and temporal use patterns, feeding areas, habitat trends, and threats. Appendix C, Table C-1 identifies 147 locations where monitoring western snowy plover populations is occurring or recommended to achieve management goals.

1.1. **Annually monitor western snowy plover abundance, population size, and distribution at breeding and wintering locations in each recovery unit using window surveys.** Comprehensive range-wide window surveys of breeding locations and wintering locations (Appendix B) should be conducted annually to determine population trends and fluctuations, and to determine whether management goal breeding numbers (Appendix B) are being achieved. The window survey described in Appendix J (Monitoring Guidelines) should be employed as the primary index of population size to minimize the probability of double-counting birds nesting at multiple locations during the same season. Window surveys are conducted over a relatively short time period to minimize double-counting of birds that change location during the season, but may not fully account for all breeding or wintering birds. Window survey methodology should be improved and correction factors estimated (Action 4.3.1) to improve the accuracy and utility of population indices. This correction may require some banding at sites where there are currently no marked birds on which to base correction factors.

1.2 **Develop and implement a program to monitor western snowy plover productivity and annual survival in each recovery unit.** Development and implementation of a program to monitor western snowy plover productivity and survival, in addition to comprehensive population size and distribution monitoring, is necessary to measure progress toward achieving recovery criteria and to assess the effectiveness of management in removing threats that affect nesting success and survival. Results from this monitoring program also may be used to update the population viability analysis and assess progress toward recovery goals (Actions 4.11 and 6). Monitoring productivity and survival likely will be much more intensive than monitoring population sizes and distribution (Action 1.1), and cannot be implemented at all breeding sites because of insufficient color band combinations to monitor the entire Pacific coast population. Plans for monitoring these demographic characteristics instead should utilize methods to sample demographic characteristics across the breeding range and in each recovery unit. Actions 4.3.2 and 4.3.3 recommend developing methodologies to estimate productivity and survival. The monitoring program should incorporate these methods and should specify the number of sites sampled in each recovery unit, how sites will be selected, and indicate control sites from intensively monitored breeding locations (*i.e.*, the coast of Oregon, extreme northern California, and the shoreline of Monterey Bay).

1.3 **Develop and implement a program to monitor at all breeding and wintering sites the habitat conditions, disturbances, predation, and other threats limiting abundance of breeding and wintering birds, clutch hatching success, chick fledging success, and survival.** Monitoring of threats to the western snowy plover is necessary to determine effectiveness of recovery actions in ameliorating or eliminating threats, assess progress toward recovery, and refine site-specific managements as necessary. A standardized threats monitoring program should be developed and applied to all breeding and wintering sites in conjunction with monitoring developed and implemented under actions 1.1 and 1.2. At a minimum, monitoring should include determining substrate characteristics and vegetation composition (level of nonnative species), frequency and levels of disturbance (*e.g.*, recreational activities, pets, vehicles, horses), and presence and abundance of predators. Appendix J (Monitoring Guidelines) provides general guidance on monitoring but may require revision as research actions under action 4 are completed. Opportunities to incorporate monitoring into Federal activities subject to section 7 of the Endangered Species Act, such as dredging and discharges regulated by the U.S. Army Corps of Engineers, should be utilized when possible.

**1.4 Develop and implement training and certification programs for western snowy plover survey coordinators and observers, consistent with recommendations in Appendix J (Monitoring Guidelines).** Classroom and field training are required for observers who survey for western snowy plovers, and before we can issue a section 10(a)(1)(A) permit. Instruction programs and materials should be developed for comparable training to occur throughout the western snowy plover range to improve consistency of data collection. Classroom topics should include, but not be limited to: (1) biology, ecology, and behavior of breeding western snowy plovers; (2) identification of adult plovers, their young, and their eggs; (3) threats to plovers and their habitats; (4) survey objectives, protocols, and techniques; (5) regulations governing the salvage of carcasses or eggs; (6) special conditions of existing recovery permits; (7) field identification of potential western snowy plover predators; (8) biology and behavior of predator and scavenger species; and (9) other activities (*e.g.*, banding). Field training should include, as appropriate: (1) locating, identifying, and monitoring nests; (2) handling eggs and capturing and handling adults or chicks; (3) specifics on the target activity for which a recovery permit is to be issued, or under which an observer will work; (4) practical field exercises; and (5) field review of appropriate classroom topics.

1.5 **Develop a submittal system for monitoring data to ensure consistent reporting among recovery units and sites, and annually review and revise the system as necessary.** Initially, range-wide survey data will be limited to results from 2 annual window surveys. As population and demographic monitoring methods are developed and implemented (Actions 1.1, 1.2, 4.3.1, 4.3.2, and 4.3.3), a more sophisticated reporting and compiling system will be necessary. Our lead office should coordinate with researchers involved with monitoring to ensure that data collection, submittal, and entry systems remain current, include correction factors that account for lack of detections during surveys, and are consistent among recovery units and sites. An annual range-wide report should be developed and distributed to all interested parties. Additionally, consistent reporting of sightings of banded western snowy plovers is needed. Sightings of banded birds provide information on the wintering sites of breeding birds, use of multiple sites by breeding and wintering plovers, and survival and dispersal of adults and juveniles. In accordance with procedures of the U.S. Geological Survey, Bird Banding Laboratory, the Point Reyes Bird Observatory should continue to act as the color band coordinator for the Pacific coast population to avoid use of duplicate color banding schemes among researchers.

1.6 **Assess and evaluate new breeding, wintering, and migration areas as they are discovered to determine threats and management needs and update lists of areas identified in Appendices B and C as data become available.** As new western snowy plover breeding and wintering areas are discovered, data should be collected to assess site boundaries, habitat characteristics, population levels, and any significant threats. The current list of important breeding and wintering locations (Appendix B) should be expanded or refined as appropriate, and any new areas incorporated into management and monitoring plans. Areas determined to be important for migration through action 4.4.4 also should be evaluated and added to the list of areas requiring protection, management, and monitoring. Management goals and needed management to ameliorate or eliminate threats should be developed for all new breeding, wintering, and migration areas and should be included in periodic revisions of Appendices B and C of this recovery plan.

**1.7 Annually coordinate monitoring of western snowy plovers and California least terns to minimize effects of disturbance to both species.** Coordination with least tern monitors and managers is needed in all areas where western snowy plovers share breeding sites with California least terns. Coordination should take place at biannual pre-and post-season California least tern monitoring meetings. Protocols for monitoring California least terns should be revised as necessary so that western snowy plovers are not detrimentally affected. Human activities within some least tern colonies in southern California include monitoring by one to four people several days per week; maintenance of tern fences; predator management; site preparation; and banding/observation efforts. Human activities associated with tern monitoring must be recognized as additional disturbance to western snowy plovers. Section 10(a)(1)(A) permits, issued under the authority of the Endangered Species Act for western snowy plovers and least terns, should include both species where applicable. Monitoring efforts for both species should be kept separate because of differences in monitoring techniques and species' behaviors. Monitors of least terns and western snowy plovers should be aware of species' differences in nest spacing, brood-rearing, foraging behavior, time of breeding, vulnerability to disturbance, and monitoring and banding techniques.

Western snowy plovers generally begin nesting at least 1 month before the arrival of breeding least terns; thus, tern management often begins well after western snowy plovers have initiated nests. Site preparation (vegetation removal and fence construction) should be coordinated to minimize disturbance to nesting western snowy plovers, and if possible to enhance breeding success for both species (as well as considering other sensitive species, including plants, that may be present). Predator management also should be coordinated to benefit both species.

1.8 **Develop post-delisting monitoring plan.** Prior to delisting a five-year monitoring plan should be developed. Methodology and scope of post-delisting monitoring should be appropriately integrated with existing monitoring efforts for continuity and comparability. Monitoring and research results should be used to guide the long-term conservation of the species.

2 **Manage breeding and wintering habitat of the Pacific coast population of the western snowy plover to ameliorate or eliminate threats and maximize survival and productivity.** The Pacific coast population of the western snowy plover is sensitive to changes in productivity and in adult and juvenile survival rates (see Appendix D). Furthermore, recovery of this species is contingent on intensive management of breeding habitat and availability of wintering habitat for more than the current number of western snowy plovers (see recovery criteria). Appendix C provides a summary of site-specific management needs at 155 breeding and wintering locations (actions 2 and 3). Management efforts may be time-consuming, costly, and sometimes require intensive management. Western snowy plover breeding habitat is extremely dynamic and factors affecting breeding success, such as types and numbers of predators, can change quickly; therefore, managers should be prepared to modify protection as needed. Action 6 recommends annual review of progress toward recovery and revision of site-specific management actions based on monitoring and research results and site-specific experience. Management and protection of western snowy plovers on Federal and State lands are especially important. In addition, protection on Federal and State lands furnishes leadership by example to local land managers. Land managers should recognize that components of breeding habitat include: areas where plovers prospect for nesting sites, make scrapes, lay eggs, feed, rest, and rear broods. Breeding habitat also includes travel corridors between nesting, resting, brood-rearing, and foraging areas. Wintering and migration habitats should also be monitored and managed to maximize survival and recruitment of western snowy plovers into the breeding population.

**2.1 Maintain natural coastal processes that perpetuate high quality breeding and wintering habitat by incorporating the following recommendations into development of participation plans, management planning, and habitat protection (action 3) for the sites identified in Appendix C and any additional sites identified through surveys and monitoring.** The dynamic nature of beach strand habitats as storm-maintained ecosystems should be recognized and allowed to function. Natural process that contribute to maintaining wide, flat, sparsely-vegetated beach strands preferred by western snowy plovers include: inlet formation, migration, and closure; erosion and deposition of sand dunes; and overwash and blowouts of beach and dune habitat. Coastal development, beach stabilization, construction of rock jetties and seawalls, sand removal and dredging, water diversion and impoundment, and planting of nonnative vegetation interfere with these processes and result in loss and degradation of habitat.

Maintenance of natural coastal processes can be accomplished through establishment of management plans, conservation easements, fee title acquisition, zoning, and other means. Coastal development, beach stabilization, resource extraction, and water diversion and/or impoundment projects should be carefully assessed for impacts to wintering western snowy plovers. Recommendations from U.S. Fish and Wildlife Service offices (under the Endangered Species Act and Clean Water Act) and/or State agencies should focus on avoiding or minimizing adverse impacts to wintering habitat. Where adverse effects cannot be avoided, agencies should document impacts so that cumulative effects on this species' habitat can be assessed and compensated. When beach development cannot be avoided, the following protections should be implemented: (1) construction should take place outside the nesting season, (2) developers and others should be advised during planning stages that stabilization of shorelines will result in additional habitat degradation and that these impacts may affect evaluation and issuance of permits under the jurisdiction of the U.S. Army Corps of Engineers or State coastal management agencies, and of measures to minimize the impacts, (3) property owners (*e.g.*, hotel or resort owners) should tailor recreational activity on the beach and dunes to prevent disturbance or destruction of nesting western snowy plovers, their eggs, and chicks, (4) lights for parking areas and other facilities should not shine on western snowy plover habitat, (5) sources of noise that would disturb western snowy plovers should be avoided, and (6) the establishment of predator perches and nesting sites should be avoided when designing facilities. Appendix C, Table C-1 identifies 86 locations which currently have development restrictions in place and 16 locations where development should be restricted or avoided to achieve management goals.

**2.1.1 Develop a prioritized list of western snowy plover wintering and breeding sites where natural coastal processes need protection, or where impaired natural coastal processes should be enhanced or restored.** Recovery Unit working groups should evaluate the sites within their recovery unit and determine where natural processes are likely to be disrupted or are in need of being enhanced or restored, or are of particular importance to maintaining high quality western snowy plover habitat. Sites should be prioritized based on their importance to western snowy plover breeding and the degree of threat to the western snowy plover and its habitat should natural processes be disrupted.

**2.1.2 Identify mechanisms necessary to protect, enhance, or restore natural coastal processes for the sites identified in action 2.1.1 and implement through incorporating into actions 3.1 -3.10.** Mechanisms to protect, enhance, or restore natural processes may include development of management plans that prohibit or restrict activities that disrupt natural process (*i.e.* dredging or sand removal, recreational activities that contribute to excessive erosion or compaction), acquisition of habitat, landowner agreements, local land use protection measures, or enhancement activities. Identification of these sites and mechanisms should be used to guide implementation of long-term management and protection under action 3.

2.2 **Create and enhance existing and potential breeding and wintering habitat.** Past and ongoing impacts to western snowy plover breeding habitat from development, artificial beach stabilization, and other projects have resulted in loss and degradation of western snowy plover habitat. Habitat enhancement and creation are needed at multiple sites to offset these losses. Where impacts cannot be avoided, projects should remediate and compensate habitat loss and degradation by maintaining natural long-shore sand budgets and minimizing interference with natural patterns of sand accretion and depletion. When these types of projects are planned, complex natural sand movement patterns should be taken into account. Beach management policies should recognize that many current erosion and sedimentation problems are the result of past property and/or inlet "protection" efforts. Habitat restoration projects in historic or potential breeding sites, where feasible, is encouraged. Creation of habitat should be emphasized in areas not subject to recreational impacts.

2.2.1 **Remove nonnative and other invasive vegetation from existing and potential habitat and replace with native dune vegetation.** Land managers should implement remedial efforts to remove or reduce vegetation that is encroaching on western snowy plover breeding habitat or obstructing movement of chicks from nesting to feeding areas. Particular attention should be given to the eradication of introduced beachgrass (*Ammophila* spp.) within coastal dunes.

2.2.1.1 **Develop and implement prioritized removal and control strategies for introduced beachgrass and other nonnative vegetation for each recovery unit.** These strategies should include early intervention to prevent expansion into breeding areas where introduced beachgrass and other nonnative vegetation have not yet spread or are in early stages of spreading. Attention also should be given to the removal of giant reed, Scotch broom, gorse, iceplant, and shore pine. Remove/manage vegetation on salt ponds, including levees.

Schedule/coordinate removal efforts to avoid disturbing nesting western snowy plovers. Appendix C, Table C-1 identifies 86 locations where removal of nonnative and other vegetation is either currently occurring or needs to be initiated to achieve management goals.

**2.2.1.2 Replace exotic dune plants with native dune vegetation where it is likely to improve habitat for western snowy plovers.** Land managers should make special efforts to reestablish native dune plants in western snowy plover nesting habitat, while concentrating on removal of nonnative vegetation. Native dune vegetation includes American dunegrass (*Leymus mollis*), beach morning glory (*Calystegia soldanella*), pink sand-verbena (*Abronia umbellata*), yellow sand verbena (*Abronia latifolia*), beach bursage (*Ambrosia chamissonis*), grey beach pea (*Lathyrus littoralis*), whiteleaf saltbush (*Atriplex leucophylla*), and California saltbush (*Atriplex californica*). These efforts should be targeted for coastal dune sites that currently support nonnative vegetation species such as introduced beachgrass (*Ammophila* spp), and should be combined with removal of this invasive plant. Seeds of local native dune plants collected within approximately 32 kilometers (20 miles) of the site to be planted should be used as replacement plant stock. Revegetation efforts should be monitored to ensure that the amount of vegetative cover is compatible with suitable breeding habitat for plovers.

**2.2.2 Deposit dredged material to enhance or create nesting habitat.** Near-shore (littoral drift) and on-shore disposal of dredged material seems to be beneficial for perpetuating high quality western snowy plover nesting habitat in some instances and should be encouraged where appropriate. However, monitoring of habitat characteristics before, during, and after projects is needed, particularly in cases of large operations occurring on sites where western snowy plovers nest or are deemed likely to nest following the disposal operation. On-shore disposal of dredged material should be scheduled outside the nesting season and, where possible, during seasons when birds are not present. In addition, dredged material must be clean sand or gravel of appropriate grain size and must be graded to a natural slope.

**2.2.2.1 Evaluate western snowy plover breeding and wintering sites listed in Appendix C and potential breeding sites to determine whether dredged materials may be used to enhance or create nesting habitat.** Recovery Unit working groups should identify sites where dredged material may be used to enhance or create nesting habitat. Evaluation of sites should include impacts (short- and long-term) to existing western snowy plover habitat, likelihood of use by western snowy plovers, whether appropriate sources of clean dredged material exist, and opportunities to utilize material from dredging projects.

**2.2.2.2 Develop and implement plans, including pre- and post-project monitoring, to use dredged material to enhance or create nesting habitat at the sites identified in action 2.2.2.1.** Plans to implement use of dredged material to enhance or create nesting habitat should be developed for sites identified in action 2.2.2.1. Plans should include measures to minimize impacts to western snowy plovers and existing habitat and should include pre- and post-project monitoring to determine effectiveness of the project in enhancing or creating nesting habitat.

**2.2.3. Implement beach nourishment activities if action 4.1.2 indicates beach nourishment activities are effective in enhancing western snowy plover habitat.** Beach nourishment activities have the potential to enhance western snowy plover habitat, but should be carefully evaluated to weigh the probable adverse and beneficial effects on plovers and on other sensitive coastal dune species.

**2.2.3.1 Evaluate and identify sites where beach nourishment activities may be effective in creating and enhancing western snowy plover habitat.** Potential sites include those sites where natural coastal processes have been disrupted (*i.e.* by coastal development, beach stabilization, construction of rock jetties and seawalls, etc.). Evaluation of sites should consider potential for adverse effects to existing western snowy plover habitat, whether appropriate sand sources are available, and whether long-term benefits are likely to occur.

**2.2.3.2 Develop and implement beach nourishment plans, including pre- and post-project monitoring for the sites identified in action 2.2.3.1.** Plans to implement beach nourishment activities to enhance or create nesting habitat should be developed for sites identified in action 2.2.3.1. Plans should include measures to minimize impacts to western snowy plovers and existing habitat and should include pre- and post-project monitoring to determine effectiveness of the project in enhancing or creating nesting habitat.

**2.2.4 Create, manage, and enhance coastal ponds and playas for breeding habitat.** Coastal ponds and playas, including salt ponds, should be enhanced and created to improve breeding habitat. Significant opportunities for management of nesting plovers currently exist within San Francisco Bay salt ponds, Moss Landing

Wildlife Area, Bolsa Chica wetlands, and south San Diego Bay salt ponds. However, salt ponds should only be created or enhanced at existing salt pond habitat; they should not be used for mitigation or compensation of coastal beach-dune or other western snowy plover habitats. Creation of habitat should be emphasized in areas that would preclude or reduce recreational impacts. Appendix C, Table C-1 identifies 15 locations where habitat enhancement is either currently in place or needs to be initiated to achieve management goals. Additional sites also may provide opportunities to enhance western snowy plover breeding habitat.

**2.3 Prevent disturbance of breeding and wintering western snowy plovers by people and domestic animals.** Disturbance by humans and domestic animals causes significant adverse impacts to breeding and wintering western snowy plovers. Because human disturbance is a primary factor affecting western snowy plover reproductive success, land managers should give the highest priority to implementation of management techniques to prevent disturbance of breeding birds. Western snowy plover breeding and wintering sites are highly variable in their amount of recreational activity. Land managers should conduct site-specific evaluations to determine whether recreational activities, domestic animals, and off-road vehicles pose a threat to plovers and implement appropriate measures. As information is gathered, it should be incorporated into conservation efforts. Management plans (Actions 3.3.1, 3.3.2, and 3.4) should include appropriate human/domestic animal access restrictions to prevent disturbance of western snowy plovers. Management techniques described below can reduce impacts of beach recreation on western snowy plovers, but they must be implemented annually as long as the demand for beach recreation continues.

**2.3.1 Prevent pedestrian disturbance.** Management measures to protect western snowy plovers should be determined on a site-by-site basis; factors to consider include the configuration of habitat as well as types and amounts of on-going pedestrian activity. On national wildlife refuges and State natural preserves within the

California State Parks system, where protection of wildlife is the paramount purpose of Federal and State ownership, western snowy plover habitat should be closed during the breeding season. Other areas also should be closed when necessary to adequately protect breeding western snowy plovers.

**2.3.1.1 Restrict access to areas used by breeding western snowy plovers, as appropriate.** Unless a beach is closed to public entry, or use is minimal, posting and/or fencing of nesting areas is recommended to discourage pedestrian use of the area and allow for plover courtship and prenest site selection, to prevent obliteration of scrapes, crushing of eggs or chicks, and repeated flushing of incubating adults. Any access restrictions should be accompanied by outreach programs to inform the public of any restrictions and provide educational material on the western snowy plover (see action 5).

**2.3.1.1.1 Seasonally close areas used by breeding western snowy plovers.** Dates of seasonal closures/restrictions should be based on the best data available, and be coordinated by geographic region for consistency in communicating with the public. Closures may be determined on a year-to-year basis and other options such as fencing may be considered first. To provide broods with access to foraging areas, closures should cover the area down to and including the water line, where practical. Areas where territorial plovers are observed also should be closed to prevent disruption of territorial displays and courtship. Because nests can be difficult to locate, especially during egg-laying, closure of these areas will also prevent accidental crushing of undetected nests. Appendix C, Table C-1 identifies 81 locations where public access is either currently restricted or it is recommended it be restricted to achieve management goals.

2.3.1.1.2 **Fence areas used by breeding western snowy plovers.** Fencing to keep people and beach activities out of nesting/brood rearing areas should not hinder chick movements, unless fencing is specifically meant to keep chicks from being harmed. Areas with a pattern of nesting activity in previous year(s) or where territorial plovers are observed should be fenced before plovers begin nest-site selection. Because nests can be difficult to locate, especially during egg-laying, closure of these areas will also prevent accidental crushing of undetected nests. Symbolic fences (one or two strands of 1/4 inch plastic-coated steel cable strung between posts) with signs identifying restricted areas substantially improve compliance of beach-goers and decrease people's confusion about where entry is prohibited. On portions of beaches that receive heavy human use during the breeding season, fencing of prime brood-rearing areas to exclude or reduce numbers of pedestrians also should be implemented to contribute to the survival and well-being of unfledged chicks. Appendix C, Table C-1 identifies 64 locations where nesting areas are fenced or where fencing is recommended to achieve management goals.

**2.3.1.1.3 Post signs in areas used by breeding western snowy plovers.** Areas with a pattern of nesting activity in previous year(s) should be posted before plovers begin nest-site selection. On portions of beaches that receive heavy human use during the breeding season, posting of prime brood-rearing areas to exclude or reduce numbers of pedestrians also should be implemented to contribute to the survival and well-being of unfledged chicks. Appendix C, Table C-1 identifies 65 locations where exclusionary signs are in place or recommended to achieve management goals.

**2.3.1.2 Locate new access points and trails well away from western snowy plover nesting and wintering habitat, and modify existing access and trials as necessary.** Recreational users such as campers, clammers, anglers, equestrians, collectors, *etc.*, should be encouraged to consistently use designated access points and avoid restricted areas. Roads, trails, designated routes, and facilities should be located as far away from western snowy plover habitat as possible. Recreationists using boats should be restricted or prohibited from areas being used by the western snowy plover. Appendix C, Table C-1 identifies 67 locations where boat use is currently and/or is recommended to be prohibited or restricted, and 81 locations where access is currently and/or is recommended to be prohibited or restricted to achieve management goals.

2.3.1.2.1 **Evaluate existing and planned access at all breeding and wintering locations and determine whether access may adversely affect western snowy plovers and their habitat.** Review of access points should include evaluating level of and timing of use by recreational users and level of effects on the western snowy plover.

2.3.1.2.2 **For sites where access is determined in action 2.3.1.2.1 to adversely affect western snowy plovers, develop and implement plans to minimize effects.** Actions that could minimize effects of access include seasonal restrictions, signs, fencing, or relocation or modification of access points or trails.

**2.3.2 Implement and enforce pet restrictions.** It is preferable that land managers prohibit pets on beaches and other habitats where western snowy plovers are present or traditionally nest or winter because any noncompliance with leash laws can cause serious adverse impacts to western snowy plovers. If pets are not prohibited, they should be leashed and under manual control of their owners at all times. Pets should be prohibited on beaches and other western snowy plover habitats if, based on observations and experience, pet owners fail to keep pets leashed and under full control.

Land managers should document the type and frequency of infractions of rules and regulations requiring pets on leash. This information, including the number of verbal warnings, written warnings, and notices to appear (citations), should be documented so that comparisons can be made between locations. This documentation could help ensure that adequate effort is being made to enforce pet regulations. Appendix C, Table C-1 identifies 120 locations where pets are currently prohibited or restricted and where they are recommended to be prohibited or restricted to achieve management goals.

**2.3.3 Annually review existing recreational activities at breeding and wintering sites listed in Appendix C and develop and implement plans to prevent disturbance from disruptive recreational activities where western snowy plovers are present.** Some recreational activities may disrupt western snowy plover breeding and foraging, attract predators, destroy nests, or degrade habitat. Management of a variety of recreational activities is needed to minimize these effects. Special events, including sporting events, media events, fireworks displays, and beach clean-ups, attract large crowds and require special attention. Special events planned in western snowy plover nesting areas should not be held during the plover nesting season. Early planning and coordination with local resource agencies should be emphasized. Fireworks should be prohibited on beaches where plovers nest. When fireworks displays are situated to avoid disturbance to western snowy plovers, careful planning also should be conducted to assure that spectators will not walk through and throw objects into plover nesting and brood-rearing areas. Sufficient personnel also must be on-site during these events to enforce plover protection measures and prevent use of illegal fireworks in the vicinity of the birds.

Flying of kites and model airplanes should be managed to avoid adverse impacts in areas where nesting plovers are present. Sports such as ball- and frisbee-throwing should be managed within hitting and throwing distance of western snowy plover nesting areas because of tendencies for stray balls and frisbees to land in closed areas where they can smash nests and where efforts to remove them can disturb territorial or incubating birds. Camping and beach fires should be prohibited in western snowy plover nesting areas during the nesting season. Appendix C, Table C-1 identifies 11 locations where kites are and/or should be prohibited and/or restricted to achieve management goals, but additional recreational activities also should be reviewed for potential adverse effects to western snowy plovers.

2.3.4 **Inform beach users of restrictions on driftwood removal through posting of signs.** Driftwood removal should not be allowed unless needed to create sufficient open habitat to induce nesting activities. In such cases, driftwood removal should occur outside of the breeding season. Appendix C, Table C-1 identifies 26 locations where driftwood collection restrictions currently occur and/or are recommended for restriction to achieve management goals. Driftwood removal should also be minimized through enforcement as identified in Action 2.3.8.

2.3.5 **Prevent disturbance, mortality, and habitat degradation by prohibiting or restricting off-road vehicles, including beach-raking machines.** Recreational off-road vehicles should be prohibited or restricted at western snowy plover breeding areas, as appropriate. Violations associated with unauthorized entry of recreational off-road vehicles into closed or fenced nesting areas should be strictly enforced. During the nonbreeding season, enforcement of violations regarding recreational off-road vehicle use should continue where western snowy plover use of beaches occurs year-round. Because of potential habitat degradation caused by mechanized beach cleaning, alternatives to this type of beach cleaning are recommended, including manual beach cleaning by agency staff and volunteers knowledgeable about the need to maintain coastal dune habitat characteristics and to protect western snowy plovers. Appendix C, Table C-1 identifies 101 locations where off-highway vehicles are currently and/or recommended for prohibition or restriction to achieve management goals.

Essential vehicles within western snowy plover nesting areas should: (1) travel on sections of beaches where unfledged chicks are present only if absolutely necessary; (2) when possible, travel through chick habitats only during daylight hours; (3) travel at less than 8 kilometers (5 miles) per hour; (4) use a guide familiar with western snowy plovers; (5) use open four-wheel motorized off-highway vehicles or nonmotorized all-terrain bicycles to improve visibility; (6) avoid driving on the wrack (marine vegetation) line and during high-tide periods; (7) travel below the high tide mark and as close to the water line as is feasible and safe; and (8) avoid previous tracks on the return trip.

2.3.6 **Implement restrictions on horseback riding in nesting areas through annual coordination with commercial and private equestrian operations and groups.** Strategies to reduce adverse impacts to nests from commercial and private equestrian use of western snowy plover habitat should include: (1) use of designated trail systems or, when absent, use of the wet sand area in areas not closed to the water line; (2) advance coordination with local resource agencies regarding locations of nests and broods; (3) compliance with closed or restricted areas; and (4) informing riders of the need for restrictions to protect habitats used by western snowy plovers and other sensitive coastal dune species. Avoid high-tide periods. Violations regarding unauthorized entry into closed or restricted breeding areas by equestrians should be strictly enforced. Appendix C, Table C-1 identifies 72 locations where restriction or prohibition of horses currently exists or is recommended to achieve management goals.

2.3.7 **Implement and enforce restrictions on livestock in nesting areas through annual coordination with land managers, landowners, and grazing lessees.** Strategies to reduce adverse impacts to nests from livestock grazing in western snowy plover habitat should include: (1) advance coordination with local resource agencies regarding locations of nests and broods; (2)

compliance with closed or restricted areas; and (3) informing landowners of the need for restrictions to protect habitats used by western snowy plovers and other sensitive coastal dune species. Violations regarding unauthorized entry into closed or restricted breeding areas by livestock should be strictly enforced. Appendix C, Table C-1 identifies 18 locations where restriction or prohibition of livestock currently exists or is recommended to achieve management goals.

**2.3.8 Enforce regulations in areas used by breeding western snowy plovers.** Land managers should monitor violations and enforce regulations within all closed and restricted areas, with particular attention to areas where nests or broods are present.

**2.3.8.1 Determine enforcement needs for western snowy plover breeding and wintering sites and provide sufficient wardens, agents, or officers to enforce protective measures in breeding and wintering habitat.** Wardens are especially needed on heavily-used beaches during the peak recreational season, which coincides with the western snowy plover breeding season in many locations. Federal, State, and local authorities should provide a coordinated law enforcement effort to eliminate activities that may adversely impact western snowy plovers, such as illegally-parked vehicles, trespassing off-road vehicles, pedestrians, pets in restricted areas, illegal or unauthorized activities (*e.g.*, fireworks, beach fires, driftwood removal), pets off leash, and littering. Patrols and enforcement are needed to ensure compliance and to make sure restrictive measures are successful. Specific actions to be implemented include patrols in protected areas (see action 2.3.8.2) and car patrols to prevent illegal driving and parking. Appendix C, Table C-1 identifies 105 locations where enforcement of regulations currently occurs or is recommended to occur to achieve management goals.

**2.3.8.2 Develop and implement annual training programs for enforcement personnel and others who work in western snowy plover breeding habitat to improve enforcement of regulations and minimize effects of enforcement actions on western snowy plovers and their habitat.** Federal, State, and local enforcement personnel and others who work in western snowy plover habitat should be trained to be familiar with the Endangered Species Act and other wildlife conservation statutes, and with the measures recommended in this recovery plan. Training, especially specific training for professional law enforcement agents regarding investigation of potential wildlife and Endangered Species Act violations, should be coordinated with local U.S. Fish and Wildlife Service Law Enforcement offices. It is essential that wardens, whether professional or volunteers, (1) be thoroughly trained in procedures for conducting patrols in a manner that minimizes risk to plovers; (2) have at least basic knowledge of western snowy plovers for public education purposes; and (3) be trained to handle potentially confrontational situations. *In cases involving take of listed species, it is essential that investigations be conducted only by trained, certified, and professional law enforcement agents*. Our local Law Enforcement office should be informed *immediately* whenever evidence of suspected take of western snowy plovers is encountered.

Enforcement personnel should be instructed in measures that can minimize effects of enforcement actions on western snowy plovers. Where the extent of habitat to be protected is large, making foot patrols infeasible, horses, four-wheel all-terrain vehicles/off-road vehicles, or nonmotorized all-terrain bicycles, are preferred over trucks, automobiles, *etc.*, because they afford improved visibility for operators. Except during emergencies, vehicle speed should not exceed 8 kilometers (5 miles) per hour and horses should be ridden at a walk only. In addition to providing maximum visibility for operators, horse and foot patrols by uniformed personnel have the added advantage of providing informational/educational interactions with beach visitors to promote compliance with plover protection measures.

Enforcement and emergency response personnel (such as search and rescue, and fire) should be well aware of potential western snowy plover locations. These locations should be named as avoidance areas as a part of their plans and training exercises. Enforcement patrols should use the same access trails as beach visitors; if additional access points are needed, they should be the minimum necessary and as far away from nesting plovers as possible.

**2.3.9 Develop and implement a program to annually coordinate with local airports, aircraft operations, and agency aircraft facilities to facilitate compliance with aviation regulations regarding minimum altitude requirements.** Each recovery unit working group should develop a list of local airports, aircraft operations, and agency aircraft facilities within each recovery unit. Working groups, land managers, and the U.S. Fish and Wildlife Service should annually inform them of western snowy plover breeding areas that should be avoided by aircraft operations or where minimum altitude requirements should be enforced to minimize disturbance of western snowy plovers. Aircraft operations within western snowy plover habitat should require a minimum altitude of 152 meters (500 feet) for aircraft and a possibly higher altitude for helicopters. Aircraft operations that have already established guidelines allowing aircraft to fly under the 152-meter (500-foot) threshold should raise the limits to this minimum threshold or higher as needed. Exceptions such as use for low-altitude military training should be addressed in coordination with the appropriate Fish and Wildlife Office through section 7 consultation.

Ultralight aircraft are a new potential source for negative effects to the snowy plover. Ultralight aircraft landed on nesting plover beaches at Point Reyes National Seashore in 2003. These aircraft are sometimes associated with an airport but often are kept on ranches or other private lands (S. Allen ***in litt.*** 2004).

In addition, land managers should report suspected violations of aviation regulations in western snowy plover nesting areas during the breeding season. Suspected violations and the aircraft's registration number should be reported to law enforcement officers and, if appropriate, the Federal Aviation Administration. If not in violation of aviation regulations (***e.g.***, helicopters), a description of the helicopter should be reported to law enforcement officers so they can notify the operator of the presence of, and potential for take of, western snowy plovers in nesting areas.

**2.4 Prevent excessive predation for western snowy plovers.** Land managers should employ an integrated approach to predator management that considers a full range of management techniques. Managers may need to reevaluate and clarify their policies on the management of predator populations and/or habitat where predation might be limiting local western snowy plover populations. In particular, policies that prohibit management of native predator populations, even when human-abetted factors have caused substantial increases in their abundance, may be counter-productive to the overall goal of protecting "natural" ecosystems.

In addition to predator management activities by on-site biologists, assistance from the U.S. Department of Agriculture (Wildlife Services

Branch) biologists, State wildlife agency furbearer biologists, biologists specializing in avian predators, and professional trappers should be sought and used as needed and appropriate. Federal, State, and local agencies and the general public should be aware of the adverse consequences to listed species if needed predator control measures are prohibited or restricted. Appendix C, Table C-1 identifies 61 locations where predator control currently occurs or is recommended to achieve management goals. Below are specific means of predator control.

**2.4.1 Manage litter and garbage and its removal to minimize attracting predators on western snowy plover habitat.** Litter and garbage in western snowy plover habitat may increase predation of western snowy plovers by providing food that attracts predators and encourages increased predator populations. Appropriate management of litter and garbage, particularly in areas that receive heavy recreational use, is needed to prevent or minimize excessive predation.

**2.4.1.1 Implement and enforce anti-littering regulations.** Litter should not be allowed in western snowy plover breeding areas to avoid attracting predators. Littering ordinances should be enforced year-round.

**2.4.1.2 Evaluate the effects of current litter and garbage management on predation of western snowy plover at breeding and wintering sites.** All sites in Appendix C should be evaluated to determine whether garbage and litter affect predation on western snowy plovers by attracting predators.

**2.4.1.3 Develop and implement garbage and litter management plans for all sites identified in action 2.4.1.2 where litter and garbage contribute to predation on western snowy plovers.** Plans for managing litter and garbage should be incorporated into long-term protection and management efforts developed and implemented under action 3. Beachgoers should be discouraged from leaving or burying trash or food scraps on the beach. Trash cans should not be located on the beach unless there is no other recourse to prevent littering. Emptying cans in the evening instead of leaving them overnight is preferable. Fish-cleaning stations should be located well away from plover breeding areas. Land managers should supply covered or scavenger-proof trash receptacles at access points and away from western snowy plover habitat, and receptacles should be routinely emptied. Until predator-proof trash containers can be installed, existing trash cans should be emptied frequently to reduce attractiveness and availability of their contents to scavenging predators. Land managers should also provide toilets at access points and away from western snowy plover habitat to discourage people from using the dunes.

Although removal of trash from the beach reduces predation threats, beach-raking should be avoided year-round to protect breeding and wintering western snowy plovers (see action 2.3.5). Beach-raking of western snowy plover habitat also should be avoided because it removes plover food sources. Trash should be selectively removed from the beach manually, but natural materials, including shells, kelp, and driftwood, should be left intact (see action 2.3.4).

2.4.2 **Annually identify predator perches and unnatural habitats attractive to predators and remove where feasible.** Planners should not allow unnatural habitats or other predator attractants to be placed near western snowy plover nesting locations. Where feasible, land managers should remove from western snowy plover breeding locations any exotic vegetation, perches, and other features that attract avian and mammalian predators. Where signs and fences are necessary as part of management to protect plover breeding areas, attempts should be made to design them in a way that will deter their use by predators (*e.g.*, install spikes on fence posts).

**2.4.3 Erect predator exclosures to reduce western snowy plover egg predation and improve productivity (number of fledglings per male) where appropriate.** Guidelines for the use of predator exclosures to protect nesting western snowy plovers are contained in Appendix F. Exclosures are a valuable tool for countering human-abetted predation threats to western snowy plover eggs, but they are not appropriate for use in all situations, nor do they provide any protection for mobile plover chicks, which generally leave the exclosure within one day of hatching and move extensively along the beach to feed. Exclosures should be used in conjunction with an integrated predator management program. Also, exclosures must be carefully constructed, monitored, and evaluated by qualified persons. In some areas, avian predators have learned over time to associate exclosures with a source of prey (J. Buffa *in litt.* 2004). String (twine) or a more substantial plastic stealth material may be needed on top of exclosures to deter avian predators. Appendix C, Table C-1 identifies 53 locations where exclosures are currently used or recommended for use to achieve management goals.

The use of exclosures (small circular, square, or triangular metal fences that can be quickly assembled) to deter predator and human intrusion is recommended as one of the most effective management tools to protect nests (see Appendix F for exclosure protocols). However, it should be recognized that while exclosures provide nest protection, they do not ensure survival of chicks to fledging age and may contribute to predation on adults, so their use should be evaluated carefully and may not substitute for other measures that reduce human disturbance (2.3) or control predation (2.4.1, 2.4.2, 2.4.3, 2.4.5).

**2.4.4 Evaluate the need for and feasibility of predator removal and implement removal where warranted.** Where predators have been identified through monitoring to adversely affect western snowy plover breeding success and/or survival and cannot be adequately controlled through use of exclosures, land managers should evaluate the need for and feasibility of predator removal. Removal of predators should be pursued where it is feasible, warranted, humanely conducted, and useful. Situations that may especially warrant predator removal include those where nonnative predators such as red fox (*Vulpes vulpes regalis*), feral cats, and Norway rats (*Rattus norvegicus*) are present, where predators have been introduced to islands, where predator range extensions have been human-abetted, or where high rates of western snowy plover adult, chick, or egg predation (which cannot be countered with predator exclosures or other aversion methods) are occurring. Nonnative predators should be lethally controlled in plover nesting habitat. Native predators should be removed or controlled by nonlethal means whenever possible. Gulls also should be discouraged from establishing and expanding nesting colonies at western snowy plover nesting areas, and land managers should determine whether existing gull colonies warrant removal. If removal is not warranted, exclosures around plover nests should be used to prevent large flocks of roosting gulls from trampling plover nests.

Federal and State permits must be obtained to legally capture, kill, or hold and release birds protected under the Migratory Bird Treaty Act and State laws. Also, individuals responsible for capturing such birds and the holding facility must have the proper Federal and State permits, and Federal land managers must document that such activities are in compliance with the National Environmental Policy Act. Biological considerations for determining whether removal of avian predators is appropriate include the time of year (to assess whether the predator is caring for young or is a fledgling itself), whether the predatory bird is a resident or migrating through western snowy plover nesting habitat, and whether the predatory bird is a sensitive species or listed under the Endangered Species Act. Because of the potential for swift and significant losses of plovers by avian predators, land managers should plan in advance to complete the necessary procedures and secure needed permits to effectively deal with cases of high negative impact on western snowy plovers. If feasible, removal of native predators should focus on problem individuals rather than populations. Possible control methods include egg addling, nest removal, translocation of problem individuals, and holding in captivity with later release after plover breeding season. State permits must also be obtained as appropriate for the capture and removal of problem mammals (*e.g.*, raccoons, skunks, and opossums). In 2001, the California Coastal Commission determined that predator management in western snowy plover habitat on Vandenberg Air Force Base was also subject to Coastal Consistency review under the Coastal Zone Management Act.

**2.4.5 Remove bird and mammal carcasses in western snowy plover nesting areas.** Where practical and not disturbing to western snowy plovers, dead birds and mammals that wash up on the beach in close proximity to plover nests should be removed to reduce the attraction of predators to plover nests. Removal of carcasses of marine mammals and species listed under the Endangered Species Act should be coordinated with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

**2.5 Protect western snowy plovers and their breeding and wintering habitat from oil or chemical spills.** Land managers should develop oil/chemical spill emergency response plans that provide for protection of known western snowy plover breeding areas. The U.S. Coast Guard should update their emergency response measures to include protective measures for the western snowy plover. In the event of a spill in the vicinity of a western snowy plover nesting or feeding area, efforts should be made to prevent oil/chemicals from reaching these beaches. Clean-up operations should be prompt, but agencies should exercise special care during remediation efforts and coordinate closely with us to prevent accidental destruction of nests and/or excessive disturbance of breeding adults, nests, or chicks. Response plans should include applicable recommendations contained in this recovery plan (*e.g.*, Action 2.3.5 regarding essential vehicles).

Efforts must be made to minimize the likelihood of oil or chemical spills in plover wintering areas. Land managers should develop oil/chemical spill emergency response plans that provide for protection of known plover wintering areas. The U.S. Coast Guard should update their emergency response measures to include protective measures for the western snowy plover. Shorebird or coastal ecosystem protection plans developed by State or local agencies to address oil/chemical spills should also include protection measures for western snowy plovers. In the event of a spill in a known western snowy plover wintering area, efforts should be made to prevent oil/chemicals from impacting plovers and unavoidable impacts should be documented. Restoration efforts should begin expeditiously, but agencies should exercise special care and coordinate closely with us to prevent excessive disturbance to wintering western snowy plovers. Further, habitat restoration efforts must be conducted in compliance with the National Environmental Policy Act and the Coastal Zone Management Act.

If western snowy plovers or their habitat sustain injury due to oil/chemical spills, the responsible parties should restore the areas to their original condition or the Federal Government (U.S. Coast Guard) should lead the clean-up effort; appropriate claims should also be filed under the Natural Resource Damage Assessment regulations to recover damages and undertake relevant restoration work. Assessment of natural resource damages is facilitated by availability of baseline data on pre-spill conditions. Therefore, whenever possible, agencies that own or manage western snowy plover habitat should collect baseline data on behavior, reproduction, distribution, abundance, and habitat use. The baseline information on plover distribution and habitat use should also be supplied to the Area Committees that develop and update regional spill contingency plans so that this information can be incorporated into pre-spill planning efforts for protection of sensitive environments and species. Oil spill emergency response personnel should be well aware of potential plover locations. These locations should be named as avoidance areas as a part of their training exercises. Appendix C, Table C-1 identifies 4 locations where contaminant removal is occurring or is recommended to achieve management goals.

2.5.1 **U.S. Fish and Wildlife Service biologists should participate in Area Committees responsible for maintaining the Area Contingency Plans for the Pacific Coast to facilitate the updating of spill response plans to include protection of western snowy plovers.** Active participation in the Area Committees would require funding for staff participation from the six U.S. Fish and Wildlife Service offices responsible for the coastlines of California, Oregon and Washington.

2.5.2 **Assign monitors to beaches that are inhabited by western snowy plovers to protect western snowy plovers from injury during spill responses.** Monitors would be responsible for identifying areas of beach that are in use by plovers and directing response personnel and vehicles around these sensitive areas. Potential monitors should be identified in advance, and, where necessary, retained under contract so they can begin work immediately in the event of a spill. Spill response may require approximately two weeks of cleanup work that should be monitored, with potentially five incidents of this magnitude per year.

**2.6 Reduce adverse impacts of recovery efforts for other sensitive species, including those within the San Francisco Bay Recovery Unit, by compensating for the loss of western snowy plover breeding and wintering habitat.** Management and recovery actions for other sensitive species carried out in western snowy plover habitat should be evaluated for adverse effects to western snowy plover habitat. All efforts should be made to conserve western snowy plover habitat and minimize adverse effects. Where this is not possible, any loss of western snowy plover habitat values should be compensated. Within coastal beach-dune habitats in Washington, Oregon, and California, compensation efforts should emphasize the removal of beachgrass (*Ammophila* spp.) for lost western snowy plover breeding habitat resulting from management for other sensitive species.

To compensate for the loss of existing western snowy plover breeding habitat values in San Francisco Bay from planned conversion to tidal marsh, appropriate salt ponds should be designated for protection and enhancement as western snowy plover breeding habitat. Currently, most western snowy plover breeding habitat occurs on levee roads, margins of active salt ponds, and pond bottoms of inactive salt ponds. Roads and levees provide lower quality habitat because of disturbance and ease of predator access. Any losses of western snowy plover breeding habitat should be replaced with habitat that provides similar or higher values (*i.e.*, salt ponds or salt pans) in concert with recovery actions implemented from the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (U.S. Fish and Wildlife Service in prep.). Habitat enhancement for western snowy plovers should be phased in with scheduled tidal marsh restoration for other listed species. During this interim period, land managers should make all efforts to achieve the recovery criteria of 500 breeding adults within the San Francisco Bay Recovery Unit by intensively managing existing western snowy plover breeding habitat.

Any replacement of western snowy plover breeding habitat in San Francisco Bay should concentrate on areas where the necessary components of western snowy plover breeding habitat can be created.

These areas include locations where unvegetated salt pans, salt ponds, islets and levees, and tidal mudflats/sandflats can be created or enhanced. Also, attempts should be made to avoid areas that are adjacent to landfills or other high concentrations of potential predators. Unless it is shown to be infeasible, creation and enhancement of western snowy plover breeding habitat should be emphasized in areas that currently support high numbers of breeding plovers and/or are not conducive to salt marsh restoration. The area to be managed for western snowy plovers should be sufficient to support a population of 500 breeding birds, estimated at 809 hectares (2,000 acres) of managed salt ponds. Most of these managed salt ponds should be located in South San Francisco Bay, which supports most of the existing western snowy plover population; however, some should also be located in the North Bay. Created or enhanced salt ponds should be intensively managed, similar to the Moss Landing Wildlife Area salt ponds. Management measures practiced at these salt ponds include maintenance of water control structures to maintain desired water levels, removal of excessive vegetation, and predator control.

2.7 **Discourage pinnipeds from usurping western snowy plover nesting areas.** Land managers should monitor pinniped colonies adjacent to western snowy plover breeding habitat and seek to keep breeding pinnipeds from occupying western snowy plover nesting areas during the breeding season where possible. Where conflicts occur, breeding pinnipeds should be discouraged from hauling out at western snowy plover breeding areas or be relocated, if feasible. Implementation of this action should be coordinated with the National Marine Fisheries Service to ensure compliance with the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361 *et seq.*).

2.7.1 **In coordination with National Marine Fisheries Service, investigate feasibility and methods for discouraging pinniped use of western snowy plover nesting areas.** Marine mammal populations have increased in many western snowy plover nesting areas. However, methods, effectiveness, and impacts of discouraging pinniped use of beaches are unknown and should be investigated. Methods considered should be evaluated for their effects on western snowy plovers and their habitat as well as effectiveness in discouraging pinniped use. Workshops, such as those conducted by NMFS, for developing methods to reduce conflicts between pinnipeds and other species and human users should be held.

**2.7.2 Identify areas where pinniped use is negatively affecting western snowy plover nesting and implement any appropriate methods identified in action 2.7.1.** If effective methods are determined through action 2.7.1, sites where pinniped use negatively affects western snowy plover nesting should be identified and methods to discourage pinniped use implemented. Implementation of any methods to discourage pinniped use should be closely coordinated with the National Marine Fisheries Service to ensure compliance with the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361 *et seq.*).

**3 Develop mechanisms for long-term management and protection of western snowy plovers and their breeding and wintering habitat.** Long-term management and protection will be needed on Federal and non-Federal lands to meet recovery criteria for each recovery unit and to meet management goals for individual breeding and wintering locations. Development of long-term protection mechanisms should include opportunities for participation of various stakeholders in development of management options.

**3.1 Establish and maintain western snowy plover working groups for each of the six recovery units to facilitate regional cooperative networks and programs.** Development of regional cooperative networks and programs, coordinating local public and private land use planning with State and Federal land use planning, recovery planning, and biodiversity conservation is needed (Figure 12). To facilitate and develop regional cooperative programs, working groups have been established for each of the six recovery units and should be maintained. U.S. Fish and Wildlife

Service field offices should facilitate exchange of information among working groups. The working groups should be composed of representatives from the Federal, State, local, and private sectors; and meet regularly to assess western snowy plover population trends and coordinate plover recovery efforts. Each of the six working groups should use this recovery plan as a guide, but members will prioritize in cooperation with our Arcata Fish and Wildlife Office what management measures need to be implemented in their recovery unit because they have on-the-ground, day-to-day, experience about what is currently being done in these areas. Working groups should assist with updating information contained in Appendices B and C, tracking whether management goals are being met, and recommending changes in management goals and site-specific management actions, if necessary. Public outreach also should be a major focus of the working groups. An interchange of ideas between all six working groups should also occur on an on-going basis.

**3.2 Develop and implement regional participation plans for each of the six recovery units that outline strategies to implement recovery actions.** The 1994 Interagency Cooperative Policy on Recovery Plan Participation and Implementation Under the Endangered Species Act (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 1994) provides for a participation plan process, which involves all appropriate agencies and affected interests in a mutually-developed strategy to implement recovery actions. Participation plans for implementing recovery actions for the western snowy plover that include all partners should be developed by each of the six recovery unit working groups. In addition to outlining a strategy to implement recovery actions, the participation plan should include strategies for evaluation of progress and needs for plan revision. Participation plans may also achieve the policy's goal of providing for timely recovery of species while minimizing social and economic impacts. Plans should identify and prioritize specific recovery activities for each location identified in Appendices B and C,while considering the needs of the entire Pacific coast population. They

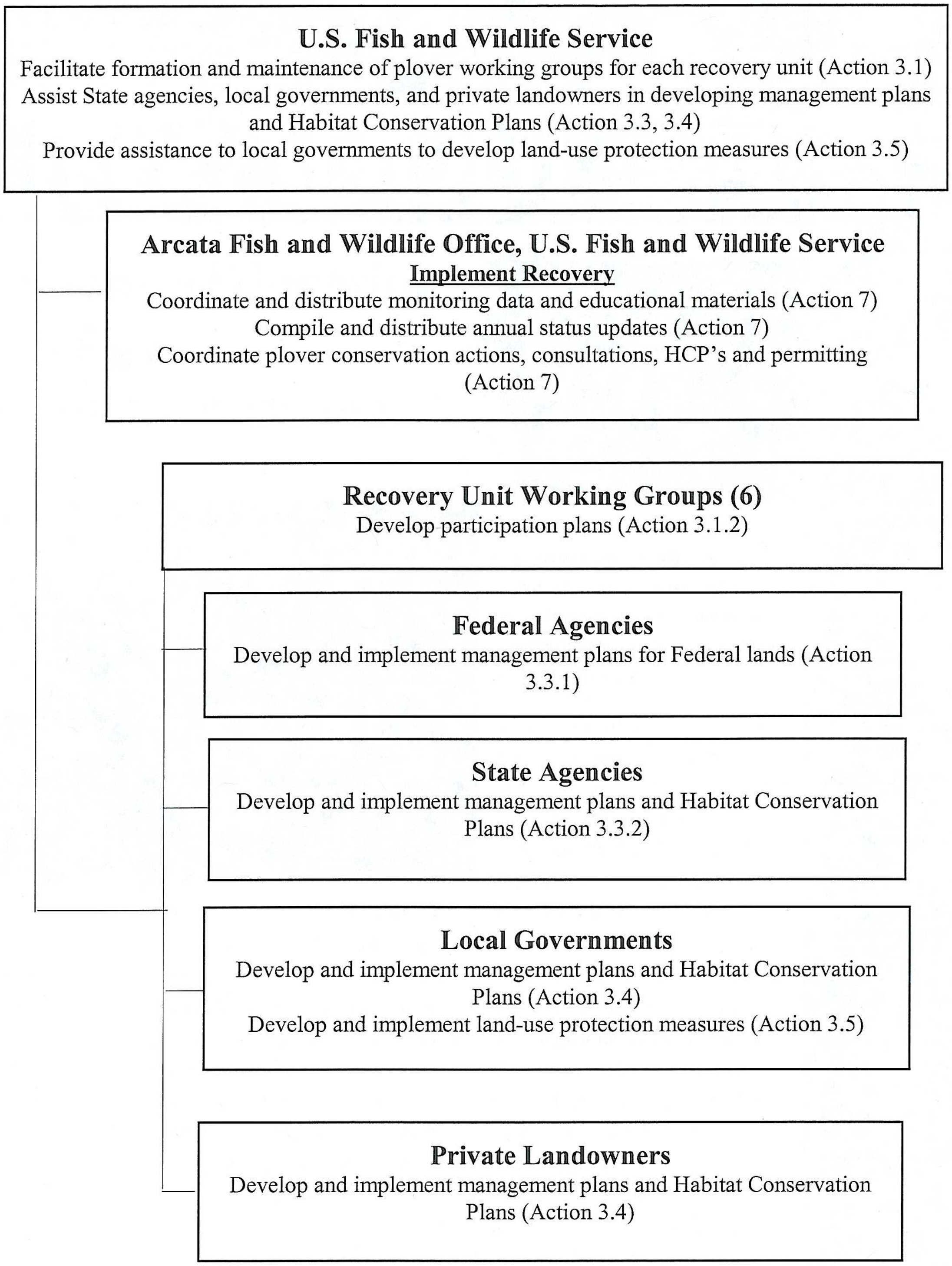



Figure 12. Chart of recovery planning and implementation efforts.

should include, but not be limited to: (1) endorsements by responsible agencies of their intent to seek economic resources for ongoing recovery actions; (2) outreach efforts to enhance the public's understanding of the western snowy plover's habitat needs (including an information and education strategy specific to area demographics and recreational activities); (3) economic incentives for conservation of western snowy plovers on private lands; and (4) all actions necessary to maintain western snowy plover productivity after delisting. Participation plans may also identify ways in which recovery actions for western snowy plovers will be covered as part of coastal ecosystem plans or other conservation measures.

3.3 **Develop and implement management plans for all Federal and State lands to provide intensive management and protection of western snowy plovers and their habitat.** Federal and State land managers should develop and implement management plans for all breeding and wintering locations (listed in Appendix B) that occur on Federal or State lands. Intensive management programs for western snowy plovers at national wildlife refuges should be implemented and annually evaluated to ensure they provide sufficient plover protection. Intensive management programs also should be implemented and periodically evaluated on lands administered by the National Park Service, U.S. Forest Service, U.S. Bureau of Land Management, U.S. Army Corps of Engineers, and Federal military bases, State wildlife areas, State ecological reserves, and State park lands (including State natural preserves and State seashores).

3.3.1 **Develop and implement management plans for Federal lands.** Federal agencies should develop or update, as appropriate, site-specific management plans that address threats to western snowy plovers, and adopt management measures for habitat protection and enhancement on Federal lands. Management plans should be implemented on an ongoing basis. Federal agencies also should review their proposed actions under the requirements of sections 7 and 10 of the Endangered Species Act prior to implementing the management plans because they may require authorization under section 7(a)(2) or 10(a)(1)(A).

**3.3.2 Develop and implement management plans and habitat conservation plans on State wildlife areas, State ecological reserves, and State beaches.** State agencies that manage State beaches, wildlife areas, or ecological reserves should develop and implement site-specific management plans and habitat conservation plans to minimize and mitigate impacts to western snowy plovers, and management measures for habitat protection and enhancement on State lands. State agencies should coordinate the development of habitat conservation plans with us and apply for section 10(a)(1)(B) permits under the Endangered Species Act if their management actions and allowed uses are resulting in incidental take of western snowy plovers.

**3.4 Develop and implement habitat conservation plans or other management plans for western snowy plover breeding and wintering sites owned or managed by local governments and private landowners.** We should provide assistance in the development of habitat conservation plans or other management plans to: (1) county and city governments that manage western snowy plover habitats; (2) private resource managers; and (3) owners of large amounts of private natural land. Habitat conservation plans are only required if an incidental take permit under section 10(a)(1)(B) of the Endangered Species Act is desired or required.

**3.5 Provide technical assistance to local governments in developing and implementing local land use protection measures through periodic workshops.** Federal and State agencies should assist local governments with jurisdiction over western snowy plover habitats in developing western snowy plover protection policies as part of new or revised local general plans, zoning policies, implementing measures, land use plans, comprehensive plans, and local coastal programs. For areas where beach closures are necessary, appropriate ordinances, administrative rules, and regulations should be developed by State and local governments to enable law enforcement officers to conduct necessary enforcement actions.

Technical assistance such as maps of western snowy plover habitats, identification of local threats, and recommended site-specific protective measures should be provided to coastal planners. At least two workshops within each recovery unit that provide local governments with basic information on the western snowy plover, its habitats, threats, and recommended protective measures should be conducted during the first 10 years of recovery plan implementation. Additional technical assistance likely will be required but should be provided on an as needed basis as new or revised general plans, policies, ordinances, and other land use protection measures are developed.

3.6 **Develop and implement cooperative programs and partnerships with the California State Coastal Commission, the Oregon Department of Land Conservation and Development, the Washington State Parks and Recreation Commission, the Oregon Parks and Recreation Department, the California Department of Parks and Recreation, and the Oregon Department of Fish and Wildlife to ensure that they use their authorities to the fullest extent possible to promote the recovery of the western snowy plover.** Federal and State agencies should assist the California State Coastal Commission, Oregon Department of Land Conservation and Development, Washington State Parks and Recreation Commission, Oregon Parks and Recreation Department, California Department of Parks and Recreation, and Oregon Department of Fish and Wildlife in reviewing, updating, and amending local coastal programs and policies for consistency with the western snowy plover recovery plan. This review should include protection of western snowy plover habitats, cumulative impacts to western snowy plovers, and policies or restrictive measures recommended in this recovery plan.

3.7 **Obtain long-term agreements with private landowners.** Agreements between Federal and State agencies and private landowners interested in western snowy plover conservation should be developed and implemented. Landowners should be informed of the significance of plover populations on their lands and be provided with information about available conservation mechanisms, such as agreements and incentive programs. For private lands with potential occurrences of western snowy plovers, permission should be sought from landowners to conduct on-site surveys. If surveys identify plover populations, landowners should be informed of their significance and offered incentives to continue current land uses that support species habitat. Appendix C, Table C-1 identifies 69 locations where landowner cooperation/cooperative agreements are occurring or are recommended to achieve management goals.

3.8 **Identify and protect western snowy plover habitat available for acquisition.** Federal, State, and private conservation organizations should protect western snowy plover habitat as it becomes available, through fee title or conservation easement, *etc.* We and other organizations should identify sites that may become available for acquisition, and we should continue to evaluate excess Federal lands for western snowy plover habitat and apply to acquire them as they become available. Each recovery unit working group should develop a list of priority properties for acquisition, and Federal, State, and nongovernmental organizations should work with land conservancy groups to implement land trades and acquisitions. Management plans for the western snowy plover should be developed during the land acquisition process.

3.9 **Ensure that section 10(a)(1)(B) permits contribute to Pacific coast western snowy plover conservation.** Recommendations contained in this recovery plan should guide the preparation of habitat conservation plans under section 10(a)(1)(B) of the Endangered Species Act for western snowy plovers on the Pacific coast by providing information to: (1) guide potential applicants in developing plans that minimize and mitigate the impacts of take and (2) assist us in evaluating the impacts of any proposed conservation plans on the recovery of the Pacific coast western snowy plover population. The section 10(a)(1)(B) permit process may be a valuable mechanism for developing the long-term protection agreements called for in Actions 3.3.2 and 3.4, especially where significant population growth has already occurred and productivity exceeds l.0 fledged chick per male.

**3.10 Ensure that consultations conducted pursuant to section 7 of the Endangered Species Act contribute to Pacific coast western snowy plover conservation.** The recovery plan should also guide the evaluation of impacts to western snowy plovers pursuant to section 7(a)(2) of the Endangered Species Act. In evaluating these impacts, we and other Federal agencies should consider each of the breeding and wintering locations listed in Appendix B as important for recovery, and should also refer to the management goal breeding numbers for applicable locations and determine how the proposed project will affect those goals. Coordination with military bases which have western snowy plover populations is important to ensure that military activities do not affect the western snowy plovers or their habitat. Appendix C, Table C-1 identifies 54 locations where military uses are either restricted or recommended for restriction to achieve management goals.

**4 Undertake scientific investigations that facilitate recovery efforts.** Major gaps remain in our understanding of useful protection measures and conservation efforts for the western snowy plover. These include effective methods for habitat restoration, predator control, and monitoring population numbers and demographic characteristics.

**4.1 Investigate effective methods for habitat restoration**.

**4.1.1 Evaluate the effectiveness of past and ongoing methods for habitat restoration by removal of introduced beachgrass and identify and carry out additional investigations necessary.** Land managers, in coordination with recovery unit working groups, should summarize methods used to date for removal of introduced beachgrass and review their effectiveness. They also should pursue any additional field studies necessary to determine the most effective and cost-efficient methods for habitat restoration through removal of introduced beachgrass. Controlled studies with improved monitoring would provide needed direction for management decisions.

**4.1.2 Evaluate the impacts and potential benefits of past and ongoing beach nourishment activities and identify and carry out any additional studies necessary to determine effects of beach nourishment activities on western snowy plover habitat.** Beach nourishment activities should be carefully evaluated to weigh the probable adverse and beneficial effects on plovers and on other sensitive coastal dune species. Pre- and post-deposition beach profiles and faunal studies (including invertebrates) should be conducted to determine effects on habitat suitability for western snowy plovers. Consideration should be given to whether the projected long-term benefits are likely to occur.

**4.2 Develop and test new predator management techniques to protect western snowy plover nests and chicks.** Because many of the techniques currently used to reduce predation have disadvantages or limitations in effectiveness, new predator management techniques should be investigated. Assistance from the U.S. Department of Agriculture, Wildlife Services Branch, from State wildlife agency furbearer biologists, and other predatory bird and mammal specialists should be sought on these matters.

**4.2.1 Develop higher-efficiency nest exclosures.** Because exclosures must be deployed quickly, and currently-designed exclosures are heavy and labor- and time-intensive to erect, new exclosure designs should be tested. Prototypes should include lightweight materials that are easier to transport and a design that is easy to assemble and install.

**4.2.2 Develop California least tern exclosures that prevent harm to western snowy plovers.** Resource managers should continue to investigate modified designs for California least tern enclosures to further minimize western snowy plover mortality.

**4.2.3 Identify, prioritize, and carry out needed investigations on control of native and nonnative predators.** Aspects of the ecology of problematic avian predators (*e.g.*, ravens and shrikes) and native mammals (*e.g.*, coyotes and gray foxes) that could be used to gain an understanding of how to control their impact on western snowy plover nesting areas during the plover breeding season should be investigated. Information also is needed on the applicability and usefulness of other control methods, including aversive techniques for conditioning predators to avoid foraging in western snowy plover nesting areas or preying on western snowy plover eggs, chicks, or adults. Investigation is also needed to develop methods to discourage gull colonies. Aversive techniques may include taste aversions, displaying predator carcasses, or installing electric fences. Effective modifications of signs and fencing to prevent their use as predator perches also requires investigation. While in many cases there appear to be practical obstacles to development of effective aversion techniques that can be efficiently applied in the field, the goal of reducing predation with minimum disruption to native predator populations that are important to overall ecosystem balance is desirable and any methods that appear potentially practical and useful should be evaluated for success and cost-effectiveness. Initial study trials might be done at sites or seasons where western snowy plovers are not present in order to minimize unplanned adverse impacts. Recovery unit working groups should identify and prioritize studies needed and inform us of their recommendations.

**4.2.4 Identify, prioritize, and carry out needed investigations on predator management at the landscape level.** Resource managers should investigate landscape-level management of predators that inhabit western snowy plover nesting areas. This management could include removal of predator nest sites and other predator attractants or habitat on lands surrounding western snowy plover breeding areas. Recovery unit working groups should identify and prioritize studies needed and inform us of their recommendations.

**4.2.5 Investigate techniques for identifying predators responsible for individual nest predation events.** Techniques should be developed to identify predators responsible for nest predation events so that appropriate management measures can be applied. Such techniques could include installation of a remote video camera to monitor western snowy plover nests and exclosures and identify problematical predators.

**4.3 Improve methods of monitoring population size and reproductive success of western snowy plovers.** Methods used to monitor western snowy plover populations have differed over time and from site to site. To measure progress toward recovery reliably, standard monitoring guidelines have been developed (Appendix J). Logistical and financial constraints likely will preclude complete coverage of all areas, so sampling methods should be developed.

**4.3.1 Improve methods of monitoring western snowy plover population size.** Not all western snowy plovers at a given location are detected during a single survey, such as the annual breeding-season window survey. Consequently, correction factors are necessary to extrapolate population size from window surveys. Correction factors are determined on a site-specific basis. Intensive monitoring and/or color banding make it possible to know the number of western snowy plovers present at a site. When a window survey is completed, the ratio of the total number of western snowy plovers to the number of western snowy plovers counted provides a correction factor that may be used for future window surveys of the site and for other sites with window surveys but without intensive monitoring. Site-specific correction factors should be obtained for all major nesting locations. When correction factors have been determined for many sites, patterns may emerge that allow correction factors to be applied more broadly.

**4.3.2 Develop sampling methods for annually estimating reproductive success within each recovery unit.** While it is extremely valuable to monitor clutch hatching success and chick fledging success at each site as a measure of habitat quality, it is critical to determine the number of young fledged per male for each recovery unit to measure the potential for population stability and growth. Measuring the number of young fledged per male requires intensive monitoring, and at sites with large numbers of birds, some method of identifying individual males. Extensive color banding of adults and their young, enabling determination of young fledged per male, has been undertaken in large portions of coastal Oregon, the shoreline of Monterey Bay, and coastal San Diego County for the past several years. These efforts should continue. Since there are insufficient color band combinations to monitor all individuals in every recovery unit, sampling procedures should be developed to color band adequate samples of males, and if necessary their chicks, in the other recovery units to obtain estimates of the number of young fledged per male. Color banding for measuring reproductive success should be integrated with banding for estimating population size.

**4.3.3 Develop methods to monitor western snowy plover survival rates within each recovery unit.** Extensive color banding of adult plovers and their young in coastal Oregon, the shoreline of Monterey Bay, and coastal San Diego County has enabled survival rates of adults and young to be calculated for several years (see Population Status and Trends and Survival sections). These efforts should continue. Information on survival rates of birds from other recovery units can be derived from birds banded for monitoring reproductive success or estimating population size.

**4.4 Conduct studies on western snowy plover habitat use and availability.**

**4.4.1 Identify western snowy plover brood habitat and map brood home ranges.** Brood movements should be mapped and distances quantified to identify how large an area must be protected for broods. Determine home ranges of western snowy plovers through radio telemetry studies. Traditionally used brood habitat should be identified and protected through actions 2 and 3.

4.4.2 **Identify components of high-quality western snowy plover brood rearing habitat.** The elements of high-quality brood habitat should be determined to facilitate creation and enhancement of suitable characteristics at other breeding locations.

4.4.3 **Quantify wintering habitat needs of western snowy plovers along the Pacific coast.** The amount of habitat needed to support wintering western snowy plovers along the Pacific coast should be determined. This effort should include estimating the numbers of western snowy plovers that can be supported at wintering locations listed in Appendix B and identifying important site characteristics. This action will require consideration of wintering habitat quality along the Pacific coast of the United States and Mexico, and quantifying the combined interior and coastal populations.

4.4.4 **Identify any important migration stop-over areas used by migrating but not by breeding or wintering western snowy plovers.** Additional information on western snowy plover migration patterns is needed because migration involves expenditure of energy that may affect survival or productivity. Although monitoring and protection of breeding and wintering locations are currently higher priorities than protection of migration sites, further investigations of, and protective measures for, migration sites should be undertaken when feasible. Threats and management needs of identified migration stop-over habitat should be evaluated and included in management monitoring, and protection tasks (see action 1.6).

4.5 **Develop and implement a research program to determine causes of adult western snowy plover mortality, including investigation of possible causes, magnitude, and frequency of catastrophic mortality.** Determine causes of mortality and the stage in the annual cycle (*e.g.*, post-breeding, migration, winter, pre-breeding, breeding) at which mortality occurs for each sex and age class. This assessment can be done through intensive, bi-weekly monitoring to determine relative health and potential for disease. Monitoring could include fat content and weight related to the season.

4.6 **Improve techniques for banding western snowy plovers.** Improve the technique for banding birds to reduce injuries. Because western snowy plover injuries are usually associated with Federal metal bands but not with plastic bands, removal of U.S. Fish and Wildlife Service lettering from the inside of the metal band should be investigated. Eliminating use of the U.S. Fish and Wildlife Service metal band also should be considered. Experimentation with new techniques must be conducted cautiously and may need to include pre-testing on nonlisted surrogate species.

4.6.1 **Compile information regarding number and types of banding injuries to western snowy plovers to determine extent and causes of banding injuries.** Several banding injuries to western snowy plovers have been reported. However, there is currently no consistent reporting of injuries to determine the extent or types of injuries. Working groups should compile information on banding injuries to use in determining the type and extent of the problem and in developing a course of action. Information collected should include number of injuries, type of injury (abrasion, foot loss, broken leg, *etc.*), probable cause of injuries (foreign object lodged between band and leg, wearing of band, *etc.*), effect of injuries on behavior (breeding, foraging, predator avoidance), type of bands (plastic or metal) associated with injuries, whether metal bands had writing on the inside or other rough areas likely to cause abrasion or lodging of foreign object.

**4.6.2 Review compiled information and determine and implement a appropriate course of action to minimize banding injuries.** The information complied in step 4.6.1 should be reviewed to determine the appropriate course of action to minimize banding injuries. Review may reveal that banding injuries are rare or have little impact on breeding success or survival, in which case no changes to banding procedures may be necessary. However, extensive numbers of injuries or impacts on breeding success and survival may require actions such as changing the location of metal bands from the tarsus to tibiotarsus, discontinuing use of metal bands, or using different band types. All decisions regarding changes to banding procedures should consider effects of such changes to the type, quantity, and quality of data that may be gathered from banding efforts, and whether such changes will affect the ability to determine population trends, monitor success of management actions, or otherwise affect recovery efforts. For example, discontinuing use of metal bands may affect the ability to gather information on survival, longevity, and dispersal useful in analyzing population viability.

**4.7 Identify effects of oil spills on western snowy plovers.** Research should be conducted on the direct and indirect effects of oil spills on western snowy plovers, including, but not limited to: (1) how oil spills affect the plover's prey base; (2) chronic effects of oiling; (3) transmission of oil on partially-oiled birds from the breast to the egg; (4) at what stage oiled plovers need to be captured or re-captured; (5) preferable methods to remove oil from soiled birds; and (6) impacts to plovers during oil clean-up and remediation activities.

**4.8 Monitor levels of environmental contaminants in western snowy plovers.** When abandoned eggs and/or dead chicks that are not needed for law enforcement investigations become available, they should be collected for potential contaminants assessment. Egg removal and salvage of dead chicks should only be done by individuals possessing proper Federal and State authorizations. Chemical analysis of salvaged specimens should be coordinated through our Division of Environmental Contaminants. All salvaged eggs should be analyzed for organochlorine pesticides, total polychlorinated biphenyls (PCB's), selenium, mercury, and boron.

All sampling should be opportunistic, based on availability of eggs that are known to be abandoned. Eggs should never be removed from the beach as long as there is any realistic chance that they might hatch. In the case of unhatched eggs from a partially hatched clutch, eggs should not be collected until at least 36 hours after the known hatch date of the other eggs. Full clutches should not be collected unless it is known that 35 or more days have elapsed since the last egg was laid. When this opportunistic sampling of failed eggs indicates potential problems with contaminants, follow up studies should be carried out (see action 4.9).

**4.9 Design and conduct contaminants studies if monitoring of contaminants in action 4.8 indicates potential contaminants effects.** When opportunistic sampling of failed eggs (action 4.8) indicates potential problems with contaminants, additional studies should be carried out to evaluate the extent of contamination in western snowy plover diets, its effects on nest success and egg hatchability, and its effects on various life stages of snowy plovers (eggs vs. adults). Thresholds when management action is required should be identified. When the target threshold is exceeded research should be conducted to identify the source.

**4.10 Identify, prioritize, and carry out needed investigations of the effects of human recreation on western snowy plovers.** Many studies on the effects of recreational activities on western snowy plovers have already been conducted. To avoid duplicating previous or ongoing efforts, recovery unit working groups should evaluate and prioritize additional study needs to determine the effects of human recreation on western snowy plover. Western snowy plover should be monitored for effects from recreational activities such as off-road vehicle riding, horseback riding, walking, jogging, fishing, aircraft, ultralight aircraft, and kite-flying.

**4.11 Revise the population viability analysis (Appendix D), if needed, when sufficient additional information on demographic characteristics (survival rates, reproductive success) is available from each recovery unit and information is obtained on the probability and magnitude of catastrophic mortality events.** As new information on population numbers, survival rates, and reproductive success are acquired from monitoring (actions 1.1 and 1.2), monitoring techniques are improved (action 4.3), and mortality sources and rates of mortality are determined (action 4.5), the population viability analysis should be reviewed and revised if additional information differs significantly from that used to construct the original analysis.

**5 Undertake public information and education programs.** Expanded efforts are needed to increase public awareness of the needs of western snowy plovers, other rare beach species, and the beach and dune ecosystem. Public outreach efforts should be a major focus of each of the working groups for the six recovery units. Appendix C, Table C-1 identifies 84 locations where public information and education is either currently occurring or is recommended to achieve management goals.

**5.1 Develop and implement public information and education programs.** Millions of beach recreationists come in contact with western snowy plover nesting and wintering areas each year. Disregard to signs, symbolic fencing, and leash laws by beach users can directly affect the productivity and health of western snowy plovers on those beaches. Public information and education efforts play a key role in obtaining compliance of beach recreationists with plover protection measures that, in turn, affect the birds' recovery. Central messages to the beach-going public include: (1) respect areas fenced or posted for protection of plovers and other rare beach species; (2) do not approach or linger near western snowy plovers or their nests; (3) if pets are permitted on beaches used by plovers, keep the pets leashed; (4) don't leave or bury trash or food scraps on beaches, as garbage attracts predators that may prey upon plover eggs or chicks; and (5) do not build wood structures that can be used as predator perches.

Because of the importance of information and education for the western snowy plover recovery effort, as part of this recovery plan, we developed an Information and Education Plan for the Western Snowy Plover, Pacific coast population (Appendix K).

5.2 **Inform Federal, State, and local resource/regulatory agencies and local planning departments of threats to breeding and wintering western snowy plovers and their habitats.** Periodic meetings and/or workshops should be held to inform Federal, State, and local resource management and regulatory agencies, and city and county planning departments about threats, research, and management needs for plovers. A network of public agency staff from each of the six recovery unit working groups should develop a coordinated approach to present this information to these agencies periodically, or as needed.

5.3 **Develop and maintain updated information and education materials on western snowy plovers.** Members of the six recovery unit working groups should develop new western snowy plover information and education materials for target audiences to stimulate public interest and awareness. In addition, all materials should be kept reasonably current regarding the status of the species and protection efforts. These materials should also explain the need for conservation of the beach and dune ecosystem and the plight of other rare beach-dwelling species. Videos detailing needed western snowy plover recovery actions by location and recovery unit should be developed, and might be efficiently produced in conjunction with updated public service advertisements.

5.4 **Alert landowners and beach-goers about access restrictions within western snowy plover habitats.** Land managers should begin providing informational and educational outreach at least 2 weeks prior to the onset of the nesting season to provide beach-goers and interested landowners with advance notice of impending restrictions on publicly-owned western snowy plover breeding habitats. This outreach is particularly important for the first year of restrictions. If necessary, follow-up publicity that includes information on citations issued to violators should be implemented to help reinforce the message.

5.5 **Provide trained personnel to facilitate protective measures, provide public education, and respond to emergency situations.** Biologists, docents, volunteers, and other personnel should be trained to patrol western snowy plover nesting areas to monitor birds, distribute educational materials, respond to emergency situations, and ensure that beach-goers stay out of fenced areas and adhere to other plover protection measures. Biologists engaged in monitoring, management, or research activities should also advance the public's understanding of plover management needs.

5.6 **Develop protocols for handling sick, displaced, injured, oiled, and dead birds or salvaged eggs.** Land managers within each recovery unit should develop protocols for all trained personnel identifying who should be contacted when injured, dead, oiled, or displaced birds are found, and who is permitted to handle these birds. Federal and State salvage permits are necessary for the disposal of dead birds and the transportation of injured birds. Federal and State endangered species permits are necessary for wildlife rehabilitators to accept and care for injured and sick birds. Coordination with biologists that are monitoring and banding western snowy plovers is essential for capture and release of injured/rehabilitated birds. Live chicks that are found should not be moved or taken for rehabilitation as these chicks are often not abandoned, even though plover adults may not be obvious at the time the chicks are seen. Protocols should also be developed on how to collect and preserve salvaged eggs used for contaminants analysis.

5.7 **Establish a distribution system and repository for information and education materials.** Land managers must distribute information and education materials to target audiences. To reach the large population of potential beach-goers within a few hours' drive of many major metropolitan areas, broad-scale information and education mechanisms should be implemented, including distribution by mass media such as newspapers, radio and television announcements, and internet web sites. Land managers should also focus their information and education efforts on user groups at beach parking lot entry stations and kiosks, visitor centers, marinas, beach-front housing developments, equestrian and angler access points, and locations providing off-road vehicle permits. Public outreach efforts should be directed to groups within the geographical location of the managed beaches (***e.g.***, to private and commercial equestrian users) and to groups outside of the area who use the beaches on a regular or seasonal basis (***e.g.***, to off-road vehicle associations from out-of-state or inland locations). Land managers, with the help of docents and volunteers, should coordinate with local school teachers to develop and present environmental education lesson plans and participatory activities for elementary and middle school groups.

We will act as a central repository for current and new information and education materials received; upon request, we will make these materials available to recovery unit working groups and the general public. We will also maintain information on western snowy plovers at our website (http://www.fws.gov/arcata). Major distributional efforts should also continue by Federal, State, and local agencies, and private conservation organizations.

**5.8 Establish a reporting and distribution system for annual monitoring data and management techniques.** Our Arcata Fish and Wildlife Office should coordinate and produce an annual report of submitted breeding and wintering monitoring data and distribute it to recovery unit working groups. This report should describe results of monitoring throughout the western snowy plover population's range. A distribution system should also be established for sharing information on predator management techniques, nest protection, etc. among working groups.

**6 Review progress towards recovery and revise recovery efforts as appropriate.** Communication, evaluation, and coordination play a major role in western snowy plover recovery efforts. Land managers within each of the six recovery unit working groups should review the effectiveness of their management activities in coordination with other members of their working group, and revise management measures as appropriate. They should also provide results of annual population monitoring and the effectiveness of management activities to their working group and to our Arcata Fish and Wildlife Office.

**6.1 Develop and implement a tracking process for the completion of recovery actions and the achievement of delisting criteria.** A tracking process should be developed to track the completion of recovery actions and progress toward delisting. Utilizing information from specific actions, the recovery criteria such as the implementation of management activities can be tracked. Information from the tracking process can be used in outreach and in helping identify when the western snowy plover can be delisted.

**6.2 Review progress toward recovery annually within each recovery unit working group and revise site-specific recovery efforts as appropriate to meet recovery goals.** Communication, evaluation, and coordination play a major role in western snowy plover recovery efforts. Land managers within each of the six recovery unit working groups should review the effectiveness of their management activities in coordination with other members of their working group, and revise management measures as appropriate. They should also provide results of annual population monitoring and the effectiveness of management activities to their working group and to our Arcata Fish and Wildlife Office.

Additionally, the working groups in conjunction with land managers should review success in meeting management goal breeding numbers recommended in Appendix B, and develop recommendations for any necessary revisions to those numbers based on site-specific conditions. Ongoing and needed management activities recommended in Appendix C also should be evaluated and revised according to site specific conditions. Revisions to management goals and management activities should be provided to our Arcata Fish and Wildlife Office.

**6.3 Assess the applicability, value, and success of this recovery plan to the recovery of the western snowy plover every 5 years until the recovery criteria are achieved.** Rather than revising the entire recovery plan, it is proposed that minor revisions, clarifications, and prioritization changes be made through an addendum, to be produced and distributed every 5 years. This addendum would address data gaps identified in this version of the recovery plan including recommended management prescriptions, specific habitat management recommendations, management goal breeding numbers, directed surveys; and necessary changes discussed in previous recovery actions. It would provide a summary of the recovery actions implemented to date, and it would be a forum to solicit comments from the Recovery Team, stakeholders, and others interested parties on any proposed major changes. Major changes, elimination, or addition of recovery actions may initiate a revision.

**6.4 Prepare a delisting package for the Pacific coast population of the western snowy plover.** If actions 6.1 through 6.3 indicate recovery criteria have been met, actions to ameliorate or eliminate threats have been implemented and determined to be effective, and analyses of threats demonstrate that threats identified during and since the listing process have been ameliorated or eliminated, prepare a delisting package.

**6.5 Prepare and implement a post-delisting monitoring plan.** If delisting is warranted, prepare a post-delisting monitoring plan. Section 4 of the Endangered Species Act requires, in cooperation with the States, monitoring for a minimum of five years all species that have been recovered (*i.e.*, delisted).

**7 Dedicate sufficient U.S. Fish and Wildlife Service staff for coordination of western snowy plover recovery implementation.** Our Arcata Fish and Wildlife Office holds lead responsibility for coordinating implementation of western snowy plover recovery. We should assure that the Arcata Fish and Wildlife Office has sufficient staff to handle the primary responsibility of implementing the western snowy plover recovery plan. Duties should include coordination and distribution of monitoring information and educational materials; transmission of copies of annual population monitoring results to our field offices that are responsible for western snowy plover issues; compilation and distribution of annual population status updates to all working groups; coordination with our other field offices in CNO and Region 1 regarding western snowy plover conservation actions, consultations, habitat conservation plans, and permits; facilitating coordination among the working groups created for the six recovery units; and fund raising to support recovery implementation actions.

**8** Establish an international conservation program with the government of Mexico to protect western snowy plovers and their breeding and wintering locations in Mexico. Meeting the recovery goals outlined in this recovery plan is dependent only on actions recommended for implementation along the Pacific coast of the United States. However, other actions are identified for Mexico to complement conservation efforts in the United States. Efforts should be made to establish an international conservation program between the U.S. Fish and Wildlife Service and Mexico's National Institute of Ecology, Ministry of Environment, Natural Resources and Fisheries. Programs to facilitate implementation of this conservation program should include Partners in Flight, North American Waterfowl Management Plan, and the Borderlands Initiative.

**8.1** **Develop a joint effort between the United States and Mexico to protect western snowy plover populations and their habitat.** Joint efforts should be implemented to determine important habitat in Mexico and protect these breeding and wintering locations from human disturbance.

**8.2** **Encourage research and monitoring of breeding and wintering western snowy plovers in Baja California, Mexico, by universities and authorities of Mexico.** Joint efforts should be made to develop and implement a long-term monitoring program for western snowy plover populations of Mexico. They should include developing methods for consistent monitoring, coordination of banding and color-marking with banders from the United States, assessment of the population status of breeding and wintering birds, and assessment of environmental impacts that may adversely affect plover populations.

8.3 **Encourage development and implementation of public information and conservation education in Mexico for western snowy plovers.** Public information and educational efforts should be coordinated and implemented by the United States and Mexico. They should include development of bilingual pamphlets for distribution to anglers, tourists, and local communities, and construction and placement of bilingual signs alerting them of the presence of nesting western snowy plovers.

9 **Coordinate with other survey, assessment, and recovery efforts for the western snowy plover throughout North America.** Western snowy plovers range through much of North America, and many individuals of the Pacific Coast population of western snowy plovers may overwinter in areas that overlap with other populations. Participation and coordination with other groups working on survey, assessment, and recovery efforts may yield valuable information on the distribution, status, and management needs for the Pacific Coast population of the western snowy plover. This coordination effort should be included in establishment of an international conservation program with Mexico.

# IV. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions needed, responsible parties, and estimated costs to recover the United States portion of the Pacific coast population of the western snowy plover. Considering the recovery criteria, results of the population viability analysis (Appendix D), and fulfillment of the recommendations contained in the recovery plan, recovery of the western snowy plover could occur in approximately 40 years. This time estimate assumes dedicated, proactive efforts toward improvements in western snowy plover management in the near-term, and subsequent management at a maintenance level commensurate with fulfillment of the recovery criteria.

The total cost of implementing actions outlined in this recovery plan over 40 years is $149,946,000. However, this figure represents only a portion of the overall costs because the cost of many actions cannot be estimated at this time. For example, costs associated with intensive protection and management on Federal and State lands (Action 3.3) should be determined by members of each of the six recovery unit working groups because they are most familiar with their site-specific needs and constraints. Costs of many actions were estimated based on current management recommendations provided in Appendix C. However, coastal ecosystems are dynamic and necessary management actions may vary with time, as site conditions change. Improvements over time in methods for predator control, control of nonnative vegetation, and monitoring are also expected and may affect actual costs.

It should be recognized that expenditure of funds for recovery of the western snowy plover will provide far-reaching benefits beyond those gained for a single species. Allocation of these funds will also benefit many other sensitive fish and wildlife species, the coastal beach-dune ecosystem, public appreciation for natural habitats, and aesthetics. These estimated costs do not reflect a cost/benefit analysis that incorporates other values or economic effects with implementation of the recommendations contained in this recovery plan.

We believe that protection and management costs could be substantially reduced by selecting protection strategies that are more restrictive of other beach uses.

While we believe that it is neither feasible nor desirable to completely eliminate beach recreation in most western snowy plover habitat, we also recognize that management strategies that protect western snowy plovers on beaches where public use is also maintained require a continuing commitment of person-power, and are inherently expensive.

The Implementation Schedule lists and ranks actions that should be undertaken within the next 5 years.  This schedule will be reviewed routinely until the recovery objective is met, and priorities and actions will be subject to revision.

## Key to Acronyms used in the Implementation Schedule

Definition of action priorities:

**Priority 1** - An action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future.

**Priority 2** - An action that must be taken to prevent a significant decline in species population or habitat quality, or some other significant negative impact short of extinction.

**Priority 3** - All other actions necessary to provide for full recovery of the species.

Definition of action durations and costs:

**Annual** - An action that will be implemented each year.

**Continual** - An action that will be implemented on a routine basis once begun.

**Ongoing** - An action that is currently being implemented and will continue until action is no longer necessary.

**As needed** - An action that will be implemented on an "as needed" basis.

**Unknown** - Either action duration or associated costs are not known at this time.

**To Be Determined (TBD)** - Costs to be determined at a later date.

**Responsible parties*:**

| | |
|---|---|
| ARMY | U.S. Army |
| BLM | U.S. Bureau of Land Management |
| CCC | California State Coastal Commission |
| CDFG | California Department of Fish and Game |
| CDPR | California Department of Parks and Recreation |
| CE | U.S. Army Corps of Engineers |
| CI | Cities |
| CO | Counties |
| CON | California Coastal Conservancy |
| EBRPD | East Bay Regional Park District |
| ES | U.S. Fish and Wildlife Service, Division of Ecological Services (includes Endangered Species and Contaminants) |
| FAA | U.S. Department of Transportation, Federal Aviation Administration |
| HARD | Hayward Area Recreation and Park District |
| IA | U.S. Fish and Wildlife Service, Office of International Affairs |
| LE | U.S. Fish and Wildlife Service, Division of Law Enforcement |
| LMAO | Land Management Agencies and Organizations and other Cooperators. (This category includes Federal and local land management agencies listed above, private organizations and individuals that own and manage snowy plover breeding and wintering habitat, and private conservation groups that provide on-site protection of lands owned by others.) |
| MPOSD | Mid-Peninsula Open Space District |
| MPRPD | Monterey Peninsula Regional Park District |
| NASA | National Aeronautics and Space Administration-Ames Research Center |
| NAVY | U.S. Navy |
| NMFS | National Marine Fisheries Service |
| NPS | National Park Service |
| ODFW | Oregon Department of Fish and Wildlife |
| ODLCD | Oregon Department of Land Conservation and Development |
| OPRD | Oregon Parks and Recreation Department |

| | |
|---|---|
| P | Private landowners (except HARD, MPOSD, and TNC) |
| PA | U.S. Fish and Wildlife Service, Public Affairs |
| PGH | Port of Grays Harbor |
| PO | Port of Oakland |
| PRBO | Point Reyes Bird Observatory Conservation Science |
| PSL | Port of San Luis Harbor District |
| RSCH | Research institutions and agencies |
| RW | U.S. Fish and Wildlife Service, Division of Refuges and Wildlife (includes Realty) |
| SDRPJPA | San Dieguito River Park Joint Powers Authority |
| TNC | The Nature Conservancy |
| TPL | Trust for Public Land |
| USAF | U.S. Air Force |
| USCG | U.S. Coast Guard |
| USFS | U.S. Forest Service |
| USFWS | U.S. Fish and Wildlife Service |
| BBL | U.S. Geological Survey, Bird Banding Laboratory |
| BRD | U.S. Geological Survey, Biological Resources Division |
| USMC | U.S. Marine Corps |
| WDFW | Washington Department of Fish and Wildlife |
| WDNR | Washington Department of Natural Resources |
| WS | U.S. Department of Agriculture, Wildlife Services Branch |
| WSPRC | Washington State Parks and Recreation Commission |

* All responsible parties listed for actions in Implementation Schedule are considered lead agencies for those actions.

## IMPLEMENTATION SCHEDULE

Western Snowy Plover Pacific Coast Population Recovery Plan

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 1 | Annually monitor abundance, population size and distribution at breeding and wintering locations. | 1.1 | annual | LMAO, CO, CI, RSCH | 2,194 | 54.9 | 54.9 | 54.9 | 54.9 | 54.9 | Assumes 157 window survey days, with 2 biologists per location at. Action needed to determine fulfillment of recovery criteria. |
| 1 | Develop and implement a program to monitor productivity and annual survival. | 1.2 | annual | LMAO, CO, CI. RSCH | TBD | | | | | | Action needed to determine fulfillment of recovery criteria. Depends partly on completion of 4.3.2 and 4.3.3. |
| 1 | Develop and implement a program to monitor habitat condition and threats at all breeding and wintering sites. | 1.3 | annual | LMAO, RSCH | 1,125 | 60 | 27 | 27 | 27 | 27 | Assumes initial cost for development of standardized monitoring program and subsequent monitoring for 155 sites. |
| 3 | Develop and implement training and certification programs for western snowy plover survey coordinators and observers. | 1.4 | continual | ES, LMAO, RSCH | 363.5 | 32 | 8.5 | 8.5 | 8.5 | 8.5 | Assumes initial cost to develop program and subsequent implementation. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Improve submittal system for monitoring data to ensure consistent reporting. | 1.5 | continual | ES, LMAO, BBL, PRBO | 346 | 32 | 8 | 8 | 8 | 8 | Assumes initial cost to develop submittal and reporting system and subsequent annual review. |
| 3 | Assess and evaluate new breeding wintering and migration areas for threats and management needs and update lists as data become available. | 1.6 | continual | ES, LMAO, PRBO | TBD | | | | | | Depends on results of annual surveys and monitoring. |
| 3 | Coordinate monitoring of snowy plovers and California least terns to minimize disturbances. | 1.7 | annual | ES, RW, NAVY, USMC, USAF, CDFG, CDPR, WS, BRD | 1,020 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | Coordinate at biannual pre- and post-season Califomia least tern monitoring meeting. Assumes 2 meetings at 2 days per meeting with 9 agency staff attending. |
| 3 | Develop a post-delisting monitoring plan. | 1.8 | TBD | ES, LMAO, CO, CI, RSCH | TBD | | | | | | |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 1 | Develop a prioritized list of wintering and breeding sites where natural coastal processes need protection and/or enhancement. | 2.1.1 | 2 yrs | ES, LMAO, CO, CI, RSCH | 59.65 | 59.65 | | | | | Assumes time to evaluate sites and development of the prioritized list. |
| 1 | Identify and implement mechanisms to protect, enhance or restore natural coastal processes. | 2.1.2 | continual | ES, LMAO, CO, CI, RSCH | TBD | | | | | | Incorporate into ongoing management in action 3. Costs will depend on mechanisms identified and carried out. |
| 1 | Develop and implement prioritized removal and control for introduced beachgrass and other non-native vegetation. | 2.2.1.1 | continual | CE, LMAO, CO, CI | TBD | | | | | | App C identifies 86 sites. Costs range for mechanical, manual and/or chemical control: $1,000 to $87,000/hectare ($400 to $35,000 per acre). |
| 2 | Replace exotic dune plants with native dune vegetation where it is likely to improve habitat. | 2.2.1.2 | continual | CE, LMAO, CO, CI | TBD | | | | | | Estimated cost of planting native vegetation: $30,000 per hectare ($12,000 per acre). Number of sites to be determined. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Evaluate breeding and wintering sites to determine whether dredged materials may be used to enhance or create nesting habitat. | 2.2.2.1 | 2 yrs | CE, ES, LMAO, CO, CI | 110 | 55 | 55 | | | | Assumes cost to evaluate each site. |
| 3 | Develop and implement plans to use dredged materials may be used to enhance or create nesting habitat. | 2.2.2.2 | ongoing | CE, ES, LMAO, CO, CI | TBD | | | | | | Costs will depend on completion of acts on 2.2.2.1. |
| 3 | Identify sites where beach nourishment may be effective in creating and enhancing habitat. | 2.2.3.1 | 2yrs | CE, ES, LMAO, CO, CI | 110 | 55 | 55 | | | | Assumes cost to evaluate each site. |
| 3 | Develop and implement beach nourishment plans for site identified in action 2.2.3.1. | 2.2.3.2 | ongoing | CE, ES, LMAO, CO, CI | TBD | | | | | | Cost dependent on number of sites identified in 2.2.3.1 and outcome of 4.1.1. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 1 | Create, manage, and enhance coastal ponds and playas for breeding habitat. | 2.2.4 | ongoing | ES, RW, CE, CDFG, NASA, HARD, LMAO | TBD | | | | | | App C identifies 15 sites. Costs dependent on type and area of restoration. |
| 1 | Seasonally close areas used by breeding snowy plovers. | 2.3.1.1.1 | annual | LMAO, CO, CON, CI | 559.2 | 13.98 | 13.98 | 13.98 | 13.98 | 13.98 | App C identifies 81 sites. Assumes cost to close these sites. |
| 1 | Fence areas used by breeding snowy plovers | 2.3.1.1.2 | annual | LMAO, CO, CON, CI | 14,840 | 371 | 371 | 371 | 371 | 371 | App C identifies 64 sites. Cost assumes 1 kilometer fencing required per site at a cost of $5,900 per kilometer. |
| 1 | Post signs in areas used by breeding snowy plovers | 2.3.1.1.3 | annual | LMAO, CO, CON, CI | 202 | 5 | 5 | 5 | 5 | 5 | App C identifies 65 sites. Cost dependent on number of signs needed at each site, but assumes cost for installation and a minimum of 4 signs at $20 per sign. |
| 1 | Evaluate effects of existing and planned access at all breeding and wintering locations and any new locations identified. | 2.3.1.2.1 | 1 year | LMAO, CO, CI | 455 | 455 | | | | | Appendix C identifies 81 sites. Assumes cost to conduct use survey for the identified sites. |
| 1 | Develop and implement plans to minimize adverse access effects. | 2.3.1.2.2 | continual | LMAO, CO, CI | TBD | | | | | | Costs depend on outcome of 2.3.1.2.1. |

| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | Cost Estimate (in $1,000 units) FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Implement and enforce pet restrictions. | 2.3.2 | continual | LMAO, CO, CI | 39,406 | 985 | 985 | 985 | 985 | 985 | Appendix C identifies 120 sites Assumes staff time to implement and enforce restrictions at the identified sites. |
| 1 | Annually review recreational activities and develop and implement plans to prevent disturbance from disruptive recreational activities at breeding and wintering sites | 2.3.3 | annual | LMAO, CO, CI | 21,948 | 549 | 549 | 549 | 549 | 549 | Assumes staff cost to develop and implement plans at each site annually. |
| 3 | Prevent driftwood removal through posting of signs | 2.3.4 | continual | LMAO, CO, CI | 1,805 | 50 | 45 | 45 | 45 | 45 | Appendix C identifies 26 sites. Cost dependent on number of signs needed at each site, but assumes cost for installation and a minimum of 4 signs at $20 per sign. |
| 1 | Prevent disturbance, mortality, and habitat degradation by prohibiting or restricting off-road vehicles and beach-raking machines. | 2.3.5 | continual | LMAO, CO, CI | 18,760 | 469 | 469 | 469 | 469 | 469 | Appendix C identifies 101 sites. Assumes staff time for monitoring on weekends. |
| 3 | Implement restrictions on horseback riding through annual coordination. | 2.3.6 | annual | LMAO, CO, CI | 1,033.7 | 25.8 | 25.8 | 25.8 | 25.8 | 25.8 | Appendix C identifies 72 sites. Assumes staff time to implement restrictions. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Implement and enforce restrictions on livestock through annual coordination. | 2.3.7 | annual | LMAO, CO, CI | 255 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | Appendix C identifies 18 sites. Assumes staff time to implement restrictions. |
| 1 | Determine enforcement needs and provide sufficient wardens, agents or officers to enforce protective measures in breeding and wintering habitat. | 2.3.8.1 | continual | LE, LMAO, CO, CI | TBD | | | | | | Cost will depend on identified enforcement needs. |
| 3 | Develop and implement training programs for enforcement personnel to improve enforcement of regulations and minimize effects of enforcement. | 2.3.8.2 | continual | LE, LMAO, CO, CI | 320 | 8 | 8 | 8 | 8 | 8 | Annual training cost estimate $8,000 per year. |
| 2 | Develop and implement a program to annually coordinate with local airports, aircraft operations regarding minimum altitude requirementss. | 2.3.9 | annual | LMAO, CO, CI, FAA, LE | 339.8 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | Assumes staff costs per recovery unit to compile list and notify aircraft operations and facilities. |
| 3 | Implement and enforce anti-littering regulations. | 2.4.1.1 | annual | LMAO, CO, CI | TBD | | | | | | Incorporate into ongoing management and Action 3. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Evaluate the effects of current litter and garbage management on predation at breeding and wintering sites. | 2.4.1.2 | 2 yrs | LMAO, CO, CI | 110 | 55 | 55 | | | | Assumes evaluation time per site. |
| 3 | Develop and implement garbage and litter management plans where litter and garbage contribute to predation. | 2.4.1.3 | continual | LMAO, CO, CI | TBD | | | | | | Costs will depend on 2.4.1.2 and plans developed. |
| 3 | Annually identify and remove predator perches and unnatural habitats attractive to predators. | 2.4.2 | continual | LMAO, CO, CI | 375.2 | 9.4 | 9.4 | 9.4 | 9.4 | 9.4 | Assumes staff time to complete action each year. |
| 1 | Erect predator exclosures to reduce egg predation and improve productivity. | 2.4.3 | annual | LMAO, CO, CI | 18,266 | 456 | 456 | 456 | 456 | 456 | App C identifies 53 sites. Assumes cost per unit installation. |
| 1 | Evaluate the need for predator removal and implement where warranted and feasible. | 2.4.4 | as needed | LMAO, CO, CI, WS, CDFG | TBD | | | | | | App C identifies 61 sites for additional predator control. Costs dependent on assessment of needs and feasability. |
| 3 | Remove bird and mammal carcasses in nesting areas. | 2.4.5 | as needed | LMAO, CO, CI | TBD | | | | | | |

| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | Cost Estimate (in $1,000 units) FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | U.S. Fish and Wildlife Service biologists should participate in Area Committees responsible for maintaining the Area Contingency Plans for the Pacific Coast to facilitate the updating of spill response plans to include protection of western snowy plovers. | 2.5.1 | annual | ES | 5,154 | 128.9 | 128.9 | 128.9 | 128.9 | 128.9 | Assumes staff time from the six ES office responsible for coastlines of CA, OR, and WA. |
| 1 | Assign monitors to beaches that are inhabited by western snowy plovers to protect western snowy plovers from injury during spill responses. | 2.5.2 | as needed | ES, USCG, LMAO, CO, CI | 1,984 | 49.6 | 49.6 | 49.6 | 49.6 | 49.6 | Assumes cost of two weeks of monitoring for five incidents per year. |
| 2 | Compensate the loss of plover breeding and wintering habitat associated with recovery efforts for other sensitive species. | 2.6 | ongoing | ES, RW, CE, LMAO | TBD | | | | | | Costs dependent on effectiveness of minimizing habitat loss. |
| 3 | Investigate feasibility and methods for discouraging pinniped use of nesting areas. | 2.7.1 | 5 yrs | ES, NMFS, NAVY, LMAO | 320 | 64 | 64 | 64 | 64 | 64 | Assumes staff time to investigate. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Identify areas where pinniped use is negatively affecting nesting and implement any appropriate methods. | 2.7.2 | TBD | ES, NMFS, NAVY, LMAO | TBD | | | | | | Costs dependent on number of sites identified and methods determined in 2.7.1. |
| 1 | Establish and maintain snowy plover working groups for each of the six recovery units. | 3.1 | continual | ES, LMAO, CO, C I, P | 3,650 | 96 | 96 | 91 | 91 | 91 | Essential mechanism to advance plover recovery. Includes biannual meeting costs and staff costs to establish new working groups. |
| 2 | Develop and implement regional participation plans for each of the six recovery units. | 3.2 | 1 yr for develop-ment, continual thereafter | ES, LMAO | 193 | | 193 | | | | Assumes staff cost to develop and implement participation plans. |
| 3 | Develop and implement management plans for Federal lands. | 3.3.1 | ongoing | RW, ARMY, BLM, CE, NASA, NAVY, NPS, USAF, USMC, USFS | TBD | | | | | | Implementation cost dependent on content of plans developed. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Develop and implement management plans and Habitat Conservation Plans on State wildlife areas, State ecological reserves, and State beaches. | 3.3.2 | 5 years | CDFG, CDPR, ODFW, OPRD, WDFW, WDNR, WSPRC | 966 | 193 | 193 | 193 | 193 | 193 | Assumes cost for each recovery unit to assist in development. Implementation cost to be determined. |
| 3 | Develop and implement Habitat Conservation Plans or other management plans for sites owned by local governments or private landowners. | 3.4 | 5 years | ES, LMAO, CO, CI, P, EBRPD, HARD, MPOSD, MPRPD, PGH, PO, SL, TNC, SDRPJPA | 966 | 193 | 193 | 193 | 193 | 193 | Assumes cost for each recovery unit to assist in development. Implementation cost to be determined. |
| 2 | Provide technical assistance to local governments in developing and implementing local land use protection measures through periodic workshops. | 3.5 | 10 years | ES, CCC, CDFG, CDPR, CON, ODFW, ODLCD, OPRD, WDNR, WDFW, WSPRC, CO, CI | TBD | | | | | | Estimated at 2 workshops per recovery unit at a cost of $ <br><br>(Patty Carol in RO) |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Develop and implement cooperative programs and partnerships with the California State Coastal Commission, the Oregon Department of Land Conservation and Development, the Washington State Parks and Recreation Commission, the Oregon Parks and Recreation Department, the California Department of Parks and Recreation, and the Oregon Department of Fish and Wildlife. | 3.6 | continual | ES, CCC, ODLCD, ODFW, OPRD, CDPR, WSPRC | TBD | | | | | | Costs may vary from year to year based on identified program needs. |
| 3 | Obtain long-term agreements with private landowners. | 3.7 | 12 years | ES, CDFG, P CDPR, ODFW, WDFW, WSPRC, LMAO | 2,319 | 193 | 193 | 193 | 193 | 193 | Assumes staff time to facilitate 6 agreements per year per recovery unit. Appendix C identifies 72 sites. |
| 3 | Identify and protect habitat available for acquisition. | 3.8 | ongoing | CON, ES, RW, LMAO | TBD | | | | | | |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Ensure that any section 10(a)(1)(B) and section 7(a)(2) permits contribute to Pacific coast western snowy plover conservation. | 3.9 | ongoing | ES, Federal agencies | 1,288 | 32`32 | 32 | 32 | 32 | 32 | Assumes staff time for annual evaluation. |
| 3 | Ensure that section 7 consultations contribute to Pacific coast western snowy plover conservation. | 3.10 | ongoing | ES, Federal agencies | 1,288 | 32`32 | 32 | 32 | 32 | 32 | Assumes staff time for annual evaluation. |
| 2 | Evaluate effectiveness of habitat restoration by removal of introduced beachgrass and identify additional studies necessary. | 4.1.1 | continual | CON, ES, LMAO, RSCH | TBD | | | | | | Depends on the number and location of sites as well as the temporal duration of the restoration project. |
| 3 | Evaluate the impacts and potential benefits of past and ongoing beach nourishment activities and identify and carry out any additional studies necessary. | 4.1.2 | ongoing | ES, LMAO, RSCH, CE, CI, CO | TBD | | | | | | |
| 2 | Develop higher-efficiency nest enclosures. | 4.2.1 | ongoing | ES, LMAO, RSCH | 20 | 10 | 5 | 3 | 2 | 0 | Compare new exclosures with current ones to determine effects on snowy plovers. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 2 | Develop California least tern enclosures that prevent harm to snowy plovers. | 4.2.2 | as needed | ES, USMC, CDFG, CDPR, LMAO, RSCH | TBD | | | | | | Costs specific to sites with California least tern enclosures. Estimated cost for materials (fencing/posts): $7 per linear foot ($23 per meter). |
| 3 | Identify, prioritize and carry out investigations on control of predators. | 4.2.3 | as needed | ES, RW, LMAO, WS, CDFG, RSCH, CO, CI, P | TBD | | | | | | Cost dependent on number and types of studies identified. |
| 3 | Investigate predator management at the landscape level. | 4.2.4 | as needed | ES, RW, LMAO, WS, RSCH, CO, CI, P | TBD | | | | | | Costs dependent on number and types of studies identified. |
| 3 | Investigate techniques for identifying nest predators. | 4.2.5 | continual | LMAO, RSCH | TBD | | | | | | |
| 2 | Improve methods of monitoring population size. | 4.3.1 | ongoing | ES, LMAO, RSCH | TBD | | | | | | Dependent on costs of intensive monitoring of some sites. |
| 2 | Develop sampling methods for annually estimating reproductive success. | 4.3.2 | 2 years | ES, RSCH | 64 | 64 | | | | | Assumes time to compile and review data and develop methodology. |
| 3 | Develop methods to monitor plover survival rates. | 4.3.3 | ongoing | ES, LMAO, RSCH | TBD | | | | | | |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Identify brood habitat and map brood home ranges. | 4.4.1 | ongoing continual | ES, LMAO, RSCH, CO, CI, P | TBD | | | | | | Costs dependent on study design. May include radio telemetry. |
| 3 | Identify components of high-quality brood rearing habitat | 4.4.2 | 1 year | ES, LMAO, RSCH, CO, CI, P | 131 | 131 | | | | | Assumes study at 6 geographically representative sites for duration of breeding season. |
| 3 | Quantify wintering habitat needs along the Pacific coast. | 4.4.3 | 5 years | ES, RSCH, BRD, PRBO | 75 | 75 | | | | | Assumes study at 6 geographically representative sites during winter months. |
| 3 | Identify important migration stop-over habitat. | 4.4.4 | ongoing | ES, LMAO | TBD | | | | | | |
| 3 | Develop and implement a research program to determine causes of adult mortality. | 4.5 | ongoing | LMAO, RSCH | TBD | | | | | | Costs dependent on study design. |
| 3 | Compile information regarding number and types of banding injuries to plovers. | 4.6.1 | 1 year | ES, RSCH, PRBO, BRD, BBL | 32 | 32 | | | | | Assumes staff time to develop, distribute and compile information requests. |
| 3 | Review compiled information (see 4.6.1) and determine and implement an appropriate course of action. | 4.6.2 | 1 year | ES, RSCH, PRBO, BRD, BBL | 32 | | | | | | Assumes staff time to review compiled information, distribution and coordination with other responsible parties. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Identify effects of oil spills on snowy plovers. | 4.7 | as needed | ES, RSCH, BRD, LMAO | TBD | | | | | | Typical range of cost for study is estimated between $25,000 - $100,000. |
| 3 | Monitor levels of environmental contaminants in snowy plovers. | 4.8 | as needed | ES, RSCH, BRD, LMAO | TBD | | | | | | Depends on number and type of samples. Cost estimate $700 per sample, but may vary depending on type of contaminant. |
| 3 | Design and conduct contaminants studies if monitoring of contaminants in action 4.8 indicates potential contaminants effects. | 4.9 | as needed | LMAO, ES, RSCH, BRD | TBD | | | | | | Depends on number of sites and samples analyzed. Cost estimates for studies range from $25,000 to $50,000 per site. |
| 3 | Identify, prioritize and carry out studies on the effects of human recreation on western snowy plovers. | 4.10 | ongoing | LMAO, ES, RSCH, PRBO, BRD | TBD | | | | | | Costs dependent on research needs identified. |
| 3 | Revise the population viability analysis when sufficient additional information is available | 4.11 | 1 year | ES, RSCH, PRBO, BRD | 25 | | | | | | Assumes cost to conduct modeling. |
| 2 | Develop and implement public information and education programs. | 5.1 | ongoing | ES, PA, LMAO | TBD | TBD | TBD | TBD | TBD | TBD | Depends on individual recovery unit strategies. See Appendix K (Information & Education Plan) for estimates of component expenses. |

| | | | | | Cost Estimate (in $1,000 units) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Inform Federal, State and local planning agencies and local planning departments of threats to breeding and wintering snowy plovers and their habitats. | 5.2 | continual | ES, LMAO, CCC, CDFG, CDPR, ODFW, ODLCD, OPRD, WDFW, WDNR, WSPRC, CO/CI | TBD | | | | | | |
| 3 | Develop and maintain updated information and education materials on snowy plovers. | 5.3 | ongoing | ES, PA, LMAO, CO, CI | TBD | | | | | | Incorporate into ongoing management and Action 3.1 through 3.10. See Appendix K |
| 3 | Alert landowners and beach-goers about access restrictions within snowy plover habitats. | 5.4 | ongoing | ES, PA, LMAO, CO, CI | TBD | | | | | | Incorporate into ongoing management and Action 3.1 through 3.10. See Appendix K |
| 3 | Provide trained personnel to facilitate protective measures, provide public education, and respond to emergency situations. | 5.5 | continual | LMAO, CO, CI | TBD | | | | | | Need to secure funds for volunteer coordinator and staff to train volunteers. Incorporate into Action 3.1 through 3.10. See Appendix K. |
| 3 | Develop protocols for handling sick, displaced, injured, oiled, and dead birds or salvaged eggs. | 5.6 | 1 with periodic review | LMAO, CO, CI | 32.2 | 32.2 | | | | | Assumes staff time to develop protocol. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Establish a distribution system and repository for information and education materials. | 5.7 | continual | ES, LMAO, CO, CI | TBD | | | | | | Incorporate into ongoing management and Action 3.1 through 3.10 and 7. See Appendix K. |
| 3 | Establish a reporting and distribution system for annual monitoring data. | 5.8 | annual | ES | 644 | 16 | 16 | 16 | 16 | 16 | Assumes time spent collecting and compiling data. |
| 2 | Develop and implement a tracking process for the completion of recovery actions and the achievement of delisting criteria. | 6.1 | continual | ES, RW, ARMY, BLM, CE, NASA, NAVY, NPS, USAF, USFS, USMC, CDFG, CDPR, ODFW, OPRD, WDFW, WDNR, WSPRC, LMAO | 688 | 64 | 16 | 16 | 16 | 16 | Assumes staff time to develop and implement tracking process. |
| 3 | Review progress toward recovery annually. | 6.2 | annual | ES, LMAO | 566 | 14 | 14 | 14 | 14 | 14 | Assumes staff time to compile and review data. |
| 3 | Assess the applicability, value and success of this plan to the recovery of the western snowy plover every 5 years. | 6.3 | every 5 years | | 258 | | | | | 32.2 | Assumes staff time to review every 5 years. |
| 3 | Prepare a delisting package for the Pacific coast population of the western snowy plover. | 6.4 | 6 months | ES | 64 | 64 | | | | | Assumes staff time to prepare delisting package. |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Prepare and implement a post-delisting monitoring plan. | 6.5 | 6 months | ES | 64 | 64 | | | | | Assumes staff time to prepare and implement post-delisting monitoring plan. |
| 1 | Dedicate sufficient U.S. Fish and Wildlife Service staff for coordination of western snowy plover recovery implementation. | 7 | continual | ES | 5,152 | 128.8 | 128.8 | 128.8 | 128.8 | 128.8 | Assumes staff time to coordinate recovery implementation |
| 3 | Develop a joint United States and Mexico effort to protect snowy plover populations and their habitat. | 8.1 | continual | ES, IA | TBD | | | | | | |
| 3 | Encourage research and monitoring of breeding and wintering snowy plovers in Baja California, Mexico by universities and authorities of Mexico. | 8.2 | continual | ES, IA, RSCH, BRD | TBD | | | | | | |
| 3 | Encourage development and implementation of public information and conservation education in Mexico. | 8.3 | continual | ES, IA, PA | TBD | | | | | | |

| | | | | | | Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Priority No. | Action Description | Action Number | Action Duration | Responsible Parties | Total Costs | FY1 | FY2 | FY3 | FY4 | FY5 | Comments/Notes |
| 3 | Coordinate with other survey, assessment, and recovery efforts for the western snowy plover throughout North America. | 9 | continual | ES, IA, RSCH, BRD | TBD | | | | | | |

Total Cost of Recovery through 2046: $149,946,000 plus additional costs that cannot be estimated at this time.

# V. REFERENCES

## A. Literature Cited


Albers, P.H. 1977. Effects of external applications of fuel oil on hatchability of mallard eggs. Pages 158-163 ***in*** D. A. Wolfe, editor. Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems. Pergamon Press, New York, N.Y.

Albers, P.H. and R.C. Szaro. 1978. Effects of No. 2 fuel oil on common eider eggs. Marine Pollution Bulletin 9:138-139.

Ainley, D.G., C.R. Grau, T.E. Roudybush, S.H. Morrell and J.M. Utts. 1981. Petroleum ingestion reduces reproduction in Cassin's auklets. Marine Pollution Bulletin 12:314-317.

American Ornithologists' Union. 1957. The A.O.U. checklist of North American birds. Fifth edition. 168 pp.

Anthony, J.L. 1985. A report on the distribution, numbers and human disturbance of snowy plovers at Damon Point, Washington. Report to the Washington Dept. of Game. Evergreen State College, WA. 24 pp.

Anthony, J.L. 1987. The snowy plover and biopolitics at Damon Point, Washington. M.E.S. Thesis, The Evergreen State College, Olympia, WA. 106 pp.

Applegate, T.E. 1998. Vandenberg Air Force Base snowy plover monitoring, Torch/Platform Irene Pipeline Oil Spill. Pp C1-C5 In: Preliminary Bird Injury Assessment for the Torch/Platform Irene Pipeline Oil Spill, R.G. Ford, editor. Unpublished report to California Department of Fish and Game, Office of Spill Prevention and Response.

Avery, M.L., M. A. Pavelka, D. L. Bergman, D. G. Decker, C. E. Knittle, and G. M. Linz. 1995. Aversive conditioning to reduce raven predation on California least tern eggs. Colonial Waterbirds 18(2):131-138.

Barbour, M.G. and J. Major. 1990. Terrestrial vegetation of California. California Native Plant Society. Special Publication Number 9, University of Davis, CA. 1028 pp.

Binford, L.C. 1989. A distributional survey of the birds of the Mexican State of Oaxaca. Ornithological Monographs 43. 418 pp.

Blus, L.J. 1982. Further interpretation of the relation of organochlorine residues in brown pelican eggs to reproductive success. Environmental Pollution (Series A) 28:15-33.

Brennan, K. 2003. Snowy plovers at Leadbetter Point, Washington, 2002 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge. 14 pp.

Brennan, K. and M. Fernandez. 2004*a*. Snowy Plovers at Leadbetter Point, Washington, 2003 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge. 16 pp.

Brennan, K and M. Fernandez. 2004*b*. Snowy Plovers at Leadbetter Point, Washington, 2004 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge.

Brennan, K., and M. Fernandez. 2006. Snowy plovers at Leadbetter Point, Washington, 2005 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge. 14 pp.

Brennan, K. and D. Jaques. 2002. Snowy Plovers at Leadbetter Point, Washington, 2001 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge.

Brittell, J.D., J.M. Brown, and R.L. Eaton. 1976. Marine shoreline fauna of Washington, Vol. II. Washington Dept. of Game and Ecology, Olympia. 341 pp.

Buick, A.M. and D.C. Paton. 1989. Impact of off-road vehicles on the nesting success of hooded plovers (*Charadrius rubricollis*) in the Coorong region of South Australia. Emu 89:159-172.

Burger, J. 1986. The effect of human activity on shorebirds in two coastal bays in the northeastern United States. Environmental Conservation 13:123-130.

Burger, J. 1993. Shorebird squeeze. Natural History 102(5):8-14.

Burger, J. 1997. Effects of oiling on feeding behavior of sanderlings and semipalmated plovers in New Jersey. Condor 99:290-298.

Burger, A.E. and D.M. Fry. 1993. Effects of oil pollution on seabirds in the northeast Pacific. Pages 254-263 ***in*** K. Vermeer, K.T. Briggs, K.H. Morgan, and D. Siegel-Causey, eds. The status, ecology, and conservation of marine birds of the North Pacific. Canadian Wildlife Service Special Publication, Ottawa.

Caffrey, C. 1993. California least tern breeding survey, 1992 season. California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section Report 93-11, Sacramento, California. Unpublished final report.

Cairns, W.E. and I.A. MacLaren. 1980. Status of the piping plover on the east coast of North America. American Birds 34(2):206-208.

California Coastal Commission. 1995. Regional cumulative assessment project. ReCAP pilot project, findings and recommendations: Monterey Bay Region. 162 pp. plus appendices.

California Department of Fish and Game. Undated [1994]. Managing non-native species in Califomia: The red fox. The Resources Agency, California Department of Fish and Game, Sacramento, CA. 8 pp.

California Department of Parks and Recreation, Off-Road Vehicle Division. 2005. Nesting season management plan for 2005. San Luis Obispo County, California.

California Native Plant Society. 1996. Policy on invasive exotic plants. http://www.cnps.org/cnps/archive/exotics.php

California Natural Diversity Database. 2001. Special Animals. California Department of Fish and Game, Wildlife and Habitat Data Analysis Branch. January 2001. 52 pp.

Cape Mohican Trustee Council. 2002. SS Cape Mohican Oil Spill Restoration Plan and Environmental Assessment. Unpublished report, National Park Service, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, California Dept. of Fish and Game, California Dept. of Parks and Recreation. 99 pp.

Carter, R.W.G. 1988. Coastal environments, an introduction to the physical, ecological and cultural systems of coastlines. 617 pp.

Carter, H.R. and R.T. Golightly, editors. 2003. Seabird injury from the 1997-98 Point Reyes Tarball Spill Incidents. Unpublished draft report, Humboldt State University, Dept. of Wildlife, Arcata, California.

Casler, B.R., C.E. Hallett, M.A. Stern, and G.A. Rosenberg. 1993. Unpublished report submitted to Oregon Department of Fish and Wildlife; Coos Bay District, Bureau of Land Management; and Oregon Dunes National Recreation Area, Suislaw National Forest. 26 pp.

Castelein, K.A., D.J. Lauten, S.R. Pixley, L.N. Renan, M.A. Stern, and C. Grinnell. 2002. The distribution and reproductive success of the western snowy plover along the Oregon coast- 2002. Page 54. The Oregon Natural Heritage Program, Portland.

Center for Disease Control. 2004. West Nile Virus. Retrieved from: http://www.cdc.gov/ncidod/dvbid/westnile/birdspecies.htm/ 9-20-04

Center for Marine Conservation. 1995. National Marine Debris Monitoring Program. Volunteer Handbook. 12 pp.

Chestnut, J. 1997. The distribution of rare species and the distribution and trend of invasive weeds on the Mobil Coastal preserve, Guadalupe-Nipomo Dunes, California. Unpublished document, The Nature Conservancy, San Francisco, CA. 135 pp.

Colwell, M.A., J. Hall, C.B. Millett, J.J. Meyer, R.R. LeValley, S.E. McAllister, A.N. Transou, D. LeValley. 2002. Final Report: 2002 Snowy Plover breeding in northern Califomia, with emphasis on Humboldt County. Unpublished Report, Mad River Biologists, Inc., McKinleyville, CA and Humboldt State University Wildlife Department, Arcata, CA. 14 pp.

Colwell, M.A., Z. Nelson, S. Mullin, C. Wilson, S.E. McAllister, K.G. Ross, and R.R. LeValley. 2005. Final Report: 2005 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Unpublished report, Mad River Biologists, Inc., and Humboldt State University Wildlife Department, Arcata, CA. 11 pp.

Colwell, M.A., S.M. Mullin, Z.J. Nelson, C.A. Wilson, J.M. Muir, W.P. Goldenberg, S.E. McAllister, and K.G. Ross. 2006. Final Report: 2006 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Unpublished report, Mad River Biologists, Inc., and Humboldt State University Wildlife Department, Arcata, CA.

Connors, P.G., V.C. Anderlini, R.W. Risebrough, M. Gilbertson, and H. Hays. 1975. Investigations of heavy metals in common tern populations. The Canadian Field-Naturalist 89:157-162.

Cooch, E., R. Pradel and N. Nur. 1996. A practical guide to capture/recapture analysis using SURGE. CNRS, Montpellier, France. Approx. 130 pages.

Craig, D.P., M.A. Stern, K.A. Mingo, D.M. Craig, and G.A. Rosenberg. 1992. Reproductive ecology of the western snowy plover on the south coast of Oregon. Submitted to Oregon Department of Fish and Wildlife, Roseburg, OR, and Coos Bay District, Bureau of Land Management, North Bend, OR. 13 pp plus tables and maps.

Davis, W.A. and S.M. Russell. 1984. Birds in southeastern Arizona. Tucson Audubon Society, Tucson, AZ. 169 pp.

Dugan, J.E., H.M. Page, and R. Castelli. 1997. Assays of fertilization success, embryonic development and larval viability in a brooding invertebrate as indicators of ecosystem condition, with emphasis on the intertidal sand crab, Emerita analoga. Research abstracts, University of California Toxic Substances Research and Teaching Program Annual Report. 4 pp.

Evans, M.I. and G.O. Keijl. 1993. Impact of Gulf War oil spills on the wader populations of the Saudi Arabian Gulf Coast. Sandgrouse 15:85-105.

Evans, M.I., P. Symens, and C.W.T. Pilcher. 1993. Short-term damage to coastal bird populations in Saudi Arabia and Kuwait following the 1991 Gulf War. Marine Pollution Bulletin 27:157-161.

Fancher, J., R. Zembal, L. Hays, and P. Knapp. 1998. Western snowy plover nesting at Bolsa Chica, Orange County, California, 1998. Fish and Wildlife Service, Carlsbad Office, October 1998.

Fancher, J., L. Hays, and P. Knapp. 2002. Western snowy plover nesting at Bolsa Chica, Orange County, California, 2002. Fish and Wildlife Service, Carlsbad Office, December 2002.

Fahy, K.A. and C.D. Woodhouse. 1995. 1995 snowy plover linear restriction monitoring project, Vandenberg Air Force Base. Prepared for Natural Resources, Vandenberg Air Force Base, CA. 37 pp.

Feeney, L.R. and W.A. Maffei. 1991. Snowy plovers and their habitat at the Baumberg area and Oliver salt ponds, Hayward, California, March 1989 through May 1990. City of Hayward, Hayward, CA. 162 pp.

Flemming, S.P., R.D. Chiasson, P.C. Smith, P.J. Austin-Smith, and R.P. Bancroft. 1988. Piping plover status in Nova Scotia related to its reproductive and behavioral responses to human disturbance. Journal of Field Ornithology 59(4):321-330.

Ford, R.G. 1998. Preliminary bird injury assessment for the Torch/Platform Irene Pipeline Oil Spill. Unpublished report to California Department of Fish and Game, Office of Spill Prevention and Response.

Foster, B. 2005. Breeding status of the western snowy plover at Marine Corps Base, Camp Pendleton, California, 2003. Unpublished report prepared for the Environmental Core, Natural and Cultural Resources Team, Naval Facilities Engineering Command, Southwest, San Diego, California. 106 pp.

Fox, R. 1990. Snowy plover distribution and nesting success and human activity during summer, 1990, on Damon Point, Washington. Unpublished report., Washington Department of Wildlife, Olympia, WA. 9 pp.

Funk, W.C., T.D. Mullins, and S.M. Haig. 2006. Conservation genetics of North American and Caribbean Snowy Plovers (Charadrius alexandrinus): population genetic structure and delineation of subspecies. Final Report. USGS Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.

Fry, D.M. and L.J. Lowenstine. 1985. Pathology of common murres and Cassin's auklets exposed to oil. Archives of Environmental Contamination and Toxicology 14:725-737.

Fry, D.M., J. Swenson, L.A. Addiego, C.R. Grau, and A. Kang. 1986. Reduced reproduction of wedge-tailed shearwaters exposed to weathered Santa Barbara crude oil. Archives of Environmental Contamination and Toxicology 15:453-463.

George, D.E. 1997. Nesting success of snowy plovers at Wilder, Laguna, Scott Creek and Waddell Beaches, Santa Cruz County, California, in 1997. Report of Point Reyes Bird Observatory, Stinson Beach, CA. 12 pp.

Golightly, R.T., Jr., M.R. Faulhaber, K.L. Sallee, and J.C. Lewis. 1994. Food habits and management of introduced red fox in southern California. Pages 15-20 *in* Halverson, W.S., and A. C. Crabb, Eds. Proceedings of the 16th Vertebrate Pest Conference. Published at University of Califomia, Davis.

Gorman, L. R. 2000. Population differentiation among Snowy Plovers (*Charadrius alexandrinus*) in North America. M.S. thesis. Oregon State University, Corvallis, OR. 23pp.

Grinnell, J., H.D. Bryant, and T.I. Storer. 1918. The game birds of California. University of California Museum of Vertebrate Zoology, Berkeley, CA. pp. 473-478.

Guinon, M. 1988. Dune restoration at Spanish Bay. Fremontia. October 1988. pp. 8-11.

Hallett, C.E., B.R. Casler, M.A. Platt, and M.A. Stern. 1995. Snowy plover distribution and reproductive success along the Oregon coast. Submitted to Oregon Department of Fish and Wildlife, Portland, OR; Coos Bay District, Bureau of Land Management, North Bend, OR; and Oregon Dunes National Recreation Area, Reedsport, OR. 40 pp.

Hamilton, R.A., and D.R. Willick. 1996. The birds of Orange County, California. Sea and Sage Press. Sea and Sage Audubon Society, Irvine, California.

Harding, E.K., D.F. Doak, J. Albertson, and J.E. Takekawa. 1998. Predator management in San Francisco Bay wetlands: past trends and future strategies. Prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 41 pp.

Hatch, D. 1997. Draft snowy plover management plan for Ocean Beach, Golden Gate National Recreation Area. 58 pp. plus tables and appendices.

Hayman, P., J. Marchant, and T. Prater. 1986. Shorebirds: an identification guide to the waders of the world. Houghton Mifflin Co., Boston. 412 pp.

Heintz, G.H., D.J. Hoffman, A.J. Krynitsky, and D.M.G. Weller. 1987. Reproduction in mallards fed selenium. Environmental Toxicology and Chemistry 6:423-433.

Hickey, C.M., G.W. Page, and K. Wilson. 1995. Nesting success of snowy plovers at Point Reyes National Seashore in 1995. Report of Point Reyes Bird Observatory, Stinson Beach, CA. 10 pp.

Hoopes, E.M., C.R. Griffin, and S.M. Melvin. 1992. Relationships between human recreation and piping plover foraging ecology and chick survival. Unpublished report. University of Massachusetts, Amherst, MA. 77 pp.

Hothem, R.L. and A.N. Powell. 2000. Contaminants in western snowy plovers and California least terns: Is there a link to population decline? Bulletin of Environmental Contamination and Toxicology 65:42-50.

Howard, J.M., R.J. Safran, and S.M. Melvin. 1993. Biology and conservation of piping plovers at Breezy Point, New York. Unpublished report. Department of Forestry and Wildlife Management, University of Massachusetts, Amherst. 34 pp.

Hughes, R. 2003. SS Jacob Luckenbach oil removal project completed. The OSPR News 10:1-5.

Hutchinson, E.S., G.W. Page, and P.E. Persons. 1987. The nesting of snowy plovers on Morro Bay sand spit during and after the 1987 maintenance dredging of Morro Bay harbor. Report of Point Reyes Bird Observatory, Stinson Beach, CA. 16 pp.

Jacobs, R.A. 1986. Snowy plover (*Charadrius alexandrinus*). Section 4.4.1, U.S. Army Corps of Engineers Wildlife Resources Management Manual, Technical Report EL-86-54, Portland, OR. 25 pp.

Jaques, D. 2001. Snowy plovers at Leadbetter Point, Washington- 2000 Annual Report. U.S. Fish and Wildlife Service, Willapa National Wildlife Refuge. 19 pp.

Jurek, R.M. 1992. Non-native red foxes in California. California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section Report 92-04. Sacramento, CA. 16 pp.

Kelly, P. and J. Rotenberry. 1996/1997. Buffer zones for ecological reserves in California: replacing guesswork with science. Native Species Network. Winter 1996/97.

Khan, R.A. and P. Ryan. 1991. Long-term effects of crude oil on common murres (Uria aalge) following rehabilitation. Bulletin of Environmental Contamination and Toxicology 46:216-222.

Kindinger, M.E. 1981. Impact of the Ixtoc I oil spill on the community structure of intertidal and subtidal infauna along south Texas beaches. M.S. Thesis, Corpus Christi State University, Corpus Christi, TX. 91 pp.

King, K.A. and C.A. Lefever. 1979. Effects of oil transferred from incubating gulls to their eggs. Marine Pollution Bulletin 10:319-321.

Kloempken, D. and S.A. Richardson. 1995. Snowy plovers and human activity at Leadbetter Point in April 1995. 8 pp. plus survey form.

Lafferty, K. 2001. Disturbance to wintering western snowy plovers. Biological Conservation 101:315-325.

Larsen, E.M. and S.A. Richardson. 1990. Some effects of a major oil spill on wintering shorebirds at Grays Harbor, Washington. Northwestern Naturalist 71:88-92.

Lauten, D.J., K. A. Castelein, E. Seckinger, and E. P. Gaines. 2006*a*. The distribution and reproductive success of the western snowy plover along the Oregon coast - 2005. The Oregon Natural Heritage Infomation Center Institute for Natural Resources, Portland, OR.

Lauten, D.J., K. A. Castelein, S. Weston, K. Eucken, and E. P. Gaines. 2006*b*. The distribution and reproductive success of the western snowy plover along the Oregon coast - 2006. The Oregon Natural Heritage Information Center Institute for Natural Resources, Portland, OR.

Lebreton, J.-D., K.P. Burnham, J. Clobert, and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67-118.

Leibezet, J.R., and T. L. George. 2002. A summary of predation by corvids on threatened and endangered species in California and management recommendations to reduce corvid predation. California Department of Fish and Game, Species Conservation and Recovery Program Report 2002-02, Sacramento, CA. 103 pp.

Leighton, F.A. 1991. The toxicity of petroleum oils to seabirds: an overview. Pages 43-57 *in* White, J. (Ed.). The effects of oil on wildlife. Sheridan Press, Hanover, PA.

LeValley, R., S. McAllister, and A. Transou. 2001. Effects of the Stuyvesant spill on reproductive success of the western snowy plover at Clam Beach, Humboldt County, California, Year 2000 Season. Unpublished draft report to California Dept. of Fish and Game. 19 pp.

Lewis, J.C., R.T. Golightly, and R.M. Jurek. 1995. Introduction of non-native red foxes in California: Implications for the Sierra Nevada red fox. Transactions of the Western Section of the Wildlife Society 31:29-32.

Lewis, J.C., K.L. Sallee, and R.T. Golightly. 1993. Introduced red fox in California. California Department of Fish and Game, Nongame Bird and Mammal Section Report 93-10. Sacramento, CA. 56 pp plus appendices.

Lingle, G.R., J.G. Sidle, A. Hecht, and E.M. Kirsch. 1999. Observations of banding-related leg injuries in the piping plover. Pp. 118-123 *in* Higgins, K.F., M.R. Brashier, and C.D. Kruse (eds). Proceedings, Piping plovers and least terns of the Great Plains and nearby. Brookings: South Dakota State University.

Lockyer, B., R.M. Frank, T. Berger, B. Hembacher, G.R. Overton, T.L. Samsonetti, S. O'Rourke, J.S. Gordon, L.W. Weidman, and M.L.Miller. 2002. Consent Decree, United States of America and State of California v. Torch Energy Services, Inc., CV-02-3977. U.S. District Court, Central District of California, Western Division.

Mabee, T.J. and V.B. Estelle. 2000. Assessing the effectiveness of predator exclosures for plovers. Wilson Bulletin 112(1):14-20.

Mangel, M., and C. Tier. 1994. Four facts every conservation biologist should know about persistence. Ecology 75:607-614.

Marshall, D.B., M.G. Hunter, and A.L. Contreras, Eds. 2003. Birds of Oregon: a general reference. Oregon State University Press, Corvallis, OR. 768pp.

Marriott, M. 2001. Pacific coast western snowy plover monitoring program at the Don Edwards San Francisco Bay NWR and Eden Landing Ecological Reserve and selected Cargill Salt Division properties. Unpublished report to San Francisco Bay NWR Complex; Fremont, CA.

McCaskie, G., and K.L. Garrett. 2005. Southern California summary. North American Birds 59:493-497.

McGrath Oil Spill Restoration Scoping Document (Berry Petroleum). 1995. 6 pp.

McIvor, L.H. 1991. Research proposal: Conditioned taste aversion: A technique to reduce red fox predation at piping plover nests on Assateague Island National Seashore. Maryland Department of Natural Resources, Annapolis, MD. 8 pp.

Meffe, G., and C. Carroll. 1994. Principles of conservation biology. Sinauer Associates, New York.

Mills, L.S., and F.W. Allendorf. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10:1509-1518.

Molina, K.C., and M. Erwin. 2006. The distribution and conservation status of the gull-billed tern (*Gelochelidon nilotica*) in North America. Waterbirds 29:271-295.

Monson, G. and A.R. Phillips. 1981. Annotated checklist of the birds of Arizona, 2d ed. University of Arizona Press, Tucson. 240 pp.

National Audubon Society. 2006. West Nile virus. Retrieved from: http://www.audubon.org/bird/wnv/ Accessed July 25, 2006.

National Research Council. 1985. Oil in the sea: inputs, fates and effects. National Academy Press, Washington, D.C. 601 pp.

National Research Council. 1995. Science and the Endangered Species Act. National Academy Press; Washington, DC. 271 pages.

Neuman, K.K., G.W. Page, L.E. Stenzel, J.C. Warriner, and J.S. Warriner. 2004. Effect of mammalian predator management on snowy plover breeding success. Waterbirds 27:257-263.

Ohlendorf, H.M., R.L. Hothem, C.M. Bunck, T.W. Aldrich, and J.F. Moore. 1986. Relationships between selenium concentrations and avian reproduction. Transactions of the Fifty-first North American Wildlife and Natural Resources Conference 51:330-342.

Oregon Department of Fish and Wildlife. 1994. Final Draft. Oregon conservation program for the western snowy plover (*Charadrius alexandrinus nivosus*). Portland, OR. 56 pp.

Oregon Department of Fish and Wildlife. 1996. Snowy plover habitat restoration on the Coos Bay North Spit using inmate labor. 21 pp.

Page, G.W. 1988. Nesting success of snowy plovers in central coastal California in 1988. Report of the Point Reyes Bird Observatory, Stinson Beach, CA. 7 pp.

Page, G.W. 1990. Nesting success of snowy plovers in central coastal California in 1989 and 1990. Report of the Point Reyes Bird Observatory, Stinson Beach, CA. 13 pp.

Page, G.W. and P.E. Persons. 1995. The snowy plover at Vandenberg Air Force Base: population size, reproductive success, and management. Point Reyes Bird Observatory, Stinson Beach, CA. 24 pp. plus appendices.

Page, G.W. and L.E. Stenzel (eds.). 1981. The breeding status of the snowy plover in California. Western Birds 12(1):1-40.

Page, G.W., J.S. Warriner, and L.E. Stenzel. 1997. Nesting success of snowy plovers on Monterey Bay in 1997. Unpublished report of Point Reyes Bird Observatory, Stinson Beach, CA. 10 pp.

Page, G.W., F.C. Bidstrup, R.J. Ramer, and L.E. Stenzel. 1986. Distribution of wintering snowy plovers in California and adjacent states. Western Birds 17(4):145-170.

Page, G.W., L.E. Stenzel, W.D. Shuford, and C.R. Bruce. 1991. Distribution and abundance of the snowy plover on its western North American breeding grounds. Journal of Field Ornithology 62(2):245-255.

Page, G.W., L.E. Stenzel, D.W. Winkler, and C.W. Swarth. 1983. Spacing out at Mono Lake: breeding success, nest density, and predation in the snowy plover. The Auk 100:13-24.

Page, G.W., J.S. Warriner, J.C. Warriner, and R.M. Halbeisen. 1977. Status of the snowy plover on the northern California coast. Part I: Reproductive timing and success. California Department of Fish and Game Nongame Wildlife Investigations, Sacramento, CA. 6 pp.

Page, G.W., J.S. Warriner, J.C. Warriner, and P.W.C. Paton. 1995*a*. Snowy plover (*Charadrius alexandrinus*). *In* The Birds of North America, No. 154 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C. 24 pp.

Page, G.W., M.A. Stern, and P.W. Paton. 1995*b*. Differences in wintering areas of snowy plovers from inland breeding sites in western North America. The Condor 97:258-262.

Page, G.W., J.S. Warriner, J.C. Warriner, D.E. George, and L.E. Stenzel. 1997. Nesting success of snowy plovers at Monterey Bay and northern Santa Cruz County pocket beaches in 1996. Report of Point Reyes Bird Observatory, Stinson Beach, CA. 12 pp.

Page, G.W., D. Dixon, C. Eyster, D.E. George, K. Neuman, L.E. Stenzel, J.C. Warriner, and J.S. Warriner. 1998. Reproduction of snowy plovers at Monterey Bay and pocket beaches of northern Santa Cruz County in 1998. Unpubl. report of Point Reyes Bird Observatory, Stinson Beach, CA. 12 pp.

Palacios, E.P., L. Alfaro, and G.W. Page. 1994. Distribution and abundance of breeding snowy plovers on the Pacific coast of Baja California. Journal of Field Ornithology 65(4):490-497.

Patton, R. 2006a. The status of western gull-billed terns at South San Diego Bay National Wildlife Refuge. Unpublished draft report for the U.S. Fish and Wildlife Service, San Diego National Wildlife Refuge Complex, Carlsbad, California. November 2006. 16 pp. plus tables and figures.

Patton, R. 2006b. Foraging by western gull-billed terns at Tijuana Slough National Wildlife Refuge and Borderfield State Park in 2006. Unpublished final report for the U.S. Fish and Wildlife Service, San Diego National Wildlife Refuge Complex, Carlsbad, California. November 2006. 10 pp. plus tables and figures.

Pearson, S.F, C. Sundstrom, K. Brennan, and M. Fernandez. 2006. Snowy plover distribution, abundance, and reproductive success: 2006 research progress report. Washington Department of Fish and Wildlife, Olympia, WA.

Persons, P.E. 1994. Western snowy plover monitoring in 1993 at Vandenberg Air Force Base, California. Unpublished report of U.S. Fish and Wildlife Service, Ventura, CA. 22 pp.

Persons, P.E. 1995. Western snowy plover population size and nesting success in 1994 at Vandenberg Air Force Base, California. A monitoring report prepared for U.S. Fish and Wildlife Service, Ventura, CA. 21 pp.

Persons, P.E. and T.E. Applegate. 1996. Western snowy plover population size and reproductive success in 1996 at Vandenberg Air Force Base, California. Point Reyes Bird Observatory, Stinson Beach, CA. 35 pp. plus maps.

Persons, P.E. and T.E. Applegate. 1997. Monitoring of the western snowy plover at Vandenberg Air Force Base in 1997: population size, reproductive success, and management. Point Reyes Bird Observatory, Stinson Beach, CA. 30 pp. plus map.

Persons, P.E. and J.A. Ellison. 2001. Nesting of the Western Snowy Plover at Morro Bay Sandspit in San Luis Obispo County, California in 2000.

Peterlein, C., and D. Roth. 2003. Distribution, protection and reproductive success of snowy plovers at Point Reyes National Seashore in 2003. Report to the National Park Service. PRBO contribution number 1071.

Pethick, J. 1984. An introduction to coastal geomorphology. 260 pp.

Pfister, C., B. Harington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biological Conservation 60:115-126.

Philip Williams & Associates, EDAW, H.T. Harvey & Associates, and Brown & Caldwell. 2006. South Bay Salt Pond Restoration Project: Final Alternatives Report. Report submitted to California State Coastal Conservancy, U.S. Fish and Wildlife Service, and California Department of Fish and Game. 122 pp.

Pickart, A.J. 1997. Control of European beachgrass (*Ammophila arenaria*) on the west coast of the United States. Proceedings, 1997, California Exotic Plant Council Annual Meeting, Concord, CA. 13 pp.

Pickart, A.J. and J.O. Sawyer. 1998. Ecology and restoration of northern California coastal dunes. California Native Plant Society, Sacramento, CA. 172 pp.

Powell, A.N. 1996. Western snowy plover use of state-managed lands in southern California, 1995. California Department of Fish and Game, Wildlife Management Division, Bird and Mammal Conservation Program Report 96-103, Sacramento, CA. 14 pp.

Powell, A.N. 2001. Habitat characteristics and nest success of snowy plovers associated with California least tern colonies. The Condor 103:785-792.

Powell, J.A. 1981. Endangered habitats for insects: California coastal sand dunes. Atala 6:41-55.

Powell, A.N. and C.L. Collier. 1994. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1994. Report to California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Portland, OR. 28 pp.

Powell, A.N. and C.L. Collier. 1995. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) at Camp Pendleton, 1995. Annual breeding season interim summary report to the Assistant Chief of Staff, Environmental Security, Marine Corps Base, Camp Pendleton, CA. 32 pp.

Powell, A.N., B.L. Peterson, and J.M. Terp. 1996. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1996. Report to the California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Carlsbad, CA, and Portland, OR. 25 pp.

Powell, A.N., J.M. Terp, C.L. Collier, and B.L. Peterson. 1995. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1995. Report to the California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Carlsbad, CA, and Portland, OR. 24 pp.

Powell, A.N., J.M. Terp, C.L. Collier, and B.L. Peterson. 1997. The status of western snowy plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1997. Report to the California Department of Fish and Game, Sacramento, CA, and U.S. Fish and Wildlife Service, Carlsbad, CA, and Portland, OR. 34 pp.

Powell, A.N., C.L. Fritz, B.L. Peterson, J.M. Terp. 2002. Status of breeding and wintering Snowy Plovers in San Diego County, California, 1994-1999. Journal of Field Ornithology 73(2):156-165.

Raup, D.M. 1991. Extinction: bad genes or bad luck? W. W. Norton & Company, New York.

Remsen, J.V., Jr. 1978. Bird species of special concern in California. California Department of Fish and Game, Sacramento, CA. 54 pp.

Richardson, S.A., P.J. Doran, W.A. Michaelis, C.S. Sundstrom-Bagley, J.L. Anthony and H.M. Bahn. 2000. A new snowy plover nesting area in Washington: Midway Beach, Pacific County. Washington Birds 7:25-35.

Roletto, J., J. Martinson, L. Grella, and L. Culp. 2000. Beach Watch Annual Report: 2000. Unpublished report, Gulf of the Farallones National Marine Sanctuary, San Francisco, California. 61 pp.

Ruhlen, T.D., S. Abbott, L.E. Stenzel, G.W. Page. 2003. Evidence that human disturbance reduces snowy plover chick survival. Journal of Field Ornithology 74(3):300-304.

Ryan, T.P. and J.L. Parkin. 1998. The western snowy plover (*Charadrius alexandrinus nivosus*) in southern San Francisco Bay. Summary of detections made during colonial waterbird monitoring surveys from 1981 to 1997. Prepared for Santa Clara Valley Water District, San Jose, CA. 19 pp.

Saul, S.M. 1982. Clam diggers and snowy plovers. Washington Wildlife 32(1):28-30.

Schultz, R. and M. Stock. 1993. Kentish plovers and tourists: competitors on sandy coasts? Wader Study Group Bulletin 68:83-91.

Schwarzbach, S.E., M. Stephenson, T. Adelsbach, T. Ruhlen, S. Abbott, L.E. Stenzel, and G.W. Page. 2003. Elevated mercury concentrations in failed eggs of snowy plovers at Point Reyes National Seashore. Unpublished manuscript. 17 pp.

Schwendiman, J. L. 1975. Coastal dune stabilization in the Pacific Northwest. International Journal of Biometeorology 21:281-289.

Seabloom, E.W. and A.M. Wiedemann. 1994. Distribution and effects of *Ammophila breviligulata* Fern. (American beachgrass) on the foredunes of the Washington coast. Journal of Coastal Research 10(2):178-188.

Shuford, W.D., G.W. Page, and C.M. Hickey. 1995. Distribution and abundance of snowy plovers wintering in the interior of California and adjacent states. Western Birds 26:82-98.

Sibley, C.G. and B. L. Monroe, Jr. 1990. Distribution and taxonomy of birds of the world. Yale University Press, New Haven and London. 1111 pp.

Slobodchikoff, C.N. and J.T. Doyen. 1977. Effects of *Ammophila arenaria* on sand dune arthropod communities. Ecology 58:1171-1175.

Smith, G.J. and V.P. Anders. 1989. Toxic effects of boron on mallard reproduction. Environmental Toxicology and Chemistry 8:943-950.

Stanley, T.R., Jr., J.W. Spann, G.J. Smith, and R. Roscoe. 1994. Main and interactive effects of arsenic and selenium on mallard reproduction and duckling growth and survival. Archives of Environmental Contamination and Toxicology 26:444-451.

Stein, R. 1993. Population size and reproductive success of snowy plovers at Skunk Point, Santa Rosa Island. Point Reyes Bird Observatory, Stinson Beach, CA. 38 pp.

Stenzel, L.E., S.C. Peaslee, and G.W. Page. 1981. II. Mainland Coast. Pages 6-16 in Page, G.W. and L.E. Stenzel, (eds.). The breeding status of the snowy plover in California. Western Birds 12(1):1-40.

Stenzel, L.E., J.C. Warriner, J.S. Warriner, K.S. Wilson, F.C. Bidstrup, and G.W. Page. 1994. Long-distance breeding dispersal of snowy plovers in western North America. Journal of Animal Ecology 63:887-902.

Stern, M.A., J.S. McIver, and G.A. Rosenberg. 1990. Investigations of the western snowy plover at the Coos Bay North Spit and adjacent sites in Coos and Curry Counties, Oregon, 1990. Report to Oregon Department of Fish and Wildlife Nongame Program. 33 pp.

Stern, M.A., J.S. McIver, and G.A. Rosenberg. 1991. Nesting and reproductive success of snowy plovers along the south Oregon coast, 1991. Report to Oregon Department of Fish and Wildlife-Nongame, Roseburg, OR, and Coos Bay District, Bureau of Land Management, North Bend, OR. 18 pp.

Stern, M.A., D.J. Lauten, K.A. Castelein, K.J. Popper, and J.A. Fukuda. 2000. Impact assessment of oil spilled from the New Carissa on the Western Snowy Plover along the Oregon Coast. Unpublished report by the Oregon Natural Heritage Program and The Nature Conservancy to TMM Co, Ltd; Coos Bay District Bureau of Land Management; Oregon Dept. of Fish and Wildlife; Dunes National Recreation Area; U.S. Fish and Wildlife Service. 32 pp.

Strong, C., and R. Dakin. 2004. Western snowy plover breeding season surveys for 2003. San Francisco Bird Observatory, Alviso, CA. 28 pp.

Strong, C., N. R. Wilson, and J. D. Albertson. 2004. Western snowy plover numbers, nesting success, and avian predator surveys in the San Francisco Bay, 2004. San Francisco Bay Bird Observatory, Alviso, CA, and Don Edwards San Francisco Bay National Wildlife Refuge, Newark, CA. 41 pp.

Sundstrom, C. 2001. 2000 Snowy plover surveys in coastal Washington (Moclips-Tokeland). Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 8 pp.

Sundstrom, C. 2002*a*. 2001 Snowy plover surveys in coastal Washington. Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 8 pp.

Sundstrom, C. 2002*b*. 2002 Snowy plover surveys in coastal Washington. Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 13 pp.

Sundstrom, C. 2003. 2003 Snowy plover surveys in coastal Washington. Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 11 pp.

Sundstrom, C. 2004. 2004 Snowy plover surveys in coastal Washington. Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 14 pp.

Sundstrom, C. 2005. 2005 snowy plover surveys in coastal Washington. Washington Department of Fish and Wildlife, Region 6, Montesano, WA.

Sundstrom-Bagley, C., W. Michaelis, J. Anthony, M. Bahn. 2000. Snowy plover distribution and nesting success in coastal Washington (1999). Washington Department of Fish and Wildlife, Region 6, Montesano, WA. 27 pp.

Tear, T.H., J.M. Scott, P.H. Hayward, and B. Griffith. 1993. Status and prospects for success of the Endangered Species Act: A look at recovery plans. Science 262:976-977.

Trivelpiece, W.Z., R.G. Butler, D.S. Miller, and D.P. Peakall. 1984. Reduced survival of chicks of oil-dosed adult Leach's storm-petrels. Condor 86:81-82.

Tucker, M.A. and A.N. Powell. 1999. Snowy plover diets in 1995 at a coastal southern California breeding site. Western Birds 30:44-48.

Tucci, L., C. Strong, and J. Albertson. 2006. Western snowy plover numbers, nesting success, and predator surveys in the San Francisco Bay - 2005 breeding season. San Francisco Bay Bird Observatory, Alviso, CA, and Don Edwards San Francisco Bay National Wildlife Refuge, Newark, CA. 33 pp.

Tuttle, D.C., R. Stein, and G. Lester. 1997. Snowy plover nesting on Eel River gravel bars, Humboldt County. Western Birds 28:174-176.

U.S. Bureau of Land Management. 1995*a*. Coos Bay Shorelands, Final Management Plan. 25 pp. plus map.

U.S. Bureau of Land Management. 1995*b*. The New River Area of Critical Concern Management Plan. 149 pp

U.S. Bureau of Land Management. 2001. Notice of Intent to Conduct Restoration Planning, M/V New Carissa Natural Resource Damage Assessment. Federal Register 66:56339-56340.

U.S. Coast Guard. 2001. Marine Casualty Investigation Report, Case Number MC99011413. 13 pp.

U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 1994. Management Plan, Oregon Dunes National Recreation Area, Siuslaw National Forest. 157 pp.

U.S. Department of Agriculture. 2002. Environmental Assessment: Predator damage management to protect the federally threatened Pacific coast population of the western snowy plover in Lane, Douglas, Coos, Curry, Clatsop, Tillamook, and Lincoln Counties, Oregon. Prepared by APHIS-WS Program, Western Region, for USFWS, BLM, USFS, in cooperation with ODFW, OPRD.

U.S. Department of Transportation, Federal Aviation Administration. 1997. Federal Aviation Regulations, Part 91, General Operating and Flight Rules.

U.S. District Court, Central District of California. 1995. Order. Environmental Defense Center, Plaintiff, v. Bruce Babbitt, Secretary of the Interior, *et al.*, Defendants. No. CV 94-5561 ER (Shx). 2 pp.

U.S. District Court, Central District of California. 1998. Order and Judgment. Environmental Defense Center *et al.*, Plaintiffs, v. Babbitt, *et al.*, Defendants. Case No. CV 94-5561 ER (Shx). 4 pp.

U.S. District Court, District of Massachusetts. 1998. Memorandum and Order. United States of America, plaintiff, v. Town of Plymouth, Massachusetts, defendant. Civil Action No. 98-10566-PBS. 29 pp.

U.S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery priority guidelines. Federal Register 48:43098-43105. September 21, 1983.

U.S. Fish and Wildlife Service. 1985. Light-footed clapper rail recovery plan, Portland, OR. 121 pp.

U.S. Fish and Wildlife Service. 1992. Status and trends report on wildlife of the San Francisco Estuary. San Francisco Estuary Project. 315 pp.

U.S. Fish and Wildlife Service. 1993*a*. Endangered and threatened wildlife and plants; determination of threatened status for the Pacific coast population of the western snowy plover; final rule. Federal Register 58(42):12864-12874.

U.S. Fish and Wildlife Service. 1993*b*. Intra-Service Formal Consultation on take of the threatened Pacific coast population of the western snowy plover for scientific purposes and/or enhancement of propagation or survival. Portland, Oregon. 9 pp.

U.S. Fish and Wildlife Service. 1993*c*. Endangered Species Technical Bulletin, Vol. XVIII, No. 2, pp. 7-9.

U.S. Fish and Wildlife Service. 1995*a*. Endangered Species Bulletin, Vol. XX, No. 5. 28 pp.

U.S. Fish and Wildlife Service. 1995*b*. Endangered and threatened wildlife and plants; proposed designation of critical habitat for the Pacific coast population of the western snowy plover; proposed rule. Federal Register 60(41):11768-11809.

U.S. Fish and Wildlife Service. 1996*a*. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts. 258 pp.

U.S. Fish and Wildlife Service. 1996*b*. Endangered and threatened wildlife and plants; final listing priority guidance for fiscal year 1997; final rule. Federal Register 61:64475-64481.

U.S. Fish and Wildlife Service. 1998. Endangered and threatened wildlife and plants; proposed listing priority guidance for fiscal years 1998 and 1999; proposed rule. Federal Register 63:10931-10935.

U.S. Fish and Wildlife Service. 1999. Endangered and threatened wildlife and plants; Designation of critical habitat for the Pacific coast population of the western snowy plover; final rule. Federal Register 64:68508-68544. December 7, 1999.

U.S. Fish and Wildlife Service. 2002. Draft Recovery Plan for the Great Lakes Piping Plover (*Charadrius melodus*). Fort Snelling, Minnesota. 121 pp.

U.S. Fish and Wildlife Service. 2004*a*. Endangered and threatened wildlife and plants; 90-day finding on a petition to delist the Pacific coast population of the western snowy plover and initiation of a 5-year review. Federal Register 69:13326-13329. March 22, 2004.

U.S. Fish and Wildlife Service. 2004*b*. Endangered and threatened wildlife and plants; Proposed designation of critical habitat for the Pacific coast population of the western snowy plover. Federal Register 69:75608-75771. December 17, 2004.

U.S. Fish and Wildlife Service. 2005. Endangered and threatened wildlife and plants; Designation of critical habitat for the Pacific coast population of the western snowy plover. Federal Register 70:56970-57018. September 29, 2005.

U.S. Fish and Wildlife Service. 2006*a*. Endangered and threatened wildlife and plants; 12-month finding on a petition to delist the Pacific coast population of the western snowy plover. Federal Register 71:20607-20624. April 21, 2006.

U.S. Fish and Wildlife Service. 2006*b*. Endangered and threatened wildlife and plants; Proposed special rule pursuant to section 4(d) of the Endangered Species Act for the Pacific coast distinct population segment of the western snowy plover. Federal Register 71:20625-20636. April 21, 2006.

U.S. Fish and Wildlife Service. 2006*c*. San Diego Bay National Wildlife Refuge Sweetwater Marsh and South San Diego Bay Units Final Comprehensive Conservation Plan and Environmental Impact Statement – August 2006.

U.S. Fish and Wildlife Service. In preparation. Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California.

U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration. 1994. Endangered and threatened wildlife and plants: Notice of interagency cooperative policy on recovery plan participation and implementation under the Endangered Species Act. Federal Register 59(126):34272-34273.

U.S. Geological Survey. 2006. West Nile virus maps. Retrieved from: http://diseasemaps.usgs.gov/wnv_us_bird.html Accessed December 27, 2006.

U.S. Navy. 2001. Integrated Natural Resources Management Plan, Naval Base Coronado.

U.S. Marine Corps. 2006. Integrated Natural Resources Management Plan, Marine Corps Base Camp Pendleton. August 2006 draft revision.

Unitt, P. 2004. San Diego County Bird Atlas. San Diego Natural History Museum and Ibis Publishing Company. San Diego, California.

Warriner, J.S., J.C. Warriner, G.W. Page, and L.E. Stenzel. 1986. Mating system and reproductive success of a small population of polygamous snowy plovers. Wilson Bulletin 98(1):15-37.

Washington Department of Fish and Wildlife. 1995. Washington State recovery plan for the snowy plover. Olympia, WA. 87 pp.

White, J.D., and S.G. Allen. 1999. Western snowy plover management plan. Report to the National Park Service, Point Reyes National Seashore, Point Reyes, CA.

White, J.D., and C.M. Hickey. 1997. Distribution, protection and nest success of snowy plovers at Point Reyes National Seashore. A report of Point Reyes Bird Observatory, Stinson Beach, CA. 11 pp.

Widrig, R.S. 1980. Snowy plovers at Leadbetter Point: An opportunity for wildlife management? Prepared for the U.S. Fish and Wildlife Service, Willapa NWR, Ilwaco, WA. 14 pp.

Widrig, R.S. 1981. Snowy plovers at Leadbetter Point. Prepared for the U.S. Fish and Wildlife Service, Willapa NWR, Ilwaco, WA. 13 pp.

Wiedemann, A.M. 1987. The ecology of European beachgrass (*Ammophila arenaria* (L.) Link). A review of the literature. Oregon Department of Fish and Wildlife Nongame Wildlife Program Technical Report #87-1-01. 18 pp.

Wiedemann, A.M., L.J. Dennis, and F.H. Smith. 1969. Plants of the Oregon coastal dunes. Department of Botany, Oregon State University. Oregon State University Book Stores, Inc., Corvallis, OR. 117 pp.

Willapa National Wildlife Refuge. 1988. Willapa National Wildlife Refuge, 1988 annual narrative report. Ilwaco, WA. 46 pp.

Williamson, D.A. 1995. Snowy plovers at Willapa Bay, Washington, 1995. Willapa National Wildlife Refuge Complex, Ilwaco, WA. 13pp.

Williamson, D.A. 1996. Snowy plovers at Willapa Bay, Washington, 1996. Willapa National Wildlife Refuge Complex, Ilwaco, WA. 13 pp.

Williamson, D.A. 1997. Snowy plovers at Willapa Bay, Washington, 1997. Willapa National Wildlife Refuge Complex, Ilwaco, WA. 15 pp.

Wilson, R.A. 1980. Snowy plover nesting ecology on the Oregon coast. MS Thesis, Oregon State University, Corvallis. 41 pp.

Wilson-Jacobs, R., and G.L. Dorsey. 1985. Snowy plover use of Coos Bay north spit, Oregon. Murrelet 66(3):75-81.

Wilson-Jacobs, R., and E.C. Meslow. 1984. Distribution, abundance, and nesting characteristics of snowy plovers on the Oregon coast. Northwest Science 58(1):40-48.

Woolington, M.C. 1985. A preliminary investigation of the effect of recreational use on nesting snowy plovers at Sutton and Siltcoos beach areas, Oregon. Oregon Department of Fish and Wildlife Nongame program. 37 pp.

## B. Personal Communications

Albertson, J. 2005. Don Edwards - San Francisco Bay National Wildlife Refuge, U.S. Fish and Wildlife Service, Newark, CA.

Applegate, T. 1996, 1999. Bioresources, Los Osos, CA.

Baye, P. 1997. Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service, Sacramento, CA.

Burns, C. U.S. Forest Service, Siuslaw National Forest, Mapleton Ranger District, Florence, OR.

Dorsey, G. 1997. U.S. Army Corps of Engineers, Portland, OR.

Fernandez, E. 1998. Don Edwards-San Francisco Bay National Wildlife Refuge, U.S. Fish and Wildlife Service, Newark, CA.

George, D. 1998. Point Reyes Bird Observatory, Stinson Beach, CA.

Grettenberger, J. 2004. Western Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, Lacey, WA.

Heaney, J. 2003. Bureau of Land Management, Coos Bay District, North Bend, OR. June 27, 2003.

Hecht, A. 1996. U.S. Fish and Wildlife Service, Hadbury, MA.

Klinger, R. 1998. The Nature Conservancy, Santa Barbara, CA.

Kolar, M. 2004. Manager, San Francisco Bay National Wildlife Refuge Complex, U.S. Fish and Wildlife Service, Newark, CA.

Mangan, L. 2003. Bureau of Land Management, Coos Bay District, North Bend, OR.

Neuman, K. 1997. California Department of Parks and Recreation, Monterey, CA.

Page, G. 1997, 1998. Point Reyes Bird Observatory, Stinson Beach, CA.

Palermo, K. 1998. U.S. Forest Service, Oregon Dunes National Recreation Area, Siuslaw National Forest, Reedsport, OR.

Pearson, D. 1996. Southern California Edison, Rosemead, CA.

Pickart, A. 1997. The Nature Conservancy, Arcata, CA.

Powell, A.N. 1998. U.S. Geological Survey, Biological Resources Division, Fayetteville, AR.

Read, N. 1998. U.S. Department of the Air Force, Vandenberg Air Force Base, California.

Sandoval, C. 2005. University of California, Santa Barbara, CA.

Stadtlander, D. 1999. Carlsbad Fish and Wildlife Office, U.S. Fish and Wildlife Service, Carlsbad, CA.

Richardson, S. 1998. Washington Department of Fish and Wildlife, Olympia, WA.

Stern, M. 1999. The Nature Conservancy, Oregon Natural Heritage Program, Portland, OR.

VanderHeyden, M. Bureau of Land Management, Coos Bay District, North Bend, OR.

Vissman, S. 2007. U.S. Fish and Wildlife Service, Carlsbad, CA.

Walton, B. 1998. Predatory Bird Research Group, University of California at Santa Cruz, Santa Cruz, CA.

Watkins, J. 2001, 2006. Arcata Fish and Wildlife Office, U.S. Fish and Wildlife Service, Arcata, California.

### C. *In Litt.* References

Albertson, J. 1999. Don Edwards-San Francisco Bay National Wildlife Refuge, U.S. Fish and Wildlife Service, Newark, California. Electronic message to U.S. Fish and Wildlife Service, Sacramento, CA, on working draft of the Western Snowy Plover Recovery Plan. 4 pp.

Allen, S. 2004. Point Reyes National Seashore, Point Reyes, CA. Electronic message to Valary Bloom, U.S. Fish and Wildlife Service, Sacramento, CA, providing comments on the Western Snowy Plover Draft Recovery Plan. 3 pp.

Bloom, V. 2005. U.S. Fish and Wildlife Service, Sacramento, CA. Electronic message to Cay Goude, U.S. Fish and Wildlife Service, Sacramento, CA, regarding snowy plover management in San Francisco Bay. 1 p.

Buffa, J. 2004. Don Edwards-San Francisco Bay National Wildlife Refuge, U.S. Fish and Wildlife Service, Newark, California. Electronic message to Valary Bloom, U.S. Fish and Wildlife Service, Sacramento, CA, providing comments on the Western Snowy Plover Draft Recovery Plan. 4 pp.

Copper, E., and B. Foster. 2001. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, providing comments and additional information on the Western Snowy Plover Pacific Coast Population Draft Recovery Plan.

Didion, J. 1999. California Department of Parks and Recreation, Sacramento, CA. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, on working draft of the Western Snowy Plover Recovery Plan. 6 pp.

Dixon, D. 1998. California Department of Parks and Recreation, Monterey, CA. Information provided to U.S. Fish and Wildlife Service, Sacramento, CA, regarding European beachgrass control and snowy plover guardian program. 5 pp.

Dyste, R. 2004. Comprehensive Planning Division, County of Santa Barbara, Santa Barbara, CA. Electronic message to Valary Bloom, U.S. Fish and Wildlife Service, Sacramento, CA, providing comments on the Western Snowy Plover Draft Recovery Plan. 3 pp.

George, D. 2001. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, on working draft of the Western Snowy Plover Recovery Plan. 1 pp.+ attachment.

Goldsmith, G. 2004. U.S. Fish and Wildlife Service, Arcata, CA. Electronic message to Jim Watkins, U.S. Fish and Wildlife Service, Arcata, CA.

Henry, S. 1998. U.S. Fish and Wildlife Service, Ventura, CA. Electronic message to U.S. Fish and Wildlife Service, Sacramento, CA. 2 pp.

Jensen, M. 2006a. U.S. Fish and Wildlife Service, Lacey, WA. Table of window survey data. 1 p.

Jensen, M. 2006b. U.S. Fish and Wildlife Service, Lacey, WA. Electronic message to Grant Canterbury, U.S. Fish and Wildlife Service, Portland OR. 1 p.

Kelly, L. 2005. U.S. Fish and Wildlife Service, Newport, OR. Comparison of the 2005 winter and 2005 summer Snowy Plover surveys of the Oregon/Washington coast. (Recovery Unit 1). 2 pp.

Long, M. 2006. U.S. Fish and Wildlife Service, Arcata, CA. Botulism antitoxin treatment for federally threatened Pacific coast population of western snowy plover in southern California. Memo to Rex Sohn, U.S.G.S. National Wildlife Health Center, Madison, WI. 2 pp.

Mesta, R. 1998. U.S. Fish and Wildlife Service, Ventura, CA. Comments provided to U.S. Fish and Wildlife Service, Sacramento, CA, on the working draft of the Western Snowy Plover Recovery Plan. 3 pp.

Moulton, C. 1997. Manager, Eureka Fisheries, Inc., Fields Landing, CA. Letter to Field Supervisor, U.S. Fish and Wildlife Service, Sacramento, CA. 2 pp.

Myers, J.P. 1988. Senior Vice President, Science and Sanctuaries, National Audubon Society, New York, N.Y. Letter to Director, U.S. Fish and Wildlife Service, Washington, D.C. 19 pp.

Page, G.W. 1988. Point Reyes Bird Observatory, Stinson Beach, CA. Letter to U.S. Fish and Wildlife Service, Portland, OR. 1 p.

Page, G.W. 2004*a*. Point Reyes Bird Observatory, Stinson Beach, CA. Letter to Field Supervisor, Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service, Sacramento, CA, providing comments on reassessment of snowy plover listing status. 20 pp.

Page, G.W. 2004*b*. Point Reyes Bird Observatory, Stinson Beach, CA. Letter to Glen Tarr, Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service, Sacramento, CA, providing comments on western snowy plover management in Monterey Bay area. 3 pp.

Page, G.W. 2005*a*. Point Reyes Bird Observatory, Stinson Beach, CA. Year 2005 breeding season snowy plover survey of California coast. Electronic file sent to U.S. Fish and Wildlife Service. 3 pp.

Page, G.W. 2005*b*. Point Reyes Bird Observatory, Stinson Beach, CA. Snowy plover banding study proposal. Electronic message to U.S. Fish and Wildlife Service, Arcata, CA. 6 pp.

Page, G. W. 2006. Point Reyes Bird Observatory, Stinson Beach, CA. Comparison of the 2005 and 2006 snowy plover surveys of the Pacific coast. Electronic file sent to U.S. Fish and Wildlife Service. 8 pp.

Palermo, K. 1998*a*. U.S. Forest Service, Oregon Dunes National Recreation Area, Siuslaw National Forest, Reedsport, OR. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, on the working draft of the Western Snowy Plover Recovery Plan. 2 pp.

Pearson, S. 2006. Washington Department of Fish and Wildlife, Olympia, WA. Electronic message to Martha Jensen, U.S. Fish and Wildlife Service, Lacey, WA. 2 pp.

Palermo, K. 1998*b*. U.S. Forest Service, Oregon Dunes National Recreation Area, Siuslaw National Forest, Reedsport, OR. Electronic message to U.S. Fish and Wildlife Service, Sacramento, CA, on European beachgrass control. 1 p.

Pickart, A. 1996. The Nature Conservancy, Arcata, CA. Information provided to U.S. Fish and Wildlife Service, Sacramento, CA, regarding the status of European beachgrass in California. 2 pp.

Price, J.B. 1992. Chief Ranger, Department of Parks and Recreation, Ventura, CA. Memorandum to Oxnard Police Department *et al.* 1 p.

Read, N. 1998. Vandenberg Air Force Base, CA. Electronic message to U.S. Fish and Wildlife Service, Sacramento, CA, on the working draft of the Western Snowy Plover Recovery Plan. 2 pp.

Read Francine, N. 2001. Department of the Air Force, Vandenberg Air Force Base, CA. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, providing comments and additional information on the Western Snowy Plover Pacific Coast Population Draft Recovery Plan. 8 pp.

Richardson, S. 2001. Bureau of Reclamation. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, providing comments and additional information on the Western Snowy Plover Pacific Coast Population Draft Recovery Plan.

Trulio, L. 2007. Electronic message to Valary Bloom, U.S. Fish and Wildlife Service, Sacramento, CA, on snowy plover habitat in San Francisco Bay.

U.S. Department of the Navy. 2001. Letter from U.S. Department of the Navy, China Lake, CA, to the U.S. Fish and Wildlife Service, Sacramento, CA, on increasing pinniped populations on San Nicholas Island.

U.S. Department of the Navy. 2007. Letter to U.S. Fish and Wildlife Service, Carlsbad, CA, requesting re-initiation of consultation at Naval Base Coronado. 13 pp.

U.S. Fish and Wildlife Service. 1995. Memorandum from Acting Field Supervisor, Ventura Field Office, Ecological Services, Ventura, CA, to Superintendent, Channel Islands National Park, National Park Service, Ventura, CA. 26 pp.

Watkins, J. 1999. U.S. Fish and Wildlife Service, Arcata, CA. Electronic message to U.S. Fish and Wildlife Service, Sacramento, CA, on the working draft of the Western Snowy Plover Recovery Plan. 11 pp.

Zielinski, E.Y. 1999. U.S. Bureau of Land Management, Portland, OR, and R.W. Williams, U.S. Forest Service, Portland, OR. Letter to U.S. Fish and Wildlife Service, Sacramento, CA, on the working draft of the Western Snowy Plover Recovery Plan. 15 pp. plus enclosures.

# APPENDIX Q – 7

Other Cited References

# News Release

**USDI Bureau of Land Management**
**Coos Bay District**
**1300 Airport Lane**
**North Bend, OR  97459**

**USDA Forest Service/Pacific Northwest Region**
**Siuslaw National Forest**
**3200 SW Jefferson Way**
**Corvallis, OR  97331**

**Contacts:  (541) 751-4353, Megan Harper, Bureau of Land Management**
**(541) 750-7075, Joni Quarnstrom, Forest Service**

FOR IMMEDIATE RELEASE
March 13, 2013

## Snowy Plover Nesting Season Begins March 15

**Southern Oregon Coast –** The nesting season for the western snowy plover, a small shorebird that lays its eggs and raises its young in the open dry sand, begins on area beaches March 15 and runs through September 15. Some area beaches have access and recreational restrictions in place during this time to help protect the nests, eggs and chicks of these threatened birds.

After March 15, signs and ropes will mark snowy plover nesting areas. In the nesting areas, beachgoers will only have access to the wet sand portion of the beach – dry sand access will be closed. ATV use, dog walking and kite flying is also restricted on some beaches.

The dry sand closures will be in effect at Sutton Beach, Siltcoos Estuary, Oregon Dunes Day Use, Tahkenitch Estuary, Tenmile Estuary (northern Coos County), the North Spit of Coos Bay, Bandon Beach State Natural Area, and New River area beaches. The access restrictions affect approximately 18 miles of beach in Oregon.

"The number of fledgling plover chicks doubled from 2010 to 2011, going from 84 to 168 birds," said Kerrie Palermo, Wildlife Biologist with the Bureau of Land Management. "People honoring the closures, along with the habitat improvement and predator control projects the agencies are implementing, are getting us closer to recovering the snowy plover population."

The Pacific coast population of the western snowy plover was listed by the U.S. Fish and Wildlife Service as threatened in 1993. The primary threats to snowy plover survival are habitat degredation, urban development, European beachgrass introduction, and predators such as crows, ravens, foxes and skunks.

More information on plover habitat and beach restrictions can be obtained from the Forest Service at 541-750-7000, or the BLM at 541-756-0100. Visit http://www.fws.gov/oregonfwo/Species/Data/WesternSnowyPlover/default.asp to learn more about the western snowy plover.

###

Kitsap Sun
Printer-friendly story
Read more at kitsapsun.com

# Mystery compound found to kill coho salmon

By Christopher Dunagan

Monday, January 21, 2013

SUQUAMISH — Stormwater runoff from highways appears to contain one or more unidentified compounds shown to be highly toxic to coho salmon and perhaps other salmon as well.

The problem has been studied only a few years. Now, experiments at Grover's Creek Hatchery in North Kitsap have confirmed that polluted stormwater has the ability to kill adult coho before they can spawn.

This "pre-spawn mortality," as it is called, could pose a serious threat to the ongoing salmon populations in many urban areas, said Nathaniel "Nat" Scholz, a biologist with NOAA's Northwest Fisheries Science Center.

The problem was first suspected in Seattle's Longfellow Creek, which receives a rush of stormwater whenever it rains. Observers noticed that many of the female coho that made it home to their natal streams were dying before they could lay their eggs, often within a few hours of a rainstorm. Leading up to their deaths, researchers noticed that the fish seemed confused, often going in different directions and turning onto their sides while swimming.

An extensive forensic analysis ruled out everything but toxic chemicals, Scholz said. Further investigations revealed that the more polluted a stream became, the more likely the fish were to experience pre-spawning mortality. Up to 90 percent of the females were dying in some streams following a rainstorm.

At first, heavy metals were suspected. After all, it has been shown in laboratory experiments that copper compounds can destroy the olfactory sense of smell in salmon. Adults exposed to copper presumably can fail to home in on their natal streams, while juveniles exposed to copper become highly vulnerable to predators, according to previous studies by Scholz and his associates.

But adult coho exposed to 10 times the level of metals found in the toxic stormwater failed to show the characteristic behavior of the dying salmon in Longfellow Creek and other urban streams.

Meanwhile, other studies demonstrated that 65 percent of coho embryos exposed to this toxic stormwater had severe physical abnormalities, such as malformed fins, bleeding on the brain and swelling around the heart, according to Julann Spromberg, who discussed the findings at a recent meeting of the Kitsap Poggie Club, a local fishing group. Typically, the malformed fish die at an early age, she said.

Still searching for the mysterious, deadly compound, NOAA researchers formed a partnership with the Suquamish Tribe to use the tribe's Grover's Creek Hatchery, which rears coho and gets a fair number of returns in most years.

The researchers collected stormwater from a highway during major rains last fall. The water first collected after a four-day dry period appeared the darkest and dirtiest. As the rains continued, the collected water looked to be less ominous.

These different samples of stormwater were placed into small tanks with clean water placed into identical tanks. The salmon were then exposed to the water for an hour or two.

To the surprise of the researchers, all of the coho exposed to the stormwater showed the behavior they had come to expect. The fish bumped into the sides of their tanks, showing no sense of direction and keeling over on their sides.

"They couldn't even figure out how to turn around, they were so out of it," Spromberg said. "There was something severely wrong with them."

Even the highway runoff that seemed the cleanest after days of rain killed the fish. On the other hand, coho exposed to water from a clean stream suffered no ill effects.

Scholz said typical highway runoff contains an enormous number of different compounds, and it is extremely difficult and costly to narrow down which ones may be affecting the fish. Because death comes so quickly, the cause must be a physiological or metabolic pathway, not any kind of disease progression, he said.

Many tissues were taken from fish in the Grover's Creek experiments in hopes of finding a problem in the heart, gills or perhaps other essential organs. The method involves testing for genetic markers to determine which organs are under stress. Results are still pending.

"The fish are telling us what is going on, given the high rates of mortality across many streams," Scholz said. "But, scientifically, this is a tricky challenge. We have to look at target organs and try to figure out why they are dying."

Scholz said the answer is likely to be one of two things. Either the mystery compound is two or more known chemicals working together synergistically — which means together they are worse — or the mystery compound is a single chemical that has never been identified for its extreme toxicity.

"We don't have evidence for either one," Scholz said. "It could be an unmonitored chemical contaminant or a group of chemicals working synergistically. We have chemists at the Northwest Science Center looking at what they can find in tires."

Because the Kitsap Peninsula is a "transitional" area between urban and rural development, researchers would like to extend their studies into a variety of local streams where the runoff comes from different types of development. Some areas have infiltrated much of the stormwater into the ground — either through old-fashioned stormwater ponds or with rain gardens and other kinds of low-impact development.

"What we want to know from the NOAA side of things is whether you can reduce pollution loading sufficiently to protect the fish," Scholz said.

Jon Oleyar, who counts salmon in Kitsap streams to estimate populations, says he has noticed the effects of pre-spawning mortality in urbanized sections of streams, such as lower Clear Creek near Silverdale and lower Dogfish Creek near Poulsbo — and other salmon may be affected as well.

"I've seen it in chinook, and I've seen it in chum, too," he said, "but I don't see a lot of it."

Chris May, manager of Kitsap County's Surface and Stormwater Management Program, said he is following the toxicity studies closely as new strategies are planned to deal with the problem.

One step Kitsap County has taken is to acquire three high-efficiency street sweepers, which actually vacuum up road dust and debris to keep it from washing into ditches and ultimately streams. The machines sweep about 700 miles a year, most frequently near stream crossings and along shorelines, he said.

The SSWM program monitors the amount of toxic chemicals found in 200 tons or so of material that gets swept up each year.

May said he hopes that street sweeping, stormwater management and other efforts can help prevent the problems of pre-spawn mortality observed in portions of King County and other urban areas.

*This story was changed from its original version to clarify previous studies on effects of copper.*

---

# Oregon DEQ
## Site Summary Report
## Former Weyerhaeuser North Bend Containerboard Mill
## North Bend, Oregon ECSI Nos. 528, 1083, and 1829
## September 7, 2006

## Introduction and Purpose

This document presents a summary of the environmental investigation and cleanup performed at the Weyerhaeuser Containerboard Mill property located in North Bend, Oregon. The purpose of this site summary report is to document the Oregon Department of Environmental Quality's (DEQ's) recommendation for a No Further Action (NFA) determination covering the recent hazardous substances investigation and removal actions completed at the main mill and the "Ingram Yard" sites.

Weyerhaeuser, the current owner of the property, entered the Voluntary Cleanup Program (VCP) under a Site-Specific Technical Consultation Cost Recovery Agreement on February 12, 2004 in order to obtain a NFA determination from DEQ for selected areas of the site.

This Site Summary Report and NFA recommendation does not include the mill's permitted industrial landfill (Solid Waste Disposal Permit #1142) or the mill's permitted industrial wastewater treatment system (NPDES Permit #101499; consisting of two settling ponds, an aerated stabilization basin, and a large former lagoon). These facilities will be closed under their respective permits in cooperation with DEQ's Solid Waste and Water Quality programs, possibly in the next few years.

## Site Description

Weyerhaeuser owns about 1,300 acres of land in the Jordan Point/North Spit area of North Bend. The parcels that are the subject of this document are located approximately one-half mile west of U. S. Highway 101 (Hwy 101) and approximately two miles north of downtown North Bend and include 1) the approximately 97-acre and 70-acre parcels located at 92770 Trans Pacific Lane, North Bend, Oregon, Tax Lots 100, (see http://www.ormap.org, Coos County, Map 25 13 4) and 200, (see http://www.ormap.org, Coos County, Map 25 13 3 & Index) (respectively), which collectively is referred to as the "main mill complex"; and 2) the approximately 200+ acre Ingram Yard property located about 1.5 miles west of the main mill complex on Trans Pacific Lane part of Tax Lot 200 (see http://www.ormap.org, Coos County, Map 25 13 & Index) (Figure 1).

The former mill complex consisted of a main mill/paper machine building, shipping warehouse and maintenance/operations buildings, several other buildings used for office space, shops, storage, and other purposes, and related improvements and infrastructure. The developed portions of the facility occupied the north central portion of the property, and the southern portions are undeveloped and consist of vegetated open spaces, stream channels, and shoreline/tidal flat areas along Coos Bay. Historically, the southern portion of the site was used for log storage. A general site plan showing the primary former facility features is shown in Figure 2. Most of the features shown on Figure 2 are no longer present because they have been dismantled/removed as part of mill decommissioning. Weyerhaeuser intends to remove most site structures to ground level. Surface features such as concrete slabs will be left in place.

Prior to construction of the mill, the area in the immediate vicinity of the mill was covered with low brush and grass. The vegetation was stripped and the area covered with several feet of dune sane to raise the elevation above high tide and flood levels. South of the building, toward Jordan Cove, large amounts of driftwood and vegetation were left in place and covered with fill sand to create a log storage yard.

The Ingram Yard property is vacant and undeveloped (Figure 1). The Ingram Yard property is bordered to the east by dune and forest areas and an industrial facility (Roseburg Forest Products, North Bend Chip Facility). It is bordered on the south by Coos Bay, on the west by the Henderson Marsh area, and on the north by Trans Pacific Lane. Because the Ingram Yard has been used in the past for industrial purposes (e.g., dredge spoils disposal, etc.), the Ingram Yard is slowly revegetating with a mix of native and non-native introduced plant species.

## Site History and Background

The mill site was originally developed as a sulfite process pulp and paper mill by the Menasha Wooden Ware Corporation (Menasha) in 1961, and Weyerhaeuser acquired the mill from Menasha in 1981. In 1995, Weyerhaeuser ceased pulp mill operations, and the facility was operated as a 100-percent recycle paper mill until it was closed in 2003. Since 2003, Weyerhaeuser has been decommissioning the facility and preparing the property for future alternative uses and possible sale.

Weyerhaeuser leased the property east of the main mill area between the railroad tracks and Coos Bay to a fish hatchery operation that existed from approximately 1980 to 1992. Structures and improvements associated with the former hatchery operation included the fish hatchery structure, four buildings, and an above-ground storage tank (AST) for diesel storage. The fish hatchery improvements have been removed, and the property is currently vacant and undeveloped.

The Ingram Yard was used as a livestock ranch and dairy prior to 1958, and as a log sorting and chipping yard from the late 1970s to early 1980s. Sand, boiler ash, and wood debris were also placed on the property during this period. Land spreading of decant-basin solids from the mill wastewater treatment facilities occurred at the Ingram Yard from 1985 to 1994. Dredge spoils from U.S. Army Corps dredging of Coos Bay were placed on the Ingram Yard property in 1972 and 1973.

Additional details concerning the site including the physical setting, hydrogeology, and operational history can be found in the document entitled *Level II Environmental Site Assessment, Former Weyerhaeuser Containerboard Mill* (PES, 2006).

## Regulatory History

This section summarizes the DEQ regulatory history related to hazardous substance releases at the facility, and excludes the history associated with the NPDES and Solid Waste permitted facilities, which will be addressed in a separate closure document.

In the following description, the main mill complex is referred to as site #1083. There are two other identification numbers that have been used in the past for specific areas within the main mill complex. These are referred to as #528 (for a small transformer oil release on the main mill complex) and #1829 (for releases associated with a former fish hatchery on the east side of the main mill complex).

In January 1984, DEQ was notified of a small transformer oil spill (about 5 gallons). DEQ staff were present to observe the cleanup, and concluded that adequate cleanup measures were taken to mitigate the release.

In 1988, the a portion of the main mill complex was added to DEQ's newly-formed Environmental Cleanup Site Information Database (ECSI) as Site #528 for Tax Lots 100 and 101 in Township 12S, Range 13W, Section 4 for the 1984 transformer-oil release.

During August 1990, an expansion joint on a fuel line north of the Recovery Plant (on the main mill complex) ruptured, resulting in oil spillage within the sand containment area surrounding the fuel tanks. As a result of this release, DEQ opened a second database entry for Tax Lot 200, T12S, R13W, Section 3 as ECSI #1083 in November 1990.

In 1994, DEQ recommended that a formal site screening be conducted to evaluate the potential for the site (ECSI #528) to pose a threat to human health and the environment due to hazardous substance releases. In August 1995, DEQ completed a Site Evaluation, and concluded that no further action was required regarding the 1984 transformer oil release.

In February 1996, the former fish hatchery site was added to the DEQ's database as ECSI #1829 due to diesel releases associated with fuel-refilling operations at the site. DEQ concluded that further evaluation was necessary, but that the priority for further evaluation was a low priority based on the limited impacts of the release.

In April 1996, DEQ's Site Assessment Section reviewed available documents regarding both the sites (ECSI #528 and #1083), and concluded that further action was necessary to fully characterize the extent and impact of hazardous substances either present or potentially present at the main mill complex. DEQ's priority for further action was considered "medium" (DEQ, 1996).

The facility was proposed to be included on the Confirmed Release List in July 1998, and was formally added to the list in January 1999. Once the remainder of the environmental cleanup and closure activities have been addressed at the site, primarily for the NPDES and Solid Waste permitted facilities, DEQ will provide a public comment period for a proposal to remove the site from the Confirmed Release List.

In February 2004, Weyerhaeuser joined DEQ's Voluntary Cleanup Program to obtain review of their investigation and cleanup activities as a part of their mill decommissioning.

A draft version of this Site Summary Report was made available for public comment during the period from May 1, 2006 until June 1, 2006. The comment period was extended until July 3, 2006 to accommodate a request for a public meeting from a group of 10 or more people. The public meeting was held on June 22, 2006, and was attended by about 24 individuals.

## Investigation and Remediation Summary

Weyerhaeuser evaluated environmental conditions within the main mill complex, including the southern portion of Jordan Point, and the Ingram Yard property as part of the facility closure and decommissioning process. Areas of concern were identified by reviewing data from past environmental assessment work (for both investigation efforts, and for multiple remediation and removal efforts), observations of current site conditions, DEQ's strategy recommendation (including a list of areas DEQ recommended for evaluation), Weyerhaeuser's knowledge of past practices, and the findings of a recent *Level I Environmental Site Assessment* (ESA) report (Delta, 2004). The list of areas of concern and a preliminary scope of work to investigate these areas were provided to and approved by DEQ during April and June 2005.

Table 1 provides details concerning releases and previous work completed in 14 areas of the mill complex that were the subject of the Level II assessment work.

Contaminants detected during investigative work over the years have included: mineral spirits, hydraulic oil, diesel, heavy-oil-range petroleum hydrocarbons (total petroleum hydrocarbons, or "TPH"), heavy metals, butylated tin compounds, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and dioxins. A summary of these detections can be found in tables 1 through 16 in the *Level II Environmental Assessment Report* (PES, 2006). With the exception of the Chip Truck Hydraulic Area, the results of the Level II Environmental Assessment indicated no cleanup was required for the remaining areas of the mill complex or the Ingram Yard, primarily due to previous remedial efforts.

As a result of their Level II investigation, Weyerhaeuser conducted additional soil-excavation work in the Chip Truck Hydraulic Lift Area (Area 4 in Table 1 and in Figure 2) during September 2005. Approximately 700 tons of hydraulic-oil-contaminated soil was removed from the site for disposal at Waste Management's Riverbend Landfill. Post-remediation sampling confirmed that contamination in this area no longer exceeded DEQ's screening levels.

## Risk Evaluation

The Level II Environmental Assessment report included an evaluation of the potential risks posed by residual contamination remaining at the main mill complex and the Ingram Yard. The major conclusions of this analysis were as follows:

- The land use for the main mill site currently is zoned industrial (zoning district code "IND") and it is not reasonably likely to change in the foreseeable future.

- Potable water is provided to the area by the Coos Bay-North Bend Water Board, and it is not likely that shallow water in the vicinity of the main mill complex or the Ingram Yard will be developed as a drinking-water source.

- Contaminant concentrations in soil and groundwater remaining at the site (i.e., post-remediation) were compared to human health risk-based screening tables (e.g., DEQ RBCs, 2005; EPA PRGs, 2004). For human health, the screening was based on occupational worker, excavation worker, and construction worker exposure scenarios for the soil ingestion, dermal contact, and inhalation pathways, and for the volatilization from groundwater into buildings pathway. No residual contaminants in soil or groundwater exceeded these screening values.

- Potential ecological impacts were evaluated for receptors (birds, mammals, invertebrates, and plants) on the main mill complex property, and for the Ingram Yard site. The Level II Environmental Assessment report concluded that ecological receptors are not exposed to residual contamination at the main mill complex because 1) post-remediation contamination is present at depth and not at the surface, and is limited in areal extent; and 2) there is little habitat on the main mill complex that would attract ecological receptors to the property.

- Potential ecological impacts also were evaluated for receptors at the Ingram Yard site. Because the property is largely undeveloped, and because there are potential ecological receptors nearby, Weyerhaeuser conducted additional sampling on the site. The results of the investigation indicated that there were low levels of contaminants present in surface soils on the property. The concentrations were then compared to DEQ's Screening Level Values (DEQ, 2001) for birds, mammals, invertebrates, and plants. No ecological screening values were exceeded for contaminants present at the Ingram Yard.

- DEQ does not have risk-based screening values for TPH in the heavy oil-range hydrocarbon range (i.e., hydraulic oil) for evaluating subsurface soil contamination in the vicinity of the south "lowerator" (Area 10 in Table 1 and in Figure 2; located at a depth greater than 5 feet), or for TPH in the mineral-spirits-range hydrocarbon range for residual contamination in the vicinity of the mineral-spirits release (Area 2 in Table 1 and in Figure 2).

- However, no specific "constituents" (e.g., polynuclear aromatic compounds such as naphthalene) in the soils in the "lowerator" area or in the post-remediation soils in the mineral-spirits release area exceeded screening levels. In addition, the hydraulic oil contamination in the "lowerator" the area is covered by an 8-inch thick concrete slab plus five feet of gravel. For these reasons, the Level II Environmental Assessment report concludes that these two areas do not currently pose a threat to human health and the environment (details provided in the Level II ESA report).

- The occurrence and amount of asbestos-containing transite siding buried in a fill area on south Jordan Point appears to be limited. Because the buried asbestos-containing material is considered a solid waste under DEQ's rules, any waste generated in the course of future site re-development should be properly managed and disposed at a DEQ-approved disposal facility.

Based on questions and comments received during the public comment period, DEQ re-examined the bioaccumulative potential (including their potential for bioconcentration and/or biomagnification) for residual contaminants in surface soils at the Ingram Yard site, and re-confirmed that they do not pose a threat to human health or ecological receptors at levels above DEQ's acceptable risk levels as outlined in OAR 340-122. However, they potentially could exceed applicable screening criteria[1] if they were disposed in waters of the State.

DEQ also conducted a more detailed analysis of the prey species and food sources for threatened or endangered (T&E) birds, including that protective of the snowy plover. According to our calculations, no adverse effects are likely to occur to upland birds from exposure to residual concentrations of dioxins present in surface soils at the Ingram Yard.

## Public Process

There was a 63-day public comment period from May 1, 2006 through July 3, 2006. Public notice was published in the Secretary of State's Bulletin and in a local newspaper (The World in Coos Bay).  Based on a written request by ten or more persons, a public meeting was be held in Coos Bay on June 22, 2006 to receive comments from interested parties. DEQ received two sets of formal comments from one individual (totaling 8 pages).

DEQ considered all public comments. As a result of public concerns, questions, and comments, DEQ is adding additional language to our NFA determination letter to notify future land owners that surface soils containing residual concentrations of dioxin from the Ingram Yard be managed carefully according to Solid Waste regulations, and not be disposed in waters of the State.

[1] DEQ is developing screening tables and guidance for evaluating bioaccumulative chemicals in sediments. A June 19, 2006 Technical Advisory Panel draft was available at the time this Site Summary Report was updated.

## Conclusions

Multiple site investigations completed at the former Weyerhaeuser Containerboard Mill identified 14 areas of potential environmental concern. Following an investigation in the summer of 2005, a total of about 700 tons of soil were removed for offsite disposal from one area with soil contamination that exceeded DEQ's screening levels. Investigation and post-remediation samples indicate little or no residual contamination exceeding DEQ screening levels in soil or groundwater with the exception of TPH-contaminated soils in the south "lowerator" area, and residual post-remediation TPH contamination in the mineral-spirits release area.

DEQ staff have evaluated the work completed at the site. Based on our evaluation, there is no apparent threat to human health or the environment posed by residual hazardous-substance contamination at the main mill complex and on the Ingram Yard parcel under current or reasonably likely future development scenarios.

## Determinations

DEQ considers the investigation and cleanup at the former Weyerhaeuser Containerboard Mill to be complete and recommends that, unless new or previously undisclosed information becomes available which warrants further investigation, no further action is required at the main mill complex and the Ingram Yard under ORS 465.200, et. seq.

However, the full extent of the hydraulic oil release in the vicinity of the south "lowerator" has not been determined due to the presence of a thick concrete slab and a railroad spur. Therefore, we recommend that a supplementary investigation (and subsequent remediation, if necessary) be conducted if the concrete slab is ever removed.

Also, there are low levels of residual TPH contamination below the concrete slab in the mineral-spirits release area. Therefore, if this area is exposed, any soils removed must be properly managed and/or disposed in accordance with DEQ rules.

In addition, the small amounts of transite siding in the fill area on south Jordan Point, if ever excavated in future site redevelopment activities, must be properly managed and disposed at a DEQ-approved disposal facility.

The monitoring wells at the facility associated with the hazardous-substance investigation and removal actions should be abandoned according to the Oregon Water Resources Department rules, unless they continue to serve a purpose for Weyerhaeuser.

Finally, while surface soils at the Ingram Yard site meet human health and ecological screening criteria, they contain low levels of potentially bioaccumulating chemicals and must not be placed in waters of the state.

## References

CH2M HILL, 1996. *Technical Memorandum 2, Phase II – Ingram Site Investigation, North Bend, Oregon*. Prepared for Weyerhaeuser. October 10, 1996.

DEQ, 1996. *Site Assessment Section – Strategy Recommendation, Weyerhaeuser – Jordan Point*. April 16, 1996.

DEQ, 2001. *Guidance for Ecological Risk Assessment, Level II Screening Level Values*. Updated December, 2001.

DEQ, 2002. Memorandum from Toxicology Group to DEQ Cleanup Project Managers, Subject: Default Background Concentrations for Metals. October 28, 2002.

DEQ, 2005. *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites, Risk-Based Concentrations for Individual Chemicals*. July, 2005.

DEQ, 2006. Former *Weyerhaeuser North Bend Containerboard Mill Response to Comments.* September 7, 2006.

Delta, 2004. *Level I Environmental Site Assessment – Weyerhaeuser Company, Horsefall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. June, 2004.

EPA, 2004. US EPA Region 9's Preliminary Remediation Goals (PRG) Table. October, 2004.

NGA, 2005. *Geophysical Site Investigation – Weyerhaeuser Mill Site, North Bend, Oregon*. Prepared for Weyerhaeuser Company. April 15, 2005.

PES, 2005. *Work Plan, Level II Environmental Assessment, Former Weyerhaeuser Containerboard Mill, North Bend, Oregon*. Prepared for Weyerhaeuser Company. May 26, 2005.

PES, 2006. *Level II Environmental Assessment, Former Weyerhaeuser Containerboard Mill, North Bend, Oregon*. April, 2006.

SEACOR, 1992a. *Soil and Groundwater Investigation Report – Weyerhaeuser Paper Company North Bend Mill, Jordan Point Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. May 14, 1992.

SEACOR, 1992b. *Soil Remediation Report – Anadromous Fish Hatchery, Jordan Point Road, North Bend, Oregon*. Prepared for Moor-Clarke Company. August 21, 1992.

SEACOR, 1992c. *Phase II Soil and Groundwater Investigation Report – Weyerhaeuser Paper Company North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. October 28, 1992.

SECOR, 1993a. *Additional Environmental Services and Feasibility Study Report for Mineral Spirits Area – Weyerhaeuser Paper Company North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. January 4, 1993.

SECOR, 1993b. *May 1993 Quarterly Groundwater Monitoring Report – Weyerhaeuser Paper Company North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. October 4, 1993.

SECOR, 1993c. *February 1993 Quarterly Groundwater Monitoring Reportand March 1993 Soil/Sediment Assessment Report – Weyerhaeuser Paper Company North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. October 8, 1993.

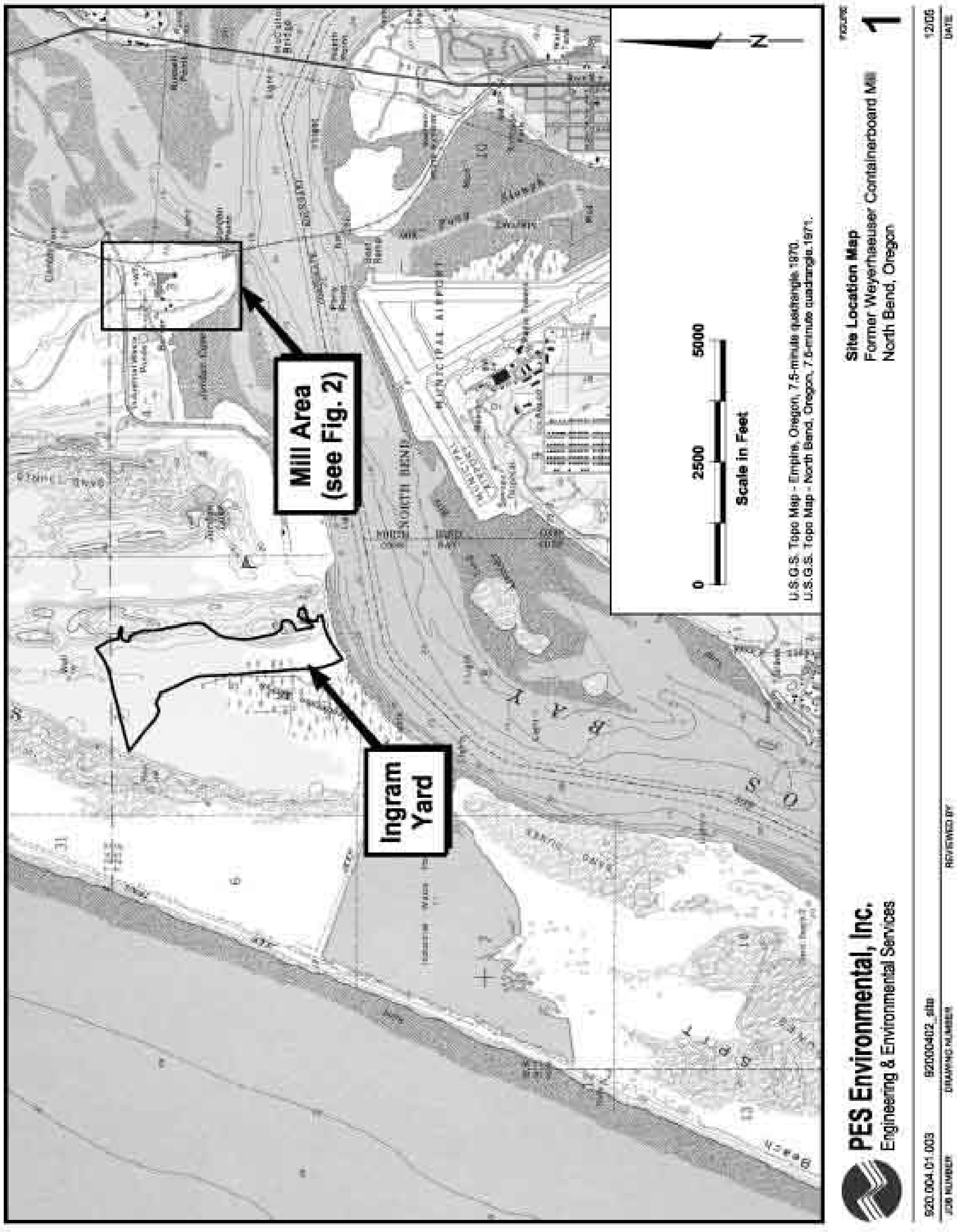
SECOR, 1995a. *Fourth Quarter 1994 Groundwater Monitoring Report – Weyerhaeuser North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. February 21, 1995.

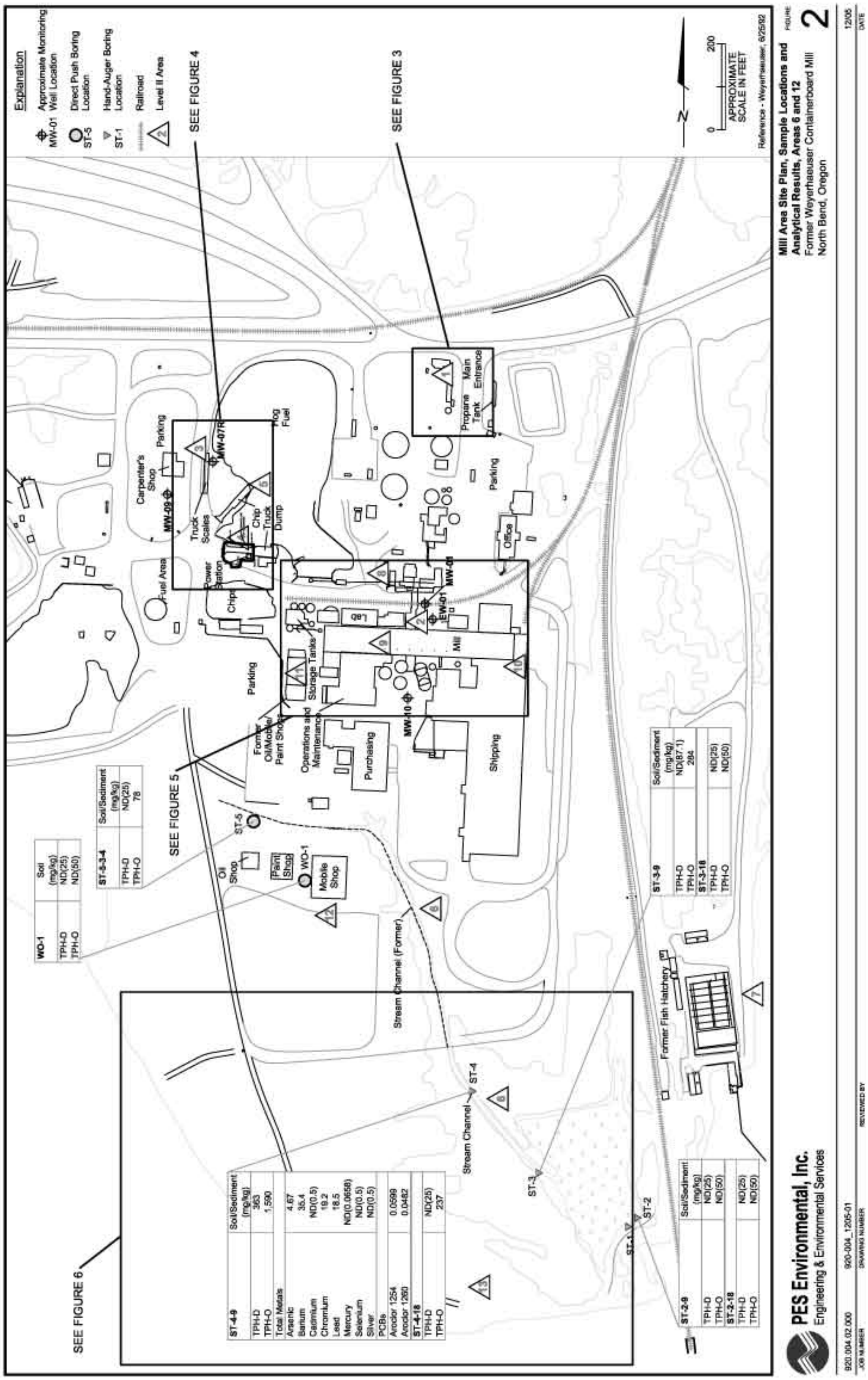
SECOR, 1995b. *Soil Boring/Sampling Investigation Report, Mineral Spirits Area - Weyerhaeuser North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. March 21, 1995.

SECOR, 1995c. *Geoprobe Soil Sampling Investigation Report - Weyerhaeuser North Bend Mill, Truck Scales Area, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. October 3, 1995.

SECOR, 1995d. *Geoprobe Sampling Investigation Report, Chip Truck and Hog Fuel Hydraulic Lift Areas - Weyerhaeuser North Bend Mill, Horsfall Beach Road, North Bend, Oregon. Prepared for Weyerhaeuser Company*. December 7, 1995.

SECOR, 1996. *Fourth Quarter 1995 Groundwater Monitoring Report – Weyerhaeuser North Bend Mill, Horsfall Beach Road, North Bend, Oregon*. Prepared for Weyerhaeuser Company. January 19, 1996.


Mill Area
(see Fig. 2)
Ingram
Yard
0
2500
5000
Scale in Feet
U.S.G.S. Topo Map - Empire, Oregon, 7.5-minute quadrangle 1970.
U.S.G.S. Topo Map - North Bend, Oregon, 7.5-minute quadrangle 1971.
PES Environmental, Inc.
Engineering & Environmental Services
Site Location Map
Former Weyerhaeuser Containerboard Mill
North Bend, Oregon
1
920.004.01.003
92000402_site
12/05


Explanation
MW-01 Approximate Monitoring Well Location
ST-5 Direct Push Boring Location
ST-1 Hand-Auger Boring Location
Railroad
Level II Area
SEE FIGURE 4
SEE FIGURE 3
SEE FIGURE 5
SEE FIGURE 6
APPROXIMATE SCALE IN FEET
Reference - Weyerhaeuser, 6/25/92
Mill Area Site Plan, Sample Locations and Analytical Results, Areas 6 and 12
Former Weyerhaeuser Containerboard Mill
North Bend, Oregon
FIGURE
2
PES Environmental, Inc.
Engineering & Environmental Services
Parking
Carpenter's Shop
Fuel Area
Power Station
Truck Scales
Chip Truck Dump
Hog Fuel
Propane Tank
Main Entrance
Office
Lab
Mill
Storage Tanks
Operations and Maintenance
Former Oil/Mobile Paint Shop
Purchasing
Shipping
Oil Shop
Paint Shop
Mobile Shop
Stream Channel (Former)
Stream Channel
Former Fish Hatchery
WO-1
TPH-D ND(25)
TPH-O ND(50)
ST-5-3-4
TPH-D ND(25)
TPH-O 78
ST-3-9
TPH-D ND(87.1)
TPH-O 284
ST-3-18
TPH-D ND(25)
TPH-O ND(50)
ST-4-9
TPH-D 363
TPH-O 1,590
Arsenic 4.67
Barium 35.4
Cadmium ND(0.5)
Chromium 19.2
Lead 18.5
Mercury ND(0.0658)
Selenium ND(0.5)
Silver ND(0.5)
Aroclor 1254 0.0599
Aroclor 1260 0.0482
ST-4-18
TPH-D ND(25)
TPH-O 237
ST-2-9
TPH-D ND(25)
TPH-O ND(50)
ST-2-18
TPH-D ND(25)
TPH-O ND(50)

| Table 1: Areas identified in DEQ Strategy Recommendation dated April 16, 1996 (DEQ ECSI # 1083) | | | |
|---|---|---|---|
| **Area** | **Previous work/data** | **DEQ identified data gaps** | **Scope of work** |
| 1 - Fuel Oil Release Area | Release from former reprocess fuel oil (RFO) or "cutter stock oil" AST. Soil excavation was conducted and soil and groundwater analyzed for TPH and BTEX. TPH in soil up to 57,200 mg/kg left in place near SE corner of excavation at 5 feet bgs. Groundwater samples east and west of source ND for TPH and BTEX. Release(s) in the RFO transfer area indicated by prior observations of soil staining. Site records indicate the area was paved over with asphalt to limit potential soil impacts. A broken pipe for the RFO storage area sump and apparently related surface staining near the boiler building was noted in December 2003. | In the fuel oil release area, future work should address residual PAH concentrations in soil. | Assessment of soils for TPH and PAHs. Evaluate need for potential groundwater assessment based on soil conditions. Consider excavation of impacted soils. |
| 2 - Mineral Spirits Release Area | Mineral spirits releases from USTs and AST system on north side of mill building. Soil excavation and soil and groundwater analysis conducted, and remediation system installed. TPH-impacted soil left in place due to adjacent structures. TPH and PAHs in groundwater based on groundwater monitoring results. Three wells (EW-1, MW-1, and MW-10) are still present in this area. | In the mineral spirits release area, future work should address residual TPH concentrations in soil and groundwater including potential downgradient (southeast) migration of contaminants. Analysis for PAHs and VOCs is appropriate. Existing structures impede groundwater sampling southeast of the source. | Redevelop and sample existing wells EW-1, MW-1 and MW-10. Further assess the extent of impacts in soil and groundwater as practical when adjacent structures are removed. Consider additional soil excavation after removal of adjacent structures. |
| 3 - Truck Scales and Carpenter's Shop Area | Three USTs (gasoline, diesel, and mineral spirits) of unknown size were removed from this area and no soil samples were collected during the removals. The gasoline and diesel USTs were located north of the truck scales and the mineral spirits UST was located north of the carpenter's shop. Soil and groundwater assessment revealed TPH impacts in soil, and TPH and PAH impacts in groundwater. Two wells (MW-07R and MW-09) are still present in this area. | In the truck scales and carpenter's shop area, future work should address residual TPH concentrations in soil and groundwater including appropriate characterization of soils in the vicinity of the former mineral spirits and gasoline/diesel USTs; and the presence of elevated TPH concentrations in groundwater (MW-7). | Redevelop and sample wells MW-07R and MW-09. Further characterize impacts to soil and groundwater including TPH, PAHs, and VOCs. |

| Table 1: Areas identified in DEQ Strategy Recommendation dated April 16, 1996 (DEQ ECSI # 1083) | | | |
|---|---|---|---|
| **Area** | **Previous work/data** | **DEQ identified data gaps** | **Scope of work** |
| 4 - Chip Truck Hydraulic Lift Area | Assessment work in this area has revealed elevated TPH concentrations in soil up to 100,000 mg/kg and a groundwater TPH concentration of 0.78 mg/L. | In the chip truck hydraulic lift area, future work should address PAH concentrations in soil and groundwater. | Further characterize impacts to soil and groundwater for TPH and PAHs. Excavate soils with TPH impacts up to 100,000 mg/kg in the chip truck hydraulic lift area. |
| 5 - Hog Fuel Hydraulic Lift Area | Assessment work in this area has revealed elevated TPH concentrations in soil up to 380 mg/kg and a groundwater TPH concentration of 1.0 mg/L. | In the hog fuel hydraulic lift area, future work should address PAH concentrations in soil and groundwater. | Further characterize impacts to soil and groundwater for TPH and PAHs. |
| 6 - Stream Channel Area | A former stream channel drained south-southeast from the maintenance shop, approximately 1,600 feet to Coos Bay. The northern portion has been culverted and paved over, but the southern 3/4 of the stream channel still exists. An earthen dam was constructed on the lower section of the channel to restrict potential releases of oil from discharging to the bay. A sediment/sludge sample collected upstream of the dam had a TPH concentration of 5,400 mg/kg (diesel and Bunker C ranges). Subsequent analyses revealed TPH concentrations up to 12,000 mg/kg downstream of the dam. | In the stream channel area, future work should address PAH concentrations in the vicinity of the current and former stream channel, as well as PCB and metal concentrations. | Further characterize impacts to the stream channel for TPH, and assess for PAHs, PCBs and metals. |

| Table 1: Areas identified in DEQ Strategy Recommendation dated April 16, 1996 (DEQ ECSI # 1083) | | | |
|---|---|---|---|
| **Area** | **Previous work/data** | **DEQ identified data gaps** | **Scope of work** |
| 7 - Anadromous Fish Hatchery | DEQ ECSI # 1829. ECSI report indicates surface and near-surface impact to soil from diesel AST. DEQ evaluation from "unsolicited report", but no specific information is included. | State based Preliminary Assessment recommended in 1996. Low priority site based on review of report conclusions. PES reviewed report that indicates soils with TPH impacts were excavated to non-detect levels. The results in the report should be sufficient for DEQ to make a NFA determination. Disposition of excavated soils that were stockpiled on-site is not known. | Review DEQ (and Weyerhaeuser?) files for more specific information regarding disposition of stockpiled soils. Assume no additional susurface assessment needed. Possible characterization of stockpiled soils. |
| 8 - Ash Bunkers | Ash bunkers/pits were located adjacent to boilers/powerhouse and used to accumulate and temporarily store ash. Overflow ash from the west bunker was stored on the ground surface on the west side of the bunker. Analytical testing of the ash has been performed. | Potential impacts to soils underlying/adjacent to the bunkers/pits from ash constituents (dioxins/furans and metals). Ground surface on the west side of the west bunker considered most likely location for potential "worse-case" impacts. | Assessment of soils for dioxins/furans and metals. |
| 9 - Paper Machine Floor Drains and Sumps | A floor drain system and several containment areas/sumps for hydraulic equipment, etc. are located on the ground floor of the main mill building below the paper machines. Oily water and oil staining of the floor drains and containment areas. | Potential impacts to fill/soil underlying the floor drains and containment areas for TPH. | Assessment of fill/soil for TPH and PAHs. |

| Table 1: Areas identified in DEQ Strategy Recommendation dated April 16, 1996 (DEQ ECSI # 1083) | | | |
|---|---|---|---|
| **Area** | **Previous work/data** | **DEQ identified data gaps** | **Scope of work** |
| 10 - "Lowerators" in shipping warehouse | Two elevators ("lowerators") were used to lower paper rolls from the upper floor of the paper machine building to the ground floor in the storage/shipping warehouse. The elevators had hydraulic lifts to raise/lower the elevators that were located beneath the elevators in sub-floor pits that have concrete walls and bases. One of these elevators was decommissioned approximately 15 years ago and the former pit was filled with gravel and capped with concrete to match the floor grade. The other elevator was recently dismantled as part of the mill decommissioning work and the elevator pit, which is approximately 10 feet deep, was found to contain water. After pumping to de-water the pit, the pit re-filled with water to approximately 6 to 8 feet below grade indicating that groundwater enters the pit. | Potential TPH impacts (from hydraulic oil) to surrounding fill/soil and potential impacts to groundwater. | Assessment of fill/soil and groundwater for TPH and PAHs. |
| 11 - Former Oil Shop, Mobile Shop, and Paint Shop | Former storage and use of petroleum products and wastes, solvents, and other chemicals used for maintenance and repair of vehicles. Former storage of paint and related materials in paint shop. Existing remnants of the shops include concrete slabs that were the former shop floors and a former service pit in the former oil shop that was filled with gravel and capped with concrete to match grade. | Potential impacts to to fill/soils underlying and adjacent to the former shops and beneath the service pit for TPH and solvents. Also potential for metals from used oil and paints | Assessment of fill/soils for TPH, PAHs, VOCs, and metals (RCRA 8). Evaluate need for potential groundwater assessment based on soil conditions. |
| 12 - Mobile Shop | Storage and use of petroleum products and wastes, solvents, and other chemicals used for maintenance and repair of vehicles. Drum storage in secondary containment areas on outside of mobile shop building. Surface staining around containment area. | Potential impacts to fill/soils underlying the containment areas from TPH and solvents. | Assessment of fill/soils for TPH, PAHs, VOCs and metals (cadmium, chromium and lead). |

| Table 1: Areas identified in DEQ Strategy Recommendation dated April 16, 1996 (DEQ ECSI # 1083) | | | |
|---|---|---|---|
| **Area** | **Previous work/data** | **DEQ identified data gaps** | **Scope of work** |
| 13 - South Jordan Point Debris/Fill Area | Areas of fill and debris that includes steel plates, wire, and asbestos-containing transite siding exist in the southern portion of Jordan Point. Debris is present on the surface and this material was encountered by Weyerhaeuser during trenching and installation of a rock wall for erosion control along the shorleine. Apparent filling in this area is evident in historical aerial photographs. In March 2005, Weyerhaeuser had a non-intrusive geophysical investigation of the area conducted to help delineate areas of fill/debris. The investigation identified several "anomoly areas" indicative of buried debris/fill. | Potential concerns associated with asbestos-containing transite siding. Documentation of fill/dedris areas for future land use/development. | Assessment of fill/debris areas to evaluate the locations, extent and types of material. Evaluate amount and composition of transite siding and other materials present. |
| 14 - Ingram Yard | The Ingram Yard has been used as a livestock ranch, dredge spoils disposal site (from Coos Bay dredging by U.S. Army Corps), and a log sorting and chipping yard. Sand, boiler ash, and wood debris have been placed on the Ingram Yard site and land-spreading of decant basin solids (sludge) has also occurred at the site. In 1996, a phase II investigation was conducted that included included review of existing analytical data for ash, sludge and dredge spoils, and sampling and analysis for metals, TPH, VOCs, PCB, and SVOCs. The quantity and distribution of of ash, sludge, and dredge spoils placed on the property were also assessed. | Potential impacts related to past placement of boiler ash, wood debris, and dredge spoils, and land spreading of decant basin solids. Dioxin/furans, metals, and tributyltin are a potential concern. | Review existing information and documentation. Assess shallow soil/fill for dioxins/furans, metals, and tributyltin. |

GRI
9725 SW Beaverton-Hillsdale Hwy, Suite 140
Beaverton, OR 97005-3364
p| 503-641-3478 f| 503-644-8034

September 21, 2012

4277-S JOINT CLOSURE WORK PLAN

Jordan Cove Energy Project
Energy Projects Development LLC
125 Central Avenue, Suite 380
Coos Bay, OR 97420

Attention: Robert L. Braddock

**SUBJECT: Work Plan for Joint Program Regulatory Closure**
**Settling Basins, Petroleum Contaminated Soil, Asbestos Waste, and Mill Waste**
**Weyerhaeuser Mill Site and Ingram Yard Properties**
**Oregon Department of Environmental Quality**
**ECSI #1083, ECSI #4704, and NPDES #101499**
**Coos County, Oregon**

At your request, GRI has prepared this work plan for joint program regulatory closure related to the Weyerhaeuser Corporation (Weyerhaeuser) mill site (Mill Site) property at 92770 Trans-Pacific Parkway and the related Ingram Yard property in Coos County, Oregon. We understand Jordan Cove Energy Project (JCEP) presently owns the Ingram Yard property and plans to purchase the Mill Site property. The purpose of this work plan is to outline the program of anticipated steps that will be completed to address Oregon Department of Environmental Quality (DEQ) Water Quality and Land Quality program closure requirements in conjunction with site redevelopment activities. Solid Waste landfill closure at the Mill Site will be addressed under separate cover at a future time.

It is the intent of this work plan to provide that hazardous/regulated materials will be managed and disposed of according to state and federal laws and regulations and in compliance with associated permits.

## BACKGROUND

JCEP plans to construct industrial facilities at the Mill Site and at the Ingram Yard property located about 1/2 mile west. The locations of these areas are shown on the Location Map, Figure 1. The Mill Site is formally described as tax lots 25S-13W-4-100 and 25S-13W-3-200 (mill) and the Ingram Yard portion of tax lots 25S-13 W-0-200.

Ingram Yard and adjacent land will be developed with a new slip for ocean-going vessels. The slip construction will generate several million cubic yards (cy) of clean sand fill that will be used to raise site grades in and adjacent to Ingram Yard; site grade at the Mill Site will be raised to about elevation 40 ft NGVD. These activities are proposed to commence in 2013.

The Mill Site property has been owned and operated by Weyerhaeuser and is listed in the DEQ cleanup, leaking underground storage tank, hazardous waste, solid waste, and water discharge programs. Portions of the site have received environmental closure (Land Quality Program: Mill Site, #ECSI 1083; Ingram Yard, #ECSI 4704), and others are still under regulatory oversight and require periodic monitoring (Water Quality Program: industrial wastewater for Mill Site, National Pollution Discharge Elimination System

[NPDES] permit #101499). In 2006, DEQ issued a conditional "No Further Action" determination for the Mill Site and Ingram Yard, and it is the intent of this work plan to be consistent with the conditions outlined in that determination (DEQ, 2006).

GRI, JCEP, and Weyerhaeuser personnel met in April 2012 to review conceptual closure of the settling basins and landfills at the Mill Site. GRI, JCEP, and DEQ personnel also met in April 2012 to discuss closure of the existing settling basins, asbestos waste areas, residual areas under mill slab remnants with total petroleum hydrocarbons (TPH), and landfills (Cell 1, 2, and 3). The Cell 3 landfill has about 63,000 cy of capacity remaining (Thiel Engineering, 2004).

**MILL SITE**

**General.** JCEP plans to redevelop the Mill Site with a new industrial facility. Existing site grades will be raised a minimum of 3 ft with clean structural fill consisting of sand from the new slip to be excavated on the Ingram Yard property. Development over the existing mill wastewater system settling basins will require overexcavation of geotechnically unsuitable (highly organic) sludge in the basins and replacement with clean compacted structural fill. The approximate locations of the settling basins are shown on the Basin Detail Plan, Figure 2. Areas where structures will be seismically designed to minimize settlements will require ground improvement below existing site grades to a depth of about 35 ft to increase the density of the loose to medium dense sand fill. Methods of ground improvement have not been selected, but could include dynamic compaction or vibro compaction. These ground improvement methods are discussed in more detail below.

**Ground Improvement Considerations.** Dynamic compaction is a ground improvement technique that densifies soils and fills by using a drop weight. The drop weight, typically hardened steel plates, is lifted by a crane and repeatedly dropped on the ground surface. The mass of the drop weight and the drop height are determined by the specialty subcontractor based on the subsurface conditions and the resulting depth of the impact crater; too much compaction in a single drop can make removal of the weight difficult. Dynamic compaction is typically completed in a grid pattern; the spacing of the drop locations is determined by the subsurface conditions and foundation loading and geometry. Densification of granular soils using dynamic compaction is generally limited to a depth of about 30 to 35 ft. Following densification, the impact craters are filled with compacted clean granular structural fill material. An advantage of dynamic compaction for this site is that spoils are not generated, and there is limited risk of contaminated material being brought to the ground surface.

Vibro compaction is a ground improvement technique used to densify granular soils using a downhole vibratory probe to depths in excess of 100 ft, if necessary. The probe is lowered vertically into the soil, typically with a standard crane. After reaching the bottom of the treatment zone, the soils are densified as the probe is raised. Some settlement of the ground surface typically occurs as the underlying soils are densified. Vibro compaction in relatively clean sand results in limited spoil return to the ground surface. As a conservative assumption of this work plan, we have assumed vibro compaction or some other method of spoil-generating ground improvement may be selected.

**Settling Basins**

The mill was operated between 1961 and 2003 and required the use of two approximately 1-acre, 20-ft-deep, unlined settling basins at the locations shown on Figure 2. The basins connect in series and were used to treat facility wastewater by settling, evaporation, and infiltration. Leachate from the lined landfill Cell 3 continues to be discharged to the basins. Overflow fluids from the basins are collected in a sump and pumped to an off-site aeration basin west of Ingram Yard. Approximately 42,000 cy of sludge is present in the two unlined basins (GSI Water Solutions, Inc., 2012; Thiel Engineering, 2004). This volume will be reconfirmed (or re-estimated, as necessary) in summer 2012 by GRI to assist JCEP with cost estimating.

**Closure Plan:** A qualified contractor will be mobilized, and a dredge will be used to remove the basin sludge to a dewatering system. The dewatering system will be specified to reduce the 42,000 cy of sludge to approximately 2,500 cy of solids cake (about 3,000 dry tons). The solids cake will then be transported to an open area in the Cell 3 landfill for permanent disposal. Liquid from the dewatering process will be drained to the settling basins for reuse in dredging or drained to a sump and discharged to the off-site aeration basin as part of the existing wastewater conveyance system.

After completion of dredging and dewatering operations, the basins will be backfilled with approximately 50,000 cy yards of compacted structural sand fill. The solids cake placed in the Cell 3 landfill will be covered with a minimum 18 in. of clean sand as an interim measure pending final closure of the landfill. The surface of the solids cake area will be sloped to drain away from the center of the landfill.

Site observation during removal and disposal will be completed by an approved environmental firm, and a daily site visit report will be prepared. A summary report documenting the removal activities will be prepared and submitted to DEQ as technical basis for the closure of the settling basin system of NPDES #101499.

**Residual TPH**

Areas with residual TPH are known to exist in the mill site at the "lowerator" and mineral spirits release areas (DEQ, 2006), see Residual Mill Contamination, Figure 3. Ground improvement activities in these areas could potentially generate spoils that are impacted with TPH.

**Closure Plan:** Spoil from the ground improvement activities in the lowerator and mineral release area will be managed as petroleum-contaminated soil and transported off-site to an approved DEQ-regulated facility. Site observation during ground improvement activities will be completed by an approved environmental firm, and a daily site visit report will be prepared. A summary report documenting the removal activities will be prepared and submitted to DEQ as partial technical basis for the closure of the residual TPH areas of #ECSI 1083.

**Asbestos-Containing Material (ACM) Waste Area**

An area with ACM waste is located in the southern portion of the Mill Site (DEQ, 2006). The general and detailed locations of ACM are shown on Figures 3 and 4, respectively. The ACM areas encroach on Coos Bay and several wetland areas. Ground improvement activities in the ACM area will be limited to methods that do not generate spoil (likely dynamic compaction). Where the new sand fill encroaches on Coos Bay and the wetland shorelines, some excavation may be required to establish a toe trench for stability of the new fill perimeter. The toe trench excavations may encounter ACM; however, trench design will be optimized to reduce the footprint of excavation, thereby decreasing the volume of potentially hazardous material excavated.

**Closure Plan:** To reduce the potential for fiber release, a minimum of 3 ft of clean sand will be placed over the area with the ACM. Any ground improvement completed in the ACM area will likely be completed with dynamic compaction with wet working area (water mister).

Toe trench excavation will be completed by equipment operators and personnel with asbestos training using water misters to suppress potential airborne asbestos. Any ACM excavated will be double bagged in accordance with DEQ asbestos regulations and disposed of as allowed by permit in landfill Cell 3. ACM placed in Cell 3 will be covered with a minimum 18 in. of clean sand as an interim measure pending final closure of the landfill. The trench work area will be self-contained and interior drained to reduce the potential for construction runoff.

Site observation during ground improvement and toe trench activities will be completed by an approved environmental firm, and a daily site visit report will be prepared. A summary report documenting the removal activities will be prepared and submitted to DEQ as partial technical basis for the closure of the asbestos waste areas of #ECSI 1083.

## INGRAM YARD

### Wood Waste

Approximately 13,000 cy of non-hazardous log yard sort debris consisting of wood and barkdust waste is located in the southern portion of Ingram Yard in the area of the proposed slip (CH2M Hill, 1996). The location of the log yard sort debris is shown as Area 6 on the Ingram Yard Detail, Figure 5. This material was generated as part of the Mill Site operation and placed in Ingram Yard.

**Closure Plan:** The log yard sort debris will be managed as permitted non-hazardous solid waste. The debris will be excavated and removed by truck to the Mill Site landfill Cell 3 for permanent disposal. Site observation during removal and disposal will be completed by an approved environmental firm, and a daily site visit report will be prepared. A summary report documenting the removal activities will be prepared and submitted to DEQ as part of the Ingram Yard closure for case file #ECSI 4704.

### Sludge Waste

Approximately 116,000 cy of non-hazardous sludge waste is located in the north and central portion of Ingram Yard. The location of the sludge waste is shown as Areas 1 through 5 on the Ingram Yard Detail, Figure 5. This material was generated as part of the Mill Site operation and placed in Ingram Yard. The material has been characterized by PES Environmental, Inc. (2006) and GRI (2007). DEQ has indicated the material is suitable for upland industrial facility disposal provided the materials are not placed in the state waters (DEQ, 2006; 2012).

**Closure Plan:** The sludge will be managed as permitted non-hazardous solid waste. The sludge in the area of the slip and below the footprint of planned industrial facility on and adjacent to Ingram Yard will be excavated and placed in a new soil berm to be constructed adjacent to the rail line along the northernmost portion of Ingram Yard. The sludge in the soil berm will be capped with a minimum of 2 ft of clean sand from the slip excavation. Any excess sludge will be relocated by truck back to the Mill Site landfill Cell 3 for permanent disposal and capped with a minimum 18 in. of clean sand as an interim measure pending final closure of the landfill. Relocation of the sludge to the new soil berm or Cell 3 will provide a final disposal location consistent with the existing closure determination (DEQ, 2006).

Site observation during removal and disposal will be completed by an approved environmental firm, and a daily site visit report will be prepared. A summary report documenting the removal activities will be prepared and submitted to DEQ as part of the Ingram Yard closure for case file #ECSI 4704.

## CONCLUDING REMARKS AND LIMITATIONS

We recommend this work plan be submitted to the DEQ Eugene office to the attention of Bill Mason for his review and comment.

The information presented in this work plan is based on our present understanding of the site environmental conditions, regulatory constraints, and site redevelopment plan. No other warranty or representation, either expressed or implied, is included or intended.

Please contact the undersigned if you have any comments or questions.

Submitted for GRI,

George A. Freitag, CEG
Associate

**References**

CH2M Hill, October 1, 1996, Figure 4 of Technical Memorandum: Phase II Ingram Site Investigation, North Bend, Oregon; prepared for Weyerhaeuser Corporation.

GRI, January 16, 2007, Phase II environmental site assessment, Jordan Cove task order no. 8, Jordan Cove LNG facility, Coos County, Oregon.

GSI Water Solutions, Inc., March 29, 2012, Technical memorandum, evaluation of sludge basin closure options, Weyerhaeuser North Bend facility, Coos County, Oregon, 2012; prepared for Weyerhaeuser Corporation.

Oregon Department of Environmental Quality ECSI Database, accessed May 25, 2012.

http://www.deq.state.or.us/lq/ECSI/ecsidetail.asp?seqnbr=1083

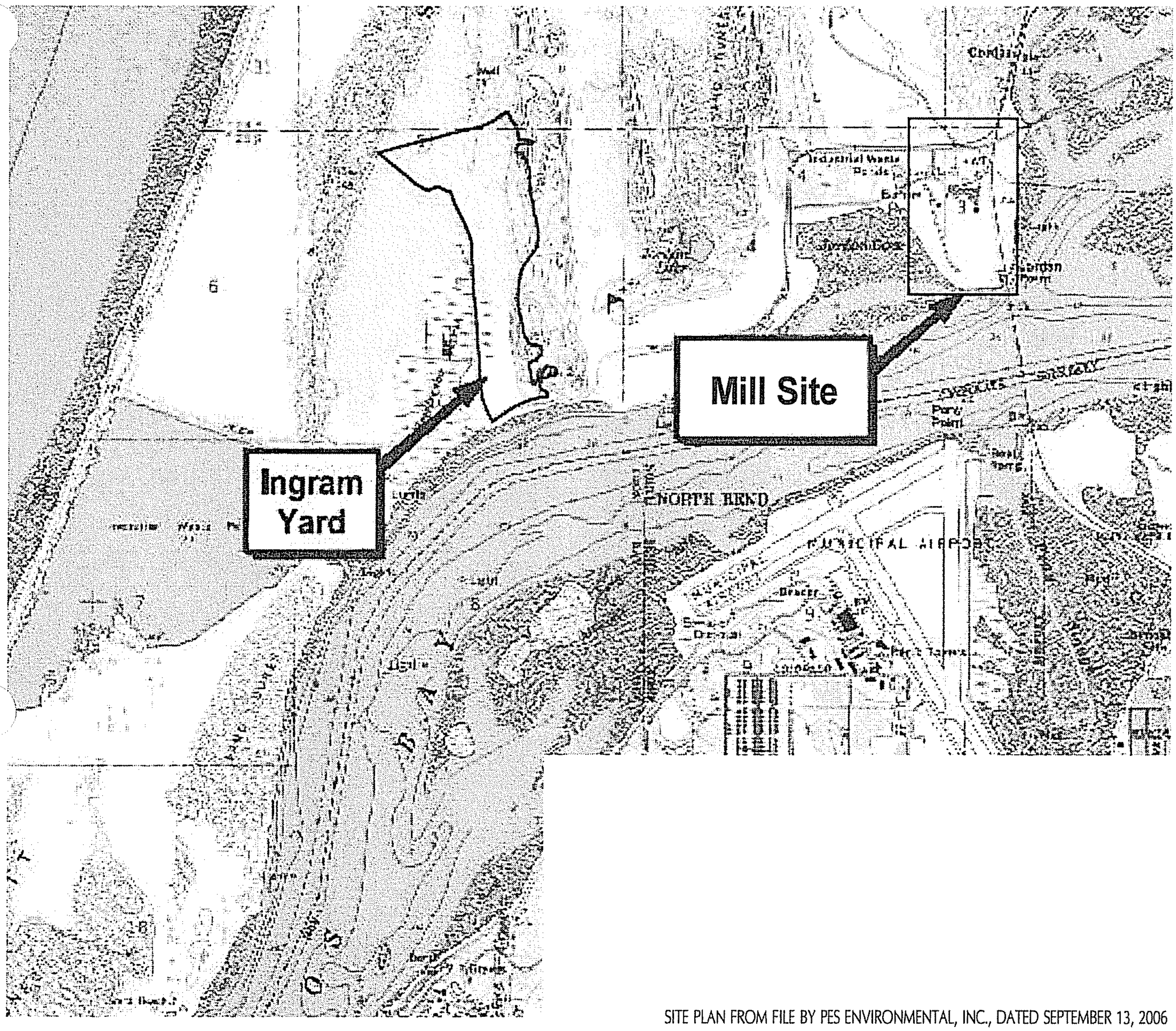
http://www.deq.state.or.us/lq/ECSI/ecsidetail.asp?seqnbr=4704

Oregon Department of Environmental Quality, September 2006, No Further Action Determination.

http://www.deq.state.or.us/Webdocs/Controls/Output/PdfHandler.ashx?p=9578873c-b8ec-4ac8-a267-599090b94aa8.pdf

PES Environmental, Inc., April 2006, Level II environmental assessment, former Weyerhaeuser containerboard mill, North Bend, Oregon.

Thiel Engineering, April 2004, Technical and cost evaluation, elements of environmental closure for the Weyerhaeuser containerboard packaging facility, North Bend, Coos County, Oregon; prepared for Weyerhaeuser Corporation.




SITE PLAN FROM FILE BY PES ENVIRONMENTAL, INC., DATED SEPTEMBER 13, 2006

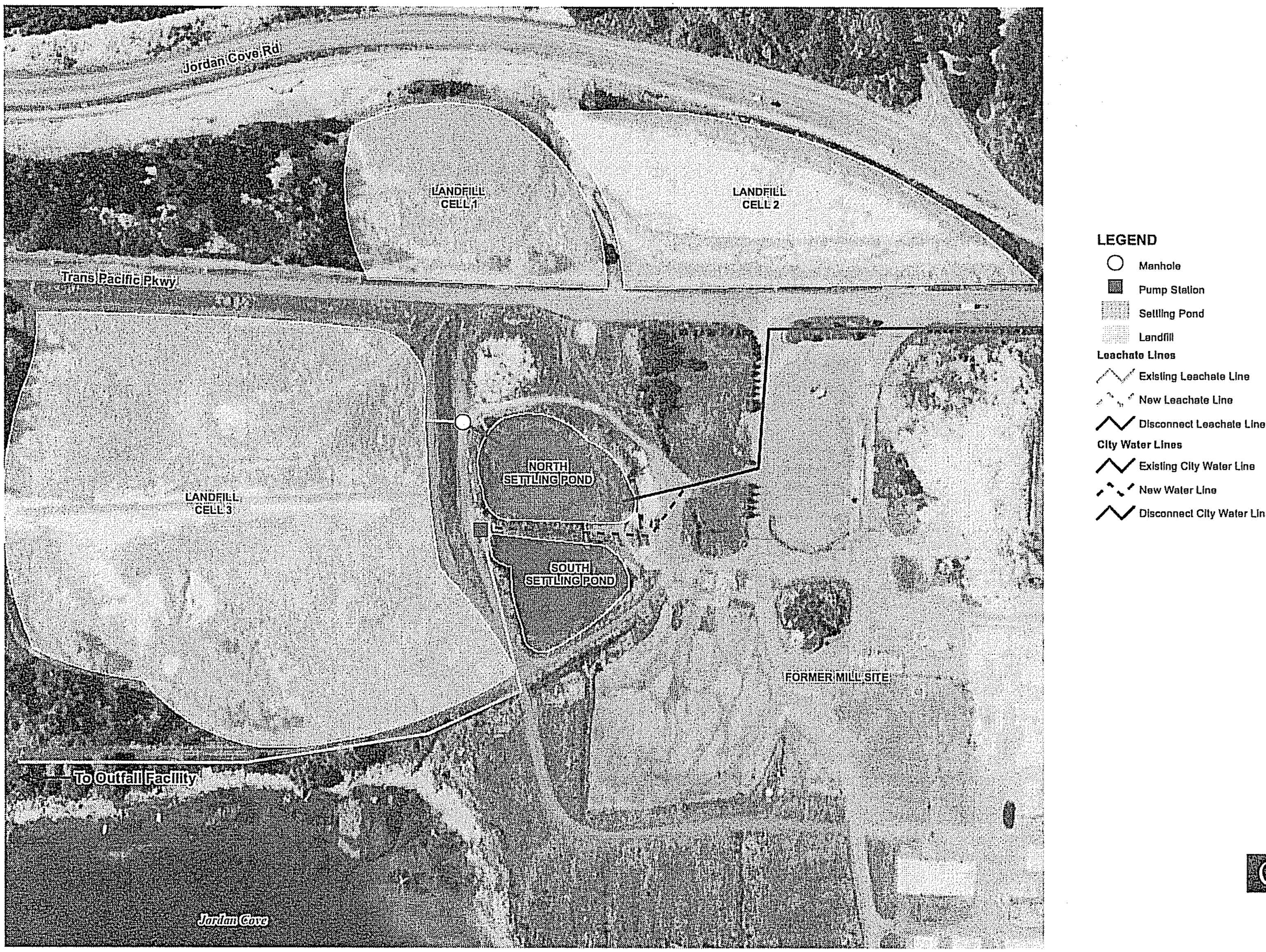
North

0 2,500 5,000 FT

GRI JORDAN COVE ENERGY PROJECT
WEYERHAEUSER MILL SITE AND INGRAM YARD
WORK PLAN FOR JOINT PROGRAM REGULATORY CLOSURE

# LOCATION MAP

SEPT. 2012 JOB NO. 4277-S FIG. 1




BASIN DETAIL PLAN FROM FILE BY GSI WATER SOLUTIONS, INC., DATED FEBRUARY 28, 2012

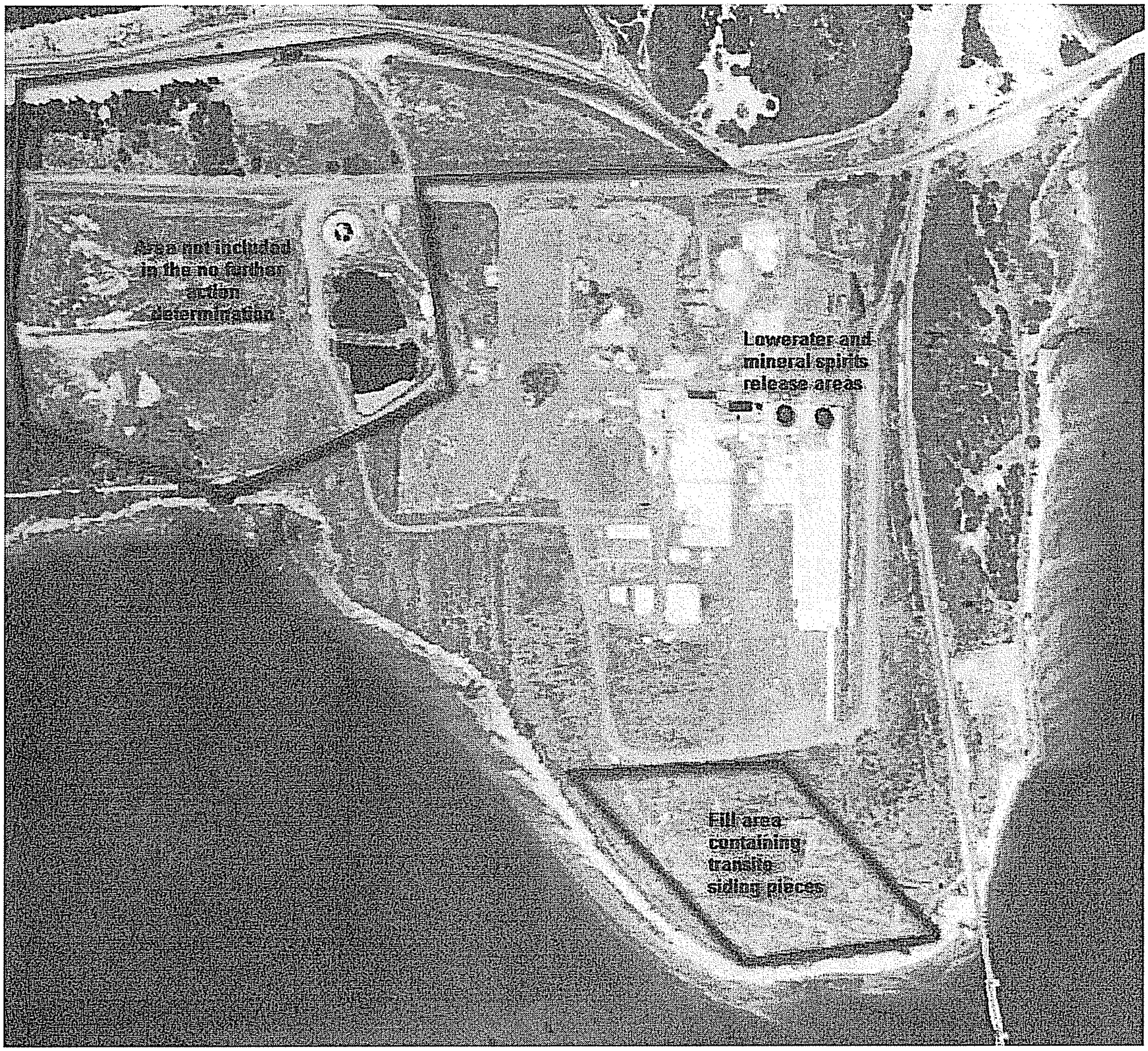
North

0 180 360 FT

GRI JORDAN COVE ENERGY PROJECT
WEYERHAEUSER MILL SITE AND INGRAM YARD
WORK PLAN FOR JOINT PROGRAM REGULATORY CLOSURE

# BASIN DETAIL PLAN

SEPT. 2012 JOB NO. 4277-S FIG. 2




RESIDUAL MILL CONTAMINATION FROM FILE BY DEQ (2012)

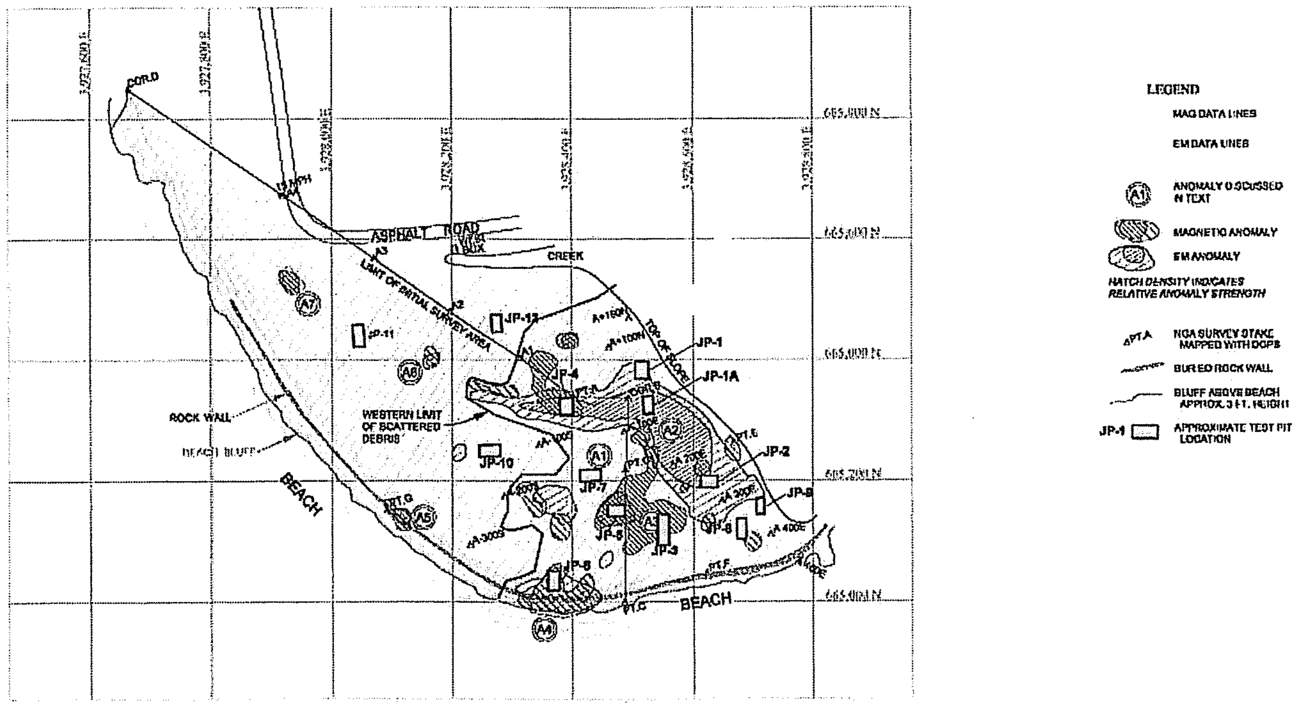
North

0 400 800 FT

GRI JORDAN COVE ENERGY PROJECT
WEYERHAEUSER MILL SITE AND INGRAM YARD
WORK PLAN FOR JOINT PROGRAM REGULATORY CLOSURE

# RESIDUAL MILL CONTAMINATION

SEPT. 2012 JOB NO. 4277-S FIG. 3




Source
Geophysical Site Investigation
prepared for: Weyerhaeuser Company
prepared by: Northwest Geophysical Associates, Inc.
dated March 2009

PES Environmental, Inc.
Engineering & Environmental Services

Geophysical Interpretation Survey
and Test Pit Locations
Area 13, South Jordan Point
Former Weyerhaeuser Containerboard Mill
North Bend, Oregon

6

ASBESTOS FILL AREA PLAN FROM FILE BY DEQ (2012)

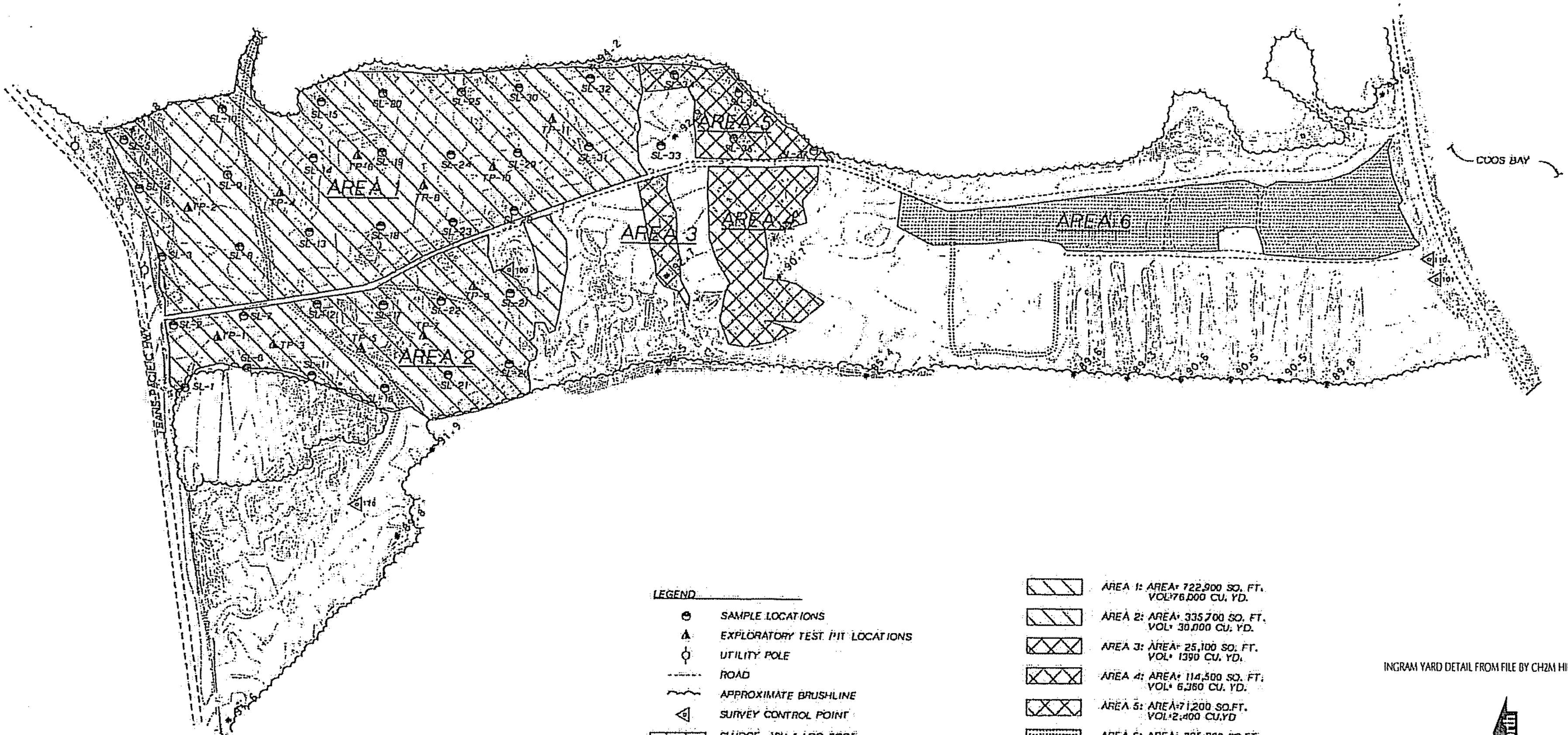
North

0 200 400 FT

GRI JORDAN COVE ENERGY PROJECT
WEYERHAEUSER MILL SITE AND INGRAM YARD
WORK PLAN FOR JOINT PROGRAM REGULATORY CLOSURE

# ASBESTOS FILL AREA PLAN

SEPT. 2012 JOB NO. 4277-S FIG. 4




LEGEND

- SAMPLE LOCATIONS
- EXPLORATORY TEST PIT LOCATIONS
- UTILITY POLE
- ROAD
- APPROXIMATE BRUSHLINE
- SURVEY CONTROL POINT
- SLUDGE, ASH & LOG SORT DEBRIS WASTE MIXTURE
- SLUDGE WASTE
- LOGYARD SORT DEBRIS (WOOD, BARKDUST WASTE)

NOTE:

ELEVATIONS SHOWN AT THE SITE ARE ASSUMED AND ARE NOT TRUE ELEVATIONS. AN ELEVATION OF 100.00 FEET WAS ASSUMED AT SURVEY CONTROL POINT #100.

AREA 1: AREA: 722,900 SQ. FT. VOL: 76,000 CU. YD.

AREA 2: AREA: 335,700 SQ. FT. VOL: 30,000 CU. YD.

AREA 3: AREA: 25,100 SQ. FT. VOL: 1390 CU. YD.

AREA 4: AREA: 114,500 SQ. FT. VOL: 6,360 CU. YD.

AREA 5: AREA: 71,200 SQ.FT. VOL: 2,400 CU.YD

AREA 6: AREA: 235,800 SQ.FT. VOL: 13,100 CU. YD.

INGRAM YARD DETAIL FROM FILE BY CH2M HILL (1996)

North

0 300 600 FT

GRI JORDAN COVE ENERGY PROJECT
WEYERHAEUSER MILL SITE AND INGRAM YARD
WORK PLAN FOR JOINT PROGRAM REGULATORY CLOSURE

# INGRAM YARD DETAIL

SEPT. 2012 JOB NO. 4277-S FIG. 5

Oregon
Theodore Kulongoski, Governor

Department of Environmental Quality
Western Region Eugene Office
1102 Lincoln Street, Suite 210
Eugene, OR 97401
(541) 686-7838
FAX (541) 686-7551
TTY (541) 687-5603

September 15, 2006

Mr. Thomas H. Scheideman Jr., PE
Site Manager, North Bend
Weyerhaeuser Company
92770 Trans Pacific Lane
PO Box 329
North Bend, OR 97459

RE: No Further Action Determination
Former Weyerhaeuser Containerboard Mill
North Bend, Coos County, Oregon
Tax Lots #25S-13W-4-100, 25S-13W-3-200,
and the Ingram Yard portion of 25S-13W-0-200
ECSI Site ID No. 1083

Dear Mr. Scheideman:

The Oregon Department of Environmental Quality (DEQ) has completed a review of the document entitled *Level II Environmental Assessment* dated May 26, 2005 and submitted to DEQ on your behalf by PES Environmental, Inc. The document focuses on the former Weyerhaeuser North Bend Containerboard Mill property consisting of tax lots numbers 25S-13W-4-100 and 25S-13W-3-200 (the "Main Mill Complex"), and the Ingram Yard portion of 25S-13W-0-200 as illustrated in the attached site map. The work described in the report was based on an investigatory scope of work recommended by your consultant and agreed to by DEQ after Weyerhaeuser joined our Voluntary Cleanup Program as described in a voluntary agreement signed February 12, 2004.

DEQ has determined that no further action is required to address environmental contamination at the Main Mill Complex and Ingram Yard properties. This determination is based on the regulations and facts as we now understand them as outlined in our final Site Summary Report dated September 7, 2006.

This decision is based on a determination that the site will remain in commercial/industrial use. Any zoning or use changes resulting in residential use of this property might not meet the protective criteria set forth in DEQ Cleanup rules, and additional assessment or cleanup could be required by DEQ.

This no further action determination does not include the mill's permitted industrial landfill (Solid Waste Disposal Permit #1142) or the mill's permitted industrial wastewater treatment system (NPDES Permit #101499; consisting of two settling ponds, an aerated stabilization basin, and a large former lagoon). These facilities will be closed under their respective permits in cooperation with DEQ's Solid Waste and Water Quality programs.

Residual contamination remains at the Main Mill Complex and Ingram Yard sites. DEQ approves leaving this contamination because the contamination is not present at concentrations that pose an unacceptable risk to human health, safety, welfare and the environment. DEQ's approval to leave contamination on the site was based on present and reasonably likely future conditions, as described in the reports named above. Any residually contaminated soil or sediment excavated during future site activities or development must be properly managed and disposed in accordance with DEQ regulations and policies. In particular, we note the following requirements (locations are illustrated in an attached figure):

1. There are low levels of residual total petroleum hydrocarbon (TPH) contamination below the concrete slab in the mineral-spirits release and south "lowerator" areas. Therefore, if these areas are exposed, any soils removed must be properly managed and/or disposed in accordance with DEQ rules;
2. The small amounts of transite siding in the fill area on south Jordan Point, if ever excavated in future site redevelopment activities, must be properly managed and disposed at a DEQ-approved disposal facility; and
3. While surface soils at the Ingram Yard site meet human health and ecological screening criteria, they contain low levels of potentially bioaccumulating chemicals and must not be placed in waters of the state. Soils and/or sediments containing residual contamination must be managed and/or disposed in accordance with DEQ rules.

In addition, we have the following recommendations:

1. The full extent of the hydraulic oil release in the vicinity of the south "lowerator" has not been determined due to the presence of a thick concrete slab and a railroad spur. Therefore, we recommend that a supplementary investigation (and subsequent remediation, if necessary) be conducted if the concrete slab is ever removed; and
2. The monitoring wells at the facility associated with the hazardous-substance investigation and removal actions should be abandoned according to the Oregon Water Resources Department rules, unless they continue to serve a purpose for Weyerhaeuser.

DEQ concludes that based on the information presented to date, the Main Mill Complex and Ingram Yard parcels associated with the former Weyerhaeuser North Bend Containerboard Mill site are currently protective of public health and the environment and requires no further action under the Oregon Environmental Cleanup Law, ORS 465.200 et seq., unless new or previously undisclosed information becomes available. We will update the Environmental Cleanup Site Information System (ECSI) database to reflect this decision.

DEQ recommends keeping a copy of all of the documentation associated with this investigation and remedial action with the permanent facility records.

If you have any questions about this letter, please contact Bill Mason, the DEQ remedial action project manager for this site, via email at mason.bill@deq.state.or.us or by phone at (541) 687-7427.

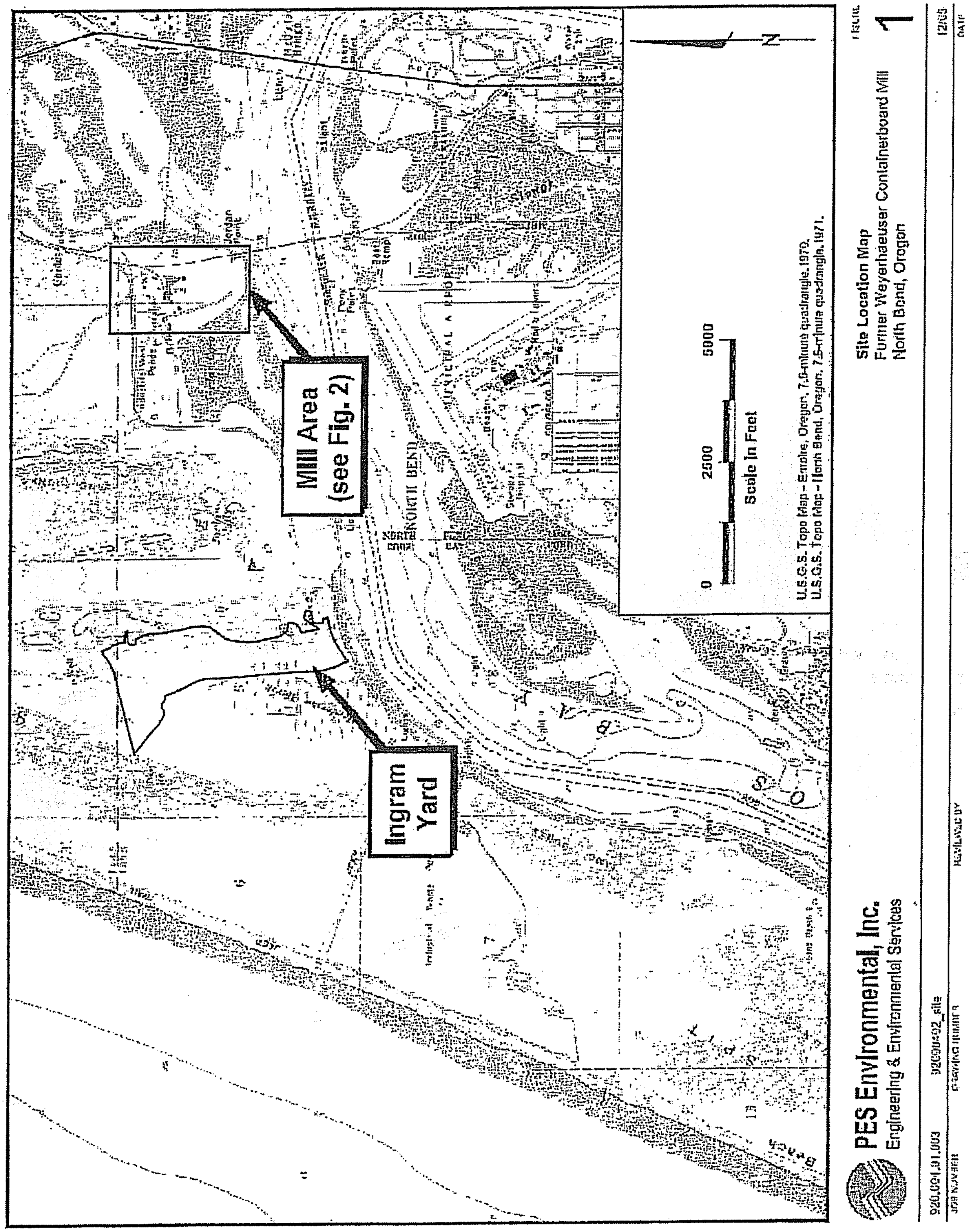
Sincerely,

Paul S. Rosenberg

Paul S. (Max) Rosenberg, Manager
Environmental Cleanup Program
Western Region

Enclosures: Site maps

cc: Marv Lewallen, Weyerhaeuser Company, 1300 SW 5th Ave, Ste 500, Portland, OR 97201-5644
Mark Winters, PES Environmental, 1011 S Bertelsen Rd, Eugene, OR 97402


Mill Area
(see Fig. 2)
Ingram
Yard
NORTH BEND
0
2500
5000
Scale In Feet
U.S.G.S. Topo Map - Empire, Oregon, 7.5-minute quadrangle, 1970.
U.S.G.S. Topo Map - North Bend, Oregon, 7.5-minute quadrangle, 1971.
PES Environmental, Inc.
Engineering & Environmental Services
Site Location Map
Former Weyerhaeuser Containerboard Mill
North Bend, Oregon
1
12/05


Lowerater and
mineral spirits
release areas
Fill area
containing
transite
siding pieces.

(http://www.fws.gov/)

# Pacific Region News Release (http://www.fws.gov/pacific)

## News Release

### *Western Snowy Plover Nesting Season Begins on Oregon Coast*

**Media Contacts:**

Daniel Elbert, (541) 867-4558

*Beachgoers are asked to respect restrictions in sensitive nesting areas*

The nesting season for western snowy plovers returns to the Oregon coast this month, and 2013 promises to deliver another banner year for this threatened species as conservation actions that have led to a record number of breeding adults resume. Beachgoers have the opportunity to actively participate in this recovery success story by honoring access restrictions to a small portion of beaches along the Oregon coast.

Beginning March 15, signs and ropes will be used to inform the public of sensitive western snowy plover nesting areas, and to direct the public to non-sensitive areas where recreational activities are permitted. At these marked beach areas, beachgoers will still have access to the wet sand portion of the beach to enjoy passive recreational activities such as walking and horseback riding. All recreational activities within the dry sand areas, however, will be prohibited. On plover nesting beaches the following recreational activities will also be prohibited on the wet sand: operating a motorized or non- motorized vehicle or flying apparatus (e.g., flying a kite) and having a dog, leashed or unleashed. These access restrictions will protect the nests, eggs and chicks of breeding plovers, which are highly sensitive to repeated disturbance. Access restrictions will be in effect through September 15, but may be lifted early if there is no more nesting by July 15.

Dry and wet sand restrictions will be in effect at Sutton/Baker Beach, on the beach from Siltcoos Estuary to Tahkenitch Estuary and from just south of the Douglas/Coos County line south to Tenmile Estuary (northern Coos County), the North Spit of Coos Bay, Bandon Beach State Natural Area, and New River area

**Pacific Region News Room**
(http://www.fws.gov/pacific/newsroom/)
**Pacific Region Home Page**
(http://www.fws.gov/pacific/)
**FWS News Releases**
(http://www.fws.gov/virtualnewsroomupda

FOLLOW US ONLINE

(https://www.facebook.com/usfwspacific
(https://twitter.com/USFWSPacific/)
(http://www.youtube.com/usfws)
(http://www.flickr.com/photos/usfwspacif
(http://usfwspacific.tumblr.com/)

beaches. These access restrictions affect approximately 48 miles along the 230 miles of sandy shore in Oregon. For more detailed information on specific locations of these areas, please consult the following webpage: http://www.oregon.gov/oprd/NATRES/docs/plover/DogFriendlyBeaches_web2013.pdf (http://www.oregon.gov/oprd/NATRES/docs/plover/DogFriendlyBeaches_web2013.pdf)

"In 2012, monitors found 231 nesting plovers along the Oregon Coast – a significant increase from a population low of 28 nesting plovers as recently as 1992," said Laura Todd of the U.S. Fish and Wildlife Service. "People who share the beach and honor the plover area access restrictions have played a huge role in getting us closer to recovering the western snowy plover."

The Pacific coast population of the western snowy plover was listed by the U.S. Fish and Wildlife Service as threatened in 1993. It is also listed as threatened under state law. The primary threats to snowy plover survival are habitat degradation, urban development, introduced European beach grass and predators such as crows, ravens, foxes and skunks.

More information on plover habitat and beach restrictions can be obtained from the U.S. Fish and Wildlife Service, 541-867-4558 ; Oregon Parks and Recreation Department, 541-888-9324 ; U.S. Forest Service, 541-750-7000 ; or the Bureau of Land Management, 541-756-0100 .

Last updated:November 21, 2013

# *Final* North Spit Plan

**An update to the Coos Bay Shorelands Plan of 1995**

December 2006

BLM

Coos Bay District

Umpqua Field Office

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

# FINAL NORTH SPIT PLAN

December 2005

An update to the Coos Bay Shorelands Plan of 1995

Umpqua Field Office
Coos Bay District
Bureau of Land Management
US Department of the Interior

Approved by:

M. Elaine Raper

M. Elaine Raper
Umpqua Field Manager

December 8, 2005

Date

# Table of Contents

# Appendices





# List of Maps



# List of Tables

# Executive Summary

## Introduction

In 1995, the Bureau of Land Management completed the Coos Bay Shorelands Final Management Plan to guide the use of BLM lands on the North Spit of Coos Bay. Under that plan and its associated Environmental Assessment (EA), the BLM established specific management objectives to provide for public use and natural resource conservation. Since then, changes in land ownership, environmental conditions and the passage of time necessitated a plan update. The North Spit Plan (the Plan) was prepared to reflect the current situation. Any proposed actions outside the scope of the previous Environmental Assessment will require a new EA. This summary provides a brief outline of the Plan and describes management objectives and actions. The Plan focuses exclusively on comprehensive management of the 1,864 acres of BLM land on the North Spit (the Spit). The remainder of the Spit is managed by other federal agencies, state agencies, and private interests.

Prepared by an interdisciplinary team of specialists, the North Spit Plan:

- describes the resources on the North Spit;
- addresses changes that have occurred since the 1995 Shorelands Plan was completed;
- clarifies management direction for BLM lands on the Spit;
- reports accomplishments; and
- describes ongoing management actions.

Overarching goals are to:

- provide a broad range of recreational opportunities on the Spit while managing for the protection, maintenance, and rehabilitation of the area's natural systems;
- protect and interpret the Spit's biological, cultural and natural resources; and to
- involve and foster open communication among all interested parties during the development and implementation of the North Spit Plan.

## Background

The North Spit of Coos Bay is a large, isolated peninsula northwest of the communities of Coos Bay, North Bend, and Charleston in Coos County, Oregon. The Spit supports a unique assemblage of habitats in a relatively confined area including estuarine, fresh water wetlands, mudflats, and forested uplands. The importance of this natural area is amplified by its proximity to one of the largest urban areas on the Coast. Consequently, the Spit experiences considerably high recreational use and pressure for industrial development.

In 1995, in recognition of the Spit's high ecological and recreational values, portions of it were given special designations by BLM to guide management and use. Approximately 725 acres of the Spit are classified as an Area of Critical Environmental Concern (ACEC). Areas of Critical Environmental Concern are public lands where special management attention is required to protect important historic, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes. The Spit is also a BLM Special Recreation Management Area (SRMA). SRMAs are defined as areas where specific recreational activities and experience opportunities will be provided on a sustained yield basis. The North Spit Plan provides for the preservation of ACEC and SRMA values through specific and compatible management actions related to recreational access, cultural and historic preservation, wildlife and plant conservation and management, and educational and interpretive opportunities.

# Public Scoping

Prior to drafting the North Spit Plan, public comments on North Spit management were solicited via letters, presentations, public service announcements, and newspaper notices. Thirty-six people responded and provided 56 specific comments. BLM determined from the comments the following general areas of concern:

Public access to the jetty and beaches
Western snowy plover management
Development of lands
All-terrain vehicle use
User fees
Protection of resources
Land exchanges
Flexibility of management
Boat dock use
Firearm use

Responses to these concerns are presented in the Plan's introduction and relevant issues are further discussed elsewhere in the document.

# Plan Format

**Part One** describes BLM's planning framework. In the BLM planning system there are three levels or tiers:

1. National and State Level: Laws, regulations, directives, and policies
2. District Level: Coos Bay District Resource Management Plan (May 1995)
3. Field Office Level: Activity Plans (site-specific plans such as the North Spit Plan)

Each of these levels is discussed in terms of its relevancy to the North Spit Plan.

**Part Two** reviews the original 1995 Shorelands Plan and outlines the status of its management actions. The 1995 Coos Bay Shorelands Plan identified issues, concerns, and opportunities on the Spit, and included specific management actions pertaining to each of the following subjects:

- Education and Interpretation
- Land Tenure and Cooperative Agreements
- Law Enforcement
- Recreation
- Vegetation
- Wildlife Habitat

Management actions listed in the 1995 Shorelands Plan were reviewed and updated (Table 2 of the Plan). The actions fall into four categories: accomplished, accomplished in part, not accomplished, and ongoing. Actions in the the Shorelands Plan that were not accomplished include those where land exchanges have removed or precluded lands from BLM jurisdiction and therefore are no longer applicable to BLM management of the Spit.

Other changes to note include those pertaining to the threatened Western snowy plover. The 1995 Shorelands Plan proposed several actions pertaining to snowy plovers and ocean beach access that were never implemented (Table 2, Management Action 5). Changes to management actions are a result of a revised public access strategy implemented subsequent to the grounding of the New Carissa in 1999. The strategy pertains to the management of public lands on the Spit and allows for public use while protecting plovers and promoting their recovery (USDI FWS 2000).

Strategy details are described in Part Three under Species of Special Management Concern and are summarized in Table S-1.

The Shorelands Plan made some recommendations that were not listed as actions. Errors are noted and additions or changes to these recommendations are listed and explained.

**Part Three** describes the cultural, natural, and recreational resources on the Spit. Resources are grouped into five categories:

- Physical, including Water, Geology, Soils, Minerals, Coal Bed Methane, Oil and Gas
- Biological, including Vegetation, Wildlife, and Fisheries
- Cultural and Historical
- Recreational
- Visual

**Part Four** presents management actions on BLM-administered lands for the next ten years. The remainder of this summary focuses on Part Four as it brings the reader up to date on management objectives, accomplishments, and ongoing and proposed activities.

# North Spit Management, 2005

Table S-1 summarizes management objectives and actions for BLM lands on the North Spit. The objectives and actions reflect the goal of the North Spit Plan to conserve the natural, cultural, and recreational values of the Spit. Due to the interrelationship of the various resources at the Spit, many actions apply to more than one objective. Objectives and actions in the North Spit Plan are consistent with BLM policies, state and federal regulations, ACEC planning documents, and the 1995 Shorelands Plan. For the North Spit Plan, objectives and proposed actions were reviewed and revised based on current conditions and needs, and will be implemented as funding allows. Objectives correspond to the resources described in Part 3 as well as to other BLM programs such as land tenure, environmental education and interpretation, site protection and administration, and monitoring and research. With the exception of the latter, the objective and actions for each resource or program are presented in alphabetical order, starting with Cultural Resources. The objective for Monitoring and Research is placed at the end because several of the resources and programs have actions under this heading.

Monitoring is used to: 1) ensure that the management goals, objectives, and actions are being followed (implementation monitoring); 2) verify if the actions are achieving the desired results (effectiveness monitoring); and 3) determine if the underlying assumptions of the Plan's goals and objectives are sound (validation monitoring). Ongoing or proposed monitoring actions are included for Cultural Resources, Environmental Education and Interpretation, Geology, Recreation, and Vegetation and Wildlife Resources.

Updated maps, tables, and appendices are presented to clarify information presented in the Plan. They include detailed descriptions, lists, and chronologies of key interest including site names, ownership boundaries, an update of 1995 management actions, wildlife and plant lists, and land tenure history. A glossary and a list of acronyms are presented to assist the reader with unfamiliar terms.

**Table S-1. Summary of Management Objectives and Actions Accomplished, Ongoing, and Proposed for the North Spit. The North Spit Plan provides more detailed explanations and supporting references. See Part 4 for a complete description of the actions.**

| Management Objectives | Actions Accomplished | Actions Ongoing | Actions Proposed |
|---|---|---|---|
| **CULTURAL RESOURCES**<br><br>**1:** Preserve important cultural resources on the Spit. | • A report was completed by noted historian Stephen Dow Beckham detailing the history of federal activities on the North Spit. | • Continue to preserve remaining historic cultural resources. | • Work with the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians and the Coquille Indian Tribe to assure continued protection and preservation of prehistoric resources.<br><br>• Remove damaged chain link fence from the perimeter of the World War II Quonset huts. |
| **ENVIRONMENTAL EDUCATION and INTERPRETATION**<br><br>**2:** Promote awareness and appreciation for the Spit's many resource values and recreational opportunities, and support a minimum impact land use ethic through educational programs such as *Leave No Trace* and *Tread Lightly*. | • A brochure was developed to provide visitors with a map of the Spit and inform them of regulations and opportunities.<br><br>• Interpretive signs and a kiosk were developed and installed. Seasonal interpreters were hired to educate the public about seasonal closures and recreational opportunities. | • Continue to host field trips for schools at the Spit for students to learn about the area.<br><br>• Continue to work cooperatively with the interagency snowy plover working team on issues pertaining to public education and outreach. | • Develop an environmental education prospectus for the District and implement its recommendations on the North Spit.<br><br>• Utilize seasonal or volunteers to contact visitors and disseminate information.<br><br>• Conduct special educational opportunities and events that involve the public.<br><br>• Interpret cultural or paleo-environmental history of the Spit in coordination with interested Indian tribes and the Coos Bay District Archaeologist.<br><br>• Rotate or replace interpretive displays as needed.<br><br>• Use the draft Western Snowy Plover Outreach Plan when planning plover outreach on the Spit.<br><br>• Raise public awareness about the environmental and recreational values of riparian and wetland areas on the Spit. |
| **LAND TENURE ADJUSTMENTS**<br><br>**3:** Prioritize land tenure adjustments based on natural resource values and recreational opportunities on non-BLM parcels, consolidate BLM properties, and safeguard public investments. | • The 1995 Shorelands Plan identified four potential land acquisitions and one disposal. Three acquisitions were accomplished. | • In accordance with the RMP, some BLM lands on the Spit within zoning districts 3-EWD, 4CS, and 6WD as delineated by the Coos County Comprehensive Plan could be offered for exchange, sale, or lease. A land disposal is currently in progress for an 80 acre BLM parcel north of the Roseburg Chip Facility along the Trans Pacific Lane.<br><br>• Several utility and access rights-of-way were issued and are currently in use. Future applications for leases, permits, and right-of-ways will be reviewed and authorizations issued on a case-by-case basis. | • Consider land tenure adjustments to ensure access to public lands as appropriate to meet objectives. Appendix 3 contains a chronological history of the land tenure adjustments affecting public lands on the Spit. |

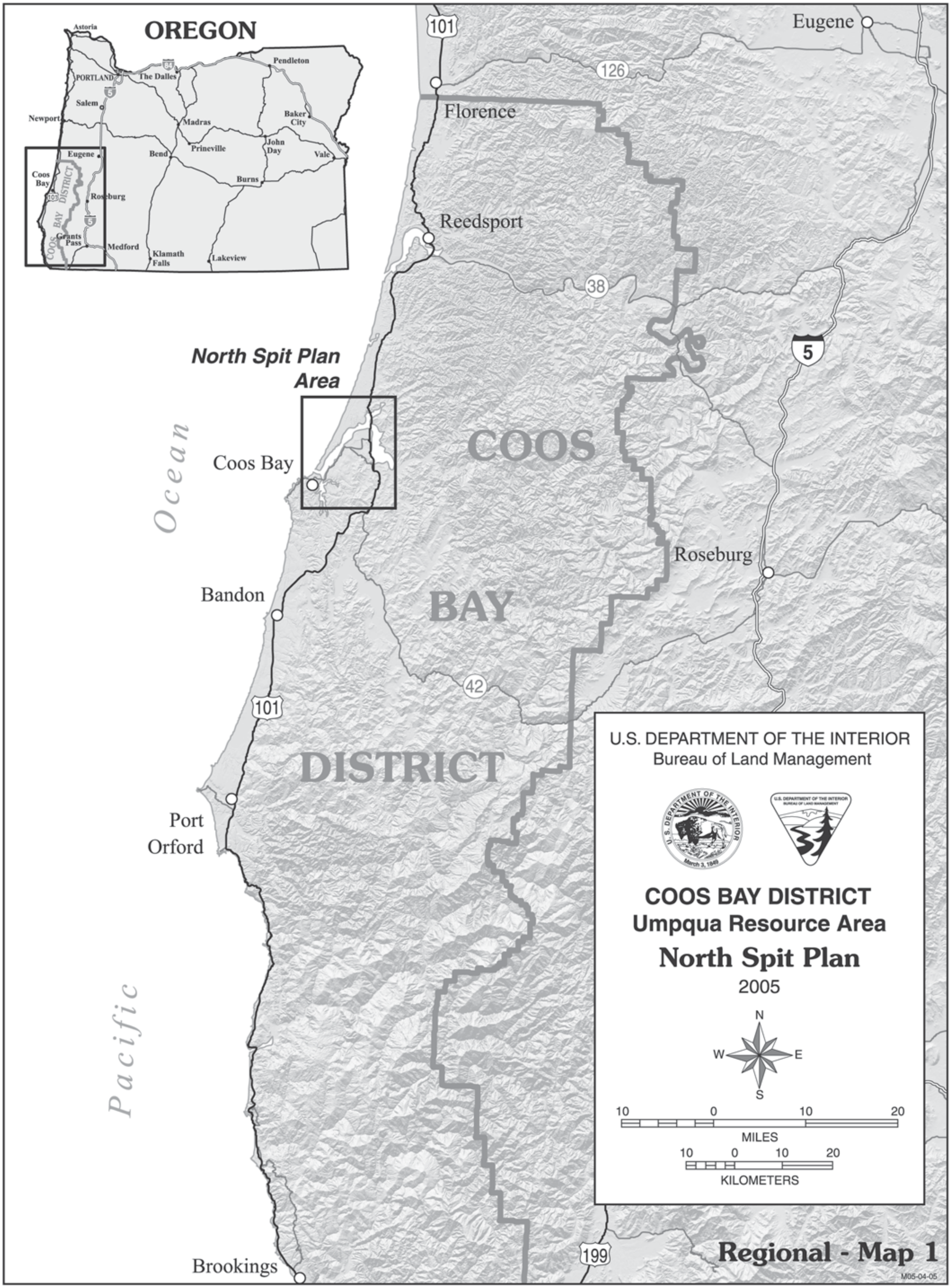
| Management Objectives | Actions Accomplished | Actions Ongoing | Actions Proposed |
|---|---|---|---|
| **RECREATION**<br><br>**4:** Manage the North Spit SRMA to provide for a range of recreation opportunities that contribute to meeting traditional as well as projected recreation demand within the region while protecting the area's natural, cultural, and scenic resources. | • Signs were placed at the ocean beach access points along the Foredune Road; other signs and maps were placed at various locations to inform visitors of regulations and recreational opportunities.<br><br>• Roads and trails that were not designated as open were closed using logs, root wads, and signs. Many of these closed routes are disappearing through natural revegetation.<br><br>• A sign strategy was developed to assist BLM in providing information to the public on regulations, recreational opportunities, and natural resources on the Spit. | • Continue to provide motorized access on the Spit to support the area's long-standing traditional recreation uses while protecting natural, cultural and scenic resources.<br><br>• Retain a recreation setting compatible with the area's Rural and Semi-Primitive Motorized ROS classification.<br><br>• Provide press releases related to seasonal access restrictions.<br><br>• Clear sand and debris from the boat ramp each spring prior to reinstalling the docks for the summer season.<br><br>• Continue to maintain the docks.<br><br>• Continue to allow primitive camping on BLM lands on the Spit except where signed to protect sensitive plants and wildlife.<br><br>• Continue to permit hunting and shooting on BLM lands on the Spit in conformance with applicable state and federal laws and regulations. These regulations prohibit shooting adjacent to and across public roadways and within developed recreation sites. | • Place improved signs along the sand roads and at ocean beach access points. Advise visitors the beach access points may be blocked and to look before driving over the foredune.<br><br>• Remove dilapidated fences and fence posts from the intersection of the Foredune Road and Trans Pacific Lane, the WWII bunker fence, and from the southern interior.<br><br>• Establish trails for pedestrian and equestrian use within the North Spit interior. Develop and support local partnerships to assist in maintaining and managing this trail system.<br><br>• Create and maintain connections between trails on BLM, the Forest Service, OPRD and Weyerhaeuser lands.<br><br>• Construct a small equestrian and hiking staging area to provide parking and visitor information at the portal to the trail system.<br><br>• Implement completed sign strategy developed to improve communication with Spit visitors. Include information about wildlife viewing opportunities at the kiosk proposed for the boat ramp. |
| **SITE PROTECTION and ADMINISTRATION**<br><br>**5:** Provide and maintain adequate visitor facilities, services, signing, and programs that are appropriate for the area's recreation opportunity setting and that serve to protect the Spit's sensitive resources. | **Fire Management**<br>See Actions Ongoing.<br><br>**Hazardous Materials Management**<br>See Actions Proposed.<br><br>**Law Enforcement**<br>See Actions Ongoing.<br><br>**Facility Management**<br>See Actions Ongoing.<br><br>**Road Maintenance and Improvement**<br>None at this time. | **Fire Management**<br>• BLM contracts with the Coos Forest Protection Association for fire response, including the lands on the Spit.<br><br>**Hazardous Materials Management**<br>See Actions Proposed.<br><br>**Law Enforcement**<br>• BLM Law Enforcement Officers enforce federal regulations on BLM lands. BLM may continue to contract with the Coos County Sheriff's Department and contribute funds to OPRD for seasonal assistance with beach patrol.<br><br>• BLM Law Enforcement Officers enforce Federal and State firearm regulations and encourage shooter safety on the Spit.<br><br>**Facility Management**<br>• Maintain existing facilities at the boat launch recreation area.<br><br>**Road Maintenance and Improvement**<br>None at this time. | **Fire Management**<br>None at this time.<br><br>**Hazardous Materials Management**<br>• Finish the Spit Life Guard Station Environmental Site Characterization.<br><br>**Law Enforcement**<br>None at this time.<br><br>**Facility Management**<br>• Consider placing alternative toilet facilities at high use areas.<br><br>**Road Maintenance and Improvement**<br>• Consider raising and widening the Re-route Road to minimize the risk of vehicular collisions. |

| Management Objectives | Actions Accomplished | Actions Ongoing | Actions Proposed |
|---|---|---|---|
| **VEGETATION and WILDLIFE RESOURCES**<br><br>**6:** Conserve, enhance, or restore natural habitats, with an emphasis on habitats that support special status plant and wildlife species. | <u>**Vegetation**</u><br>• Plant communities were mapped and digitized.<br><br><u>**Special Status Plant Species and Communities**</u><br>• Pink sandverbena was reintroduced.<br><br>• A permanent vehicle re-route was constructed to protect the Point Reyes bird's-beak population on the bay side.<br><br><u>**Exotic Plants and Noxious Weeds**</u><br>• Gorse was removed from the Coast Guard Lifesaving station.<br><br>• Scotch broom was cleared from HRAs.<br><br><u>**Wildlife**</u><br>None at this time.<br><br><u>**Special Status Wildlife Species**</u><br>Nest boxes were installed for purple martins. | <u>**Vegetation**</u><br>• Coordinate with other agencies and institutions to restore degraded and disturbed plant communities.<br><br><u>**Special Status Plant Species and Communities**</u><br>• Facilitate the recovery of the pink sandverbena by collecting seeds for dispersal to other sites along the coast.<br><br>• In cooperation with the Port and the DSL maintain protective barriers around the Point Reyes bird's-beak population.<br><br>• Continue inventory and management for SSS.<br><br><u>**Exotic Plants and Noxious Weeds**</u><br>• European beach grass is removed annually from plover areas.<br><br><u>**Wildlife**</u><br>None at this time.<br><br><u>**Special Status Wildlife Species**</u><br>• Continue to implement snowy plover conservation actions:<br>1. Closing the upper, dry sand portion of the ocean beach to all public access from the FAA Tower south to the BLM boundary during the Western snowy plover nesting season (March 15- September 15 annually). The lower, wet sand beach is restricted to motorized use as authorized by OPRD. Inland snowy plover nesting areas on BLM land are also signed closed to all use during the nesting season, and are open to nonmotorized use the remainder of the year.<br>2. Removing beachgrass from the inland snowy plover areas to maintain open, sandy habitat suitable for nesting plovers.<br>3. Implement predator control to protect the plover population from further declines caused by predation.<br>4. Monitor plover nesting to gauge the success of management actions and progress toward plover recovery.<br><br>• Continue to implement recovery plans for other species as necessary. | <u>**Vegetation**</u><br>• Refine the classification of plant associations on the Spit.<br><br>• Conduct a complete inventory of all plant species.<br><br><u>**Special Status Plant Species and Communities**</u><br>On the North Spit Area of Critical Environmental Concern:<br>• Implement beach and dune ecosystem restoration.<br><br>• Establish additional special status plant populations.<br><br>• Develop opportunities to increase the amount of habitat suitable for rare species and to link isolated populations.<br><br>• Collect special status plant seeds for future use.<br><br>• Identify opportunities to restore rare plant communities.<br><br><u>**Exotic Plants and Noxious Weeds**</u><br>• Continue treatments to remove noxious and exotic species. Restore treated areas with native seeds and plants.<br><br>• Use best management practices to prevent the further spread of exotic plants and noxious weeds.<br><br><u>**Wildlife**</u><br>• Survey for great blue herons and great egret rookeries.<br><br>• Conduct wildlife inventories at selected wetlands.<br><br>• Survey for nesting raptor species.<br><br><u>**Special Status Wildlife Species**</u><br>• Develop and implement survey protocols to locate special status species.<br><br>• Actively manage habitats to promote the conservation of special status species and raptors. |
| **WATER RESOURCES**<br><br>**7:** Maintain wetland areas in a condition supportive of a healthy aquatic ecosystem. | • BLM participated in the creation of wetlands on BLM adjacent to Weyerhaeuser's Overlook wetlands site. | None at this time. | • Support wetland mitigation projects consistent with the Henderson Marsh Mitigation Plan. |

| Management Objectives | Actions Accomplished | Actions Ongoing | Actions Proposed |
|---|---|---|---|
| **MONITORING and RESEARCH**<br><br>**8:** Facilitate improved management of the Spit through monitoring to learn more about the natural and cultural resources of the area and to assess the effects of management actions. | **Cultural Resources**<br>None at this time.<br><br>**Environmental Education and Interpretation**<br>See Actions Ongoing.<br><br>**Geology**<br>None at this time.<br><br>**Recreation**<br>See Actions Ongoing.<br><br>**Vegetation and Wildlife Resources**<br>See Actions Ongoing. | **Cultural Resources**<br>None at this time.<br><br>**Environmental Education and Interpretation**<br>• Evaluate the effectiveness of educational brochures and signs.<br><br>**Geology**<br>None at this time.<br><br>**Recreation**<br>• Continue to use traffic and trail counters and field staff observations to monitor visitor use and to report findings in the Recreation Management Information System.<br><br>• Continue to monitor camping on BLM lands on the Spit.<br><br>**Vegetation and Wildlife Resources**<br>• Monitor noxious weed species to document existing population areas, effectiveness of management actions for removal, and the spread of these species to new sites.<br><br>• Evaluate and explore effective management strategies to meet recovery goals for the Western snowy plover. Monitor human and natural disturbance effects on breeding plovers.<br><br>• Continue to support the Oregon Natural Heritage Information Center in its efforts to monitor Western snowy plover reproductive success.<br><br>• Continue to monitor great blue heron and great egret rookeries.<br><br>• Continue to monitor selected special status species on the Spit.<br><br>• Continue to monitor the condition of riparian-wetland vegetation. If signs of excessive disturbance caused by unauthorized motorized recreation become evident, adjust patrols, signing and barriers to reduce or prevent impacts | **Cultural Resources**<br>• Monitor stability of important cultural resources and propose actions to continue their preservation.<br><br>**Environmental Education and Interpretation**<br>• Evaluate the effectiveness of environmental education programs and interpretive materials on a regular basis, and make modifications as necessary.<br><br>**Geology**<br>• Track elevation changes on the ocean foredune and monitor the effects of weather and beach grass removal on foredune erosion.<br><br>**Recreation**<br>• Monitor the condition of beach access routes.<br><br>**Vegetation and Wildlife Resources**<br>• Monitor special status species' population status and trends. Pursue collaborative efforts to study SSS reproductive ecology, threats, habitats, and effects of management treatments and practices.<br><br>• Monitor the status and trends of globally ranked plant communities within the North Spit ACEC.<br><br>• Seek collaborative opportunities to survey migratory shorebirds and waterfowl to establish population status and trends. |

# Acronyms and Abbreviations

| | |
|---|---|
| ACEC | Area of Critical Environmental Concern |
| APHIS | Animal and Plant Health Inspection Service |
| ATV | All Terrain Vehicle |
| BA | Bureau Assessment, Biological Assessment |
| BLM | Bureau of Land Management |
| BO | Biological Opinion |
| BS | Bureau Sensitive |
| BT | Bureau Tracking |
| DEQ | Department of Environmental Quality (Oregon) |
| DSL | Division of State Lands (Oregon) |
| CFR | Code of Federal Regulations |
| COE | United States Army Corps of Engineers |
| CSU | Controlled Surface Use |
| EA | Environmental Assessment |
| ESA | Endangered Species Act |
| FAA | Federal Aviation Administration |
| FC | Federal Candidate |
| FLPMA | Federal Lands Policy and Management Act |
| FS | United States Forest Service |
| FWS | United States Fish and Wildlife Service |
| HMMP | Henderson Marsh Mitigation Plan |
| HRA | Habitat Restoration Area |
| Mgal/d | Millions of gallons per day |
| NEPA | National Environmental Policy Act |
| NSO | No Surface Occupancy |
| NWI | National Wetlands Inventory |
| OAR | Oregon Administrative Rule |
| ODA | Oregon Department of Agriculture |
| ODFW | Oregon Department of Fish and Wildlife |
| ODNRA | Oregon Dunes National Recreation Area |
| OHV | Off-highway vehicle |
| ONHP | Oregon Natural Heritage Program |
| ORNHIC | Oregon Natural Heritage Information Center |
| OSMB | Oregon State Marine Board |
| OPRD | Oregon Parks and Recreation Department |
| RMP | Resource Management Plan |
| ROS | Recreation Opportunity Spectrum |
| SRMA | Special Recreation Management Area |
| SSS | Special Status Species |
| SSSP | Special Status Species Program |
| USDA | United States Department of Agriculture |
| USDI | United States Department of Interior |
| USDOD | United States Department of Defense |
| UST | Underground Surface Tank |
| VRM | Visual Resource Management |
| The 1995 Shorelands Plan | The 1995 Coos Bay Shorelands Plan |
| The Jetty | The North Jetty of Coos Bay |
| The Port | The Oregon International Port of Coos Bay |
| The Spit | The North Spit of Coos Bay |


OREGON
Astoria
Portland
The Dalles
Pendleton
Salem
Newport
Madras
Baker City
Eugene
Bend
Prineville
John Day
Vale
Coos Bay
Roseburg
Burns
Grants Pass
Medford
Klamath Falls
Lakeview
COOS BAY DISTRICT
Eugene
101
126
Florence
Reedsport
38
5
North Spit Plan Area
Coos Bay
Ocean
COOS
Roseburg
Bandon
BAY
42
101
DISTRICT
Port Orford
Pacific
Brookings
199
U.S. DEPARTMENT OF THE INTERIOR
Bureau of Land Management
COOS BAY DISTRICT
Umpqua Resource Area
North Spit Plan
2005
N
W
E
S
10
0
10
20
MILES
10
0
10
20
KILOMETERS
Regional - Map 1
M05-04-05

# INTRODUCTION

The North Spit of Coos Bay (the Spit) is a sandy, vegetated point of land separating the waters of Coos Bay from the Pacific Ocean (Map 1). It is northwest of the communities of Coos Bay, North Bend, and Charleston in Coos County, Oregon. The Bureau of Land Management (BLM) administers 1,864 acres of public domain lands on the Spit, primarily acquired from the Army Corps of Engineers (COE) in 1984. It is comprised of narrow, sandy beaches on the Pacific Ocean side and a combination of sand beaches, mudflats, and salt marshes on the bay side. The interior of the Spit is characterized by stabilized and shifting sand dunes, fresh water wetlands, and upland stands of shore pine and Sitka spruce. Non-native European beach grass and Scotch broom dominate much of the deflation plain.

The diverse natural resources and recreational opportunities found on the Spit attract a variety of people and present unique management challenges for state and federal agencies. The North Spit Plan combines background and current information on the Spit's major resources and recreational values, defines management objectives for those resources, and outlines BLM's planned actions to meet those objectives.

## Purpose and Scope

The North Spit Plan provides updated direction for comprehensive management of the North Spit. Prior planning efforts by BLM for the Spit include the Coos Bay Shorelands Draft Management Plan (USDI BLM 1989) and the Coos Bay Shorelands Draft Management Plan and Environmental Assessment (USDI BLM 1994). The Final Supplemental Environmental Impact Statement on Management of Habitat for Late Successional and Old Growth Forest Related Species Within the Range of the Northern Spotted Owl and its Record of Decision (i.e. the Northwest Forest Plan; Interagency 1994) and the Coos Bay District's Resource Management Plan and Environmental Impact Statement and its Record of Decision (RMP; USDI BLM 1995) were incorporated into the Coos Bay 1995 Shorelands Final Management Plan (1995 Shorelands Plan; USDI BLM 1995). The purposes of the North Spit Plan are to address changes that have occurred since the 1995 Shorelands Plan was completed; clarify management direction for BLM lands on the Spit; report accomplishments; and describe ongoing management actions described in the 1989 plan. The 1994 Environmental Assessment (EA) associated with the 1995 Shorelands Plan remains valid. In the future, site specific EAs will be prepared when necessary to evaluate the effects of any new ground disturbing activities.

Lands on the Spit are owned and managed by several public agencies and private interests. BLM has no authority over lands not under its jurisdiction; hence management actions proposed in the North Spit Plan pertain only to the BLM-administered lands on the Spit. When necessary, BLM works with adjacent landowners per written agreements to accomplish joint management goals. The COE administers 245 acres on the Spit and their primary mission is to maintain the North Jetty (the Jetty) at the entrance to Coos Bay. The COE allows public access on their lands; however the Jetty itself was not designed for public use. The US Forest Service (FS) manages the Oregon Dunes National Recreation Area (ODNRA) to the north of the Spit. Many developed and undeveloped recreational opportunities are available in that area. The Oregon Parks and Recreation Department (OPRD) manages the Pacific Ocean beaches below the high tide line. The OPRD management guidelines for the Spit are described in the Draft Ocean Shore Management Plan and Habitat Conservation Plan for the Western snowy plover (Oregon Natural Heritage Information Center [ORNHIC] and OPRD 2004). The Division of State Lands (DSL) manages lands below the mean low tide, including submersed lands. The primary access to the bay side of the Spit is currently through lands owned by the Oregon International Port of Coos Bay (the Port). Coos County's zoning designations for the Spit are Conservation Shorelands, Natural Shorelands, Water-dependent Development Shorelands, and Development Shorelands (Coos County 1986). Privately owned lands include: a Roseburg Forest Resources chip facility and a Weyerhaeuser Company cardboard plant that is currently closed. In the past, BLM and Weyerhaeuser worked together on wetland mitigation plans and actions, including wetlands creation. State (the Oregon Department of Fish and Wildlife [ODFW]) and federal (the US Fish and Wildlife Service [FWS]) agencies provide regulatory oversight for the fish and wildlife resources found on the Spit.

# Vision and Goals

BLM's vision is to manage the public lands on the Spit as a predominately natural landscape by conserving botanical, cultural, and wildlife resources while providing recreational, educational, and interpretive opportunities for the benefit of local and regional visitors and economies. The two overarching goals of the North Spit Plan are:

- To provide a broad range of recreational opportunities on the Spit while managing for the protection, maintenance, and rehabilitation of the area's natural systems and cultural resources.

- To involve and foster open communication among local, regional, and national publics, and with other agencies and units of the government during the development of the North Spit Plan and as management of the Spit continues into the future.

# Plan Development and Public Involvement

## Scoping

As required under BLM's planning regulations (43 FR 1600), an interdisciplinary team of BLM specialists brought their professional expertise and experience to bear on the issues and concerns of managing the Spit (see below). Regulations also require public involvement and comment through the planning process. To this end, in 2003, BLM conducted public scoping to better understand the concerns regarding management of BLM-administered lands on the Spit. Public input was solicited via letters, presentations, public service announcements, and newspaper notices. Thirty-six people responded and provided 56 specific comments (Table 1).

## Additional Public Involvement

The BLM conducted a formal comment period on the DRAFT North Spit Plan from August 1 through August 31, 2005. Public input was solicited via letters, newspaper notices, and through fliers handed out in the field. Comments are listed by categiry in Table 2. Some of the comments BLM received during and after the official comment period for the DRAFT Plan made it clear there was misinformation circulating concerning restrictions to assecc activities on the North Spit. BLM held a public forum on October 20, 2005, to clarify information and to listen to the public's interests and recommendations related to recreation and natural resources. Three new action items are presented in this Final North Spit Plan as a result of the public forum. The items are improving information available about the North Spit, possibly placing picnic tables at the boat launch facility and investigating the possible opening of the Foredune Road to motorized use from the South Dike Road intersection to the USFS boundary to the north.

**Table 1. Summary of public comments received during 2003 scoping for the North Spit Plan and BLM response.**

| 2003 Public Comment | BLM Response |
|---|---|
| Availability of Jetty access for COE | The COE's right-of-way over BLM lands for Jetty work is not affected by the North Spit Plan. |
| Concern about plover decisions including road and beach closures | BLM will cooperate with OPRD, ODFW, and the FWS regarding plover habitat and nesting season restrictions. |
| Develop commercial ocean front property | BLM does not have the authority to develop commercial property. |
| Opposes all-terrain vehicle use | Motorized travel off of designated routes on BLM lands on the Spit is prohibited. Route designation occurred in the 1995 Shorelands Plan, page 11. |
| Opposes development | No development by BLM is planned at this time. |
| Opposes fees | No fees are planned. |
| Opposes land exchange/wants free land | BLM does not have authority to give away the public lands. Land tenure adjustments will be assessed as necessary under NEPA. |
| Protect natural and cultural resources | BLM will continue with ongoing protection efforts. |
| Remain flexible with land use; work with the Port | BLM promotes good working relations with the Port and other partners. |
| Replace boat docks | Docks will be repaired and replaced as necessary. |
| Restrict target shooting | BLM, county, and state law enforcement will enforce safe use of firearms. |
| Retain bay and ocean beach access | Pedestrian and equestrian access to BLM lands will remain except for beach access in designated areas during the plover nesting season. Motorized access will remain available on the three designated open routes. |
| Storm water drainage issues | BLM will investigate these issues with the Port. |
| Supports day use fees | No fees are planned. |
| Supports off-road vehicle (ORV) use | ORVs are permitted on the designated open routes on BLM lands. |

**Table 2. Additional Public Input.**

| Comments on the DRAFT North Spit Plan | No. of Comments during Comment Period for Draft Plan | No. of Comments from Public Forum | BLM Response |
|---|---|---|---|
| Bicycle trails - supports | 1 | | Bicycles are permitted on the Spit, however the loose sand makes bicycling difficult without paved trails. There are no plans to pave any trails at this time. |
| Bicycle trails - against | 1 | | BLM will continue to support multiple use activities. |
| Build a boat ramp | 1 | | This was completed in 1993. See Map 3 for location. |
| BLM should re-do the 2000 Biological Opinion for the western snowy plover | 2 | | BLM is planning to reinitiate consultation to update the 2000 Biological Opinion, based on additional information on visitor use and to clarify areas and activities under BLM's jurisdiction. |
| Build a retaining wall at Half Moon Bay | 1 | | This is on COE property and this Plan only addresses BLM-administered lands. |
| Cannot ride from Saunders Lake to the north jetty | | 1 | BLM will investigate the possible opening of the Foredune Road north to the USFS boundary, as a Recreation Action item. |
| Concern about losing hunting grounds | | 1 | BLM proposes no changes to legal hunting on the spit. |
| Equestrian trails - supports | 59 | 3 | BLM will continue to work with local volunteer groups to identify and maintain trails. |
| Equestrian and pedestrian trails - against | 1 | | BLM will continue to support multiple use activities. |
| Grade area by paved road and South Dike Road intersection; add a sani-can | | 2 | This parcel is being considered for sale at this time. The COE has a right-of-way for the area. It is possible BLM may create a small trailhead staging area there, pending current negotiations. |
| Improve information available about the North Spit | | 10 | BLM staff is working on this now and it was added into the action items. |
| Keep it the way it is | 2 | 10 | No additional development or access restrictions by BLM are planned at this time. |
| Keep access to bay regardless of land sales | | 1 | BLM only has jurisdiction on BLM lands. |
| Keep access to bay side open | | 1 | This is Port land, not BLM |

**Table 2. Additional Public Input. (continued)**

| Comments on the DRAFT North Spit Plan | No. of Comments during Comment Period for Draft Plan | No. of Comments from Public Forum | BLM Response |
|---|---|---|---|
| Bicycle trails - supports | 1 | | Bicycles are permitted on the Spit, however the loose sand makes bicycling difficult without paved trails. There are no plans to pave any trails at this time. |
| Bicycle trails - against | 1 | | BLM will continue to support multiple use activities. |
| Build a boat ramp | 1 | | This was completed in 1993. See Map 3 for location. |
| BLM should re-do the 2000 Biological Opinion for the western snowy plover | 2 | | BLM is planning to reinitiate consultation to update the 2000 Biological Opinion, based on additional information on visitor use and to clarify areas and activities under BLM's jurisdiction. |
| Minimize signs, gates, fences and maps | | 1 | BLM plans to remove some fences and possibly one gate. Signs are needed for safety and to inform those not familiar with the area. |
| Mitigation plan concerns (Henderson Marsh) | | 1 | The wording in the draft was changed to clarify the issue. |
| Monitor effectiveness of signs and information; coordinate with USFS; use volunteers | | 3 | This is standard procedure for BLM and it will continue for the North Spit. |
| Picnic tables should be installed at the boat ramp | 1 | 5 | This will be considered and was added as an Action item. |
| Plan departs from its underlying EA | 1 | | There are no additional ground disturbing actions in the Plan, or additional environmental impacts, thus NEPA is not required. |
| Planning – Evidence suggests its preparation could be in violation of NEPA, FLPMA, and the Federal Advisory Committee Act | 1 | | There are no ground disturbing actions in the Plan, thus additional NEPA is not required. The trail work was conducted under a volunteer agreement and it implemented MA13 in the 1995 Shorelands Plan, thus it would not be a FACA violation. |
| Plan proposals cultivate conflict. They erode traditional uses, further segregate uses, and elevate some uses above others. | 2 | 1 | The Plan makes no changes to the existing motorized and non-motorized (segregated use) access designations that have been in effect since 1985 when BLM amended the Master Framework Plan for the Coos Bay District and in 1995 with the Coos Bay District RMP and the Coos Bay Shorelands Plan. Traditional uses are not restricted and BLM welcomes volunteer groups to help us maintain trails. |
| Plan relies on irrelevant and inaccurate data (SCORP, Oregon State Parks Surveys) | 1 | | The SCORP is the best available survey resource for recreational activities and is used to assess current uses, trends and demand at the state level and subregional level. The Ocean Shore Plan survey is also relevant as it included a subsurvey from Ten Mile Creek to Coos Bay, including the North Spit. BLM also utilizes three traffic counters on the spit. |

**Table 2. Additional Public Input. (continued)**

| Comments on the DRAFT North Spit Plan | No. of Comments during Comment Period for Draft Plan | No. of Comments from Public Forum | BLM Response |
|---|---|---|---|
| Bicycle trails - supports | 1 | | Bicycles are permitted on the Spit, however the loose sand makes bicycling difficult without paved trails. There are no plans to pave any trails at this time. |
| Bicycle trails - against | 1 | | BLM will continue to support multiple use activities. |
| Build a boat ramp | 1 | | This was completed in 1993. See Map 3 for location. |
| BLM should re-do the 2000 Biological Opinion for the western snowy plover | 2 | | BLM is planning to reinitiate consultation to update the 2000 Biological Opinion, based on additional information on visitor use and to clarify areas and activities under BLM's jurisdiction. |
| Plan will cost BLM money and work the agency cannot afford | 1 | | The Coos Bay District BLM receives funding to support outdoor recreation on the public lands from a variety of appropriated funding sources. The minimal improvements proposed in the Update are well within the fiscal constraints of the Coos Bay District recreation and maintenance budget. In addition, group volunteer agreements assist in long term maintenance of trails and other projects. |
| Shooting - concerned you cannot shoot a firearm across a trail | 1 | | BLM trails and the unmaintained sand roads are not considered public roads, thus shooting is not restricted. |
| Shooting - restrict firearms | 1 | | BLM staff will track this as an issue identified by the public. |
| Shooting (firearms) safety concerns | 5 | | BLM will track this as an issue identified by the public. BLM will also include firearm safety messages in North Spit information. |
| Supports crab dock construction | 2 | 4 | This popular suggestion is hampered by funding constraints. Estimates to construct a crab dock are several hundred thousand dollars. The location is questionable with known sand and wood debris deposition, and so there are no plans for construction. |
| Supports OHV trails | 2 | 2 | This triggered a new action item in the Recreation section that will investigate the possibility of opening the Foredune Road north to the USFS boundary. |
| Weeds Program – use "Casoron" herbicide; Policy questions | | 1 | BLM is not authorized to use certain chemicals on public lands. Beach grass is not listed as "noxious," therefore, BLM cannot use "Caroson." BLM weed policy is set at the national level and cannot be changed at the field level. |

Comments received which are outside the scope of this planning document:

- It could lead to prolonging the Coos Bay District RMP revision process
- Its ties to the New Carissa DARP are obvious and the DARP is itself a NEPA/FLPMA concern
- The ACEC designation on the North Spit should be eliminated
- BLM is over emphasizing Policy 6840
- The Draft should note that the ocean beach was declared a road in 1913 and the Coos County Board of Commissioners declared a county road across the north spit at the old ferry crossing and up the beach to Tenmile Creek in 1856.

## BLM Interdisciplinary Team Members

| | |
|---|---|
| Tim Barnes | Geologist |
| Nancy Brian | Botanist |
| John Colby | Hydrologist |
| Linda Petterson | Realty Specialist |
| Sharon Morse | Interpretive Specialist |
| Steve Samuels | Archaeologist |
| Madeleine Vander Heyden | Wildlife Biologist, ACEC Manager |
| Dan VanSlyke | Fisheries Biologist |
| Tim Votaw | Hazardous Materials Coordinator |
| Dave Wash | Outdoor Recreation Planner |
| Nancy Zepf | Outdoor Recreation Planner |

This plan consists of four parts: Part One describes BLM's planning framework; Part Two reviews the original 1995 Shorelands Plan and outlines the status of its management actions; Part Three provides current information on the cultural, natural, and recreational resources on the Spit; and Part Four presents management actions on BLM-administered lands for the next ten years.

# PART 1 – PLANNING FRAMEWORK

Part One describes BLM's planning framework. In the BLM planning system there are three levels or tiers which are described below:

1. National and State Level: Laws, Regulations, and Policy
2. District Level: Coos Bay District Resource Management Plan (May 1995)
3. Field Office Level: Activity Plans (site-specific plans such as this one)

These levels are described in detail below.

## National and State Level

The management actions put forth in the North Spit Plan are guided by public laws, Executive Orders, regulations, and directives of the Secretary of the Interior. BLM policy must be consistent with these higher authorities as they provide a framework to ensure that management actions will maintain, enhance, or rehabilitate the natural resources present on the Spit while providing for public access. Pertinent federal laws, regulations and policies are summarized below.

- *Federal Land Policy and Management Act (FLPMA)* — Directs the BLM to plan for and manage the public lands in a manner that "protects the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archaeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use by encouraging collaboration and public participation throughout the planning process. In addition, the public lands must be managed in a manner that recognizes the Nation's need for domestic sources of minerals, food, timber, and fiber from the public lands."

- *National Environmental Policy Act (NEPA)* — Requires environmental analysis prior to surface disturbing activity on federal lands.

- *National Historic Preservation Act (NHPA)* — Protects important historic properties.

- *Endangered Species Act (ESA)* — Protects flora and fauna listed as threatened or endangered and at risk of extinction.

- *Code of Federal Regulations, Title 43, 8300 — Recreation Management*
  Recreation regulations guiding the inventory, planning, and management of recreational resources, including off-highway vehicle management on the public lands.

- *Executive Orders 11644 and 11988, Use of Off-Road Vehicles on Public Lands* —
  Provides a uniform federal policy for the management of off-highway vehicles on lands administered by the Departments of Interior, Agriculture, Defense and Tennesee Valley Authority.

- *Executive Order 11990, Protection of Wetlands, and BLM Manual 1737, Riparian-Wetland Area Management* — Describes the policies, responsibilities, and guidance for the identification, protection, restoration, and maintenance of fresh, brackish, and saline wetlands.

- *Special Status Species Policy (SSSP)* — Directs the BLM to conserve special status species (SSS) and the ecosystems upon which they depend so as not to contribute to the need to list these species under the ESA (USDI BLM 2001a).

# District Level

The Coos Bay District operates under its Resource Management Plan (RMP) and its Record of Decision as supplemented and amended (USDI BLM 1995a., 1995), which is in conformance with the Final Supplemental Environmental Impact Statement on Management of Habitat for Late Successional and Old Growth Forest Related Species Within the Range of the Northern Spotted Owl and its Record of Decision as supplemented and amended (i.e., the Northwest Forest Plan; Interagency 1994). The RMP addresses the designation and management of special areas such as the Spit to protect their unique natural, cultural, and recreational values.

The RMP made four specific designations for lands on the Spit:

- Area of Critical Environmental Concern (ACEC)
- Special Recreation Management Area (SRMA)
- Motorized Access Limited to Designated Roads and Trails
- Visual Resource Management Classes II, III and IV

## The North Spit Area of Critical Environmental Concern

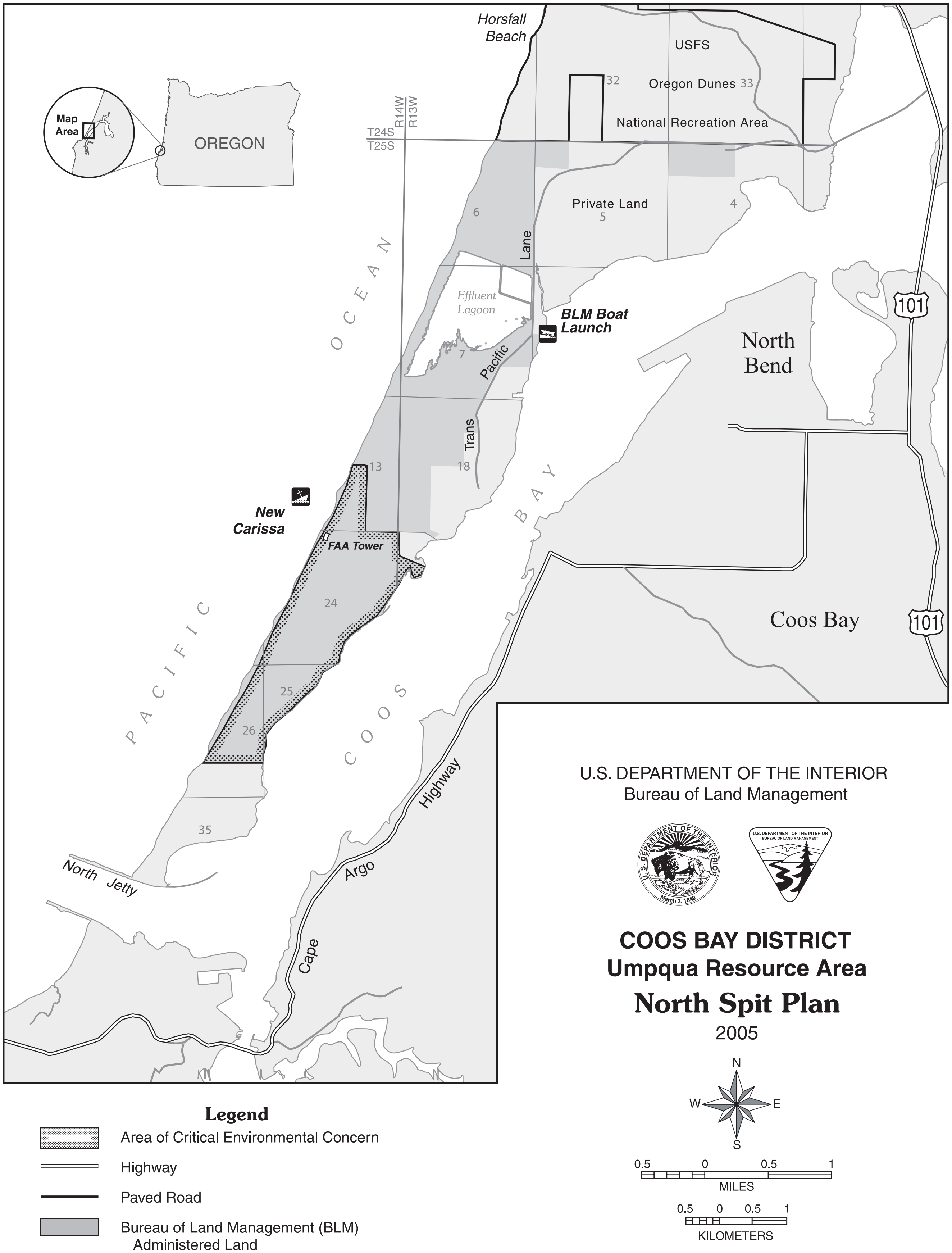
Areas of Critical Environmental Concern (ACECs) are public lands where special management attention is required to protect important historic, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes (43 CFR 1601.0-5). The District RMP designated 580 acres of the Spit as an ACEC primarily for the conservation of its outstanding biological values (USDI BLM 1995; Map 2). An additional 145 acres were obtained from private ownership, raising the ACEC's total to 725 acres.

Prior to 1995, the Audubon Society, FWS, ODFW, The Nature Conservancy, and the COE (USDI FWS 1980) recognized the Spit's high value for wildlife and expressed concern for its conservation. As one of the largest undeveloped spits on the Oregon Coast, its close proximity to a populated urban area was creating a high demand for resources and recreational use (Wilson-Jacobs 1983; USDI BLM 1980). Although adjacent private lands provided important natural areas they were under development pressure, and management objectives for the adjacent ODNRA focused primarily on motorized recreation. Consequently, protecting and preserving natural resources under BLM management was determined imperative to the conservation of the Spit's rich biological community (USDI BLM 1994). The Spit was also designated as an ACEC for its cultural and historic resources, and its scenic value to the communities of North Bend and Coos Bay (USDI BLM 1994).

In 1992, three broad objectives were identified by an interdisciplinary team tasked with developing a management strategy for the North Spit ACEC: 1) no net loss of wetlands; 2) maintain and enhance threatened and endangered species habitat; and 3) maintain and enhance a diversity of habitats for animals and plants (USDI BLM 1992). In addition, cultural and historic values would be preserved, and educational and interpretive information provided to the public. In accordance with BLM policy, recreational and other uses would be managed to provide for visitor access and enjoyment while leaving all other ACEC values unimpaired (USDI BLM 1988). The North Spit Plan incorporates these objectives and goals by providing for the preservation of ACEC values through specific and compatible management actions related to recreational access, cultural and historic preservation, wildlife and plant conservation and management, and educational and interpretive opportunities.

## Special Recreation Management Area

The designation of the North Spit as a Special Recreation Management Area (SRMA) in the District RMP formally recognized the high recreational value of the Spit's public lands. SRMAs are defined as areas "…where a commitment has been made to provide specific recreation activity and experience opportunities on a sustained yield basis." Through the SRMA designation in the




## Area of Critical Environmental Conern - Map 2

M05-12-05

RMP, the BLM has made a long-term commitment to manage the physical, social, and managerial settings on the North Spit to sustain recreational activities and experience opportunities.

In addition to SRMA designations, the RMP identified recreation management objectives for the entire Coos Bay District. Specific objectives from the RMP that direct recreation management are:
- Manage scenic, natural, and cultural resources to enhance visitor experience expectations and to satisfy public land users.
- Support locally-sponsored tourism initiatives and community economic strategies by providing recreation projects and programs that benefit both short- and long-term implementation.
- Manage off-highway vehicle use on BLM-administered land to protect natural resources, provide visitor safety, and minimize conflicts among various users.
- Continue to provide non-motorized recreation opportunities and create additional opportunities where consistent with other management objectives.

The BLM planning process defers the specific details on how these resources are to be managed to the activity planning stage, in this case through the Coos Bay Shorelands Management Plan and subsequent updates such as this document.

## Motorized Access – Limited to Designated Roads and Trails

In 1972, Executive Order 11644 established a unified federal policy for motorized vehicle management on public lands administered by the Departments of the Interior and Agriculture, the Secretary of the Defense and the Tennessee Valley Authority. This Executive Order required each respective agency to develop and issue regulations and administrative procedures to provide for the designation of specific areas and trails where motorized use would be permitted and where it would be prohibited. As directed, each of these agencies developed regulations through the Code of Federal Regulations to govern the designation and management of off-highway vehicles.

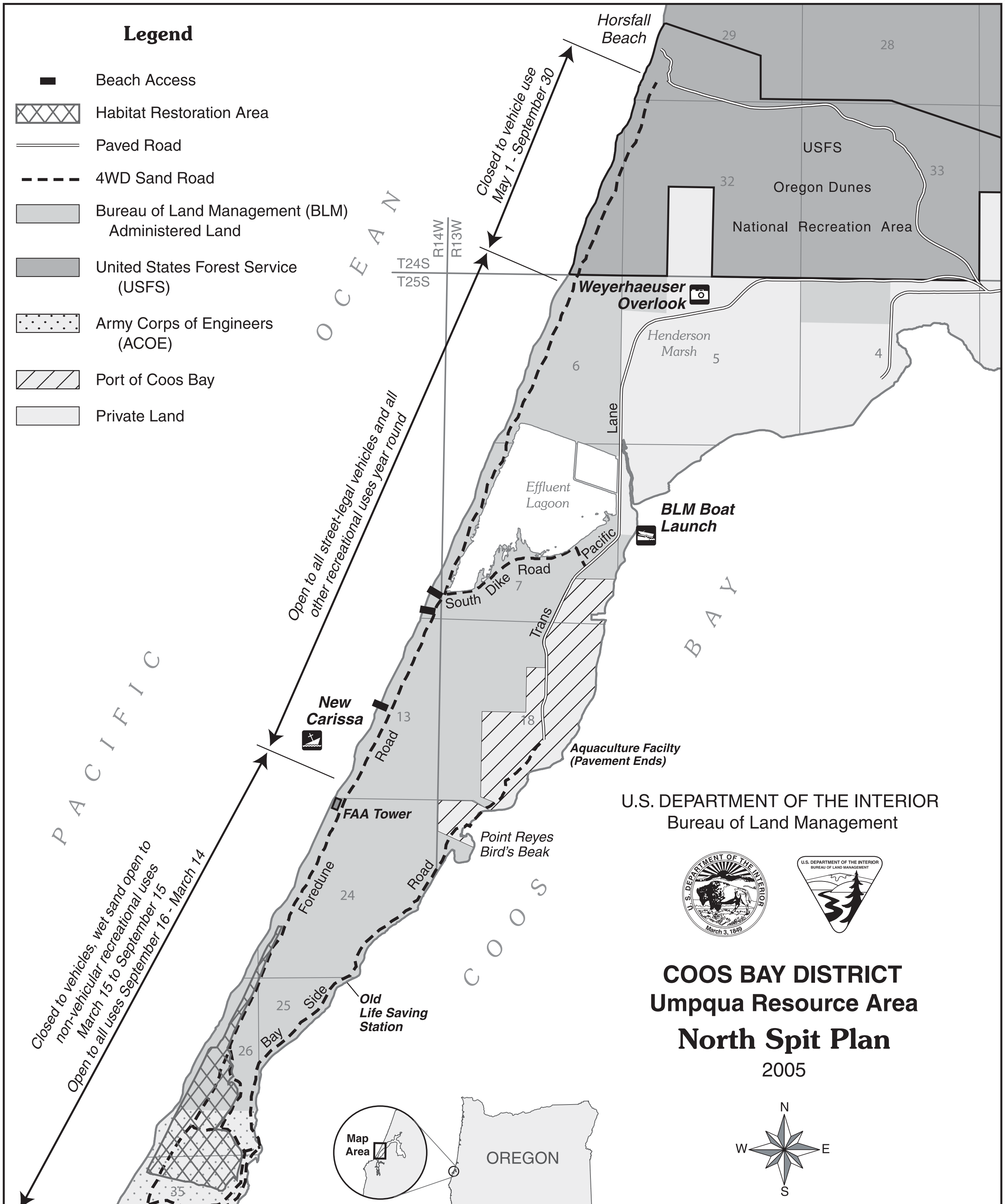
On the public lands of the North Spit, administered by the Secretary of the Defense through the US Army Corps of Engineers, off highway vehicle management has been directed by the Rules and Regulations Governing Public Use of Water Resource Development Projects Administered by the Chief of Engineers (36 CFR Part 327). Through these regulations, the operation of a vehicle off authorized roadways is prohibited except at locations and times designated by the District Commander. Since no designation had been made by the Corps of Engineers on the North Spit, these parcels were effectively closed to off-highway vehicle use prior to these lands being transferred to the BLM.

The BLM's management of off-highway vehicles is directed through the Federal Land Policy and Management Act and the Code of Federal Regulations in 43 CFR to designate areas and trails as open, limited, or closed to motorized access through the resource management planning process. The public lands on the Spit were designated through the Coos Bay District RMP as Limited to Designated Roads and Trails. The individual roads and trails were then inventoried and designated as open or closed through the Coos Bay Shorelands Plan of 1995. The four roads/trails designated as open by this plan were the South Dike Road, the Foredune Road, the Re-route Road, and the Bay Side Road (Map 3). The remaining trails were designated as closed to motorized use.

# Field Office Level

The North Spit is managed by the Umpqua Field Office of the Coos Bay District. At the field office level, site specific plans are developed to guide management activities. A chronology of planning efforts for the Spit includes:

- The Coos Bay Shorelands Draft Management Plan (USDI BLM 1989);
- The Coos Bay Shorelands Draft Management Plan and Environmental Assessment (USDI BLM 1994; EA No. OR120-93-07);
- The Coos Bay 1995 Shorelands Final Management Plan (USDI BLM 1995b), and lastly;
- The North Spit Plan, 2005.




U.S. DEPARTMENT OF THE INTERIOR
Bureau of Land Management

**COOS BAY DISTRICT**
**Umpqua Resource Area**

## North Spit Plan

2005

# Land Ownership and Landmarks - Map 3

# PART 2 – THE COOS BAY SHORELANDS FINAL MANAGEMENT PLAN, 1995

Part Two reviews the original 1995 Shorelands Plan and outlines the status of its management actions. In 1995, the Coos Bay Shorelands Plan was approved to guide management of lands on the Spit. It identified issues, concerns, and opportunities on the Spit, and included specific management actions pertaining to each of the following subjects:

- Education and Interpretation
- Land Tenure and Cooperative Agreements
- Law Enforcement
- Recreation
- Vegetation
- Wildlife Habitat

Management actions listed in the 1995 Shorelands Plan were reviewed and updated (Table 3). The actions fall into four categories: accomplished, accomplished in part, not accomplished, and ongoing. Actions in the plan that were not accomplished include those where land exchanges have removed or precluded lands from BLM jurisdiction, consequently these actions are no longer applicable to BLM management of the Spit. All ongoing and planned actions are listed in Part Four of the North Spit Plan.

In the case of Western snowy plover management, actions have evolved through a multi-agency process. The 1995 Shorelands Plan proposed several actions pertaining to snowy plovers and ocean beach access that were never implemented (Table 3, Management Action 5). Changes to management actions are a result of a revised public access strategy implemented subsequent to the grounding of the New Carissa in 1999. The strategy pertains to the management of public lands on the Spit and allows for public use while protecting plovers and promoting their recovery (USDI FWS 2000). Strategy details are described in Part Three under Species of Special Management Concern.

The following actions described in the text of the 1995 Shorelands Plan (Actions 4, 7, 11, 12, 13, 16, and 20) were not incorporated into the original Management Action Chart. Action 4 – Bay Beach Access is not BLM land; Action 7 –Campground Construction - No construction will be developed; Action 11RV Dump Station – no RV dump station will be installed; Action 12 – Equestrian Staging Area – No area to be developed at this time; Action 13 – Non-motorized trails – trails will be available but not maintained; Action 16 – Barrier-free interpretive loop – No loop will be developed; Action 20 – Coos Head – no day use site will be developed.

## Text Changes

The 1995 Shorelands Plan made some recommendations that were not listed as actions. Errors, additions, or changes to these recommendations are as follows:

1. Page 10, first paragraph – "The BLM will petition to Oregon State Parks to prohibit the following activities on the CBS (Coos Bay Shorelands) ocean beaches: removing surfcast kelp and driftwood, allowing dogs to run free, and falcon flying." This action is no longer under consideration as the ocean beaches are under the OPRD's jurisdiction.

2. Page 10, second paragraph related to the potential discovery of a plover nest on the Foredune Road – Delete: "In addition, the road will be seasonally closed for 200 feet from the nest site until chicks have left the nesting area, or rerouted temporarily to avoid active nests." The road

is currently re-routed every six months. Other actions that may occur to protect nesting plovers will be done in cooperation with the FWS and other agencies as required.

3. Pages 11, OHV Access – There are seven bullets describing allowable motorized access.The three items below are no longer applicable.

   - Remove – “Wet sand along the ocean beaches year round.” Wet sand is under the jurisdiction of OPRD.
   - Remove – “260-acre open sand area (by permit only…)”. This management action was inconsistent with the regulations and policies that were in effect in 1995 and was inconsistent with the land use allocations identified in the Coos Bay District RMP of 1995. An activity level plan, such as the Shorelands Plan, was not sufficient for changing the OHV designation status of this 260 acre parcel from Limited to Open. This statement was removed through a plan maintenance action in 2000. This area remains a Limited Area as per the Record of Decision in the RMP.
   - Remove – “80-acre parcel near the Roseburg Chip Facility (by permit only…).” This management action was inconsistent with the regulations and policies that were in effect at that time and was inconsistent with the land use allocations identified in the Coos Bay District RMP of 1995. An activity level plan, such as the Shorelands Plan, was not sufficient for changing the OHV designation status of this 80 acre parcel from Limited to Open. This statement was removed through a plan maintenance action in 2000. This area remains a Limited Area as per the Record of Decision in the RMP.

4. Pages 13, 14 – Management Action 5 – Ocean Beach Access:BLM was to petition OPRD to enact restrictions on the ocean beach. There are 14 action items, including rationale. Remove all actions as the wet sand beach is under the jurisdiction of OPRD.

5. Page 16 – Management Action 12 – Equestrian Staging Areas.Equestrian use in the Central Coast Region of the Oregon Coast has increased by 39% since the last Shorelands Plan was written. The Spit has become one of the more popular equestrian riding areas in the region and a need has been identified to provide an adequate staging area for the off-loading/loading of horses.

6. Page 16 – Management Action 13 - Non-Motorized Trails.The BLM proposed the designation of approximately 12 miles of hiking/equestrian trails in the 1995 Shorelands Plan. The BLM will implement this action and will identify a trailhead/staging area. The agency may develop new trail segments and will establish local partners to assist in the management and maintenance of the trail system (see Recreation, Part Three).

**Table 3. Management actions as described in the Coos Bay Shorelands Final Management Plan (USDI 1995) and their current status.**

| Management Action | Status | Comments |
|---|---|---|
| Biological mapping of plant communities and wildlife habitats. | Accomplished. | Plant communities were mapped and preliminary information reported for plant alliances and vegetation classes based on the Oregon Dunes NRA assessment (Christy et al. 1998). Information on wildlife habitats may be obtained from the mapped plant alliances. |
| Cadastral survey (to determine mean high tide on the bay side). | Not accomplished. | This action was originally proposed in relation to the Point Reyes bird's-beak. The plant has been protected by re-routing vehicles around it and placing root wads to protect the area as authorized by the management agency (Port and DSL). Additional maintenance actions on state lands will be conducted per written agreements from the appropriate agency. |
| Land tenure adjustments (Page 10 in 1995 Shorelands Plan). | Accomplished, in part. | Priorities 2, 3, and 4 have been accomplished. If Priority 1 is accomplished, the bay side access road will come under BLM jurisdiction and will be designated as open for motorized access. |
| MA-1. North Dike road improvement and turnaround construction. | Not accomplished. | This road is owned by Weyerhaeuser. |
| MA-2. Extension of Trans Pacific Parkway (now called Trans Pacific Lane) for 1/3 mile to day-use facility. | Not accomplished. | The area proposed for the road extension belongs to the Port. If the lands are acquired by BLM, the extension would not be paved, nor would a day use area be built. The road would be designated as open for motorized access. |
| MA-2. Bay Side road construction, includes post and cable installation. | Accomplished, in part. | This area is under the Port's jurisdiction. Post and cable installation and a road reroute to protect the Point Reyes bird's-beak was completed and will be maintained. |
| MA-3. Petition DSL to prohibit motor vehicles on 1/2 - 3/4 mile section of bay beach around salt marshes. | Not accomplished. | BLM's re-route has been effective thus precluding the need for the prohibition (see above). |
| MA-5. Petition to OPRD to close dry sand portion of ocean beaches, south of effluent pond between March 15 and Sept 15 (Western snowy plover nesting season). | Not accomplished. | Because much of the dry sand portion of the ocean beach is under BLM jurisdiction, the annual closure request to OPRD is not necessary. However, changes in plover management are reflected in a different closure area: BLM closes the dry sand from the FAA (Federal Aviation Administration) tower (not the effluent pond) south to within one mile of the Jetty. |
| MA-5. Petition OPRD to close ocean beaches from south end of effluent pond to Forest Service boundary. | Not accomplished. | This did not occur and is not necessary for the protection of snowy plovers. BLM will cooperate with OPRD when the final Ocean Shores Management Plan is completed (OPRD 2004). |

| Management Action | Status | Comments |
|---|---|---|
| MA-5. Petition OPRD to close ocean beaches from 30 minutes after sunset to 30 minutes prior to sunrise. | Not accomplished. | BLM will cooperate with OPRD's final Ocean Shores Management Plan when it is completed (OPRD 2004). |
| MA-5. Signs indicating designated access routes to ocean beaches, south of effluent pond. | Ongoing. | Signs are maintained as necessary. |
| MA-5. Signs indicating non-authorized access points to ocean beaches south of effluent pond. | Not accomplished. | Non-authorized access points to the ocean beach were not signed. Signs indicating authorized access points were placed. |
| MA-5. Informational signs explaining beach access. | Ongoing. | Signs are in place. New OPRD signs will be used in the future. |
| MA-5. News releases and updates on ocean beach access. | Ongoing. | Information is provided to the media as needed. |
| MA-5. Public meetings discussing beach access. | Ongoing. | Meetings primarily occur through OPRD'S planning effort and North Spit Plan public scoping. BLM accepts public comments and suggestions at any time. |
| MA-6. 260-acre and 80-acre open sand areas open to OHVs by permit only. | Not accomplished. | No permits were requested. Motorized access is permitted on sand roads designated as open. This policy was inconsistent with the OHV designations created in the RMP. |
| MA-6. Signs marking perimeter of open sand areas. | Not accomplished. | Motorized access remains open on designated sand roads. This action was inconsistent with the OHV designations created in the RMP. |
| MA-8. Pack-in camping permitted throughout the CBS with length of stay not to exceed 14 days. | Ongoing. | Allowed except in designated snowy plover areas during the nesting season. |
| MA-8. Vehicles remain within 100 feet of designated roads. | Ongoing. | Allowed except where signed to protect natural resources. |
| MA-10. MA-10. Placement of garbage cans and vault toilets at day-use facility (near anadromous facility). | Not accomplished. | The area is not under BLM jurisdiction. No new developments are planned on BLM lands. The correct name of the anadromous plant is the North Bay Aquaculture Facility and it is owned by the Port. |

| Management Action | Status | Comments |
|---|---|---|
| MA-10. Maintenance of vault toilets and garbage cans at day-use facility. | Not accomplished. | The area is not under BLM jurisdiction. |
| MA-14. Firearms policy. | Not accomplished. | Federal and state regulations cover the discharge of firearms in developed and undeveloped areas. Enforcement occurs through federal, state, and county patrols. |
| MA-15. Development and installation of Watchable Wildlife signs along bay and at north dike day-use facility. | Not accomplished. | These areas are not under BLM jurisdiction. Wildlife information may be provided at the proposed boat launch information kiosk. The potential remains for a "Watchable Wildlife" site to be developed. |
| MA-17. Closing of non-designated roads and trails using logs or root wads. | Ongoing. | BLM will maintain vehicle barriers to the interior of the Spit as necessary to deter resource damage from unauthorized motor vehicle use. |
| MA-18. Management of European beach grass. | Ongoing. | Occurs within the snowy plover Habitat Restoration Areas. |
| MA-19. Noxious weed control. | Ongoing. | Occurs under BLM's weed management program. |
| MA-21. Timber, standing or down, cutting prohibited. | Ongoing. | Dependent upon standard Bureau procedures including NEPA compliance and Small Sales Permits. |
| MA-22. Development of interagency, inter-tidal agreement to manage salt marshes within the Coos Bay estuary. | Not accomplished. | These areas are not under BLM jurisdiction. Any work done in the salt marshes necessitates permits from the appropriate agencies prior to the start of the project. No new projects are proposed. |
| MA-23. Salt marsh restoration (depends on rate of natural re-vegetation of salt marsh). | Not accomplished. | See above. |
| MA-24. Introduction of pink sand verbena. | Accomplished. | Pink sand verbena seeds are collected for dispersal at other coastal sites. |
| Monitoring of dry sand closure during Western snowy plover nesting season. | Ongoing. | Occurs in compliance with FWS' Biological Opinion. |

| Management Action | Status | Comments |
|---|---|---|
| Monitor permanent traffic counters. | Ongoing. | Traffic counters are maintained and data collected.  Counters may be moved to different locations as warranted. |
| Monitor salt marsh bird's-beak population. | Ongoing. | The correct name is Point Reyes bird's beak.  No additional protections are required, however BLM will maintain the existing vehicle re-route and root wad barrier on the bay side of the Spit, as permitted by DSL. |
| Monitor Western snowy plover nesting exclosure and brood success. | Ongoing. | Cooperative effort with ORNHIC, OPRD, ODFW, FWS, and COE. |
| Monitor great blue heron and great egret rookery. | Ongoing. | The rookery was abandoned in 2000.  Surveys will be conducted to locate additional rookeries on BLM lands.  A new rookery was discovered in 2002 on ODNRA lands and in 2004 on the northeast side of the Spit on BLM. |

# Part 3 –North Spit Resources

## Introduction

Part Three describes the cultural, natural, and recreational resources on the Spit. Management actions are listed in Part Four. Resources are grouped into five categories:

- Physical, including Water, Geology, Soils, Minerals, Coal Bed Methane, Oil and Gas
- Biological, including Vegetation, Wildlife, and Fisheries
- Cultural and Historical
- Recreational
- Visual

### Physical: Water Resources

#### *Climate*

The Central Oregon Coast has a temperate maritime climate characterized by cool, dry summers and mild, wet winters. Rainfall occurs primarily from November through March and averages 63 inches per year at the North Bend Municipal Airport near the Spit. The average annual maximum and minimum temperatures at the North Bend Municipal Airport for the period January 1931 to December 2004 are 60ºF and 45ºF respectively. Temperatures above 90ºF or below 20ºF are rare (Western Regional Climate Center 2004).

Prevailing winds are from the north-northwest in the summer and from the south-southeast in the winter (Oregon Climate Service 2004). Summer days are characterized by foggy mornings, sunny afternoons, and cool evenings. Afternoon northwesterly winds are quite cool. Precipitation is light and spotty; however, fog or low overcast clouds may persist all day, and fog drip may contribute to available moisture. Winter weather is characterized by frequent rains with intermittent clearing periods. Snow may fall on the beach every few years when Arctic air meets an onshore flow of moist air.

#### *Groundwater*

The groundwater supply in the Coos Dune Sheet aquifer is large. The Coos Bay – North Bend Water Board has 18 freshwater production wells just north of the BLM-administered lands on the Spit. Although these 90 to 120 foot deep wells can produce up to 4 million gallons per day (Mgal/d), they are currently not being used (Schab 2004). According to Jones (1992), model simulations indicate that 10 Mgal/d could be pumped with minimal risk of seawater intrusion into the dune aquifer. The model also indicates that a maximum of 17 Mgal/d could be pumped without causing intrusion, but the risk associated with pumping this quantity over time is uncertain.

Both the Water Board and the Weyerhaeuser Company monitor groundwater levels and groundwater quality (Souza 2004). The Water Board maintains 55 monitoring wells in the dunes between the Spit and Tenmile Creek. Eight of the wells are sampled for chlorides and the remainder of the wells are used to measure static water levels. The production wells mentioned previously are monitored monthly for seven water quality parameters.

Between 1982 and 1997, several groundwater monitoring wells were installed near the Weyerhaeuser containerboard mill and the former effluent lagoon, and on adjacent property managed by the Bureau of Land Management. The wells were installed for environmental assessment, and permit-required characterization and water quality monitoring related to wastewater discharge an solid waste disposal.

Weyerhaeuser currently has 9 serviceable groundwater monitoring wells in or adjacent to the former effluent lagoon. Twenty-five other wells in the same area were decommissioned between October 2004 and January 2005 to reduce maintenance and eliminate potential risks related to the integrity of wellheads and surface seals.

Weyerhaeuser also has 13 serviceable groundwater monitoring wells in the vicinity of the former containerboard mill on the Spit. Seven additional wells in the same area were decommissioned in October 2004 (Souza 2005)

### *Wetlands*

Vegetation mapping using 1999 aerial photographs and ground-truthing indicates that roughly 27% (669 acres) of the North Spit is open water or supports vegetation indicative of semipermanently flooded, seasonally flooded, and saturated areas. The US Fish and Wildlife Service's National Wetlands Inventory (NWI) identifies several wetland types on the Spit. Marine, intertidal habitats of high salinity are found along the Pacific Ocean shore, and intertidal and subtidal estuarine wetlands of moderate salinity are located on the bay side of the Spit. Freshwater, nontidal (palustrine) wetlands are scattered in low lying portions of the deflation plain east of the ocean and foredune.

The goals of the NWI is to classify and map the nation's wetlands and evaluate wetland status and trends. National Wetlands Inventory maps covering the Spit were published in 1989 and contain information on the location and classification of wetlands. This information is overlaid on the Charleston and Empire 7.5 minute (1:24,000) US Geological Survey topographic maps. The NWI maps were based on interpretation of visible hydrologic features and wetland vegetation using high-altitude aerial photographs (1:58,000) taken in August and September 1982. Because dynamic systems like the Spit wetlands vary seasonally and annually, these maps likely differ from current conditions.

Wetlands mapped by the NWI must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes (plants adapted to live in anaerobic (oxygen free) soil conditions; (2) the substrate is predominantly undrained hydric soil (soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part); and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979).

The NWI maps were not intended to delineate regulated wetlands. Delineation is defined as a determination of wetland presence that includes marking the wetland boundaries on the ground and/or on a detailed map prepared by a professional land surveyor or similar accurate methods (Oregon Administrative Rules 141-090-0020). Delineation of jurisdictional (regulated) wetlands is determined by on-the-ground examination of hydrology, vegetation, and soils (USDOD 1987). It requires that specific vegetation, soils, and hydrology attributes be found to make a positive wetland determination.

**Palustrine Wetlands.** Seasonal precipitation that infiltrates into the relatively porous dune sheet recharges groundwater and sometimes appears as standing water in relatively small, freshwater deflation plain wetlands east of the foredune. The 1989 NWI maps covering the Spit show roughly 300 acres of unconsolidated shore, emergent, scrub-shrub, and forested wetlands scattered throughout BLM-administered land. Unconsolidated shore habitats include beaches, bars, and flats with less than 30% areal vegetative cover other than pioneering plants. Emergent wetlands (marshes) are characterized by erect, rooted, herbaceous hydrophytes. This vegetation is present for most of the 335 day growing season (USDA FS 1993) and these wetlands are usually dominated by perennial plants. Scrub-shrub wetlands are dominated by woody vegetation less than 6 meters (20 feet) tall, and forested wetlands have woody vegetation that is 6 meters tall or taller. Swamps are wetlands dominated by trees or shrubs. A shrub swamp often occurs as a transitional phase between habitats evolving from a marsh to a swamp.

Temporarily and seasonally flooded unconsolidated shore, emergent, and scrub-shrub habitats were mapped on the Spit. Temporarily flooded areas occur where the surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface. Seasonally flooded wetlands have surface water present for extended periods, especially early in the growing season. Surface water is absent by the end of the growing season in most years.

Deflation plain wetlands are a direct result of foredune establishment (USDA FS 1993). Over the past several decades, the foredune has essentially cut off the supply of wind blown sand to the inland open sand dunes. Winds continue to move the remaining inland dune sands toward the bay, stripping sand from the eastern edge of the deflation plain and further exposing the water table. This deflation also occurs further inland in troughs among dunes. Rapid plant succession follows exposure of the water table and early seral stage wetlands (e.g.: grass, sedge, rush, low shrub) progress toward later seral stages (tall shrub, shore pine). Because the surface of the deflation plain is at the summer ground water level, only plants tolerant of perennially wet soils can survive.

**Estuarine Wetlands.** Based on the 1989 NWI maps, roughly 300 acres of intertidal, estuarine wetlands are located on the bay side of the Spit south of the North Bay Aquaculture Facility. A majority of these habitats (nearly 265 acres) are classified as aquatic bed and unconsolidated shore wetlands that are regularly flooded (tidal water floods and exposes the land surface at least once daily) and irregularly flooded (tidal water floods the land surface less than daily). Aquatic bed habitats are dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Approximately 35 acres of regularly and irregularly flooded, emergent wetlands (marshes) border the beach on both sides of the dredge disposal lobe. Vegetated marshes develop on deposits of fine sediment in low velocity areas of the estuary. Additional deposition in areas of established vegetation alters site characteristics and suitability of the habitat for different plant species (Coats 1995).

**Marine Wetlands.** Marine, intertidal habitats are found along the high energy Pacific Ocean shore. Two habitats are recognized by the NWI: unconsolidated shore (beach) that is regularly flooded (inundated daily), and unconsolidated shore that is irregularly flooded (inundated less than daily).

**Henderson Marsh Mitigation Plan.** Although not a signatory party, BLM has been involved with the Henderson Marsh Mitigation Plan (HMMP) because the original plan identified sites on federal lands to be used for wetland mitigation.

Historically the lands known as Henderson Marsh were owned by private individuals and used for grazing. Menasha Woodenware Corporation acquired the land and, in 1959, developed plans for a paper mill which required the construction of a waste water treatment lagoon. The original plan was to place the lagoon in Henderson Marsh. Through the intervention of state and federal wildlife management agencies, the lagoon was sited on federal land in the deflation plain southwest of Henderson Marsh (Map 3). Menasha agreed to hold the lands in Henderson Marsh available for waterfowl management, including public hunting, and to construct and maintain dikes, spillways, and tidegates to improve waterfowl habitat.

In 1978, plans were developed to fill a significant portion of the Henderson Marsh. Because filling required compensation for wetland losses, a task force was formed in 1979 to create a mitigation plan. In 1981, Weyerhaeuser purchased the Menasha holdings on the Spit including Henderson Marsh. The HMMP was finalized in 1984 and signed by Weyerhaeuser, the Oregon Department of Fish and Wildlife, and the US Fish and Wildlife Service. The HMMP allows for the filling of 160 acres of freshwater and saltwater wetlands and identifies mitigation actions on public and private lands to compensate for the loss of these wetlands.

BLM has provided technical advice to Weyerhaeuser on mitigation projects, and participated in the development of a wetlands monitoring protocol. In addition, a limited amount of open water pond and wetland habitat was constructed on federal land for mitigation. A weir and reverse tidegate system was installed in upper Jarvis Creek when the Trans Pacific Lane was built to create a brackish water regime west of the road corridor and hold open water to a larger surface area. This area immediately north of the effluent lagoon is permanently flooded and classified as a subtidal, estuarine wetland on the Empire NWI map. Approximately 5 acres of estuarine and 24 acres of freshwater habitat were created or enhanced by installing the water control structure. Another 6 acres of ponds were created further north on BLM-administered land.

## Physical: Geology and Soils

### *Eolian and Oceanic Processes*

Two separate, but interrelated, geomorphologic forces on the earth's surface occur to form and shape a sediment dominated beach and its associated dunes. These processes are oceanic and eolian (wind). The oceanic process is the mechanism that delivers eroded sediment to the beach front. The eolian process is the mechanism that mobilizes unincorporated beach sediment inland. The oceanic process creates, molds, and removes beaches, spits, and headlands. The eolian process creates and mobilizes the ridges, dunes, dune fields, and deflation plains.

**Eolian Process.** Numerous dune fields exist along the Oregon Coast, including the Coos Bay Dune Sheet, located north of Coos Bay. Components needed for dune formation are abundant loose sand, wind, and a favorable terrain. Other ingredients that play important roles in dune-

***North Spit deflation plain.***

forming include water and vegetation. Human alteration of these components influence the sand migration process (Lund 1973). The coastal dune fields are within two miles of the ocean shore with most immediately adjacent to sand beaches.

Three episodes of dune advance in the Coos Bay dune sheet and other dune fields are documented (Cooper 1958). The earliest is represented today by a strip of thoroughly vegetated dunes that in most places achieved the greatest landward advance. The second advance generally fell short of the first, and its present condition ranges from complete stabilization to still vigorous activity. The third episode is represented by the large areas of active dunes that until recently had open access to the ocean beaches that supplied them with sand. The landward edges of these dune fields are well defined by the presence of precipitation ridges with steep slip faces that slowly invade and bury adjacent vegetation, including forested areas. The precipitation ridge often blocks stream drainage, creating ponds and lakes (Komar 2000).

The eastern face of the migrating dune, called the precipitation ridge (Cooper 1958) will migrate several feet a year by the accumulation of sand along a slope on the inner boundary of the active dune belt. Because both winter and summer wind patterns are landward, sand supply is provided year-round (Lund 1973). This migration of sand is sufficient to cover existing forests as well as other vegetation (Lund 1973; Komar 2000). Along the dune field north of Coos Bay, dune advancement has been measured at 6 to 18 feet per year (Alt and Hyndman 2001).

Water and vegetation reduce the rate at which sand shifts (Lund 1973). In many areas dunes are being actively molded by winds while in other areas vegetation now covers formerly mobile dunes (Komar 2000). Where eolian sand moving across a smooth surface meets an obstruction, the carrying velocity is lost behind the obstruction. This causes the sand to be deposited. Such evidence can be seen in summer at many places along the dry sand part of the beach where sand is accumulating on the lee side of a log or some other object. Native vegetation and natural debris have naturally stopped enough sand to create a low beach ridge, but much of the sand was able to move past the ridge and enter the dune-building activity behind the shore (Lund 1973).

However, as described by Lund (1973):

> *"... with the introduction of European beach grass on the West Coast, the conditions along the shore underwent a pronounced and rapid change, and in the past 25 or 30 years a foredune has built up along the shore that has effectively shut off movement of sand from the beach at all but a few places along the Oregon coast..."*

The newly created foredune is a ridge of coalesced (grown together) hillocks superimposed on an earlier, low beach ridge. The hillocks nearest the beach stop most of the sand and continue to grow while the ones farther from the beach stay about the same size or grow slowly. During winter storms, waves reach the base of the foredune ridge and erode it back to an abrupt edge. Thus in places, banks several feet high are formed which block the inland migration of sand, increasing the effectiveness of the foredune as a barrier (Lund 1973). The Spit foredune is representative of the stabilizing affects of European beach grass (Beckham 2000).

With the foredune stopping the supply of sand to the dunes along most of the Oregon coast, the interior dunes are now consuming themselves. As the dune field narrows at the expense of the western sand supply, a deflation plain forms and expands. The deflation plain is caused by the vertical removal of loose sand to the point that the summer groundwater table is reached. The saturation of the sand makes it harder for wind to move it, increasing its stability in wind velocities. As erosion stops, vegetation propagates in the deflation plain. This zone at the western edge of the active dune belt or field thereby demarks the end of dune activity (Lund 1973). However, when stabilizing vegetation is removed from the dunes, the mobilization of sand can be reinitiated (Komar 2000).

**Oceanic Process.** Oceanic processes supply material to the beach front, circulate the sediment within the littoral (situated near a shore) cell, and are the cause of beach and dune alteration.

Along the Oregon Coast, waves tend to arrive from the southwest during the winter and from the northwest during the summer, corresponding to prevailing wind directions. As a result, there is a seasonal reversal in the direction of littoral drift (migration of sand within the oceanic process); north during the winter, south during the summer. The net littoral drift is the difference between these northward and southward sand movements (Komar 2000).

In general and with few exceptions, net littoral drift is zero due to the large rocky headlands that extend sufficiently into deep water to prevent sand and coarse sediment migration. On many coasts, sand spits grow in the direction of littoral drift. However, sand spits are documented in both north and south directions within zero net drift littoral cells (Komar 2000). Human made features such as jetties impact this sand migration, causing deposition behind the jetties, with accompanying erosion from other areas of the beach front. The Spit grew as sand accumulated southward (Beckham 2000).

The erosion mechanism of the oceanic process is aided by a number of systems, individually or in combination, such as raising ocean levels, storm energies, upland landslides, and rip current embayments (landward erosion of the beach, forming steeper sloped scallops in the beach front). It is estimated that currently the Oregon Coast is retreating by two feet per year (Orr and Orr 2000). The oceanic processes that supply sediment to create beaches, spits, ridges and dunes (foredunes) also supplies the energies needed to destroy and reshape these features.

Breaching and overwashes are common on spits and barrier islands along the East and Gulf Coasts of the United States, where the sea level is rising with respect to the land. Natural breaching of well established spits along the Oregon Coast is not common. The Northwest Coast is rising tectonically, and this probably accounts for the rarity of spit breaching (Komar 2000). However, northwest spit erosion was documented on the Siletz Spit where the foredune retreated a hundred feet within three weeks during winter storms in 1973 (Komar 2000).

Other events may deliver a series of waves related or unrelated to plate subsidence. These tsunamis, whether from a Cascadia Event, other distant plate movements, or submarine landslides, may deliver waves with sufficient height and energy to overtop the spit, relocating sand and dunes and creating breaches. Such effects were witnessed on the New River Spit from tsunamis delivered by the 1964 Good Friday Earthquake in Alaska (Komar et al. 1999). Large portions of the North Spit are within the tsunami runup boundary (Priest 1995a and 1995b).

European beach grass trapped the migrating sand causing the creation and elevation of the foredune thus greatly increasing the Spit's stability (Beckham 2000). The Spit's existence, alterations, and dynamics were created and are maintained by the manipulation of oceanic and eolian processes common to the Northwest Coast, and actions that alter these processes may potentially impact Spit dynamics. Grass removal may compromise the stability of the Spit, exasperating erosional conditions and potentially leading to overwash where dune elevations are sufficiently lowered.

## Physical: Minerals

### *Silica*

Historical investigations have been made as to the silica value of Spit sands. Production of silica sands from the Spit, used in glass manufacturing, was documented at 25,000 tons per year (Geitgey 1990). Preliminary studies indicate that the Spit may have mineral potentials for glass and foundry sands, (and other minerals), however current economics may not be sufficient for their development.

## Physical: Coal Bed Methane, Oil and Gas

Coal Bed Methane (CBM) is a relatively recent resource, with development occurring within the last 20 years. Although considered an unconventional resource, it currently reflects 8% of the country's reserves. Potential economic reserves lie between 1,000 and 4,000 feet below the ground. Surface coals have lost the CBM to atmospheric escape. Coal extraction can be developed after methane extraction; however, the depth, with current economics and technology, is usually beyond resource development. Removal of CBM does not reduce the energy capability of the coal bed.

The coal bed methane is held within the molecular structure of the coal, kept below vapor pressure by water confinement. This is different than natural gases and oils, which are formed from mature organics, separated from the source rock, and migrate to a trapping structure. In CBM extraction, the drilling first encounters water within the coal seam. As this water is removed, the pressure is reduced, releasing the methane from the coal seam. This is then collected from a wellhead system (Pappajohn 2002).

Geologic mapping indicates that the Spit is located within the Coos Basin, which includes numerous coal and organic bearing formations. It is inferred that the Spit is underlain by the Coaledo Formation, consisting of coal bearing sediment beds (Madin et al. 1995). Currently, mineral leases have been granted by DSL for the exploration and mineral extraction of submerged lands adjacent to the Spit. While speculative, the potential for oil and gas development does exist under the Spit. Historically, oil and gas leases were issued on the Spit (Fritz 1992).

The BLM has a well developed mineral leasing program, and the Spit lands maintain a "No Surface Occupancy" (NSO) and "Controlled Surface Use" (CSU) for leaseable minerals. The lands have been withdrawn from location and entry for locatable and salable minerals. Leaseable, locatable, and salable minerals are difficult to list because the history of the law has resulted in a definition of minerals that includes economics of minerals. As an example, sand can be considered as a "salable" material, sold by competitive and noncompetitive sales by the unit for construction. Sand can also be claimed under the locatable laws because of the economically valuable silica component of sand, provided the silica content is sufficient to meet an "uncommon" mineral definition.

## Biological: Vegetation

### *Botanical Surveys*

Inventory of the flora of the Spit is incomplete (Appendix 1). Only four botanical surveys were conducted on the Spit. In 1989, an informal vascular plant survey was conducted for a small portion of the western shore of the Spit between the North Bay Aquaculture Facility and the site of the 1892 US life-saving station (Stansell 1989). In 1998, a sedge (Carex spp.) survey was conducted as part of a Challenge Cost Share project (Zika et al.1998). In 2003, BLM staff prepared a preliminary map of the vegetation alliances (see below). A vegetation alliance is a plant association based on the National Vegetation Classification System, a hierarchical classification designed to standardize vegetation classification in the United States. In 2004, BLM staff conducted a survey of the 80 acre BLM parcel located south of the Trans Pacific Lane (Sperling 2004).

The vegetation alliances of the Spit were mapped using June 1999 aerial photography and ground-truthing. Alliance polygons were digitized and represent vegetation classes as defined by the National Vegetation Classification Standard (The Nature Conservancy 1994). They are similar to the plant associations found in the ODNRA (Christy, Kagan, and Wiedemann 1998). The five vegetation classes on the Spit and their overall percentage are as follows: forest (25%), woodland (2%), shrubland (17%), dwarf-shrubland (trace %), and herbaceous (32%). Approximately 24% of the Spit is not vegetated, but is characterized by open sand, disturbed areas, blacktop, and open water.

Further refinement of the vegetation map is needed, however some characteristics can be described. The Spit forest and woodland areas commonly include shore pine (*Pinus contorta* ssp. *contorta*) and Sitka spruce (*Picea sitchensis*). The shrubland is characterized by salal (*Gaultheria shallon*), evergreen huckleberry (*Vaccinium ovatum*), willow (*Salix* spp.), wax myrtle (*Morella californica*), sword fern (*Polystichum munitum*), European beach grass (*Ammophila arenaria*), rhododendron (*Rhododendron macrophyllum*), coyote brush (*Baccharis pilularis*), and Scotch broom (*Cytisus scoparius*). The dwarf-shrubland is composed of bog blueberry (*Vaccinium uliginosum*) and tufted hairgrass (*Deschampsia caespitosa*). The herbaceous community includes salt rush (*Juncus lesueurii*), slough sedge (*Carex obnupta*), Pacific silverweed (*Argentina egedii*), seashore lupine (*Lupinus littoralis*), beach morning-glory (*Calystegia soldanella*), beach silver-top (*Glehnia littoralis*), American bluegrass (*Poa macrantha*), American dunegrass (*Leymus mollis*), floating-leaved pondweed (*Potamogeton natans*), and European beach grass (*Ammophila arenaria*). The salt water marsh is a type of herbaceous community and is characterized by pickleweed (*Salicornia virginica*), fleshy jaumea (*Jaumea carnosa*), and salt grass (*Distichlis spicata*).

### *Botanical Resources*

The Spit marks the southern limit of the subarctic beach flora and the northern limit of the dry Mediterranean beach flora (USDI BLM 1994). It has approximately 75 nonvascular and over 140 vascular plant species (Appendix 1). Additional species will undoubtedly be discovered as the area is botanically explored and a systematic survey is conducted. As a comparison, about 260 vascular plant species are reported from the adjacent ODNRA (Christy, Kagan, and Wiedemann 1998).

Four sites within the ODNRA (South Horsfall Campground, Tenmile Creek Research Natural Area, Umpqua Lighthouse State Park, and Eel Creek) located directly north of the Spit have been identified as having ecological cells and special species unique to the Coast Range Ecoregion (Natural Heritage Advisory Council 2003). Similar cells and species are present at the Spit.

One globally significant community on the Spit is the unstabilized coastal dune wildrye and beach pea vine (*Leymus mollis* ssp. *mollis – Lathyrus japonicus*) community. The Natural Heritage Program uses a prioritization system for determining global significance of plant communities (Kagan et al. 2004). Globally, species are ranked from 1-5 based on the number, quality, and condition of the occurrences; the narrowness of range; the trends in populations and habitats; and the threats to and the fragility of the element being assessed. The wildrye and beach pea vine community is a G1 plant community that is considered critically imperiled globally with typically five or fewer occurrences (Kagan et al. 2004). This community type was likely much larger on the Spit prior to the 1930s. Currently, only isolated patches remain and are threatened by invasion of European beach grass. The occurrence of this unique plant community on the federally managed lands on the North Spit is important to the conservation of the community. The District's RMP calls for recognition, protection, and restoration of unique special habitats (USDI BLM 1995).

### *Special Status Species*

Twenty-two special status plant species within the Bureau sensitive and assessment categories are located on BLM lands on the Spit. These include nine vascular plant species and thirteen nonvascular plant species (Table 4). Populations of the two vascular Bureau sensitive species, the pink sand verbena (*Abronia umbellata* ssp. *breviflora*) and the Point Reyes bird's-beak (*Cordylanthus maritimus* ssp. *palustris*), are discussed below.

Pink sand verbena is a federal species of concern, is listed as endangered by the State of Oregon, and is a Bureau Sensitive species. This annual herb historically occurred from British Columbia, Canada, to Marin County, California. It is believed to be extirpated from Washington; two plants were observed in 2000 on Vancouver Island. Habitat for pink sand verbena includes sandy beaches above the high tide line and possibly dunes further inland. The primary threats to pink sand verbena are loss of habitat from the encroachment of European beach grass and disturbance from OHVs. In 1993, a population of this species was established on the Spit on COE land within a Western snowy plover Habitat Restoration Area (HRA). The practice of removing European beach grass each year to promote open sand habitat for nesting plovers has benefited the pink sand verbena. The population has gradually increased in number and aerial extent. In 2003, over 111,500 reproductive plants were documented within the COE lands. The population now extends onto neighboring lands outside of the HRA enclosure.

***Pink sand verbena.***

Point Reyes bird's-beak is a federal species of concern, is listed endangered by the State of Oregon, and is a Bureau Sensitive species. Historically, this annual, hemi-parasitic herb occurred along a 900 mile section of coastline, from Netarts Bay, Oregon, south to Morrow Bay, California. Today, it is known only from Netarts Bay, Yaquina Bay, and Coos Bay. The primary threat to the Point Reyes bird's-beak is habitat loss from development, OHVs, and water pollution from petroleum spills. A population of the species is located on the bay side on lands managed by the Port and BLM (Map 3). The 2001 population at Spit was estimated at about 20,000 plants.

**Table 4. Bureau sensitive and assessment plant species documented (D) and suspected (S) on the North Spit by scientific name, common name or group, presence, status, and habitat. Bureau tracking species are noted in Appendix 1. Note: BA = Bureau assessment, BS = Bureau sensitive, SE = State Endangered, and SoC = Federal Species of Concern.**

| Scientific Name<br>(Common Name or Group) | Presence | Status | Habitat |
|---|---|---|---|
| **Vascular Plants** | | | |
| *Abronia umbellata* ssp. *breviflora*<br>(pink sandverbena) | D | BS, SoC, SE | Coastal beaches and dunes |
| *Brodiaea terrestris*<br>(dwarf brodiaea) | S | BA | Stabilized dunes |
| *Carex brevicaulis*<br>(short-stemmed sedge) | S | BA | Stabilized dunes and meadows |
| *Cicendia quadrangularis*<br>(timort) | S | BA | Coastal wetlands, valley grasslands, northern oak woodlands, foothills, and woodlands |
| *Cochlearia officinalis*<br>(spoonwort) | S | BA | Coastal headlands |
| *Cordylanthus maritimus* ssp. *palustris*<br>(Point Reyes bird's-beak) | D | BS, SoC, SE | Salt marshes |
| *Hydrocotyle verticillata*<br>(whorled marsh pennywort) | S | BA | Swampy ground, lake margins, and wetlands |
| *Limonium californicum*<br>(western marsh-rosemary ) | D | BA | Salt marshes |
| *Ophioglossum pusillum* (adder's-tongue) | S | BA | Marsh edges, low pastures, grassy roadside ditches, and coastal wetlands |

| Scientific Name (Common Name or Group) | Presence | Status | Habitat |
|---|---|---|---|
| **Nonvascular Plants** | | | |
| *Bryoria pseudocapillaris* (Lichen) | D | BS | Rock, conifer bark, and Sitka spruce in exposed coastal headlands |
| *Bryoria spiralifera* (Lichen) | D | BS | Shore pine and Sitka spruce in coastal habitats, often with *Ramalina menziesii* |
| *Bryoria subcana* (Lichen) | S | BA | Bark and wood of Sitka spruce, Western hemlock, Douglas-fir, and hardwood forests along coastal bays, streams, and dune forests within 30 miles of ocean |
| *Diplophyllum plicatum* (Liverwort) | D | BA | Tree boles of old-growth western hemlock, western red cedar, and Douglas-fir |
| *Erioderma sorediatum* (Lichen) | D | BA | Ericaceous shrubs in coastal forests, documented at North Spit and Eel Creek Campgrounds (ODNRA) |
| *Heterodermia leucomelos* (Lichen) | D | BA | Spruce and shore pine branches on forested headlands in the coastal fog zone |
| *Leioderma sorediatum* (Lichen) | D | BA | Thin moss mats on rhododendron and huckleberry branches near coast, documented at North Spit and Eel Creek Campground (ODNRA) |
| *Ramalina pollinaria* (Lichen) | S | BA | Coastal, reported from New River ACEC |
| *Rhizopogon exiguous* (Fungi) | S | BS | Coastal, known site at Mapleton, hypogenous fungi in coniferous forests |
| *Sulcaria badia* (Lichen) | S | BA | Hardwood, conifer bark, and spruce branches in lowlands, valley fringes, and coast, 300-600 m |
| *Teloschistes flavicans* (Lichen) | S | BA | Coastal forests, shore pine and Sitka spruce |
| *Thaxterogaster pavelekii* (Fungi) | S | BS | Coastal forests in Washington, Oregon, and California |
| *Triquetrella californica* (Moss) | S | BA | Exposed to shaded soil, rocks, or sand in coastal shore pine and Sitka spruce |

## *Exotic and Noxious Weed Species*

Approximately 24 exotic or non-native plant species occur on the Spit (Appendix 1). Additional exotic species are expected as the area is botanically explored and a systematic survey is conducted. Exotic plants are those that did not occur before the arrival of European culture, are not indigenous to a given area, occur as a result of introduction, or have escaped from gardens and become naturalized. Some exotic species are pioneer plants that are normally limited to a single generation before a dense cover of other native plants develop. Others, like European beach grass, colonize or invade a habitat by vegetative reproduction and exclude native species. Invasive plants displace native vegetation and consequently may diminish habitat quality for wildlife. Invasive weedy species at the Spit are found primarily in terrestrial habitats.

The history of European beach grass exemplifies the impact of an exotic species. During 1891-93, rooted plants were hand planted by the COE in an effort to reclaim the Spit (Beckham 2000). Between 1910 and 1934, additional plantings were also made along the southwestern Oregon coast (McLaughlin and Brown 1942). European beach grass now covers approximately 19% of the Spit. It is found in pure stands, intermixed with other herbaceous species, and as an understory associate within forest and woodland communities. European beach grass reduces the native plant richness (the number of species) by as much as half (Barbour and Johnson 1988). It has the ability to out compete native foredune plant species (Barbour, Dejong, and Paulik 1985) by altering the habitat (Pickart, Brown, and Avery 1990). Blowing sand is trapped, burying other species and precluding resource competition. European beach grass can withstand sand burial of up to one meter per year. In fact, sand burial promotes leaf elongation and underground stem development (Ranwell et al. 1959). Runners in the root system are the primary means of beach grass reproduction. Despite high seed production of up to 20,000 seeds per plant per year, most beach grass seedlings die within a few weeks of germination (Huiskes 1979). Significant differences are seen when comparing areas dominated by European beach grass with those covered by native dune species, such as American dunegrass. Foredunes dominated by European beach grass are steep and give way to a series of dunes and swales parallel to the coast. In contrast, dunes dominated by American dunegrass rise gradually and lead to dunes and swales perpendicular to the coast (Barbour and Johnson 1988).

Some exotic plant species are designated as noxious weeds by the state's Noxious Weed Control Program. Noxious weeds are considered injurious to public health, agriculture, recreation, and wildlife on any public or private property by the (Oregon Department of Agriculture 2003). The seven noxious weeds present or suspected at Spit include: Scotch broom (*Cytisus scoparius*), French broom (*Genista monospessulana*), common gorse (*Ulex europaeas*), Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), Canadian thistle (*Cirsium arvense*), and bull thistle (*C. vulgare*). Methods to remove noxious weeds on the Spit may include herbicides, mechanical means, hand cutting and pulling, and the application of fire.

### *Timber and Special Forest Products*

The Spit was designated as a non-commercial forest in the RMP. Consequently, no commercial timber management occurs on the Spit. No commercial harvest of Special Forest Products is permitted within the North Spit ACEC unless the harvest benefits the ACEC or clearly does not impact any special status plants or animals (USDI BLM 2003b).

## Biological: Wildlife

The BLM is responsible for managing habitats of all existing native vegetation and wildlife species on BLM land. Therefore, wildlife management on the Spit focuses on the management of habitats for native wildlife species (Appendix 2), with special emphasis on the protection of rare habitats and sites important to special status species (Table 5; see below).

### *Wildlife Habitats*

A mosaic of habitats supports an abundant and diverse array of wildlife on the Spit. The interspersion of coastal environments and upland late-seral forest combined with the relative isolation of the Spit creates a very rich and productive wildlife area heavily used by shorebirds, waterfowl, raptors, and many other species (Northwest Biological Consulting; Appendix 2). Although not all the habitats described below are under BLM administration, wildlife species cross jurisdictional boundaries as they travel among habitats to forage or nest. Additionally, species using the Coos Bay estuary may be directly affected by adjacent uplands management, including recreational use of the Spit.

**The Coos Bay Estuary.** Including saltmarshes, open water, mudflats, and sandflats, estuaries are among the most productive environments in the world due to the dynamic interaction of riverine and marine systems (Buchanan et al. 2001). As interfaces between salt and freshwater and between terrestrial and aquatic habitats, they receive large influxes of nutrients from watersheds, marshes, and tidal action. Consequently, the habitats found in this environment support a rich wildlife community. The estuary supports some of the highest numbers of dabbling ducks using Coos Bay (Varoujean 1985) and a March 1992 aerial survey placed Coos Bay with the third highest waterfowl count on the Oregon coast (Oregon Wetlands Joint Venture 1994).

Salt marshes are an important component of estuarine ecosystems, providing roosting areas for shorebirds and gulls, and haul-out areas for harbor seals. Raptors, including bald eagles, falcons, and hawks, hunt over the salt marsh, and use logs as resting or hunting perches (USDI BLM 1994). Approximately 90% of the salt marshes associated with the Coos Bay estuary were eliminated following European settlement (Buchanan et al. 2001), thus accentuating the value of the remaining marshes.

The open water habitats of the Coos Bay estuary include both shallow and deep water habitats used by many species of wildlife (USDI FWS 1980). Waterfowl and seabirds forage on fish and invertebrates, their numbers and species diversity varying throughout the year but highest during the spring and fall migrations. Bald eagles and osprey feed on fish and waterfowl using the Bay, and peregrine falcons hunt waterfowl and shorebirds during their spring and fall migration.

Harbor seals and California sea lions forage within the bay throughout the year and use the dredge material islands as haul-out sites. Occasionally they may be found resting on the Spit's beaches. Although foraging seals do not appear to be affected by activities on the Spit, they are very sensitive to disturbance on their haul-out sites.

***Snowy Plover with chick.***

**Table 5. Special status wildlife species documented (D), suspected (S) and potentially (P) on the North Spit by name, presence, status, and habitat. Note: BA = Bureau assessment, BAO = Bureau assessment Oregon only, BS = Bureau sensitive, BSO = Bureau sensitive Oregon only, FE = Federally Endangered, FT = Federally Threatened, and FC = Federal Candidate.**

| NAME | Presence | Status | Habitat |
|---|---|---|---|
| ***AMPHIBIANS*** | | | |
| California Slender Salamander<br>*Batrachoseps attenuatus* | S | BAO | Late seral forests, large down logs |
| ***REPTILES*** | | | |
| Northwestern Pond Turtle<br>*Clemmys marmorata* | D | BSO | Lentic water (ponds, slow sections of rivers) Nests in open areas adjacent to water, can overwinter in forest |
| ***BIRDS*** | | | |
| Arctic Peregrine Falcon<br>*Falco peregrinus tundrius* | D | BS | Cliffs, may perch in trees |
| American Peregrine Falcon<br>*Falco peregrinus anatum* | D | BS | Cliffs, may perch in trees |
| Cacklin Goose<br>*Branta canadensis leucopareia* | D | BS | Coastal grasslands |
| Dusky Canada Goose<br>*Branta canadensis occidentalis* | D | BSO | Open grasslands, wet meadows |
| Bald Eagle<br>*Haliaeetus leucocephalus* | D | FT | Large trees for nesting/perching, near water |
| Bobolink<br>*Dolichonyx oryzivorus* | D | BAO | Grasslands, open areas |
| Brown Pelican<br>*Pelecanus occidentalis* | D | FE | Forages off shore, uses jetties and beaches to roost |
| Marbled Murrelet<br>*Brachyramphus marmoratus* | D | FT | Late-seral forest, remnant large trees |
| Oregon Vesper Sparrow<br>*Pooecetes gramineus affinis* | D | BSO | Grassland |
| Purple Martin<br>*Progne subis* | D | BSO | Large remnant trees and snags, near water, edges |
| Streaked Horned Lark<br>*Eremophila alpestris strigata* | D | FC | Coastal dunes; open ground with short grass or scattered bushes |
| Trumpeter Swan<br>*Cygnus buccinator* | P | BAO | Marsh, wet meadows, bogs, ponds |
| Upland Sandpiper<br>*Bartramia longicauda* | D | BSO | Coast; open grasslands |
| Western Snowy Plover<br>*Charadrius alexandrinus nivosus* | D | FT | Beaches and inland areas of open sand |
| White-tailed Kite<br>*Elanus leucurus* | D | BAO | Pastures, open grasslands; typically low elevations |
| ***MAMMALS*** | | | |
| Fisher<br>*Martes pennanti* | P | FC | Closed or multi-canopy forest, snags, dead parts of live trees, large live branches |
| Townsend's Big-eared Bat<br>*Corynorhinus townsendii* | P | BSO | Breed in caves and mines, bridges for night roosts |
| ***INVERTEBRATES*** | | | |
| Salamander Slug<br>*Gliabates oregonius* | P | BSO | Moist coniferous forest with leaf litter |
| Spotted Tail-dropper<br>*Prophysaon vanattae pardalis* | P | BSO | Moist, mature forests |
| Newcombs Littorine Snail<br>*Algamorda newcombiana* | *P* | BSO | Saltwater at edge of bays and estuaries |

Mudflats and sandflats are found on the Spit's bay side. These areas are tidally-inundated, and support an abundance of marine invertebrate species, including many of the most productive shellfish beds on Oregon's south coast (Northwest Biological Consulting 1980). These sandflats and mudflats also provide foraging habitat for a variety of birds and mammals. Resident and migrant shorebirds congregate there, especially during low tides, to forage on the invertebrates in the shallow waters and exposed mudflats (Varoujean 1985). Coos Bay is one of the six most important areas for shorebirds between San Francisco Bay and British Columbia (Oregon Wetlands Joint Venture 1993) and the Spit's mudflats consistently support the greatest number of wading birds in the Coos Bay estuary (Varoujean 1985). The concentration of shorebirds and wading birds in these habitats provide prey for bald eagles, northern harriers, and peregrine falcons, and ravens, gulls, raccoons, mink and skunks forage in the shallow waters and exposed flats for shellfish, invertebrates and carrion.

**Jetties.** The Jetty and the training jetty on the southern tip of the Spit provide roosting habitat for gulls and cormorants, and shorebirds (e.g., turnstones and surfbirds) forage on invertebrates inhabiting the rocks (Map 3). Flocks of California brown pelicans, a federally-listed endangered species, use the jetties for roosting and feeding (Northwest Biological Consulting 1980).

**Beaches and Sand Dunes.** Aquatic and terrestrial invertebrates, fish, and carrion found on the beach provide a rich food source which attracts a variety of wildlife species. Shorebirds are among the most abundant groups using the beach habitats, and are an important food source for raptors, particularly peregrine falcons during their fall and spring migration along the Oregon coast (Wilson-Jacobs 1983). Shorebirds forage primarily on the beaches and mudflats and eat insects, shellfish, and other marine invertebrates. The threatened Western snowy plover also nests on the upper beach, laying its eggs in small hollows (scrapes) above the high tide line and behind the foredune. After hatching, the flightless chicks forage in the vicinity of the nest sites until they fledge. In combination with the inland sandy sites east of the foredune, the Spit provides nesting habitat for the largest breeding population of coastal snowy plovers in Oregon (USDI FWS 1993). Larger birds such as gulls, terns, ravens, and crows feed opportunistically along the shoreline on a variety of shellfish, carrion, insects, eggs, and chicks, and often rest in large flocks at the ocean's edge. In addition to peregrine falcons, several other raptors occur on the Spit, including bald eagle, osprey, northern harrier, and turkey vulture. Most raptor species forage opportunistically on both live animals and carrion found on the beach. Terrestrial mammals that forage along the beach for shellfish, carrion, and invertebrates include raccoons, mink, skunks, gray foxes, opossums, and various small rodents. Although less frequently than other animals, black bears, bobcats, Roosevelt elk, and black-tailed deer feed on the beach too, and drift logs washed up onto the beach are used as foraging and resting perches for falcons and as windbreaks by roosting shorebirds (Buchanan et al. 2001).

Inland sand dunes with little or no vegetation are used extensively by certain species of terrestrial insects, primarily beetles, centipedes, and millipedes. Flying insects found just off the surface of the sand are common and fed upon heavily by barn swallows. The small amount of hiding cover in the open sand renders prey species vulnerable, thus making these areas valuable foraging habitat for many predators, including raptors (e.g., northern harriers and kestrels), gray foxes, coyotes, and other species that eat insects, rodents and reptiles. Crows, ravens, turkey vultures, and other birds use the dunes for resting and foraging, and burrowing owls have been documented foraging and roosting in the open sand during the winter (USDI BLM 1994).

In contrast to the homogeneity of the open sand dunes, stabilized sand communities are quite variable, ranging from sparsely vegetated areas with scattered beach grass hummocks, to habitats with more developed plant communities dominated by dense beach grass containing scattered clumps of shrubs and conifers (see Botanical Resources). The amount of cover and available prey or plant foods determine which species occur in these habitats. Black-tailed deer and rabbits occur throughout these communities, and passerine bird species feeding on plant seeds and insects take cover in the dense shrubbery. Mammalian predators such as skunks, foxes, coyotes, raccoons, mink, and bobcats prey on small mammals, birds, eggs, reptiles, and insects in and under logs deposited by winter storms.

Sparsely-vegetated hummock areas are used for foraging throughout the year by northern harriers, red-tailed hawks and bald eagles (USDI BLM 1994) and shrubs and logs are used as perch sites. Raptors use all of the stabilized sand habitats, but the sparsely-vegetated areas are believed to provide better hunting because small mammals and reptiles are more vulnerable to attack by aerial predators.

**Freshwater Wetlands and Ponds.** The freshwater wetlands of the deflation plain support a diverse wildlife community and are some of the most productive habitats on the Spit (Wilson-Jacobs 1983). Ranging from areas dominated by grasses and sedges to tall shrub thickets, the wetlands are used by many wildlife species to fulfill all or a portion of their habitat requirements. Wetlands provide critical breeding and rearing habitat for amphibians, including red-legged frogs and numerous invertebrates provide prey for various species of wildlife.

The structurally diverse low shrub and thicket habitats contain the highest number of species in the wetland environment (USDA FS 1972). Muskrats, voles, rabbits, and other small mammals find food and shelter in the diverse vegetation and vertical structure of these areas. Predatory mammals (including shrews, mink, skunks, bobcats, foxes, and coyotes) forage on invertebrates, amphibians, birds, and small mammals, and during the spring and summer, bats forage extensively on flying insects.

A combination of structurally complex habitat features and an abundant variety of available food sources support a variety of bird species. Waterfowl, shorebirds, passerines and raptors nest or forage in the freshwater wetlands, and migratory birds rest and feed there while traveling. Approximately one-third of all North American bird species depend upon wetlands during some part of their life, and approximately three-quarters of these species are non-game birds whose ecological significance is poorly understood (USDI FWS 1984).

Ponds provide areas of open water adjacent to the more heavily vegetated freshwater shrublands and thickets, and support a community of aquatic invertebrates, fish and amphibians. Many of the species inhabiting the ponds are important food sources for other animals. Although the inland open water sites of the Spit are not considered high quality nesting habitat for most species of waterfowl, they are used for foraging by a variety of migrating waterfowl during the spring, fall, and winter (Thornburgh 1991).

**Forests.** The shorepine and Sitka spruce forests found on the eastern edge of the deflation plain constitute the habitat with the greatest structural complexity on the Spit; on the adjacent ODNRA, this type of habitat supported the greatest diversity of wildlife species (USDA FS 1972). The trees, snags and down logs not found in other plant communities on the Spit provide important breeding, foraging, and cover habitat for a variety of wildlife species. Upland amphibians (e.g., the western redback salamander and ensatina) seek cover in down logs, and many bird species (including raptors, woodpeckers, and passerines) nest and forage in these habitats. In past years, the stand of late-seral Sitka spruce on BLM land contained the largest mixed heronry of great blue herons and great egrets on Coos Bay (Northwest Biological Consulting 1980). That heronry was abandoned in 2000 for unknown reasons. Two new rookeries were subsequently discovered: one on the ODNRA in 2002 and one on BLM in 2004. It is possible that these heronries may contain birds from the abandoned site. Coos Bay is the most northerly nesting site for great egrets.

### *Wildlife Species of Special Management Concern*

The interface of the marine, freshwater, and terrestrial environments described above provides habitat for many special status wildlife species (SSS Table 5). Several are dependent upon snags, large trees, and coarse woody debris: habitat elements characteristic of older forests that have become limited in availability and distribution throughout Western Oregon. Others are associated with wetlands, or habitats uniquely identified with areas of open sand and coastal grasslands. In addition to SSS, special management provisions are in place for the conservation of other species collectively termed Buffer Species. Specifically, BLM is directed to establish protective buffers around the nests of great blue herons, great egrets, and certain raptor species such as ospreys, red-tailed hawks, sharp-shinned hawks, and Cooper's hawks (USDI BLM 1995a). Depending upon the species, up to 15 acres may be delineated near nest sites to minimize human disturbance, and nest platforms, boxes and other structures may be constructed where natural availability is low. Management for great blue herons and great egrets includes monitoring known rookeries and surveying appropriate habitat for new ones.

Little is known about the distribution and abundance of most of these species on the District; consequently much of the information related to wildlife on the Spit is based on literature pertaining to wildlife-habitat associations and incidental observations. As discussed above, in the absence of site-specific information, recreational and other activities are managed to minimize effects to wildlife habitats thus minimizing potential impacts to species. When assessing the effects of a proposed project, species are assumed present given the availability of suitable habitat. Special status species that are designated as "potentially" present on the Spit are those for which suitable habitat is present but no individuals have been documented (Table 5). One such species is the Pacific fisher, a Federal Candidate for listing under the ESA. Consequently, there is heightened concern for their population status and conservation needs.

In Oregon, fishers appear to have been extirpated from their historical range with the exception of two small disjunct populations in the Siskiyou Mountains and in the southern Cascade Range (Aubry and Lewis 2003). Although possible, the presence of fisher on the Spit is unlikely given the rarity of the species and the lack of large, well-connected tracts of mature forest with continuous canopies. Most forested areas on the Spit are interspersed with areas of open sand and research indicates that fishers are reluctant to cross openings greater than 25 meters (Powell and Zielinski 1994). Furthermore, fishers on the Spit would be separated from Coast Range populations by Highway 101, human developments, and fragmentation of mature forest. It is uncertain the extent to which fishers can recover from extirpation given that their populations are isolated and their apparent inability to colonize unoccupied areas (Aubry and Lewis 2003).

The Coos Bay District wildlife sightings database contains several fisher observations in Coos County; none of these sightings were in the vicinity of the Spit. Remote camera surveys for fisher in other parts of the District between 1994 and 1997 failed to detect fishers. Efforts are underway to further refine the species' distribution in Oregon.

Several other species of interest are discussed below.

**Marbled Murrelet and Bald Eagle.** The occurrence of large diameter trees with large branches in close proximity to the ocean renders the Spit suitable for marbled murrelets and bald eagles. Limited surveys for murrelets were initiated in 2005, and surveys for bald eagles conducted in the area by the Oregon Cooperative Wildlife Research Unit have not documented nesting eagles on BLM land. The area is suitable for roosting and hunting, and eagles are occasionally seen foraging on Spit beaches.

**Purple Martin.** Purple martins are the largest members of the swallow family in North America. They forage above many types of open habitats, particularly near water and nest in snags with cavities. They were once much more common in Oregon prior to the removal of snags by logging and competitive exclusion from the remaining snags by introduced European starlings (Sharp 1996). Oregon nest sites include snags in forest clearcuts and burns and snags in coastal dunes (Rodenkirk 2003). Suitable nest trees occur on the Spit, many located near ponds and wetlands in close proximity to the bay and ocean beaches. In addition to natural structures, purple martins readily nest in bird houses. Currently, there are 24 nest boxes on pilings in the bay near the boat launch facility (Map 3). Twenty-one of these boxes were used by purple martins in 2004. The boxes are maintained and monitored yearly.

**Peregrine Falcons.** The American peregrine falcon (*Falco peregrinus anatum*) and the Arctic peregrine falcon (*Falco peregrinus tundrius*) require cliffs for nesting but may be found perching in trees while hunting or migrating. Whereas the Arctic peregrine is an occasional winter migrant, the American peregrine nests on the Coos Bay District and may occasionally be seen on the Spit while hunting or migrating.

**Northwestern Pond Turtle.** One of two freshwater turtles of the Pacific Northwest, the northwestern pond turtle is in decline in Oregon because mortality exceeds reproduction for a number of reasons. Threats include habitat loss and degradation, which in conjunction with predation and disease, has led to small disjunct populations with low recruitment rates (Marshall et al. 1996). Western pond turtles may inhabit a variety of aquatic habitats providing that suitable sites are available for basking (e.g., logs, rocks, and islands) and there is sufficient aquatic and emergent vegetation. Mud substrates and leaf litter are important components for breeding and hibernating, as are shallow bank margins for traveling between the water and the adjacent upland (O'Neil et al. 2001). A western pond turtle was documented on the adjacent ODNRA. Wetlands on BLM land likely contain western pond turtles.

**Western Snowy Plover.** The coastal population of the Western snowy plover uses sandy beaches along the Pacific Coast from southern Washington to Baja California for breeding and wintering. It receives the highest priority for management on the Spit due to its low population numbers and the significance of the Spit as nesting habitat. In 1993, the coastal population of the Western snowy plover was listed as a Federally threatened species due to declining population numbers and loss of nesting habitat (USDI FWS 1993).

In February 1999, the ocean freighter New Carissa grounded on the Spit and began leaking oil. To ensure public safety, the Spit was closed through an emergency order to public access. At the end of 1999, two portions of the New Carissa wreck remained mired, releasing oil and depositing tar balls (Map 3). To address concerns related to impacts on snowy plovers, BLM, FWS, ODFW, and COE collaborated on a Biological Assessment to allow public use of the Spit while protecting plovers and promoting their recovery (USDI BLM 2000). The following ongoing actions are a result of the subsequent Biological Opinion for management of federal lands on the North Spit of Coos Bay (USDI FWS 2000).

**Public Access and Snowy Plovers.** From the FAA Tower south to the BLM boundary, the upper, dry sand portion of the beach is closed to all public access during the Western snowy plover nesting season (March 15- September 15 annually; Map 3). The area is clearly marked with ropes and signs. Restrictions on motorized use of the adjacent lower, wet sand area are authorized by OPRD. Inland snowy plover nesting areas on BLM land are also signed closed to all use during the nesting season, and are open to nonmotorized use the remainder of the year.

**Habitat Restoration Areas.** Approximately 170 acres of the inland Spit area are managed for snowy plovers; 100 acres by COE and 70 acres by BLM. The Habitat Restoration Areas (HRAs) were largely unsuitable for plovers prior to restoration due primarily to the presence of European beach grass. BLM annually removes beach grass to create suitable open, sandy habitat for snowy plovers. No new HRAs are currently planned.

**Predator Control.** In 2000, the BLM led a multi-agency effort to produce an EA on predator control throughout the range of the coastal population of snowy plovers (USDA FS and USDI BLM 2002). The selected action consists of an integrated predator damage management program to protect the plover population from further decline. Actions were initiated in 2003 and include an expanded assessment to determine and reduce the predator species responsible for nest, chick, and adult predation. The Animal Plant and Health Inspection Service (APHIS) conducts these activities. Targeted species include American crows, common ravens, and small mammalian predators. Most traps are located in areas closed to the public (e.g., the HRAs and the upper beach), clearly signed, and unlikely to cause injury to domestic animals and humans.

**Population Monitoring.** The Oregon Natural Heritage Information Center monitors plover nesting. Intensive surveys are conducted throughout the six month nesting season to determine population size and reproductive success. All chicks are banded for identification and an attempt is made each year to locate them to assess survivorship and track their productivity. From this information, it was determined that the Spit contains the most productive snowy plover population segment on the Oregon Coast. Since 1990, the Spit has produced over 40% of all plovers fledged each year in Oregon (Lauten et al. 2003). Through intensive monitoring, the success of management actions can be assessed and progress toward plover recovery determined.

**Designated Snowy Plover Critical Habitat.** On December 7, 1999 the FWS published a Final Rule designating critical habitat for the Pacific coast population of the Western snowy plover (USDI FWS 1999). Critical habitat on the Spit includes the ocean beach from Horsfall to the Jetty and all of the federal lands at the south end of the Spit.

**Other Planning Efforts for the Snowy Plover.** The FWS is preparing a final recovery plan for the Pacific Coast population of the western snowy plover in Washington, Oregon, and California. OPRD has a leading role in managing plover habitat in Oregon. To guide beach management, it is preparing management and conservation plans (ORNIC and OPRD 2004; OPRD 2004). BLM will implement the final plans on BLM lands.

## Biological: Fisheries

No fish surveys have been conducted on BLM lands on the Spit. Potential fish-bearing waters on BLM lands occur above the mean high tide. They include natural ponds and a created mitigation pond and wetland to the north of the effluent lagoon (see Water Resources). These areas are likely to contain introduced largemouth bass, other sunfish species, such as bluegill, and threespine stickleback. There are no SSS fish species on BLM land on the Spit due to lack of suitable habitat.

## Cultural and Historical Resources

### *Social and Historical Setting*

Before the introduction of European beach grass, the North Spit of the Coos River was highly unstable and subject to major changes during the heavy winds of summer and winter (Beckham 2000). At least two river channels cut through the Spit, turning a portion of the area into an island during much of the year (Pullen 2004). Despite these changes, historical records indicate the area was heavily utilized prehistorically.

The North Spit of Coos Bay was an ideal place for a wide variety of food procurement for native peoples. The Coos Indians built fish weirs along the shore to catch salmon, gathered clams and crabs at low tide, hunted for deer, elk, and waterfowl in the Spit's marshes, and gathered various types of berries that grew abundantly along the edges of the marshes (Peterson and Powers 1977; Zenk 1990).

In the 1940s, John Harrington was able to obtain information about villages on the Spit while interviewing elders of the Coos Indian tribe. Prior to the changes introduced by American exploration and settlement, there were at least half a dozen villages along the inner shoreline of the Spit, although their locations are not precisely known (Zenk 1990). There are also undoubtedly native burial sites or cemeteries on the Spit, as the Coos people usually buried their dead within or adjacent to their villages (Zenk 1990).

Between 1820 and 1850, British and American trappers camped up and down the coast. Documented parties camped on the Spit in 1826 and again in 1828 (Beckham 1986, 2000; Peterson and Powers 1977). Between this time and the beginning of Euro-American settlement in 1851, the Native population of the area was decimated by the spread of infectious diseases (Boyd 1999). In 1855, violence between settlers and Native Americans flared to the south along the Rogue River, resulting in a response by the US Army. Along with other southwest Oregon coastal groups, the Coos people were forcibly removed from their homes and relocated, first to Fort Umpqua near Reedsport, and then to a new reservation at Yachats in 1860 (Zenk 1990). In 1875, some of the survivors of this relocation were moved to the Coast reservation at Siletz, while others, refusing to be moved again, returned to their ancestral homelands around Coos Bay (Zenk 1990).

Located adjacent to the largest estuary between the Columbia River and San Francisco, the Spit served as an important transportation link between Coos Bay and settlements on the Lower Umpqua during the late 1800s. Wagons and stagecoaches traveled down the beach during low tide from Winchester Bay to a point across from Empire, where, weather permitting, scows carried the passengers across the bay (Beckham 1986, 2000). In the 1880s, Fred Jarvis took over the Coos-Umpqua stage route and established what is known as the Jarvis Landing Beach Road on the Spit.

As the industrial capacity of the fledgling coastal towns increased, so did the need to improve the harbor and the bar at the mouth of the bay. Roads were almost non-existent, and the only markets for fish, lumber, farm produce, and coal lay far to the south in San Francisco. However, traversing the Coos Bay bar was often a dangerous enterprise, and when the weather closed in, it could be months before safe passage was assured. This was an untenable situation for a community focused on water transportation for its goods. In 1880, the COE was awarded a contract to construct a jetty near Barview. By the fall of 1881, the jetty cribs extended 1,384 feet into the bay (Beckham 2000). Throughout the rest of the 1880s, the COE monitored the jetty and realized that further work was needed before the harbor mouth could be stabilized.

In 1890, at the southern tip of the North Spit the COE began construction of the North Jetty, a rock sea wall nearly two miles long (Beckham 2000). Government Works, a village of laborers and engineers, was built on pilings along the inner shoreline near the North Jetty construction site. An aggressive program of sand stabilization was begun by the COE along with jetty construction. Nearly 1,000 acres of European beach grass eventually was hand-planted to stabilize the dunes (Beckham 2000).

In 1892, a US life-saving station was built on the Spit to rescue sailors stranded by adverse weather conditions (Map 3). It was located on the bay side about two miles north of the harbor entrance. Between 12 and 16 families lived at the station during its peak use. The facility included a dock, workshops, and two crew buildings (Beckham 2000).

The ocean took a heavy toll on the Jetty. During the 1920s, Congress funded the construction of a South Jetty and the reconstruction of the North Jetty (Beckham 2000). Major reconstruction work was again completed on the North Jetty during 1939 and 1940, when a railroad was used to transport materials (Beckham 2000). The railroad route came around Jordan Cove and down the bay side, cut across the Spit at the dike road (along the south edge of the effluent pond), turned south through an unstabilized dune field and followed the foredune south around the southern tip of the Spit and ended at Government Works.

Concrete bunkers were erected along the Spit during World War II, in hopes of slowing the anticipated Japanese invasion of the West Coast. There were no recorded conflicts during WWII in the Coos Bay area.

### *Prehistoric Sites*

Although considerable documentation supports the presence of numerous Native American sites on the Spit, only two sites are officially on record with the Oregon State Historic Preservation Office. Site 35CS26 was located between Jordan Cove and the North Slough. Site 35CS27 was reportedly along the inner shoreline on the southern end of the spit, but was never specifically located. A recent intensive survey of this shoreline failed to reveal any evidence of this site (Pullen 2004).

The Coos Indians unquestionably used the Spit for various activities. However, this area is very unstable and any remaining evidence could have been destroyed either by erosion or shifts in the river channel, or could have been covered by sand movement. Continued dumping of dredge spoils along the shoreline has further clouded the identification of prehistoric middens, as both types of deposits are largely composed of shells. Although there is little evidence of extant prehistoric archaeological deposits on BLM-administered land, the instability of the sand dunes on the Spit may uncover cultural sites in the future.

### *Historic Sites*

Preservation and identification of historic sites is constrained by the potential for dynamic changes to the Spit landforms. Campsites used by trapping expeditions during the 1820s probably left little evidence, long since removed. However, the four month-long camp (Camp Castaway) created by the US Army survivors of the beached vessel *Captain Lincoln* in 1852 (Beckham 2000; Dodge 1898; Peterson and Powers 1977) may have left more substantial evidence.

The sand road across the Spit used by the Coos-Umpqua stage route isn't likely to have any remnants as the effluent ponds and South Dike Road have substantially altered the land surface on that part of the Spit. Initial Jetty construction transported jetty materials (piling and rock) via barge from Empire to Government Works. Subsequent reconstruction efforts involved creation of a railroad. Evidence of this railroad line has been found both under the present day Foredune Road and in open dunes near the intersection of the South Dike and Foredune Roads.

Other remnants of construction and reconstruction of the Jetty are likely to be concentrated in the area occupied by Government Works (Beckham 2000). Today, this area has largely been reclaimed by the Coos River, and is known as Half Moon Bay (Map 3).

The life-saving station retains historic interest, although most structures have been removed. Remnants of the dock remain, as do building foundations, walkways and other landscape improvements. Because there were numerous fatal shipwrecks during the station's operation there exists a possibility that a cemetery exists on the "tree island" just west of the station. This is a likely location for the cemetery because prior to sand stabilization by introduced European beach grass, this area was the only portion of the Spit with sufficient elevation to withstand winter storm wave action (Beckham 2000). Today, this "tree island" is densely vegetated and cultural site locations are unknown.

Nearby, three World War II vintage Quonset huts remain open to the public. These structures are over 50 years old, and therefore may be considered for inclusion onto the National Register of Historic Places.

## Recreational Resources

The diversity of environments and landforms (dunes, wetlands, seasonal ponds, extensive ocean and bay beaches, forests, and meadows) that make the Spit valuable for wildlife also place these lands in demand for outdoor recreation. The value to these public lands for outdoor recreation is further amplified by its close proximity to one of the largest population centers on the Oregon Coast, Coos Bay/North Bend. Most of the private and Port of Coos Bay property on the Spit is zoned for development. It is reasonably foreseeable that these private and Port of Coos Bay parcels will eventually become closed to public access and recreation as further development occurs on the bay front. The public lands managed by the BLM on the Spit are destined to become the largest and most accessible tract of public green space available for the Coos Bay area communities.

In 1992, the BLM developed a boat launch facility and courtesy dock to provide access to the Coos Bay estuary on the Spit. This recreation complex includes a paved parking lot, flush restrooms, interpretive wayside exhibits, and facilities for a volunteer host. The boat launch facility was developed with funding from the Oregon State Marine Board (OSMB), Oregon Department of Fish and Wildlife, Coos County, and the Northwest Steelheaders.

In recognition of the site's value for outdoor recreation, the Spit was designated as a Special Recreation Management Area (SRMA) in the Coos Bay District Resource Management Plan in May 1995. Through the SRMA designation, the BLM made a long-term commitment to manage the Spit to sustain outdoor recreation and the experience opportunities these activities depend upon in a manner that is compatible with the conservation of the areas' wildlife and cultural resources. Recreation management projects completed by the BLM on the Spit include:

- Designation of routes and trails as open, limited, and closed for off-highway vehicle use through the 1995 Coos Bay District RMP and Coos Bay Shorelands Plan of 1995.
- Installation of visitor management signs within the Spit interior to manage OHV recreation and to protect wetland and snowy plover nesting habitat.
- Providing BLM law enforcement and Coos County contract law enforcement support as well as funding a visitor assistance/biological technician position to implement visitor services and resource protection patrols throughout the year.
- Inventory and preliminary planning for a 12-14 mile hiking and equestrian trail system.

## Visitor Use

In the BLM's national recreation tracking data base, the Recreation Management Information System (RMIS), the North Spit reported 27,100 visits and 9,774 visitor days for the period of October 1, 2003 to September 31, 2004. These estimates were developed using electronic, seismic and laser counters at key locations. The counter numbers are recorded weekly in summer and monthly in winter. While counters may not be 100% accurate, they are a standard, valid method to collect visitor use data. There are counters at the boat ramp, one nearer to the jetty, and one on the South Dike Road. Visitor numbers from the counters show that in FY 2003, about 7,250 people used the restrooms at the boat launch, 13,100 vehicles entered the boat ramp, and about 420 boats were launched. Data from the counter near the Jetty shows the average number of vehicles per month at 200, or about 2, 460 vehicles per year. Using a visitor/vehicle estimate of 2.5 (based on a visitor survey in the summer of 2000), approximately 6,150 people travel the sand road out to the Jetty each year by 4-wheel drive or ATV.

**Recreation Demand and Trend.** Every five years, state park and recreation departments around the United States are required to conduct a statewide assessment of outdoor recreation demand, needs and trends to qualify for Federal Land and Water Conservation Fund Act grants. The Oregon Statewide Comprehensive Outdoor Recreation Plan for 2003-2007 (SCORP) offers the best view into outdoor recreation demand within the state on a region by region basis. BLM Manual 8332.08 – Recreation Area Management Plans encourages the use of SCORP data to obtain statewide and regional trends. The SCORP is the product of extensive phone and mail-in surveys of Oregon households as well as out-of-state residents from Washington, Idaho and California. Based on this statistically valid study, a number of observations can be made about the recreation potential on the North Spit:

- The North Spit offers good opportunities for six of the top ten highest demand recreation activities in the state. In ranking order these are: 1. Running/Walking for Exercise; 2. Walking for Pleasure; 3. Bird Watching; 4. Nature/Wildlife Observation; 5. Sightseeing; and 10. Ocean Beach Activities.
- Statewide, ocean beach-related activities rose significantly from 4.45 million user occasions in 1987 to 7.6 million user occasions in 2001. For the North and Central coastal regions, "beach activities" were the #1 growth activity from 1987 to 2002 (an increase of 2.7 million user occasions). On the South Coast, "beach activities" were the #2 growth activity during this same time period (an increase of 0.4 million user occasions).
- The #1 growth activity in the South Coast region was ATV recreation – up 144% (185,181 annual user occasions) from the 1987 survey estimates. This growth reflects the sharp increase in ATV sales over the last decade and the corresponding growth in off-highway vehicle recreation in the Oregon Dunes National Recreation Area – the premier dune riding location in the Pacific Northwest.
- The SCORP also identified the highest recreation priorities for the state on a region by region basis. Within the South Coast Region, residents responded that one of their top three recreation management priorities was to "Conserve Coastal Areas and Preserve Coastal Access for Recreation."

Ocean shore related recreational use was further studied by the Oregon Department of Parks and Recreation in 2001 as part of the Ocean Shore Management Plan. The Ocean Shore Recreational Use Study conducted by Oregon State University examined activities and management preferences of actual beach users during the summer of 2000. While the BLM does not directly manage the thin strip of land that comprises the Ocean Shore Management Area, it does manage the dry sand and foredune adjacent to this area. Therefore, the data provides a good perspective into actual user behavior, values and activities within the ocean shore areas managed by both the BLM and OPRD.

- Within the South Coast Region, from the Umpqua River to the California border, the top 10 recreational activities among those surveyed were: Walking 93.2%, Scenic Enjoyment 81.9%, Picnicking 56.7%, Exercise 51.2%, Beachcombing 38%, Recreation Activities Involving Dogs 35.2% (highest rate on the coast), Driftwood Collection 26.4%, Birding 24.3 %, Kite Use 22.4% and Camping 16.8%.
- On a much more localized level, within Segment 5 of the South Coast Region- the 15 mile section from Ten Mile Creek to Coos Bay, the top activities were: Vehicle Use 54% (highest rate in the study), Relaxing 21%, Walking 16%, and Recreation Activities Involving Dogs 4%. The high rate of OHV use in this study is partially due to the fact that nearly 2/3 of this survey unit is within the popular riding areas offered in the ODNRA.

The Spit directly supports or provides immediate access to a wide variety of outdoor recreation activities, including most of the high demand activities identified in the SCORP and Ocean Shore studies. These activities include: hiking, walking/running, horseback riding, motorized boating, primitive dispersed camping, motor-vehicle touring/sightseeing, 4-wheel drive and ATV trail riding, picnicking and social gatherings, waterfowl and deer hunting, backpacking, berry and mushroom picking, outdoor photography, dog exercise and training, recreational shooting, ocean and bay shore fishing, crabbing, clamming, birding and wildlife viewing, surfing, sea kayaking, canoeing, and wind surfing.

The Spit has been an important local recreation resource for generations, supporting traditional uses such as beach combing, fishing, crabbing, clamming and surfing. Motorized use is a key element in supporting these activities on the spit.

Since the 1995 Shorelands Plan was written, a number of new outdoor recreation activities have made an appearance in the region and are likely to find a place on the Spit. These include kite sailing, paint ball, geo-caching, sand boarding, and long distance hiking on the Oregon Coast Trail, to name a few. The public lands are generally open to any and all new recreation activities, unless and until adverse resource impacts occur or serious visitor conflicts develop.

### *Recreation Opportunity Spectrum*

The concept of managing recreation opportunities and visitor experiences is a dominant theme throughout the objectives presented in the Coos Bay RMP. However, the actual details of which opportunities would be provided for and where they would occur are not well defined. The classification and management of recreation opportunities is typically accomplished through a planning process known as the Recreation Opportunity Spectrum or ROS.

The ROS provides a conceptual framework for the inventory, planning and management of the recreation resource setting and recognizes that people differ in their needs and in the outdoor experiences they desire. The ROS is used to classify lands into a range of recreation opportunity classes based on the physical, social, and managerial setting inherent in the landscape. Six opportunity classes are identified in this planning framework and range from the Primitive at one end of the spectrum to Urban at the other.

**Recreational Opportunity Spectrum**

Applying this recreation planning framework to the current physical, social and managerial setting that exists on the Spit provides for two distinct recreation opportunity settings – Rural and Semi-Primitive Motorized. A strong theme heard from the public during the scoping process for this plan update was for the Spit to remain essentially unchanged from its current condition. The ROS is an excellent tool to ensure that landscapes and recreation settings do not undergo incremental changes that degrade the quality of the recreation opportunity that the place provides.

**Rural Setting.** The immediate area surrounding the developed North Sit Boat Ramp and the public lands within 100 feet of the paved section of the Trans Pacific Parkway fit well within the setting descriptions and management parameters common to a Rural ROS setting. The characteristics that comprise this setting include:

- The natural environment is culturally modified. The setting backdrop may range from locations where cultural alterations are not obvious to the casual observer to places where alterations are a dominant aspect of the landscape.
- For the visitor, self reliance on outdoor skills is of little importance in this setting and there is an expectation that recreation activities will involve very little challenge or risk.
- The opportunity to observe and affiliate with other users may be important to visitors in this setting. Interactions between users and evidence of other visitors may be high at times.
- The convenience of facilities to support outdoor recreation is expected by visitors.
- There are obvious and prevalent on-site controls (i.e., gated roads, barriers, fences, and regulatory signs).
- Access and travel facilities are designed to accommodate conventional motorized vehicle access.

Management objectives in this setting are intended to provide an environment that is natural appearing while providing easy access to recreation opportunities. Objectives for recreation management within a Rural ROS setting include the following:

- Access to recreation opportunities for people with disabilities is "easy" and meets Americans with Disabilities Act (ADAAG) standards.
- Some facilities are designed primarily for user comfort and convenience. Synthetic materials may be used in fabricating facilities, but more harmonious materials may also be incorporated. Facility designs can be more complex and refined than in more primitive settings.
- Moderate to heavy site modifications are allowed in order to provide for outdoor recreation facilities.
- Interpretation may be accomplished through the use of complex wayside exhibits and some personalized services.

**Semi-Primitive Motorized Setting.** The majority of the North Spit, except for the developed recreation complex at the boat ramp and the areas immediately adjacent to the Trans Pacific Lane, would best be characterized by a physical and social setting comparable to a Semi-Primitive Motorized ROS classification. The characteristics common to this ROS setting includes the following:

- The overall setting is characterized by a predominantly natural appearing environment.
- Visitors have a moderate probability of experiencing solitude, closeness to nature, and tranquility.
- The concentration of users is low, but there is often evidence of other visitors on trails.
- Motorized access may require the use of 4-wheel drive vehicles and may impose a high degree of self-reliance, challenge and risk
- Visitors encounter a minimum of subtle on-site controls and restrictions.

In addition to these general characteristics, the North Spit possesses several other factors that further support this more primitive recreation setting classification. These are:

- The necessity to use 4-wheel drive to access the sandy interior roads, ocean shore and bay beaches combined with the dynamic nature of traveling in an environment that frequently changes due to the effects of tide, storms and wind.
- The dense coastal vegetation and rolling topography provide effective screening between the interior trails and the motorized network. In addition, the vegetation and pounding surf tends to absorb many of the sounds generated by human activity on the Spit. These physical factors make for a recreation setting that provides an experience of isolation within a relatively small area.
- The inherent challenges common to a semi-primitive setting impose limitations that help to keep visitor use numbers relatively low. Due to this factor, this management setting is more compatible with the BLM's wildlife management goals for the North Spit by protecting sensitive species habitat from over use and excessive impact.

In keeping with this ROS classification, recreation development and management would be constrained within the following parameters:

- Recreation facilities, when developed, are primarily for the purpose of resource protection.
- Facilities are rustic and rudimentary and make use of undimensioned native materials rather than synthetic materials.
- Access for people with disabilities is "difficult" and challenging.
- Interpretation, when it occurs, is accomplished through very limited on-site facilities, maps, brochures and guidebooks.

The Oregon Statewide Trail Plan showed that users who engaged in trail-based outdoor recreation activities, both motorized and non-motorized, strongly preferred to participate in these activities in settings at the more primitive end of the opportunity spectrum (e.g., semi-primitive motorized to primitive). This quality was also brought out in the public scoping that was done for this plan update by the large number of comments stating that people wanted the North Spit to "stay the same."

### *Adjacent Recreation Resources*

The BLM public lands on the Spit are surrounded by regionally and nationally significant outdoor recreation resources. The most notable of these is the Oregon Dunes National Recreation Area managed by the US Forest Service. This vast recreation area extends for 40 miles along the Oregon Coast and supports a wide variety of human-powered as well as off-highway vehicle recreation opportunities. The segment of the ODNRA, north of the Spit, supports extensive opportunities for OHV recreation and attracts over 400,000 visitors per year. In the area immediately between the Horsefall Beach OHV staging area and BLM public lands, the Forest Service offers a non-motorized setting favoring hiking and equestrian opportunities.

In 2001, Weyerhaeuser created a wetland adjacent to the Trans Pacific Lane as a mitigation measure under the Henderson Marsh Mitigation Plan (see Water Resources). A hiking trail and parking lot was created at the site along with interpretive signs, a picnic area and an overlook (Map 3).

On the ocean side of the Spit, the Oregon Parks and Recreation Department administers the Ocean Shore Management Unit and the Oregon Coast Trail. One of the more popular sightseeing destinations on the North Spit, the wreckage of the New Carissa, is located within the Ocean Shore Management Unit and can be seen from a viewpoint along the Foredune Road.

### *Motorized Access*

The public lands on the North Spit were never legally open to cross country off-highway vehicle travel. Under the management of the US Army Corps of Engineers, these lands were officially closed, except for access via established roadways, by the Code of Federal Regulations 36 CFR.

***Bay side camping.***

After the BLM acquired these lands in 1984, the agency prepared the North Spit Plan Amendment to the Master Framework Plan (MFP) and placed these lands under an interim designation of Limited to Designated Existing Roads and made limited OHV use legal on the North Spit for the first time. The December 1985 MFP makes reference to the off highway vehicle opportunity presented by the dunes, but defers this decision until a full analysis of the impacts could be conducted. The full analysis of impacts and final motorized vehicle designations for the Coos Bay District, including the North Spit, did not take place until the Coos Bay District RMP was completed ten years later in 1995.

During the RMP planning process, a range of alternatives for motorized vehicle access were analyzed after extensive public participation through the Final Coos Bay District Proposed Resource Management Plan/Environmental Impact Statement. Through the Record of Decision and Resource Management Plan that followed the EIS, all of the 1,660 acres in the Coos Bay Shorelands SRMA were formally designated as Limited to Designated Roads and Trails in May 1995. This more controlled alternative was chosen over a Limited to Existing Roads and Trails designation to make this activity more manageable, control route proliferation and to ensure the conservation of sensitive resources on the Spit.

The decision on which roads and trails would be open for use was later resolved through the Coos Bay Shorelands Plan of 1995 when the individual roads and trails were inventoried and then designated as open or closed. The four roads/trails designated as open by this plan were the South Dike Road, the Foredune Road, the Re-Route Road, and the Bay Side Road (Map 3). The remaining trails were then designated as closed to motorized use.

The Coos Bay Shorelands Plan included two management actions that stated OHV use in the sand dune areas on the Spit would be allowed to occur under a permit. Implementation of this permit concept would have made these areas defacto open areas and would have been in conflict with the land use allocation handed down by the Coos Bay District Resource Management Plan. Because this management action was inconsistent with the BLM's own policy and regulations and the Record of Decision for the RMP, these management actions were removed from the Coos Bay Shorelands Plan through a plan maintenance action in 2000.

On the lands immediately adjacent to the BLM parcels on the Spit, OHV recreation is prohibited on the beach between the northern BLM boundary and the Bull Run Sand Road north of Horsfall Beach from May 1 to September 30 to provide for a non-motorized recreation setting. The foredune and forest lands in the ODNRA south of the Horsfall Beach Road to the BLM boundary are closed year-round to OHV use to provide for non-motorized recreation and to protect sensitive resources. The COE lands on the North Jetty are still closed to OHV use, except for motorized use on established roadways. The Oregon Department of Parks and Recreation Department has closed the ocean beach adjacent to BLM to all ATV use and closes the ocean shore to motorized use from March 15 to September 15. On the private parcels and on Port of Coos Bay lands, use is controlled and limited to established roadways where access is allowed.

While OHV cross country use on the North Spit has been officially controlled by federal and state regulations for a long time, actual enforcement of these restrictions is relatively recent. The listing of the snowy plover in 1993 and the grounding of the New Carissa and the subsequent emergency closure in 1999 promoted the agency to place more resources and management focus toward controlling this use on the Spit.

The BLM has placed most of its enforcement efforts in those areas on the Spit with the highest resource values (e.g. snowy plover nesting habitat and interior wetlands). Compliance with OHV designations in these areas has been goodin the interior of the Spit. Compliance varies on the beach and in plover areas. This is not the case in the 80 acre dune area located next to the Roseburg chip facility. This area is used as a defacto "open area" by people who choose not to use the legal and managed OHV open areas, located 1.5 miles away, in the ODNRA.

***New Carissa 2002.***

## Visual Resources

The public lands on the south shore of the North Spit are a dominant visual resource element in the overall scenic backdrop of the Coos Bay estuary. The quality of visual resources directly influences a community's potential for tourism, high-end real estate development, and the area's desirability for business and residential relocation.

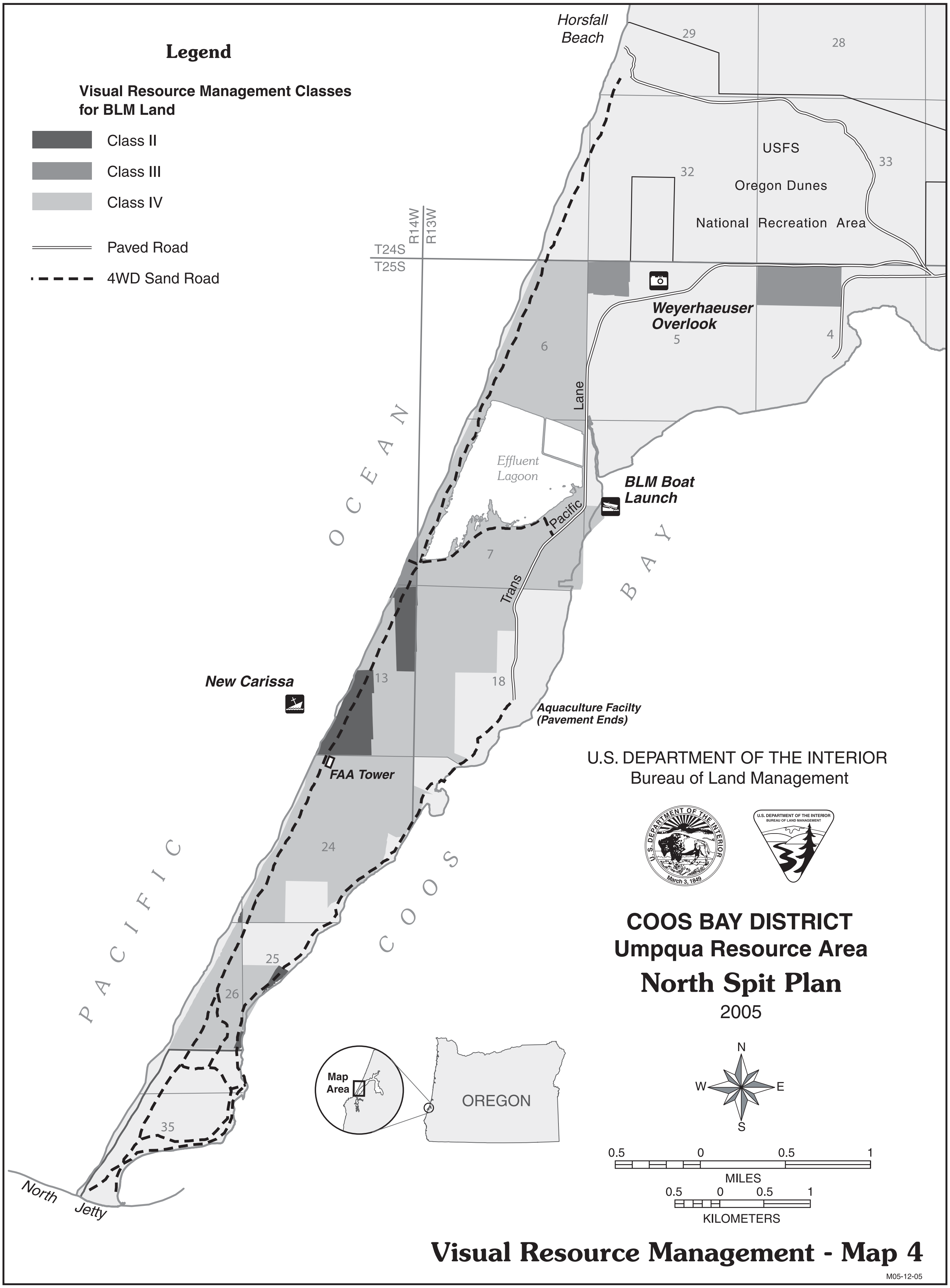
Visual resources on the public lands are managed through the BLM's land use planning process. Through this inventory and classification process, public lands are placed in one of four visual resource management classes. These management classes range from the total preservation of the existing landscape in Class I, to allowing major modifications of the landscape character in Class IV (Map 4). The lands on the North Spit were classified in the Coos Bay District RMP as follows:

- Class II. The public lands in the northwest corner of the ACEC and within the SRMA in T25S, R14W, Section 13 and T25S, R13W Section 18 were given this fairly protective classification to preserve the quality of the recreation setting. Objectives for Visual Resource Management in this area are to retain the existing character of landscape. Changes in any of the basic elements (form, line, color, texture) caused by a management activity should not be evident in the characteristic landscape. Contrasts are seen, but must not attract attention.

- Class III. Within two parcels adjacent to the Trans Pacific Lane in T25S, R13W in Sections 5 and 4, public lands were classified as Class III. Objectives for VRM management in these parcels would be to partially retain the existing character of landscape. Contrasts to the basic elements caused by a management activity are evident, but should remain subordinate to the existing landscape.

- Class IV. The majority of the public lands on the North Spit are VRM Class IV. VRM objectives in these areas allow for major modifications of the existing character of the landscape. Contrasts that are created by management activities may attract attention and be a dominant feature of the landscape in terms of scale, but should repeat the form, line, color, and texture of the characteristic landscape.

***Driving the sand roads on the North Spit.***


Legend
Visual Resource Management Classes for BLM Land
Class II
Class III
Class IV
Paved Road
4WD Sand Road
Horsfall Beach
USFS
Oregon Dunes
National Recreation Area
Weyerhaeuser Overlook
Effluent Lagoon
BLM Boat Launch
Lane
Pacific
Trans
PACIFIC OCEAN
COOS BAY
New Carissa
FAA Tower
Aquaculture Facilty (Pavement Ends)
North Jetty
T24S
T25S
R14W
R13W
U.S. DEPARTMENT OF THE INTERIOR
Bureau of Land Management
COOS BAY DISTRICT
Umpqua Resource Area
North Spit Plan
2005
Map Area
OREGON
MILES
KILOMETERS
Visual Resource Management - Map 4
M05-12-05

# PART 4 –NORTH SPIT MANAGEMENT, 2005

## Introduction

Part Four presents management actions on BLM-administered lands for the next ten years. Management actions are described in alphabetical order except for Monitoring and Research which is found at the end of the section. There are no management actions for fish on BLM lands on the Spit. Geology management actions are located under Monitoring and Research.

The aim of the North Spit Plan is to conserve the natural, cultural, and recreational values of the Spit. Management objectives reflect that aim and are consistent with BLM policies and state and federal regulations. These objectives were described in detail in the Draft Shorelands Plan (USDI BLM 1989), incorporated in the Final Shorelands Plan (USDI BLM 1995), and included in North Spit ACEC planning documents (USDI BLM 1999). For the North Spit Plan, these objectives were reviewed and revised based on current conditions and needs, and will be implemented as funding allows. They are listed below, followed by the reasons for action, planned actions, and actions accomplished or ongoing since the 1995 Shorelands Plan. Due to the interrelationship of the various resources at the Spit, many actions apply to more than one objective.

## Management Objectives

**Objective 1 –** Preserve important cultural resources on the Spit.

**Objective 2 –** Promote awareness and appreciation for the Spit's many resource values and recreational opportunities, and support a minimum impact land use ethic through educational programs such as *Leave No Trace* and *Tread Lightly*.

**Objective 3 –** Prioritize land tenure adjustments based on natural resource values and recreational opportunities on non-BLM parcels, consolidation of BLM properties, and the safeguarding of public investments.

**Objective 4** – Manage the North Spit SRMA to provide for a range of recreational opportunities that contribute to meeting traditional as well as projected recreation demand within the region while protecting the area's natural, cultural, and scenic resources.

**Objective 5 –** Provide and maintain adequate visitor facilities, services, signing, and programs that are appropriate for the area's recreation opportunity setting and that serve to protect the Spit's sensitive resources.

**Objective 6 –** Conserve, enhance, or restore natural habitats, with an emphasis on habitats that support special status plant and wildlife species.

**Objective 7 –** Maintain wetland areas in a condition supportive of a healthy aquatic ecosystem.

**Objective 8 –** Facilitate improved management of the Spit through monitoring to learn more about the natural and cultural resources of the area and to assess the effects of management actions.

### Cultural Resources

**Objective 1.** Preserve important cultural resources on the Spit.

### Reasons for Action

- By law, BLM is required to protect cultural resources. These laws include the Archaeological Resources Protection Act, American Indian Religious Freedoms Act, National Historic Preservation Act, and the Native American Graves and Repatriations Act.

- The Coquille Indian Tribe (CIT) and Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI), both federally-recognized tribes, have expressed concern about protection of cultural sites along the Southern Oregon Coast. The Spit is within the ancestral territory of the CTCLUSI.

### Actions Accomplished or Ongoing

- In 2000, a report was completed by noted historian Stephen Dow Beckham detailing the history of federal activities on the North Spit (Beckham 2000). The majority of this report concerns the construction and maintenance of the North Jetty, beginning in 1890. The history of the U.S. Lifesaving Service station is also described in detail.

- Continue to preserve remaining historic cultural resources.

### Proposed Actions

- Work with the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians as well as the Coquille Indian Tribe to assure continued protection and preservation of prehistoric resources.

- Remove damaged chain link fence from the perimeter of the World War II Quonset huts.

## Environmental Education and Interpretation

**Objective 2.** Promote awareness and appreciation for the Spit's many resource values and recreational opportunities, and support a minimum impact land use ethic through educational programs such as *Leave No Trace* and *Tread Lightly*.

### Reasons for Action

- Environmental education and interpretation can encourage responsible use of the Spit area, thereby reducing resource degradation, violations, and vandalism. Education and interpretation can enhance the visitors' experience.

- Education and interpretation may be used to communicate the BLM's management goals to visitors.

### Environmental Education and Interpretive Themes

The environmental education and interpretation conducted at the Spit should be planned and implemented according to the following themes:

**Theme #1:** The Spit landscape is an intricate web of related parts that is constantly changing due to natural and human actions.

> **Topics:** natural history · system dynamics · interrelationships · ecosystem concepts · plants and animals found at the Spit · dune systems · introduced species · hydrology · biodiversity · threatened and endangered species · habitats

**Theme #2:** Due to its close proximity to both the ocean and Coos Bay, people have used the Spit for a variety of purposes, including recreation, industry, military installations, commerce, transportation, etc.; all of these actions have shaped the land in some way.

> **Topics:** human history · human impacts · land use planning · introduced species · weeds · management goals · New Carissa · recreation opportunities

**Theme #3:** Good stewardship is essential in maintaining the health and integrity of the Spit.

> **Topics:** appropriate behavior · Watchable Wildlife methods · Leave No Trace / Tread Lightly outdoor ethic · management support and challenges · involving visitors

## Actions Accomplished

- A brochure was developed to provide visitors with a map of the Spit and inform them of regulations and opportunities.

- A variety of interpretive signs and a kiosk have been developed and installed at the boat launch ramp, the overlook to the New Carissa, and various access points. Seasonal interpreters have been hired in past summers to educate the public about seasonal closures and recreational opportunities.

## Ongoing Actions

- Continue to host field trips for schools at the Spit for students to learn about the area.

- BLM will continue to work cooperatively with the interagency snowy plover working team on issues pertaining to public education and outreach.

## Proposed Actions

- When a prospectus for environmental education and interpretation is developed for the District, include a section concerning the Spit. Use its recommendations when developing and conducting programs and interpretive materials.

- Utilize seasonal or volunteer interpreter(s) when feasible to contact visitors and disseminate information about the Spit on areas suited for recreation, seasonally closed areas, compliance issues, etc.

- Special educational opportunities may include: National Public Lands Day events, Elderhostel tours, beach clean ups, Christmas bird counts, or similar activities that involve the public.

- Ensure that any interpretation which deals with cultural or paleo-environmental history is coordinated with interested Indian tribes and the Coos Bay District Archaeologist.

- Rotate or replace interpretive displays as needed. Where applicable develop supplemental materials to support interpretation and environmental education, such as informational kiosks, trail guides, brochures, and educational kits.

- Use the draft Western Snowy Plover Outreach Plan (Western Snowy Plover Working Team 2004) when considering any outreach that deals with plovers on the Spit.

- Raise public awareness about the environmental and recreational values of riparian-wetland areas on the Spit.

## Land Tenure Adjustments

**Objective 3.** Prioritize land tenure adjustments based on natural resource values and recreational opportunities on non-BLM parcels, consolidation of BLM properties, and the safeguarding of public investments.

### Reasons for Action

- Adjacent landowner management objectives may not be consistent with BLM's objectives. For example, land ownership patterns on the Spit could limit or stop access to much of the public land.

### Actions Accomplished

- The 1995 Shorelands Plan identified four potential land acquisitions and one disposal. Three acquisitions were accomplished.

### Ongoing Actions

- In accordance with the RMP, BLM-administered lands on the Spit within zoning districts 3-EWD, 4CS, and 6WD as delineated by the Coos County Comprehensive Plan could be offered for exchange, sale, or lease to accommodate local economic expansion and industrial development. A land disposal is currently in progress for an 80 acre BLM parcel north of the Roseburg Chip Facility along the Trans Pacific Lane.

- All of the lands on the Spit administered by the BLM are public domain lands and therefore subject to public land laws. Under these laws, BLM manages for specific uses such as permits, rights-of-way, leases, special use permits, etc. Several utility and access rights-of-way were issued and are currently in use. Future applications for leases, permits, and right-of-ways will be reviewed and authorizations issued on a case-by-case basis.

### Proposed Actions

- Consider land tenure adjustments to ensure access to public lands as appropriate to meet objectives.

## Recreation

**Objective 4.** Manage the North Spit SRMA to provide for a range of recreation opportunities that contribute to meeting traditional as well as projected recreation demand within the region while protecting the area's natural, cultural, and scenic resources.

### Reasons for Action

- The BLM designated the North Spit as an SRMA to preserve opportunities for outdoor recreation and to manage this activity in a manner that is compatible with protecting the natural and cultural resource values of the ACEC.

- Visitors differ widely in their preferences for recreation activities, settings and facilities. Balancing these needs within the limited space available on the North Spit is necessary to provide for a quality resource-based experience, reduce conflicts between users and protect natural resource values.

- The Oregon Parks and Recreation Department Statewide Trail Plan identified trail connectivity between agency management jurisdictions as a key statewide trail management goal. Creating and maintaining connectivity between trail opportunities on BLM lands on the North Spit and the adjacent trail systems managed by the USFS, OPRD, and Weyerhaeuser would enhance overall trail opportunities in the region.

## Actions Accomplished

- Signs were placed at the ocean beach access points along the Foredune Road; other signs and maps were placed at various locations to inform visitors of regulations and recreational opportunities.
- Roads and trails that were not designated open were closed using logs, root wads, and signs. Many of these closed routes are disappearing through natural revegetation.
- A sign strategy was developed to assist BLM in providing information to the public on regulations, recreational opportunities, and natural resources on the Spit.

## Ongoing Actions

- Continue to provide and manage motorized access on the Spit to support the area's long-standing traditional recreation uses while protecting natrual, cultural and scenic resources.
- Manage the North Spit to retain a recreation setting compatible with the area's Rural and Semi-Primitive Motorized ROS classification.
- Provide timely press releases for public service announcements and newspaper notices prior to any seasonal access restrictions as needed.
- Clear sand and debris from the boat ramp each spring prior to reinstalling the docks for the summer season.
- Continue to allow primitive camping on BLM lands on the Spit, except in areas where signed to protect sensitive plants and wildlife.
- Continue to maintain the docks at the boat launch as funding allows.
- Continue to permit hunting and shooting on BLM lands on the Spit in conformance with applicable state and federal laws and regulations. These regulations prohibit shooting adjacent to and across public roadways and within developed recreation sites.

## Proposed Actions

- Increase information available about theNorth Spit,
- Place improved regulatory and information signs along the sand roads and at ocean beach access points. Advise visitors to inspect the three existing access points before they commit to driving onto the beach – the passability of these access points can change on a daily basis due to waves, high tides and winter storms.
- Remove dilapidated fences and fence posts from three locations on the Spit: the fence at the intersection of the Foredune Road and Trans Pacific Lane, the WWII bunker fence, and fencing material from the southern interior.
- Establish trails for pedestrian and equestrian use within the North Spit interior. Develop and support local partnerships to assist in maintaining and managing this trail system.
- Create and maintain connections between trail opportunities on BLM lands and the adjacent trail systems on Forest Service, OPRD and Weyerhaeuser lands.
- Determine feasibility of designating the Foredune Road open to motorized access from the South Dike Road north to the USFS boundary
- Construct a small equestrian and hiking staging area to provide parking and visitor information at the portal to the trail system.

- Implement the completed sign strategy developed to improve communication with Spit visitors.
- Explore the potential for placing picnic tables at the boat launch facility.
- Include information about wildlife viewing opportunities into the educational kiosk proposed for the boat ramp area.

## Site Protection and Administration

**Objective 5.** Provide and maintain adequate visitor facilities, services, signing, and programs that are appropriate for the area's recreation opportunity setting and that serve to protect the Spit's sensitive resources.

### Reasons for Action

- Visitation to the Spit is expected to grow as more people become aware of the area, and as tourism along the southern Oregon Coast increases.
- Facilities, designated roads and trails, signs, and other management tools (e.g., on-site hosts) reduce and prevent resource damage.
- Contracted services with Coos County agencies enhance fire response and law enforcement support for the area.

### Fire Management

### Accomplished and Ongoing Actions

- BLM contracts with the Coos Forest Protection Association for fire response, including the lands on the Spit. Contracted duties might include: specific action and preparedness plans; prevention, detection, initial attack, and suppression services; resource protection; fire notification services; fire investigation; debriefings and contract reviews; and reports.

### Proposed Actions

None at this time.

### Hazardous Materials Management

### Accomplished and Ongoing Actions

See below.

### Proposed Actions

- Finish the sampling and report for the Spit Life Guard Station Environmental Site Characterization.

The structures at the Spit Life Guard Station were serviced by a variety of fueled devices such as generators and power plants. In 1991, the Bureau of Land Management initiated a demolition and removal of the structures, and contracted for the location, assessment and removal of four known underground petroleum storage tanks (USTs) from the site. In late 2002, Oregon Department of Environmental Quality (DEQ) informed the Coos Bay District Hazardous Materials Coordinator that the removal of the USTs had not been finalized and documented under the UST program closure rules. A subsequent records search by BLM concurred. In consultation with DEQ, it was determined that a site assessment was necessary to comply with the state rules and to receive a No Further Action Required determination and closure of the case file. A draft plan for this site assessment and a report to DEQ was prepared, and implementation is planned pending funding. This project is known as the Spit Life Guard

Station Environmental Site Characterization, OR DEQ Log Number 06-91-0030; UST Facility ID # 10718. This is the only hazardous materials project on public lands on the Spit.

### Law Enforcement

#### Accomplished and Ongoing Actions

- BLM Law Enforcement Officers are trained and authorized to enforce federal regulations on BLM lands. The BLM also continues to contract with the Coos County Sheriff's Department, and contribute funds to OPRD for seasonal assistance with beach patrol.

- Continue to have law enforcement officers enforce Federal and Oregon State firearm regulations and encourage shooter safety while on patrol on the Spit.

#### Proposed Actions

None at this time.

### Facility Management

#### Accomplished Actions

None at this time.

#### Ongoing Actions

- Maintain existing facilities at the boat launch recreation area.

#### Proposed Actions

- Consider placing alternative toilet facilities at high use areas.

### Road Maintenance and Improvement

#### Accomplished and Ongoing Actions

None at this time.

#### Proposed Actions

- Consider raising and widening the Re-route Road to minimize the risk of vehicular collisions.

## Vegetation and Wildlife Resources

**Objective 6.** Conserve, enhance, or restore natural habitats, with an emphasis on habitats that support special status plant and wildlife species.

#### Reasons for Action

- The BLM is required to follow federal laws and regulations and has established a policy to prevent the need to list fish, wildlife, and plants under the Endangered Species Act. Furthermore, the BLM is directed to encourage management which will lead to the successful recovery and eventual delisting of federally recognized Endangered Species.

- Over the years, alterations to the habitat have interfered with natural community succession. For example, fires were suppressed, groundwater was pumped, and open sandy areas were vegetated by exotic plants.

- Exotic (non-native) vegetation species, such as European beach grass, and noxious weeds, such as Scotch broom, are replacing native vegetation and opportunistically becoming established on sites otherwise unoccupied by grass or shrub species. This spread of exotic and noxious vegetation is altering habitats and interfering with natural succession.

- Resource and vegetative management is necessary to maintain the natural communities, successional processes, and ecosystem health.

- Historic nesting areas of the Western snowy plover were altered by the introduction of European beach grass, increased predation, and accelerated human access and activity on beaches.

- Balanced management actions ensure protection and limit disturbance to plants and wildlife.

## Vegetation

### Actions Accomplished

- Plant communities were mapped and digitized for use with a Geographic Information System (GIS).

### Ongoing Actions

- Coordinate with other agencies and institutions to restore degraded and disturbed plant communities.

### Proposed Actions

- Complete the study of vegetation alliances to determine the plant associations of the Spit.

- Conduct a complete inventory of the vascular and non-vascular flora of the Spit to document all the present plant species.

## Special Status Plant Species and Communities

### Actions Accomplished

- Pink sandverbena was reintroduced under a cooperative agreement with the Institute of Applied Ecology.

- A permanent vehicle re-route was constructed along the bay side and barriers were installed to protect the Point Reyes bird's-beak population in the saltmarsh.

### Ongoing Actions

- Facilitate the recovery of the pink sandverbena by collecting seeds for dispersal to other sites along the coast. Coordinate conservation activities with management of Western snowy plover.

- In cooperation with the Port and the DSL, maintain protective barriers around the Point Reyes bird's-beak population on the bay side of the Spit.

- Continue inventory and management for SSS.

### Proposed Actions

The following actions only pertain to the North Spit Area of Critical Environmental Concern:

- Implement beach and dune ecosystem restoration for multiple species.
- Establish additional special status plant populations as warranted.
- Develop opportunities for collaborative habitat management to increase the amount of habitat suitable for rare species and to link isolated populations with one another.
- Collect special status plant seeds as necessary for storage at the Berry Botanic Garden's Cryogenic Seed Bank.
- Identify opportunities for restoration of globally ranked plant communities.

## Exotic Plants and Noxious Weeds

### Actions Accomplished

- Gorse was removed from the Coast Guard Lifesaving station.
- Scotch broom was cleared from HRAs.

### Ongoing Actions

- European beach grass is removed annually from HRAs.

### Proposed Actions

- Continue weed treatments on the Spit to remove exotic and noxious species. Use integrated pest management practices, such as fire, mechanical or manual removal, and herbicide application. Restore treated areas by spreading native seed and planting native plants.
- Use best management practices to prevent the further spread of exotic plants and noxious weeds.

## Wildlife

### Actions Accomplished or Ongoing

None at this time.

### Proposed Actions

- Survey suitable habitat for great blue herons and great egret rookeries.
- Conduct wildlife inventories at selected wetlands.
- Survey to locate the nests of protection buffer species raptors: osprey, red-tailed hawk, sharp-shinned hawk and Cooper's hawk.

## Special Status Wildlife Species

### Actions Accomplished or Ongoing

- Continue to implement Western snowy plover conservation actions as directed by the Biological Opinion (USDI FWS 2000). BLM will implement the Western snowy plover Pacific Coast Recovery Plan when finalized. Ongoing actions include the following:

  1. Closing the upper, dry sand portion of the ocean beach to all public access from the FAA Tower south to the BLM boundary during the Western snowy plover nesting season (March 15- September 15 annually; Map 3). The area is clearly marked with ropes and signs. Restrictions on motorized use of the adjacent lower, wet sand area are authorized by OPRD. Inland snowy plover nesting areas on BLM land are also signed closed to all use during the nesting season, and are open to nonmotorized use the remainder of the year.

  2. Removing beachgrass from the inland snowy plover Habitat Restoration Areas (HRAs) to maintain suitable open, sandy habitat suitable for nesting plovers (Map 3).

  3. Administering a contract with the Animal Plant and Health Inspection Service (APHIS) that implements an integrated predator damage management program to protect the plover population from further declines caused by predation. Targeted species include American crows, common ravens, and small mammalian predators. Most traps are located in areas closed to the public (e.g., the HRAs and the upper beach), clearly signed, and are designed to prevent injury to domestic animals and humans.

  4. Administering a contract with the Oregon Natural Heritage Information Center to intensively monitor plover nesting efforts and thereby gauge the success of management actions and determine progress toward plover recovery.

- Continue to coordinate with the FWS to implement recovery plans to protect other threatened and endangered species, as necessary.

- Nest boxes were installed for purple martins.

### Proposed Actions

- Develop and implement survey protocols to locate special status species.

- Actively manage habitats to promote the conservation of special status species and protection buffer species.

## Water Resources

**Management Objective 7**. Maintain wetland areas in a condition supportive of a healthy aquatic ecosystem.

### Reasons for Action

- The BLM has a responsibility to conserve native wildlife and plant species and the ecosystems upon which they depend. Many of these species are associated with wetlands.

### Actions Accomplished

- BLM participated in the creation of wetlands on BLM adjacent to Weyerhaeuser's Overlook wetlands site as part of the Henderson Marsh Mitigation Plan.

### Ongoing Actions

- Consider wetland project proposals consistent with the 1984 Henderson March Mitigation Plan. Proposal will require environmental review.

### Proposed Actions

None at this time.

## Monitoring and Research

**Objective 8.** Facilitate improved management of the Spit through monitoring to learn more about the natural and cultural resources of the area and to assess the effects of management actions.

### Reasons for Action

- Ensure compliance with federal and state laws and regulations.
- Fill existing information gaps to enable the BLM to better manage the area in the future.
- Evaluate existing management strategies to provide feedback on meeting established objectives.
- Broaden human understanding of the area.
- Identify recovery and conservation needs for special status species.
- Identify the nature and extent of human-caused impacts to sensitive resources early enough to take effective action to minimize adverse affects.
- Understand the dynamics of coastal ecosystems.

### Cultural Resources

### Actions Accomplished or Ongoing

None at this time.

### Proposed Actions

- Monitor stability of important cultural resources and propose actions to continue their preservation.

### Environmental Education and Interpretation

### Actions Accomplished or Ongoing

- Evaluate the effectiveness of educational brochures and signs.

### Proposed Actions

- Evaluate the effectiveness of environmental education programs and interpretive materials on a regular basis, and make modifications as necessary.

## Geology

### Actions Accomplished or Ongoing

None at this time.

### Proposed Actions

- Track elevation changes on the ocean foredune and monitor the effects of weather and beach grass removal on foredune erosion.

## Recreation

### Actions Accomplished or Ongoing

- Continue to use traffic and trail counters and field staff observations to monitor visitor use and to report findings in the Recreation Management Information System.

- Continue to monitor camping on BLM lands on the Spit.

### Proposed Actions

- Monitor the condition of beach access routes.

## Vegetation and Wildlife Resources

### Actions Accomplished or Ongoing

- Monitor noxious weed species to document existing population areas, effectiveness of management actions for removal, and the spread of these species to new sites.

- Evaluate and explore effective management strategies to meet recovery goals for the Western snowy plover. Monitor human and natural disturbance effects on breeding plovers.

- Continue to support the Oregon Natural Heritage Information Center in its efforts to monitor Western snowy plover reproductive success.

- Continue to monitor great blue heron and great egret rookeries.

- Continue to monitor selected special status species on the Spit.

- Continue to monitor the condition of riparian-wetland vegetation. If signs of excessive disturbance caused by unauthorized motorized recreation become evident, adjust patrols, signing and barriers to reduce or prevent impacts.

### Proposed Actions

- Monitor special status species' population status and trends. Pursue collaborative efforts to study SSS reproductive ecology, threats, habitats, and effects of management treatments and practices.

- Monitor the status and trends of globally ranked plant communities within the North Spit ACEC.

- Seek collaborative opportunities to survey migratory shorebirds and waterfowl to establish population status and trends.

# Bibliography

Alt, D. D., and D. W. Hyndman. 2001. Roadside geology of Oregon. Mountain Press Publishing Company, pp. 91-99.

Aubry, K. B., and J. C. Lewis. 2003. Extirpation and reintroduction of fishers (*Martes pennanti*) in Oregon: implications for their conservation in the Pacific states. Biological Conservation 14:79-90.

Barbour, M. G., and A. F. Johnson. 1988. Beach and dune. Pages 223-262 *in* Terrestrial vegetation of California. M.G. Barbour and J. Major, editors. California Native Plant Society, Special Publication Number 9.

Barbour, M. G., T. M. DeJong, and B. M. Pavlik. 1985. Marine beach and dune plant communities. Pages 296-322 *in* Physiological ecology of North American plant communities. B. F Chabot and H. A. Mooney, editors. Chapman and Hall, New York, NY.

Beckham, S. D. 1986. Land of the Umpqua: A history of Douglas County, Oregon. Douglas County Commissioners, Roseburg, OR.

Beckham, S. D. 2000. Coos Bay North Spit: Historical investigations of federal activities in coastal Oregon. Unpublished report on file at the Coos Bay District, North Bend, OR. 140 pp.

Boyd, R. 1999. The coming of the spirit of pestilence: Introduced infectious diseases and population decline among Northwest Coast Indians, 1774-1874. University of Washington Press, Seattle, WA.

Buchanan, J. B., D. H. Johnson, E. L. Greda, G. A. Green, T. R. Wahl, and S. J. Jeffries. 2001. Wildlife of coastal and marine habitats. Chapter 15 *in* Wildlife-habitat relationships in Oregon and Washington. D. Johnson and T. O'Neil, editors. Oregon State University Press, Corvallis, OR. 736 pp.

Christy, J. A., J. S. Kagan, and A. M. Wiedemann. 1998. Plant associations of the Oregon Dunes National Recreation Area, Siuslaw National Forest, Oregon. USDA, Forest Service, Pacific Northwest Region, Tech. Paper R6-NR-ECOL-TP-09-98. Portland, OR. 183 pp.

Coats, R. N. 1995. Design guidelines for tidal channels in coastal wetlands. Philip Williams and Associates, San Francisco, CA.

Contreras, A. 1998. Birds of Coos County, Oregon: Status and distribution. Cape Arago Audubon Society in cooperation with Oregon Field Ornithologists (OFO), OFO Special Publication Number 12. 161 pp.

Cooper, W. S. 1958. Coastal sand dunes of Oregon and Washington. The Geological Society of America. Memoir 72. 169 pp.

Coos County. 1986. The Coos County Zoning and Land Development Ordinance.

Cowardin, L. M., V. Carter, F. C. Golet, F. C., and E. T. LaRoe. 1979. Classification of wetland habitats and deepwater habitats of the United States. FWS/OBS-79/31. US Department of the Interior, Fish and Wildlife Service, Office of Biological Services. 131 pp.

Dodge, O. 1969. Pioneer history of Coos and Curry Counties 2nd Edition with Errata. Republished by Coos-Curry Pioneer and Historical Association, Coquille, OR.

Executive Order 11644. Use of Off-Road Vehicles on the Public Lands, Richard M. Nixon, February 8, 1972, The White House. 2 pp.

Federal Interagency Committee for Wetland Delineation. 1989. Federal manual for identifying and delineating jurisdictional wetlands. Cooperative technical publication: US Army Corps of Engineers, US Environmental Protection Agency, US Fish and Wildlife Service, and USDA Soil Conservation Service. Washington, D.C. 76 pp.

Fritz, L., 1992. Mineral resources potential report for the withdrawal of the North Spit of Coos Bay, Oregon from mineral entry under the Mining Law of 1872: United States Department of the Interior, Bureau of Land Management internal report, Coos Bay District, North Bend, OR. 13 pp. + Appendices.

Geitgey, R. P. 1990. Silica in Oregon: State of Oregon Department of Geology and Mineral Industries Special Paper No. 22. Portland, OR. 18 pp. + 2 Plates.

Huiskes, A. H. L. 1979. The natural establishment of *Ammophila arenaria* from seed. Oikos 29: 133-136.

Interagency. 1994. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Vol. I and II. USDA Forest Service and USDI Bureau of Land Management (Lead agencies), Portland, OR.

Jones, M. A. 1992. Ground-water availability from a dune-sand aquifer near Coos Bay and North Bend, Oregon. US Geological Survey Open-File Report 90-563. Portland, OR. 76 pp.

Kagan, J. S., J. A. Christy, M. P. Murray, and J. A. Titus. 2004. Classification of native vegetation of Oregon.

Komar, P. D. 1992. Ocean processes and hazards along the Oregon coast. Oregon Geology 54 (1):3-19.

Komar, P. D. 1997. The Pacific Northwest coast: living with the shores of Oregon and Washington. Duke University Press. London, UK. 195 pp.

Komar, P. D., J. J. Marra, and G. Diaz-Mendez. 1999. A study of the New River Spit, Oregon, to acquire information relevant to an adjustment of the statutory vegetation line. Report to the Oregon Parks and Recreation Department, Salem, OR. 44 pp.

Lauten, D. J., K. A. Castelein, B. V. Smithers, K. C. Jander, E. Elliott-Smith, and E. P. Gaines. 2003. The distribution and reproductive success of the Western snowy plover along the Oregon coast – 2003. Unpublished report. The Oregon Natural Heritage Information Center, Portland, OR. 52 pp.

Lund, E. H. 1973. Landforms along the coast of southern Coos County, Oregon. Ore Bin 35(12):189-210.

Madin, I. P., G. W. McInelly, and H. M. Kelsey. 1995. Geologic map of the Charleston Quadrangle, Coos County, Oregon. State of Oregon Department of Geology and Mineral Industries Geological Map Series GMS-94.

Marshall, D. B., M. W. Chilcote, and H. Weeks. 1996. Species at risk: sensitive, threatened and endangered vertebrates of Oregon. 2nd ed. Oregon Department of Fish and Wildlife. Portland, OR.

McLaughlin, W. T., and R. L. Brown. 1942. Controlling coastal sand dune in the Pacific Northwest. US Department of Agriculture. 46 pp.

Natural Heritage Advisory Council. 2003. Oregon Natural Heritage Plan. [Online] Available http://oregonstate.edu/ornhic/draftplan.pdf.

Northwest Biological Consulting. 1980. Wildlife and biological profile of the North Spit of Coos Bay, OR. A report submitted to the US Fish and Wildlife Service, Boise Area Office, Boise, ID. 90 pp.

O'Neil, T. A., D. H. Johnson. C. Barrett, M. Trevithick. K. A. Bettinger, C. Kiilsgaard, M. Vander Heyden, E. L. Greda, D. Stinson, B. G. Marcot, P. J. Doran. S. Tank, and L. Wunder. 2001. CD-ROM: Matrices for wildlife-habitat relationships in Oregon and Washington. *In* D.J. Johnson and T.A. O'Neil, eds. Wildlife habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR. 736 pp.

Oregon Climate Service. 2004. Wind Rose Tables – Zone 1. [Online] Available http://www.ocs.oregonstate.edu/index.html.

Oregon Department of Agriculture. 2003. 2003 noxious weed policy and classification system. Noxious Weed Control Program, 9 pp.

Oregon Natural Heritage Information Center and the Oregon Parks and Recreation Department. 2004. Draft Habitat Conservation plan for the Western snowy plover. [Online] Available www.prd.state.or.us/osmp_hcp.php

Oregon Parks and Recreation Department. Oregon Statewide Comprehensive Outdoor Recreation Plan 2003-2007. Salem, OR [Online] Available www.oregon.gov/OPRD/PLANS/scorp_review.shtml

Oregon Parks and Recreation Department. Oregon Statewide Trails Plan 2004. Salem, OR [Online] Available www.oregon.gov/OPRD/PLANS

Oregon Parks and Recreation Department. 2004. Draft ocean shores management plan. Salem, OR. [Online] Available www.prd.state.or.us/osmp_hcp.php

Oregon Natural Heritage Information Center. 2004. Rare, threatened, and endangered species of Oregon. [Online] Available http://oregonstate.edu/ornhic.

Oregon Wetlands Joint Venture. 1994. Southern Oregon coast implementation plan. West Linn, OR. 17 pp.

Orr, E. L. and W. N. Orr. 2000. Geology of Oregon. Fifth Edition, Kendall/Hunt Publishing Company. 254 pp.

Peterson, E. R. and A. Powers. 1977. A century of Coos and Curry: history of Southwest Oregon. Coos-Curry Pioneer and Historical Association, Coquille, OR.

Pickart. A. J., D. R. Brown, and W. Avery. 1990. Experimental eradication of European beach grass (*Ammophila arenaria*), Humboldt County, California. Unpublished report submitted to J. O. Sawyer Jr. Menzies' wallflower research program, Humboldt State University, CA.

Powell, R. A. and W. J. Zielinski. 1994. Fisher. Pages 38-73 *In* L.F. Ruggiero et al., editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station Gen. Tech. Rep. RM-254. Fort Collins, CO. 167pp.

Priest, G. R. 1995a. Tsunami hazard map of the Empire Quadrangle, Coos County, Oregon. State of Oregon Department of Geology and Mineral Industries open file report O-95-44. Portland, OR.

Priest, G. R. 1995b. Tsunami hazard map of the Charleston Quadrangle, Coos County, Oregon: State of Oregon Department of Geology and Mineral Industries open file report O-95-47. Portland, OR.

Ranwell, D., W. Newborough, and I. Anglesey. 1959. The dune system and dune slack habitat. Journal of Ecology 47: 571-601.

Rodenkirk, T. 2003. Purple martin nest box project 2003. Annual report prepared for the Bureau of Land Management, Coos Bay District, North Bend, OR. 12 pp.

Sharp, B. E. 1996. Avian population trends in the Pacific Northwest. Bird Populations 3:26-45.

Souza, S. 2005. Principal, Environmental Consulting Division, Sol Coast Consulting and Design, LLC. Personal communicaton June 21, 2005

Sperling, J. 2004. Amendment to Environmental Assessment EA-95.001.1792. Botanical assessment of proposed land sale on the North Spit of Coos Bay, OR. Unpublished report, Coos Bay District, North Bend, OR.

Stansell, V. 1989. Partial plant list beach front from the Port's Aquaculture facility to Life-saving Station. Unpublished species list on file at the Coos Bay District, North Bend, OR.

The Nature Conservancy. 1994. Final Draft Standardized National Vegetation Classification System. [Online] Available http://biology.usgs.gov/npsveg/classification/indexdoc.htm.

Thornburgh, L. 1991. Site guide: Coos Bay and Bandon area, Coos County, Oregon. Birds 17(3)82-84.

US Code of Federal Regulations, Title 36, Corps of Engineers, Army, DoD, Ch. III, 2004 Edition, Part 327 – Rules and Regulations Governing Public Use of Water Resource Development Projects Administered by the Chief of Engineers. Section 327.2 Vehicles, pages 6 - 7.

US Code of Federal Regulations, Title 43, Public Lands: Interior, Parts 1000 to End. 2003 Edition, Subchapter H – Recreation Programs, 8340 – Off Road Vehicles, pages 905 – 908.

US Department of Agriculture, Forest Service. 1972. The Oregon Dunes National Recreational Area resource inventory. US Forest Service Pacific Northwest Region, Portland, OR. 294 pp.

US Department of Agriculture, Forest Service. 1993. Draft environmental impact statement for the Oregon Dunes National Recreation Area management plan.

US Department of Agriculture, Forest Service. 1982. ROS Users Guide, 37 pp.

US Department of Agriculture, NRC. 2004. The PLANTS database, Version 3.5. [Online] Available http;//plants.usda.gov. National Plant Data Center, Baton Rouge, LA.

US Department of Agriculture and US Department of Interior. 2002. Environmental assessment: predator damage management to protect the federally threatened pacific coast population of the Western snowy plover in Oregon. Prepared by USDA, APHIS, Wildlife Services Program and the Siuslaw National Forest, USDI, Fish and Wildlife Service and Bureau of Land Management, and in cooperation with the Oregon Department of Fish and Wildlife and the Oregon Parks and Recreation Department. Portland, OR.

US Department of Defense, Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. Wetlands Research Program Technical Report Y-87-1 (on-line edition). Waterways Experiment Station, Vicksburg, MS.

US Department of Interior, Bureau of Land Management. 1981. Bureau of Land Management Planning for Recreation Resources Policy. Manual 8320, Re1. 8-12.

US Department of Interior, Bureau of Land Management. 1982. Bureau of Land Management Off Road Vehicle General Policy. Manual 8340, Re1. 8-18.

US Department of Interior, Bureau of Land Management. 1984. Bureau of Land Management Visual Resource Management Manuals 8400, Re1. 8-24.

US Department of Interior, Bureau of Land Management. 1984. North Spit Amendment to the Master Framework Plan.

US Department of Interior, Bureau of Land Management. 1988. Bureau of Land Management Areas of Critical Environmental Concern Policy. Manual 1613, Re1. 1-1541.

US Department of Interior, Bureau of Land Management. 1989. Coos Bay Shorelands draft management plan. Coos Bay District, North Bend, OR. 38 pp.

US Department of Interior, Bureau of Land Management. 1992. North Spit ACEC Team Meeting Notes. On file, Coos Bay District, North Bend, OR.

US Department of the Interior, Bureau of Land Management. 1994. Coos Bay Shorelands draft plan and environmental assessment. Coos Bay District, North Bend, OR.

US Department of Interior, Bureau of Land Management. 1995a. Coos Bay District record of decision and resource management plan and associated environmental impact statement, Volumes I, II, & III, North Bend, OR.

US Department of Interior, Bureau of Land Management. 1995b. Coos Bay Shorelands final management plan. Coos Bay District, North Bend, OR. 26 pp.

US Department of Interior, Bureau of Land Management. 2000. Biological assessment for the management of federal lands on the North Spit of Coos Bay during the 2000-2001 Western snowy plover nesting and wintering seasons. Coos Bay District, North Bend, OR. 36 pp.

US Department of Interior, Bureau of Land Management. 2001a. Bureau 6840 special status species manual. Release 6-121 (supersedes Release 6-116).

US Department of Interior, Bureau of Land Management. 2001b. National Management Strategy for Motorized Off-Highway Vehicle Use on Public Lands, Rel. 1-01.

US Department of Interior, Bureau of Land Management. 2003a. BLM's priorities for recreation and visitor services. BLM work plan fiscal years 2003-2007. Report on file, Coos Bay District, North Bend, OR.

US Department of Interior, Bureau of Land Management. 2003b. Sale of Special Forest Products within the Coos Bay District. Categorical exclusion review CX OR120-04-05. Coos Bay District, North Bend, OR. 4 pp.

US Department of Interior, Fish and Wildlife Service. 1980. Pages 39-44 *in* Important fish and wildlife habitats of Oregon: An inventory. US Fish and Wildlife Service, Oregon-Idaho Area Office, Boise, ID.

US Department of Interior, Fish and Wildlife Service. 1984. An overview of wetland functions. US Fish and Wildlife Service, Fort Collins, CO. 68 pp.

US Department of Interior, Fish and Wildlife Service. 1993. Final Rule. Endangered and threatened wildlife and plants: determination of threatened status for the Pacific coast population of the Western snowy plover. Federal Register 58(42):12864-12874.

US Department of Interior, Fish and Wildlife Service. 1999. Final Rule. Endangered and threatened wildlife and plants: designation of critical habitat for the Pacific coast population of the Western snowy plover. Federal Register 60(234):68507-68544.

US Department of Interior, Fish and Wildlife Service. 2000. Biological opinion for the management of federal lands on the North Spit of Coos Bay during the 2000-2001 Western snowy plover nesting and wintering seasons. Portland, OR. 22 pp.

US Department of Interior, Fish and Wildlife Service. 2003. Western snowy plover (*Charadrius alexandrinus nivosus*) pacific coast population draft recovery plan. Sacramento, CA. 492 pp.

Varoujean, D. H. 1985. Abundance and distribution of shorebirds, waterfowl, wading birds, gulls, and crows in Coos Bay, Oregon. Oregon Department of Fish and Wildlife Nongame Program Technical Report No. 85-2-01. Oregon Department of Fish and Wildlife Service, Portland, OR. 36 pp.

Wagner, D. 2000. Bryophytes of the Coos Bay District, USDI Bureau of Land Management, Southwestern Oregon. Unpublished report on file at the Coos Bay District, North Bend, OR. 28 pp. + 8 Tables.

Western Regional Climate Center. 2004. North Bend FAA Airport, Oregon (356073). [Online] Available http://www.wrcc.dri.edu.

Western Snowy Plover Working Team. 2004. Draft Western snowy plover outreach plan. Internal document on file, Coos Bay District Office, North Bend, OR.

Wilson-Jacobs, Ruth. 1983. Wildlife use of Coos Bay North Spit, Oregon. A report to the US Department of Defense, US Army Corps of Engineers, Portland District. Portland, OR. 67 pp.

Zenk, H. B. 1990. Siuslawans and Coosans. Pages 572-579 *In* Handbook of North American Indians, Vol. 7, Northwest Coast. US Government Printing Office, Washington, D.C.

Zika, P. F., B. Wilson, N. Otting, B. Newhouse, D. Lytjen, K. Kuykendall, and R. Brainerd. 1998. *Carex* (sedge) inventory of Coos Bay District, Bureau of Land Management. Cooperative Challenge Cost Share Project. Unpublished report on file at the Coos Bay District, North Bend, OR.

**Personal communications:**

Pappajohn, S. 2002. Personal Communication at Interagency Meeting, Salem, Oregon: Principal of GeoTrends-Hampton, Incorporated. August 27, 2002.

Pullen, R. 2004. Outdoor Recreation Planner, Bureau of Land Management, Coos Bay District, North Bend, OR.

Schab, R. 2004. RE: Coos Bay Shorelands update**.** ROB@cbnbh2o.com (18 May).

Souza, S. 2004. Spit Wells. Shannon@solcoast.com (15 July).

# Appendix 1. North Spit Plant List.

Preliminary nonvascular and vascular plant species list for the North Spit. Information drawn from Coos Bay District herbarium, staff survey lists, Stansell (1989), Wagner (2000), and Zika et al. (1998). Common names in parentheses, taxonomy as per USDA, NRC (2004), E = exotic or non-native, * = special status species, and # = Bureau tracking species.

**NONVASCULAR PLANTS**
(lichens, sac fungi, club fungi, liverworts, hornworts, and mosses)

KINGDOM FUNGI

CLASS ASCOMYCETES & DISCOMYCETES (Lichens)
**Bryoria pseudocapillaris* Brodo & D.Hawksw. (brown beard lichen)
**Bryoria spiralifera* Brodo & D.Hawksw. (horsehair)
*Cavernularia hultenii* Degel. (Hulten's pitted lichen)
**Erioderma sorediatum* D.J. Galloway & P.M. Jorg. (ncn)
**Heterodermia leucomelos* (L.) Poelt (shield lichen)
*Hypogymnia enteromorpha* (Aceh.) Nyl. (beaded bone lichen)
*Hypogymnia physodes* (L.) Nyl. (hooded bone lichen)
*Hypotrachyna sinuosa* (Sm.) Hale (ncn)
**Leioderma soridiatum* D.J. Galloway & P.M. Jorg. (ncn)
*Nephroma laevigatum* Ach. (seaside kidney lichen)
*Nephroma resupinatum* (L.) Ach. (kidney lichen)
*Parmelia hygrophila* Goward & Ahti (shield lichen)
*Parmelia sulcata* Hale (waxpaper lichen)
*Parmeliopsis hyperopta* (Ach.) Arnold (ncn)
*Parmotrema arnoldii* (Du Rietz) Hale (eyelash lichen)
*Peltigera membranacea* (Ach.) Nyl. (membranous felt lichen)
*Plastismatia glauca* (L.) Culb. & C.Culb. (ragbag)
*Platismatia herrei* (Imshaug) Culb.& C.Culb. (Herre's ragged lichen)
*Pseudocyphellaria anomala* Brodo & Ahti (specklebelly)
*#*Pseudocyphellaria perpetua* McCune & Miadlikowska (ncn)
*Ramalina farinacea* (L.) Ach. (farinose cartilage lichen)
*Ramalina menziesii* Taylor (fishnet lichen)
*Ramalina roesleri* (Hochst. *ex* Schaerer) Hue (ncn)
*Ramalina thraustai* (Ach.) Nyl. (ncn)
*Sphaerophorus globosus* (Hudson) (globe ball lichen)
*Tuckermannopsis chlorophylla* (Willd.) Vainio (ncn) [=*Cetraria chlorophylla*]
*Tuckermannopsis orbata* (Nyl.) Fink (ncn) [=*Cetraria orbata*]

CLASS ASCOMYCOTINA (Sac Fungi)
None known at this time

CLASS HYMENOMYCETES & GASTEROMYCETES (Club Fungi)
*Boletus edulis* Bull. ex Fr. (king bolete, cep, steinpilz, porcini)
*Clavaria purpurea* (purple fairy club)
*Cortinarius allutus* (Secr.) Fr. (ncn)
*Cortinarius brunneus* (ncn)
*Cortinarius californicus* (ncn)

DIVISION BRYOPHYTA

CLASS HEPATICOPSIDE (Liverworts)
Calypogeia azurea Stotler & Crotz (blue pouchwort)
*Cephalozia bicuspidata* (L.) Dum. (two-horned pincerwort)

*Cephalozia lunulifolia* (Dum.) Dum. (ncn)
*Cephaloziella divaricata* (Sm.) Schiffn. (ncn)
**Diplophyllum plicatum* Lindb. (giant folded leaf liverwort)
*Frullania nisquallensis* Sull. (hanging millipede liverwort)
*Geocalyx graveolens* (Schrad.) Nees (ncn)
*Lepidozia reptans* (L.) Dum. (little hands liverwort)
*Lophocolea cuspidata* (Nees) Limpr. (ncn)
*Lophocolea heterophylla* (Schrad.)Dum. (ncn)
*Porella navicularis* (Lehm. & Lindenb.) Pfieff. (tree ruffle liverwort)
*Radula complanata* (L.) Dum. (flat-leaved liverwort)
*Riccardia latifrons* (Lindb.) Lindb. (ncn)
*Scapania bolanderi* Aust. (yellow-ladle liverwort)

CLASS ANTHOCEROTOPSIDA (Hornworts)
None known at this time.

CLASS MUSCOPSIDA (Mosses)
*Aulacomnium androgynum* (Hedw.) Schwaegr. (lover's moss)
*Aulacomnium palustre* (Hedw.) Schwaegr. (ribbed bog moss or glow moss)
*Brachythecium rivulare* Schimp. in B.S.G. (ncn)
*Bryum capillare* Hedw. (ncn)
*Campylium polygamum* (Schimp. in B.S.G.) C. Jens. (ncn)
*Campylopus introflexus* (Hedw.) Brid. (ncn)
*Ceratodon purpureus* (Hedw.) Brid. (red roof moss)
*Claopodium crispifolium* (Hook.) Ren. &Card. (rough moss)
*Dichelyma falcatum* (Hedw.) Myr. (ncn)
*Dicranoweisia cirrata* (Hedw.) Lindb. ex Milde (curly thatch moss)
*Dicranum fuscescens* Turn. (curly Heron's-bill moss)
*Dicranum scoparium* Hedw. (broom moss
*Dicranum tauricum* Sapeh. (broken-leaf moss)
*Drepanocladus aduncus* (Hedw.)Warnst. (ncn)
*Drepanocladus sendtner* (Schimp.)Warnst. (ncn)
*Eurhynchium oreganum* (Sull.) Jaeg. (Oregon beaked moss)
*Eurhynchium praelongum* (Hedw.) Schimp. in B.S.G. (slender beaked moss*)*
*Homalothecium fulgescens* (Mitt. ex C. Muell.) Lawt. (yellow moss)
*Homalothecium pinnatifidum* (Sull. & Lesq.) Lawt. (ncn)
*Hylocomium splendens* (Hedw.) Schimp. in B.S.G. (stair step moss)
*Hypnum circinale* Hook. (coiled-leaf moss)
*Isothecium stoloniferum* Brid. (cat-tail moss)
*Neckera douglasii* Hook. (Douglas' neckera)
*Orthotrichum consimile* Mitt. (ncn)
*Orthotrichum lyellii* Hook. & Tayl. (Lyell's bristle moss)
*Plagiothecium undulatum* (Hedw.) Schimp. in B.S.G. (wavy-leaved cotton moss)
*Pohlia wahlenbergii* (Web. &Mohr)Andrews (ncn)
*Polytrichum juniperinum* Hedw. (juniper haircap moss)
*Polytrichum piliferum* Hedw. (awned haircap moss)
*Pseudotaxiphyllum elegans* (Brid.) Iwats. (small flat moss)
*Racomitrium elongatum* Ehrh. ex Frisv. (roadside rock moss)
*Rhizomnium glabrescens* (Kindb.)T. Kop. (fan moss)
*Tortula princes* De Not. (ncn)
*Trachybryum megaptilum* (Sull.) Schof. (ncn)
*Ulota phyllantha* Brid. (ncn)

**VASCULAR PLANTS**

FERNS AND FERN ALLIES

DENNSTAEDTIACEAE — BRACKEN FERN FAMILY
*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underwood (northern bracken fern)

DRYOPTERIDACEAE — WOOD FERN FAMILY
*Polystichum munitum* (Kaulfuss) K. Presl (pineland sword fern)

POLYPODIACEAE — POLYPODY FAMILY
*Polypodium scouleri* Hook. & Grev. (leathery polypody)

GYMNOSPERMS

CUPRESSACEAE — CYPRESS FAMILY
*Chamaecyparis lawsoniana* (A. Murray) Parl (Port-Orford-cedar)

PINACEAE — PINE FAMILY
*Pinus contorta* Dougl. ex Loud. var. *contorta* (shore pine)
*Pinus attenuata* Lemmon (knob-cone pine)
*Picea sitchensis* (Bong.) Carr. (Sitka spruce)
*Pseudotsuga menziesii* (Mirbel.) Franco var. *menziesii* (Douglas-fir)

DICOTYLEDONS

APIACEAE — CARROT FAMILY
*Angelica lucida* L. (seacoast angelica)
*Glehnia littoralis* F. Schmidt ex Miq. (American silvertop)
*Lilaeopsis occidentalis* Coult. & Rose (western grasswort)

ARALIACEAE — GINSENG FAMILY
*Hedera helix* L. (English-ivy) E

ASTERACEAE — ASTER FAMILY
*Achillea millefolium* L. (common yarrow)
*Ambrosia chamissonis* (Less.) Greene (silver burr-ragweed) E
*Anaphalis margaritacea* (L.) Benth. (pearly-everlasting)
*Artemisia pycnocephala* (Less.) DC. (beach wormwood)
*Baccharis pilularis* DC. (coyotebrush)
*Cirsium arvense* (L.) Scop. (Canadian thistle) E
*Corethrogyne californica* var. *obovata* DC. var. *obovata* (Benth.) Kuntze (California sandaster)
*Erechtites glomerata* (Desf. ex Poir.) DC. (cut-leaf burnweed) [=*E. arguta*]
*Erechtites minima* (Poir.) DC. (coastal burnweed) E
*Gamochaeta purpurea* (L.) Cabrera (spoon-leaf purple everlasting) [=*Gnaphalium chilense*]
*Grindelia stricta* DC. (Oregon gumweed)
*Hieracium albiflorum* Hook. (white-flower hawkweed)
*Hypochaeris radicata* L. (hairy cat's-ear) E
*Jaumea carnosa* (Less.) Gray (marsh jaumea)
*Leontodon taraxacoides* (Vill.) Mérat ssp. *taraxacoides* (lesser hawkbit) [=*L. leysseri*] E
*Pseudognaphalium stramineum* (Kunth) A. Anderb. (cotton-batting-plant) [=*Gnaphalium purpureum*]
*Sonchus* L. (sow-thistle) E
*Symphyotrichum chilense* (Nees) Nesom (Pacific American-aster) [=*Aster chilense*]
*Tanacetum camphoratum* Less. (camphor tansy) E

BETULACEAE — BIRCH FAMILY
*Alnus rubra* Bong. (red alder)

BRASSICACEAE — MUSTARD FAMILY
*Brassica rapa* L. var. *rapa* (rape) E
*Cakile edentula* (Bigelow) Hook. (American searocket)
*Cakile maritima* Scop. (European searocket) E
*Cardamine nuttallii* Greene var. *nuttallii* (Nuttall’s toothwort)
*Draba verna* L. (spring whitlow-grass)
*Raphanus sativus* L. (radish) E

CAPRIFOLIACEAE — HONEYSUCKLE FAMILY
*Lonicera involucrata* (Richards.) Banks ex Spreng. (four-line honeysuckle)
*Sambucus nigra* L. ssp. *caerulea* (Raf.) R. Bolli (black elder)

CARYOPHYLLACEAE — PINK FAMILY
*Cardionema ramosissimum* (Weinm.) A. Nels. & J.F. Macbr. (sandcarpet)
*Cerastium arvense* L. (field mouse-ear chickweed) E
*Honckenya peploides* (L.) Ehrh. (seaside sandplant)
*Spergularia canadensis* (Pers.) G. Don (Canadian sandspurry)
*Spergularia macrotheca* (Hornem.) Heynh. (sticky sandspurry)
*Spergularia salina* J. & K. Presl (saltmarsh sandspurry) [=*S. marina*]

CHENOPODIACEAE — GOOSEFOOT FAMILY
*Atriplex patula* L. (halberd-leaf orache)
*Atriplex prostrata* Bouchér ex DC. (hastate orache) [=*A. hastata*]
*Salicornia depressa* Standl. (woody saltwort) [=*S. virginica*]

CONVOLVULACEAE — MORNING-GLORY FAMILY
*Calystegia soldanella* (L.) R. Br. (seashore false bindweed)

CUSCUTACEAE — DODDER FAMILY
*Cuscuta salina* Engelm. var. *major* (Yuncker goldenthread)

ERICACEAE — HEATH FAMILY
*Arbutus menziesii* Pursh (Pacific madrone)
*Arctostaphylos columbiana* Piper (bristly manzanita) [includes *A. tracyi*]
*Arctostaphylos uva-ursi* (L.) Spreng. (red bearberry)
*Gaultheria shallon* Pursh (salal)
*Vaccinium ovatum* Pursh (evergreen blueberry)
*Vaccinium oxycoccos* L. (small cranberry)
*Vaccinium uliginosum* L. (alpine blueberry)

FABACEAE — PEA FAMILY
*Cytisus scoparius* (L.) Link (Scotch broom) E
Genista monspessulana (L.) L. Johnson (French broom) E
*Lathyrus japonicus* Willd. (sea vetchling)
*Lotus corniculatus* L. (garden bird’s-foot-trefoil)
*Lotus unifoliolatus* (Hook.) Benth. (American bird’s-foot-trefoil)
*Lupinus littoralis* Dougl. (Chinook lupine)
*Medicago lupulina* L. (black medick)
*Melilotus officinalis* (L.) Lam. (yellow sweet-clover) [=*M. alba*]
*Trifolium arvense* L. (rabbit-foot clover)
*Trifolium pratense* L. (red clover)
*Trifolium repens* L. (white clover) E
*Trifolium wormskioldii* Lehm. (cow clover)
*Ulex europaeus* L. (common gorse) E

*Veronica scutellata* L. (grass-leaf speedwell)
*Vicia americana* Muhl. ex Willd. (American purple vetch)
*Vicia hirsuta* (L.) S.F. Gray (tiny vetch)

GENTIANACEAE — GENTIAN FAMILY
*Centaurium erythraea* Rafn (European centaury) E
*Gentiana sceptrum* Griseb. (king's-scepter gentian)

GERANIACEAE — GERANIUM FAMILY
*Geranium* sp. L. (crane's-bill) E

GROSSULARIACEAE — CURRANT FAMILY
*Ribes sanguineum* Pursh (blood currant)

MYRICACEAE — BAYBERRY FAMILY
*Morella californica* (Cham.) Wilbur (Pacific bayberry) [=*Myrica californica*]

NYCTAGINACEAE — FOUR-O'CLOCK FAMILY
**Abronia latifolia* Eschsch. (yellow sandverbena)
*#*Abronia umbellata* Lam. ssp. *breviflora* (Standl.) Munz (pink sandverbena)

ONAGRACEAE — EVENING-PRIMROSE FAMILY
*Camissonia cheiranthifolia* (Hornem. ex Spreng.) Raimann (beach suncup)
*Epilobium ciliatum* Raf. (fringed willowherb) [=*E. franciscanum*]
*Ludwigia peploides* (Kunth) Raven (floating primrose-willow)

PLANTAGINACEAE — PLANTAIN FAMILY
*Plantago maritima* L. var. *juncoides* (Lam.) Gray (goosetongue)

PLUMBAGINACEAE — LEADWORT FAMILY
**Limonium californicum* (Boiss.) Heller (western marsh-rosemary)

POLYGONACEAE — BUCKWHEAT FAMILY
*Polygonum paronychia* Cham. & Schlecht. (beach knotweed)
*Rumex acetosella* L. (common sheep sorrel) E
*Rumex* sp. L. (dock, sorrel)

PORTULACACEAE — PURSLANE FAMILY
*Claytonia perfoliata* Donn ex Willd. ssp. *perfoliata* (miner's-lettuce) [=*Montia perfoliata*]

PRIMULACEAE — PRIMROSE FAMILY
*Anagallis minima* (L.) Krause (chaffweed)
*Glaux maritima* L. (sea-milkwort)

RANUNCULACEAE — BUTTERCUP FAMILY
*Ranunculus flammula* L. var. *flammula* (greater creeping spearwort)

ROSACEAE — ROSE FAMILY
*Argentina egedii* (Wormsk.) Rydb. (Pacific silverweed) [=*Potentilla pacifica*]
*Fragaria chiloensis* (L.) P. Mill. (beach strawberry)
*Galium aparine* L. (sticky-willy)
*Malus fusca* (Raf.) Schneid. (Oregon crabapple)
*Rubus armeniacus* Focke (Himalayan blackberry) [=*R. procerus, R. discolor*] E
*Rubus spectabilis* Pursh (salmon raspberry)
*Rubus ursinus* Cham. & Schlecht. (California dewberry)

SALICACEAE — WILLOW FAMILY
*Salix hookeriana* Barratt ex Hook. (coastal willow)

VIOLACEAE — Violet Family
*Viola* spp. (ndentification pending)

SCROPHULARIACEAE — FIGWORT FAMILY
*Castilleja ambigua* Hook. & Arn. ssp. *ambigua* (johnnynip) [=*Orthocarpus castillejoides*]
**Cordylanthus maritimus* ssp. *palustris* (Behr) Chuang & Heckard (Point Reyes bird's-beak)
*Nuttallanthus texanus* (Scheele) D.A. Sutton (Texas toadflax)
*Parentucellia viscosa* (L.) Caruel (yellow glandweed) E

<u>MONOCOTYLEDONS</u>

CYPERACEAE — SEDGE FAMILY
*Carex lenticularis* Michx. var. *limnophila* (Holm) Cronq. (lakeshore sedge)
*Carex lyngbyei* Hornem. (Lyngbye's sedge)
*Carex obnupta* Bailey (slough sedge)
*Carex pansa* Bailey (sand-dune sedge)
*Carex unilateralis* Mackenzie (one-sided sedge)
*Carex viridula* Michx. ssp. *viridula* (little green sedge)
*Eleocharis macrostachya* Britt. (pale spike-rush)
*Eleocharis obtusa* (Willd.) J.A. Schultes (blunt spike-rush)
*Eleocharis palustris* (L.) Roemer & J.A. Schultes (common spike-rush)
*Schoenoplectus americanus* (Pers.) Volk. ex Schinz & R. Keller (chairmaker's club-rush)
[=*Scirpus americanus*]
*Schoenoplectus maritimus* (L.) Lye (saltmarsh club-rush)

IRIDACEAE — IRIS FAMILY
*Sisyrinchium californicum* (Ker-Gawl.) Ait. (golden blue-eyed-grass)

JUNCACEAE  RUSH FAMILY
*Juncus effusus* L. (lamp rush)
*Juncus falcatus* E. Mey. (sickle-leaf rush)
*Juncus gerardii* Loisel. (saltmarsh rush)
*Juncus lesueurii* Boland. (salt rush)

JUNCAGINACEAE — ARROW-GRASS FAMILY
*Triglochin concinna* Burtt-Davy (slender arrow-grass)
*Triglochin maritima* L. (seaside arrow-grass)
*Triglochin striata* Ruiz & Pavón (three-rib arrow-grass)

LILIACEAE -- LILY FAMILY
*Lilium columbianum* hort. ex Baker (Columbian lily)

ORCHIDACEAE — Orchid Family
*Goodyera oblongifolia* Raf. (green-leaf rattlesnake-plantain)
*Listera* sp. R. Br. ex Ait. f. (twayblade)
*Spiranthes romanzoffiana* Cham. (hooded ladies'-tresses)

POACEAE — GRASS FAMILY
*Agrostis stolonifera* L. (spreading bent) E
*Aira praecox* L. (early silver-hair grass)
*Ammophila arenaria* (L.) Link (European beach grass) E
*Bromus hordeaceus* L. (soft brome) E
*Bromus tectorum* L. (cheat grass) E
*Cynosurus echinatus* L. (bristly dog's-tail grass) E

*Dactylis glomerata* L. (orchard grass) E
*Distichlis spicata* (L.) Greene (coastal salt grass)
*Festuca idahoensis* Elmer (bluebunch fescue)
*Festuca rubra* L. (red fescue)
*Holcus lanatus* L. (common velvet grass) E
*Hordeum brachyantherum* Nevski (meadow barley)
*Hordeum jubatum* L. (fox-tail barley)
*Leymus mollis* (Trin.) Pilger (American lyme grass)
*Parapholis incurva* (L.) C.E. Hubbard (curved sickle grass)
*Poa confinis* Vasey (coastline blue crass)
*Puccinellia nuttalliana* (J.A. Schultes) A.S. Hitchc. (Nuttall's alkali grass)
**#Puccinellia pumila* (Vasey) A.S. Hitchc. (dwarf alkali grass)

# Appendix 2. North Spit Wildlife List.

Wildlife inventories are incomplete for the North Spit. Information on birds was drawn from staff observations and detailed data on the birds of Coos County (Contreras 1998). Information on other wildlife species is based on habitat associations, BLM files, and documented observations. Questions marks refer to information that is speculative.

**BIRDS**
**Legend**

Status:

**B**- breeding species
**M**- migrant (usually May/June and August-October)
**MS**- spring migrant only (usually May-June)
**MF**- fall migrant only (usually August-October)
**PB**- post breeding migrant (typically appearing in summer/fall)
**W-** wintering species (normally Oct/Nov- April/May)
**Y**- Year-round resident
**O**- offshore species occasionally seen from land
**S**- over-summering nonbreeder (typically, a few birds seen most years into summer)

Abundance:

**C-** common to abundant, easily observed in appropriate habitat.
**FC**- fairly common, usually observed in appropriate habitat.
**U**- uncommon, not always observed in appropriate habitat.
**R**- rare, not seen every year.
**V**- vagrant, very rare species with few records.
**I**- irregular, numbers fluctuate year-to-year.
**D**- dead specimen found on beach.

**Bolded** species are probable breeders.

SWANS/GEESE/DUCKS (Family Anatidae)

Tundra Swan (*Cygnus columbianus)* **W-U**
Greater White-fronted Goose (*Anser albifrons)* **MF-U, MS-R**
Snow Goose (*Chen caerulescens*) **M-R**
**Canada Goose** (*Branta Canadensis)* **Y-C**
Canada Goose (Aleutian subspecies, *Branta canadensis ssp. leucopareia)* **M-U**
Emperor Goose (*Chen canagica*) **V**
Brant *(Branta bernicula*) **MS-C, W-U, MF-U, OS-R**
**Wood Duck** *(Aix sponsa)* **Y-U**
American Wigeon *(Anas americana)* **W-C**
Eurasian Wigeon (*Anas penelope)* **W-U**
Green-winged Teal *(Anas crecca)* **W-C, OS-R**
**Mallard** *(Anas platyrhynchos*) **Y-C**
Gadwall *(Anas strepera*) **W-U, OS-R**
**Northern Shoveler** (*Anas clypeata)* **W-FC, B-R**
Northern Pintail *(Anas acuta*) **W-C, OS-R**
Cinnamon Teal *(Anas cyanoptera)* **M-U**
Blue-winged Teal (*Anas discors)* **MS-U, MF-R**
Canvasback (*Aythya valisineria )* **W-C, OS-R**
Redhead *(Aythya Americana)* **M-U, W-I**
**Ring-necked Duck** (*Aythya collaris)* **Y-C, B-R**

Greater Scaup *(Aythya marila)* **W-C, OS-U**
Lesser Scaup *(Aythya affinis*) **W-U, OS-R**
Steller's Eider (*Polysticta stelleri*) **V**
Harlequin Duck (*Histrionicus histrionicus*) **W-U**
Long-tailed Duck (*Clangula hyemalis)* **W-U**
Black Scoter *(Melanitta nigra)* **W-U**
Surf Scoter *(Melanitta perspicillata)* **W-C**
White-winged Scoter *(Melanitta fusca)* **W-U**
Common Goldeneye (*Bucephala clangula*) **W-C**
Barrow's Goldeneye (*Bucephala islandica*) **W-R**
Bufflehead *(Bucephala albeola)* **W-C, OS-R**
Red-breasted Merganser *(Mergus serrator)* **W-C**
Hooded Merganser (*Lophodytes cucullatus)* **W-U**
**Ruddy Duck** (*Oxyura jamaicensis)* **W-C, B-R**

PHEASANT (Family Phasianidae)

**Ring-necked Pheasant** *(Phasianus colchicus*) **Y-U**

QUAIL (Family Odontophoridae)

California Quail *(Callipepla californica*) **Y-R?**

LOONS (Family Gaviidae)

Common Loon *(Gavia immer*) **W-C, OS-U**
Pacific Loon *(Gavia pacifica*) **W-FC**
Red-throated Loon *(Gavia stellata*) **W-FC**
Yellow-billed Loon (*Gavia adamsii)* **V**

GREBES (Family Podicipedidae)

**Pied-billed Grebe** (*Podilymbus podiceps)* **Y-U**
Red-necked Grebe (*Podiceps grisegena)* **W-FC**
Horned Grebe (*Podiceps auritus )***W-C**
Eared Grebe (*Podiceps nigricollis)* **W-U**
Western Grebe (*Aechmophorus occidentalis)* **W-C, OS-R**
Clark's Grebe (*Aechmophorus clarkii)* **W-U**

SHEARWATERS (Family Procellariidae)

Northern Fulmar (*Fulmarus glacialis)* **O: MF-U, W-U**
Murphy's Petrel (*Pterodroma ultima*) **D**
Sooty Shearwater (*Puffinus griseus )* **O: MF-C, W-R**

STORM-PETRELS (Family Hydrobatidae)

Fork-tailed Storm-Petrel (*Oceanodroma furcata*) **O: M-R, W-R**
Leach's Storm-Petrel (*Oceanodroma leucorhoa*) **V**

PELICANS (Family Pelecanidae)

Brown Pelican (*Pelecanus occidentalis)* **PB-C**
American White Pelican (*Pelecanus erythrorhynchos)* **V**

CORMORANTS (Family Phalacrocoracidae)

**Double-crested Cormorant** (*Phalacrocorax auritus)* **Y-C**
Pelagic Cormorant (*Phalacrocorax pelagicus)* **Y-C**
Brandt's Cormorant (*Phalacrocorax penicillatus)* **Y-U**

HERONS (Family Ardeidae)

**American Bittern** (*Botaurus lentiginosus)* **B-U, W-R**
**Great Blue Heron** *(Ardea herodias)* **Y-C**
**Great Egret** *(Casmerodius albus)* **Y-C**
Snowy Egret (*Egretta thula*) **W-R**
Cattle Egret (*Bubulcus ibis*) **V**
**Green Heron** (*Butorides virescens*) **B-U**
Black-crowned Night-Heron (*Nycticorax nycticorax*) **M-R**

IBIS (Family Threskiornithidae)

White-faced Ibis (*Plegadis chihi*) **V**

VULTURES (Family Cathartidae)

**Turkey Vulture** *(Cathartes aura)* **B-C**

KITES/HAWKS/EAGLES (Family Accipitridae)

**Osprey** *(Pandion haliaetus*) **B-C, W-R**
**White-tailed Kite** *(Elanus caeruleus)* **W-C, B-R?**
Bald Eagle *(Haliaeetus leucocephalus*) **Y-U**
**Northern Harrier** *(Circus cyaneus*) **W-C, B-R**
**Sharp-shinned Hawk** *(Accipiter striatus*) **Y-U, B-R?**
**Cooper's Hawk** *(Accipiter cooperii*) **Y-U, B-R?**
**Red-tailed Hawk** *(Buteo jamaicensis*) **Y-FC**
Rough-legged Hawk (*Buteo lagopus*) **MF-R, W-I**
**Red-shouldered Hawk** (*Buteo lineatus*) **W-FC, B-R?**

FALCONS (Family Falconidae)

American Kestrel (*Falco sparverius*) **M-U**
Merlin *(Falco columbarius*) **W-U**
Peregrine Falcon *(Falco peregrinus*) **Y-U**
Prairie Falcon (*Falco mexicanus*) **V**
Gyrfalcon (*Falco rusticolus* ) **V**

RAILS/COOTS (Family Rallidae)

**Virginia Rail** *(Rallus limicola*) **Y-U**
**Sora** *(Porzana carolina*) **B-U, W-R**
American Coot *(Fulica americana*) **W-FC**

PLOVERS (Family Charadriidae)

Black-bellied Plover *(Pluvialis squatarola*) **W-U, M-FC**
Pacific Golden-plover (*Pluvialis fulva)* **MF-U, MS-R**
American Golden-plover (*Pluvialis dominica)* **MF-U, MS-R**
**Semipalmated Plover** *(Charadrius semipalmatus*) **Y-FC, B-R**
**Snowy Plover** (*Charadrius alexandrinus)* **Y-U**
**Killdeer** *(Charadrius vociferus*) **Y-C**

OYSTERCATCHER (Family Haematopodidae)

Black Oystercatcher (*Haematopus bachmani)* **W-U**

STILTS/AVOCETS (Family Recurvirostridae)

Black-necked Stilt (*Himantopus mexicanus)* **V**
American Avocet (*Recurvirostra americana)* **M-R**

SANDPIPERS (Family Scolopacidae)

Greater Yellowlegs *(Tringa melanoleuca*) **M-C, W-U**
Lesser Yellowlegs *(Tringa flavipes*) **M-U**
Wandering Tattler (*Heteroscelus incanus*) **M-U**
**Spotted Sandpiper** *(Actitus macularia*) **B-U, W-R**
Solitary Sandpiper (*Tringa solitaria*) **M-R**
Willet (*Catoptrophorus semipalmatus)* **M-U**
Whimbrel *(Numenius phaeopus*) **M-C**
Long-billed Curlew (*Numenius americanus)* **M-U**
Marbled Godwit (*Limosa fedoa)* **M-U, W-R**
Ruddy Turnstone (*Arenaria inter)* **M-U**
Black Turnstone *(Arenaria interpres*) **M-FC**, **W-FC**
Sanderling (*Calidris alba)* **W-C, OS-R**
Surfbird **(***Aphriza virgata***)** **W-U**
Red Knot (*Calidris canutus)* **M-U**
Semipalmated Sandpiper (*Calidris pusilla)* **MF-U, MS-R**
Red-necked Stint (*Calidris ruficollis*) **V**
Little Stint (*Calidris minuta*) **V**
Western Sandpiper *(Calidris mauri*) **M-C, W-U, OS-R**
Least Sandpiper *(Calidris minutilla*) **M-C, W-U, OS-R**
Baird's Sandpiper (*Calidris bairdii)* **MF-U, MS-R**
Pectoral Sandpiper (*Calidris melanotos)* **M-FC, MS-R**
Rock Sandpiper (*Calidris ptilocnemis*) **W-U**
Dunlin *(Calidris alpina*) **M-C, W-U**
Curlew Sandpiper (*Calidris ferruginea*) **V**
Stilt Sandpiper (*Calidris himantopus)* **MF-R**
Buff-breasted Sandpiper (*Tryngites subruficollis)* **MF-U**
Ruff (*Philomachus pugnax)* **MF-R**
Upland Sandpiper (*Bartramia longicauda)* **V**
Short-billed Dowitcher *(Limnodromus griseus*) **M-C, OS-R**
Long-billed Dowitcher *(Limnodromus scolopaceus*) **M-C, W-U, OS-R**
Wilson's Snipe *(Gallinago delicata*) **W-FC**
**Wilson's Phalarope** (*Phalaropus tricolor*) **M-R, B-R**
Red-necked Phalarope *(Phalaropus lobatus*) **M-U**
Red Phalarope (*Phalaropus fulicaria)* **O: M-U, W-I**

GULLS/TERNS (Family Laridae)

Pomarine Jaeger (*Stercorarius pomarinus*) **O: M-R**
Parasitic Jaeger (*Stercorarius parasiticus*) **O: M-R**
Franklin's Gull (*Larus pipixcan*) **M-R**
Bonaparte's Gull *(Larus philadelphia*) **M-U, W-I**
Little Gull (*Larus minutus*) **V**
Heermann's Gull (*Larus heermanni*) **PB-FC**
California Gull *(Larus californicus*) **W-C, PB-C, OS-U**
**Western Gull** *(Larus occidentalis*) **Y-C**
Glaucous-winged Gull *(Larus glaucescens*) **W-C**

Glaucous Gull (*Larus hyperboreus)* **W-R**
Herring Gull (*Larus argentatus*) **W-U**
Thayer's Gull (*Larus thayeri)* **W-U**
Mew Gull (*Larus canus)* **W-C**
Ring-billed Gull (*Larus delawarensis)* **W-C, OS-U**
Black-legged Kittiwake (*Rissa tridactyla)* **O: W-FC**
Red-legged Kittiwake (*Rissa brevirostris*) **V, D**
Sabine's Gull (*Xema sabini*) **O: M-R**
Elegant Tern (*Sterna elegans)* **PB-I**
Caspian Tern *(Sterna caspia)* **M-C, OS-U**
Common Tern (*Sterna hirundo*) **M-R**

AUKS (Family Alcidae)

Common Murre *(Uria aalge*) **Y-C**
**Pigeon Guillemot** (*Cepphus columba)* **B-C, W-R**
Marbled Murrelet *(Brachyramphus marmoratus*) **O: Y-U**
Rhinoceros Auklet (*Cerorhinca monocerata)* **Y-R**
Cassin's Auklet (*Ptychoramphus aleuticus*) **O: M-R**
Xantus' Murrelet (*Synthliboramphus hypoleucus*) **D**
Ancient Murrelet (*Synthliboramphus antiquus*) **O: W-R**
Tufted Puffin (*Fratercula cirrhata*) **O: M-R**
Horned Puffin (*Fratercula corniculata*) **D**

PIGEONS/DOVES (Family Columbidae)

**Rock Pigeon** (*Columba livia*) **Y-C**
**Band-tailed Pigeon** *(Columba fasciata*) **M-U, B-R?**
**Mourning Dove** *(Zenaida macroura*) **B-C, W-R**

OWLS (Family Strigidae)

**Great-horned Owl** *(Bubo virginianus*) **Y-U, B-U**
Snowy Owl (*Bubo scandiaca*) **V**
Short-eared Owl (*Asio flammeus*) **MF-R, W-R**
Western Screech-Owl (*Otus kennicottii)* **Y-R?**
Burrowing Owl (*Athene cunicularia*) **M-R**, **W-R**

NIGHTJARS (Family Caprimulgidae)

**Common Nighthawk** *(Chordeiles minor*) **M-U, B-R?**

SWIFTS (Family Apodidae)

Black Swift (*Cypseloides niger*) **MS-U**
**Vaux's Swift** (*Chaetura vauxi*) **M-FC, B-R?**

HUMMINGBIRDS (Family Trochilidae)

**Anna's Hummingbird** *(Calypte anna*) **Y-U**
**Rufous Hummingbird** *(Selasphorus rufus*) **B-C**

KINGFISHER (Family Alcedinidae)

**Belted Kingfisher** *(Ceryle alcyon)* **Y-C**

<u>WOODPECKERS</u> (Family Picidae)

**Northern Flicker** *(Colaptes auratus)* **Y-C**
**Downy Woodpecker** *(Picoides pubescens*) **Y-U**
**Hairy Woodpecker** *(Picoides villosus*) **Y-U**
**Pileated Woodpecker** *(Dryocopus pileatus)* **Y-U**
Red-breasted Sapsucker (Sphyrapicus ruber) **Y-R, B?**

<u>FLYCATCHERS</u> (Family Trannidae)

**Olive-sided Flycatcher** *(Contopus borealis*) **B-U**
**Western Wood-Pewee** *(Contopus sordidulus*) **M-FC**, **B-U**
Willow Flycatcher (*Empidonax traillii*) **M-U**
Hammond's Flycatcher (*Empidonax hammondii*) **M-R**
Dusky Flycatcher (*Empidonax oberholseri*) **M-R**
**Pacific Slope Flycatcher** *(Empidonax difficilis*) **B-C**
**Black Phoebe** *(Sayornis nigricans*) **W-C, B-U**
Say's Phoebe (*Sayornis saya*) **M-R**
Ash-throated Flycatcher (*Myiarchus cinerascens*) **M-R**
Tropical Kingbird (*Tyrannus melancholicus*) **PB-R**
Western Kingbird (*Tyrannus verti*) **M-R**
Scissor-tailed Flycatcher (*Tyrannus forficatus*) **V**

<u>SHRIKES</u> (Family Lannidae)

Northern Shrike (*Lanius excubitor)* **W-U**
Loggerhead Shrike (*Lanius ludovicianus*) **V**

<u>VIREOS</u> (Family Vireonidae)

**Hutton's Vireo** *(Vireo huttoni*) **Y-U**
**Warbling Vireo** *(Vireo gilvus*) **M, B-R**
Cassin's Vireo (*Vireo cassinii)* **M-R**

<u>JAYS/CROWS/RAVENS</u> (Family Corvidae)

**Steller's Jay** *(Cyanocitta stelleri*) **Y-C**
Western Scrub-Jay (*Aphelocoma californica*) **M-R**
**American Crow** *(Corvus brachyrhynchos*) **Y-C**
**Common Raven** *(Corvus corax)* **Y-C**

<u>HORNED LARKS</u> (Family Alaudidae)

Streaked Horned Lark (*Eremophila alpestris strigata)* **M-U, W-R**

<u>SWALLOWS</u> (Family Hirundinidae)

**Tree Swallow** *(Tachycineta bicolor*) **B-C, W-R**
**Violet-green Swallow** *(Tachycineta thalassina*) **B-U**
**Purple Martin** *(Progne subis*) **B-U**
**Northern Rough-winged Swallow** *(Stelgidopteryx serripennis*) **B-U**
**Barn Swallow** *(Hirundo rustica*) **B-FC**
**Cliff Swallow** *(Hirundo pyrrhonota)* **B-C**
Bank Swallow *(Riparia riparia)* **M-R**

<u>CHICKADEES</u> (Family Paridae)

**Black-capped Chickadee** *(Parus atricapillus*) **Y-C**
**Chestnut-backed Chickadee** *(Parus rufescens*) **Y-C**

BUSHTITS (Family Aegithalidae)

**Bushtit** *(Psaltriparus minimus*) **Y-U**

NUTHATCHES (Family Sittidae)

**Red-breasted Nuthatch** *(Sitta canadensis*) **B-U, W-I**
White-breasted Nuthatch (*Sitta carolinensis*) **V**

CREEPERS (Family Certhiidae)

**Brown Creeper** *(Certhia americana*) **W-U, B-R**

WRENS (Family Troglodytidae)

**Marsh Wren** *(Cistothorus palustris*) **Y-C**
**Bewick's Wren** *(Thryomanes bewickii)* **Y-FC**
**Winter Wren** (*Troglodytes troglodytes*) **W-C, B-U**
House Wren *(Troglodytes aedon*) **M-R**
Rock Wren (*Salpinctes obsoletus*) **V**
Sedge Wren (Cistothorus platensis) **V**

KINGLETS (Family Regulidae)

Ruby-crowned Kinglet *(Regulus calendula)* **W-C**
**Golden-crowned Kinglet** *(Regulus satrapa*) **Y-C**

GNATCATCHERS (Family Sylviidae)

Blue-gray Gnatcatcher (*Polioptila caerulea*) **V**

THRUSHES (Family Turdidae)

Western Bluebird (Sialia mexicana) **M-R, W-R**
Mountain Bluebird (*Sialia currucoides*) **V**
Varied Thrush *(Ixoreus naevius*) **W-C**
**Swainson's Thrush** (*Catharus ustulatus*) **B-C**
Hermit Thrush *(Catharus guttatus*) **W-FC**
**American Robin** *(Turdus migratorius*) **Y-C**

WRENTIT (Family Timaliidae)

**Wrentit** *(Chamaea fasciata*) **Y-C**

MIMIC THRUSHES (Family Mimidae)

Northern Mockingbird *(Mimus polyglottus*) **Y-R**
Sage Thrasher (*Oreoscoptes montanus*) **V**

STARLINGS (Family Sturnidae)

**European Starling** (*Sturnus vulgaris*) **Y-C**

PIPITS (Family Motacillidae)
American Pipit *(Anthus rubescens)* **M-C, W-U**

<u>WAXWINGS</u> (Family Bombycillidae)

**Cedar Waxwing** *(Bombycilla cedrorum)* **B-U**

<u>WARBLERS</u> (Family Parulidae)

**Orange-crowned Warbler** *(Vermivora celata)* **B-C, W-R**
Nashville Warbler *(Vermivora ruficapilla)* **M-R**
Virginia's Warbler (*Vermivora virginiae*) **V**
Yellow Warbler *(Dendroica petechia)* **M-C**
**Yellow-rumped Warbler** *(Dendroica coronata)* **Y-C**
**Black-throated Gray Warbler** *(Dendroica nigrescens)* **B-FC**
Black-and-white Warbler (*Mniotilta varia*) **V**
MacGillivray's Warbler *(Oporornis tolmiei)* **M-R**
**Common Yellowthroat** *(Geothlypis trichas)* **M-C, B-FC, W-R**
**Wilson's Warbler** *(Wilsonia pusilla)* **B-R**
Hermit Warbler (*Dendroica occidentalis)* **M-R**
Townsend's Warbler *(Dendroica occidentalis)* **W-U**
Palm Warbler (*Dendroica palmarum)* **M-FC, W-R**

<u>TANAGERS</u> (Family Thraupidae)

**Western Tanager** *(Piranga ludoviciana)* **B-U**

<u>SPARROWS</u> (Family Emberizidae)

**Song Sparrow** *(Melospiza melodia)* **Y-C**
Lincoln's Sparrow (*Melospiza lincolnii)* **W-U**
**White-crowned Sparrow** *(Zonotrichia leucophrys)* **Y-C**
Golden-crowned Sparrow *(Zonotrichia atricapilla)* **W-FC**
White-throated Sparrow (*Zonotrichia albicollis*) **W-U**
Harris's Sparrow (*Zonotrichia querula*) **V**
Fox Sparrow (*Passerella iliaca*) **W-C**
**Dark-eyed Junco** (*Junco hyemalis*) **Y-C**
**Savannah Sparrow** *(Passerculus sandwichensis)* **B-C, W-U**
Chipping Sparrow *(Spizella passerina)* **M-R**
Clay-colored Sparrow (*Spizella pallida*) **M-R, W-R**
American Tree Sparrow (*Spizella arborea*) **V**
**Spotted Towhee** *(Pipilo maculatus)* **B-C, W-U**
Oregon Vesper Sparrow *(Pooecetes gramineus affinis)* **M-R, W-R**
Lapland Longspur (*Calcarius lapponicus)* **MF-U, MS-R, W-R**
Chestnut-collared Longspur (*Calcarius ornatus*) **V**
Snow Bunting (*Plectrophenax nivalis*) **V**

<u>GROSBEAKS/BUNTINGS</u> (Family Cardinalidae)

**Black-headed Grosbeak** *(Pheucticus melanocephalus)* **B-U?**
Lazuli Bunting *(Passerina amoena)* **M-R**

<u>BLACKBIRDS</u> (Family Icteridae)

Bobolink (*Dolichonyx oryzivorus*) **V**
**Red-winged Blackbird** *(Agelaius phoeniceus)* **Y-C**
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) **M-R**
**Brewer's Blackbird** (*Euphagus cyanocephalus*) **Y-R, B-R?**

**Brown-headed Cowbird** *(Molothrus ater*) **B-FC**
**Western Meadowlark** (Sturnella neglecta) **W-C, B-R?**

FINCHES (Family Fringillidae)

**Pine Siskin** *(Carduelis pinus*) **M-I, B-U?**
**American Goldfinch** *(Carduelis tristis*) **B-FC, W-R**
**Purple Finch** *(Carpodacus purpureus*) **B-C, W-R**
**House Finch** *(Carpodacus mexicanus*) **Y-C**
**Red Crossbill** (*Loxia curvirostra)* **Y-FC**
Evening Grosbeak *(Coccothraustes vespertinus)* **M-U?**

WEAVERS (Family Passeridae)

**House Sparrow** *(Passer domesticus*) **Y-R**

## Mammals[1]

OPOSSUMS (Family Didelphiidae)

Virginia Opossum (*Didelphis virginianus)*

SHREWS (Family Soricidae)

Vagrant Shrew (*Sorex vagrans)*
Trowbridge Shrew (*Sorex trowbridgii)*
Pacific Shrew (*Sorex pacificus*)
Pacific Water Shrew *(Sorex bendirii*)

MOLES (Talpidae)

Shrew Mole (*Neurotrichus gibbsii*)
Townsend's Mole (*Scapanus townsendii*)
Coast Mole (*Scapanus orarius*)

EVENING BATS (Family Vespertilionidae)

Little Brown Bat (*Myotis lucifugus*)
Long-eared Myotis (*Myotis evotis*)
Hoart Bay (*Lasiurus cinereus*)
Townsend's Big-eared Bat (*Corynorhinus townsendii*)
Long-legged Myotis (*Myotis volans*)
California Myotis (*Myotis californicus*)
Big Brown Bat (*Eptesicus fuscus*)
Yuma Myotis (*Myotis yumanensis*)
Silver-haired Bat (*Lasionycteris noctivagans*)

RABBITS (Family Leporidae)

Brush Rabbit (*Sylvilagus bachmani*)

SQUIRRELS (Family Sciuridae)

California Ground Squirrel (*Spermophilus beecheyi*)
Northern Flying Squirrel (*Glaucomys sabrinus*)

[1]Potential or documented occurences.

Townsend's Chipmunk (*Eutamias townsendi*)
Douglas' Squirrel (*Tamiasciurus douglasii*)

POCKET GOPHERS (Family Geomyidae)

Western Pocket Gopher (*Thomomys mazama*)

BEAVERS (Family Castoridae)

American Beaver (*Castor Canadensis*)

MICE/VOLES/MUSKRATS/RATS (Family Muridae)

Deer Mouse (*Peromyscus maniculatus*)
Long-tailed Vole (*Microtus longicaudus*)
Townsend's Vole (*Microtus townsendii*)
Creeping Vole (*Microtus oregoni*)
Western Red-backed Vole (*Clethrionomys californicus*)
Red Tree Vole (*Phenacomys longicaudus*)
Oregon or Creeping Vole (*Microtus oregoni*)
White-footed Vole (*Arborimus albipes*)
Bushy-tailed Woodrat (*Neotoma cinerea*)
Muskrat (*Ondatra zibethicus*)
Norway Rat (*Rattus norvegicus*)
Black Rat (*Rattus rattus*)
House Mouse (*Mus musculus*)

JUMPING MICE (Family Zapodidae)

Pacific Jumping Mouse (*Zapus trinotatus*)

PORCUPINES (Family Erethizontidae)

Porcupine (*Erethizon dorsatum*)

FOXES (Family Canidae)

Coyote (*Canis latrans*)
Gray Fox (*Vulpes velox*)

BEARS (Family Ursidae)

Black Bear (*Ursus americanus*)

RACCOONS (Family Procyonidae)

Raccoon (*Procyon lotor*)

WEASELS/SKUNKS/OTTER/MINK/MARTENS (Family Mustelidae)

Long-tailed Weasel (*Mustela frenata*)
Ermine (*Mustela erminea*)
Striped Skunk (*Mephitis mephitis*)
Spotted Skunk (*Spilogale gracilis*)
River Otter (*Lutra canadensis*)
Mink (*Mustela vison*)

American Marten (*Martes Americana*)
Fisher *(Martes pennanti)*

CATS (Family Felidae)

Mountain Lion (*Felis concolor*)
Bobcat (*Lynx rufus*)

DEER (Family Cervidae)

Black-tailed Deer (*Odocoileus hemionus columbians*)
Roosevelt Elk (*Cervise elaphus roosevelti*)

HAIR SEALS (Family Phocidae)

Harbor Seal (*Phoca vitulina*)

EARED SEALS (Family Otariidae)

Steller Sea Lion (*Eumetopias jubatus*)
California Sea lion (*Zalophus californianus*)

## Amphibians[1]

MOLE SALAMANDERS (Family Ambystomatidae)

Northwestern Salamander (*Ambystoma gracile*)
Pacific Giant Salamander (*Dicamptodon ensatus*)

LUNGLESS SALAMANDERS (Family Plethodontidae)

Clouded Salamander (*Aneides ferreus*)
Ensatina (*Ensatina eschscholtzi*)
Dunn's Salamander (*Plethodon dunni*)
Western Redback Salamander (*Plethodon vehiculum*)
California Slender Salamander (*Batrachoseps attenuatus*)

NEWTS (Family Salamandridae)

Roughskin Newt (*Taricha granulosa*)

TREE FROGS (Family Hylidae)

Pacific Treefrog (*Ascaphus regilla*)

TRUE FROGS (Family Ranidae)

Northern Red-legged Frog (*Rana aurora*)
Bullfrog (*Rana catesbeiana*)

## Reptiles[1]

SEA TURTLES (Family Dermochelyidae)

Leather-back Sea Turtle (*Dermochelys coriacea*)

[1]Potential or documented occurences.

WATER AND BOX TURTLES (Family Emydidae)

Northwestern Pond Turtle (*Clemmys marmorata*)

ALLIGATOR LIZARDS (Family Anguidae)

Northern Alligator Lizard (*Elgaria coerulea*)

IGUANIDS (Family Iguanidae)

Western Fence Lizard (*Sceloporus occidentalis*)
Northern Alligator Lizard (*Elgaria coerulea*)

BOAS (Family Bioidae)

Rubber Boa (*Charina bottae*)

COLUBRID SNAKES (Family Colubridae)

Northwestern Garter Snake (*Thamnophis ordinoides*)
Common Garter Snake (Thamnophis sirtalis)
Western Terrestrial Garter Snake (*Thamnophis elegans*)

# Appendix 3. Plan Conformance

## PLAN CONFORMANCE / NEPA COMPLIANCE RECORD
## North Spit Management Plan

Coos Bay District Office
Development of the North Spit Plan

The North Spit Management Plan is the ten year update to the 1995 Coos Bay Shorelands Management Plan (Shorelands Plan) and addresses the lands on the North Spit of Coos Bay under Buerau of Land Management jurisdiction. The North Spit of Coos Bay is a sandy, vegetated point of land separating the waters of Coos Bay from the Pacific Ocean. It is northwest of the communities of Coos Bay, North Bend, and Charleston in Coos County in southwestern Oregon. The BLM lands on the North Spit are all public domain lands, and provide habitat for several Special Status Species (SSS). BLM intends to conserve and improve when feasible, habitat for SSS on the North Spit, while preserving the recreational opportunities available.

**Plan Conformance Review**

The North Spit Plan incorporated the 1989 Draft Coos Bay Shorelands Management Plan, the 1994 Coos Bay Shorelands Draft Plan and Environmental Assessment, and the Final Coos Bay Shorelands Management Plan, signed September, 1995.

The North Spit is in compliance with the Coos Bay District Resource Management Plan (RMP) which was completed and signed in 1995.

Nancy Zepf 4-19-05
Nancy Zepf, ID Team Reviewer

**NEPA Review**

Existing Environmental Impact Statement (EIS) Review:
This plan is in conformance with the Coos Bay District Resource Management Plan and Environmental Impact Statement /Record of Decision, 1995.

The Draft Coos Bay Shorelands Plan Environmental Assessment No. EA120-93-07* is in conformance with the following existing decisions from the Coos Bay District Resource Management Plan (RMP)/ EIS Record of Decision (ROD).

1. The District RMP designated nearly half of the BLM lands on the Spit as an ACEC for outstanding values for wildlife, scenery, wetlands, SSS and recreation.
2. The District RMP designated motorized access on the Spit as "Motorized Access is Limited to designated roads and trails." The designated roads and trails have not changed.

3. The District RMP designated all the lands on the Spit as a Special Recreation Management Area due to the known popularity of the area and the challenges of managing for both recreation and SSS habitat.
4. The direct and indirect impacts of the North Spit Plan are less than those identified in the Shorelands Plan, due to land tenure adjustments (see * below).
5. There would be no additional cumulative impacts from the implementation of the North Spit Plan.
6. Public involvement that occurred during the development of the North Spit Plan occurred the same way as if a NEPA document was produced. No new issues were identified.

*The EA number was changed from EA No. OR126-93-07 (which is in the official draft plan booklet, to EA No. OR120-93-07. The change occurred due to the re-organization of the district in the early 1990's. OR126 referred to the Tioga Resource Area, which did not exist after the re-organization. OR 120 refers to the Coos Bay District. Many of the management actions proposed in the previous planning documents for the Spit included actions on lands the BLM identified as desirable to acquire through exchange. Three of the four proposed land exchanges have occurred, however, a key parcel used by the public for access, has not been acquired. Therefore, many of the management actions proposed for that parcel have been dropped in the updated North Spit Plan because they are not on BLM lands.

The North Spit Plan was written by an interdisciplinary team of BLM staff. Natural resource information was reviewed and updated. BLM management requirements for SSS and the designations in the RMP were further explained. There are no new public restrictions proposed, nor is there any surface-distrubing activity proposed. No new issues were identified. If BLM proposes surface disturbing projects, a new Environmental Analysis will be done. The basic goals and objectives from the District RMP, through the Shorelands drafts and final documents remain virtually the same: Allow recreational activities while conserving habitat for all species, with special attention on the SSS.

Steve Morris 4-19-05
Steve Morris, NEPA Reviewer

**Decision**

I have reviewed this Plan Conformance and NEPA Compliance Record and have determined that the North Spit Management Plan is in conformance with the approved land use plan and that no further environmental analysis is required. It is my decision to implement the plan as described.

M. Elaine Raper — 4/21/05

M. Elaine Raper
Umpqua Area Manager

Date

# Appendix 4. History of Land Tenure on the North Spit.

| | |
|---|---|
| 1857 | First survey of the North Spit. |
| 1878 | Beginning of numerous attempts to build a jetty on the east shore of the estuary. |
| 1882 | Cash entry patent to Sec. 24 Lot 4. |
| 1884 | Cash entry patent to Sec. 25 Lot 1. |
| 1887 | Sec. 25 Lot 2 Withdrawn to the Treasury Department for lifesaving purposes. The Life Saving Station was constructed and fully staffed by August 1891. The US later also acquired Sec. 24 Lot 4 and Sec. 25 Lot 1. |
| 1889 | The east shore was abandoned as a location of the jetty and planning began for construction on the North Spit. |
| 1889 | (June) Cash entry patent to Sec. 26 Lot 3. |
| 1889 | (November) All public domain land in T.25S., R13 & 14 W., withdrawn to the War Department for the Coos Bay Harbor. |
| 1890 | Congress appropriated money for the jetty construction. The Corps of Engineers began reclamation of the North Spit and jetty construction. |
| 1891 | The US acquired Section 26 Lot 3. |
| 1915 | Life Saving Station relocated to Coos Head because the location made it difficult to monitor the bar and quickly respond to accidents. US Navy assumed use of the old station on the North Spit. The Navy used the site as Radio Compass Station (on-shore facility for determining the direction of received radio signals) |
| 1947 | The Navy closed the Radio Compass Station on the North Spit and relocated to Coos Head. |
| 1950 | The Navy declared the old Radio Compass Station surplus. The withdrawn land (Sec. 25 Lot 2) was transferred to the Corps of Engineers. The parcels purchased in fee were disposed of by sale. |
| 1984 | The Corps of Engineers relinquished a portion of their withdrawal on the North Spit. BLM determined that it was suitable for return to the public domain and accepted jurisdiction. By accepting jurisdiction, BLM inherited numerous permits and leases issued by the COE. As these authorizations expired, they were replaced by FLPMA right of ways. |
| 1989 | A resurvey by BLM established that none of the buildings were on the land (sec. 24 Lot 4) purchased by Edward Altoffer in 1950. BLM demolished the buildings and removed the underground tanks. Attempts to purchase the land from Altoffer failed due to appraisal issues. Altoffer later sold the land to another party. |
| 1992 | BLM acquired a parcel in T.25S., R13 W., Sec. 8 for a boat ramp. |

1997 BLM acquired Sec. 25 Lot 1 and a 5-acre parcel located next to the BLM Boat Ramp in a land exchange with Weyerhaeuser. In the exchange, the Weyerhaeuser Company picked up the land encumbered by their effluent pond in T.25S., R13 W. The pond had been authorized under a lease by the COE.

2000 BLM acquired Sec. 24 Lot 4 by fee purchase.

2001 The Corps of Engineers relinquished the lands remaining under their withdrawal on the North Spit. BLM determined that it was suitable for return to the public domain and accepted jurisdiction.

# Appendix 5. Glossary

**Area of Critical Environmental Concern:** an area of BLM-administered lands where special management attention is needed to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources, or other natural systems or processes; or to protect life and provide safety from natural hazards (as defined in BLM Manual 8300).
**Biodiversity:** the full range of variety and variability within and among living organisms and the ecological complexes in which they occur.
**Breach**: term used in this plan to explain an opening in the foredune between Coos Bay and the Pacific Ocean, caused by floodwaters, ocean surf run-up, or by planned mechanical intervention.
**Cascadia seismic event:** a rupture of the interlocked North American Plate and the Juan de Fuca Plate along the subduction planes. The energy released is expected to generate an 8.8 magnitude earthquake.
**Cascadia subduction zone:** the generally north-south zone along the Northwest coast where the Juan de Fuca Plate is being over-ridden by the North American Plate.
**Community:** a group of plants and animals that occupy a given locale.
**Coniferous:** cone-bearing trees or shrubs; mostly evergreens such as pine, cedar, spruce, etc.
**Cubic foot per second (cfs):** a unit of measurement of the rate of water flow past a given point equal to one cubic foot in one second.
**Deflation plain:** area behind the foredune where wind has eroded the sand to the water table, forming a wet surface resistant to further erosion.
**Dune:** a hill of drifting sand formed by wind action.
**Ecosystem:** an assemblage of integrated organisms plus the local environment.
**Eolian:** (Aeolian) pertaining to the action or the effect of the wind, as in eolian sand dune deposits.
**Estuary:** the zone between the fresh water of a stream and the salt water of an ocean. An estuarine system extends upstream until ocean derived salt measures less than 0.5% during average annual flow. Estuaries are low energy systems and may include subtidal and intertidal areas with aquatic beds.
**Estuarine:** of, relating to, or found in an estuary.
**Exotic:** introduced species; not indigenous to a given area.
**Globally ranked plant community:** a prioritization system for determining global significance of plant communities. G1 communities are the most imperiled whereas G5 communities are widespread and secure.
**Good Friday Earthquake, 1964:** a tectonic event that originated in Alaska. The earthquake occurred on March 27, 1964, Good Friday and was a 9.2 magnitude, the second largest earthquake ever recorded. The earthquake triggered a tsunami that impacted Pacific coastlines including Oregon, California, Washington, and Alaska.
**Herbicide:** a chemical substance capable of killing or inhibiting plants.
**Interpretation:** a communication process that forges emotional and intellectual connections between the interests of the audience and the inherent meanings in the resource.
**Introduced species:** also referred to as exotic species, these are plants or animals occurring as a result of introduction or unnatural range expansion. These are species that did not occur before the arrival of European culture.
**Littoral cell:** segment of the shore or beach that is bound by headlands which extend sufficiently seaward to prevent along-shore transport of beach sediment, creating a relatively closed sediment system.
**Native:** a species indigenous to a given area; any species known to occur before the arrival of European culture or which has moved in through natural range extension.
**Non-vascular:** refers to the lichens, fungi, liverworts, hornworts, and mosses.
**Noxious weeds:** any plant designated by the Oregon State Weed Board that is injurious to public health, agriculture, recreation, wildlife, or any public or private property.
**Plant community:** a general term for an assemblage of plants growing together at a site which show a definite association or affinity to each other
**Precipitation ridge:** the leading landward edge of a dune field at the point of advancement of the dune.

**Riparian:** living on or adjacent to a water supply such as a riverbank, lake, or pond.
**Riverine:** relating to or resembling a river, in this case a coastal freshwater system.
**Special Recreation Management Area:** an area where a commitment has been made to provide specific recreation activity and experience opportunities. These areas usually require a high level of investment and/or management. They include recreation sites, but recreation sites alone do not constitute SRMAs (as defined in BLM Manual 8300).
**Special status species:** animals and plants considered being of conservation interest because of their rarity or vulnerability to extirpation or extinction, or they are under-represented in protected areas. BLM SSS are those designated by the BLM State Director, usually in cooperation with the Oregon Department of Agriculture and the Oregon Natural Heritage Information Center. The Oregon and Washington SSS policy identifies three tiers: Bureau Sensitive (BS), Bureau Assessment (BA), and Bureau Tracking (BT). BA species are those which are not presently eligible for official federal or state status but are of concern in Oregon or Washington and may at a minimum, need protection or mitigation in BLM activities. BT species are those which may become threatened or endangered in the future and are not considered SSS for management purposes. Surveys for SSS may be conducted prior to implementing proposed actions that may adversely affect special status species and their habitats.
**Succession:** the transition of plant species of a given area through a definite ecological stage (e.g., through succession of species composition, grasslands become tree-bearing forests).
**Threatened species:** plants and animals listed as threatened on the Endangered Species List that are in danger of becoming extinct.
**Vascular plants:** refers to vessels or ducts that conduct fluids in plants; includes the fern and fern allies, gymnosperms, dicotyledons, and monocotyledons.
**Wetland:** an area subjected to periodic inundation, usually with soil and vegetative characteristics that separates it from non-inundated area.



GPO U.S. GOVERNMENT PRINTING OFFICE: 2006 — 576-093 / 03040 Region No. 10

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
Coos Bay DISTRICT OFFICE
Umpqua Field Office
1300 Airport Lane
North Bend, Oregon 97459

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

PRIORITY MAIL
POSTAGE AND FEES PAID
Bureau of Land Management
Permit No. G-76

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

UNITED STATES
DEPARTMENT OF THE
INTERIOR
BUREAU OF LAND
MANAGEMENT
Coos Bay District Office

**BLM/OR/WA/PL-06/008-1792**

Federal Register

Monday,
February 11, 2008

Part III

# Department of Commerce

## National Oceanic and Atmospheric Administration

50 CFR Parts 223 and 226

**Endangered and Threatened Species: Final Threatened Listing Determination, Final Protective Regulations, and Final Designation of Critical Habitat for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon; Final Rule**

**DEPARTMENT OF COMMERCE**

**National Oceanic and Atmospheric Administration**

**50 CFR Parts 223 and 226**

**[Docket No. 071227892–7894–01]**

**RIN 0648–AW39**

## Endangered and Threatened Species: Final Threatened Listing Determination, Final Protective Regulations, and Final Designation of Critical Habitat for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon

**AGENCY:** National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

**ACTION:** Final rule.

**SUMMARY:** We are issuing a final determination to list the Oregon Coast coho salmon (*Oncorhynchus kisutch*) evolutionarily significant unit (ESU) as a threatened species under the Endangered Species Act (ESA). We are also issuing final protective regulations and a final critical habitat designation for the Oregon Coast coho ESU.

**DATES:** The listing determination, protective regulations, and designated critical habitat are effective on May 12, 2008. With respect to the protective regulations, the take prohibitions for the Oregon Coast coho ESU do not apply to research and enhancement activities specified in an application for a permit or approval under the protective regulations, provided that the application has been received by the Assistant Administrator for Fisheries (AA), NOAA, no later than June 10, 2008. This ''grace period'' for pending research and enhancement applications will remain in effect until the issuance or denial of authorization, or March 31, 2009, whichever occurs earliest.

**ADDRESSES:** NMFS, Protected Resources Division, 1201 NE Lloyd Boulevard, Suite 1100, Portland, Oregon 97232.

**FOR FURTHER INFORMATION CONTACT:** Scott Rumsey, NMFS, Northwest Region, Protected Resources Division, at (503) 872–2791, or Marta Nammack, NMFS, Office of Protected Resources, at (301) 713–1401. Reference materials regarding this determination are available upon request or on the Internet at *http://www.nwr.noaa.gov.*

**SUPPLEMENTARY INFORMATION:**

### Previous Federal ESA Actions Related to Oregon Coast Coho

In 1995, we completed a comprehensive status review of West Coast coho salmon (Weitkamp *et al.*, 1995) that resulted in proposed listing determinations for three coho ESUs, including a proposal to list the Oregon Coast coho ESU as a threatened species (60 FR 38011; July 25, 1995). On October 31, 1996, we announced a 6-month extension of the final listing determination for the ESU, pursuant to section 4(b)(6)(B)(I) of the ESA, noting substantial disagreement regarding the sufficiency and accuracy of the available data relevant to the assessment of extinction risk and the evaluation of protective efforts (61 FR 56211). On May 6, 1997, we withdrew the proposal to list the Oregon Coast coho ESU as threatened, based in part on conservation measures contained in the Oregon Coastal Salmon Restoration Initiative (later renamed the Oregon Plan for Salmon and Watersheds; hereafter referred to as the Oregon Plan) and an April 23, 1997, Memorandum of Agreement (MOA) between NMFS and the State of Oregon which further defined Oregon's commitment to salmon conservation (62 FR 24588). We concluded that implementation of harvest and hatchery reforms, and habitat protection and restoration efforts under the Oregon Plan and the MOA substantially reduced the risk of extinction faced by the Oregon Coast coho ESU. On June 1, 1998, the U.S. District Court for the District of Oregon issued an opinion finding that our May 6, 1997, determination to not list Oregon Coast coho was arbitrary and capricious (*Oregon Natural Resources Council* v. *Daley,* 6 F. Supp. 2d 1139 (D. Or. 1998)). The Court vacated our determination to withdraw the proposed rule to list the Oregon Coast coho ESU and remanded the determination to NMFS for further consideration. On August 10, 1998, we issued a final rule listing the Oregon Coast coho ESU as threatened (63 FR 42587), basing the determination solely on the information and data contained in the 1995 status review (Weitkamp *et al.*, 1995) and the 1997 proposed rule.

In 2001 the U.S. District Court in Eugene, Oregon, set aside the 1998 threatened listing of the Oregon Coast coho ESU (*Alsea Valley Alliance* v. *Evans,* 161 F. Supp. 2d 1154, (D. Or. 2001)) (Alsea). In response to the *Alsea* ruling and several listing and delisting petitions, we announced that we would conduct an updated status review of 27 West Coast salmonid ESUs, including the Oregon Coast coho ESU (67 FR 6215, February 11, 2002; 67 FR 48601, July 25, 2002).

In 2003 we convened the Pacific Salmonid Biological Review Team (BRT) (an expert panel of scientists from several Federal agencies including NMFS, the U.S. Fish and Wildlife Service (FWS), and the U.S. Geological Survey (USGS)) to review the extinction risks of naturally spawning populations in the 27 ESUs under review, including the Oregon Coast coho ESU (Good *et al.*, 2005; NMFS, 2003a). In making its recommendation, the BRT used a process where each member of the BRT was given 10 votes to divide among three conclusions. Members were allowed to assign votes to more than one conclusion, allowing them to express their relative degree of confidence in particular conclusions. The three options were ''In Danger of Extinction,'' ''Likely to Become Endangered,'' and ''Not Warranted.'' Fifty-six percent of the votes supported the conclusion that naturally spawning Oregon coast coho were likely to become endangered in the foreseeable future, and 44 percent supported the conclusion that naturally spawning Oregon coast coho was ''Not Warranted'' (that is, not likely to become in danger of extinction in the foreseeable future). The BRT noted considerable uncertainty regarding the future viability of the ESU given the uncertainty in predicting future ocean conditions for coho survival, as well as uncertainty in whether current freshwater habitats are of sufficient quality and quantity to support the recent high abundance levels and sustain populations during future downturns in ocean conditions. Although the BRT couched its conclusion in terms of the statutory definition of a threatened species (that is, not in danger of extinction, but likely to become endangered in the foreseeable future), the BRT's conclusion did not constitute a recommendation to list the species. Our listing determination also considered the risks and benefits from artificial propagation programs included in the ESU, efforts being made to protect the species, and the five factors listed under section 4(a)(1) of the ESA.

On June 14, 2004, based primarily on the BRT voting results, we proposed to list the Oregon Coast coho ESU as a threatened species (69 FR 33102). However, the proposed listing recognized that further information would likely become available and that this information could affect the outcome of the final determination. In the proposed rule, we noted that Oregon was initiating a comprehensive assessment of the viability of the Oregon Coast coho ESU and of the adequacy of actions under the Oregon Plan for conserving Oregon Coast coho. As part of that proposed rule we proposed amendments to existing protective regulations issued under ESA section

4(d) (''4(d) regulations'') for all threatened West Coast salmon and steelhead (50 CFR 223.203). These amendments were needed to: (1) Provide flexibility in fisheries and hatchery management; and (2) simplify and clarify the existing regulations so that they may be more efficiently and effectively accessed and interpreted by all affected parties.

On December 14, 2004, we proposed designations of critical habitat for 13 ESUs of Pacific salmon and steelhead in the Pacific Northwest, including the Oregon Coast coho ESU (69 FR 74572). We proposed critical habitat in 72 of 80 occupied watersheds, contained in 13 subbasins, totaling approximately 6,665 stream miles along the Oregon Coast, south of the Columbia River and north of Cape Blanco (Oregon). The estimated economic impact of the areas proposed for critical habitat was approximately $15.7 million. Eight occupied watersheds were proposed for exclusion because the high benefits of exclusion (due to economic impacts) outweighed the low benefits of inclusion (due to the low inherent conservation value for the listed species). These excluded watersheds included approximately 134 stream miles and represented a 15 percent reduction (approximately $2.75 million) in the economic impact of the proposed designation. To assess economic impacts we measured the co-extensive impacts because, based on the existing record, we could not distinguish between the costs associated with the species' listing from the costs of separately designating critical habitat.

In January 2005 the State of Oregon released a draft Oregon Coastal Coho Assessment (Oregon's Draft Viability Assessment), which (1) evaluated the current viability of the Oregon Coast coho ESU, and (2) evaluated the certainty of implementation and effectiveness of the Oregon Plan measures in addressing the factors for decline of the Oregon Coast coho ESU. The latter evaluation was intended to satisfy the joint NMFS—FWS Policy on Evaluating Conservation Efforts (''PECE''; 68 FR 15100; March 28, 2003). Oregon's Draft Viability Assessment concluded that the Oregon Coast coho ESU is currently viable and that measures under the Oregon Plan have stopped, if not reversed, the deterioration of Oregon Coast coho habitats. The Draft Viability Assessment also concluded that it is highly likely that existing monitoring efforts would detect any significant future deterioration in the ESU's viability, or degradation of environmental condition, allowing a timely and appropriate response to conserve the ESU. On February 9, 2005, we published a notice of availability of Oregon's Draft Viability Assessment for public review and comment in the **Federal Register** (70 FR 6840) and noted that information presented in the draft and final assessments would be considered in making the final listing determination for the Oregon Coast coho ESU.

We forwarded the public comments we received on Oregon's Draft Viability Assessment, as well as our technical reviews, for Oregon's consideration in developing its final assessment. The public comments and our review highlighted areas of uncertainty or disagreement regarding the sufficiency and accuracy of Oregon's Draft Viability Assessment, including: the assumption that Oregon Coast coho populations are inherently resilient at low abundance, and that this compensatory response will prevent extinction during periods of low marine survival; the apparent de-emphasis of abundance as a useful indicator of extinction risk; assumptions regarding the duration and severity of future periods of unfavorable marine and freshwater conditions; the ability of monitoring and adaptive management efforts to detect population declines or habitat degradation, and to identify and implement necessary protective measures; and the ability of Oregon Plan measures to halt or reverse habitat degradation once detected.

On May 13, 2005, Oregon issued its final Oregon Coastal Coho Assessment (Oregon's Final Viability Assessment). Oregon's Final Viability Assessment included several changes intended to address concerns raised regarding the sufficiency and accuracy of the draft assessment. Oregon's Final Viability Assessment concluded that: (1) The Oregon Coast coho ESU is viable under current conditions, and should be sustainable through a future period of adverse environmental conditions (including a prolonged period of poor ocean productivity); (2) given the assessed viability of the ESU, the quality and quantity of habitat is necessarily sufficient to support a viable ESU; and (3) the integration of laws, adaptive management programs, and monitoring efforts under the Oregon Plan will maintain and improve environmental conditions and the viability of the ESU into the foreseeable future.

On June 28, 2005 (70 FR 37217), we announced a 6-month extension of the final listing determination for the Oregon Coast coho ESU, finding that ''there is substantial disagreement regarding the sufficiency or accuracy of the available data relevant to the determination * * * for the purposes of soliciting additional data'' (section 4(b)(6)(B)(i) of the ESA). We announced a 30-day public comment period to solicit information regarding the validity of Oregon's Final Viability Assessment, particularly in light of the concerns raised with respect to Oregon's Draft Viability Assessment. In September 2005 we issued final critical habitat designations for 12 Pacific Northwest ESUs (70 FR 52685; September 2, 2005), but we did not issue a final critical habitat designation for Oregon Coast coho because it was only proposed for listing at that time.

On January 19, 2006, we issued a final determination that listing the Oregon Coast coho ESU under the ESA was not warranted (71 FR 3033). As part of this determination, we withdrew the proposed ESA section 4(d) regulations and critical habitat designation for the ESU. In reaching our determination not to list Oregon Coast coho, we found that the BRT's slight majority opinion that the ESU is ''likely to become endangered'' and the conclusion of the Oregon Final Viability Assessment that the ESU is viable represented competing reasonable inferences from the available scientific information and considerable associated uncertainty. The difference of opinion centered on whether the ESU was at risk because of the ''threatened destruction, modification, or curtailment of its habitat or range.'' We conducted an analysis of current habitat status and likely future habitat trends (NMFS, 2005a) and found that: (1) The sufficiency of current habitat conditions was unknown; and (2) likely future habitat trends were mixed (i.e., some habitat elements were likely to improve, some were likely to decline, others were likely to remain in their current condition). We concluded that there was insufficient evidence to support the conclusion that the ESU was more likely than not to become an endangered species in the foreseeable future throughout all or a significant portion of its range.

Our decision not to list the Oregon Coast coho ESU was challenged in *Trout Unlimited.* On October 9, 2007, the U.S. District Court for the District of Oregon invalidated our January 2006 decision not to list Oregon Coast coho (*Trout Unlimited* v. *Lohn, Civ. No. 06–01493 ST* (*D. Oreg., October 9, 2007*). The Court found that Oregon's Viability Assessment does not represent the best available science, and that we improperly considered it in reaching our final listing decision. The Court ordered us to issue a new final listing rule consistent with the ESA. This listing decision has been made in compliance with the Court's order.

**ESA Statutory Provisions**

*Listing Determinations*

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become endangered in the foreseeable future (sections 3(6) and 3(20), respectively). The statute requires us to determine whether any species is endangered or threatened because of any of five factors: the present or threatened destruction of its habitat, overexploitation, disease or predation, the inadequacy of existing regulatory mechanisms, or any other natural or manmade factors (section 4(a)(1)(A)–(E)). We are to make this determination based solely on the best available scientific information after conducting a review of the status of the species and taking into account any efforts being made by states or foreign governments to protect the species. The focus of our evaluation of these five factors is to evaluate whether and to what extent a given factor represents a threat to the future survival of the species. The focus of our consideration of protective efforts is to evaluate whether these efforts substantially have and will continue to address the identified threats and so ameliorate a species' risk of extinction. In making our listing determination, we must consider all factors that may affect the future viability of the species, including whether regulatory and conservation programs are inadequate and allow threats to the species to persist or worsen, or whether these programs are likely to mitigate threats to the species and reduce its extinction risk. The steps we follow in implementing this statutory scheme are to: review the status of the species, analyze the factors listed in section 4(a)(1) of the ESA to identify threats facing the species, assess whether certain protective efforts mitigate these threats, and make our best prediction about the species' future persistence.

As indicated above, the PECE provides direction for considering protective efforts identified in conservation agreements, conservation plans, management plans, or similar documents (developed by Federal agencies, state and local governments, tribal governments, businesses, organizations, and individuals) that have not yet been implemented, or have been implemented but have not yet demonstrated effectiveness. The policy articulates several criteria for evaluating the certainty of implementation and effectiveness of protective efforts to aid in determining whether a species warrants listing under the ESA. Evaluation of the certainty that an effort will be implemented includes whether: the necessary resources (e.g., funding and staffing) are available; the requisite agreements have been formalized such that the necessary authority and regulatory mechanisms are in place; there is a schedule for completion and evaluation of the stated objectives; and (for voluntary efforts) the necessary incentives are in place to ensure adequate participation. The evaluation of the certainty of an effort's effectiveness is made on the basis of whether the effort or plan: Establishes specific conservation objectives; identifies the necessary steps to reduce threats or factors for decline; includes quantifiable performance measures for the monitoring of compliance and effectiveness; incorporates the principles of adaptive management; and is likely to improve the species' viability at the time of the listing determination.

PECE also notes several important caveats. Satisfaction of the above mentioned criteria for implementation and effectiveness establishes a given protective effort as a candidate for consideration, but does not mean that an effort will ultimately change the risk assessment. The policy stresses that, just as listing determinations must be based on the viability of the species at the time of review, so they must be based on the state of protective efforts at the time of the listing determination. The PECE does not provide explicit guidance on how protective efforts affecting only a portion of a species' range may affect a listing determination, other than to say that such efforts will be evaluated in the context of other efforts being made and the species' overall viability.

*Protective Regulations*

ESA section 9(a) take and other prohibitions (16 U.S.C. 1538(a)(1)(B)) apply to all species listed as endangered. Hatchery stocks determined to be part of endangered ESUs are afforded all of the full section 9 protections. In the case of threatened species, ESA section 4(d) leaves it to the Secretary of Commerce's (Secretary) discretion to determine whether and to what extent regulatory requirements may be appropriate, by directing the Secretary to issue regulations determined to be necessary and advisable for the conservation of the species. We have flexibility under section 4(d) to tailor protective regulations based on the contributions of available conservation measures. The 4(d) regulations may prohibit, with respect to threatened species, some or all of the acts which section 9(a) of the ESA prohibits with respect to endangered species.

*Critical Habitat*

Section 3 of the ESA defines critical habitat as (1) specific areas within the geographical area occupied by the species at the time of listing, on which are found those physical or biological features that are essential to the conservation of the listed species and that may require special management considerations or protection, and (2) specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of a listed species. In designating critical habitat our regulations direct us to focus on ''primary constituent elements,'' or PCEs, in identifying these physical or biological features. Section 4 of the ESA requires us to consider the economic impacts, impacts on national security, and other relevant impacts of specifying any particular area as critical habitat. We may exclude any area from critical habitat if we determine that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless the failure to designate such an area will result in the extinction of the species.

At the time of a proposed listing determination, ESA section 4(a)(3) and our regulations require us to specify critical habitat to the maximum extent ''prudent and determinable.'' Critical habitat designation is not prudent if: (1) The species is threatened by taking or other human activity and the identification of critical habitat can be expected to increase such threat(s); or (2) critical habitat designation would not be beneficial to the species. Critical habitat is not determinable if: (1) Sufficient information is lacking to perform the required analyses of the impact of the designation; or (2) the biological needs of the species are not sufficiently well known to identify an area as critical habitat. In our proposed rule to designate specific areas as critical habitat (69 FR 74572; December 14, 2004), we determined that designating critical habitat for this species is prudent and determinable. The record continues to support this determination.

The ESA requires that a final regulation designating critical habitat be published concurrently with the final determination listing a species as threatened or endangered, unless: (1) It is essential to the conservation of such species that the species be listed promptly (e.g., in instances when a species is listed by emergency rule); or (2) critical habitat of such species is not then determinable. Section 7(a)(2) of the ESA requires that each Federal agency shall, in consultation with, and with the assistance of, NMFS, ensure that any action authorized, funded or carried out by such agency is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of its designated critical habitat.

**Summary of Public and Independent Review**

Our regulations require that we allow a period of at least 60 days for the public to review and comment on a proposed rule to list, delist, or reclassify a species, or to designate or revise critical habitat. We may extend or reopen the comment period upon finding that there is good cause to do so by publishing notice in the **Federal Register**. We are required to hold at least one public hearing if any person so requests within 45 days of the publication of a proposed rule. Notice of the location and time of any hearings is published in the **Federal Register**.

A 1994 joint NMFS–FWS policy (Independent Review Policy) requires us to solicit independent expert review from at least three qualified specialists, concurrent with the public comment period following a proposed rule (59 FR 34270; July 1, 1994). In December 2004 the Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review (Peer Review Bulletin), establishing minimum peer review standards, a transparent process for public disclosure, and opportunities for public input. The OMB Peer Review Bulletin, implemented under the Information Quality Act (Pub. L. 106–554), is intended to ensure the quality of agency information, analyses, and regulatory activities and provide for a more transparent review process.

*Listing Determination and Protective Regulations*

We solicited public comment on the proposed listing determination and ESA section 4(d) regulations for the Oregon Coast coho ESU for a total of 208 days (69 FR 33102, June 14, 2004; 69 FR 53031, August 31, 2004; 69 FR 61348, October 18, 2004; 70 FR 6840, February 9, 2005; 70 FR 37217, June 28, 2005). In addition, we held eight public hearings in the Pacific Northwest concerning the June 2004 West Coast salmon and steelhead proposed 4(d) regulations and proposed listing determinations, including the proposed determination for the Oregon Coast coho ESU (69 FR 53031, August 31, 2004; 69 FR 61348, October 18, 2004). In compliance with the 1994 Independent Review Policy we solicited technical review of the June 2004 proposed 4(d) regulations and listing determinations, including the proposed determination for the Oregon Coast coho ESU, from over 50 independent experts selected from the academic and scientific community, Native American tribal groups, Federal and state agencies, and the private sector. The individuals from whom we solicited review of the proposals and the underlying science were selected because of their demonstrated expertise in a variety of disciplines including: Artificial propagation; salmonid biology, taxonomy, and ecology; genetic and molecular techniques and analyses; population demography; quantitative methods of assessing extinction risk; fisheries management; local and regional habitat conditions and processes; and conducting scientific analyses in support of ESA listing determinations. The individuals solicited represent a broad spectrum of perspectives and expertise. The individuals solicited include those who have been critical of past agency actions in implementing the ESA for West Coast salmon and steelhead, as well as those who have been supportive of these actions. These individuals were not involved in producing the scientific information for our determinations and were not employed by the agency. We received comments from four of these experts. In addition to these solicited reviews, several independent scientific panels and academic societies provided technical review of the proposals and the supporting documentation. With respect to the Peer Review Bulletin's requirements for ''adequate [prior] peer review,'' we believe the independent expert review under the 1994 Independent Review Policy, and the comments received from several academic societies and expert advisory panels, collectively satisfy the Peer Review Bulletin's requirements (NMFS, 2005b).

In response to our requests for information and comments on the June 2004 proposed listing determinations, we received over 28,250 comments by fax, standard mail, and e-mail. The majority of the comments received were from interested individuals who submitted form letters or form e-mails that addressed general issues not specific to the Oregon Coast coho ESU. Comments were also submitted by state and tribal natural resource agencies, fishing groups, environmental organizations, home builder associations, academic and professional societies, expert advisory panels, farming groups, irrigation groups, and individuals with expertise in Pacific salmonids. The majority of commenters focused on the consideration of hatchery-origin fish in ESA listing determinations, with only a few comments specifically addressing the Oregon Coast coho ESU. We also received comments from 4 of the 50 independent experts from whom we had requested technical review of the scientific information underlying the June 2004 proposed listing determinations. Their comments did not specifically address the proposed determination for the Oregon Coast coho ESU. The reader is referred to the final hatchery listing policy (70 FR 37204; June 28, 2005) and the final listing determinations and ESA section 4(d) regulations for 16 salmon ESUs (70 FR 37160; June 28, 2005) for a summary and discussion of issues raised by the comments that were not specific to the Oregon Coast coho ESU. The comments addressing the proposed listing determination for the Oregon Coast coho ESU are summarized below. We did not receive any comments that addressed the proposed 4(d) regulations in the specific context of the Oregon Coast coho ESU.

*Critical Habitat*

We solicited public comment on the proposed critical habitat designation for Oregon Coast coho for a total of 105 days (69 FR 74578, December 14, 2004; 70 FR 6394; February 7, 2005). We also contacted the appropriate Federal, state, and local agencies, scientific organizations, and other interested parties and invited them to comment on the proposed rule. To facilitate public participation, we made the proposed rule available via the Internet as soon as it was signed by the AA of NMFS (approximately 2 weeks prior to actual publication). In addition, we held four public hearings in the Pacific Northwest between January 11, 2005, and January 25, 2005. We received 5,230 written comments (5,111 of these were ''form e-mails'' with nearly identical verbiage) during the comment period on the proposed rule. Eight comments addressed specifically, or in part, the proposed critical habitat designation for the Oregon Coast coho ESU.

In compliance with the Peer Review Bulletin, prior to publishing the proposed rule we submitted the initial biological assessments of our Critical Habitat Analytical Review Teams (CHARTs) to state and tribal comanagers and asked them to review those findings. These comanager reviews resulted in several changes to the CHARTs' preliminary assessments (for example, revised fish distribution as well as conservation value ratings) and helped ensure that the CHARTs' revised findings incorporated the best available scientific data. Consistent with the 1994 Independent Review Policy, we later solicited technical review of the entire critical habitat proposal (including the underlying biological and economic reports) from 45 independent experts selected from the academic and scientific community, Native American tribal groups, Federal and state agencies, and the private sector. We also solicited opinions from three individuals with economics expertise to review the draft economics analysis supporting the proposed rule. All three of the economics reviewers and three of the biological reviewers submitted written opinions on our proposal. We have determined that the independent expert review and comments received regarding the science involved in this rulemaking constitute adequate prior review under section II.2 of the OMB Peer Review Bulletin (NMFS, 2005c) and satisfy the 1994 Independent Review Policy.

We reviewed all comments received from the peer reviewers and the public for substantive issues and new information regarding critical habitat for all 13 ESUs addressed in the proposed rule. The reader is referred to the final critical habitat designations for 12 Pacific Northwest ESUs (70 FR 52685; September 2, 2005) for a summary and discussion of general issues, or issues specific to other ESUs. The comments addressing the proposed critical habitat designation for the Oregon Coast coho ESU are summarized below.

**Comments Specific to Oregon Coast Coho**

Below we address the comments received that directly pertain to: (1) The listing determination for the Oregon Coast coho ESU, and (2) the designation of critical habitat for the Oregon Coast coho ESU. (Copies of the full text of comments received are available upon request, see **ADDRESSES** and **FOR FURTHER INFORMATION CONTACT,** above.)

*Comments Regarding the Listing Determination*

*Comment 1:* The Oregon Department of Fish and Wildlife (ODFW) expressed concern regarding the proposed inclusion of the North Fork Nehalem River coho hatchery program in the Oregon Coast coho ESU. ODFW explained that the hatchery program propagates two different stocks: The North Fork Nehalem River hatchery coho stock (ODFW stock #32) and the Fishhawk Lake hatchery coho stock (ODFW stock #99). ODFW noted that both stocks, although founded using local natural-origin fish, are presently managed as isolated broodstocks. Although the level of divergence between these hatchery stocks and the local wild populations is not known, ODFW noted that our hatchery reviews (NMFS, 2003b, 2004a, 2004b) acknowledged that the level of divergence may be substantial. ODFW recommended that both the North Fork Nehalem River and Fishhawk Lake hatchery stocks be excluded from the ESU.

ODFW also noted that the recently founded Calapooya Creek (Umpqua River basin, Oregon) hatchery coho stock was not included in our hatchery reviews. The Calapooya Creek program was a small, short-term (in operation from 2001–2003), research hatchery program conducted to evaluate the use of hatchery-reared fish in the supplementation of a wild coho population. The program is no longer releasing fish, and had adults returning through 2006. ODFW suggested that, had we included this stock in our initial evaluations, the progeny expected to return through 2006 would have been considered as part of the Oregon Coast coho ESU.

*Response:* We agree with ODFW's comments that the North Fork Nehalem River and Fishhawk Lake stocks propagated by the Nehalem hatchery coho program are substantially reproductively isolated from the local natural populations, and diverged substantially from the evolutionary legacy of the ESU. Moreover, since our 2006 final determination these two programs have been discontinued, with the last adults returning in 2007 (NMFS, 2007a). We conclude that the North Fork Nehalem River and Fishhawk Lake hatchery coho stocks are not part of the Oregon Coast coho ESU.

We did not include the Calapooya Creek coho hatchery stock in our hatchery reviews as the program is no longer collecting fish for broodstock or releasing smolts. We agree with ODFW that returns from Calapooya Creek hatchery stock, having been derived from local natural-origin fish, likely were no more than moderately diverged from the local natural populations. However, given that the program has been terminated, and 2006 was the last year of returns, the Calapooya Creek hatchery stock will not be considered part of the Oregon Coast coho ESU.

At the time of the 2004 proposed rule and our January 2006 final determination not to list the ESU, Cow Creek (ODFW stock #37), the North Umpqua River (ODFW stock #18), the Coos Basin (ODFW stock #37), and the Coquille River (ODFW stock #44) hatchery coho programs were considered part of the Oregon Coast coho ESU. The latter three of these programs have been discontinued since our 2006 final determination (NMFS, 2007a). The last year of returns for these programs is 2007. Given that the North Umpqua River, Coos Basin, and Coquille River hatchery programs have been terminated, and this winter (2007) is the last year of returns, these stocks will not be considered part of the Oregon Coast coho ESU.

*Comment 2:* A comment submitted by the Pacific Rivers Council (PRC) included a July 2003 report investigating the potential benefits of a modeled conservation hatchery program in supplementing Oregon Coast coho (Oosterhout and Huntington, 2003). PRC asserted that the report supports their position that hatchery fish should be considered as only a threat to wild salmonid populations, and that any potential short-term benefits of artificial propagation are outweighed by the long-term damaging genetic and ecological effects on wild populations. The Oosterhout and Huntington (2003) report modeled an ''idealized conservation hatchery'' program and evaluated the success of supplementation efforts under different scenarios of habitat quality and marine survival. The authors conclude from their modeling study that supplementation, even under optimized model assumptions, poses long-term ecological and genetic risks, and any short-term gains in salmon abundance are temporary.

*Response:* The use of artificial propagation represents a broad spectrum of hatchery practices and facilities, as well as a variety of ecological settings into which hatchery-origin fish are released. For this reason it is essential to assess hatchery programs on a case-by-case basis. Our assessment of the benefits, risks, and uncertainties of artificial propagation concluded that the specific hatchery programs considered to be part of the Oregon Coast coho ESU collectively do not substantially reduce the extinction risk of the ESU in-total (NMFS, 2004b). We noted that these hatchery programs likely contribute to an increased abundance of total natural spawners in the short term, although their contribution to the productivity of the supplemented populations is unknown. Our assessment is consistent with the findings of Oosterhout and Huntington (2003). The findings of scientific studies, such as the subject study on simulated conservation hatchery programs and their impacts on natural coho populations, inform our consideration of the benefits and risks to be expected from artificial propagation. However, it would be inappropriate to rely on theoretical conclusions about the effectiveness of hatchery programs while ignoring program-specific information regarding broodstock origin, hatchery practices, and performance of hatchery- and natural-origin fish.

*Comment 3:* Douglas County Board of Commissioners (Oregon) submitted a report (Cramer *et al.*, 2004) that concludes that NMFS' earlier viability analyses overstate the risks to Oregon Coast coho populations, and that the 2003 BRT's findings warrant reconsideration. The Cramer *et al.* (2004) report asserts that previous viability assessments failed to adequately consider connectivity among spawner aggregations, underestimated juvenile over-winter survival in smaller stream reaches, and underestimated coho population stability. The report asserts that sharp reductions in ocean harvest rates since 1994, declining influence of hatchery-origin fish, and improved monitoring and evaluation under the Oregon Plan confer a very low risk of extinction even if future marine survival rates are low and remain low.

*Response:* The Cramer *et al.* (2004) report does not present any substantial new information, other than including an additional year of abundance data that was not available to the BRT. The report emphasizes selective aspects of the available data including: reduction of threats by changes in fishery and harvest management; and improved biological status evidenced by increasing spawning escapements and successful juvenile rearing throughout the ESU. These observations and analyses were fully considered in the BRT's review (Good *et al.*, 2005; NMFS, 2003a). The Cramer *et al.* (2004) report does not, by itself, add to our consideration of the BRT's findings.

*Comment 4:* Several commenters felt that effective regulatory controls and monitoring programs are in place to ensure that harvest and hatchery practices no longer threaten the ESU.

*Response:* Many noteworthy and important regulatory changes have been made that adequately address historically harmful practices. Changes in ocean and freshwater fisheries management have resulted in sharp reductions in fishing mortality in Oregon Coast coho populations, and likely have contributed to recent population increases. It is unlikely that those harvest controls will weaken in the future, in light of Federal management of ocean fisheries. Reforms in hatchery management practices have limited the potential for adverse ecological interactions between hatchery-origin and natural fish, and have markedly reduced risks to the genetic diversity and reproductive fitness for the majority of naturally spawned populations in the ESU. It is also unlikely those reforms will be weakened in the future.

*Comment 5:* One commenter was critical of the Oregon Forest Practices Act, and argued that it is inadequate to prevent the future degradation of riparian habitats, particularly on private non-industrial forestlands. The commenter noted that the Forest Practices Act applies only to the commercial harvest of trees, and that non-commercial land owners may cut riparian trees without restriction if they do not sell the wood. The commenter noted that this unregulated practice is particularly evident in areas with increased rural residential development along streambanks.

Other commenters doubted whether regulations, restoration programs, and other protective efforts would improve habitat conditions in the foreseeable future. One commenter noted that there is an insufficient data record to evaluate the success of protective efforts aimed at restoring riparian habitats, particularly in increasing the recruitment of large woody debris. Several other commenters doubted whether forest management under the Oregon Plan has resulted, or will result, in an increased amount of large-diameter trees (important for the recruitment of large woody debris in coho rearing areas). The commenters argued that the shorter rotations being implemented on private industrial forest lands reduce the size of trees delivered to streams in landslides, and thus may result in diminished stream complexity in important coho rearing habitats.

*Response:* Our review suggests that there are likely to be improvements in some aspects of habitat condition, declines in others, and a continuation of current conditions in still others (NMFS, 2005a). For example, the Northwest Forest Plan instituted riparian habitat buffers and other measures on Federal lands that improved many of the historical forestry practices that led to the loss and degradation of riparian habitats. Development and implementation of Total Maximum Daily Loads under the Federal Clean Water Act are likely to result in improved water quality. Restoration efforts have treated approximately seven percent of the stream miles within the range of the ESU over the last 7 years with the intent of restoring stream complexity and riparian habitats and improving water quality, though it is unclear how much restoration is likely to occur in the future, given funding uncertainties.

Forest practices on state and private land include some improvements over historically harmful practices, such as the establishment of riparian management areas under revisions to Oregon forest practice rules in the 1990s. However, there are also offsetting practices that are expected to degrade habitat conditions and complexity, such as shorter harvest rotations, road construction, and logging on unstable slopes and along debris flow paths (NMFS, 2005a).

For agricultural lands, riparian management is governed by agricultural water quality management plans under Oregon Senate Bill 1010, as well as by subsequently developed riparian rules which synthesize elements of individual Senate Bill 1010 plans for a given basin. These agricultural plans and rules do not specify the vegetation composition or size of the riparian areas to be established. The lack of specificity of these agricultural plans makes the enforcement and effectiveness of these plans uncertain (NMFS, 2005a). Any modest improvements in riparian vegetation on agricultural lands under current rules that might be expected may be offset by habitat declines resulting from urban and rural development (NMFS, 2005a). On balance, habitat conditions on agricultural lands are not likely to show significant improvement or decline.

Future urbanization and development within the range of the ESU is projected at approximately 20 percent population growth, representing slightly more than 30,000 people over the next 40 years (NMFS, 2005a). Most of this development is expected to be concentrated in lowland areas with high intrinsic potential for rearing coho. Current urban or rural growth boundaries encompass approximately nine percent of high intrinsic potential riparian habitat areas, so future urbanization and development activities could have significant implications for some coho populations. The degree of potential impacts on coho habitat (both positive and negative) is highly uncertain and depends largely on the spatial distribution of future urbanization and development activities, their proximity to riparian areas, and the kinds of development activities undertaken and the land management practices used.

*Comment 6:* Several commenters expressed concern that inadequate funding has limited the ability of many

Oregon agencies to monitor non-permitted habitat-affecting activities, effectively enforce regulations, and ensure proper reporting of permitted activities. The commenters felt that these inadequacies should be considered evidence of uncertainty that some as yet, unproven elements under the Oregon Plan will be implemented.

*Response:* The commenters are correct that the availability of necessary funding and staffing resources is an important consideration in evaluating how likely it is that a given protective effort will be implemented. Our review has noted that funding declines have led to the loss of staff at the Oregon Department of Environmental Quality, Department of Forestry, and ODFW (NMFS, 2005a). The reduced funding has slowed the completion of Total Maximum Daily Load water quality standards, and reduced the ability to monitor water quality, habitat structure and complexity, and fish populations.

*Comments Regarding the Designation of Critical Habitat*

*Comment 7:* One Federal commenter provided information recommending changes to designated stream reaches in several watersheds due to errors in interpreting existing salmon distribution maps, recent field surveys, and the location of impassible barriers. This commenter also questioned the inclusion of Jackson and Josephine counties as within the range of areas designated as critical habitat for Oregon Coast coho salmon.

*Response:* In light of the specific comments received, we have reviewed all the data regarding habitat areas occupied by coho salmon and the location of impassible barriers. This review included discussions with local ODFW biologists familiar with the areas in question. The majority of suggested revisions were found to be warranted, and, as a result, we have updated the endpoints delineating areas occupied by coho salmon, including those designated as critical habitat, in ten watersheds (see ''*Summary of Changes from the Proposed Critical Habitat Designation*''). We have also removed Josephine and Jackson counties from the relevant critical habitat table in our regulations. These counties overlap slightly with upland areas in watersheds occupied by Oregon Coast coho salmon, but they do not contain stream reaches designated as critical habitat for this ESU.

*Comment 8:* Two commenters questioned the ''medium'' conservation-value rating assigned by the CHART to the habitat area for Devils Lake coho. These areas are within a larger Devils Lake/Moolack Frontal watershed. The commenters cited recent genetic data establishing that coho from Rock Creek/Devils Lake are genetically distinct from other populations in the ESU. The commenters believed that the coho in Devils Lake possess a unique and distinct genetic heritage warranting a ''high'' conservation value rating.

*Response:* The CHART considered these comments along with recent population identification work (Lawson *et al.*, 2007) and genetic analyses by Johnson and Banks (2007). The team maintained that the Devils Lake/Moolack Frontal watershed (which contains Devils Lake) was still of medium conservation value, noting that Devil's Lake coho are one of ten small and dependent populations in this watershed and appear to be most closely related to coho in the nearby Siletz River. The team acknowledged that Devils Lake was the most productive of these ten populations but that the overall watershed did not warrant a high conservation value relative to other adjacent watersheds with more extensive habitat areas and functionally independent populations (e.g., the Siletz River and Yaquina River watersheds). Regardless, Devils Lake and all other habitat areas in the Devils Lake/Moolack Frontal watershed are designated as critical habitat for Oregon Coast coho salmon.

*Comment 9:* One tribal government expressed support of the proposed exclusion of Indian lands from the area eligible for critical habitat designation. The tribe agreed with our proposal that designating Indian lands as critical habitat would adversely impact tribal partnerships with us and limit the benefits that result from collaboration. Additionally, the tribe felt that the proposal to not designate Indian lands as critical habitat appropriately acknowledges tribal sovereignty and authority in managing natural resources on their lands.

*Response:* This final rule maintains the exclusion of Indian lands for the reasons described in the *Exclusions Based on Impacts to Tribes* section below.

*Comment 10:* Several commenters argued that the conservation benefits provided by certain conservation measures on non-Federal lands provide sufficient protections so that there would be minimal benefit of designating the affected areas as critical habitat. One commenter felt that existing forest protections under the Oregon Forest Protection Act and associated best management practices adequately protect the PCEs found on private and state forest lands in the State of Oregon. Another commenter felt that protections under the Oregon Plan have demonstrated conservation benefits that warrant the exclusion of affected areas from designation as critical habitat. Another commenter felt that existing regulatory and other mechanisms under these conservation measures are inadequate to protect the ESU and its habitats. The commenter argued that it is essential to designate critical habitat in these areas where existing regulatory mechanisms do not prevent or alter certain activities that would adversely modify habitat.

*Response:* The comments imply that if an area is covered by a management plan, it either does not meet the ESA section 3(5)(a) definition of critical habitat or it must be excluded from critical habitat under ESA section 4(b)(2). Neither assertion is correct.

Section 3(5)(a) of the ESA defines critical habitat as occupied areas containing physical or biological features that are (1) essential to the conservation of the species and (2) which may require special management considerations or protections. Consistent with the statute, in identifying areas meeting the definition of critical habitat for this ESU, we identified the physical or biological features essential to the conservation of the ESU, identified the occupied areas where these features are present, and then determined whether these features in each area may require special management considerations and protections. The bases for these conclusions are described further below and in a separate report (NMFS, 2007b).

Section 4(b)(2) of the ESA gives the Secretary discretion to exclude areas from critical habitat if he determines that benefits of exclusion outweigh the benefits of designation. Exercising the discretion to exclude an area from critical habitat requires evidence of a benefit of exclusion. Section 4(b)(2) and the supporting legislative history make clear that the consideration and weight given to impacts are within the Secretary's (H.R. 95–1625) discretion and that exclusion is not required even when the benefits of exclusion outweigh the benefits of designation. In other critical habitat designations for Pacific salmon and steelhead, the Secretary excluded areas from critical habitat on private lands covered by habitat conservation plans because there was evidence in the record that exclusion would enhance the relationship between the landowner and the agency. That improved relationship was expected to result in improved implementation of the plan and incentives for the development of other plans, increasing conservation benefits for fish (70 FR 52630; September 2, 2005). Regarding private and state lands subject to Oregon's forest practice laws, there is no conservation agreement in place between landowners and NMFS, nor any evidence in the record supporting a conclusion that conservation actions of landowners subject to these laws would improve as a result of exclusion. The same is true for lands generally covered by the Oregon Plan. Based on our review of available information, we found there were insufficient data and analysis to conclude that there is a benefit of exclusion. Absent evidence of a benefit of exclusion, we could not conclude that the benefits of exclusion outweigh the benefits of inclusion.

*Comment 11:* Two Federal commenters felt that all Federal lands merited exclusion from designation as critical habitat. They contended that conservation benefits under PACFISH, the Northwest Forest Plan, and National Forest Land and Resource Management Plans (LRMPs) provide necessary protection and special management that eliminates the need to designate habitats on Federal lands as critical. These commenters contended that designating critical habitat on these Federal lands was unnecessarily duplicative of existing ESA section 7 consultation processes, inefficient (e.g., citing costs of re-initiating consultation), while offering no additional conservation benefit to the listed species. They believed that excluding Federal lands would be consistent with our exclusion of military lands that are subject to Integrated Natural Resource Management Plans, which they felt contain similar provisions for the protection and restoration of listed species.

*Response:* ESA section 4(b)(2) provides the Secretary with discretion to exclude areas from the designation of critical habitat if the Secretary determines that the benefits of exclusion outweigh the benefits of designation, and the Secretary finds that exclusion of the area will not result in extinction of the species. In the proposed rule, and the reports supporting it, we explained the policies that guided us and provided supporting analysis for a number of proposed exclusions. We also noted a number of additional potential exclusions, including those associated with the Oregon Coast coho salmon due to conservation measures within the Northwest Forest Plan on Federal lands, explaining that we were considering them because the Secretary of the Interior had recently made similar exclusions in designating critical habitat for the bull trout. In the final rule designating critical habitat for 12 Pacific Northwest ESUs (70 FR 52630; September 2, 2005), we considered extensive comments supporting and opposing the exclusion of Federal lands, as well as comments concerning alternative approaches for assessing the benefits of exclusion versus inclusion of lands as critical habitat. That final rule also stated the following with regard to the potential exclusion of Federal lands and alternative approaches to designation:

> We will continue to study this issue and alternative approaches in future rulemakings designating critical habitat. In particular, we intend to analyze the planning and management framework for each of the ownership categories proposed for consideration for exclusion. In each case, we envision that the planning and management framework would be evaluated against a set of criteria, which could include at least some or all of the following:
>
> 1. Whether the land manager has specific written policies that create a commitment to protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.
>
> 2. Whether the land manager has geographically specific goals for protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.
>
> 3. Whether the land manager has guidance for land management activities designed to achieve goals for protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.
>
> 4. Whether the land manager has an effective monitoring system to evaluate progress toward goals for protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.
>
> 5. Whether the land manager has a management framework that will adjust ongoing management to respond to monitoring results and/or external review and validation of progress toward goals for protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.
>
> 6. Whether the land manager has effective arrangements in place for periodic and timely communications with NOAA on the effectiveness of the planning and management framework in reaching mutually agreed goals for protection or appropriate management of the physical or biological features essential to long-term conservation of ESA-listed salmon and steelhead.

NMFS has continued dialogue with the Federal land management agencies since that time. Although we have not yet developed the type of information that would allow us to exclude Federal lands at this time, we will work with the land management agencies to develop the information and consider exclusion of Federal lands, as well as alternative approaches to designation, where the analysis provides appropriate support. We anticipate that further analyses using principles such as those above can result in additional data to inform the ESA Section 4(b)(2) analysis regarding possible exclusion of Federal lands from critical habitat designations.

*Comment 12:* One commenter and a peer reviewer expressed concern that the economic analysis failed to consider the full range of economic benefits of salmon habitat conservation and, therefore, provided a distorted picture of the economic consequences of designating versus excluding eligible habitat areas. The commenter expressed concern that the economic impact of not designating particular areas would impede recovery efforts, and this cost should be considered in the economic analysis. The commenter cited the lack of consideration in the economic analysis of the potential benefits of critical habitat designation to: (1) Other aquatic and riparian species; (2) water quality; (3) recreation; and (4) increased recreational, commercial, and tribal harvest opportunities that would be available with recovery.

*Response:* As described in the economic analysis (NMFS, 2007c) and ESA section 4(b)(2) report (NMFS, 2007d), we did not have information available at the scale of this designation that would allow us to quantify the benefits of designation in terms of increased fisheries. Such an estimate would have required us to estimate the additional number of fish likely to be produced as a result of the designation, and would have required us to determine how to allocate the economic benefit from those additional fish to a particular watershed. Instead, we considered the ''benefits of designation'' in terms of conservation value ratings for each particular area (see ''Methods and Criteria Used to Designate Critical Habitat'' section below). We also lacked information to quantify and include in the economic analysis the economic benefit that might result from such things as improved water quality or flood control, or improved condition of other species.

Moreover, we did not have information at the scale of this designation that would allow us to consider the relative ranking of these types of benefits on the ''benefits of designation'' side of the ESA section 4(b)(2) balancing process. Our primary focus was to determine, consider, and balance the benefits of designating these areas to the conservation of the listed species. Given the uncertainties involved in quantifying or even ranking these ancillary types of benefits, we did not include them in our analysis.

**Final Species Determination**

The Oregon Coast coho ESU includes all naturally spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco (63 FR 42587; August 10, 1998). One hatchery stock is considered part of the ESU: The Cow Creek (ODFW stock # 37) hatchery coho stock.

On June 14, 2004, we proposed that five artificial propagation programs should be considered part of the ESU (69 FR 33102), including the North Fork Nehalem River (ODFW stock # 32), the North Umpqua River (ODFW stock # 18), Coos Basin (ODFW stock # 37), and the Coquille River (ODFW stock # 44) coho hatchery programs. Informed by our analysis of the comments received from ODFW, and other recently available information (see Comment 1 and response, above), we conclude that these four hatchery programs are not part of the Oregon Coast coho ESU.

**Assessment of the Species' Status**

The steps we follow in making a listing determination are to: Review the status of the species, analyze the factors listed in section 4(a)(1) of the ESA to identify threats facing the species, assess whether certain protective efforts mitigate these threats, and predict the species' future persistence. Below we summarize the information we evaluated in reviewing the status of the Oregon Coast coho ESU. We considered the information included in the record for our January 2006 determination in a manner consistent with the Court's ruling in *Trout Unlimited*. We also considered additional status information that was readily available since our January 2006 decision, to determine if this new information is consistent with our conclusion based on the January 2006 (as the Court has ordered us to consider it).

We begin a typical listing determination for a salmon ESU by gathering the most recent available and relevant biological information and appointing a panel of Federal scientists (the BRT) familiar with the biology and population dynamics of salmon. This panel reviews the status information, considers and discusses various possible interpretations of the information, and prepares a written report containing its recommendations as well as the basis for them. In addition, the documents underlying the BRT's conclusions are made available to the decision maker for consideration. Typically, the BRT's review takes about 3–6 months to complete.

At the same time, regulatory staff gather updated information about the status and trends for other related factors, including the potential contributions (both positive and negative) from hatchery programs, the condition of the habitat, and the expected implementation and effectiveness of conservation efforts. This information is considered together with the BRT's recommendations in forming a final determination and preparing a written explanation of that determination.

While the above steps were conducted for Oregon Coast coho prior to the issuance of the 2004 proposed rule, the court order in *Trout Unlimited* requiring a final determination and the time allowed for making that final determination do not permit us to follow our typical practice anew for Oregon Coast coho. The available record contains a BRT recommendation and report made in 2003, based on status information through 2002. The information in the record about the condition of the habitat and the effectiveness of conservation efforts is also mostly data collected prior to 2003. We have also considered draft reports of the Technical Recovery Team for the Oregon Coast. These draft reports are directed primarily at the population structure of and recovery criteria for the Oregon Coast coho ESU, rather than the determination required for a listing decision.

Quantitative information available to us for this determination also includes numerical information on the abundance of Oregon Coast coho through 2006, preliminary spawner survey information for 2007, and estimates of the ocean survival for coho through 2006. Comparison of the abundance of the naturally-produced coho with the marine survival index suggests the possibility that much of the variability in coho numbers over the last decade or so may be due to fluctuations in the availability of food in the near-shore ocean (NMFS, 2007k). In addition, there is some indication that juvenile survival is limited by the supply of nutrients from the carcasses of spawning adult coho (Bilby *et al.*, 2001). It is possible that existing freshwater habitat is adequate to support a viable ESU, and that the fluctuations observed in Oregon Coast coho populations are partially driven by the supply of carcasses. The 2003 BRT did not explicitly consider the relationship between coho abundance and marine food availability, or the relationship between juvenile survival and the supply of carcasses. Our current record lacks the information and analyses necessary to assess the present status of freshwater habitat conditions and functional processes in the ESU. Oregon has aggressively implemented habitat conservation efforts, yet we lack the data necessary to resolve the benefits realized from these efforts by coho populations given the considerable variability in other environmental processes. In short, the recently available abundance information is not necessarily indicative of degraded freshwater habitat conditions, nor is it convincingly suggestive of a declining long-term trend for the ESU. Given the opportunity for further scientific review, it is possible that an improved understanding of the roles marine conditions and stream-nutrient supply play in determining coho population dynamics, might require revision of this determination. In summary, if we had been permitted to consider all the scientific information in the record, and if we had been allowed more time to do a complete scientific review of new information in a manner consistent with our typically thorough and comprehensive analytical processes, there is a reasonable possibility that we would have reached a different final listing determination.

*Consideration of Information in the January 2006 Record*

*Biological Review Team Findings*—The 2003 BRT considered data available through 2002. The abundance and productivity of Oregon Coast coho since the previous status review (NMFS, 1997a) represented some of the best and worst years on record. Yearly adult returns for the Oregon Coast coho ESU were in excess of 160,000 natural spawners in 2001 and 2002, far exceeding the abundance observed for the past several decades. These encouraging increases in spawner abundance in 2000–2002 were preceded, however, by three consecutive brood years (the 1994–1996 brood years returning in 1997–1999, respectively) exhibiting recruitment failure (recruitment failure is when a given year class of natural spawners fails to replace itself when its offspring return to the spawning grounds 3 years later). These 3 years of recruitment failure were the only such instances observed thus far in the entire 55-year abundance time series for Oregon Coast coho salmon (although comprehensive population-level survey data have only been available since 1980). The encouraging 2000–2002 increases in natural spawner abundance occurred in many populations in the northern portion of the ESU, populations that were the most depressed at the time of the last review (NMFS, 1997a). Although encouraged by the increase in spawner abundance in 2000–2002, the BRT noted that the long-term trends in ESU productivity were still negative due to the low abundances observed during the 1990s.

The majority of the BRT felt that the recent increases in coho returns were most likely attributable to favorable ocean conditions and reduced harvest rates. The BRT was uncertain as to whether such favorable marine conditions would continue into the future. Despite the likely benefits to spawner abundance levels gained by the dramatic reduction of harvest rates on Oregon Coast coho populations (PFMC, 1998), harvest cannot be significantly further reduced in the future to compensate for declining productivity due to other factors. The BRT was concerned that if the long-term decline in productivity reflected deteriorating conditions in freshwater habitat, this ESU could face very serious risks of local extirpations if ocean conditions reverted back to poor productivity conditions. Approximately 30 percent of the ESU has suffered habitat fragmentation by culverts and thermal barriers, generating concerns about ESU spatial structure. Additionally, the lack of response to favorable ocean conditions for some populations in smaller streams and the different patterns between north and south coast populations may indicate compromised connectivity among populations. The degradation of many lake habitats and the resultant impacts on several lake populations in the Oregon Coast coho ESU also pose risks to ESU diversity. The BRT noted that hatchery closures, reductions in the number of hatchery smolt releases, and improved marking rates of hatchery fish have significantly reduced risks to diversity associated with artificial propagation.

The BRT found high risk to the ESU's productivity, and comparatively lower risk to the ESU's abundance, spatial structure, and diversity. Informed by this risk assessment, a slight majority of the BRT concluded that the Oregon Coast coho ESU was ''likely to become endangered within the foreseeable future.'' However, a substantial minority of the BRT concluded that the ESU was ''not in danger of extinction or likely to become endangered within the foreseeable future.'' The minority believed that the large number of spawners in 2001–2002 and a high projected abundance for 2003 suggested that this ESU was not ''in danger of extinction'' or ''likely to become endangered within the foreseeable future.'' Furthermore, the minority believed that recent strong returns following 3 years of recruitment failure demonstrated that populations in this ESU are resilient.

*Consideration of Artificial Propagation*—Our review of the five hatchery programs that were proposed to be listed as part of the ESU concluded that they collectively do not substantially reduce the extinction risk of the ESU (NMFS, 2003a, 2004a, 2004b; see proposed rule for a more detailed explanation of this assessment, 69 FR 33102; June 14, 2004). Our final determination that the North Umpqua River, Coos Basin, Coquille River, North Fork Nehalem River, and Fishhawk Lake coho hatchery programs are not part of the ESU does not alter our previous conclusion that artificial propagation does not contribute appreciably to the viability of the ESU.

In *Trout Unlimited* v. *Lohn* (Civ. No. 06–0483–JCC (W. D. Wash., June 13, 2006), the U.S. District Court for the Western District of Washington set aside our 2005 Hatchery Listing Policy, finding that the Policy's consideration of both natural and hatchery fish in ESA listing determinations departs from the ESA's central purpose to promote and conserve naturally self-sustaining populations. Although the extinction risk assessment in the 2006 record evaluated the status of the ESU in-total (including both within-ESU natural and hatchery fish), we found that consideration of artificial propagation does not reduce the risk of extinction of the ESU. Therefore, the above described assessment of extinction risk does not require revision in light of the ruling in the above case.

*Preliminary Results of Oregon Coast Coho Recovery Planning*—NMFS' Technical Recovery Team (TRT) for the Oregon and Northern California Coast is charged with describing the historical population structure, developing biological recovery criteria with which to evaluate the status of an ESU relative to recovery, and identifying those factors limiting or impeding recovery. Prior to our 2006 determination not to list the Oregon Coast coho ESU, the TRT provided a preliminary report on its progress in developing these products for the Oregon Coast coho ESU (NMFS, 2005d). The TRT's preliminary report underscored the uncertainty associated with assessing the future status of the ESU. The TRT stated that ''at this time our evaluation indicates, with a moderate degree of uncertainty, that the ESU is persistent'' (the TRT defines a ''persistent'' ESU as one that is able to persist (i.e., not go extinct) over a 100-year period without artificial support, relating the term to ''the simple risk of extinction, which is the primary determination of endangered status under the ESA''). The TRT further stated that ''our evaluation of biological viability based on current and recent past conditions shows a high degree of uncertainty with respect to the statement that the ESU is sustainable'' (the TRT defines a ''sustainable'' ESU as ''one that, in addition to being persistent, is able to maintain its genetic legacy and long-term adaptive potential for the foreseeable future * * * so that risk of extinction will not increase in the future,'' relating the term to ''threatened status under the ESA'').

*Biological Implications of Ocean-Climate Conditions*—In an August 12, 2005, memorandum, NMFS' Northwest Fisheries Science Center (NWFSC) summarized the most recent information available on West Coast ocean conditions, described observations of impacts on marine communities, and offered predictions of the implications of recent ocean conditions on West Coast salmon stocks, including the Oregon Coast coho ESU (NMFS, 2005e). The memorandum described recent observations of anomalous ocean conditions that may portend lower returns of coho salmon for the fall of 2005 and the next several years. The memorandum noted that indices of ocean-climate variation are suggestive of a regime shift in ocean-climate conditions that in the past have been associated with warmer water temperature, poor primary productivity, and generally less favorable conditions for coho marine survival. The recent in-situ observations confirm delayed coastal upwelling, anomalously warm sea surface temperatures, altered zooplankton community structure, and low survey abundances of juvenile salmon, possibly indicating low marine survival. Strong upwelling occurred in mid-July 2005 resulting in cooler sea surface temperatures, increased primary productivity, and generally more favorable conditions for salmon survival. It was unclear whether this delayed onset of coastal upwelling would compensate for earlier unfavorable conditions which occurred during critical life-history stages for coho salmon. The memorandum noted that model projections indicate that fish populations that prey on juvenile coho salmon may be reduced, possibly compensating somewhat for unfavorable marine survival conditions for coho returns in 2006. The memorandum concluded that the NWFSC was relatively confident that the negative biological implications of recent ocean conditions for the Oregon Coast coho ESU would be dramatic over the next few years.

*Conclusions Regarding the Status of the Oregon Coast Coho ESU*

We conclude, after considering the above information contained in the record of our January 2006 determination (in a manner consistent with the Court's order), that the Oregon Coast coho ESU is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. This finding is based, in part, on the BRT's slight majority conclusion that the ESU is ''likely to become endangered in the foreseeable future.'' The TRT's subsequent preliminary assessment of ESU viability (NMFS, 2005d) was consistent with the BRT's assessment, finding a high degree of uncertainty whether the ESU is sustainable for the foreseeable future. Although returns in 2001 and 2002 were extremely encouraging, there remained concern whether future ocean conditions would favor such high levels of recruitment. The NWFSC's August 2005 memorandum describing the implications of recent ocean-climate conditions (NMFS, 2005e) did not assuage this concern, concluding that recent ocean conditions portended unfavorable marine survival conditions for Oregon Coast coho in the near term.

*Consideration of New Information Since the January 2006 Determination*

The ESA requires that listing determinations be made solely on the basis of the best scientific and commercial data available. To that end, we also considered new status and trend information made available since the 2003 BRT report, and since our January 2006 ''not warranted'' determination to ensure that our present listing determination for the Oregon Coast coho ESU has considered the best information available. We evaluated these new data to determine whether they supported our risk assessment based on the information contained in the January 2006 record alone.

Since the BRT convened in January 2003, the total abundance of natural spawners in the Oregon Coast coho ESU has declined each year (i.e., 2003–2006). The abundance of total natural spawners in 2006 (111,025 spawners) was approximately 43 percent of the recent peak abundance in 2002 (255,372 spawners). In 2003, ESU-level productivity (evaluated in terms of the number of spawning recruits resulting from spawners 3 years earlier) was above replacement (approximately 3.2 recruits per spawner). ESU-level productivity was essentially at replacement in 2004 (approximately 0.99 recruits per spawner), but below replacement in 2005 and 2006. The productivity observed in 2006 (approximately 0.49 recruits per spawner) is the lowest observed since 1991. From 2003–2006 harvest rates remained low, averaging approximately 12 percent of the total run. Marine survival from 2003–2006 (estimated in terms of the number of returning hatchery adults resulting from the number of hatchery smolts released 2 years earlier) was generally at or above the average during 1990–2006. The decline in ESU productivity from 2003–2006, while marine survival conditions were generally favorable, suggests that factors other than ocean conditions are responsible for the decline.

In August 2007, the Oregon and Northern California Coast TRT released a draft report entitled ''Biological Recovery Criteria for the Oregon Coast coho Salmon Evolutionarily Significant Unit'' (Wainwright *et al.*, 2007). This draft report presents biological criteria for assessing the ESU's progress toward recovery, and also applies these criteria in assessing the current biological status of the ESU. The TRT considered the population data available through 2004. This draft report thus represents a more recent assessment of the ESU's status relative to the 2003 BRT's review. The results of the recent draft report are consistent with the TRT's preliminary progress report described above (NMFS, 2005d), finding that there is low to moderate certainty that the ESU is sustainable for the foreseeable future. The recent draft report considered the population data available through 2004, and thus does not reflect the declining abundance and productivity observed in 2005 and 2006.

Preliminary spawner survey data for 2007 (the average peak number of spawners per mile observed during random coho spawning surveys in 41 streams) suggest that the 2007–2008 return of Oregon Coast coho is either (1) much reduced from abundance levels in 2006, or (2) exhibiting delayed run timing from previous years. As of December 13, 2007, the average peak number of spawners per mile was below 2006 levels in 38 of 41 surveyed streams (ODFW, 2007). It is possible that the timing of peak spawner abundance is delayed relative to previous years, and that increased spawner abundance in late December 2007 and January 2008 will compensate for the low levels observed thus far in the 2007–2008 spawning season.

Our review of the above new abundance and productivity information and the TRT's 2007 draft report does not indicate that the status of the Oregon Coast coho ESU has improved since the 2003 BRT report. The recent 5-year geometric mean abundance (2002–2006) of approximately 152,960 total natural spawners remains well above that of a decade ago (approximately 52,845 from 1992–1996). However, the decline in productivity from 2003 to 2006, despite generally favorable marine survival conditions and low harvest rates, is of concern.

After reviewing the scientific and commercial information available in the record concerning the status of the Oregon Coast Coho (in a manner consistent with the Court's order) and adding to the record the Draft 2007 TRT report, 2003–2006 abundance and marine survival information, and preliminary spawner survey information for 2007, we conclude that this information requires a conclusion that the ESU is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. The recent declines in the ESU's abundance and productivity are not necessarily indicative of a substantial degradation of the ESU's status. Similar interannual variability in abundance and productivity has been observed previously for the Oregon Coast coho ESU, and similar variability is expected to occur in the future. The principal inquiry in determining if the ESU warrants listing is whether present habitat conditions are sufficient to support a viable ESU, and whether future freshwater habitat conditions are expected to degrade. The present and future status of freshwater habitat for the Oregon Coast coho ESU remains uncertain. As noted above, we believe that if we had been permitted to consider all the scientific information in the record, and if we had been allowed more time for a complete scientific review of new information in a manner consistent with our typically thorough and comprehensive analytical processes, there is a reasonable possibility that we would have reached a different final listing determination.

**Final Listing Determination**

*Consideration of ESA Section 4(a)(1) Factors*

Section 4(a)(1) of the ESA and NMFS' implementing regulations (50 CFR part 424) requires us to add a species to the

List of Endangered and Threatened Species if it is endangered or threatened because of any one or a combination of the following factors: (1) The present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or human-made factors affecting its continued existence. We have previously detailed the impacts of various factors contributing to the decline of Pacific salmonids as part of our prior listing determinations for 27 ESUs, as well as in supporting technical reports (e.g., NMFS, 1997b, ''Coastal coho habitat factors for decline and protective efforts in Oregon;'' NMFS, 1997c, ''Factors Contributing to the Decline of Chinook Salmon—An Addendum to the 1996 West Coast Steelhead Factors for Decline Report;'' NMFS, 1996a, ''Factors for Decline—A Supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act''). Our prior listing determinations and technical reports concluded that all of the factors identified in section 4(a)(1) of the ESA have played a role in the decline of West Coast salmon and steelhead. In our 1998 threatened listing determination for the Oregon Coast coho ESU (63 FR 42588; August 10, 1998), we concluded that the decline of Oregon Coast coho populations is the result of several longstanding, human-induced factors (e.g., habitat degradation, water diversions, harvest, and artificial propagation) that exacerbate the adverse effects of natural environmental variability (e.g., floods, drought, and poor ocean conditions). The following discussion briefly summarizes our findings regarding the threats currently facing the Oregon Coast coho ESU. While these threats are treated in general terms, it is important to underscore that impacts from certain threats are more acute for some populations in the ESU.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

In many Oregon coastal streams, past human activities (e.g., logging, agriculture, gravel mining, urbanization) have resulted in impediments to fish passage, degradation of stream complexity, increased sedimentation, reduced water quality and quantity, loss and degradation of riparian habitats, and loss and degradation of lowland, estuarine, and wetland coho rearing habitats. The relevant issues are whether current habitat conditions are adequate to support the ESU's persistence (that is, whether the species is endangered or threatened because of present destruction, modification, or curtailment of its habitat or range) and whether habitat conditions are likely to worsen in the future (that is, whether the species is endangered or threatened because of threatened destruction, modification, or curtailment of its habitat or range). Regarding the first issue, the 2003 BRT noted uncertainty about the adequacy of current habitat conditions, and this uncertainty contributed to the slight majority finding that the ESU was likely to become an endangered species within the foreseeable future.

Regarding the second issue, the threat of future habitat declines, the 2003 BRT noted that ''if the long-term decline in productivity [of the Oregon Coast coho ESU] reflects deteriorating conditions in freshwater habitat, this ESU could face very serious risks of local extinction during the next cycle of poor ocean conditions.'' The BRT thus identified potential future habitat declines as a potential concern. As part of our January 2006 determination we evaluated the likely future trend of various habitat elements and the likely impact of future population growth (NMFS, 2005a). With respect to population growth and urbanization, we found that approximately 3.4 percent of ''high intrinsic potential'' habitat areas for coho (e.g., lowland stream reaches particularly important to juvenile coho rearing and overwintering survival) are within currently designated urban growth areas, suggesting that future human population growth may not represent a significant threat to the ESU (NMFS, 2005a). With respect to lowland and upland habitat areas under various types of land use and ownership, we found that some areas are likely to improve, some are likely to decline, and others are likely to remain in their current condition. Overall, there is a high level of uncertainty associated with projections of future habitat conditions due to underlying economic and sociopolitical factors influencing forest harvest and restoration rates, urban conversion of agricultural and forest lands, and the enforcement and implementation of land-use plans and regulations. Based on our analysis, we found that there is insufficient evidence to conclude that the Oregon Coast coho ESU was more likely than not to become an endangered species because of the ''threatened destruction, modification, or curtailment of its habitat or range.'' It remains uncertain whether future freshwater habitat conditions will be adequate to support a viable coho ESU, particularly during periods of unfavorable ocean conditions and poor marine survival.

B. Overutilization for Commercial, Recreational, Scientific or Educational Purposes

Harvest rates on Oregon Coast coho populations ranged between 60 and 90 percent between the 1960s and 1980s (Good *et al.*, 2005). Modest harvest restrictions were imposed in the late 1980s, but harvest rates remained high until most directed coho salmon harvest was prohibited in 1994. These restrictive harvest regulations, developed concurrently with the Oregon Plan and subsequently revised, have imposed conservative restrictions on directed and incidental fishery mortality, and appropriately consider marine survival conditions and the biological status of naturally produced coho populations. Under these revised regulations, harvest rates are stipulated to be between 0 and 8 percent during critically low spawner abundance, and may increase to a maximum exploitation rate of 45 percent under high survival and abundance conditions (Oregon, 2005). Empirical data over the last 10 years show that harvest mortality for Oregon Coast coho has been maintained below 15 percent since the adoption of the revised regulations (Oregon, 2005). We agree with the 2003 BRT's finding that overutilization has been effectively addressed for Oregon Coast coho populations.

C. Disease or Predation

Past species introductions and habitat modifications have resulted in increased non-native predator populations, notably in coastal lake habitats. Predation by increased populations of marine mammals (principally sea lions) may influence salmon abundance in some local populations when other prey species are absent and where physical conditions lead to the concentration of adults and juveniles (e.g., Cooper and Johnson, 1992). However, the extent to which marine mammal predation threatens the persistence of Oregon coast coho populations is unknown.

Infectious disease is one of many factors that can influence adult and juvenile salmon survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Specific diseases such as bacterial kidney disease, ceratomyxosis, columnaris, furunculosis, infectious hematopoietic necrosis virus, redmouth and black spot disease, erythrocytic inclusion body syndrome, and whirling disease, among others, are present and known to affect West Coast salmonids (Rucker *et al.*, 1953; Wood, 1979; Leek, 1987; Foott *et al.*, 1994; Gould and Wedemeyer, undated). In general, very little current or historical information exists to quantify trends over time in infection levels and disease mortality rates. However, studies have shown that naturally spawned fish tend to be less susceptible to pathogens than hatchery-reared fish (Buchanon *et al.*, 1983; Sanders *et al.*, 1992). Native salmon populations have co-evolved with specific communities of these organisms, but the widespread use of artificial propagation has introduced exotic organisms not historically present in a particular watershed. Habitat conditions such as low water flows and high temperatures can exacerbate susceptibility to infectious diseases.

Aggressive hatchery reform efforts implemented by the State of Oregon have reduced the magnitude and distribution of hatchery fish releases in the ESU, and, consequently, the interactions between hatchery- and natural-origin fish and the potential transmission of infectious diseases. Additionally, regulations controlling hatchery effluent discharges into streams have reduced the potential of pathogens being released into coho habitats.

D. The Inadequacy of Existing Regulatory Mechanisms

Existing regulations governing coho harvest have dramatically improved the ESU's likelihood of persistence. These regulations are unlikely to be weakened in the future. Of the wide range of land uses and other activities affecting salmon habitat, however, some are more amenable to regulation than others. In the range of Oregon Coast coho, the regulation of some activities and land uses will alter past harmful practices, resulting in habitat improvements; the regulation of other activities is inadequate to alter past harmful practices, resulting in habitat conditions continuing in their present state; and the regulation of still other activities and land uses will lead to further degradation (NMFS, 2005a).

E. Other Natural or Manmade Factors Affecting Its Continued Existence

Natural variability in ocean and freshwater conditions has at different times exacerbated or mitigated the effects on Oregon Coast coho populations of habitat limiting factors. There is considerable uncertainty in predicting ocean-climate conditions into the foreseeable future and their biological impacts on the Oregon Coast coho ESU. Variability in ocean-climate conditions is expected, and coho productivity and abundance are similarly expected to fluctuate in response to this natural environmental variability. It is unknown whether unfavorable ocean conditions will predominate in the foreseeable future.

Prior to the 1990s, coho hatchery programs along the Oregon coast posed substantial risks to the survival, reproductive fitness, and diversity of natural populations. High numbers of hatchery coho were released in most of the basins in the ESU, most programs propagated non-native broodstocks, and naturally spawning hatchery-origin strays were common in most natural production areas. Oregon's aggressive hatchery reform efforts have resulted in substantial reductions of this threat. Hatchery coho are released in less than half of the populations in the ESU, and the magnitude of releases has declined from a peak of 35 million smolts in 1981, to approximately 800,000 in 2005. Hatchery programs are currently constrained to releasing no more than 200,000 smolts in any basin. The reduction in the number of hatchery fish released has reduced the potential for competition with, and predation on, natural coho. The proportion of hatchery-origin fish in natural spawning areas has been reduced to below 10 percent in all but two populations in the ESU. All hatchery coho releases in the ESU are now marked, affording improved monitoring and assessment of the co-existing naturally produced coho populations. Broodstock management practices have been modified to minimize the potential for hatchery-origin fish to pose risks to the genetic diversity of local natural populations. We conclude the ESU is not in danger of extinction or likely to become endangered in the foreseeable future because of hatchery practices.

**Efforts Being Made To Protect the Species**

Section 4(b)(1)(A) of the ESA requires the Secretary to make listing determinations solely on the basis of the best scientific and commercial data available after taking into account efforts being made to protect a species. In making listing determinations we first assess the species' level of extinction risk, identify factors that threaten its continued existence, and assess existing efforts being made to protect the species to determine if those measures ameliorate the risks it faces. The reader is referred to the June 14, 2004, proposed rule for a summary of efforts, including those under the Oregon Plan, being made to protect Oregon Coast coho populations (69 FR 33102, at 33142). Harvest reductions and improvements in hatchery management are noteworthy in that they have been fully implemented and their effectiveness is manifested in the improved status of Oregon Coast coho populations. The benefits of these accomplishments in hatchery and harvest management under the Oregon Plan, however, were fully considered in the 2003 BRT's assessment of ESU extinction risk. In our June, 14, 2004, proposed listing for the Oregon Coast coho ESU (69 FR 33102), we evaluated all other relevant protective efforts and determined that they did not substantially alter our finding that the ESU is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Since our January 2006 determination, the State of Oregon released a draft Coho Conservation Plan for Oregon Coast coho. The draft Conservation Plan culminated a 2-year development process including significant input and involvement from local stakeholders. The draft conservation plan establishes ambitious conservation goals and is an important step in describing limiting factors and threats, identifying specific conservation actions to address these factors and threats, and designing a robust research and monitoring program to evaluate the effectiveness of conservation actions that contribute to rebuilding the Oregon Coast coho ESU. As reflected in the comments that we provided on the draft Conservation Plan (NMFS, 2007e), the plan lacks the necessary detail, specificity, and commitment of resources to provide sufficient certainty of implementation and effectiveness to alter our assessment that the ESU is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

**Final Listing Determination**

The ESA defines an endangered species as any species in danger of extinction throughout all or a significant portion of its range, and a threatened species as any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Section 4(b)(1) of the ESA requires that the listing determination be based solely on the best scientific and commercial data available, after conducting a review of the status of the species and taking into account those efforts, if any, being made to protect such species.

The information included in the record of our January 2006 determination (as the Court has ordered us to consider it) indicates that the Oregon Coast coho ESU is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. New abundance and productivity data do not suggest that the ESU's biological status has improved since our January 2006 determination. Efforts being made to protect the species, at present, do not provide sufficient certainty of implementation or effectiveness to mitigate the assessed level of extinction risk. Therefore, we conclude that the Oregon Coast coho ESU warrants listing under the ESA as a threatened species.

**Prohibitions and Protective Regulations**

On June 28, 2005, as part of the final listing determinations for 16 ESUs of West Coast salmon, we amended and streamlined the previously promulgated ESA section 4(d) regulations for threatened salmon and steelhead (70 FR 37160). We finalized an amendment to provide the necessary flexibility to ensure that fisheries and artificial propagation programs are managed consistently with the conservation needs of threatened salmon and steelhead. Under this change the section 4(d) protections apply to natural and hatchery fish with an intact adipose fin, but not to listed hatchery fish that have had their adipose fin removed prior to release into the wild. Additionally, we made several simplifying and clarifying changes to the 4(d) regulations, including updating an expired limit (section 223.203(b)(2)), providing a temporary exemption for ongoing research and enhancement activities, and applying the same set of 14 limits to all threatened salmon and steelhead.

*Description of Protective Regulations Being Afforded Oregon Coast Coho*

Consistent with the June 2005 amended ESA section 4(d) regulations, this final rule applies the ESA section 9(a)(1) take and other prohibitions (subject to the ''limits'' discussed below) to unmarked members of the Oregon Coast coho ESU with an intact adipose fin. (The clipping of adipose fins in juvenile hatchery fish just prior to release into the natural environment is a commonly employed method for the marking of hatchery production). We believe this approach provides needed flexibility to appropriately manage the artificial propagation and directed take of threatened salmon and steelhead for the conservation and recovery of the listed species.

The June 2005 amended ESA section 4(d) regulations simplified the previously promulgated 4(d) rules by applying the same set of 14 ''limits'' to all threatened salmon and steelhead. These limits allow us to exempt certain activities from the take prohibitions, provided that the applicable programs and regulations meet specific conditions to adequately protect the listed species. In this final rule we are applying this same set of 14 limits to the Oregon Coast coho ESU. Comprehensive descriptions of each 4(d) limit are contained in ''A Citizen's Guide to the 4(d) Rule'' (available on the Internet at *http://www.nwr.noaa.gov*), and in previously published **Federal Register** notices (65 FR 42422, July 10, 2000; 65 FR 42485, July 10, 2000; 69 FR 33102; June 14, 2004; 70 FR 37160, June 28, 2005). These ''limits'' include: activities conducted in accordance with ESA section 10 incidental take authorization (50 CFR 223.203(b)(1)); scientific or artificial propagation activities with pending permit applications at the time of rulemaking (§ 223.203(b)(2)); emergency actions related to injured, stranded, or dead salmonids (§ 223.203(b)(3)); fishery management activities (§ 223.203(b)(4)); hatchery and genetic management programs (§ 223.203(b)(5)); activities in compliance with joint tribal/state plans developed within *United States (U.S.)* v. *Washington* or *U.S.* v. *Oregon* (§ 223.203(b)(6)); scientific research activities permitted or conducted by the states (§ 223.203(b)(7)); state, local, and private habitat restoration activities (§ 223.203(b)(8)); properly screened water diversion devices (§ 223.203(b)(9)); routine road maintenance activities (§ 223.203(b)(10)); certain park pest management activities (§ 223.203(b)(11)); certain municipal, residential, commercial, and industrial development and redevelopment activities (§ 223.203(b)(12)); management activities on state and private lands within the State of Washington (§ 223.203(b)(13)); and activities undertaken consistent with an approved tribal resource management plan (§ 223.204).

Limit § 223.203(b)(2) exempts scientific or artificial propagation activities with pending applications for ESA section 4(d) approval. The limit was amended as part of the June 28, 2005, final rule to temporarily exempt such activities from the take prohibitions during a ''grace period,'' provided that a complete application for 4(d) approval was received within a specified period from the notice's publication (70 FR 37160). The limit was again modified in February 2006 when the 4(d) regulations were extended to the Upper Columbia River steelhead DPS (71 FR 5178; February 1, 2006). The deadlines associated with this exemption have expired. Consistent with the 2004 proposed rule to list Oregon Coast coho and extend 4(d) regulations to the ESU (69 FR 33102; June 14, 2004), we believe it is necessary and advisable for the conservation and recovery of Oregon Coast coho to allow research and enhancement activities to continue uninterrupted while we process the necessary permits and approvals. Provided we receive a complete application by June 10, 2008, the take prohibitions will not apply to research and enhancement activities which affect Oregon Coast coho until the application is rejected as insufficient, a permit or 4(d) approval is issued, or until March 31, 2009, whichever occurs earliest. The length of this ''grace period'' is necessary because we process applications for 4(d) approval annually.

*Other Protective ESA Provisions*

Section 7(a)(4) of the ESA requires that Federal agencies confer with NMFS on any actions likely to jeopardize the continued existence of a species proposed for listing and on actions likely to result in the destruction or adverse modification of proposed critical habitat. For listed species, section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or conduct are not likely to jeopardize the continued existence of a listed species or to destroy or adversely modify its critical habitat. If a proposed Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into consultation with NMFS or the FWS, as appropriate. Examples of Federal actions likely to affect salmon include authorized land management activities of the USFS and the BLM, as well as operation of hydroelectric and storage projects of the Bureau of Reclamation (BOR) and the U.S. Army Corps of Engineers (USACE). Such activities include timber sales and harvest, permitting livestock grazing, hydroelectric power generation, and flood control. Federal actions, including the USACE section 404 permitting activities under the Clean Water Act, USACE permitting activities under the River and Harbors Act, Federal Energy Regulatory Commission (FERC) licenses for non-Federal development and operation of hydropower, and Federal salmon hatcheries, may also require consultation.

Sections 10(a)(1)(A) and 10(a)(1)(B) of the ESA provide NMFS with authority to grant exceptions to the ESA's ''take'' prohibitions. Section 10(a)(1)(A) scientific research and enhancement permits may be issued to entities (Federal and non-Federal) conducting research that involves a directed take of listed species. A directed take refers to the intentional take of listed species. We have issued section 10(a)(1)(A) research/enhancement permits for currently listed ESUs for a number of activities, including trapping and tagging, electroshocking to determine population presence and abundance, removal of fish from irrigation ditches, and collection of adult fish for artificial propagation programs. Section 10(a)(1)(B) incidental take permits may be issued to non-Federal entities performing activities which may incidentally take listed species. The types of activities potentially requiring a section 10(a)(1)(B) incidental take permit include the operation and release of artificially propagated fish by state or privately operated and funded hatcheries, state or academic research that may incidentally take listed species, the implementation of state fishing regulations, logging, road building, grazing, and diverting water into private lands.

## Identification of Those Activities That Would Constitute a Violation of Section 9 of the ESA

NMFS and the FWS published in the **Federal Register** on July 1, 1994 (59 FR 34272), a policy that NMFS shall identify, to the maximum extent practicable at the time a species is listed, those activities that would or would not constitute a violation of section 9 of the ESA. The intent of this policy is to increase public awareness of the effect of this listing on proposed and ongoing activities within the species' range. At the time of the final rule, we must identify to the extent known specific activities that will not be considered likely to result in violation of section 9, as well as activities that will be considered likely to result in violation. We believe that, based on the best available information, the following actions will not result in a violation of section 9:

1. Possession of fish from the Oregon Coast coho ESU that are acquired lawfully by permit issued by NMFS pursuant to section 10 of the ESA, or by the terms of an incidental take statement issued pursuant to section 7 of the ESA; or

2. Federally funded or approved projects that involve activities such as silviculture, grazing, mining, road construction, dam construction and operation, discharge of fill material, stream channelization or diversion for which section 7 consultation has been completed, and when activities are conducted in accordance with any terms and conditions provided by NMFS in an incidental take statement accompanying a biological opinion.

There are many activities that we believe could potentially take salmon by harming them. ''Harm'' is defined by our regulations as ''an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering'' (50 CFR 222.102 (harm)). Activities that may harm the Oregon Coast coho ESU resulting in a violation of the section 9 take and other prohibitions, include, but are not limited to:

1. Land-use activities that degrade habitats for the Oregon Coast coho ESU (e.g., logging, grazing, farming, urban development, road construction in riparian areas and areas susceptible to mass wasting and surface erosion);

2. Destruction/alteration of the habitats for the Oregon Coast coho ESU, such as removal of large woody debris and ''sinker logs'' or riparian shade canopy, dredging, discharge of fill material, draining, ditching, diverting, blocking, gravel mining, or altering stream channels or surface or ground water flow;

3. Discharges or dumping of toxic chemicals or other pollutants (e.g., sewage, oil, gasoline) into waters or riparian areas supporting the Oregon Coast coho ESU;

4. Violation of discharge permits;

5. Application of pesticides affecting water quality or riparian areas for the Oregon Coast coho ESU;

6. Interstate and foreign commerce of fish from the Oregon Coast coho ESU and import/export of fish from the Oregon Coast coho ESU without a threatened or endangered species permit;

7. Collecting or handling of fish from the Oregon Coast coho ESU. Permits to conduct these activities are available for purposes of scientific research or to enhance the conservation or survival of the species; and

8. Introduction of non-native species likely to prey on fish from the Oregon Coast coho ESU or displace them from their habitat.

These lists are not exhaustive. They are intended to provide some examples of the types of activities that might or might not be considered by NMFS as constituting a take of fish in the Oregon Coast coho ESU under the ESA and its regulations. Questions regarding whether specific activities would constitute a violation of the section 9 take and other prohibitions, and general inquiries regarding prohibitions and permits, should be directed to NMFS (see **ADDRESSES**).

## Designating Critical Habitat

## Methods and Criteria Used to Designate Critical Habitat

The following paragraphs and sections describe the relevant definitions and guidance found in the ESA and our implementing regulations, and the key methods and criteria we used to designate critical habitat after incorporating, as appropriate, comments and information received on the proposed rule.

Section 4 of the ESA (16 U.S.C. 1533(b)(2) and our regulations at 50 CFR 424.12(a) require that we designate critical habitat, and make revisions thereto, ''on the basis of the best scientific data available.'' Section 3 of the ESA (16 U.S.C. 1532(5)) defines critical habitat as ''(i) the specific areas within the geographical area occupied by the species, at the time it is listed * * * on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed upon a determination by the Secretary that such areas are essential for the conservation of the species.'' Section 3 of the ESA (16 U.S.C. 1532(3)) also defines the terms ''conserve,'' ''conserving,'' and ''conservation'' to mean ''to use, and the use of, all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary.''

Pursuant to our regulations, when identifying physical or biological features essential to conservation, we consider the following requirements of the species: (1) Space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing of offspring;

and, generally, (5) habitats that are protected from disturbance or are representative of the historical geographical and ecological distributions of the species (see 50 CFR 424.12(b)). In addition to these factors, we also focus on the more specific primary constituent elements (PCEs) within the occupied areas that are essential to the conservation of the species. The regulations identify PCEs as including, but not limited to: ''roost sites, nesting grounds, spawning sites, feeding sites, seasonal wetland or dryland, water quality or quantity, host species or plant pollinator, geological formation, vegetation type, tide, and specific soil types.'' For an area containing PCEs to meet the definition of critical habitat, we must conclude that the PCEs in that area ''may require special management considerations or protection.'' Our regulations define special management considerations or protection as ''any methods or procedures useful in protecting physical and biological features of the environment for the conservation of listed species.'' Both the ESA and our regulations, in recognition of the divergent biological needs of species, establish criteria that are species specific rather than a ''one size fits all'' approach.

Our regulations state that, ''[t]he Secretary shall designate as critical habitat areas outside the geographic area presently occupied by the species only when a designation limited to its present range would be inadequate to ensure the conservation of the species' (50 CFR 424.12(e)). Accordingly, when the best available scientific data do not demonstrate that the conservation needs of the species so require, we will not designate critical habitat in areas outside the geographic area occupied by the species.

Section 4 of the ESA (16 U.S.C. 1533(b)(2)) requires that, before designating critical habitat, we consider the economic impacts, impacts on national security, and other relevant impacts of specifying any particular area as critical habitat, and the Secretary may exclude any area from critical habitat if the benefits of exclusion outweigh the benefits of designation, unless excluding an area from critical habitat will result in the extinction of the species. This exercise of discretion must be based upon the best scientific and commercial data. Once critical habitat for a salmon or steelhead ESU is designated, section 7(a)(2) of the ESA requires that each Federal agency, in consultation with and with the assistance of NMFS, ensure that any action they authorize, fund, or carry out is not likely to result in the destruction or adverse modification of critical habitat.

**Identifying the Geographical Area Occupied by the Species and Specific Areas Within the Geographical Area**

In past critical habitat designations, we had concluded that the limited availability of species distribution data prevented mapping salmonid critical habitat at a scale finer than occupied river basins (65 FR 7764; February 16, 2000). Therefore, the 2000 designations defined the ''geographical area occupied by the species, at the time of listing'' as all accessible river reaches within the current range of the listed species.

In the 2004 proposed rule to designate critical habitat for 13 ESUs of Pacific salmon and steelhead (69 FR 74572; December 14, 2004) we described in greater detail that, since the previous designations in 2000, we can now be more precise about the ''geographical area occupied by the species'' because Federal, state, and tribal fishery biologists have made progress documenting and mapping actual species distribution at the level of stream reaches. Moreover, much of the available data can now be accessed and analyzed using Geographic Information System (GIS) software to produce consistent and fine-scale maps (NMFS, 2007b; StreamNet, 2005). The current maps document fish presence by identifying occupied stream reaches where the species has been observed. It also identifies stream reaches where the species is presumed to occur based on the professional judgment of biologists familiar with the watershed (although in some cases there are streams classified as occupied based on professional judgment when in fact the species has been observed but the GIS data have not been updated). We made use of these finer-scale data for the final critical habitat designations for 12 Pacific Northwest ESUs (70 FR 52630; September 2, 2005), as well as for the current critical habitat designation. We believe that this approach enables a more accurate delineation of the ''geographical area occupied by the species'' referred to in the ESA definition of critical habitat. We received some comments on this approach, some in support and some against it (see comments in final critical habitat designations for 12 Pacific Northwest ESUs, 70 FR 52630, September 2, 2005). However, none of the latter comments described a specific methodology that would yield a better approach than what we used.

We are now also able to identify ''specific areas'' (ESA section 3(5)(a)) and ''particular areas'' (ESA section 4(b)(2)) at a finer scale than in 2000. Since 2000, various Federal agencies have mapped fifth field hydrologic units (referred to as ''HUC5s'' or ''watersheds'') throughout the Pacific Northwest using USGS mapping conventions (Seaber *et al.*, 1986). This information is now generally available via the internet (NMFS, 2007b), and we have expanded our GIS resources to use these data. As in the 2000 designations (in which we used larger fourth field hydrologic units), we used the HUC5s to organize critical habitat information systematically and at a scale that is applicable to the spatial distribution of salmon. Organizing information at this scale is especially relevant to salmonids, since their innate homing ability allows them to return to the watersheds where they were born. Such site fidelity results in spatial aggregations of salmonid populations that generally correspond to the area encompassed by subbasins or HUC5 watersheds (Washington Department of Fisheries *et al.*, 1992; Kostow, 1995; McElhany *et al.*, 2000). As noted above regarding our use of finer scale data, none of the comments received provided us with a specific alternative methodology that would yield a better approach than the watershed-scale approach we adopted.

The USGS maps watershed units as polygons, bounding a drainage area from ridge-top to ridge-top, encompassing streams, riparian areas and uplands. Within the boundaries of any watershed, there are stream reaches not occupied by the species. Land areas within the HUC5 boundaries are also generally not ''occupied'' by the species (though certain areas such as flood plains or side channels may be occupied at some times of some years). We used the watershed boundaries as a basis for aggregating occupied stream reaches, for purposes of delineating ''specific'' areas at a scale that often corresponds well to salmonid population structure and ecological processes. Although we are designating only the streams and not the entire watershed, our documents frequently refer to the ''specific areas'' as ''watersheds'' because that is the term often used as a convenient shorthand. We also refer to the stream reaches as ''habitat areas.'' Each watershed was reviewed by the CHART to verify occupation, PCEs, and special management considerations (see ''Critical Habitat Analytical Review Team'' section below).

The watershed-scale aggregation of stream reaches also allowed us to analyze the impacts of designating a ''particular area,'' as required by ESA section 4(b)(2). As a result of watershed processes, many activities occurring in riparian or upland areas and in non-fish-bearing streams may affect the physical or biological features essential to conservation in the occupied stream reaches. The watershed boundary thus describes an area in which Federal activities have the potential to affect critical habitat (Spence *et al.*, 1996). Using watershed boundaries for the economic analysis ensured that all potential economic impacts were considered. Section 3(5) defines critical habitat in terms of ''specific areas,'' and section 4(b)(2) requires the agency to consider certain factors before designating ''particular areas.'' In the case of West Coast salmon and steelhead, the biology of the species, the characteristics of their habitat, the nature of the impacts, and the limited information currently available at finer geographic scales made it appropriate to consider ''specific areas'' and ''particular areas'' as the same unit for purposes of economic exclusions.

Occupied estuarine and marine areas were also considered in the context of defining ''specific areas.'' In our proposed rule (69 FR 74572; December 14, 2004) we noted that estuarine areas are crucial for juvenile salmonids, given their multiple functions as areas for rearing/feeding, freshwater-saltwater acclimation, and migration (Simenstad *et al.*, 1982; Marriott *et al.*, 2002). Within the geographic range of the Oregon Coast coho ESU all estuaries fall within the boundaries of a HUC5 and so were assessed along with upstream freshwater habitats within the watershed. In all occupied estuarine areas we were able to identify physical or biological features essential to the conservation of the species, and that may require special management considerations or protection. For those estuarine areas designated as critical habitat we are again delineating them in similar terms to our past designations, as being defined by a line connecting the furthest land points at the estuary mouth.

In previous designations of salmonid critical habitat we did not designate offshore marine areas (with the exception of deep waters in Puget Sound (65 FR 7764, February 16, 2000; 70 FR 52630, September 2, 2005). In the Pacific Ocean, we concluded that there may be essential habitat features, but we could not identify any special management considerations or protection associated with them as required under section 3(5)(A)(I) of the ESA (65 FR 7776; February 16, 2000). Since that time we have carefully considered the best available scientific information, and related agency actions, such as the designation of Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act. We believe that forage species are a feature in the Pacific Ocean that are essential for salmon conservation and that may require special management considerations or protection, at least for those forage species that are a target of human harvest. However, because salmonids are opportunistic feeders we could not identify ''specific areas'' beyond the nearshore marine zone where these or other essential features are found within this vast geographic area occupied by salmon and steelhead. In contrast to estuarine and nearshore areas, we conclude that it is not possible to identify ''specific areas'' in the Pacific Ocean that contain essential features for salmonids, and, therefore, we are not designating critical habitat in offshore marine areas. We requested comment on this issue in our proposed rule but did not receive comments or information that would change our conclusion (70 FR 52630, September 2, 2005).

*Primary Constituent Elements*

In determining what areas are critical habitat, agency regulations at 50 CFR 424.12(b) require that we ''consider those physical or biological features that are essential to the conservation of a given species * * *, including space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, and rearing of offspring; and habitats that are protected from disturbance or are representative of the historical geographical and ecological distribution of a species.'' The regulations further direct us to ''focus on the principal biological or physical constituent elements * * * that are essential to the conservation of the species,'' and specify that the ''known primary constituent elements shall be listed with the critical habitat description.'' The regulations identify PCEs as including, but not limited to: ''roost sites, nesting grounds, spawning sites, feeding sites, seasonal wetland or dryland, water quality or quantity, host species or plant pollinator, geological formation, vegetation type, tide, and specific soil types.''

NMFS biologists developed a list of PCEs that are essential to the species' conservation and based on the unique life history of salmon and steelhead and their biological needs (Hart, 1973; Beauchamp *et al.*, 1983; Laufle *et al.*, 1986; Pauley *et al.*, 1986, 1988, and 1989; Groot and Margolis, 1991; Spence *et al.*, 1996). Guiding the identification of PCEs was a decision matrix we developed for use in ESA section 7 consultations (NMFS, 1996b) which describes general parameters and characteristics of most of the essential features under consideration in this critical habitat designation. We identified these PCEs and requested comment on them in the advance notice of proposed rulemaking (ANPR)(68 FR 55931; September 29, 2003) and proposed rule (69 FR 74636; December 14, 2005) but did not receive information to support changing them. These PCEs include sites essential to support one or more life stages of the ESU (sites for spawning, rearing, migration and foraging). These sites in turn contain physical or biological features essential to the conservation of the ESU (for example, spawning gravels, water quality and quantity, side channels, forage species). The specific PCEs include:

1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. These features are essential to conservation because without them the species cannot successfully spawn and produce offspring.

2. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. These features are essential to conservation because without them juveniles cannot access and use the areas needed to forage, grow, and develop behaviors (e.g., predator avoidance, competition) that help ensure their survival.

3. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner. Similarly, these features are essential for adults because they allow fish in a non-feeding condition to successfully swim

upstream, avoid predators, and reach spawning areas on limited energy stores.

4. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation. These features are essential to conservation because without them juveniles cannot reach the ocean in a timely manner and use the variety of habitats that allow them to avoid predators, compete successfully, and complete the behavioral and physiological changes needed for life in the ocean. Similarly, these features are essential to the conservation of adults because they provide a final source of abundant forage that will provide the energy stores needed to make the physiological transition to fresh water, migrate upstream, avoid predators, and develop to maturity upon reaching spawning areas.

5. Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels. As in the case with freshwater migration corridors and estuarine areas, nearshore marine features are essential to conservation because without them juveniles cannot successfully transition from natal streams to offshore marine areas. We have focused our designation on nearshore areas in Puget Sound because of its unique and relatively sheltered fjord-like setting (as opposed to the more open coastlines of Washington and Oregon).

6. Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation. These features are essential for conservation because without them juveniles cannot forage and grow to adulthood. However, for the reasons stated previously in this document, it is difficult to identify specific areas containing this PCE as well as human activities that may affect the PCE condition in those areas. Therefore, we have not designated any specific areas based on this PCE but instead have identified it because it is essential to the species' conservation, and specific offshore areas may be identified in the future (in which case any revision to this designation would be subject to separate rulemaking).

The occupied habitat areas designated in this final rule contain PCEs required to support the biological processes for Oregon Coast coho using the habitat. The CHART verified this for each watershed/nearshore zone by relying on the best available scientific data (including species distribution maps, watershed analyses, and habitat surveys) during its review of occupied areas and resultant assessment of area conservation values (NMFS, 2007b). The contribution of the PCEs varies by site and biological function such that the quality of the elements may vary within a range of acceptable conditions. The CHART took this variation into account when it assessed the conservation value of an area.

Special Management Considerations or Protections

An occupied area meets the definition of critical habitat only if it contains physical and biological features that ''may require special management considerations or protection.'' Agency regulations at 50 CFR 424.02(j) define ''special management considerations or protection'' to mean ''any methods or procedures useful in protecting physical and biological features of the environment for the conservation of listed species.''

As part of the biological assessment described below under ''Critical Habitat Analytical Review Team,'' a team of biologists examined each habitat area to determine whether the physical or biological features may require special management consideration. These determinations are identified for each area in the final CHART report for the Oregon Coast coho ESU (NMFS, 2007b). Consistent with the final critical habitat designations for 12 Pacific Northwest ESUs (70 FR 52630; September 2, 2005), the CHART identified a variety of activities that threaten the physical and biological features essential to listed salmon and steelhead (see review by Spence *et al.*, 1996), including: (1) Forestry; (2) grazing; (3) agriculture; (4) road building/maintenance; (5) channel modifications/diking; (6) urbanization; (7) sand and gravel mining; (8) mineral mining; (9) dams; (10) irrigation impoundments and withdrawals; (11) river, estuary, and ocean traffic; (12) wetland loss/removal; (13) beaver removal; and (14) exotic/invasive species introductions. In addition to these, the harvest of salmonid prey species (e.g., forage fishes such as herring, anchovy, and sardines) may present another potential habitat-related management activity (Pacific Fishery Management Council, 1999).

*Unoccupied Areas*

ESA section 3(5)(A)(ii) defines critical habitat to include ''specific areas outside the geographical area occupied'' if the areas are determined by the Secretary to be ''essential for the conservation of the species.'' NMFS regulations at 50 CFR 424.12(e) emphasize that we ''shall designate as critical habitat areas outside the geographical area presently occupied by a species only when a designation limited to its present range would be inadequate to ensure the conservation of the species.'' For the Oregon Coast coho ESU we are not designating unoccupied areas at this time. The CHART did not identify any unoccupied areas that may be essential for the conservation of the Oregon Coast coho ESU. Thus, we are not designating any unoccupied areas at this time. Any future designation of unoccupied areas would be based on the required determination that such area is essential for the conservation of the ESU and would be subject to separate rulemaking with the opportunity for notice and comment.

*Lateral Extent of Critical Habitat*

In past designations we have described the lateral extent of critical habitat in various ways, ranging from fixed distances to ''functional'' zones defined by important riparian functions (65 FR 7764; February 16, 2000). Both approaches presented difficulties, and this was highlighted in several comments (most of which requested that we focus on aquatic areas only) received in response to the ANPR (68 FR 55926; September 29, 2003). Designating a set riparian zone width will (in some places) accurately reflect the distance from the stream on which PCEs might be found, but in other cases may over- or understate the distance. Designating a functional buffer avoids that problem, but makes it difficult for Federal agencies to know in advance what areas are critical habitat. To address these issues we have defined the lateral extent of designated critical habitat as the width of the stream channel defined by the ordinary high-water line as defined by the USACE in 33 CFR 329.11. This approach is consistent with the specific mapping requirements described in agency regulations at 50 CFR 424.12(c)). In areas for which ordinary high-water has not been defined pursuant to 33 CFR 329.11, the width of the stream channel shall be defined by its bankfull elevation. Bankfull elevation is the level at which water begins to leave the channel and move into the floodplain

(Rosgen, 1996) and is reached at a discharge which generally has a recurrence interval of 1 to 2 years on the annual flood series (Leopold *et al.*, 1992). Such an interval is commensurate with the juvenile freshwater life phases of coho salmon. Therefore, it is reasonable to conclude that for an occupied stream reach this lateral extent is regularly ''occupied.'' Moreover, the bankfull elevation can be readily discerned for a variety of stream reaches and stream types using recognizable water lines (e.g., marks on rocks) or vegetation boundaries (Rosgen, 1996).

As underscored in previous critical habitat designations, the quality of aquatic habitat within stream channels is intrinsically related to the adjacent riparian zones and floodplain, to surrounding wetlands and uplands, and to non-fish-bearing streams above occupied stream reaches. Human activities that occur outside the stream can modify or destroy physical and biological features of the stream. In addition, human activities that occur within and adjacent to reaches upstream (e.g., road failures) or downstream (e.g., culverts and dams) of designated stream reaches can also have demonstrable effects on physical and biological features of designated reaches.

In the relatively few cases where we are designating lake habitats (e.g., Devils, Siltcoos, Tahkenitch, Sand, and Tenmile lakes), we believe that the lateral extent may best be defined as the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of ordinary high water, whichever is greater. In estuarine areas we believe that extreme high water is the best descriptor of lateral extent. As noted above for stream habitat areas, human activities that occur outside the area inundated by extreme or ordinary high water can modify or destroy physical and biological features of the estuarine habitat areas, and Federal agencies must be aware of these important habitat linkages as well.

*Critical Habitat Analytical Review Team*

To assist in the designation of critical habitat, we convened a CHART for the Oregon Coast domain. The CHART consisted of eight Federal biologists and habitat specialists from NMFS, USFS, and BLM, with demonstrated expertise regarding salmonid habitat and related protective efforts within the domain. The CHART was tasked with assessing biological information pertaining to areas under consideration for designation as critical habitat. The CHART also reconvened to review the public comments and any new information regarding the ESU and its habitat. Its work and determinations are documented in a final CHART report (NMFS, 2007b).

The CHART examined each habitat area within a watershed to determine whether the stream reaches or lakes occupied by the Oregon Coast coho contain the physical or biological features essential to conservation. As noted previously, the CHART also relied on its experience conducting ESA section 7 consultations and existing management plans and protective measures to determine whether these features may require special management considerations or protection. In addition to occupied areas, the definition of critical habitat also includes unoccupied areas if we determine the area is essential for conservation. Accordingly, the CHART was next asked whether there were any unoccupied areas within the historical range of the ESU that may be essential for conservation. The CHART did not identify any such unoccupied areas.

The CHART was next asked to determine the relative conservation value of each area for each ESU. The CHART scored each habitat area based on several factors related to the quantity and quality of the physical and biological features. It next considered each area in relation to other areas and with respect to the population occupying that area. Based on a consideration of the raw scores for each area, and a consideration of that area's contribution in relation to other areas and in relation to the overall population structure of the ESU, the CHART rated each habitat area as having a ''high,'' ''medium,'' or ''low'' conservation value. The preliminary CHART ratings were reviewed by several state and tribal comanagers in advance of the proposed rule, and the CHART made needed changes prior to that rule. State and tribal comanagers also evaluated our proposed rule (69 FR 74572; December 14, 2004) and provided comments and new information which were also reviewed and incorporated as needed by the CHART in the preparation of this final designation.

The rating of habitat areas as having a high, medium, or low conservation value provided information useful to inform the Secretary's exercise of discretion in determining whether the benefits of exclusion outweigh the benefits of designation (i.e., ESA section 4(b)(2)). The higher the conservation value for an area, the greater the likely benefit of the ESA section 7 protections. We recognized that the ''benefit of designation'' would also depend on the likelihood of a consultation occurring and the improvements in species' conservation that may result from changes to proposed Federal actions. To address this concern, we asked the CHART to develop a profile for a ''low leverage'' watershed—that is, a watershed where it was unlikely there would be a section 7 consultation, or where a section 7 consultation, if it did occur, would yield few conservation benefits. For watersheds not meeting the ''low leverage'' profile, we considered their conservation rating to be a fair assessment of the benefit of designation. For watersheds meeting the ''low leverage'' profile, we considered the benefit of designation to be an increment lower than the conservation rating. For example, a watershed with a ''high'' conservation value but ''low leverage'' was considered to have a ''medium'' benefit of designation, and so forth (NMFS, 2007b).

As discussed earlier, the scale chosen for the ''specific area'' referred to in section 3(5)(a) was a watershed, as delineated by USGS methodology. There were some complications with this delineation that required us to adapt the CHARTs' approach for some areas. In particular, a large stream or river might serve as a rearing and migration corridor to and from many watersheds, yet be embedded itself in a watershed. In any given watershed through which it passes, the stream may have a few or several tributaries. For rearing/migration corridors embedded in a watershed, the CHART was asked to rate the conservation value of the watershed based on the tributary habitat. We assigned the rearing/migration corridor the rating of the highest-rated watershed for which it served as a rearing/migration corridor. The reason for this treatment of migration corridors is the role they play in the salmon's life cycle. Salmon are anadromous—born in fresh water, migrating to salt water to feed and grow, and returning to fresh water to spawn. Without a rearing/migration corridor to and from the sea, salmon cannot complete their life cycle. It would be illogical to consider a spawning and rearing area as having a particular conservation value and not consider the associated rearing/migration corridor as having a similar conservation value.

**Application of ESA Section 4(b)(2) (16 U.S.C. 1533(b)(2))**

The foregoing discussion describes those areas that are eligible for designation as critical habitat—the specific areas that fall within the ESA section 3(5)(A) definition of critical habitat. However, specific areas eligible for designation are not automatically designated as critical habitat. Section 4(b)(2) of the ESA requires the Secretary to first consider the economic impact, impact on national security, and any other relevant impact of designation. The Secretary has the discretion to exclude an area from designation if he determines the benefits of exclusion (that is, avoiding the impact that would result from designation) outweigh the benefits of designation based upon best scientific and commercial data. The Secretary may not exclude an area from designation if exclusion will result in the extinction of the species. Because the authority to exclude is discretionary, exclusion is not required for any areas. In this rulemaking, the Secretary has applied his statutory discretion to exclude areas from critical habitat for several different reasons (NMFS, 2007d).

In this exercise of discretion, the first issue we must address is the scope of impacts relevant to the ESA section 4(b)(2) evaluation. We proposed new critical habitat designations for 13 Pacific Northwest ESUs, including the Oregon Coast coho ESU (69 FR 74572; December 14, 2004), because the previous designations were vacated following a Court ruling that we had inadequately considered the economic impacts of designating critical habitat. (*National Association of Homebuilders* v. *Evans*, 2002 WL 1205743 No. 00–CV–2799 (D.D.C.) (NAHB)). The *NAHB* court had agreed with the reasoning of the Court of Appeals for the Tenth Circuit in *New Mexico Cattle Growers Association* v. *U.S. Fish and Wildlife Service*, 248 F.3d 1277 (10th Cir. 2001). In that decision, the Tenth Circuit stated ''[t]he statutory language is plain in requiring some kind of consideration of economic impact in the critical habitat designation phase.'' The court concluded that, given the FWS' failure to distinguish between ''adverse modification'' and ''jeopardy'' in its 4(b)(2) analysis, the FWS must analyze the full impacts of critical habitat designation, regardless of whether those impacts are coextensive with other impacts (such as the impact of the jeopardy requirement).

In redesignating critical habitat for the 13 Pacific Northwest ESUs, we followed the Tenth Circuit Court's directive regarding the statutory requirement to consider the economic impact of designation. Areas designated as critical habitat are subject to ESA section 7 requirements, which provide that Federal agencies ensure that their actions are not likely to destroy or adversely modify critical habitat. To evaluate the economic impact of critical habitat we first examined our voluminous section 7 consultation record for Oregon Coast coho as well as other ESUs of salmon and steelhead. (For thoroughness, we examined the consultation record for other ESUs to see if it provided information relevant to Oregon Coast coho.) That record includes consultations on habitat-modifying Federal actions both where critical habitat has been designated and where it has not. We could not discern a distinction between the impacts of applying the jeopardy provision versus the adverse modification provision in occupied critical habitat. Given our inability to detect a measurable difference between the impacts of applying these two provisions, the only reasonable alternative seemed to be to follow the recommendation of the Tenth Circuit, approved by the *NAHB* court—to measure the coextensive impacts; that is, measure the entire impact of applying the adverse modification provision of section 7, regardless of whether the jeopardy provision alone would result in the identical impact.

The Tenth Circuit's opinion only addressed ESA section 4(b)(2)'s requirement that economic impacts be considered. The court did not address how ''other relevant impacts'' were to be considered, nor did it address the benefits of designation. Because section 4(b)(2) requires a consideration of other relevant impacts of designation, and the benefits of designation, and because our record did not support a distinction between impacts resulting from application of the adverse modification provision versus the jeopardy provision, we are uniformly considering coextensive impacts and coextensive benefits, without attempting to distinguish the benefit of a critical habitat consultation from the benefit that would otherwise result from a jeopardy consultation that would occur even if critical habitat were not designated. To do otherwise would distort the balancing test contemplated by section 4(b)(2).

The principal benefit of designating critical habitat is that Federal activities that may affect such habitat are subject to consultation pursuant to section 7 of the ESA. Such consultation requires every Federal agency to ensure that any action it authorizes, funds or carries out is not likely to result in the destruction or adverse modification of critical habitat. This complements the section 7 provision that Federal agencies ensure that their actions are not likely to jeopardize the continued existence of a listed species. Another benefit is that the designation of critical habitat can serve to educate the public regarding the potential conservation value of an area and thereby focus and contribute to conservation efforts by clearly delineating areas of high conservation value for certain species. It is unknown to what extent this process actually occurs for Oregon Coast coho, and what the actual benefit is to Oregon Coast coho, as there are also concerns, noted above, that a critical habitat designation may discourage such conservation efforts.

The balancing test in ESA section 4(b)(2) contemplates weighing benefits that are not directly comparable—the benefit associated with species conservation balanced against the economic benefit, benefit to national security, or other relevant benefit that results if an area is excluded from designation. Section 4(b)(2) does not specify a method for the weighing process. Agencies are frequently required to balance benefits of regulations against impacts; Executive Order (E.O.) 12866 established this requirement for Federal agency regulations. Ideally such a balancing would involve first translating the benefits and impacts into a common metric. Executive branch guidance from the OMB suggests that benefits should first be monetized (i.e., converted into dollars). Benefits that cannot be monetized should be quantified (for example, numbers of fish saved). Where benefits can neither be monetized nor quantified, agencies are to describe the expected benefits (OMB, 2003).

It may be possible to monetize benefits of critical habitat designation for a threatened or endangered species in terms of willingness-to-pay (OMB, 2003). However, we are not aware of any available data that would support such an analysis for salmon. In addition, ESA section 4(b)(2) requires analysis of impacts other than economic impacts that are equally difficult to monetize, such as benefits to national security of excluding areas from critical habitat. In the case of salmon designations, impacts to Northwest tribes are an ''other relevant impact'' that also may be difficult to monetize.

An alternative approach, approved by OMB (OMB, 2003), is to conduct a cost-effectiveness analysis. A cost-effectiveness analysis ideally first involves quantifying benefits, for example, percent reduction in extinction risk, percent increase in productivity, or increase in numbers of fish. Given the state of the science, it would be difficult to quantify reliably the benefits of including particular areas in the critical habitat designation. Although it is difficult to monetize or quantify benefits of critical habitat designation, it is possible to differentiate among habitat areas based on their relative contribution to conservation. For example, habitat areas can be rated as having a high, medium, or low conservation value. The qualitative ordinal evaluations can then be combined with estimates of the economic costs of critical habitat designation in a framework that arguably moves the designation to a more efficient outcome. Individual habitat areas are assessed using both their biological evaluation and economic cost, so that areas with high conservation value and lower economic cost might be considered to have a higher priority for designation, while areas with a low conservation value and higher economic cost might have a higher priority for exclusion. While this approach can provide useful information to the decision-maker, there is no rigid formula through which this information translates into exclusion decisions. Every geographical area containing habitat eligible for designation is different, with a unique set of ''relevant impacts'' that may be considered in the exclusion process. Regardless of the analytical approach, ESA section 4(b)(2) makes clear that what weight the agency gives various impacts and benefits, and whether the agency excludes areas from the designation, is discretionary.

*Exclusions Based on Impacts to Tribes*

A broad array of activities on Indian lands may trigger section 7 consultation under the ESA. For this analysis, we considered what those activities may be and what the likely effect would be on conservation of the Oregon Coast coho ESU if the activities were not subject to section 7 consultation. (We realize that the activities in question would still be subject to section 7 consultation and to the requirement that Federal agencies not jeopardize species' continued existence. However, as described above, because we cannot discern a difference in the application of the jeopardy and adverse modification requirements in our consultations for Oregon coast coho, we are considering coextensive impacts and coextensive benefits.) To determine the benefit of designation, we considered the number of stream miles within Indian lands, whether those stream miles were located in high, medium, or low conservation value areas, and the number of expected section 7 consultations in those areas (NMFS, 2007f).

There are several benefits to excluding Indian lands. The longstanding and distinctive relationship between the Federal and tribal governments is defined by treaties, statutes, executive orders, judicial decisions, and agreements, which differentiate tribal governments from the other entities that deal with, or are affected by, the Federal Government. This relationship has given rise to a special Federal trust responsibility involving the legal responsibilities and obligations of the United States toward Indian Tribes and the application of fiduciary standards of due care with respect to Indian lands, tribal trust resources, and the exercise of tribal rights. Pursuant to these authorities, Indian lands are recognized as unique and have been retained by Indian Tribes or have been set aside for tribal use. These lands are managed by Indian Tribes in accordance with tribal goals and objectives within the framework of applicable treaties and laws.

In addition to the distinctive trust relationship, for salmon and steelhead in the Northwest, there is a unique partnership between the Federal Government and Indian tribes regarding salmon management. Two of the four tribes with land in Oregon coast coho critical habitat are active participants in local watershed restoration and management aimed at coho conservation (NMFS, 2007f).

The benefits of excluding Indian lands from designation include: (1) The furtherance of established national policies, our Federal trust obligations, and our deference to the tribes in management of natural resources on their lands; (2) the maintenance of effective long-term working relationships to promote the conservation of Oregon coast coho; and (3) continued respect for tribal sovereignty over management of natural resources on Indian lands through established tribal natural resource programs. Regarding benefits of designation, many actions on Indian lands involve the Bureau of Indian Affairs (BIA), triggering a section 7 consultation. This means the benefit of designating Indian land is potentially high. However, coho habitat on Indian lands represents a tiny proportion of overall habitat—2.7 stream miles (4.35 km) out of a total of 6,652. Accordingly, we find the benefits of promoting tribal sovereignty and the trust responsibility outweigh the benefits of applying ESA section 7 to Federal activities on these 2.7 miles (4.35 km) of coho habitat (NMFS, 2007f).

The Indian lands specifically excluded from critical habitat are those defined in the Secretarial Order, including: (1) Lands held in trust by the United States for the benefit of any Indian tribe; (2) land held in trust by the United States for any Indian Tribe or individual subject to restrictions by the United States against alienation; (3) fee lands, either within or outside the reservation boundaries, owned by the tribal government; and (4) fee lands within the reservation boundaries owned by individual Indians. We have determined that these exclusions, together with the other exclusions described in this rule, will not result in extinction of the species (NMFS, 2007d).

*Exclusions Based on Economic Impacts*

Our assessment of economic impact generated considerable interest from commenters on the ANPR (68 FR 55926; September 29, 2003) and the proposed rule (69 FR 74572; December 14, 2004). Based on new information and comments received on the proposed rule we have updated our estimates of economic impacts of designating each of the particular areas found to meet the definition of critical habitat (NMFS, 2007d). This report is available from NMFS (see **ADDRESSES**).

The first step in the overall economic analysis was to identify existing legal and regulatory constraints on economic activity that are independent of critical habitat designation, such as Clean Water Act (CWA) requirements. Coextensive impacts of the ESA section 7 requirement to avoid jeopardy were not considered part of the baseline.

Next, from the consultation record, we identified Federal activities that might affect habitat and that might result in an ESA section 7 consultation. (We did not consider Federal actions, such as the approval of a fishery, that might affect the species directly but not affect its habitat.) We identified ten types of activities including: Hydropower dams; non-hydropower dams and other water supply structures; Federal lands management, including grazing (considered separately); transportation projects; utility line projects; instream activities, including dredging (considered separately); activities permitted under the Environmental Protection Agency's (EPA's) National Pollution Discharge Elimination System; sand and gravel mining; residential and commercial development; and agricultural pesticide applications. Based on our consultation record and other available information, we determined the modifications each type of activity was likely to undergo as a result of section 7 consultation (regardless of whether the modification might be required by the jeopardy or the adverse modification provision). We developed an expected direct cost for each type of action and projected the likely occurrence of each type of project in each watershed, using existing spatial databases (e.g., the USACE 404(d) permit database). Finally, we aggregated the costs from the various types of actions and estimated an annual impact, taking into account the probability of consultation occurring and the likely rate of occurrence of that project type.

This analysis allowed us to estimate the coextensive economic impact of designating each ''particular area'' (that is, each habitat area, or aggregated occupied stream reaches in a watershed). Expected annual economic impacts in the Oregon Coast coho ESU ranged from zero to $869,861 per habitat area, with a median of $222,419. Where a watershed included both tributaries and a migration corridor that served other watersheds, we estimated the separate impacts of designating the tributaries and the migration corridor. We did this by identifying those categories of activities most likely to affect tributaries and those most likely to affect larger migration corridors.

Because of the methods we selected and the data limitations, portions of our analysis both under- and over-estimate the coextensive economic impact of ESA section 7 requirements. For example, we lacked complete data on the likely impact on flows at non-Federal hydropower projects, which would increase economic impacts. Also, we did not have information about potential changes in irrigation flows associated with section 7 consultation. These impacts would increase the estimate of coextensive costs. On the other hand, we estimated an impact on all activities occurring within the geographic boundaries of a watershed, even though in some cases activities would be far removed from occupied stream reaches and so might not require modification (or even consultation). In addition, we were unable to document significant costs of critical habitat designation that occur outside the section 7 consultation process, including costs resulting from state or local regulatory burdens imposed on developers and landowners as a result of a Federal critical habitat designation.

In determining whether the economic benefit of excluding a habitat area might outweigh the benefit of designation to the species, we took into account many data limitations, including those described above. The ESA requires that we make critical habitat designations within a short time frame ''with such data as may be available'' at the time. Moreover, the approach we adopted accommodated many of these data limitations by considering the relative benefits of designation and exclusion, giving priority to excluding habitat areas with a relatively lower benefit of designation and a relatively higher economic impact (NMFS, 2007d).

The circumstances of the Oregon Coast coho ESU are well suited to this approach. Coho salmon is a wide-ranging species that occupies numerous habitat areas with thousands of stream miles. Not all occupied areas, however, are of equal importance to conserving the ESU. Within the currently occupied range there are areas that support highly productive populations, areas that support less productive populations, and areas that support production in only some years. Some populations within the ESU may be more important to long-term conservation of the ESU than other populations. Therefore, in many cases it may be possible to construct different scenarios for achieving conservation. Different scenarios might have more or less certainty of achieving conservation, and more or less economic impact.

Our first step in constructing an exclusion scenario was to identify all areas we would consider for an economic exclusion, based on dollar thresholds. The next step was to examine whether any of the areas eligible for exclusion make an important contribution to conservation, in the context of the areas that remained (that is, those areas not identified as eligible for exclusion). We did not consider habitat areas for exclusion if they had a high conservation value rating. Based on the rating process used by the CHART we judged that all of the high value areas make an important contribution to conservation.

In developing criteria for the first step, we chose dollar thresholds that we anticipated would lead most directly to a more cost-effective scenario. We considered for exclusion low value habitat areas with an economic impact greater than $91,556 and medium value habitat areas with an economic impact greater than $323,138. These criteria we selected for identifying habitat areas as eligible for exclusion do not represent an objective determination that, for example, a given low value area is worth a certain dollar amount and no more. The statute directs us to balance dissimilar values under a statutorily-limited time frame. The statute emphasizes the discretionary nature of the section 4(b)(2) balancing task. Moreover, while our approach follows the Tenth Circuit's direction to consider coextensive economic impacts, we nevertheless must acknowledge that not all of the costs will be avoided by exclusion from designation. Finally, the cost estimates developed by our economic analysis do not have obvious break points that would lead to a logical division between ''high,'' ''medium,'' and ''low'' costs. Given these factors, a judgment that any particular dollar threshold is objectively ''right,'' would be neither necessary nor possible. Rather, what economic impact is ''high,'' and therefore might outweigh the benefit of designating a medium or low conservation value habitat area, is a matter of agency discretion and policy.

In the second step of the process, we asked the CHART whether any of the habitat areas eligible for exclusion make an important contribution to conservation. The CHART considered this question in the context of all of the areas eligible for exclusion as well as the information they had developed in providing the initial conservation ratings. The following section describes the results of applying the two-step process to the Oregon Coast coho ESU. The results are discussed in greater detail in a separate report that is available for public review and comment (NMFS, 2007d). We have determined that the exclusions, together with the other exclusions described in this rule (i.e., Indian lands), will not result in extinction of the species (NMFS, 2007d).

*Summary of Changes From the Proposed Critical Habitat Designation*

We evaluated the comments and new information received on the proposed rule to ensure that they represented the best scientific data available and made a number of general types of changes to the critical habitat designations, including:

(1) We revised habitat maps and related biological assessments based on a final CHART assessment (NMFS, 2007b) of information provided by commenters, peer reviewers, and agency biologists (including CHART members). We also evaluated watersheds to determine how well the conservation value rating corresponded to the benefit of designation, in particular the likelihood of an ESA section 7 consultation occurring in that area and whether the consultation would yield conservation benefits if it was likely to occur.

(2) We revised our economic analysis based on information provided by commenters and peer reviewers as well as our own efforts as referenced in the proposed rule and described in the final economic analysis (NMFS, 2007c). Major changes included assessing new impacts associated with pesticide consultations, revising Federal land management costs to take into account wilderness areas, and modifying the

analysis of Federal grazing land impacts to more accurately reflect the likely geographic extent of ESA section 7 implementation. We also documented the economic costs of changes in flow regimes for some hydropower projects. To account for inflationary changes in the economic impacts, we adjusted the cost estimates based on changes in a producer price index over the period 2005 to 2007 (NMFS 2007c).

(3) We conducted a new ESA section 4(b)(2) analysis based on economic impacts to take into account the above revisions. This resulted in the final exclusion of many of the same watersheds proposed for exclusion. It also resulted in some areas originally proposed for exclusion not being excluded. The analysis is described further in the 4(b)(2) report (NMFS, 2007d).

(4) In the regulations, we've removed reference to ''units'' to avoid possible confusion with the concept of ''recovery units'' as described in our section 7 handbook.

The following section summarizes the changes to the proposed critical habitat rule. These changes are also reflected in final agency reports pertaining to the biological, economic, and policy assessments supporting these designations (NMFS, 2007b; NMFS, 2007c; and NMFS, 2007d). We conclude that these changes are warranted based on new information and analyses that constitute the best scientific data available.

**Description of Specific Changes**

The CHART elevated the conservation value rating for five watersheds within the Umpqua River basin. The changes were made as a result of recent population identification work (Lawson *et al.*, 2007) that further subdivides this basin into four (versus two) independent populations. We made several changes to the delineation of occupied habitat areas based on comments and field surveys indicating that our original coho distribution maps/data were in error. As a result of revised economic data for this ESU and our final 4(b)(2) assessment, we are no longer excluding habitat areas in three watersheds that were previously proposed for designation. We have also removed Josephine and Jackson counties from the relevant critical habitat table in our regulations. These counties overlap slightly with upland areas in watersheds occupied by Oregon Coast coho salmon, but they do not contain stream reaches designated as critical habitat for this ESU. Table 1 summarizes the changes made for specific watersheds in the range of this ESU.

TABLE 1.—CHANGES TO CRITICAL HABITAT DESIGNATION FOR OREGON COAST COHO

| Subbasin | Watershed code | Watershed name | Changes from proposed rule |
|---|---|---|---|
| NEHALEM | 1710020206 | Lower Nehalem River/Cook Creek. | Added 1.3 miles (2.1 km) of occupied habitat areas. |
| WILSON/TRASK/NESTUCCA | 1710020302 | Nestucca River | Added 4.2 miles (6.8 km) of occupied habitat areas and removed 3 miles (4.8 km) of unoccupied stream reaches. |
| NORTH UMPQUA | 1710030106 | Boulder Creek | No longer excluded from designation. |
| NORTH UMPQUA | 1710030110 | Rock Creek/North Umpqua River. | Added 1.8 miles (2.9 km) of occupied habitat areas. |
| SOUTH UMPQUA | 1710030202 | Jackson Creek | Elevated HUC5 conservation value from Low to Medium. No longer excluded from designation. |
| SOUTH UMPQUA | 1710030204 | Elk Creek/South Umpqua | Elevated HUC5 conservation value from Low to Medium. No longer excluded from designation. |
| SOUTH UMPQUA | 1710030205 | South Umpqua River | Removed 2 miles (3.2 km) of unoccupied stream reaches. |
| SOUTH UMPQUA | 1710030207 | Middle Cow Creek | Elevated HUC5 conservation value from Medium to High. |
| SOUTH UMPQUA | 1710030209 | Lower Cow Creek | Removed 3 miles (4.8 km) of unoccupied stream reaches. |
| SOUTH UMPQUA | 1710030211 | Myrtle Creek | Elevated HUC5 conservation value from Medium to High. |
| UMPQUA | 1710030301 | Upper Umpqua River | Removed 2 miles (3.2 km) of unoccupied stream reaches. |
| UMPQUA | 1710030303 | Elk Creek | Removed 1 mile (1.6 km) of unoccupied stream reaches and elevated HUC5 conservation value from Medium to High. |
| UMPQUA | 1710030304 | Middle Umpqua River | Removed 1.5 mile (2.4 km) of unoccupied stream reaches. |
| UMPQUA | 1710030305 | Lake Creek | Removed 5.3 mile (8.5 km) of unoccupied stream reaches. |
| COQUILLE | 1710030504 | East Fork Coquille | Removed 1.5 mile (2.4 km) of unoccupied stream reaches. |

**Final Critical Habitat Designation**

We are designating approximately 6,568 stream miles (10,570 km) and 15 square miles (38.8 sq km) of lake habitat within the geographical area presently occupied by the Oregon Coast coho ESU (see Table 2). The Oregon Coast coho ESU is the only listed species in this domain, so the areas designated as critical habitat do not overlap with critical habitat areas designated for other listed ESUs.

TABLE 2.—APPROXIMATE QUANTITY OF HABITAT AND OWNERSHIP WITHIN WATERSHEDS CONTAINING HABITAT AREAS DESIGNATED AS CRITICAL HABITAT FOR THE EVOLUTIONARILY SIGNIFICANT UNIT OF OREGON COAST COHO SALMON (ONCORHYNCHUS KISUTCH)

| Streams mi (km) | Lakes sq mi (sq km) | Nearshore marine mi (km) | Land ownership type (percent) | | | |
|---|---|---|---|---|---|---|
| | | | Federal | Tribal | State | Private |
| 6,568 (10,570) | 15 (38.8) | n/a | 32.9 | <0.1 | 9.1 | 58.0 |

The areas designated, summarized below, are all occupied and contain physical and biological features essential to the conservation of the species and that may require special management considerations or protection. No unoccupied areas were identified that are considered essential for the conservation of the species. There are 80 watersheds within the range of this ESU. Eight watersheds received a low conservation value rating, 27 received a medium rating, and 45 received a high rating to the ESU (NMFS, 2007b). As a result of the balancing process for economic impacts described above, the Secretary is excluding from the designation the five watersheds listed in Table 3. Of the habitat areas eligible for designation, approximately 84 stream miles (135 km) or 1.3 percent are being excluded because the economic benefits of exclusion outweigh the benefits of designation. Total potential estimated economic impact, with no exclusions, would be $22.2 million. The exclusions identified in Table 3 would reduce the total estimated economic impact to $20.1 million (NMFS, 2007d).

TABLE 3.—HABITAT AREAS WITHIN THE GEOGRAPHICAL RANGE OF THE EVOLUTIONARILY SIGNIFICANT UNIT OF OREGON COAST COHO SALMON (ONCORHYNCHUS KISUTCH) AND EXCLUDED FROM CRITICAL HABITAT

| Subbasin | Watershed code | Watershed name | Area proposed for exclusion |
|---|---|---|---|
| North Fork Umpqua River subbasin | 1710030108 | Steamboat Creek | Entire watershed. |
| North Fork Umpqua River subbasin | 1710030109 | Canton Creek | Entire watershed. |
| South Fork Umpqua River subbasin | 1710030201 | Upper South Umpqua River | Entire watershed. |
| Umpqua River subbasin | 1710030305 | Lake Creek | Entire watershed. |
| Coquille River subbasin | 1710030501 | Coquille South Fork, Lower | Entire watershed. |

## Effects of Critical Habitat Designation

### *ESA Section 7 Consultation*

Section 7(a) of the ESA requires Federal agencies, including NMFS, to evaluate their actions with respect to any species that is proposed or listed as endangered or threatened and with respect to its critical habitat, if any is proposed or designated. Regulations implementing this provision of the ESA are codified at 50 CFR 402.

If a species is listed or critical habitat is designated, ESA section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of such a species or to destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency (action agency) must enter into consultation with us. Through this consultation, we would review actions to determine if they would destroy or adversely modify critical habitat.

If we issue a biological opinion concluding that a project is likely to result in the destruction or adverse modification of critical habitat, we will also provide reasonable and prudent alternatives to the project, if any are identifiable. Reasonable and prudent alternatives are defined at 50 CFR 402.02 as alternative actions identified during consultation that can be implemented in a manner consistent with the intended purpose of the action, that are consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that we believe would avoid destruction or adverse modification of critical habitat. Reasonable and prudent alternatives can vary from slight project modifications to extensive redesign or relocation of the project. Costs associated with implementing a reasonable and prudent alternative are similarly variable.

Regulations at 50 CFR 402.16 require Federal agencies to reinitiate consultation on previously reviewed actions in instances where critical habitat is subsequently designated and the Federal agency has retained discretionary involvement or control over the action or such discretionary involvement or control is authorized by law. Consequently, some Federal agencies may request reinitiation of consultation or conference with us on actions for which formal consultation has been completed, if those actions may affect designated critical habitat or adversely modify or destroy proposed critical habitat.

Activities on Federal lands that may affect these ESUs or their critical habitat will require ESA section 7 consultation. Activities on private or state lands requiring a permit from a Federal agency, such as a permit from the USACE under section 404 of the CWA, a section 10(a)(1)(B) permit from NMFS, or some other Federal action, including funding (e.g., Federal Highway Administration (FHA) or Federal Emergency Management Agency (FEMA) funding), will also be subject to the section 7 consultation process. Federal actions not affecting listed species or critical habitat and actions on non-Federal and private lands that are not Federally funded, authorized, or permitted do not require section 7 consultation.

### *Activities Affected by Critical Habitat Designation*

Section 4(b)(8) of the ESA requires that we evaluate briefly and describe, in any proposed or final regulation that designates critical habitat, those activities involving a Federal action that may adversely modify such habitat or that may be affected by such designation. A wide variety of activities may affect critical habitat and, when carried out, funded, or authorized by a Federal agency, require that an ESA section 7 consultation be conducted. Generally these include water and land management actions of Federal agencies (e.g., USFS, BLM, USACE, BOR, the FHA, the National Resource Conservation Service (NRCS), National Park Service (NPS), BIA, and FERC) and related or similar actions of other Federally regulated projects and lands, including livestock grazing allotments by the USFS and BLM; hydropower sites licensed by the FERC; dams built or operated by the USACE or BOR; timber sales and other vegetation management activities conducted by the USFS, BLM, and BIA; irrigation diversions authorized by the USFS and BLM; road building and maintenance activities authorized by the FHA, USFS, BLM, NPS, and BIA; and mining and road building/maintenance activities authorized by the states of Washington, Oregon, and Idaho. Other actions of concern include dredge and fill, mining, diking, and bank stabilization activities authorized or conducted by the USACE, habitat modifications authorized by the FEMA, and approval of water quality standards and pesticide labeling and use restrictions administered by the EPA.

The Federal agencies that will most likely be affected by this critical habitat designation include the USFS, BLM, BOR, USACE, FHA, NRCS, NPS, BIA, FEMA, EPA, and the FERC. This designation will provide these agencies, private entities, and the public with clear notification of critical habitat designated for listed salmonids and the boundaries of the habitat. This designation will also assist these agencies and others in evaluating the potential effects of their activities on listed salmon and their critical habitat and in determining if ESA section 7 consultation with NMFS is needed.

As noted above, numerous private entities also may be affected by this critical habitat designation because of the direct and indirect linkages to an array of Federal actions, including Federal projects, permits, and funding. For example, private entities may harvest timber or graze livestock on Federal land or have special use permits to convey water or build access roads across Federal land; they may require Federal permits to armor stream banks, construct irrigation withdrawal facilities, or build or repair docks; they may obtain water from Federally funded and operated irrigation projects; or they may apply pesticides that are only available with Federal agency approval. These activities will need to be analyzed with respect to their potential to destroy or adversely modify critical habitat. In some cases, proposed activities may require modifications that may result in decreases in activities such as timber harvest and livestock and crop production. The transportation and utilities sectors may need to modify the placement of culverts, bridges, and utility conveyances (e.g., water, sewer and power lines) to avoid barriers to fish migration. Developments occurring in or near salmon streams (e.g., marinas, residential, or industrial facilities) that require Federal authorization or funding may need to be altered or built in a manner that ensures that critical habitat is not destroyed or adversely modified as a result of the construction, or subsequent operation, of the facility. These are just a few examples of potential impacts, but it is clear that the effects will encompass numerous sectors of private and public activities. If you have questions regarding whether specific activities will constitute destruction or adverse modification of critical habitat, contact NMFS (see **ADDRESSES** and **FOR FURTHER INFORMATION CONTACT**).

## Classification

### *Administrative Procedure Act*

The proposed listing determination, proposed protective regulations, and proposed critical habitat designation addressing 27 ESUs generated substantial public interest. In addition to comments received during 12 public hearings, we received 33,480 written comments. Many of the comments addressing the critical habitat designation expressed concerns about how the rule would be implemented. Our experience in implementing previous listing determinations, protective regulations, and critical habitat designations suggests that neither the Administrative Procedure Act (APA) and ESA implementing regulations' minimum of a 30-day delay in effective date, nor the 60-day delay in effective date required by the Congressional Review Act for a ''major rule,'' are sufficient for this final rule. In order to provide for efficient administration of the rule once effective, we are providing a 90-day delay in effective date. As a result this rule will be effective on May 12, 2008. This will allow us the necessary time to provide for outreach to and interaction with the public, to minimize confusion and educate the public about activities that may be affected by the rule, and to work with Federal agencies and applicants to provide for an orderly implementation of the rule.

### *National Environmental Policy Act (NEPA)*

ESA listing decisions are exempt from the requirement to prepare an environmental assessment or environmental impact statement under the NEPA. See NOAA Administrative Order 216–6.03(e)(1) and *Pacific Legal Foundation* v. *Andrus,* 657 F.2d 825 (6th Cir. 1981). Thus, we have determined that the final listing determination for Oregon Coast coho described in this notice is exempt from the requirements of the NEPA. Similarly, we have determined that we need not prepare environmental analyses for critical habitat designations made pursuant to the ESA. See *Douglas County* v. *Babbitt,* 48 F.3d 1495 (9th Cir. 1995), cert. denied, 516 U.S. 1042 (1996).

We conducted Environmental Assessments (EAs) under the NEPA analyzing the ESA section 4(d) regulations promulgated in 2000 for Pacific salmonids (65 FR at 42422 and 42481; July 10, 2000) and the amendments to the 4(d) regulations promulgated in 2005 (70 FR 37160; June 28, 2005). Both EAs analyzed the protective regulations for the Oregon Coast coho ESU which are being finalized in this notice. We solicited comment on the EAs as part of the proposed rules, as well as during a subsequent comment period following formal notice in the **Federal Register** of the availability of the draft EAs for review. We have reviewed new information available since the 2000 and 2005 analyses and determined that none of the new information would change the earlier analyses, nor would it change our conclusion that adoption of the 4(d) rule will have no significant impacts on the human environment (NMFS, 2007g).

### *Regulatory Flexibility Act*

Under the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of rulemaking for any proposed or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effects of the rule on small entities (i.e., small businesses, small organizations, and small government jurisdictions). For the proposed designation of critical habitat for 13 ESUs, including Oregon coast coho, we published an Initial Regulatory Flexibility Act Analysis for public comment. We received comments specific to some of the ESUs, but not to Oregon Coast coho. We received one general comment, stating that our analysis should include more references. We have prepared a final regulatory flexibility analysis for the designation of critical habitat, which is available upon request (see **ADDRESSES**) and which includes additional references. This analysis estimates that the number of regulated small entities potentially affected by the final critical habitat designation for the Oregon Coast coho salmon ESU is 920, and the estimated coextensive costs of section 7 consultation incurred by small entities is $5,072,840. As described in the analysis, we considered various alternatives for designating critical habitat for this ESU. We considered and rejected the alternative of not designating critical habitat for the ESU because such an approach did not meet the legal requirements of the ESA. We also examined and rejected an alternative in which all the eligible habitat areas in the ESU are designated (i.e., no areas are excluded) because many of the areas considered to have a low conservation value also had relatively high economic impacts that might be mitigated by excluding those areas from designation. A third alternative we examined and rejected would exclude all habitat areas with a low or medium conservation value. While this alternative furthers the goal of reducing economic impacts, we could not make a determination that the benefits of excluding all habitat areas with low and medium conservation value outweighed the benefits of designation. Moreover, for some habitat areas the incremental economic benefit from excluding that area is relatively small. Therefore, after considering these alternatives in the context of the section 4(b)(2) process of weighing benefits of exclusion against benefits of designation, we determined that the current approach to designation (i.e., designating some but not all areas with low or medium conservation value) provides an appropriate balance of conservation and economic mitigation and that excluding the areas identified in this rulemaking would not result in extinction of the ESU. It is estimated that small entities will save $281,687 in compliance costs due to the exclusions made in the final designation.

ESA section 4(d) regulations for Oregon Coast coho were originally proposed on December 30, 1999 (64 FR 73479). The rule adopted here is substantially the same as that proposed in 1999. At that time we published an Initial Regulatory Flexibility Act analysis, which considered four alternative approaches to protective regulations. We concluded that there were no legally viable alternative to the one we proposed in 1999 that would have less impact on small entities and still fulfill agency obligations to protect listed salmonids. We received five public comments on the Initial Regulatory Flexibility Act analysis and the economic impacts of the proposed 4(d) rule. When the rule was adopted in 2000, we completed a Final Regulatory Flexibility Act analysis, which responded to public comments, and reached the same conclusion as the initial analysis. The 2000 4(d) regulations for Oregon Coast coho were invalidated when the underlying listing was vacated in 2001. In 2004 when we proposed to again list Oregon Coast coho, we also proposed to reinstate the 4(d) regulations. We did not conduct a new Regulatory Flexibility Act analysis at that time because there were no new issues to consider.

In preparing the final ESA section 4(d) regulations adopted here, we determined it was advisable to update our Regulatory Flexibility Act analysis, to ensure that we were considering current information. Our updated analysis led us to again conclude that among the available alternative approaches, the one adopted here minimizes economic costs, disruptions, and burdens, for the reasons expressed in the 2000 analysis (attached to NMFS, 2007i) and summarized at 65 FR 42422, 42473 (July 10, 2000). The economic assessment and analysis (NMFS, 2007i) are available upon request (see **ADDRESSES**).

*Paperwork Reduction Act (PRA)*

Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the PRA, unless that collection of information displays a currently valid OMB Control Number.

This final rule does not contain a collection-of-information requirement for purposes of the PRA.

*Regulatory Planning and Review—E.O. 12866*

We prepared a Regulatory Impact Review in 2000 when the ESA section 4(d) regulations were initially adopted and concluded that among the alternative regulatory approaches, the proposed 4(d) rule would maximize net benefits and minimize costs, within the constraints of the ESA. We have reviewed that analysis and new information available since the analysis was initially prepared, including OMB Circular A–4 (2003). We have determined that none of the new information would change the earlier analysis or conclusion (NMFS, 2007i).

The critical habitat component of this notice is a significant rule and has been reviewed by the OMB. As noted above, we have prepared several reports to support the exclusion process under section 4(b)(2) of the ESA. The economic costs of the critical habitat designations are described in our economic report (NMFS, 2007c). The benefits of the designations are described in the CHART report (NMFS, 2007b) and the 4(b)(2) report (NMFS, 2007d). The CHART report uses a biologically-based ranking system for gauging the benefits of applying section 7 of the ESA to particular watersheds. Because data are not available to monetize these benefits, we have adopted a framework that implicitly evaluates the benefits and costs based on a biological metric as outlined in the section 4(b)(2) report (NMFS, 2007b). This approach is consistent with the spirit of OMB's Circular A–4 in that it attempts to assess the benefits and costs even when limitations in data may not allow quantification or monetization. By taking this approach, we seek to designate sufficient critical habitat to meet the biological goal of the ESA while imposing the least burden on society, as called for by E.O. 12866.

The annual total coextensive economic impact of the critical habitat designations is approximately $15.7 million (in contrast to a $18.4 million annual economic impact from designating *all* eligible areas considered in the 4(b)(2) process for this ESU). This amount includes impacts that are coextensive with the implementation of the jeopardy requirement of section 7 (NMFS, 2007c).

We did not estimate the economic impacts associated solely with the listing of Oregon Coast coho ESU under the ESA.

*E.O. 13084—Consultation and Coordination With Indian Tribal Governments*

E.O. 13084 requires that, if we issue a regulation that significantly or uniquely affects the communities of Indian tribal governments and imposes substantial direct compliance costs on those communities, we must consult with those governments or the Federal Government must provide the funds necessary to pay the direct compliance costs incurred by the tribal governments. The final listing determination and protective regulations included in this rule do not impose substantial direct compliance costs on the communities of Indian tribal governments. Accordingly, the requirements of section 3(b) of E.O. 13084 do not apply to the listing and protective regulations components of this final rule. Nonetheless, we intend to inform potentially affected tribal governments and to solicit their input and coordinate on future management actions.

The Departments of Commerce and Interior Secretarial Order ''American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act'' (June 5, 1997) provides that the Services * * * ''shall consult with the affected Indian tribe(s) when considering the designation of critical habitat in an area that may impact tribal trust resources, tribally owned fee lands, or the exercise of tribal rights. Critical habitat shall not be designated in such areas unless it is determined essential to conserve a listed species.'' Pursuant to the Secretarial Order and in response to written and oral comments provided by various tribes in Washington, Oregon, and Idaho, we met and corresponded with many of the affected tribes concerning the inclusion of Indian lands in final critical habitat designations. These discussions resulted in significant clarifications regarding the tribes' general position to exclude their lands, as well as specific issues regarding our interpretation of Indian lands under the Secretarial Order.

As described above (see Exclusions Based on Impacts to Tribes) and in our assessment of Indian lands associated with this final rulemaking (NMFS, 2007f), we have determined that Indian lands should be excluded from the final critical habitat designations for the Oregon Coast coho ESU. The Indian lands specifically excluded from critical habitat are those defined in the Secretarial Order, including: (1) Lands held in trust by the United States for the benefit of any Indian tribe; (2) land held in trust by the United States for any Indian Tribe or individual subject to restrictions by the United States against alienation; (3) fee lands, either within or outside the reservation boundaries, owned by the tribal government; and (4) fee lands within the reservation boundaries owned by individual Indians. We have determined that these exclusions, together with the other exclusions described in this final rule, will not result in extinction of the species (NMFS, 2007d).

*E.O. 13211*

On May 18, 2001, the President issued an Executive Order on regulations that significantly affect energy supply, distribution, and use. E.O. 13211 requires agencies to prepare Statements of Energy Effects when undertaking certain actions. This rule may be a significant regulatory action under E.O. 12866. We have determined, however, that the energy effects of the regulatory action are unlikely to exceed the energy impact thresholds identified in E.O. 13211.

The available data do not allow us to separate precisely these incremental impacts from the impacts of all conservation measures on energy production and costs. There is historical evidence, however, that the ESA section 7 jeopardy standard alone is capable of imposing all of these costs (NMFS, 2007j). While this evidence is indirect, it is sufficient to draw the conclusion that the designation of critical habitat for this one ESU does not significantly affect energy supply, distribution, or use.

*Unfunded Mandates Reform Act (2 U.S.C. 1501 et seq.)*

In accordance with the Unfunded Mandates Reform Act, we make the following findings:

(a) This final rule listing Oregon Coast coho and designating critical habitat will not produce a Federal mandate. In general, a Federal mandate is a provision in legislation, statute, or regulation that would impose an enforceable duty upon state, local, tribal governments, or the private sector and includes both ''Federal intergovernmental mandates'' and ''Federal private sector mandates.'' These terms are defined in 2 U.S.C. 658(5)–(7). ''Federal intergovernmental mandate'' includes a regulation that ''would impose an enforceable duty upon State, local, or tribal governments'' with two exceptions. It excludes ''a condition of Federal assistance.'' It also excludes ''a duty arising from participation in a voluntary Federal program,'' unless the regulation ''relates to a then-existing Federal program under which $500,000,000 or more is provided annually to State, local, and tribal governments under entitlement authority,'' if the provision would ''increase the stringency of conditions of assistance'' or ''place caps upon, or otherwise decrease, the Federal Government's responsibility to provide funding'' and the state, local, or tribal governments ''lack authority'' to adjust accordingly. (At the time of enactment, these entitlement programs were: Medicaid; Aid to Families with Dependent Children work programs; Child Nutrition; Food Stamps; Social Services Block Grants; Vocational Rehabilitation State Grants; Foster Care, Adoption Assistance, and Independent Living; Family Support Welfare Services; and Child Support Enforcement). ''Federal private sector mandate'' includes a regulation that ''would impose an enforceable duty upon the private sector, except (i) a condition of Federal assistance; or (ii) a duty arising from participation in a voluntary Federal program.''

ESA listing and the designation of critical habitat do not impose a legally binding duty on non-Federal government entities or private parties. Under the ESA, the only regulatory effect is that Federal agencies must ensure that their actions do not jeopardize the continued existence of the species or destroy or adversely modify critical habitat under section 7. While non-Federal entities who receive Federal funding, assistance, permits or otherwise require approval or authorization from a Federal agency for an action may be indirectly impacted by the listing or designation of critical habitat, the legally binding duty to avoid jeopardy and the destruction or adverse modification of critical habitat rests squarely on the Federal agency. Furthermore, to the extent that non-Federal entities are indirectly impacted because they receive Federal assistance or participate in a voluntary Federal aid program, the Unfunded Mandates Reform Act would not apply; nor would the listing or critical habitat shift the costs of the large entitlement programs listed above to state governments.

(b) The ESA section 4(d) regulations prohibit any person from taking a listed member of the Oregon Coast coho ESU, except under certain circumstances. This prohibition applies to state and local government actions as well as private individuals. The 4(d) regulations prohibit certain activities, but do not impose an ''enforceable duty'' with associated costs to implement. As such, the 4(d) regulations are not considered an unfunded mandate for the purposes of the Unfunded Mandates Reform Act.

*Takings*

The final threatened listing determination is a non-discretionary action and therefore is not subject to the requirements of E.O. 12630. In accordance with E.O. 12630, this final rule does not have significant takings implications. Under E.O. 12630, ''Actions undertaken by governmental officials that result in a physical invasion or occupancy of private property, and regulations imposed on private property that *substantially affect its value or use,* may constitute a taking of property'' [emphasis added]. Neither the critical habitat designation nor 4(d) regulations can be expected to substantially affect the value or use of property. A takings implication assessment is not required.

The designation of critical habitat confers the ESA section 7 protection against ''the destruction or adverse modification of [critical] habitat.'' The designation of critical habitat in this rule affects only Federal agency actions, and will not increase or decrease the current restrictions on private property concerning take of salmon. While it is possible that real estate market values may temporarily decline following designation, due to the perception that critical habitat designation may impose additional regulatory burdens on land use, our experience is that such impacts do not occur or are short lived (NMFS, 2007d). Owners of areas that are included in the designated critical habitat will continue to have the opportunity to use their property in ways consistent with the survival of listed salmon. Therefore, the designation of critical habitat does not substantially affect the value or use of private property, and does not constitute a taking.

The adoption of ESA section 4(d) regulations includes a prohibition against ''take'' of a listed species (the definition of ''take'' is to ''harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.''). The take prohibition applies to any person subject to the jurisdiction of the United States, and may be perceived as affecting the value or use of property. However, the 4(d) regulations do not substantially affect the value or use of property for the following reasons. First, private property is already subject to state and local land-use regulations. Second, any action on private property authorized, funded, or carried out by a Federal agency that may take listed species is already subject to the section 7 ''no jeopardy'' protection by virtue of the listing determination. Third, our experience with Pacific salmonid 4(d) regulation since 1997 is that any declines in property value are either in perception only or short lived. Land owners quickly realize that the 4(d) regulations do not impose restrictions in addition to pre-existing land-use laws and the listing itself, or they conduct actions on their property in ways consistent with the survival of listed salmon by availing themselves to the exceptions provided under the 4(d) limits.

*E.O. 13132—Federalism*

E.O. 13132 requires agencies to take into account any Federalism impacts of regulations under development. It includes specific consultation directives for situations where a regulation will preempt state law, or impose substantial direct compliance costs on state and local governments (unless required by statute). Neither of those circumstances is applicable to this final rule. In fact, the adopted ESA section 4(d) regulations provide mechanisms by which NMFS, in the form of limits to take prohibitions, may defer to state and local governments where they provide adequate protections for threatened salmonids.

With respect to the designation of critical habitat, this final rule does not have significant federalism effects. In keeping with Department of Commerce policies, we requested information from, and coordinated development of, this critical habitat designation with appropriate state resource agencies in the State of Oregon. The designation may have some benefit to the State and local resource agencies in that the areas essential to the conservation of the species are more clearly defined, and the PCEs of the habitat essential to the conservation of the species are specifically identified. While making these clarifications does not alter where and what federally sponsored activities may occur, it may assist local governments in long-range planning (rather than waiting for case-by-case section 7 consultations to occur).

*Civil Justice Reform*

One commenter asserted that we failed to properly conduct and provide a Civil Justice Reform analysis pursuant to E.O. 12988. The Department of Commerce has determined that this final rule does not unduly burden the judicial system and meets the requirements of sections 3(a) and 3(b)(2) of the E.O. We are designating critical habitat in accordance with the provisions of the ESA. This final rule uses standard property descriptions and identifies the PCEs within the designated areas to assist the public in understanding the habitat needs of the Oregon Coast coho ESU.

**References**

A list of the referenced materials is available on the Internet at *http://www.nwr.noaa.gov*, or upon request (see **ADDRESSES** section above).

**List of Subjects in 50 CFR Parts 223 and 226**

Endangered and threatened species, Exports, Reporting and recordkeeping requirements.

Dated: February 1, 2008.

**Samuel Rauch, III,**

*Deputy Assistant Administrator for Regulations, National Marine Fisheries Service.*

■ For the reasons set out in the preamble, 50 CFR parts 223 and 226 are amended as follows:

## PART 223—THREATENED MARINE AND ANADROMOUS SPECIES

■ 1. The authority citation for part 223 continues to read as follows:

**Authority:** 16 U.S.C. 1531–1543.

■ 2. In § 223.102, the table heading is revised and paragraph (c)(24) of the table is added to read as follows:

**§ 223.102 Enumeration of threatened marine and anadromous species.**

* * * * *

| Species [1] | | Where listed | Citation(s) for listing determination(s) | Citation(s) for critical habitat designation(s) |
|---|---|---|---|---|
| Common name | Scientific name | | | |
| * | * | * * * | * | * |
| (c) * * * | | | | |
| (24) Oregon Coast Coho. | *Oncorhynchus kisutch* | U.S.A., OR, all naturally spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco, including the Cow Creek (ODFW stock #37) coho hatchery program. | 73 FR [*Insert FR page number where the document begins*]; 2/11/08. | 73 FR [*Insert FR page number where the document begins*]; 2/11/08. |
| * | * | * * * | * | * |

■ 3. In § 223.203, paragraph (b)(2) is revised to read as follows:

**§ 223.203 Anadromous fish.**

* * * * *

(b) * * *

(2) The prohibitions of paragraph (a) of this section relating to Oregon Coast coho salmon, listed in § 223.102(a)(24), do not apply to activities specified in an application for a permit for scientific purposes or to enhance the conservation or survival of the species, provided that the application has been received by the Assistant Administrator for Fisheries, NOAA (AA), no later than June 10, 2008. The prohibitions of this section apply to these activities upon the Assistant Administrator's rejection of the application as insufficient, upon

issuance or denial of a permit, or March 31, 2009, whichever occurs earliest.

* * * * *

## PART 226—DESIGNATED CRITICAL HABITAT

■ 4. The authority citation of part 226 continues to read as follows:

**Authority:** 16 U.S.C. 1533.

■ 5. In § 226.212, the section's heading and introductory text are revised and paragraphs (a)(13) and (u) are added to read as follows:

### § 226.212 Critical habitat for 13 Evolutionarily Significant Units (ESUs) of salmon and steelhead (Oncorhynchus spp.) in Washington, Oregon and Idaho.

Critical habitat is designated in the following states and counties for the following ESUs as described in paragraph (a) of this section, and as further described in paragraphs (b) through (g) of this section. The textual descriptions of critical habitat for each ESU are included in paragraphs (i) through (u) of this section, and these descriptions are the definitive source for determining the critical habitat boundaries. General location maps are provided at the end of each ESU description (paragraphs (i) through (u) of this section) and are provided for general guidance purposes only, and not as a definitive source for determining critical habitat boundaries.

(a) * * *

| ESU | State—Counties |
|---|---|
| * * * | * * * * |
| (13) Oregon Coast coho salmon | *OR*—Benton, Clatsop, Columbia, Coos, Curry, Douglas, Lane, Lincoln, Polk, Tillamook, Washington, and Yamhill. |

* * * * *

(u) Oregon Coast Coho Salmon (*Oncorhynchus kisutch*). Critical habitat is designated to include the areas defined in the following subbasins:

(1) Necanicum Subbasin 17100201—*Necanicum River Watershed 1710020101.* Outlet(s) = Arch Cape Creek (Lat 45.8035, Long −123.9656); Asbury Creek (45.815, −123.9624); Ecola Creek (45.8959, −123.9649); Necanicum River (46.0113, −123.9264); Short Sand Creek (45.7595, −123.9641) upstream to endpoint(s) in: Arch Cape Creek (45.8044, −123.9404); Asbury Creek (45.8150, −123.9584); Beerman Creek (45.9557, −123.8749); Bergsvik Creek (45.8704, −123.7650); Brandis Creek (45.8894, −123.8529); Charlie Creek (45.9164, −123.7606); Circle Creek (45.9248, −123.9436); Circle Creek Trib A (45.9335, −123.9457); North Fork Ecola Creek (45.8705, −123.9070); West Fork Ecola Creek (45.8565, −123.9424); Grindy Creek (45.9179, −123.7390); Hawley Creek (45.9259, −123.8864); Joe Creek (45.8747, −123.7503); Johnson Creek (45.8885, −123.8816); Klootchie Creek (45.9450, −123.8413); Klootchie Creek Trib A (45.9250, −123.8447); Lindsley Creek (45.9198, −123.8339); Little Humbug Creek (45.9235, −123.7653); Little Joe Creek (45.8781, −123.7852); Little Muddy Creek (45.9551, −123.9559); Mail Creek (45.8887, −123.8655); Meyer Creek (45.9279, −123.9135); Mill Creek (46.0245, −123.8905); Mill Creek Trib 1 (46.0142, −123.8967); Neacoxie Creek (46.0245, −123.9157); Neawanna Creek (45.9810, −123.8809); Necanicum River (45.9197, −123.7106); North Fork Necanicum River (45.9308, −123.7986); North Fork Necanicum River Trib A (45.9398, −123.8109); South Fork Necanicum River (45.8760, −123.8122); Shangrila Creek (45.9706, −123.8778); Short Sand Creek (45.7763, −123.9406); Thompson Creek (46.0108, −123.8951); Tolovana Creek (45.8581, −123.9370); Unnamed (45.8648, −123.9371); Unnamed (45.8821, −123.9318); Unnamed (45.8881, −123.7436); Unnamed (45.8883, −123.9366); Unnamed (45.8906, −123.7460); Unnamed (45.8912, −123.9433); Unnamed (45.8950, −123.8715); Unnamed (45.9026, −123.9540); Unnamed (45.9046, −123.9578); Unnamed (45.9050, −123.9585); Unnamed (45.9143, −123.8656); Unnamed (45.9161, −123.9000); Unnamed (45.9210, −123.8668); Unnamed (45.9273, −123.8499); Unnamed (45.9292, −123.8900); Unnamed (45.9443, −123.9038); Unnamed (45.9850, −123.8999); Unnamed (46.0018, −123.8998); Volmer Creek (45.9049, −123.9139); Warner Creek (45.8887, −123.7801); Williamson Creek (45.9522, −123.9060).

(2) Nehalem Subbasin 17100202—(i) *Upper Nehalem River Watershed 1710020201.* Outlet(s) = Nehalem River (Lat 45.9019, Long −123.1442) upstream to endpoint(s) in: Bear Creek (45.7781, −123.4252); Bear Creek (45.8556, −123.2205); Beaver Creek (45.7624, −123.2073); Beaver Creek Trib A (45.8071, −123.2143); Beaver Creek Trib B (45.7711, −123.2318); Carlson Creek (45.7173, −123.3425); Castor Creek (45.7103, −123.2698); Cedar Creek (45.8528, −123.2928); Clear Creek, Lower North Fork (45.8229, −123.3111); Clear Creek (45.8239, −123.3531); Coal Creek Trib B (45.8149, −123.1174); Coal Creek (45.7978, −123.1293); Coon Creek (45.8211, −123.1446); Dell Creek (45.7919, −123.1559); Derby Creek (45.7225, −123.3857); Dog Creek (45.8957, −123.0741); Elk Creek (45.8256, −123.1290); Fall Creek (45.8626, −123.3247); Ginger Creek (45.8520, −123.3511); Ivy Creek (45.8938, −123.3160); Jim George Creek (45.8009, −123.1041); Kenusky Creek (45.8859, −123.0422); Kist Creek (45.7826, −123.2507); Lousignont Creek (45.7424, −123.3722); Lousignont Creek, North Fork (45.7463, −123.3576); Martin Creek (45.8474, −123.4025); Maynard Creek (45.8556, −123.3038); Military Creek (45.8233, −123.4812); Nehalem River (45.7269, −123.4159); Nehalem River, East Fork (45.8324, −123.0502); Olson Creek (45.8129, −123.3853); Pebble Creek (45.7661, −123.1357); Pebble Creek, West Fork (45.7664, −123.1899); Robinson Creek (45.7363, −123.2512); Rock Creek (45.8135, −123.5201); Rock Creek, North Fork (45.8616, −123.4560); Rock Creek, South Fork (45.7598, −123.4249); Rock Creek Trib C (45.7957, −123.4882); South Fork Rock Creek Trib A (45.7753, −123.4586); South Fork Nehalem River (45.7073, −123.4017); Selder Creek (45.8975, −123.3806); South Fork Clear Creek (45.8141, −123.3484); South Prong Clear Creek (45.7832, −123.2975); Step Creek (45.6824, −123.3348); Swamp Creek (45.8217, −123.2004); Unnamed (45.7270, −123.3419); Unnamed (45.8095, −123.0908); Unnamed (45.7558, −123.2630); Unnamed (45.7938, −123.3847); Unnamed (45.7943, −123.4059); Unnamed (45.8197, −123.0679); Unnamed (45.8477, −123.0734); Unnamed (45.8817, −123.1266); Unnamed (45.8890, −123.3817); Unnamed (45.9019, −123.1346); Weed Creek (45.8707, −123.4049); Wolf Creek,

South Fork (45.7989, −123.4028); Wolf Creek (45.7768, −123.3556).

(ii) *Middle Nehalem River Watershed 1710020202.* Outlet(s) = Nehalem River (Lat 45.9838, Long −123.4214) upstream to endpoint(s) in: Adams Creek (46.0263, −123.2869); Archibald Creek (45.9218, −123.0829); Beaver Creek (46.0554, −123.2985); Boxler Creek (46.0486, −123.3521); Calvin Creek (45.9514, −123.2976); Cedar Creek (45.9752, −123.1143); Cook Creek (45.9212, −123.1087); Cow Creek (46.0500, −123.4326); Crooked Creek (45.9043, −123.2689); Deep Creek (45.9461, −123.3719); Deep Creek Trib A (45.9127, −123.3794); Deep Creek Trib B (45.9314, −123.3809); Deer Creek (45.9033, −123.3142); Eastman Creek (46.0100, −123.2262); Fall Creek (45.9438, −123.2012); Fishhawk Creek (46.0596, −123.3857); Fishhawk Creek, North Fork (46.0907, −123.3675); Fishhawk Creek, Trib C (46.0808, −123.3692); Ford Creek (46.0570, −123.2872); Gus Creek (45.9828, −123.1453); Johnson Creek (46.0021, −123.2133); Lane Creek (45.9448, −123.3253); Little Deer Creek (45.9378, −123.2780); Lousignont Creek (46.0342, −123.4186); Lundgren Creek (46.0240, −123.2092); McCoon Creek (46.0665, −123.3043); Messing Creek (46.0339, −123.2260); Nehalem River (45.9019, −123.1442); Northrup Creek (46.0672, −123.4377); Oak Ranch Creek (45.9085, −123.0834); Sager Creek (45.9388, −123.4020); Unnamed (45.9039, −123.2044); Unnamed (45.9067, −123.0595); Unnamed (45.9488, −123.2220); Unnamed (45.9629, −123.3845); Unnamed (45.9999, −123.1732); Unnamed (46.0088, −123.4508); Unnamed (46.0208, −123.4588); Unnamed (46.0236, −123.2381); Unnamed (46.0308, −123.3135); Unnamed (46.0325, −123.4650); Unnamed (46.0390, −123.3648); Unnamed (46.0776, −123.3274); Unnamed (46.0792, −123.3409); Unnamed (46.0345, −123.2956); Warner Creek (46.0312, −123.3817); Wrong Way Creek (46.0789, −123.3142).

(iii) *Lower Nehalem River Watershed 1710020203.* Outlet(s) = Nehalem River (Lat 45.7507, Long −123.6530) upstream to endpoint(s) in: Alder Creek (45.9069, −123.5907); Beaver Creek (45.8949, −123.6764); Big Creek (45.8655, −123.6476); Bull Heifer Creek (45.9908, −123.5322); Buster Creek (45.9306, −123.4165); Cedar Creek (45.8931, −123.6029); Cow Creek (45.8587, −123.5206); Crawford Creek (45.9699, −123.4725); Cronin Creek, Middle Fork (45.7719, −123.5747); Cronin Creek, North Fork (45.7795, −123.6064); Cronin Creek, South Fork (45.7456, −123.5596); Destruction Creek (45.8750, −123.6571); East Humbug Creek (45.9454, −123.6358); Fishhawk Creek (45.9666, −123.5895); Fishhawk Creek (46.0224, −123.5374); George Creek (45.8461, −123.6226); George Creek (45.9118, −123.5766); Gilmore Creek (45.9609, −123.5372); Hamilton Creek (46.0034, −123.5881); Klines Creek (45.8703, −123.4908); Larsen Creek (45.8757, −123.5847); Little Fishhawk Creek (45.9256, −123.5501); Little Rock Creek (45.8886, −123.4558); McClure Creek (45.8560, −123.6227); Moores Creek (45.8801, −123.5178); Nehalem River (45.9838, −123.4214); Quartz Creek (45.8414, −123.5184); Spruce Run Creek (45.8103, −123.6028); Squaw Creek (45.9814, −123.4529); Stanley Creek (45.8861, −123.4352); Strum Creek (45.9321, −123.4275); Trailover Creek (46.0129, −123.4976); Unnamed (45.8083, −123.6280); Unnamed (45.8682, −123.6168); Unnamed (45.9078, −123.6630); Unnamed (45.9207, −123.4534); Unnamed (45.9405, −123.6338); Unnamed (45.9725, −123.5544); West Humbug Creek (45.9402, −123.6726); Walker Creek (45.9266, −123.4423); Walker Creek (46.0391, −123.5142); West Brook (45.9757, −123.4638).

(iv) *Salmonberry River Watershed 1710020204.* Outlet(s) = Salmonberry River (Lat 45.7507, Long −123.6530) upstream to endpoint(s) in: Pennoyer Creek (45.7190, −123.4366); Salmonberry River (45.7248, −123.4436); Salmonberry River, North Fork (45.7181, −123.5204); Wolf Creek (45.6956, −123.4485).

(v) *North Fork of Nehalem River Watershed 1710020205.* Outlet(s) = Nehalem River, North Fork (Lat 45.7317, Long −123.8765) upstream to endpoint(s) in: Acey Creek (45.7823, −123.8292); Anderson Creek (45.7643, −123.9073); Big Rackheap Creek (45.7546, −123.8145); Boykin Creek (45.8030, −123.8595); Buchanan Creek (45.8270, −123.7901); Coal Creek (45.7897, −123.8676); Coal Creek, West Fork (45.7753, −123.8871); Cougar Creek (45.8064, −123.8090); Fall Creek (45.7842, −123.8547); Fall Creek (45.8226, −123.7054); Gods Valley Creek (45.7689, −123.7793); Grassy Lake Creek (45.7988, −123.8193); Gravel Creek (45.7361, −123.8126); Henderson Creek (45.7932, −123.8548); Jack Horner Creek (45.8531, −123.7837); Lost Creek (45.7909, −123.7195); Nehalem River, Little North Fork (45.9101, −123.6972); Nehalem River, North Fork (45.8623, −123.7463); Nehalem River, North Fork, Trib R (45.8287, −123.6625); Nehalem River, North Fork, Trib T (45.8492, −123.6796); Rackheap Creek (45.7677, −123.8008); Sally Creek (45.8294, −123.7468); Soapstone Creek (45.8498, −123.7469); Soapstone Creek, Trib A (45.8591, −123.7616); Sweethome Creek (45.7699, −123.6616); Unnamed (45.7457, −123.8490); Unnamed (45.7716, −123.7691); Unnamed (45.7730, −123.7789); Unnamed (45.7736, −123.7607); Unnamed (45.7738, −123.7534); Unnamed (45.7780, −123.7434); Unnamed (45.7784, −123.7742); Unnamed (45.7794, −123.7315); Unnamed (45.7824, −123.7396); Unnamed (45.7833, −123.7680); Unnamed (45.7841, −123.7299); Unnamed (45.7858, −123.7660); Unnamed (45.7898, −123.7424); Unnamed (45.7946, −123.7365); Unnamed (45.7966, −123.7953); Unnamed (45.8008, −123.7349); Unnamed (45.8193, −123.7436); Unnamed (45.8322, −123.7789); Unnamed (45.8359, −123.7766); Unnamed (45.8569, −123.7235); Unnamed (45.8629, −123.7347); Unnamed (45.8662, −123.7444); Unnamed (45.8962, −123.7189).

(vi) *Lower Nehalem River/Cook Creek Watershed 1710020206.* Outlet(s) = Nehalem River (Lat 45.6577, Long −123.9355) upstream to endpoint(s) in: Alder Creek (45.7286, −123.9091); Anderson Creek (45.6711, −123.7470); Bastard Creek (45.7667, −123.6943); Bob's Creek (45.7444, −123.9038); Cook Creek (45.6939, −123.6146); Cook Creek, East Fork (45.6705, −123.6440); Daniels Creek (45.6716, −123.8606); Dry Creek (45.6449, −123.8507); Dry Creek (45.6985, −123.7422); East Foley Creek (45.6621, −123.8068); Fall Creek (45.7489, −123.7778); Foley Creek (45.6436, −123.8933); Gallagher Slough (45.7140, −123.8657); Hanson Creek (45.6611, −123.7179); Harliss Creek (45.6851, −123.7249); Helloff Creek (45.7545, −123.7603); Hoevett Creek (45.6894, −123.6276); Jetty Creek (45.6615, −123.9103); Lost Creek (45.7216, −123.7164); Neahkahnie Creek (45.7197, −123.9247); Nehalem River (45.7507, −123.6530); Peterson Creek (45.6975, −123.8098); Piatt Canyon (45.6844, −123.6983); Roy Creek (45.7174, −123.8038); Snark Creek (45.7559, −123.6713); Unnamed (45.6336, −123.8549); Unnamed (45.6454, −123.8663); Unnamed (45.6483, −123.8605); Unnamed (45.6814, −123.8786); Unnamed (45.7231, −123.9016).

(3) Wilson/Trask/Nestucca Subbasin 17100203—(i) *Little Nestucca River Watershed 1710020301.* Outlet(s) = Little Nestucca River (Lat 45.1827, Long −123.9543) upstream to endpoint(s) in: Austin Creek (45.1080, −123.8748);

Austin Creek, West Fork (45.1074, −123.8894); Baxter Creek (45.1149, −123.7705); Bear Creek (45.1310, −123.8500); Bowers Creek (45.1393, −123.9198); Cedar Creek (45.0971, −123.8094); Fall Creek (45.1474, −123.8767); Hiack Creek (45.0759, −123.8042); Kautz Creek (45.0776, −123.8317); Kellow Creek (45.1271, −123.9072); Little Nestucca River (45.0730, −123.7825); Little Nestucca River, South Fork (45.0754, −123.8393); Louie Creek (45.1277, −123.7869); McKnight Creek (45.1124, −123.8363); Small Creek (45.1151, −123.8227); Sourgrass Creek (45.0917, −123.7623); Sourgrass Creek, Trib A (45.1109, −123.7664); Squaw Creek (45.1169, −123.8938); Stillwell Creek (45.0919, −123.8141); Unnamed (45.1169, −123.7974).

(ii) *Nestucca River Watershed 1710020302.* Outlet(s) = Nestucca Bay (Lat 45.1607, Long −123.9678) upstream to endpoint(s) in: Alder Creek (45.1436, −123.7998); Alder Creek (45.2436, −123.7364); Bays Creek (45.3197, −123.7240); Bear Creek (45.3188, −123.6022); Bear Creek (45.3345, −123.7898); Beulah Creek (45.2074, −123.6747); Bible Creek (45.2331, −123.5868); Boulder Creek (45.2530, −123.7525); Buck Creek (45.1455, −123.7734); Cedar Creek (45.3288, −123.4531); Clarence Creek (45.2649, −123.6395); Clear Creek (45.1725, −123.8660); Crazy Creek (45.1636, −123.7595); Dahl Fork (45.2306, −123.7076); East Beaver Creek (45.3579, −123.6877); East Creek (45.3134, −123.6348); Elk Creek (45.3134, −123.5645); Elk Creek, Trib A (45.2926, −123.5381); Elk Creek, Trib B (45.2981, −123.5471); Fan Creek (45.2975, −123.4994); Farmer Creek (45.2593, −123.9074); Foland Creek (45.2508, −123.7890); Foland Creek, West Fork (45.2519, −123.8025); George Creek (45.2329, −123.8291); Ginger Creek (45.3283, −123.4680); Hartney Creek (45.2192, −123.8632); Horn Creek (45.2556, −123.9212); Lawrence Creek (45.1861, −123.7852); Limestone Creek (45.2472, −123.7169); Mina Creek (45.2444, −123.6197); Moon Creek (45.3293, −123.6762); North Beaver Creek (45.3497, −123.8961); Nestucca River (45.3093, −123.4077); Niagara Creek (45.1898, −123.6637); Pheasant Creek (45.2121, −123.6366); Pollard Creek (45.1951, −123.7958); Powder Creek (45.2305, −123.6974); Saling Creek (45.2691, −123.8474); Sanders Creek (45.2254, −123.8959); Slick Rock Creek (45.2683, −123.6106); Swab Creek (45.2889, −123.7656); Testament Creek (45.2513, −123.5488); Three Rivers (45.1785, −123.7557); Tiger Creek (45.3405, −123.8029); Tiger Creek, Trib A (45.3346, −123.8547); Tony Creek (45.2575, −123.7735); Turpy Creek (45.2537, −123.7620); Unnamed (45.1924, −123.8202); Unnamed (45.2290, −123.9398); Unnamed (45.3018, −123.4636); Unnamed (45.3102, −123.6628); Unnamed (45.3148, −123.6616); Unnamed (45.3158, −123.8679); Unnamed (45.3292, −123.8872); Walker Creek (45.2914, −123.4207); West Beaver Creek (45.3109, −123.8840); West Creek (45.2899, −123.8514); Wildcat Creek (45.3164, −123.8187); Wolfe Creek (45.3113, −123.7658); Woods Creek (45.1691, −123.8070).

(iii) *Tillamook River Watershed 1710020303.* Outlet(s) = Tillamook River (Lat 45.4682, Long −123.8802) upstream to endpoint(s) in: Bear Creek (45.4213, −123.8885); Beaver Creek (45.4032, −123.8861); Bewley Creek (45.3637, −123.8965); Esther Creek (45.4464, −123.9017); Fawcett Creek (45.3824, −123.7210); Joe Creek (45.3754, −123.8257); Killam Creek (45.4087, −123.7276); Mills Creek (45.3461, −123.7915); Munson Creek (45.3626, −123.7681); Simmons Creek (45.3605, −123.7364); Sutton Creek (45.4049, −123.8568); Tillamook River (45.3595, −123.9115); Tomlinson Creek (45.4587, −123.8868); Unnamed (45.3660, −123.8313); Unnamed (45.3602, −123.8466); Unnamed (45.3654, −123.9050); Unnamed (45.3987, −123.7105); Unnamed (45.4083, −123.8160); Unnamed (45.4478, −123.8670); Unnamed (45.3950, −123.7348).

(iv) *Trask River Watershed 1710020304.* Outlet(s) = Trask River (Lat 45.4682, Long −123.8802) upstream to endpoint(s) in: Bales Creek (45.3712, −123.5786); Bark Shanty Creek (45.4232, −123.5550); Bear Creek (45.4192, −123.7408); Bill Creek (45.3713, −123.6386); Blue Bus Creek (45.4148, −123.5949); Boundry Creek (45.3493, −123.5470); Clear Creek #1 (45.4638, −123.5571); Clear Creek #2 (45.5025, −123.4683); Cruiser Creek (45.4201, −123.4753); Dougherty Slough (45.4684, −123.7888); East Fork of South Fork Trask River (45.3563, −123.4752); Edwards Creek (45.3832, −123.6676); Elkhorn Creek, Trib C (45.4080, −123.4440); Elkhorn Creek (45.3928, −123.4709); Gold Creek (45.4326, −123.7218); Green Creek (45.4510, −123.7361); Hatchery Creek (45.4485, −123.6623); Headquarters Camp Creek (45.3317, −123.5072); Hoquarten Slough (45.4597, −123.8480); Joyce Creek (45.3881, −123.6386); Michael Creek (45.4799, −123.5119); Mill Creek (45.4100, −123.7450); Miller Creek (45.3582, −123.5666); Pigeon Creek (45.3910, −123.5656); Rawe Creek (45.4395, −123.6351); Rock Creek (45.3515, −123.5074); Samson Creek (45.4662, −123.6439); Scotch Creek (45.4015, −123.5873); Steampot Creek (45.3875, −123.5425); Stretch Creek (45.3483, −123.5382); Summit Creek (45.3481, −123.6054); Summit Creek, South Fork (45.3473, −123.6145); Trask River, North Fork, Middle Fork (45.4472, −123.3945); Trask River, North Fork, North Fork (45.5275, −123.4177); Trask River, South Fork (45.3538, −123.6445); Trib A (45.3766, −123.5191); Trib B (45.3776, −123.4988); Unnamed (45.3639, −123.6054); Unnamed (45.4105, −123.7741); Unnamed (45.4201, −123.6320); Unnamed (45.4220, −123.7654).

(v) *Wilson River Watershed 1710020305.* Outlet(s) = Wilson River (Lat 45.4816, Long −123.8708) upstream to endpoint(s) in: Beaver Creek (45.4894, −123.7933); Ben Smith Creek (45.5772, −123.5072); Cedar Creek (45.5869, −123.6228); Cedar Creek, North Fork (45.6066, −123.6151); Deo Creek (45.6000, −123.3716); Drift Creek (45.6466, −123.3944); Elk Creek (45.6550, −123.4620); Elk Creek, West Fork (45.6208, −123.4717); Elliott Creek (45.5997, −123.3925); Fall Creek (45.4936, −123.5616); Fox Creek (45.5102, −123.5869); Hatchery Creek (45.4835, −123.7074); Hughey Creek (45.4540, −123.7526); Idiot Creek (45.6252, −123.4296); Jones Creek (45.6028, −123.5702); Jordan Creek (45.5610, −123.4557); Jordan Creek, South Fork (45.5099, −123.5279); Kansas Creek (45.4861, −123.6434); Morris Creek (45.6457, −123.5409); Tuffy Creek (45.5787, −123.4702); Unnamed (45.4809, −123.8362); Unnamed (45.5758, −123.5226); Unnamed (45.5942, −123.4259); Unnamed (45.6002, −123.5939); Unnamed (45.6151, −123.4385); White Creek (45.5181, −123.7223); Wilson River, Devil's Lake Fork (45.6008, −123.3301); Wilson River, North Fork (45.6679, −123.5138); Wilson River, North Fork, Little (45.5283, −123.6771); Wilson River, North Fork, West Fork (45.6330, −123.5879); Wilson River, North Fork, West Fork, North Fork (45.6495, −123.5779); Wilson River, South Fork (45.5567, −123.3965); Wolf Creek (45.5683, −123.6129).

(vi) *Kilchis River Watershed 1710020306.* Outlet(s) = Kilchis River (Lat 45.4927, Long −123.8615) upstream to endpoint(s) in: Clear Creek (45.5000, −123.7647); Coal Creek (45.5004, −123.8085); Company Creek (45.5892, −123.7370); French Creek (45.6318, −123.6926); Kilchis River, Little South Fork (45.5668, −123.7178); Kilchis River, North Fork (45.6044, −123.6504); Kilchis River, South Fork (45.5875, −123.6944); Mapes Creek (45.5229, −123.8382); Murphy Creek (45.5320, −123.8341); Myrtle Creek (45.5296, −123.8156); Sam Downs Creek (45.5533, −123.7144); Schroeder Creek (45.6469, −123.7064); Unnamed (45.5625, −123.7593).

(vii) *Miami River Watershed 1710020307.* Outlet(s) = Miami River (Lat 45.5597, Long −123.8904) upstream to endpoint(s) in: Diamond Creek (45.6158, −123.8184); Hobson Creek (45.5738, −123.8970); Illingsworth Creek (45.5547, −123.8693); Miami River (45.6362, −123.7533); Miami River, Trib S (45.6182, −123.8004); Miami River, Trib T (45.6546, −123.7463); Minich Creek (45.5869, −123.8936); Moss Creek (45.5628, −123.8319); Peterson Creek (45.6123, −123.8996); Prouty Creek (45.6304, −123.8435); Stuart Creek (45.6042, −123.8442); Unnamed (45.6317, −123.7906); Unnamed (45.6341, −123.7900); Waldron Creek (45.5856, −123.8483).

(viii) *Tillamook Bay Watershed 1710020308.* Outlet(s) = Tillamook Bay (Lat 45.5600, Long −123.9366) upstream to endpoint(s) in: Douthy Creek (45.5277, −123.8570); Electric Creek (45.5579, −123.8925); Hall Slough (45.4736, −123.8637); Jacoby Creek (45.5297, −123.8665); Kilchis River (45.4927, −123.8615); Larson Creek (45.5366, −123.8849); Miami River (45.5597, −123.8904); Patterson Creek (45.5359, −123.8732); Tillamook Bay (45.4682, −123.8802); Vaughn Creek (45.5170, −123.8516); Wilson River (45.4816, −123.8708).

(ix) *Spring Creek/Sand Lake/Neskowin Creek Frontal Watershed 1710020309.* Outlet(s) = Crescent Lake (45.6360, −123.9405); Neskowin Creek (45.1001, −123.9859); Netarts Bay (45.4339, −123.9512); Rover Creek (45.3290, −123.9670); Sand Creek (45.2748, −123.9589); Watesco Creek (45.5892, −123.9477) upstream to endpoint(s) in: Andy Creek (45.2905, −123.8744); Butte Creek (45.1159, −123.9360); Crescent Lake (45.6320, −123.9376); Davis Creek (45.3220, −123.9254); Fall Creek (45.0669, −123.9679); Hawk Creek (45.1104, −123.9436); Jackson Creek (45.3568, −123.9611); Jewel Creek (45.2865, −123.8905); Jim Creek (45.0896, −123.9224); Lewis Creek (45.0835, −123.8979); Meadow Creek (45.0823, −123.9824); Neskowin Creek (45.0574, −123.8812); Prospect Creek (45.0858, −123.9321); Reneke Creek (45.2594, −123.9434); Rover Creek (45.3284, −123.9438); Sand Creek (45.3448, −123.9156); Sloan Creek (45.0718, −123.8998); Watesco Creek (45.5909, −123.9353); Whiskey Creek (45.3839, −123.9193).

(4) Siletz/Yaquina Subbasin 17100204–(i) *Upper Yaquina River Watershed 1710020401.* Outlet(s) = Yaquina River (Lat 44.6219, Long −123.8741) upstream to endpoint(s) in: Bales Creek (44.6893, −123.7503); Bales Creek, East Fork (44.6927, −123.7363); Bales Creek, East Fork, Trib A (44.6827, −123.7257); Bales Creek (44.6610, −123.8749); Bones Creek (44.6647, −123.6762); Bryant Creek (44.6746, −123.7139); Buckhorn Creek (44.6676, −123.6677); Buttermilk Creek (44.6338, −123.6827); Buttermilk Creek, Trib A (44.6518, −123.7173); Carlisle Creek (44.6451, −123.8847); Cline Creek (44.6084, −123.6844); Cook Creek (44.6909, −123.8583); Crystal Creek (44.6500, −123.8132); Davis Creek (44.6500, −123.6587); Eddy Creek (44.6388, −123.7951); Felton Creek (44.6626, −123.6502); Haxel Creek (44.6781, −123.8046); Hayes Creek (44.6749, −123.7749); Humphrey Creek (44.6697, −123.6329); Klamath Creek (44.6927, −123.8431); Little Elk Creek (44.6234, −123.6628); Little Elk Creek,Trib A (44.6196, −123.7583); Little Yaquina River (44.6822, −123.6123); Lytle Creek (44.6440, −123.5979); Miller Creek (44.6055, −123.7030); Oglesby Creek (44.6421, −123.7271); Oglesby Creek, Trib A (44.6368, −123.7100); Peterson Creek (44.6559, −123.7868); Randall Creek (44.6721, −123.6570); Salmon Creek (44.6087, −123.7379); Simpson Creek (44.6775, −123.8780); Sloop Creek (44.6654, −123.8595); Spilde Creek (44.6636, −123.5856); Stony Creek (44.6753, −123.7020); Thornton Creek (44.6923, −123.8208); Trapp Creek (44.6455, −123.8307); Twentythree Creek (44.6887, −123.8751); Unnamed (44.6074, −123.6738); Unnamed (44.6076, −123.7067); Unnamed (44.6077, −123.6633); Unnamed (44.6123, −123.6646); Unnamed (44.6188, −123.7237); Unnamed (44.6202, −123.7201); Unnamed (44.6367, −123.7444); Unnamed (44.6415, −123.6237); Unnamed (44.6472, −123.7793); Unnamed (44.6493, −123.6789); Unnamed (44.6707, −123.7908); Unnamed (44.6715, −123.6907); Unnamed (44.6881, −123.6089); Unnamed (44.6908, −123.7298); Wakefield Creek (44.6336, −123.6963); Yaquina River (44.6894, −123.5907); Young Creek (44.6372, −123.6027).

(ii) *Big Elk Creek Watershed 1710020402.* Outlet(s) = Elk Creek (Lat 44.6219, Long −123.8741) upstream to endpoint(s) in: Adams Creek (44.5206, −123.6349); Baker Creek (44.5230, −123.6346); Bear Creek (44.5966, −123.8299); Beaver Creek (44.6040, −123.7999); Beaverdam Creek (44.5083, −123.6337); Bevens Creek (44.5635, −123.7371); Bull Creek (44.5408, −123.8162); Bull Creek (44.5431, −123.8142); Bull Creek, Trib A (44.5359, −123.8276); Cougar Creek (44.5070, −123.6482); Cougar Creek (44.5861, −123.7563); Deer Creek (44.6020, −123.7667); Devils Well Creek (44.6324, −123.8438); Dixon Creek (44.6041, −123.8659); Elk Creek (44.5075, −123.6022); Feagles Creek (44.4880, −123.7180); Feagles Creek, Trib B (44.5079, −123.6909); Feagles Creek, West Fork (44.5083, −123.7117); Grant Creek (44.5010, −123.7363); Harve Creek (44.5725, −123.8025); Jackass Creek (44.5443, −123.7790); Johnson Creek (44.5466, −123.6336); Lake Creek (44.5587, −123.6826); Leverage Creek (44.5536, −123.6343); Little Creek (44.5548, −123.6980); Little Wolf Creek (44.5590, −123.7165); Peterson Creek (44.5576, −123.6450); Rail Creek (44.5135, −123.6639); Spout Creek (44.5824, −123.6561); Sugarbowl Creek (44.5301, −123.5995); Unnamed (44.5048, −123.7566); Unnamed (44.5085, −123.6309); Unnamed (44.5108, −123.6249); Unnamed (44.5144, −123.6554); Unnamed (44.5204, −123.6148); Unnamed (44.5231, −123.6714); Unnamed (44.5256, −123.6804); Unnamed (44.5325, −123.7244); Unnamed (44.5332, −123.7211); Unnamed (44.5361, −123.7139); Unnamed (44.5370, −123.7643); Unnamed (44.5376, −123.6176); Unnamed (44.5410, −123.8213); Unnamed (44.5504, −123.8290); Unnamed (44.5530, −123.8282); Unnamed (44.5618, −123.8431); Unnamed (44.5687, −123.8563); Unnamed (44.5718, −123.7256); Unnamed (44.5734, −123.6696); Unnamed (44.5737, −123.6566); Unnamed (44.5771, −123.7027); Unnamed (44.5821, −123.8123); Unnamed (44.5840, −123.6678); Unnamed (44.5906, −123.7871); Unnamed (44.5990, −123.7808); Unnamed (44.5865, −123.8521); Wolf Creek (44.5873, −123.6939); Wolf Creek, Trib A (44.5862, −123.7188); Wolf Creek, Trib B (44.5847, −123.7062).

(iii) *Lower Yaquina River Watershed 1710020403.* Outlet(s) = Yaquina River (Lat 44.6098, Long −124.0818) upstream to endpoint(s) in: Abbey Creek (44.6330, −123.8881); Babcock Creek (44.5873, −123.9221); Beaver Creek (44.6717, −123.9799); Blue Creek (44.6141, −123.9936); Boone Slough, Trib A (44.6134, −123.9769); Depot Creek, Little (44.6935, −123.9482); Depot Creek, Trib A (44.6837, −123.9420); Drake Creek (44.6974, −123.9690); East Fork Mill Creek (44.5691, −123.8834); Flesher Slough (44.5668, −123.9803); King Slough (44.5944, −124.0323); Little Beaver Creek (44.6531, −123.9728); McCaffery Slough (44.5659, −124.0180); Mill Creek (44.5550, −123.9064); Mill Creek, Trib A (44.5828, −123.8750); Montgomery Creek (44.5796, −123.9286); Nute Slough (44.6075, −123.9660); Olalla Creek (44.6810, −123.8972); Olalla Creek, Trib A (44.6511, −123.9034); Parker Slough (44.5889, −124.0119); Unnamed (44.5471, −123.9557); Unnamed (44.5485, −123.9308); Unnamed (44.5520, −123.9433); Unnamed (44.5528, −123.9695); Unnamed (44.5552, −123.9294); Unnamed (44.5619, −123.9348); Unnamed (44.5662, −123.8905); Unnamed (44.5827, −123.9456); Unnamed (44.5877, −123.8850); Unnamed (44.6444, −123.9059); Unnamed (44.6457, −123.9996); Unnamed (44.6530, −123.9914); Unnamed (44.6581, −123.8947); Unnamed (44.6727 −123.8942); Unnamed (44.6831, −123.9940); West Olalla Creek (44.6812, −123.9299); West Olalla Creek, Trib A (44.6649, −123.9204); Wessel Creek (44.6988, −123.9863); Wright Creek (44.5506, −123.9250); Wright Creek, Trib A (44.5658, −123.9422); Yaquina River (44.6219, −123.8741).

(iv) *Middle Siletz River Watershed 1710020405.* Outlet(s) = Siletz River (Lat 44.7375, Long −123.7917) upstream to endpoint(s) in: Buck Creek, East Fork (44.8410, −123.7970); Buck Creek, South Fork (44.8233, −123.8095); Buck Creek, West Fork (44.8352, −123.8084); Cerine Creek (44.7478, −123.7198); Deer Creek (44.8245, −123.7268); Deer Creek, Trib A (44.8178, −123.7397); Elk Creek (44.8704, −123.7668); Fourth of July Creek (44.8203, −123.6810); Gunn Creek (44.7816, −123.7679); Holman River (44.8412, −123.7707); Mill Creek, North Fork (44.7769, −123.7361); Mill Creek, South Fork (44.7554, −123.7276); Palmer Creek (44.7936, −123.8344); Siletz River (44.8629, −123.7323); Sunshine Creek (44.7977, −123.6963); Unnamed (44.7691, −123.7851); Unnamed (44.7747, −123.7740); Unnamed (44.7749, −123.7662); Unnamed (44.8118, −123.6926); Unnamed (44.8188, −123.6995); Unnamed (44.8312, −123.6983); Unnamed (44.8583, −123.7573); Whiskey Creek (44.8123, −123.6937).

(v) *Rock Creek/Siletz River Watershed 1710020406.* Outlet(s) = Rock Creek (Lat 44.7375, Long −123.7917) upstream to endpoint(s) in: Beaver Creek (44.7288, −123.6773); Big Rock Creek (44.7636, −123.6969); Brush Creek (44.6829, −123.6582); Cedar Creek (44.7366, −123.6586); Fisher Creek (44.7149, −123.6359); Little Rock Creek (44.7164, −123.6155); Little Steere Creek (44.7219, −123.6368); Rock Creek, Trib A (44.7414, −123.7508); Steere Creek (44.7336, −123.6313); Unnamed (44.7175, −123.6496); William Creek (44.7391, −123.7277).

(vi) *Lower Siletz River Watershed 1710020407.* Outlet(s) = Siletz Bay (Lat 44.9269, Long −124.0218) upstream to endpoint(s) in: Anderson Creek (44.9311, −123.9508); Bear Creek (44.8682, −123.8891); Bentilla Creek (44.7745, −123.8555); Butterfield Creek (44.8587, −123.9993); Cedar Creek (44.8653, −123.8488); Cedar Creek, Trib D (44.8606, −123.8696); Coon Creek (44.7959, −123.8468); Dewey Creek (44.7255, −123.9724); Drift Creek (44.9385, −123.8211); Erickson Creek (44.9629, −123.9490); Euchre Creek (44.8023, −123.8687); Fowler Creek (44.9271, −123.8440); Gordey Creek (44.9114, −123.9724); Hough Creek (44.8052, −123.8991); Jaybird Creek (44.7640, −123.9733); Long Prairie Creek (44.6970, −123.7499); Long Tom Creek (44.7037, −123.8533); Mann Creek (44.6987, −123.8025); Mill Creek (44.6949, −123.8967); Miller Creek (44.7487, −123.9733); North Creek (44.9279, −123.8908); North Roy Creek (44.7916, −123.9897); Ojalla Creek (44.7489, −123.9427); Quarry Creek (44.8989, −123.9360); Reed Creek (44.8020, −123.8835); Reed Creek (44.8475, −123.9267); Roots Creek (44.8300, −123.9351); South Roy Creek (44.7773, −123.9847); Sam Creek (44.7086, −123.7312); Sampson Creek (44.9089, −123.8173); Savage Creek (44.8021, −123.8608); Scare Creek (44.8246, −123.9954); Schooner Creek, North Fork (44.9661, −123.8793); Schooner Creek, South Fork (44.9401, −123.8689); Scott Creek (44.7414, −123.8268); Sijota Creek (44.8883, −124.0257); Siletz River (44.7375, −123.7917); Skunk Creek (44.8780, −123.9073); Smith Creek (44.9294, −123.8056); Stemple Creek (44.8405, −123.9492); Tangerman Creek (44.7278, −123.8944); Thayer Creek (44.7023, −123.8256); Thompson Creek (44.7520, −123.8893); Unnamed (44.7003, −123.7669); Unnamed (44.8904, −123.8034); Unnamed (44.8927, −123.8400); Unnamed (44.7034, −123.7754); Unnamed (44.7145, −123.8423); Unnamed (44.7410, −123.8800); Unnamed (44.7925, −123.9212); Unnamed (44.8396, −123.8896); Unnamed (44.9035, −123.8635); Unnamed (44.9240, −123.7913); West Fork Mill Creek (44.7119, −123.9703); Wildcat Creek (44.8915, −123.8842).

(vii) *Salmon River/Siletz/Yaquina Bay Watershed 1710020408.* Outlet(s) = Salmon River (Lat 45.0474, Long −124.0031) upstream to endpoint(s) in: Alder Brook (45.0318, −123.8428); Bear Creek (44.9785, −123.8580); Boulder Creek (45.0428, −123.7817); Calkins Creek (45.0508, −123.9615); Crowley Creek (45.0540, −123.9819); Curl Creek (45.0150, −123.9198); Deer Creek (45.0196, −123.8091); Frazer Creek (45.0096, −123.9576); Gardner Creek (45.0352, −123.9024); Indian Creek (45.0495, −123.8010); Little Salmon River (45.0546, −123.7473); McMullen Creek (44.9829, −123.8682); Panther Creek (45.0208, −123.8878); Panther Creek, North Fork (45.0305, −123.8910); Prairie Creek (45.0535, −123.8129); Rowdy Creek (45.0182, −123.9751); Salmon River (45.0269, −123.7224); Slick Rock Creek (44.9903, −123.8158); Sulphur Creek (45.0403, −123.8216); Telephone Creek (45.0467, −123.9348); Toketa Creek (45.0482, −123.9088); Trout Creek (44.9693, −123.8337); Unnamed (44.9912, −123.8789); Unnamed (45.0370, −123.7333); Unnamed (45.0433, −123.7650); Widow Creek (45.0373, −123.8530); Widow Creek, West Fork (45.0320, −123.8643); Willis Creek (45.0059, −123.9391).

(viii) *Devils Lake/Moolack Frontal Watershed 1710020409.* Outlet(s) = Big Creek (Lat 44.6590, Long −124.0571); Coal Creek (44.7074, −124.0615); D River (44.9684, −124.0172); Fogarty Creek (44.8395, −124.0520); Moolack Creek (44.7033, −124.0622); North Depoe Bay Creek (44.8098, −124.0617); Schoolhouse Creek (44.8734, −124.0401); Spencer Creek (44.7292, −124.0582); Wade Creek (44.7159, −124.0600) upstream to endpoint(s) in: Big Creek (44.6558, −124.0427); Coal Creek (44.7047, −124.0099); Devils Lake (44.9997, −123.9773); Fogarty Creek (44.8563, −124.0153); Jeffries Creek (44.6425, −124.0315); Moolack Creek (44.6931, −124.0150); North Depoe Bay Creek (44.8157, −124.0510); Rock Creek (44.9869, −123.9317); South Depoe Bay Creek (44.7939, −124.0126); Salmon Creek (44.8460, −124.0164); Schoolhouse Creek (44.8634, −124.0151); South Fork Spencer Creek (44.7323, −123.9974); Spencer Creek, North Fork (44.7453, −124.0276); Unnamed (44.8290, −124.0318); Unnamed (44.9544, −123.9867); Unnamed (44.9666, −123.9731); Unnamed

(44.9774, −123.9706); Wade Creek (44.7166, −124.0057).

(5) Alsea Subbasin 17100205—(i) *Upper Alsea River Watershed 1710020501.* Outlet(s) = Alsea River, South Fork (Lat 44.3767, Long −123.6024) upstream to endpoint(s) in: Alder Creek (44.4573, −123.5188); Alsea River, South Fork (44.3261, −123.4891); Baker Creek (44.4329, −123.5522); Banton Creek (44.3317, −123.6020); Brown Creek (44.3151, −123.6250); Bummer Creek (44.3020, −123.5765); Cabin Creek (44.4431, −123.5328); Crooked Creek (44.4579, −123.5099); Dubuque Creek (44.3436, −123.5527); Ernest Creek (44.4234, −123.5275); Hayden Creek (44.4062, −123.5815); Honey Grove Creek (44.3874, −123.5078); North Fork Alsea River (44.4527, −123.6102); Parker Creek (44.4702, −123.5978); Peak Creek (44.3358, −123.4933); Record Creek (44.3254, −123.6331); Seeley Creek (44.4051, −123.5177); Swamp Creek (44.3007, −123.6108); Tobe Creek (44.3273, −123.5719); Trout Creek (44.3684, −123.5163); Unnamed (44.3108, −123.6225); Unnamed (44.3698, −123.5670); Unnamed (44.4574, −123.5001); Unnamed (44.3708, −123.5740); Unnamed (44.3713, −123.5656); Unnamed (44.3788, −123.5528); Unnamed (44.4270, −123.5492); Unnamed (44.4518, −123.6236); Yew Creek (44.4581, −123.5373); Zahn Creek (44.4381, −123.5425).

(ii) *Five Rivers/Lobster Creek Watershed 1710020502.* Outlet(s) = Five Rivers (Lat 44.3584, Long −123.8279) upstream to endpoint(s) in: Alder Creek (44.2947, −123.8105); Bear Creek (44.2824, −123.9123); Bear Creek (44.3588, −123.7930); Bear Creek (44.2589, −123.6647); Briar Creek (44.3184, −123.6602); Buck Creek (44.2428, −123.8989); Camp Creek (44.2685, −123.7552); Cascade Creek (44.3193, −123.9073); Cascade Creek, North Fork (44.3299, −123.8932); Cedar Creek (44.2732, −123.7753); Cherry Creek (44.3061, −123.8140); Coal Creek (44.2881, −123.6484); Cook Creek (44.2777, −123.6445); Cougar Creek (44.2723, −123.8678); Crab Creek (44.2458, −123.8750); Crazy Creek (44.2955, −123.7927); Crooked Creek (44.3154, −123.7986); Elk Creek (44.3432, −123.7969); Fendall Creek (44.2764, −123.7890); Five Rivers (44.2080, −123.8025); Green River (44.2286, −123.8751); Green River, East Fork (44.2255, −123.8143); Jasper Creek (44.2777, −123.7326); Little Lobster Creek (44.2961, −123.6266); Lobster Creek, East Fork (44.2552, −123.5897); Lobster Creek, South Fork (44.2326, −123.6060); Lobster Creek (44.2237, −123.6195); Lord Creek (44.2411, −123.7631); Martha Creek (44.2822, −123.6781); Meadow Creek (44.2925, −123.6591); Phillips Creek (44.3398, −123.7613); Preacher Creek (44.2482, −123.7440); Prindel Creek (44.2346, −123.7849); Ryan Creek (44.2576, −123.7971); Summers Creek (44.2589, −123.7627); Swamp Creek (44.3274, −123.8407); Unnamed (44.2845, −123.7007); Unnamed (44.2129, −123.7919); Unnamed (44.2262, −123.7982); Unnamed (44.2290, −123.8559); Unnamed (44.2327, −123.8344); Unnamed (44.2356, −123.8178); Unnamed (44.2447, −123.6460); Unnamed (44.2500, −123.8074); Unnamed (44.2511, −123.9011); Unnamed (44.2551, −123.8733); Unnamed (44.2614, −123.8652); Unnamed (44.2625, −123.8635); Unnamed (44.2694, −123.8180); Unnamed (44.2695, −123.7429); Unnamed (44.2696, −123.8497); Unnamed (44.2752, −123.7616); Unnamed (44.2760, −123.7121); Unnamed (44.2775, −123.8895); Unnamed (44.2802, −123.7097); Unnamed (44.2802, −123.8608); Unnamed (44.2823, −123.7900); Unnamed (44.2853, −123.7537); Unnamed (44.2895, −123.9083); Unnamed (44.2940, −123.7358); Unnamed (44.2954, −123.7602); Unnamed (44.2995, −123.7760); Unnamed (44.3024, −123.9064); Unnamed (44.3066, −123.8838); Unnamed (44.3070, −123.8280); Unnamed (44.3129, −123.7763); Unnamed (44.3214, −123.8161); Unnamed (44.3237, −123.9020); Unnamed (44.3252, −123.7382); Unnamed (44.3289, −123.8354); Unnamed (44.3336, −123.7431); Unnamed (44.3346, −123.7721); Wilkinson Creek (44.3296, −123.7249); Wilson Creek (44.3085, −123.8990).

(iii) *Drift Creek Watershed 1710020503.* Outlet(s) = Drift Creek (Lat 44.4157, Long −124.0043) upstream to endpoint(s) in: Boulder Creek (44.4434, −123.8705); Bush Creek (44.5315, −123.8631); Cape Horn Creek (44.5153, −123.7844); Cedar Creek (44.4742, −123.9699); Cougar Creek (44.4405, −123.9144); Deer Creek (44.5514, −123.8778); Drift Creek (44.4688, −123.7859); Ellen Creek (44.4415, −123.9413); Flynn Creek (44.5498, −123.8520); Gold Creek (44.4778, −123.8802); Gopher Creek (44.5217, −123.7787); Horse Creek (44.5347, −123.9072); Lyndon Creek (44.4395, −123.9801); Needle Branch (44.5154, −123.8537); Nettle Creek (44.4940, −123.7845); Slickrock Creek (44.4757, −123.9007); Trout Creek (44.4965, −123.9113); Trout Creek, East Fork (44.4705, −123.9290); Unnamed (44.4995, −123.8488); Unnamed (44.4386, −123.9200); Unnamed (44.4409, −123.8738); Unnamed (44.4832, −123.9570); Unnamed (44.4868, −123.9340); Unnamed (44.4872, −123.9518); Unnamed (44.4875, −123.9460); Unnamed (44.4911, −123.9227); Unnamed (44.5187, −123.7996); Unnamed (44.5260, −123.7848); Unnamed (44.5263, −123.8868); Unnamed (44.5326, −123.8453); Unnamed (44.5387, −123.8440); Unnamed (44.5488, −123.8694); Unnamed (44.4624, −123.8216).

(iv) *Lower Alsea River Watershed 1710020504.* Outlet(s) = Alsea River (Lat 44.4165, Long −124.0829) upstream to endpoint(s) in: Alsea River (44.3767, −123.6024); Arnold Creek (44.3922, −123.9503); Barclay Creek (44.4055, −123.8659); Bear Creek (44.3729, −123.9623); Bear Creek (44.3843, −123.7704); Beaty Creek (44.4044, −123.6043); Benner Creek (44.3543, −123.7447); Brush Creek (44.3826, −123.8537); Bull Run Creek (44.4745, −123.7439); Canal Creek (44.3322, −123.9460); Canal Creek, East Fork (44.3454, −123.9161); Carns Canyon (44.4027, −123.7550); Cedar Creek (44.3875, −123.7946); Cove Creek (44.4403, −123.7107); Cow Creek (44.3620, −123.7510); Darkey Creek (44.3910, −123.9927; Digger Creek (44.3906, −123.6890); Fall Creek (44.4527, −123.6864); Fall Creek (44.4661, −123.6933); George Creek (44.3556, −123.8603); Grass Creek (44.3577, −123.8798); Hatchery Creek (44.3952, −123.7269); Hatchery Creek (44.4121, −123.8734); Hoover Creek (44.3618, −123.8583); Lake Creek (44.3345, −123.8725); Lint Creek (44.3850, −124.0490); Maltby Creek (44.3833, −123.6770); Meadow Fork (44.3764, −123.8879); Mill Creek (44.4046, −123.6436); Minotti Creek (44.3750, −123.7718); Nye Creek (44.4326, −123.7648); Oxstable Creek (44.3912, −123.9603); Phillips Creek (44.3803, −123.7780); Red Creek (44.3722, −123.9162); Risley Creek (44.4097, −123.9380); Schoolhouse Creek (44.3897, −123.6545); Scott Creek, East Fork (44.4252, −123.7897); Scott Creek, West Fork (44.4212, −123.8225); Skinner Creek (44.3585, −123.9374); Skunk Creek (44.3998, −123.6912); Slide Creek (44.3986, −123.8419); Starr Creek (44.4477, −124.0130); Sudan Creek (44.3817, −123.9717); Sulmon Creek (44.3285, −123.7008); Sulmon Creek, North Fork (44.3421, −123.6374); Sulmon Creek, South Fork (44.3339, −123.6709); Swede Fork

(44.3852, −124.0295); Unnamed (44.3319, −123.9318); Unnamed (44.3356, −123.9464); Unnamed (44.3393, −123.9360); Unnamed (44.3413, −123.9294); Unnamed (44.3490, −123.9058); Unnamed (44.3548, −123.6574); Unnamed (44.3592, −123.6363); Unnamed (44.3597, −123.9042); Unnamed (44.3598, −123.6563); Unnamed (44.3598, −123.6562); Unnamed (44.3600, −123.6514); Unnamed (44.3656, −123.9085); Unnamed (44.3680, −123.9629); Unnamed (44.3794, −123.8268); Unnamed (44.3800, −123.9134); Unnamed (44.3814, −123.7650); Unnamed (44.3822, −124.0555); Unnamed (44.3823, −124.0451); Unnamed (44.3989, −123.6050); Unnamed (44.4051, −124.0527); Unnamed (44.4166, −123.8149); Unnamed (44.4537, −123.7247); Walker Creek (44.4583, −124.0271); Weist Creek (44.3967, −124.0256); West Creek (44.3588, −123.9493).

(v) *Beaver Creek/Waldport Bay Watershed 1710020505.* Outlet(s) = Beaver Creek (Lat 44.5233, Long −124.0734); Deer Creek (44.5076, −124.0807); Thiel Creek (44.5646, −124.0709) upstream to endpoint(s) in: Beaver Creek, North Fork, Trib G (44.5369, −123.9195); Beaver Creek, South Fork (44.4816, −123.9853); Beaver Creek, South Fork, Trib A (44.4644, −124.0332); Bowers Creek (44.5312, −124.0117); Bunnel Creek (44.5178, −124.0265); Deer Creek (44.5057, −124.0721); Elkhorn Creek (44.5013, −123.9572); Elkhorn Creek (44.4976, −123.9685); Lewis Creek (44.5326, −123.9532); North Fork Beaver Creek (44.5149, −123.8988); Oliver Creek (44.4660, −124.0471); Peterson Creek (44.5419, −123.9738); Pumphouse Creek (44.5278, −124.0569); Simpson Creek (44.5255, −124.0390); Thiel Creek (44.5408, −124.0254); Tracy Creek (44.5411, −124.0500); Unnamed (44.4956, −123.9751); Unnamed (44.5189, −124.0638); Unnamed (44.5225, −123.9313); Unnamed (44.5256, −123.9399); Unnamed (44.5435, −124.0221); Unnamed (44.5461, −124.0311); Unnamed (44.5472, −124.0591); Unnamed (44.5482, −124.0249); Unnamed (44.5519, −124.0279); Unnamed (44.5592, −124.0531); Worth Creek (44.5013, −124.0207).

(vi) *Yachats River Watershed 1710020506.* Outlet(s) = Yachats River (Lat 44.3081, Long −124.1070) upstream to endpoint(s) in: Axtell Creek (44.3084, −123.9915); Beamer Creek (44.3142, −124.0124); Bend Creek (44.2826, −124.0077); Carson Creek (44.3160, −124.0030); Dawson Creek (44.2892, −124.0133); Depew Creek (44.3395, −123.9631); Earley Creek (44.3510, −123.9885); Fish Creek (44.3259, −123.9592); Glines Creek (44.3436, −123.9756); Grass Creek (44.2673, −123.9109); Helms Creek (44.2777, −123.9954); Keller Creek (44.2601, −123.9485); Little Beamer Creek (44.2993, −124.0213); Reedy Creek (44.3083, −124.0460); South Beamer Creek (44.2852, −124.0325); Stump Creek (44.2566, −123.9624); Unnamed (44.2596, −123.9279); Unnamed (44.2657, −123.9585); Unnamed (44.2660, −123.9183); Unnamed (44.2684, −123.9711); Unnamed (44.2837, −123.9268); Unnamed (44.2956, −123.9316); Unnamed (44.3005, −123.9324); Unnamed (44.3163, −123.9428); Unnamed (44.3186, −123.9568); Unnamed (44.3259, −123.9578); Unnamed (44.3431, −123.9711); West Fork Williamson Creek (44.3230, −124.0008); Williamson Creek (44.3300, −124.0026); Yachats River (44.2468, −123.9329); Yachats River, North Fork (44.3467, −123.9972); Yachats River, School Fork (44.3145, −123.9341).

(vii) *Cummins Creek/Tenmile Creek/Mercer Lake Frontal Watershed 1710020507.* Outlet(s) = Berry Creek (Lat 44.0949, Long −124.1221); Big Creek (44.1767, −124.1148); Bob Creek (44.2448, −124.1118); Cape Creek (44.1336, −124.1211); Cummins Creek (44.2660, −124.1075); Rock Creek (44.1833, −124.1149); Sutton Creek (44.0605, −124.1269); Tenmile Creek (44.2245, −124.1083) upstream to endpoint(s) in: Bailey Creek (44.1037, −124.0530); Berry Creek (44.0998, −124.0885); Big Creek (44.1866, −123.9781); Big Creek, South Fork (44.1692, −123.9688); Big Creek, Trib A (44.1601, −124.0231); Bob Creek (44.2346, −124.0235); Cape Creek (44.1351, −124.0174); Cape Creek, North Fork (44.1458, −124.0489); Cummins Creek (44.2557, −124.0104); Fryingpan Creek (44.1723, −124.0401); Levage Creek (44.0745, −124.0588); Little Cummins Creek (44.2614, −124.0851); McKinney Creek (44.2187, −123.9985); Mercer Creek (44.0712, −124.0796); Mill Creek (44.2106, −124.0747); Quarry Creek (44.0881, −124.1124); Rath Creek (44.0747, −124.0901); Rock Creek (44.1882, −124.0310); Tenmile Creek (44.2143, −123.9351); Tenmile Creek, South Fork (44.2095, −123.9607); Unnamed (44.1771, −124.0908); Unnamed (44.0606, −124.0805); Unnamed (44.0624, −124.0552); Unnamed (44.0658, −124.0802); Unnamed (44.0690, −124.0490); Unnamed (44.0748, −124.0478); Unnamed (44.0814, −124.0464); Unnamed (44.0958, −124.0559); Unnamed (44.1283, −124.0242); Unnamed (44.1352, −124.0941); Unnamed (44.1712, −124.0558); Unnamed (44.1715, −124.0636); Unnamed (44.2011, −123.9634); Unnamed (44.2048, −123.9971); Unnamed (44.2146, −124.0358); Unnamed (44.2185, −124.0270); Unnamed (44.2209, −123.9368); Wapiti Creek (44.1216, −124.0448); Wildcat Creek (44.2339, −123.9632).

(viii) *Big Creek/Vingie Creek Watershed 1710020508.* Outlet(s) = Big Creek (Lat 44.3742, Long −124.0896) upstream to endpoint(s) in: Big Creek (44.3564, −124.0613); Dicks Fork Big Creek (44.3627, −124.0389); Reynolds Creek (44.3768, −124.0740); South Fork Big Creek (44.3388, −124.0597); Unnamed (44.3643, −124.0355); Unnamed (44.3662, −124.0573); Unnamed (44.3686, −124.0683).

(6) Siuslaw Subbasin 17100206—(i) *Upper Siuslaw River Watershed 1710020601.* Outlet(s) = Siuslaw River (Lat 44.0033, Long −123.6545) upstream to endpoint(s) in: Bear Creek (43.8482, −123.5172); Bear Creek, Trib A (43.8496, −123.5059); Bierce Creek (43.8750, −123.5559); Big Canyon Creek (43.9474, −123.6582); Bottle Creek (43.8791, −123.3871); Bounds Creek (43.9733, −123.7108); Buck Creek, Trib B (43.8198, −123.3913); Buck Creek, Trib E (43.8152, −123.4248); Burntwood Creek (43.9230, −123.5342); Cabin Creek (43.8970, −123.6754); Camp Creek (43.9154, −123.4904); Canyon Creek (43.9780, −123.6096); Clay Creek (43.8766, −123.5721); Collins Creek (43.8913, −123.6047); Conger Creek (43.8968, −123.4524); Doe Creek (43.8957, −123.3558); Doe Hollow Creek (43.8487, −123.4603); Dogwood Creek (43.8958, −123.3811); Douglas Creek (43.8705, −123.2836); Edris Creek (43.9224, −123.5531); Esmond Creek (43.8618, −123.5772); Esmond Creek, Trib 1 (43.9303, −123.6518); Esmond Creek, Trib A (43.8815, −123.6646); Farman Creek (43.8761, −123.2562); Fawn Creek (43.8743, −123.2992); Fawn Creek (43.9436, −123.6088); Fryingpan Creek (43.8329, −123.4241); Fryingpan Creek (43.8422, −123.4318); Gardner Creek (43.8024, −123.2582); Haight Creek (43.8406, −123.4862); Haskins Creek (43.8785, −123.5851); Hawley Creek (43.8599, −123.1558); Hawley Creek, North Fork (43.8717, −123.1751); Holland Creek (43.8775, −123.4156); Jeans Creek (43.8616, −123.4714); Johnson Creek (43.8822, −123.5332); Kelly Creek (43.8338, −123.1739); Kline Creek (43.9034, −123.6635); Leopold Creek (43.9199, −123.6890); Leopold

Creek, Trib A (43.9283, −123.6630); Letz Creek, Trib B (43.7900, −123.3248); Lick Creek (43.8366, −123.2695); Little Siuslaw Creek (43.8048, −123.3412); Lucas Creek (43.8202, −123.2233); Luyne Creek (43.9155, −123.5068); Luyne Creek, Trib A (43.9179, −123.5208); Michaels Creek (43.8624, −123.5417); Mill Creek (43.9028, −123.6228); Norris Creek (43.8434, −123.2006); North Creek (43.9223, −123.5752); North Fork Siuslaw River (43.8513, −123.2302); Oxbow Creek (43.8384, −123.5433); Oxbow Creek, Trib C (43.8492, −123.5465); Pheasant Creek (43.9120, −123.4247); Pheasant Creek, Trib 2 (43.9115, −123.4411); Pugh Creek (43.9480, −123.5940); Russell Creek (43.8813, −123.3425); Russell Creek, Trib A (43.8619, −123.3498); Sandy Creek (43.7684, −123.2441); Sandy Creek, Trib B (43.7826, −123.2538); Shaw Creek (43.8817, −123.3289); Siuslaw River, East Trib (43.8723, −123.5378); Siuslaw River, North Fork, Upper Trib (43.8483, −123.2275); Smith Creek (43.8045, −123.3665); South Fork Siuslaw River (43.7831, −123.1569); Trail Creek (43.9142, −123.6241); Tucker Creek (43.8159, −123.1604); Unnamed (43.7796, −123.2019); Unnamed (43.7810, −123.2818); Unnamed (43.8278, −123.2610); Unnamed (43.8519, −123.2773); Unnamed (43.8559, −123.5520); Unnamed (43.8670, −123.6022); Unnamed (43.8876, −123.5194); Unnamed (43.8902, −123.5609); Unnamed (43.8963, −123.4171); Unnamed (43.8968, −123.4731); Unnamed (43.8992, −123.4033); Unnamed (43.9006, −123.4637); Unnamed (43.9030, −123.6434); Unnamed (43.9492, −123.6924); Unnamed (43.9519, −123.6886); Unnamed (43.9784, −123.6815); Unnamed (43.9656, −123.7145); Whittaker Creek (43.9490, −123.7004); Whittaker Creek, Trib B (43.9545, −123.7121).

(ii) *Wolf Creek Watershed 1710020602.* Outlet(s) = Wolf Creek (Lat 43.9548, Long −123.6205) upstream to endpoint(s) in: Bill Lewis Creek (43.9357, −123.5708); Cabin Creek (43.9226, −123.4081); Eames Creek (43.9790, −123.4352); Eames Creek, Trib C (43.9506, −123.4371); Elkhorn Creek (43.9513, −123.3934); Fish Creek (43.9238, −123.3872); Gall Creek (43.9865, −123.5187); Gall Creek, Trib 1 (43.9850, −123.5285); Grenshaw Creek (43.9676, −123.4645); Lick Creek (43.9407, −123.5796); Oat Creek, Trib A (43.9566, −123.5052); Oat Creek, Trib C (43.9618, −123.4902); Oat Creek (43.9780, −123.4761); Panther Creek (43.9529, −123.3744); Pittenger Creek (43.9713, −123.5434); Saleratus Creek (43.9796, −123.5675); Saleratus Creek, Trib A (43.9776, −123.5797); Swamp Creek (43.9777, −123.4197); Swing Log Creek (43.9351, −123.3339); Unnamed (43.9035, −123.3358); Unnamed (43.9343, −123.3648); Unnamed (43.9617, −123.4507); Unnamed (43.9668, −123.6041); Unnamed (43.9693, −123.4846); Van Curen Creek (43.9364, −123.5520); Wolf Creek (43.9101, −123.3234).

(iii) *Wildcat Creek Watershed 1710020603.* Outlet(s) = Wildcat Creek (Lat 44.0033, Long −123.6545) upstream to endpoint(s) in: Bulmer Creek (44.0099, −123.5206); Cattle Creek (44.0099, −123.5475); Fish Creek (44.0470, −123.5383); Fowler Creek (43.9877, −123.5918); Haynes Creek (44.1000, −123.5578); Kirk Creek (44.0282, −123.6270); Knapp Creek (44.1006, −123.5801); Miller Creek (44.0767, −123.6034); Pataha Creek (43.9914, −123.5361); Potato Patch Creek (43.9936, −123.5812); Salt Creek (44.0386, −123.5021); Shady Creek (44.0647, −123.5838); Shultz Creek (44.0220, −123.6320); Unnamed (43.9890, −123.5468); Unnamed (44.0210, −123.4805); Unnamed (44.0233, −123.4996); Unnamed (44.0242, −123.4796); Unnamed (44.0253, −123.4963); Unnamed (44.0283, −123.5311); Unnamed (44.0305, −123.5275); Unnamed (44.0479, −123.6199); Unnamed (44.0604, −123.5624); Unnamed (44.0674, −123.6075); Unnamed (44.0720, −123.5590); Unnamed (44.0839, −123.5777); Unnamed (44.0858, −123.5787); Unnamed (44.0860, −123.5741); Unnamed (44.0865, −123.5935); Unnamed (44.0945, −123.5838); Unnamed (44.0959, −123.5902); Walker Creek (44.0469, −123.6312); Walker Creek, Trib C (44.0418, −123.6048); Wildcat Creek (43.9892, −123.4308); Wildcat Creek, Trib ZH (43.9924, −123.4975); Wildcat Creek, Trib ZI (44.0055, −123.4681).

(iv) *Lake Creek Watershed 1710020604.* Outlet(s) = Lake Creek (Lat 44.0556, Long −123.7968) upstream to endpoint(s) in: Chappell Creek (44.1158, −123.6921); Conrad Creek (44.1883, −123.4918); Druggs Creek (44.1996, −123.5926); Fish Creek (44.1679, −123.5149); Green Creek (44.1389, −123.7930); Greenleaf Creek (44.1766, −123.6391); Hula Creek (44.1202, −123.7087); Johnson Creek (44.1037, −123.7327); Lake Creek (44.2618, −123.5148); Lamb Creek (44.1401, −123.5991); Leaver Creek (44.0754, −123.6285); Leibo Canyon (44.2439, −123.4648); Little Lake Creek (44.1655, −123.6004); McVey Creek (44.0889, −123.6875); Nelson Creek (44.1229, −123.5558); North Fork Fish Creek (44.1535, −123.5437); Pontius Creek (44.1911, −123.5909); Pope Creek (44.2118, −123.5319); Post Creek (44.1828, −123.5259); Stakely Canyon (44.2153, −123.4690); Steinhauer Creek (44.1276, −123.6594); Swamp Creek (44.2150, −123.5687); Swartz Creek (44.2304, −123.4461); Target Canyon (44.2318, −123.4557); Unnamed (44.1048, −123.6540); Unnamed (44.1176, −123.5846); Unnamed (44.1355, −123.5473); Unnamed (44.1355, −123.6125); Unnamed (44.1382, −123.5539); Unnamed (44.1464, −123.5843); Unnamed (44.1659, −123.5658); Unnamed (44.1725, −123.5981); Unnamed (44.1750, −123.5914); Unnamed (44.1770, −123.5697); Unnamed (44.1782, −123.5419); Unnamed (44.1798, −123.5834); Unnamed (44.1847, −123.5862); Unnamed (44.2042, −123.5700); Unnamed (44.2143, −123.5873); Unnamed (44.2258, −123.4493); Unnamed (44.2269, −123.5478); Unnamed (44.2328, −123.5285); Unnamed (44.2403, −123.5358); Unnamed (44.2431, −123.5105); Unnamed (44.2437, −123.5739); Unnamed (44.2461, −123.5180); Unnamed (44.2484, −123.5501); Unnamed (44.2500, −123.5691); Unnamed (44.2573, −123.4736); Unnamed (44.2670, −123.4840); Wheeler Creek (44.1232, −123.6778).

(v) *Deadwood Creek Watershed 1710020605.* Outlet(s) = Deadwood Creek (Lat 44.0949, Long −123.7594) upstream to endpoint(s) in: Alpha Creek (44.1679, −123.6951); Bear Creek (44.1685, −123.6627); Bear Creek, South Fork (44.1467, −123.6743); Buck Creek (44.2003, −123.6683); Deadwood Creek (44.2580, −123.6885); Deadwood Creek, West Fork (44.1946, −123.8023); Deer Creek (44.1655, −123.7229); Failor Creek (44.1597, −123.8003); Fawn Creek (44.2356, −123.7244); Karlstrom Creek (44.1776, −123.7133); Misery Creek (44.1758, −123.7950); North Fork Panther Creek (44.2346, −123.7362); Panther Creek (44.2273, −123.7558); Raleigh Creek (44.1354, −123.6926); Rock Creek (44.1812, −123.6683); Schwartz Creek (44.1306, −123.7258); Unnamed (44.2011, −123.7273); Unnamed (44.1806, −123.7693); Unnamed (44.1845, −123.6824); Unnamed (44.1918, −123.7521); Unnamed (44.1968, −123.7664); Unnamed (44.2094, −123.6674); Unnamed (44.2149, −123.7639); Unnamed (44.2451, −123.6705);

Unnamed (44.2487, −123.7137); Unnamed (44.2500, −123.6933).

(vi) *Indian Creek/Lake Creek Watershed 1710020606.* Outlet(s) = Indian Creek (Lat 44.0808, Long −123.7891) upstream to endpoint(s) in: Cremo Creek (44.1424, −123.8144); Elk Creek (44.1253, −123.8821); Gibson Creek (44.1548, −123.8132); Herman Creek (44.2089, −123.8220); Indian Creek (44.2086, −123.9171); Indian Creek, North Fork (44.2204, −123.9016); Indian Creek, West Fork (44.2014, −123.9075); Long Creek (44.1395, −123.8800); Maria Creek (44.1954, −123.9219); Pyle Creek (44.1792, −123.8623); Rogers Creek (44.1851, −123.9397); Smoot Creek (44.1562, −123.8449); Taylor Creek (44.1864, −123.8115); Unnamed (44.1643, −123.8993); Unnamed (44.1727, −123.8154); Unnamed (44.1795, −123.9180); Unnamed (44.1868, −123.9002); Unnamed (44.1905, −123.8633); Unnamed (44.1967, −123.8872); Unnamed (44.2088, −123.8381); Unnamed (44.2146, −123.8528); Unnamed (44.2176, −123.8462); Unnamed (44.2267, −123.8912); Velvet Creek (44.1295, −123.8087).

(vii) *North Fork Siuslaw River Watershed 1710020607.* Outlet(s) = North Fork Siuslaw River (Lat 43.9719, Long −124.0783) upstream to endpoint(s) in: Billie Creek (44.0971, −124.0362); Cataract Creek (44.0854, −123.9497); Cedar Creek (44.1534, −123.9045); Condon Creek (44.1138, −123.9984); Coon Creek (44.0864, −124.0318); Deer Creek (44.1297, −123.9475); Drew Creek (44.1239, −123.9801); Drew Creek (44.1113, −123.9854); Elma Creek (44.1803, −123.9434); Hanson Creek (44.0776, −123.9328); Haring Creek (44.0307, −124.0462); Lawrence Creek (44.1710, −123.9504); Lindsley Creek (44.0389, −124.0591); McLeod Creek (44.1050, −123.8805); Morris Creek (44.0711, −124.0308); Porter Creek (44.1490, −123.9641); Russell Creek (44.0680, −123.9848); Sam Creek (44.1751, −123.9527); Slover Creek (44.0213, −124.0531); South Russell Creek (44.0515, −123.9840); Taylor Creek (44.1279, −123.9052); Uncle Creek (44.1080, −124.0174); Unnamed (43.9900, −124.0784); Unnamed (43.9907, −124.0759); Unnamed (43.9953, −124.0514); Unnamed (43.9958, −124.0623); Unnamed (43.9999, −124.0694); Unnamed (44.0018, −124.0596); Unnamed (44.0050, −124.0556); Unnamed (44.0106, −124.0650); Unnamed (44.0135, −124.0609); Unnamed (44.0166, −124.0371); Unnamed (44.0194, −124.0631); Unnamed (44.0211, −124.0663); Unnamed (44.0258, −124.0594); Unnamed (44.0304, −124.0129); Unnamed (44.0327, −124.0670); Unnamed (44.0337, −124.0070); Unnamed (44.0342, −124.0056); Unnamed (44.0370, −124.0391); Unnamed (44.0419, −124.0013); Unnamed (44.0441, −124.0321); Unnamed (44.0579, −124.0077); Unnamed (44.0886, −124.0192); Unnamed (44.0892, −123.9925); Unnamed (44.0941, −123.9131); Unnamed (44.0976, −124.0033); Unnamed (44.1046, −123.9032); Unnamed (44.1476, −123.8959); Unnamed (44.1586, −123.9150); West Branch North Fork Siuslaw River (44.1616, −123.9616); Wilhelm Creek (44.1408, −123.9774).

(viii) *Lower Siuslaw River Watershed 1710020608.* Outlet(s) = Siuslaw River (Lat 44.0160, Long −124.1327) upstream to endpoint(s) in: Barber Creek (44.0294, −123.7598); Beech Creek (44.0588, −123.6980); Berkshire Creek (44.0508, −123.8890); Bernhardt Creek (43.9655, −123.9532); Brush Creek (44.0432, −123.7798); Brush Creek, East Fork (44.0414, −123.7782); Cedar Creek (43.9696, −123.9304); Cleveland Creek (44.0773, −123.8343); Demming Creek (43.9643, −124.0313); Dinner Creek (44.0108, −123.8069); Divide Creek (44.0516, −123.9421); Duncan Inlet (44.0081, −123.9921); Hadsall Creek (43.9846, −123.8221); Hadsall Creek, Trib D (43.9868, −123.8500); Hadsall Creek, Trib E (43.9812, −123.8359); Hanson Creek (44.0364, −123.9628); Hoffman Creek (43.9808, −123.9412); Hollenbeck Creek (44.0321, −123.8672); Hood Creek (43.9996, −123.7995); Karnowsky Creek (43.9847, −123.9658); Knowles Creek (43.9492, −123.7315); Knowles Creek, Trib L (43.9717, −123.7830); Lawson Creek, Trib B (43.9612, −123.9659); Meadow Creek (44.0311, −123.6490); Munsel Creek (44.0277, −124.0788); Old Man Creek (44.0543, −123.8022); Pat Creek (44.0659, −123.7245); Patterson Creek (43.9984, −124.0234); Rice Creek (44.0075, −123.8519); Rock Creek (44.0169, −123.6512); South Fork Waite Creek (43.9929, −123.7105); San Antone Creek (44.0564, −123.6515); Shoemaker Creek (44.0669, −123.8977); Shutte Creek (43.9939, −124.0339); Siuslaw River (44.0033, −123.6545); Skunk Hollow (43.9830, −124.0626); Smith Creek (44.0393, −123.6674); Spencer Creek (44.0676, −123.8809); Sulphur Creek (43.9822, −123.8015); Sweet Creek (43.9463, −123.9016); Sweet Creek, Trib A (44.0047, −123.8907); Sweet Creek, Trib D (43.9860, −123.8811); Thompson Creek (44.0974, −123.8615); Turner Creek (44.0096, −123.7607); Unnamed (43.9301, −124.0434); Unnamed (43.9596, −124.0337); Unnamed (43.9303, −124.0487); Unnamed (43.9340, −124.0529); Unnamed (43.9367, −124.0632); Unnamed (43.9374, −124.0442); Unnamed (43.9481, −124.0530); Unnamed (43.9501, −124.0622); Unnamed (43.9507, −124.0533); Unnamed (43.9571, −124.0658); Unnamed (43.9576, −124.0491); Unnamed (43.9587, −124.0988); Unnamed (43.9601, −124.0927); Unnamed (43.9615, −124.0527); Unnamed (43.9618, −124.0875); Unnamed (43.9624, −123.7499); Unnamed (43.9662, −123.7639); Unnamed (43.9664, −123.9252); Unnamed (43.9718, −124.0389; Unnamed (43.9720, −124.0075); Unnamed (43.9751, −124.0090); Unnamed (43.9784, −124.0191); Unnamed (43.9796, −123.9150); Unnamed (43.9852, −123.9802); Unnamed (43.9878, −123.9845); Unnamed (43.9915, −123.9732); Unnamed (43.9938, −123.9930); Unnamed (43.9942, −123.8547); Unnamed (43.9943, −123.9891); Unnamed (43.9954, −124.1185); Unnamed (43.9956, −123.7074); Unnamed (43.9995, −123.9825); Unnamed (44.0023, −123.7317); Unnamed (44.0210, −123.7874); Unnamed (44.0240, −123.8989); Unnamed (44.0366, −123.7363); Unnamed (44.0506, −123.9068); Waite Creek (43.9886, −123.7220); Walker Creek (44.0566, −123.9129); Wilson Creek (44.0716, −123.8792).

(7) Siltcoos Subbasin 17100207—(i) *Waohink River/Siltcoos River/Tahkenitch Lake Frontal Watershed 1710020701.* Outlet(s) = Siltcoos River (Lat 43.8766, Long −124.1548); Tahkenitch Creek (43.8013, −124.1689) upstream to endpoint(s) in: Alder Creek (43.8967, −124.0114); Bear Creek (43.9198, −123.9293); Bear Creek Trib (43.9030, −123.9881); Bear Creek, South Fork (43.9017, −123.9555); Bell Creek (43.8541, −123.9718); Billy Moore Creek (43.8876, −123.9604); Carle Creek (43.9015, −124.0210); Carter Creek (43.9457, −124.0123); Dismal Swamp (43.8098, −124.0871); Elbow Lake Creek (43.7886, −124.1490); Fiddle Creek (43.9132, −123.9164); Fivemile Creek (43.8297, −123.9776); Grant Creek (43.9373, −124.0278); Harry Creek (43.8544, −124.0220); Henderson Canyon (43.8648, −123.9654); Henderson Creek (43.9427, −123.9704); John Sims Creek (43.8262, −124.0792); King Creek (43.8804, −124.0300); Lane Creek (43.8437, −124.0765); Leitel Creek

(43.8181, −124.0200); Mallard Creek (43.7775, −124.0852); Maple Creek (43.9314, −123.9316); Maple Creek, North Prong (43.9483, −123.9510); Miles Canyon (43.8643, −124.0097); Miller Creek (43.9265, −124.0663); Mills Creek (43.8966, −124.0397); Morris Creek (43.8625, −123.9541); Perkins Creek (43.8257, −124.0448); Rider Creek (43.9210, −123.9700); Roache Creek (43.9087, −124.0049); Schrum Creek (43.9194, −124.0492); Schultz Creek (43.9245, −123.9371); Stokes Creek (43.9161, −123.9984); Tenmile Creek (43.9419, −123.9447); Unnamed (43.8928, −124.0461); Unnamed (43.7726, −124.1021); Unnamed (43.7741, −124.1313); Unnamed (43.7756, −124.1363); Unnamed (43.7824, −124.1342); Unnamed (43.7829, −124.0852); Unnamed (43.7837, −124.0812); Unnamed (43.7849, −124.0734); Unnamed (43.7862, −124.0711); Unnamed (43.7865, −124.1107); Unnamed (43.7892, −124.1163); Unnamed (43.7897, −124.0608); Unnamed (43.7946, −124.0477); Unnamed (43.7964, −124.0643); Unnamed (43.8015, −124.0450); Unnamed (43.8078, −124.0340); Unnamed (43.8095, −124.1362); Unnamed (43.8112, −124.0608); Unnamed (43.8152, −124.0981); Unnamed (43.8153, −124.1314); Unnamed (43.8172, −124.0752); Unnamed (43.8231, −124.0853); Unnamed (43.8321, −124.0128); Unnamed (43.8322, −124.0069); Unnamed (43.8323, −124.1016); Unnamed (43.8330, −124.0217); Unnamed (43.8361, −124.1209); Unnamed (43.8400, −123.9802); Unnamed (43.8407, −124.1051); Unnamed (43.8489, −124.0634); Unnamed (43.8500, −123.9852); Unnamed (43.8504, −124.1248); Unnamed (43.8504, −124.0024); Unnamed (43.8507, −124.0511); Unnamed (43.8589, −124.1231); Unnamed (43.8596, −124.0438); Unnamed (43.8605, −124.1211); Unnamed (43.8669, −124.0717); Unnamed (43.8670, −124.0327); Unnamed (43.8707, −124.0689); Unnamed (43.8802, −124.0605); Unnamed (43.8862, −124.0570); Unnamed (43.8913, −123.9380); Unnamed (43.8919, −124.0771); Unnamed (43.8976, −124.0725); Unnamed (43.9032, −124.0651); Unnamed (43.9045, −124.0548); Unnamed (43.9057, −124.0606); Unnamed (43.9065, −124.0656); Unnamed (43.9105, −124.0453); Unnamed (43.9106, −124.0203); Unnamed (43.9202, −124.0786); Unnamed (43.9209, −124.0734); Unnamed (43.9237, −124.0155); Unnamed (43.9249, −124.0074); Unnamed (43.9274, −124.0759); Unnamed (43.9275, −124.0308); Unnamed (43.9360, −124.0892); Unnamed (43.9365, −124.0297); Unnamed (43.9424, −124.0981); Unnamed (43.9438, −124.0929); Unnamed (43.9453, −124.0752); Unnamed (43.9518, −123.9953).

(8) North Fork Umpqua Subbasin 17100301—(i) *Boulder Creek Watershed 1710030106.* Outlet(s) = Boulder Creek (Lat 43.3036, Long −122.5272) upstream to endpoint(s) in: Boulder Creek (Lat 43.3138, Long −122.5247)

(ii) *Middle North Umpqua Watershed 1710030107.* Outlet(s) = North Umpqua River (Lat 43.3322, Long −123.0025) upstream to endpoint(s) in: Calf Creek (43.2852, −122.6229); Copeland Creek (43.2853, −122.5325); Deception Creek (43.2766, −122.5850); Dry Creek (43.2967, −122.6016); Honey Creek (43.3181, −122.9414); Limpy Creek (43.3020, −122.6795); North Umpqua River (43.3027, −122.4938); Panther Creek (43.3019, −122.6801); Steamboat Creek (43.3491, −122.7281); Susan Creek (43.3044, −122.9058); Williams Creek (43.3431, −122.7724).

(iii) *Rock Creek/North Umpqua River Watershed 1710030110.* Outlet(s) = Rock Creek (Lat 43.3322, Long −123.0025) upstream to endpoint(s) in: Conley Creek (43.3594, −122.9663); Harrington Creek (43.4151, −122.9550); Kelly Creek (43.3592, −122.9912); McComas Creek (43.3536, −122.9923); Miller Creek (43.3864, −122.9371); Rock Creek (43.4247, −122.9055); Rock Creek, East Fork (43.3807, −122.8270); Rock Creek, East Fork, North Fork (43.4147, −122.8512); Shoup Creek (43.3882, −122.9674); Unnamed (43.3507, −122.9741); Woodstock Creek (43.3905, −122.9258).

(iv) *Little River Watershed 1710030111.* Outlet(s) = Little River (Lat 43.2978, Long −123.1012) upstream to endpoint(s) in: Buck Peak Creek (43.1762, −123.0479); Buckhorn Creek (43.2592, −123.1072); Cavitt Creek (43.1464, −122.9758); Copperhead Creek (43.1626, −123.0595); Emile Creek (43.2544, −122.8849); Evarts Creek (43.2087, −123.0133); Jim Creek (43.2257, −123.0592); Little River (43.2065, −122.8231); McKay Creek (43.2092, −123.0356); Tuttle Creek (43.1440, −122.9813); White Rock Creek (43.1540, −123.0379); Wolf Creek (43.2179, −122.9461).

(v) *Lower North Umpqua River Watershed 1710030112.* Outlet(s) = North Umpqua River (Lat 43.2682, Long −123.4448) upstream to endpoint(s) in: Bradley Creek (43.3350, −123.1025); Clover Creek (43.2490, −123.2604); Cooper Creek (43.3420, −123.1650); Cooper Creek (43.3797, −123.2807); Dixon Creek (43.2770, −123.2911); French Creek (43.3349, −123.0801); Huntley Creek (43.3363, −123.1340); North Umpqua River (43.3322, −123.0025); Oak Creek (43.2839, −123.2063); Short Creek (43.3204, −123.3315); Sutherlin Creek (43.3677, −123.2114); Unnamed (43.3285, −123.2016).

(9) South Fork Umpqua Subbasin 17100302—(i) *Jackson Creek Watershed 1710030202.* Outlet(s) = Jackson Creek (Lat 42.9695, Long −122.8795) upstream to endpoint(s) in: Beaver Creek (Lat 42.9084, Long −122.7924); Jackson Creek (Lat 42.9965, Long −122.6459); Ralph Creek (Lat 42.9744, Long −122.6976); Squaw Creek (Lat 42.9684, Long −122.6913);Tallow Creek (Lat 42.98814, Long −122.6965); Whiskey Creek (Lat 42.9593, Long −122.7262); Winters Creek (Lat 42.9380, Long −122.8271).

(ii) *Middle South Umpqua River Watershed 1710030203.* Outlet(s) = South Umpqua River (Lat 42.9272, Long −122.9504) upstream to endpoint(s) in: Boulder Creek (43.1056, −122.7379); Budd Creek (43.0506, −122.8185); Deadman Creek (43.0049, −122.8967); Dompier Creek (42.9553, −122.9166); Dumont Creek (43.0719, −122.8224); Francis Creek (43.0202, −122.8231); South Umpqua River (43.0481, −122.6998); Sam Creek (43.0037, −122.8412); Slick Creek (43.0986, −122.7867).

(iii) Elk Creek/South Umpqua Watershed 1710030204. Outlet(s) = Elk Creek (Lat 42.9272, Long −122.9504) upstream to endpoint(s) in: Brownie Creek (Lat 42.8304, Long −122.8746); Callahan Creek (Lat 42.8778, Long −122.9609); Camp Creek (Lat 42.8667, Long −122.8958); Dixon Creek (Lat 42.8931, Long −122.9152); Drew Creek (Lat 42.8682, Long −122.9358); Flat Creek (Lat 42.8294, Long −122.8250); Joe Hall Creek (Lat 42.8756, Long −122.8202); Tom Creek (Lat 42.8389, Long −122.8959).

(iv) *South Umpqua River Watershed 1710030205.* Outlet(s) = South Umpqua River (Lat 42.9476, Long −123.3368) upstream to endpoint(s) in: Alder Creek (42.9109, −123.2991); Canyon Creek (42.8798, −123.2410); Canyon Creek, West Fork (42.8757, −123.2734); Canyon Creek, West Fork, Trib A (42.8834, −123.2947); Coffee Creek (42.9416, −122.9993); Comer Brook (42.9082, −123.2908); Days Creek (43.0539, −123.0012); Days Creek, Trib 1 (43.0351, −123.0532); Doe Hollow (42.9805, −123.0812); Fate Creek (42.9943, −123.1028); Green Gulch (43.0040, −123.1276); Hatchet Creek

(42.9251, −122.9757); Jordan Creek (42.9224, −123.3086); Lavadoure Creek (42.9545, −123.1049); Lick Creek (42.9213, −123.0261); May Creek (43.0153, −123.0725); Morgan Creek (42.9635, −123.2409); O'Shea Creek (42.9256, −123.2486); Perdue Creek (43.0038, −123.1192); Poole Creek (42.9321, −123.1106); Poole Creek, East Fork (42.9147, −123.0956); South Umpqua River (42.9272, −122.9504); Shively Creek (42.8888, −123.1635); Shively Creek, East Fork (42.8793, −123.1194); Small Creek (42.9631, −123.2519); St. John Creek (42.9598, −123.0514); Stinger Gulch Creek (42.9950, −123.1851); Stouts Creek, East Fork (42.9090, −123.0424); Stouts Creek, West Fork (42.8531, −123.0167); Sweat Creek (42.9293, −123.1899); Wood Creek (43.0048, −123.1486).

(v) *Middle Cow Creek Watershed 1710030207.* Outlet(s) = Cow Creek (Lat 42.8114, Long −123.5947) upstream to endpoint(s) in: Bear Creek (42.8045, −123.3635); Booth Gulch (42.7804, −123.2282); Bull Run Creek (42.7555, −123.2366); Clear Creek (42.8218, −123.2610); Cow Creek (42.8487, −123.1780); Dads Creek (42.7650, −123.5401); East Fork Whitehorse Creek (42.7925, −123.1448); Fortune Branch (42.8051, −123.2971); Hogum Creek (42.7574, −123.1853); Lawson Creek (42.7896, −123.3752); Little Bull Run Creek (42.7532, −123.2479); McCullough Creek (42.7951, −123.4421); Mynatt Creek (42.8034, −123.2828); Panther Creek (42.7409, −123.4990); Perkins Creek (42.7331, −123.4997); Quines Creek (42.7278, −123.2396); Rattlesnake Creek (42.7106, −123.4774); Riffle Creek (42.7575, −123.6260); Section Creek (42.7300, −123.4373); Skull Creek (42.7527, −123.5779); Starveout Creek (42.7541, −123.1953); Stevens Creek (42.7255, −123.4835); Susan Creek (42.8035, −123.5762); Swamp Creek (42.7616, −123.3518); Tennessee Gulch (42.7265, −123.2591); Totten Creek (42.7448, −123.4610); Unnamed (42.7964, −123.4200); Unnamed (42.8101, −123.3150); Whitehorse Creek (42.7772, −123.1532); Wildcat Creek (42.7738, −123.2378); Windy Creek (42.8221, −123.3296); Wood Creek (42.8141, −123.4111); Woodford Creek (42.7458, −123.3180).

(vi) *West Fork Cow Creek Watershed 1710030208.* Outlet(s) = West Fork Cow Creek (Lat 42.8118, Long −123.6006) upstream to endpoint(s) in: Bear Creek (42.7662, −123.6741); Bobby Creek (42.8199, −123.7196); Elk Valley Creek (42.8681, −123.7133); Elk Valley Creek, East Fork (42.8698, −123.6812); Goat Trail Creek (42.8002, −123.6828); Gold Mountain Creek (42.8639, −123.7787); No Sweat Creek (42.8024, −123.7081); Panther Creek (42.8596, −123.7506); Slaughter Pen Creek (42.8224, −123.6565); Sweat Creek (42.8018, −123.6995); Walker Creek (42.8228, −123.7614); Wallace Creek (42.8311, −123.7696); West Fork Cow Creek (42.8329, −123.7733).

(vii) *Lower Cow Creek Watershed 1710030209.* Outlet(s) = Cow Creek (Lat 42.9476, Long −123.3368) upstream to endpoint(s) in: Ash Creek (42.9052, −123.3385); Boulder Creek (42.8607, −123.5494); Brush Creek (42.8526, −123.4369); Buck Creek (42.8093, −123.4979); Buck Creek (42.9347, −123.5163); Cattle Creek (42.8751, −123.5374); Cedar Gulch (42.8457, −123.5038); Council Creek (42.8929, −123.4366); Cow Creek (42.8114, −123.5947); Darby Creek (42.8553, −123.6123); Doe Creek (42.9333, −123.5057); Gravel Creek (42.8596, −123.4598); Iron Mountain Creek (42.9035, −123.5175); Island Creek (42.8957, −123.4749); Jerry Creek (42.9517, −123.4009); Little Dads Creek (42.8902, −123.5655); Martin Creek (42.8080, −123.4763); Middle Creek, South Fork (42.8298, −123.3870); Panther Creek (42.8417, −123.4492); Peavine Creek (42.8275, −123.4610); Russell Creek (42.9094, −123.3797); Salt Creek (42.9462, −123.4830); Shoestring Creek (42.9221, −123.3613); Smith Creek (42.8489, −123.4765); Smith Creek (42.9236, −123.5482); Table Creek (42.9114, −123.5695); Union Creek (42.8769, −123.5853); Unnamed (42.8891, −123.4080).

(viii) *Middle South Umpqua River Watershed 1710030210.* Outlet(s) = South Umpqua River (Lat 43.1172, Long −123.4273) upstream to endpoint(s) in: Adams Creek (43.0724, −123.4776); Barrett Creek (43.0145, −123.4451); Clark Brook (43.0980, −123.2897); East Willis Creek (43.0151, −123.3845); Judd Creek (42.9852, −123.4060); Kent Creek (43.0490, −123.4792); Lane Creek (42.9704, −123.4001); Porter Creek (43.0444, −123.4597); Rice Creek (43.0181, −123.4779); Richardson Creek (43.0766, −123.2881); South Umpqua River (42.9476, −123.3368); Squaw Creek (43.0815, −123.4688); Van Dine Creek (43.0326, −123.3473); West Willis Creek (43.0172, −123.4355).

(ix) *Myrtle Creek Watershed 1710030211.* Outlet(s) = North Myrtle Creek (Lat 43.0231, Long −123.2951) upstream to endpoint(s) in: Ben Branch Creek (43.0544, −123.1618); Big Lick (43.0778, −123.2175); Bilger Creek (43.1118, −123.2372); Buck Fork Creek (43.1415, −123.0831); Cedar Hollow (43.0096, −123.2297); Frozen Creek (43.1089, −123.1929); Frozen Creek, Left Fork (43.1157, −123.2306); Harrison Young Brook (43.0610, −123.2850); Lally Creek (43.0890, −123.0597); Lee Creek (43.1333, −123.1477); Letitia Creek (43.0710, −123.0907); Little Lick (43.0492, −123.2234); Long Wiley Creek (43.0584, −123.1067); Louis Creek (43.1165, −123.0783); North Myrtle Creek (43.1486, −123.1219); Riser Creek (43.1276, −123.0703); Rock Creek (43.0729, −123.2620); South Myrtle Creek (43.0850, −123.0103); School Hollow (43.0563, −123.1753); Short Wiley Creek (43.0589, −123.1158); Slide Creek (43.1110, −123.1078); Unnamed (43.1138, −123.1721); Weaver Creek (43.1102, −123.0576).

(x) *Ollala Creek/Lookingglass Watershed 1710030212.* Outlet(s) = Lookingglass Creek (Lat 43.1172, Long −123.4273) upstream to endpoint(s) in: Archambeau Creek (43.2070, −123.5329); Bear Creek (43.1233, −123.6382); Berry Creek (43.0404, −123.5543); Bushnell Creek (43.0183, −123.5289); Byron Creek, East Fork (43.0192, −123.4939); Byron Creek, North Fork (43.0326, −123.4792); Coarse Gold Creek (43.0291, −123.5742); Flournoy Creek (43.2227, −123.5560); Little Muley Creek (43.0950, −123.6247); Lookingglass Creek (43.1597, −123.6015); McNabb Creek (43.0545, −123.4984); Muns Creek (43.0880, −123.6333); Olalla Creek (42.9695, −123.5914); Perron Creek (43.0960, −123.4904); Porter Creek (43.1381, −123.5569); Sheilds Creek (43.0640, −123.6189); Tenmile Creek (43.1482, −123.6537); Tenmile Creek, North Fork (43.1260, −123.6069); Thompson Creek (42.9860, −123.5140); Willingham Creek (42.9600, −123.5814).

(xi) *Lower South Umpqua River Watershed 1710030213.* Outlet(s) = South Umpqua River (Lat 43.2682, Long −123.4448) upstream to endpoint(s) in: Callahan Creek (43.2291, −123.5355); Damotta Brook (43.2030, −123.2987); Deer Creek, North Fork (43.2166, −123.1437); Deer Creek, South Fork (43.1875, −123.1722); Deer Creek, South Fork, Trib 1 (43.1576, −123.2393); Deer Creek, South Fork, Middle Fork (43.1625, −123.1413); Doerner Creek (43.2370, −123.5153); Elgarose Creek (43.2747, −123.5105); Marsters Creek (43.1584, −123.4489); Melton Creek (43.1294, −123.2173); Roberts Creek (43.1124, −123.2831); South Umpqua River (43.1172, −123.4273); Stockel Creek (43.2205, −123.4392); Tucker Creek (43.1238, −123.2378); Unnamed (43.2184, −123.1709); Willow Creek (43.2543, −123.5143).

(10) Umpqua Subbasin 17100303(i) *Upper Umpqua River Watershed 1710030301.* Outlet(s) = Umpqua River

(Lat 43.6329, Long −123.5662) upstream to endpoint(s) in: Bear Creek (43.3202, −123.6118); Bear Creek (43.5436, −123.4481); Bottle Creek (43.4060, −123.5043); Brads Creek (43.5852, −123.4651); Camp Creek (43.2969, −123.5361); Case Knife Creek (43.4288, −123.6665); Cedar Creek (43.5360, −123.5969); Cougar Creek (43.3524, −123.6166); Doe Creek (43.5311, −123.4259); Fitzpatrick Creek (43.5819, −123.6308); Galagher Canyon (43.4708, −123.4394); Heddin Creek (43.5909, −123.6466); Hubbard Creek (43.2526, −123.5544); Leonard Creek (43.4448, −123.5402); Little Canyon Creek (43.4554, −123.4560); Little Wolf Creek (43.4232, −123.6633); Little Wolf Creek, Trib D (43.4052, −123.6477); Lost Creek (43.4355, −123.4902); Martin Creek (43.5539, −123.4633); McGee Creek (43.5125, −123.5632); Mehl Creek (43.5491, −123.6541); Mill Creek (43.3178, −123.5095); Miner Creek (43.4518, −123.6764); Panther Canyon (43.5541, −123.3484); Porter Creek (43.4348, −123.5530); Rader Creek (43.5203, −123.6517); Rader Creek, Trib A (43.4912, −123.5726); Umpqua River (43.2682, −123.4448); Unnamed (43.5781, −123.6170); Unnamed (43.5630, −123.6080); Unnamed (43.4011, −123.6474); Unnamed (43.4119, −123.6172); Unnamed (43.4212, −123.6398); Unnamed (43.4640, −123.6734); Unnamed (43.4940, −123.6166); Unnamed (43.5765, −123.4710); Waggoner Creek (43.5282, −123.6072); Whiskey Camp Creek (43.4587, −123.6755); Williams Creek (43.5952, −123.5222); Wolf Creek (43.4707, −123.6655).

(ii) *Calapooya Creek Watershed 1710030302.* Outlet(s) = Calapooya Creek (Lat 43.3658, Long −123.4674) upstream to endpoint(s) in: Bachelor Creek (43.5480, −123.2062); Banks Creek (43.3631, −123.1755); Beaty Creek (43.4406, −123.0392); Boyd Creek (43.4957, −123.1573); Brome Creek (43.4016, −123.0490); Burke Creek (43.3987, −123.4463); Buzzard Roost Creek (43.4584, −123.0990); Cabin Creek (43.5421, −123.3294); Calapooya Creek, North Fork (43.4867, −123.0280); Coon Creek (43.4218, −123.4349); Coon Creek (43.5245, −123.0429); Dodge Canyon Creek (43.4362, −123.4420); Driver Valley Creek (43.4327, −123.1960); Field Creek (43.4043, −123.0917); Gassy Creek (43.3862, −123.1133); Gilbreath Creek (43.4218, −123.0931); Gossett Creek (43.4970, −123.1045); Haney Creek (43.4763, −123.1086); Hinkle Creek (43.4230, −123.0382); Hog Creek (43.4767, −123.2516); Jeffers Creek (43.4522, −123.1047); Long Valley Creek (43.4474, −123.1460); Middle Fork South Fork Calapooya Creek (43.4772, −122.9952); Markam Creek (43.3751, −123.1479); Marsh Creek (43.5223, −123.3348); Mill Creek (43.4927, −123.1315); Norton Creek (43.5046, −123.3736); Pine Tree Creek (43.4179, −123.0688); Pollock Creek (43.5326, −123.2685); Salt Creek (43.5161, −123.2504); Salt Lick Creek (43.4510, −123.1168); Slide Creek (43.3926, −123.0919); Timothy Creek (43.4862, −123.0896); Unnamed (43.4469, −123.4268); Unnamed (43.4481, −123.4283); Unnamed (43.4483, −123.4134); Unnamed (43.4658, −122.9899); Unnamed (43.4707, −122.9896); Unnamed (43.4908, −123.0703); Unnamed (43.5173, −123.0564); Wheeler Canyon (43.4840, −123.3631); White Creek (43.4637, −123.0451); Williams Creek (43.4703, −123.4096).

(iii) *Elk Creek Watershed 1710030303.* Outlet(s) = Elk Creek (Lat 43.6329, Long −123.5662) upstream to endpoint(s) in: Adams Creek (43.5860, −123.2202); Allen Creek (43.6375, −123.3731); Andrews Creek (43.5837, −123.3920); Asker Creek (43.6290, −123.2668); Bear Creek (43.6195, −123.3703); Bear Creek (43.7119, −123.1757); Bennet Creek (43.6158, −123.1558); Big Tom Folley Creek (43.7293, −123.4053); Big Tom Folley Creek, North Fork (43.7393, −123.4917); Big Tom Folley Creek, Trib A (43.7231, −123.4465); Billy Creek, East Fork (43.5880, −123.3263); Billy Creek, South Fork (43.5725, −123.3603); Blue Hole Creek (43.5677, −123.4405); Brush Creek (43.5662, −123.4140); Buck Creek (43.6981, −123.1818); Cowan Creek (43.5915, −123.2615); Cox Creek (43.6356, −123.1794); Curtis Creek (43.6839, −123.1734); Dodge Canyon (43.6225, −123.2509); Elk Creek (43.5097, −123.1620); Ellenburg Creek (43.7378, −123.3296); Fitch Creek (43.6986, −123.3152); Five Point Canyon (43.5707, −123.3526); Flagler Creek (43.5729, −123.3382); Green Creek (43.6851, −123.4688); Green Ridge Creek (43.5920, −123.3958); Halo Creek (43.5990, −123.2658); Hancock Creek (43.6314, −123.5188); Hanlon Creek (43.6190, −123.2785); Hardscrabble Creek (43.7111, −123.3517); Huntington Creek (43.5882, −123.2808); Jack Creek (43.7071, −123.3819); Johnny Creek (43.7083, −123.3972); Johnson Creek (43.6830, −123.2715); Lancaster Creek (43.6442, −123.4361); Lane Creek (43.5483, −123.1221); Lees Creek (43.6610, −123.1888); Little Sand Creek (43.7655, −123.2778); Little Tom Folley Creek (43.6959, −123.5393); McClintock Creek (43.6664, −123.2703); Parker Creek (43.6823, −123.4178); Pass Creek (43.7527, −123.1528); Pheasant Creek (43.7758, −123.2099); Rock Creek (43.7759, −123.2730); Saddle Butte Creek (43.7214, −123.5219); Salt Creek (43.6796, −123.2213); Sand Creek (43.7709, −123.2912); Shingle Mill Creek (43.5314, −123.1308); Simpson Creek (43.6629, −123.2553); Smith Creek (43.6851, −123.3179); Squaw Creek (43.6010, −123.4284); Taylor Creek (43.7642, −123.2712); Thief Creek (43.6527, −123.1459); Thistleburn Creek (43.6313, −123.4332); Unnamed (43.5851, −123.3101); Walker Creek (43.5922, −123.1707); Ward Creek (43.7486, −123.2023); Wehmeyer Creek (43.6823, −123.2404); Wilson Creek (43.5699, −123.2681); Wise Creek (43.6679, −123.2772); Yoncalla Creek (43.5563, −123.2833).

(iv) *Middle Umpqua River Watershed 1710030304.* Outlet(s) = Umpqua River (Lat 43.6556, Long −123.8752) upstream to endpoint(s) in: Burchard Creek (43.6680, −123.7520); Butler Creek (43.6325, −123.6867); Cedar Creek (43.7027, −123.6451); House Creek (43.7107, −123.6378); Little Mill Creek (43.6729, −123.8252); Little Paradise Creek (43.6981, −123.5630); Paradise Creek (43.7301, −123.5738); Patterson Creek (43.7076, −123.6977); Purdy Creek (43.6895, −123.7712); Sawyer Creek (43.6027, −123.6717); Scott Creek (43.6885, −123.6966); Umpqua River (43.6329, −123.5662); Unnamed (43.6011, −123.7084); Unnamed (43.5998, −123.6803); Unnamed (43.6143, −123.6674); Unnamed (43.6453, −123.7619); Unnamed (43.6461, −123.8064); Unnamed (43.6923, −123.7534); Unnamed (43.7068, −123.6109); Unnamed (43.7084, −123.7156); Unnamed (43.7098, −123.6300); Unnamed (43.7274, −123.6026); Weatherly Creek (43.7205, −123.6680); Wells Creek (43.6859, −123.7946).

(v) *Upper Smith River Watershed 1710030306.* Outlet(s) = Smith River (Lat 43.7968, Long −123.7565) upstream to endpoint(s) in: Amberson Creek (43.7787, −123.4944); Argue Creek (43.7656, −123.6959); Beaver Creek (43.7865, −123.6949); Beaver Creek (43.8081, −123.4041); Big Creek (43.7372, −123.7112); Blackwell Creek (43.8145, −123.7460); Blind Creek (43.7518, −123.6551); Bum Creek (43.8044, −123.5802); Carpenter Creek (43.7947, −123.7258); Clabber Creek (43.7919, −123.5878); Clearwater Creek (43.8138, −123.7375); Cleghorn Creek (43.7508, −123.4997); Clevenger Creek (43.7826, −123.4087); Coldwater Creek (43.8316, −123.7232); Deer Creek (43.8109, −123.5362); Devils Club Creek

(43.7916, −123.6148); Elk Creek (43.8004, −123.4347); Halfway Creek (43.7412, −123.5112); Hall Creek (43.7732, −123.3836); Haney Creek (43.8355, −123.5006); Hardenbrook Creek (43.7943, −123.5660); Hefty Creek (43.7881, −123.3954); Herb Creek (43.8661, −123.6782); Jeff Creek (43.8079, −123.6033); Marsh Creek (43.7831, −123.6185); Mosetown Creek (43.7326, −123.6613); Mosetown Creek, East Fork (43.7185, −123.6433); North Sister Creek (43.8492, −123.5771); Panther Creek (43.8295, −123.4464); Pearl Creek (43.8263, −123.5350); Peterson Creek (43.7575, −123.3947); Plank Creek (43.7635, −123.3980); Redford Creek (43.7878, −123.3520); Rock Creek (43.7733, −123.6222); Russell Creek (43.8538, −123.6971); South Sister Creek (43.8366, −123.5611); Salmonberry Creek (43.8085, −123.4482); Scare Creek (43.7631, −123.7260); Sleezer Creek (43.7535, −123.3711); Slideout Creek (43.7831, −123.5685); Smith River, Little South Fork (43.7392, −123.4583); Smith River, South Fork (43.7345, −123.3843); Smith River (43.7529, −123.3310); Spring Creek (43.7570, −123.3276); Summit Creek (43.7985, −123.3487); Sweden Creek (43.8618, −123.6468); Tip Davis Creek (43.7739, −123.3301); Twin Sister Creek (43.8348, −123.7168); Unnamed (43.7234, −123.6308); Unnamed (43.7397, −123.6984); Unnamed (43.7433, −123.4673); Unnamed (43.7492, −123.6911); Unnamed (43.7495, −123.5832); Unnamed (43.7527, −123.5210); Unnamed (43.7533, −123.7046); Unnamed (43.7541, −123.4805); Unnamed (43.7708, −123.4819); Unnamed (43.7726, −123.5039); Unnamed (43.7748, −123.6044); Unnamed (43.7775, −123.6927); Unnamed (43.7830, −123.5900); Unnamed (43.7921, −123.6335); Unnamed (43.7955, −123.7013); Unnamed (43.7993, −123.6171); Unnamed (43.8020, −123.6739); Unnamed (43.8034, −123.6959); Unnamed (43.8133, −123.5893); Unnamed (43.8197, −123.4827); Unnamed (43.8263, −123.5810); Unnamed (43.8360, −123.6951); Unnamed (43.8519, −123.5910); Unnamed (43.8535, −123.6357); Unnamed (43.8541, −123.6155); Unnamed (43.8585, −123.6867); Upper Johnson Creek (43.7509, −123.5426); West Fork Halfway Creek (43.7421, −123.6119); Yellow Creek (43.8193, −123.5545).

(vi) *Lower Smith River Watershed 1710030307.* Outlet(s) = Smith River (Lat 43.7115, Long −124.0807) upstream to endpoint(s) in: Bear Creek (43.8087, −123.8202); Beaver Creek (43.8983, −123.7559); Black Creek (43.7544, −123.9967); Brainard Creek (43.7448, −124.0105); Buck Creek (43.7719, −123.7823); Cassady Creek (43.7578, −123.9744); Cedar Creek (43.8541, −123.8562); Chapman Creek (43.8181, −123.9380); Coon Creek (43.8495, −123.7857); Crane Creek (43.8592, −123.7739); Edmonds Creek (43.8257, −123.9000); Eslick Creek (43.8153, −123.9894); Eslick Creek, East Fork (43.8082, −123.9583); Franz Creek (43.7542, −124.1006); Frarey Creek (43.7683, −124.0615); Georgia Creek (43.8373, −123.8911); Gold Creek (43.9002, −123.7470); Harlan Creek (43.8635, −123.9319); Holden Creek (43.7901, −124.0178); Hudson Slough (43.7725, −124.0736); Johnson Creek (43.8291, −123.9582); Johnson Creek (43.8480, −123.8209); Joyce Creek (43.7892, −124.0356); Joyce Creek, West Fork (43.7708, −124.0457); Kentucky Creek (43.9313, −123.8153); Middle Fork of North Fork Smith River (43.8780, −123.7687); Moore Creek (43.8523, −123.8931); Moore Creek (43.8661, −123.7558); Murphy Creek (43.7449, −123.9527); Noel Creek (43.7989, −124.0109); Otter Creek (43.7216, −123.9626); Otter Creek, North Fork (43.7348, −123.9597); Paxton Creek (43.8847, −123.9004); Peach Creek (43.8963, −123.8599); Perkins Creek (43.7362, −123.9151); Railroad Creek (43.8086, −123.8998); Smith River, West Fork (43.9102, −123.7073); Smith River (43.7968, −123.7565); Spencer Creek (43.8429, −123.8321); Spencer Creek, West Fork (43.8321, −123.8685); Sulphur Creek (43.8512, −123.9422); Unnamed (43.7031, −123.7463); Unnamed (43.7106, −123.7666); Unnamed (43.7203, −123.7601); Unnamed (43.7267, −123.7396); Unnamed (43.7286, −123.7798); Unnamed (43.7322, −124.0585); Unnamed (43.7325, −123.7337); Unnamed (43.7470, −123.7416); Unnamed (43.7470, −123.7711); Unnamed (43.7569, −124.0844); Unnamed (43.7606, −124.0853); Unnamed (43.7623, −124.0753); Unnamed (43.7669, −124.0766); Unnamed (43.7734, −124.0674); Unnamed (43.7855, −124.0076); Unnamed (43.7877, −123.9936); Unnamed (43.8129, −123.9743); Unnamed (43.8212, −123.8777); Unnamed (43.8258, −123.8192); Unnamed (43.8375, −123.9631); Unnamed (43.8424, −123.7925); Unnamed (43.8437, −123.7989); Unnamed (43.8601, −123.7630); Unnamed (43.8603, −123.8155); Unnamed (43.8655, −123.8489); Unnamed (43.8661, −123.9136); Unnamed (43.8688, −123.7994); Unnamed (43.8831, −123.8534); Unnamed (43.8883, −123.7157); Unnamed (43.8906, −123.7759); Unnamed (43.8916, −123.8765); Unnamed (43.8922, −123.8144); Unnamed (43.8953, −123.8772); Unnamed (43.8980, −123.7865); Unnamed (43.8997, −123.7993); Unnamed (43.8998, −123.7197); Unnamed (43.9015, −123.8386); Unnamed (43.9015, −123.8949); Unnamed (43.9023, −123.8241); Unnamed (43.9048, −123.8316); Unnamed (43.9075, −123.7208); Unnamed (43.9079, −123.8263); Vincent Creek (43.7035, −123.7882); Wassen Creek (43.7419, −123.8905); West Branch North Fork Smith River (43.9113, −123.8958).

(vii) *Lower Umpqua River Watershed 1710030308.* Outlet(s) = Umpqua River (Lat 43.6696, Long −124.2025) upstream to endpoint(s) in: Alder Creek (43.6310, −124.0483); Bear Creek (43.7053, −123.9529); Butler Creek (43.7157, −124.0059); Charlotte Creek (43.6320, −123.9307); Dean Creek (43.6214, −123.9740); Dry Creek (43.6369, −124.0595); Franklin Creek (43.6850, −123.8659); Hakki Creek (43.6711, −124.0161); Indian Charlie Creek (43.6611, −123.9404); Johnson Creek (43.6711, −123.9760); Koepke Slough (43.6909, −124.0294); Little Franklin Creek (43.6853, −123.8863); Luder Creek (43.6423, −123.9046); Miller Creek (43.6528, −124.0140); Oar Creek (43.6620, −124.0289); Providence Creek (43.7083, −124.1289); Scholfield Creek (43.6253, −124.0112); Umpqua River (43.6556, −123.8752); Unnamed (43.6359, −123.9572); Unnamed (43.6805, −124.1146); Unnamed (43.6904, −124.0506); Unnamed (43.6940, −124.0340); Unnamed (43.7069, −123.9824); Unnamed (43.7242, −123.9369); Winchester Creek (43.6657, −124.1247); Wind Creek, South Fork (43.6346, −124.0897).

(11) Coos Subbasin 17100304—(i) *South Fork Coos Watershed 1710030401.* Outlet(s) = South Fork Coos (Lat 43.3905, Long −123.9634) upstream to endpoint(s) in: Beaver Slide Creek (43.2728, −123.8472); Bottom Creek (43.3751, −123.7065); Bottom Creek, North Fork (43.3896, −123.7264); Buck Creek (43.2476, −123.8023); Burnt Creek (43.2567, −123.7834); Cedar Creek (43.3388, −123.6303); Cedar Creek, Trib E (43.3423, −123.6749); Cedar Creek, Trib F (43.3330, −123.6523); Coal Creek (43.3426, −123.8685); Eight River Creek (43.2638, −123.8568); Fall Creek (43.2535, −123.7106); Fall Creek (43.4106, −123.7512); Fivemile Creek

(43.2341, −123.6307); Gods Thumb Creek (43.3440, −123.7013); Gooseberry Creek (43.2452, −123.7081); Hatcher Creek (43.3021, −123.8370); Hog Ranch Creek (43.2754, −123.8125); Lake Creek (43.2971, −123.6354); Little Cow Creek (43.1886, −123.6133); Lost Creek (43.2325, −123.5769); Lost Creek, Trib A (43.2224, −123.5961); Mink Creek (43.3068, −123.8515); Panther Creek (43.2593, −123.6401); Shotgun Creek (43.2920, −123.7623); Susan Creek (43.2720, −123.7654); Tioga Creek (43.2110, −123.7786); Unnamed (43.2209, −123.7789); Unnamed (43.2305, −123.8360); Unnamed (43.2364, −123.7818); Unnamed (43.2548, −123.8569); Unnamed (43.2713, −123.8320); Unnamed (43.2902, −123.6662); Unnamed (43.3168, −123.6491); Unnamed (43.3692, −123.8320); Unnamed (43.3698, −123.8321); Unnamed (43.3806, −123.8327); Unnamed (43.3846, −123.8058); Unnamed (43.3887, −123.7927); Unnamed (43.3651, −123.7073); Wilson Creek (43.2083, −123.6691).

(ii) *Millicoma River Watershed 1710030402.* Outlet(s) = West Fork Millicoma River (Lat 43.4242, Long −124.0288) upstream to endpoint(s) in: Bealah Creek (43.4271, −123.8445); Buck Creek (43.5659, −123.9765); Cougar Creek (43.5983, −123.8788); Crane Creek (43.5545, −123.9287); Dagget Creek (43.4862, −124.0557); Darius Creek (43.4741, −123.9407); Deer Creek (43.6207, −123.9616); Deer Creek, Trib A (43.6100, −123.9761); Deer Creek, Trib B (43.6191, −123.9482); Devils Elbow Creek (43.4439, −124.0608); East Fork Millicoma River (43.4204, −123.8330); Elk Creek (43.5441, −123.9175); Fish Creek (43.6015, −123.8968); Fox Creek (43.4189, −123.9459); Glenn Creek (43.4799, −123.9325); Hidden Creek (43.5646, −123.9235); Hodges Creek (43.4348, −123.9889); Joes Creek (43.5838, −123.9787); Kelly Creek (43.5948, −123.9036); Knife Creek (43.6163, −123.9310); Little Matson Creek (43.4375, −123.8890); Marlow Creek (43.4779, −123.9815); Matson Creek (43.4489, −123.9191); Otter Creek (43.5935, −123.9729); Panther Creek (43.5619, −123.9038); Rainy Creek (43.4293, −124.0400); Rodine Creek (43.4434, −123.9789); Schumacher Creek (43.4842, −124.0380); Totten Creek (43.4869, −124.0457); Trout Creek (43.5398, −123.9814); Unnamed (43.4686, −124.0143); Unnamed (43.5156, −123.9366); Unnamed (43.5396, −123.9373); Unnamed (43.5450, −123.9305); West Fork Millicoma River (43.5617, −123.8788).

(iii) *Lakeside Frontal Watershed 1710030403.* Outlet(s) = Tenmile Creek (43.5618, −124.2308) upstream to endpoint(s) in: Adams Creek (43.5382, −124.1081); Alder Creek (43.6012, −124.0272); Alder Gulch (43.5892, −124.0665); Benson Creek (43.5813, −124.0086); Big Creek (43.6085, −124.0128); Blacks Creek (43.6365, −124.1188); Clear Creek (43.6040, −124.1871); Hatchery Creek (43.5275, −124.0761); Johnson Creek (43.5410, −124.0018); Murphy Creek (43.6243, −124.0534); Noble Creek (43.5897, −124.0347); Parker Creek (43.6471, −124.1246); Roberts Creek (43.5557, −124.0264); Saunders Creek (43.5417, −124.2136); Shutter Creek (43.5252, −124.1398); Swamp Creek (43.5550, −124.1948); Unnamed (43.5203, −124.0294); Unnamed (43.6302, −124.1460); Unnamed (43.6353, −124.1411); Unnamed (43.6369, −124.1515); Unnamed (43.6466, −124.1511); Unnamed (43.5081, −124.0382); Unnamed (43.6353, −124.16770; Wilkins Creek (43.6304, −124.0819); Winter Creek (43.6533, −124.1333).

(iv) *Coos Bay Watershed 1710030404.* Outlet(s) = Big Creek (Lat 43.3326, Long −124.3739); Coos Bay (43.3544, −124.3384) upstream to endpoint(s) in: Bear Creek (43.5048, −124.1059); Bessey Creek (43.3844, −124.0253); Big Creek (43.2834, −124.3374), Big Creek (43.3980, −123.9396); Big Creek, Trib A (43.2999, −124.3711); Big Creek, Trib B (43.2854, −124.3570); Blossom Gulch (43.3598, −124.2410); Boatman Gulch (43.3445, −124.2483); Boone Creek (43.2864, −124.1762); Cardwell Creek (43.2793, −124.1277); Catching Creek (43.2513, −124.1586); Coalbank Creek (43.3154, −124.2503); Coos Bay (43.3566, −124.1592); Daniels Creek (43.3038, −124.0725); Davis Creek (43.2610, −124.2633); Day Creek (43.3129, −124.2888); Deton Creek (43.4249, −124.0771); Echo Creek (43.3797, −124.1529); Elliot Creek (43.3037, −124.2670); Farley Creek (43.3146, −124.3415); Ferry Creek (43.2628, −124.1728); Goat Creek (43.2700, −124.2109); Haywood Creek (43.3067, −124.3419); Hendrickson Creek (43.3907, −124.0594); Isthmus Slough (43.2622, −124.2049); Joe Ney Slough (43.3382, −124.2958); John B Creek (43.2607, −124.2814); Johnson Creek (43.4043, −124.1389); Kentuck Creek (43.4556, −124.0894); Larson Creek (43.4930, −124.0764); Laxstrom Gulch (43.3372, −124.1350); Lillian Creek (43.3550, −124.1330); Mart Davis Creek (43.3911, −124.0927); Matson Creek (43.3011, −124.1161); McKnight Creek (43.3841, −123.9991); Mettman Creek (43.4574, −124.1293); Millicoma River (43.4242, −124.0288); Monkey Ranch Gulch (43.3392, −124.1458); Morgan Creek (43.3460, −124.0318); North Slough (43.5032, −124.1408); Noble Creek (43.2387, −124.1665); Packard Creek (43.4058, −124.0211); Palouse Creek (43.5123, −124.0667); Panther Creek (43.2733, −124.1222); Pony Slough (43.4078, −124.2307); Rogers Creek (43.3831, −124.0370); Ross Slough (43.3027, −124.1781); Salmon Creek (43.3618, −123.9816); Seaman Creek (43.3634, −124.0111); Seelander Creek (43.2872, −124.1176); Shinglehouse Slough (43.3154, −124.2225); Smith Creek (43.3579, −124.1051); Snedden Creek (43.3372, −124.2177); Southport Slough (43.2981, −124.2194); Stock Slough (43.3277, −124.1195); Storey Creek (43.3238, −124.2969); Sullivan Creek (43.4718, −124.0872); Talbott Creek (43.2839, −124.2954); Theodore Johnson Creek (43.2756, −124.3457); Unnamed (43.5200, −124.1812); Unnamed (43.2274, −124.3236); Unnamed (43.2607, −124.2984); Unnamed (43.2772, −124.3246); Unnamed (43.2776, −124.3148); Unnamed (43.2832, −124.1532); Unnamed (43.2888, −124.1962); Unnamed (43.2893, −124.3406); Unnamed (43.2894, −124.2034); Unnamed (43.2914, −124.2917); Unnamed (43.2942, −124.1027); Unnamed (43.2984, −124.2847); Unnamed (43.3001, −124.3022); Unnamed (43.3034, −124.2001); Unnamed (43.3051, −124.2031); Unnamed (43.3062, −124.2030); Unnamed (43.3066, −124.3674); Unnamed (43.3094, −124.1947); Unnamed (43.3129, −124.1208); Unnamed (43.3149, −124.1347); Unnamed (43.3149, −124.1358); Unnamed (43.3149, −124.1358); Unnamed (43.3169, −124.0638); Unnamed (43.3224, −124.2390); Unnamed (43.3356, −124.1542); Unnamed (43.3356, −124.1526); Unnamed (43.3357, −124.1510); Unnamed (43.3357, −124.1534); Unnamed (43.3368, −124.1509); Unnamed (43.3430, −124.2352); Unnamed (43.3571, −124.2372); Unnamed (43.3643, −124.0474); Unnamed (43.3741, −124.0577); Unnamed (43.4126, −124.0599); Unnamed (43.4203, −123.9824); Unnamed (43.4314, −124.0998); Unnamed (43.4516, −124.1023); Unnamed (43.4521, −124.1110); Unnamed (43.5345, −124.1946); Vogel Creek (43.3511, −124.1206); Wasson Creek (43.2688, −124.3368); Willanch Creek (43.4233, −124.1061); Willanch Creek, Trib A (43.4032, −124.1169); Wilson Creek (43.2652, −124.1281); Winchester Creek (43.2145, −124.3116); Winchester Creek, Trib E (43.2463, −124.3067); Woodruff Creek (43.4206, −123.9746); Wren Smith Creek (43.3131, −124.0649).

(12) Coquille Subbasin 17100305—(i) *Middle Fork Coquille Watershed 1710030502.* Outlet(s) = Middle Fork Coquille River (Lat 43.0340, Long −124.1161) upstream to endpoint(s) in: Anderson Creek (43.0087, −123.9445); Axe Creek (43.0516, −123.9468); Bear Creek (43.0657, −123.9284); Belieu Creek (43.0293, −123.9470); Big Creek (43.0991, −123.8983); Brownson Creek (43.0879, −123.9583); Endicott Creek (43.0401, −124.0710); Fall Creek (43.0514, −123.9910); Indian Creek (43.0203, −124.0842); Little Rock Creek (42.9913, −123.8335); McMullen Creek (43.0220, −124.0366); Middle Fork Coquille River (42.9701, −123.7621); Myrtle Creek (42.9642, −124.0170); Rasler Creek (42.9518, −123.9643); Rock Creek (42.9200, −123.9073); Rock Creek (43.0029, −123.8440); Salmon Creek (43.0075, −124.0273); Sandy Creek (43.0796, −123.8517); Sandy Creek, Trib F (43.0526, −123.8736); Sheilds Creek (42.9184, −123.9219); Slater Creek (42.9358, −123.7958); Slide Creek (42.9957, −123.9040); Smith Creek (43.0566, −124.0337); Swamp Creek (43.0934, −123.9000); Unnamed (43.0016, −123.9550); Unnamed (43.0681, −123.9812); Unnamed (43.0810, −123.9892).

(ii) *Middle Main Coquille Watershed 1710030503.* Outlet(s) = South Fork Coquille River (Lat 43.0805, Long −124.1405) upstream to endpoint(s) in: Baker Creek (42.8913, −124.1297); Beaver Creek (42.9429, −124.0783); Catching Creek, Middle Fork (42.9913, −124.2331); Catching Creek, South Fork (42.9587, −124.2348); Coquille River, South Fork (42.8778, −124.0743); Cove Creek (43.0437, −124.2088); Dement Creek (42.9422, −124.2086); Gettys Creek (43.0028, −124.1988); Grants Creek (42.9730, −124.1041); Horse Hollow (43.0382, −124.1984); Knight Creek (43.0022, −124.2663); Koontz Creek (43.0111, −124.2505); Long Tom Creek (42.9342, −124.0992); Matheny Creek (43.0495, −124.1892); Mill Creek (42.9777, −124.1663); Rhoda Creek (43.0007, −124.1032); Roberts Creek (42.9748, −124.2385); Rowland Creek (42.9045, −124.1845); Russell Creek (42.9495, −124.1611); Unnamed (42.9684, −124.1033); Ward Creek (43.0429, −); 124.2358); Warner Creek (43.0196, −124.1187); Wildcat Creek (43.0277, −124.2225); Wolf Creek (43.0136, −124.2318); Woodward Creek (42.9023, −124.0658).

(iii) *East Fork Coquille Watershed 1710030504.* Outlet(s) = East Fork Coquille River (Lat 43.1065, Long −124.0761) upstream to endpoint(s) in: Bills Creek (43.1709, −123.9244); China Creek (43.1736, −123.9086); East Fork Coquille River (43.1476, −123.8936); Elk Creek (43.1312, −123.9621); Hantz Creek (43.1832, −123.9713); South Fork Elk Creek (43.1212, −123.9200); Steel Creek (43.1810, −123.9354); Unnamed (43.0908, −124.0361); Unnamed (43.0925, −124.0495); Unnamed (43.0976, −123.9705); Unnamed (43.1006, −124.0052); Unnamed (43.1071, −123.9163); Unnamed (43.1655, −123.9078); Unnamed (43.1725, −123.9881); Weekly Creek (43.0944, −124.0271); Yankee Run (43.1517, −124.0483); Yankee Run, Trib C (43.1626, −124.0162).

(iv) *North Fork Coquille Watershed 1710030505.* Outlet(s) = North Fork Coquille River (Lat 43.0805, Long −124.1405) upstream to endpoint(s) in: Alder Creek (43.2771, −123.9207); Blair Creek (43.1944, −124.1121); Cherry Creek, North Fork (43.2192, −123.9124); Cherry Creek, South Fork (43.2154, −123.9353); Coak Creek (43.2270, −124.0324); Coquille River, Little North Fork (43.2988, −123.9410); Coquille River, North Fork (43.2974, −123.8791); Coquille River, North Fork, Trib E (43.1881, −124.0764); Coquille River, North Fork, Trib I (43.2932, −123.8920); Coquille River, North Fork, Trib Y (43.3428, −123.9678); Evans Creek (43.2868, −124.0561); Fruin Creek (43.3016, −123.9198); Garage Creek (43.1508, −124.1020); Giles Creek (43.3129, −124.0337); Honcho Creek (43.2628, −123.8954); Hudson Creek (43.2755, −123.9604); Jerusalem Creek (43.1844, −124.0539); Johns Creek (43.0760, −124.0498); Little Cherry Creek (43.2007, −123.9594); Llewellyn Creek (43.1034,124.1063); Llewellyn Creek, Trib A (43.0969, −124.0995); Lost Creek (43.1768, −124.1047); Lost Creek (43.2451, −123.9745); Mast Creek (43.2264, −124.0207); Middle Creek (43.2332, −123.8726); Moon Creek (43.2902, −123.9493); Moon Creek, Trib A (43.2976, −123.9837); Moon Creek, Trib A–1 (43.2944, −123.9753); Neely Creek (43.2960, −124.0380); Park Creek (43.2508, −123.8661); Park Creek, Trib B (43.2702, −123.8782); Schoolhouse Creek (43.1637, −124.0949); Steele Creek (43.2203, −124.1018); Steinnon Creek (43.2534, −124.1076); Unnamed (43.1305, −124.0759); Unnamed (43.2047, −124.0314); Unnamed (43.2127, −124.1101); Unnamed (43.2165, −123.9144); Unnamed (43.2439, −123.9275); Unnamed (43.2444, −124.0868); Unnamed (43.2530, −124.0848); Unnamed (43.2582, −124.0794); Unnamed (43.2584, −123.8846); Unnamed (43.2625, −124.0474); Unnamed (43.2655, −123.9269); Unnamed (43.2676, −124.0367); Vaughns Creek (43.2378, −123.9106); Whitley Creek (43.2899, −124.0115); Wimer Creek (43.1303, −124.0640); Wood Creek (43.1392, −124.1274); Wood Creek, North Fork (43.1454, −124.1211).

(v) *Lower Coquille Watershed 1710030506.* Outlet(s) = Coquille River (Lat 43.1237, Long −124.4261) upstream to endpoint(s) in: Alder Creek (43.1385, −124.2697); Bear Creek (43.0411, −124.2893); Beaver Creek (43.2249, −124.1923); Beaver Creek (43.2525, −124.2456); Beaver Slough, Trib A (43.2154, −124.2731); Bill Creek (43.0256, −124.3126); Budd Creek (43.2011, −124.1921); Calloway Creek (43.2060, −124.1684); Cawfield Creek (43.1839, −124.1372); China Creek (43.2170, −124.2076); Cold Creek (43.2038, −124.1419); Coquille River (43.0805, −124.1405); Coquille River, Trib A (43.2032, −124.2930); Cunningham Creek (43.2349, −124.1378); Dutch John Ravine (43.1744, −124.1781); Dye Creek (43.2274, −124.1569); Fahys Creek (43.1676, −124.3861); Fat Elk Creek (43.1373, −124.2560); Ferry Creek (43.1150, −124.3831); Fishtrap Creek (43.0841, −124.2544); Glen Aiken Creek (43.1482, −124.1497); Grady Creek (43.1032, −124.1381); Gray Creek (43.1222, −124.1286); Hall Creek (43.0583, −124.2516); Hall Creek, Trib A (43.0842, −124.1745); Harlin Creek (43.1326, −124.1633); Hatchet Slough, Trib A (43.1638, −124.3065); Hatchet Slough (43.1879, −124.3003); Lampa Creek (43.0531, −124.2665); Little Bear Creek (43.0407, −124.2783); Little Fishtrap Creek (43.1201, −124.2290); Lowe Creek (43.1401, −124.3232); Mack Creek (43.0604, −124.3306); Monroe Creek (43.0705, −124.2905); Offield Creek (43.1587, −124.3273); Pulaski Creek (43.1398, −124.2184); Randleman Creek (43.0818, −124.3039); Rich Creek (43.0576, −124.2067); Rink Creek (43.1764, −124.1369); Rock Robinson Creek (43.0860, −124.2306); Rollan Creek (43.1266, −124.2563); Sevenmile Creek (43.2157, −124.3350); Sevenmile Creek, Trib A (43.1853, −124.3187); Sevenmile Creek, Trib C (43.2081, −124.3340); Unnamed (43.1084, −124.2727); Unnamed 43.1731, −124.1852); Unnamed (43.1924, −124.1378); Unnamed (43.1997, −124.3346); Unnamed (43.2281, −124.2190); Unnamed

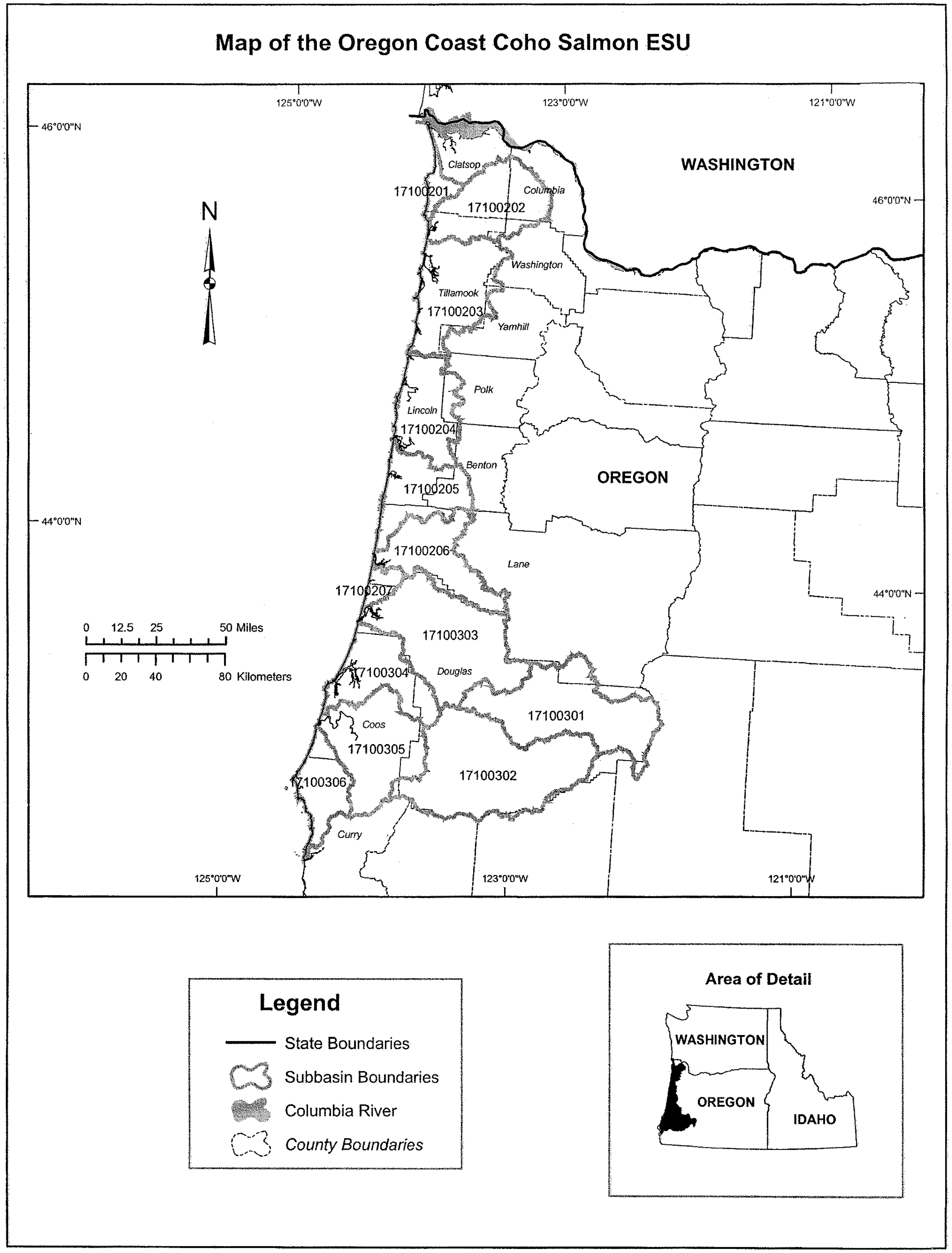
(43.2424, −124.2737); Waddington Creek (43.1105, −124.2915).

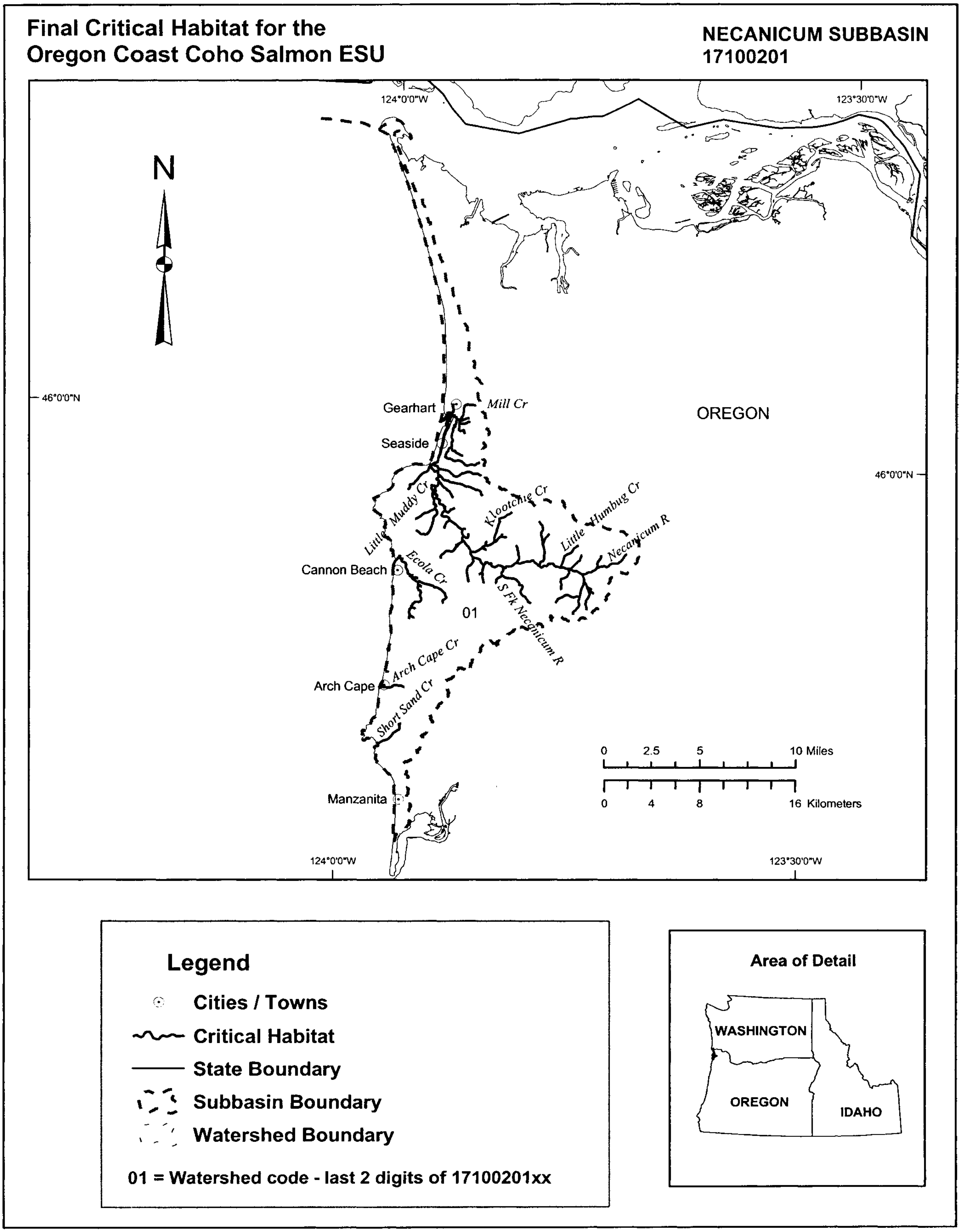
(13) Sixes Subbasin 17100306'(i) *Sixes River Watershed 1710030603.* Outlet(s) = Sixes River (Lat 42.8543, Long −124.5427) upstream to endpoint(s) in: Beaver Creek (42.7867, −124.4373); Carlton Creek (42.8594, −124.2382); Cold Creek (42.7824, −124.2070); Crystal Creek (42.8404, −124.4501); Dry Creek (42.7673, −124.3726); Edson Creek (42.8253, −124.3782); Hays Creek (42.8455, −124.1796); Little Dry Creek (42.8002, −124.3838); Murphy Canyon (42.8516, −124.1541); Sixes River (42.8232, −124.1704); Sixes River, Middle Fork (42.7651, −124.1782); Sixes River, North Fork (42.8878, −124.2320); South Fork Sixes River (42.8028, −124.3022); Sugar Creek (42.8217, −124.2035); Unnamed (42.8189, −124.3567); Unnamed (42.7952, −124.3918); Unnamed (42.8276, −124.4629).

(ii) *New River Frontal Watershed 1710030604.* Outlet(s) = New River (Lat 43.0007, Long −124.4557); Twomile Creek (43.0440, −124.4415) upstream to endpoint(s) in: Bethel Creek (42.9519, −124.3954); Boulder Creek (42.8574, −124.5050); Butte Creek (42.9458, −124.4096); Conner Creek (42.9814, −124.4215); Davis Creek (42.9657, −124.3968); Floras Creek (42.9127, −124.3963); Fourmile Creek (42.9887, −124.3077); Fourmile Creek, South Fork (42.9642, −124.3734); Langlois Creek (42.9238, −124.4570); Little Creek (43.0030, −124.3562); Long Creek (42.9828, −124.3770); Lower Twomile Creek (43.0223, −124.4080); Morton Creek (42.9437, −124.4234); New River (42.8563, −124.4602); North Fourmile Creek (42.9900, −124.3176); Redibough Creek (43.0251, −124.3659); South Twomile Creek (43.0047, −124.3672); Spring Creek (43.0183, −124.4299); Twomile Creek (43.0100, −124.3291); Unnamed (43.0209, −124.3386); Unnamed (43.0350, −124.3506); Unnamed (43.0378, −124.3481); Unnamed (43.0409, −124.3544); Unnamed (42.8714, −124.4586); Unnamed (42.9029, −124.4222); Unnamed (42.9031, −124.4581); Unnamed (42.9294, −124.4421); Unnamed (42.9347, −124.4559); Unnamed (42.9737, −124.3363); Unnamed (42.9800, −124.3432); Unnamed (43.0058, −124.4066); Willow Creek (42.8880, −124.4505).

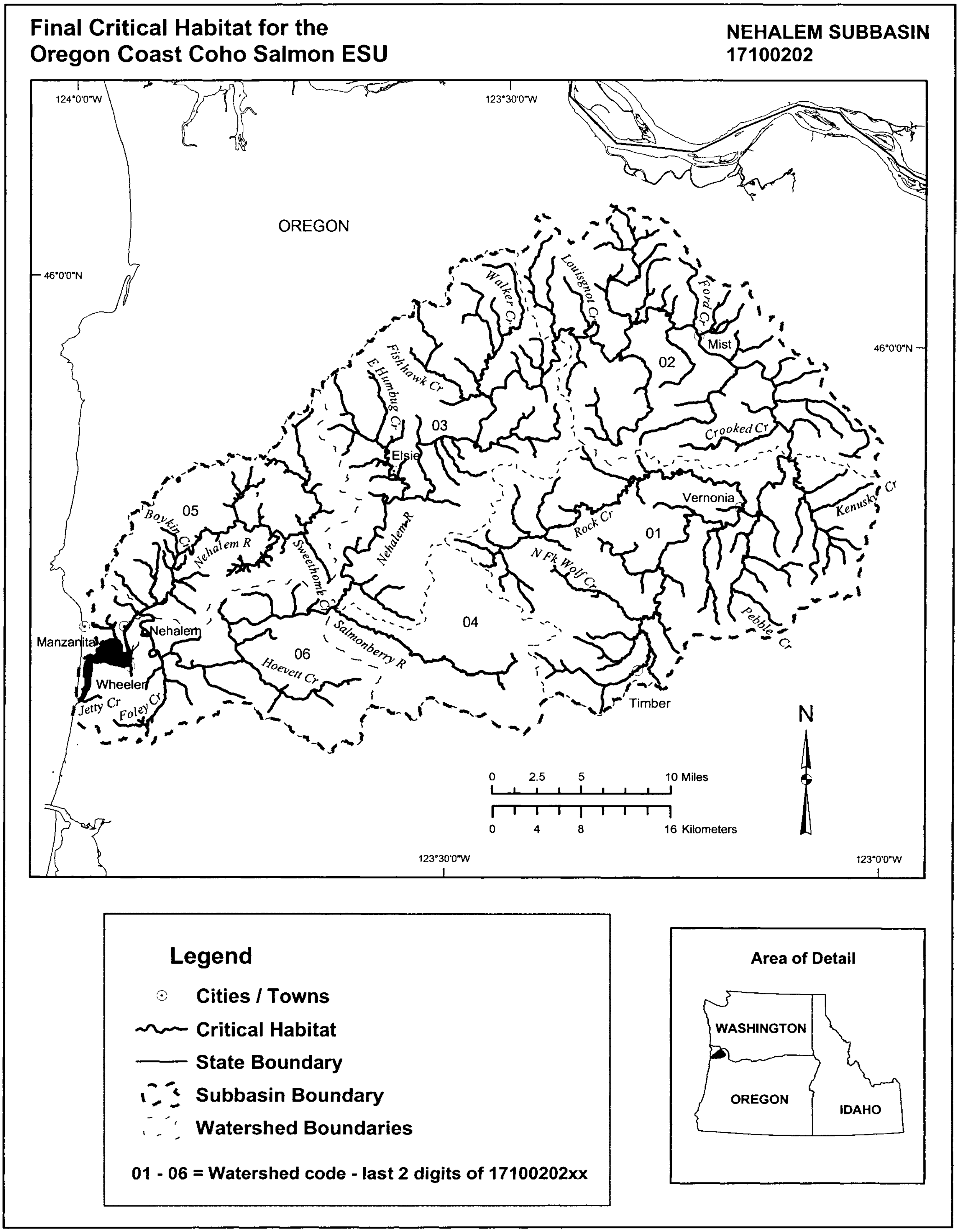
(14) Maps of critical habitat for the Oregon Coast coho salmon ESU follow:

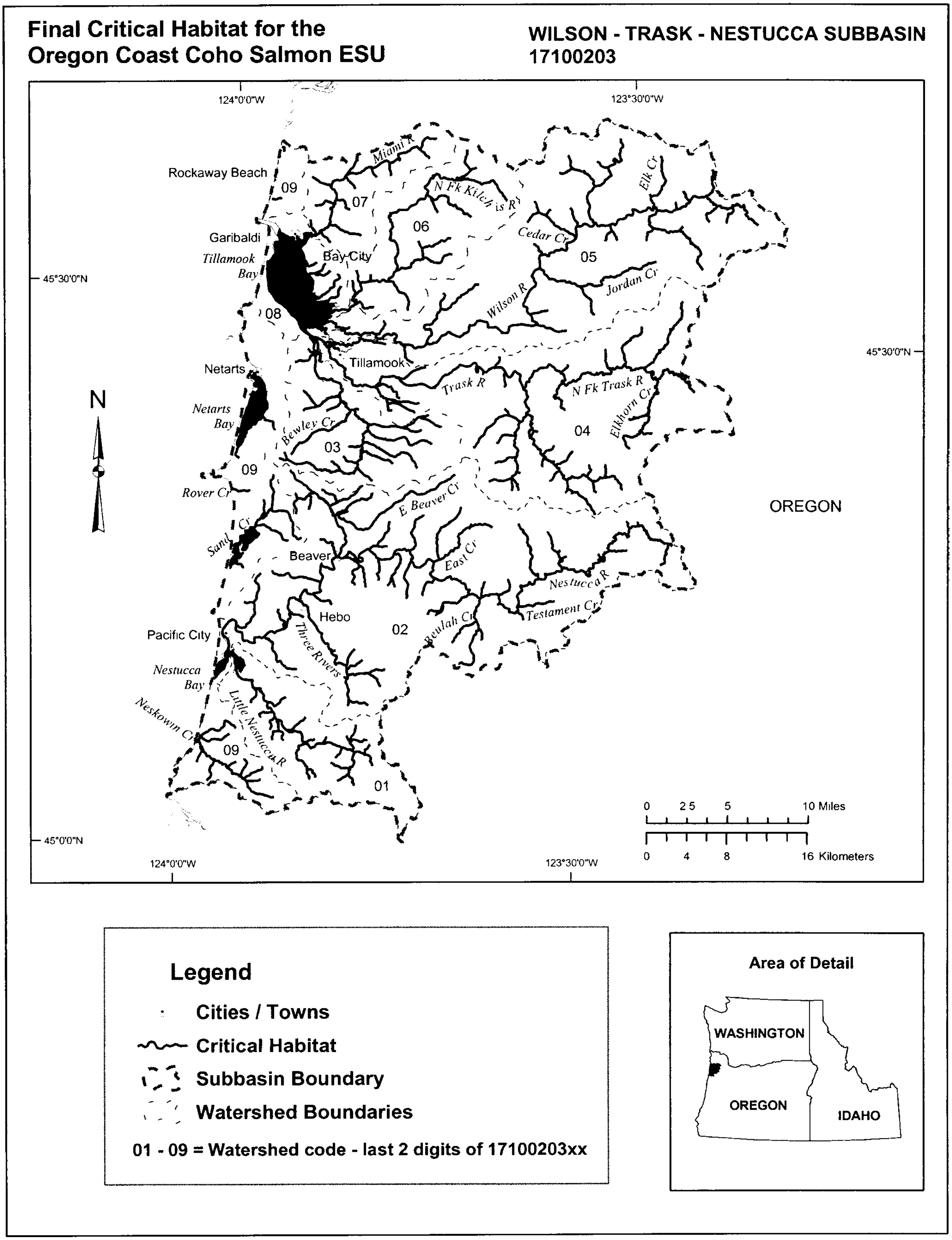
BILLING CODE 3510–22–P

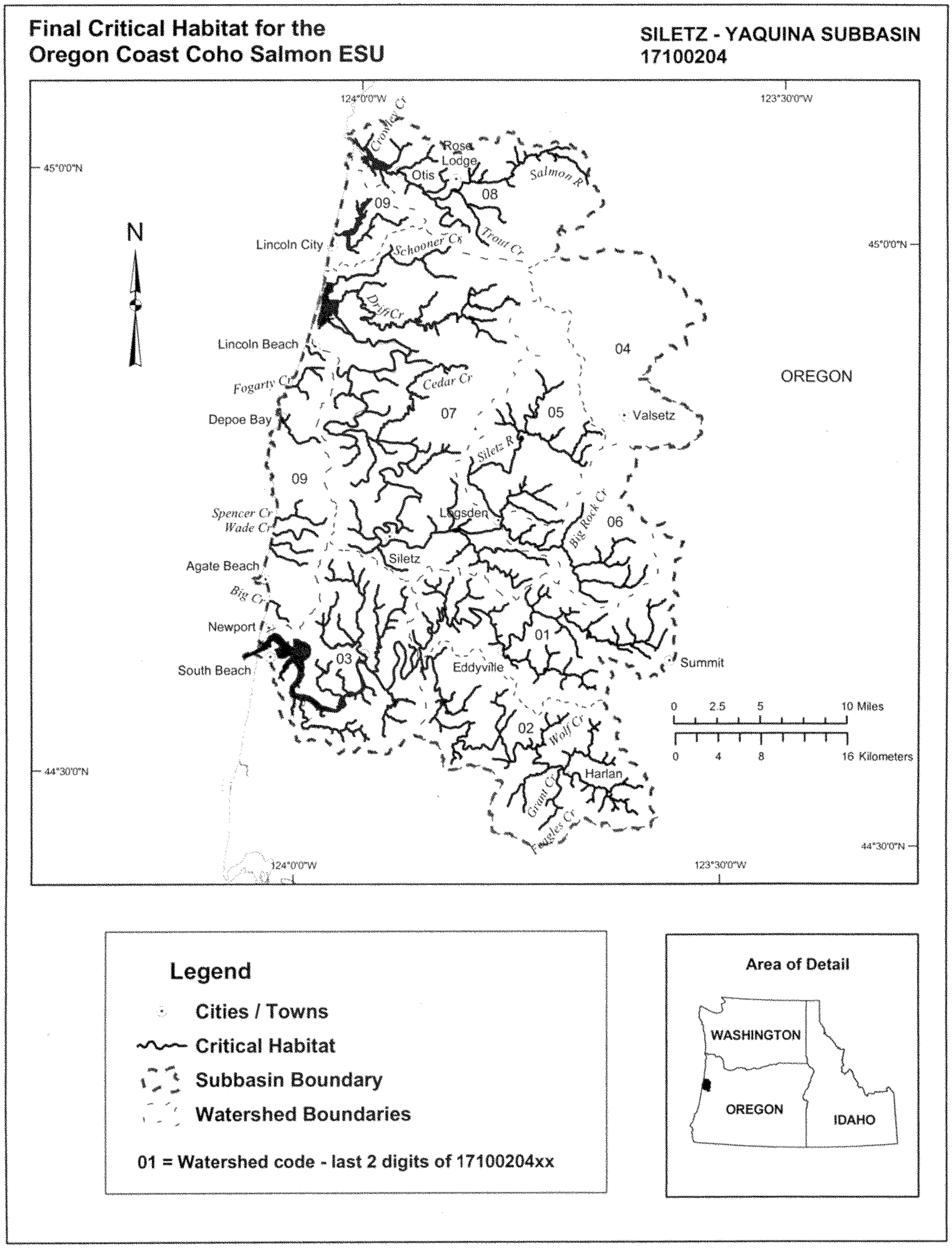

Map of the Oregon Coast Coho Salmon ESU
125°0'0"W
123°0'0"W
121°0'0"W
46°0'0"N
44°0'0"N
WASHINGTON
OREGON
N
Clatsop
Columbia
Washington
Tillamook
Yamhill
Polk
Lincoln
Benton
Lane
Douglas
Coos
Curry
17100201
17100202
17100203
17100204
17100205
17100206
17100207
17100301
17100302
17100303
17100304
17100305
17100306
0 12.5 25 50 Miles
0 20 40 80 Kilometers
Legend
State Boundaries
Subbasin Boundaries
Columbia River
County Boundaries
Area of Detail
WASHINGTON
OREGON
IDAHO

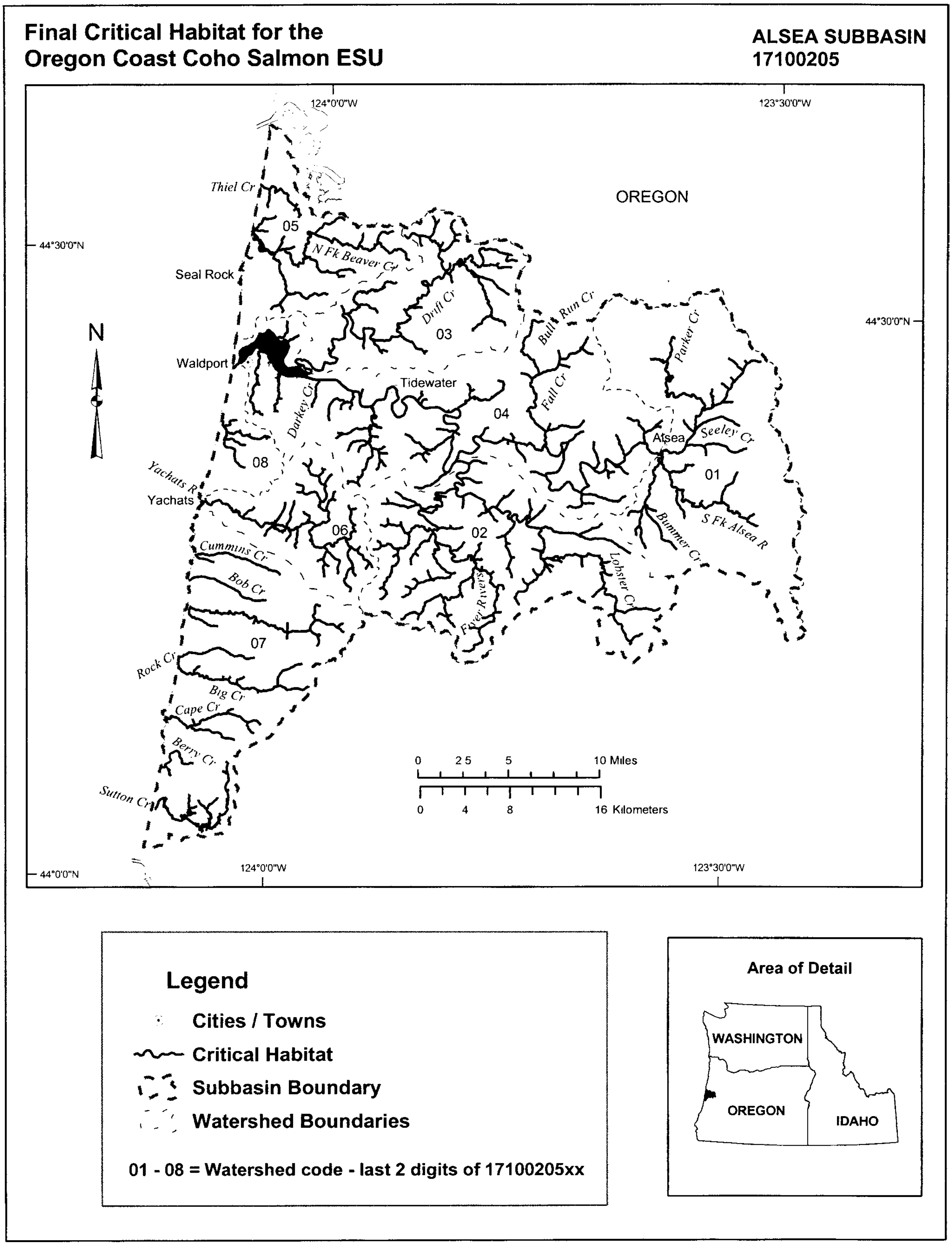


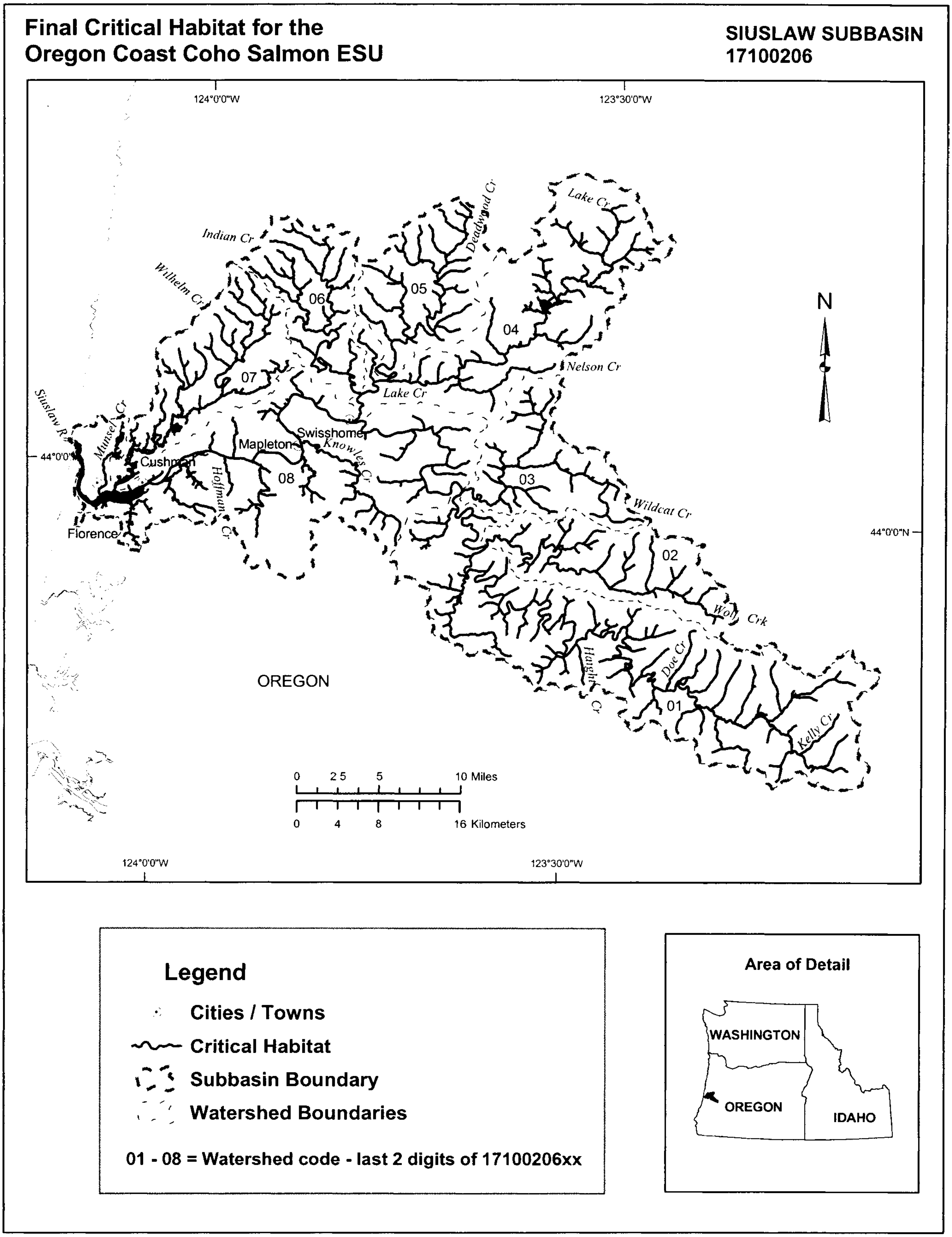
Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
NECANICUM SUBBASIN
17100201
N
124°0'0"W
123°30'0"W
46°0'0"N
Gearhart
Mill Cr
Seaside
OREGON
Little Muddy Cr
Klootchie Cr
Little Humbug Cr
Necanicum R
Cannon Beach
Ecola Cr
S Fk Necanicum R
01
Arch Cape Cr
Arch Cape
Short Sand Cr
Manzanita
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
State Boundary
Subbasin Boundary
Watershed Boundary
01 = Watershed code - last 2 digits of 17100201xx
Area of Detail
WASHINGTON
OREGON
IDAHO


Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
NEHALEM SUBBASIN
17100202
OREGON
124°0'0"W
123°30'0"W
123°0'0"W
46°0'0"N
Walker Cr
Louisignot Cr
Ford Cr
Mist
02
Fishhawk Cr
E Humbug Cr
03
Elsie
Crooked Cr
Vernonia
Kenusky Cr
Rock Cr
01
05
Boykin Cr
Nehalem R
Sweethome Cr
N Fk Wolf Cr
04
Salmonberry R
06
Hoevett Cr
Pebble Cr
Nehalem
Manzanita
Wheeler
Jetty Cr
Foley Cr
Timber
N
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
State Boundary
Subbasin Boundary
Watershed Boundaries
01 - 06 = Watershed code - last 2 digits of 17100202xx
Area of Detail
WASHINGTON
OREGON
IDAHO

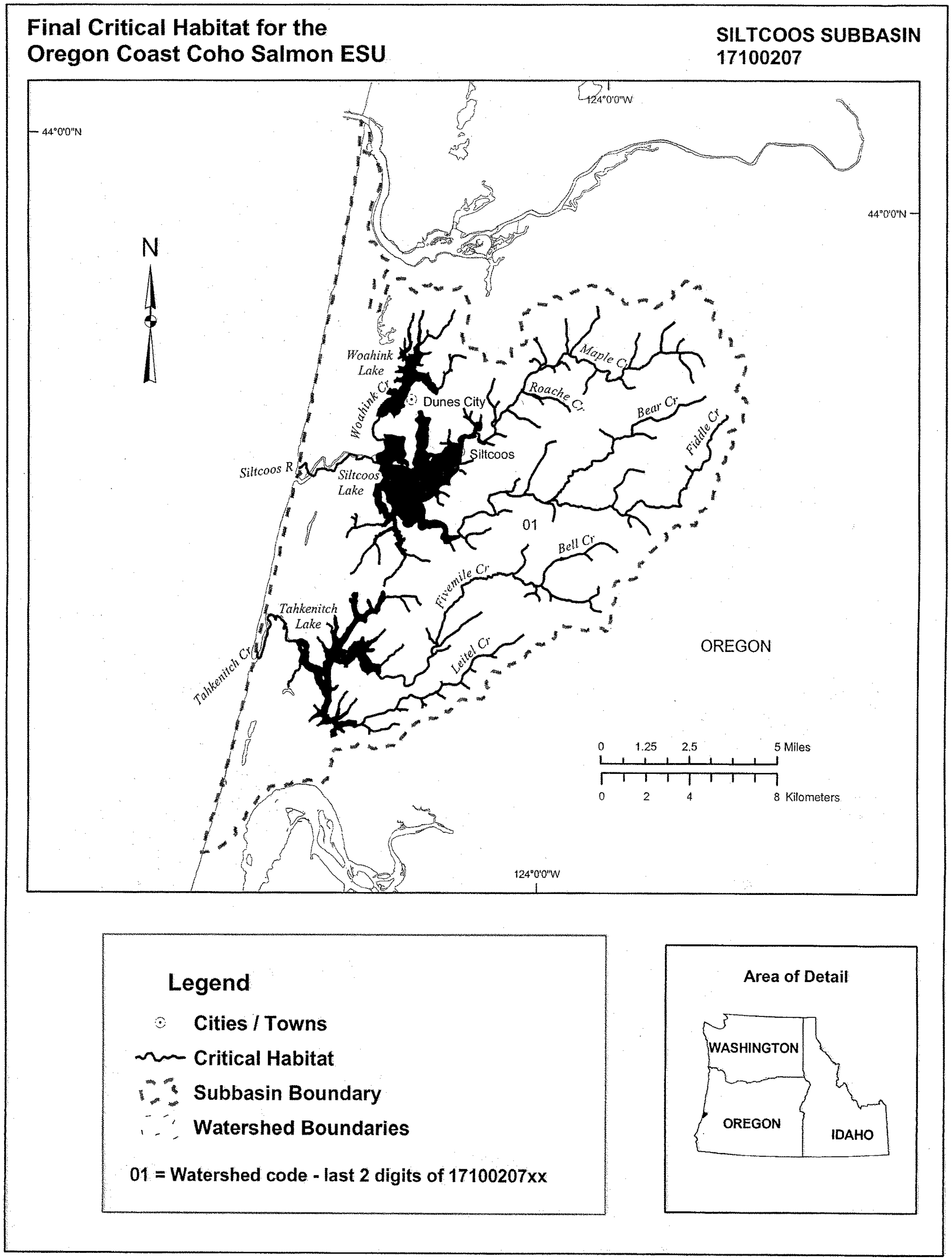

Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
WILSON - TRASK - NESTUCCA SUBBASIN
17100203
124°0'0"W
123°30'0"W
45°30'0"N
45°0'0"N
Rockaway Beach
Garibaldi
Tillamook Bay
Bay City
Tillamook
Netarts
Netarts Bay
Rover Cr
Sand Cr
Beaver
Hebo
Pacific City
Nestucca Bay
Neskowin Cr
Miami R
N Fk Kilchis R
Cedar Cr
Elk Cr
Jordan Cr
Wilson R
Trask R
N Fk Trask R
Elkhorn Cr
Bewley Cr
E Beaver Cr
East Cr
Nestucca R
Testament Cr
Beulah Cr
Three Rivers
Little Nestucca R
01
02
03
04
05
06
07
08
09
OREGON
N
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 09 = Watershed code - last 2 digits of 17100203xx
Area of Detail
WASHINGTON
OREGON
IDAHO

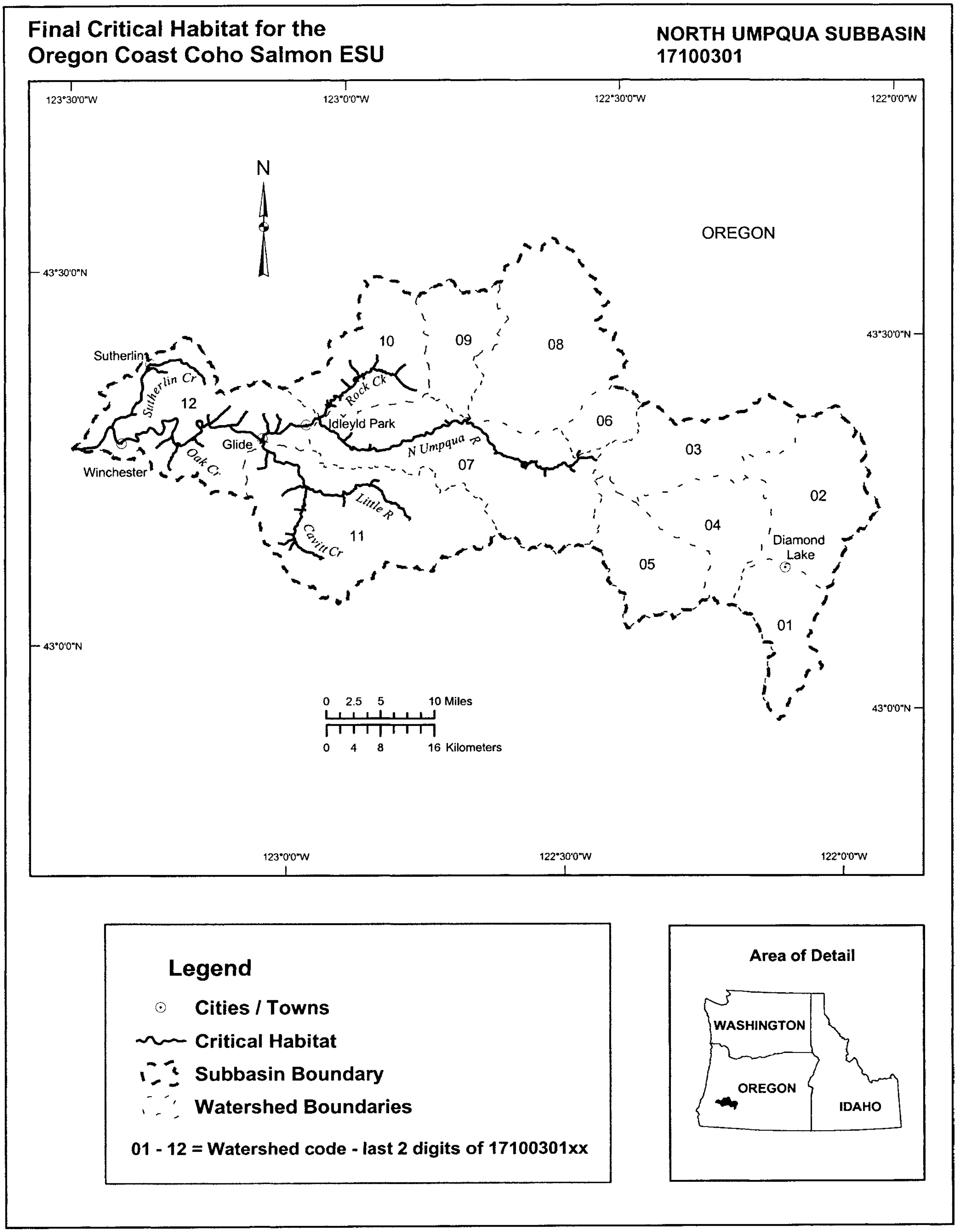

Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
SILETZ - YAQUINA SUBBASIN
17100204
124°0'0"W
123°30'0"W
45°0'0"N
44°30'0"N
N
Crowley Cr
Rose Lodge
Otis
Salmon R
08
09
Trout Cr
Lincoln City
Schooner Cr
Drift Cr
Lincoln Beach
04
OREGON
Fogarty Cr
Cedar Cr
07
05
Valsetz
Depoe Bay
Siletz R
09
Spencer Cr
Wade Cr
Logsden
Big Rock Cr
06
Siletz
Agate Beach
Big Cr
Newport
01
South Beach
03
Eddyville
Summit
0 2.5 5 10 Miles
0 4 8 16 Kilometers
02
Wolf Cr
Harlan
Grant Cr
Feagles Cr
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 = Watershed code - last 2 digits of 17100204xx
Area of Detail
WASHINGTON
OREGON
IDAHO

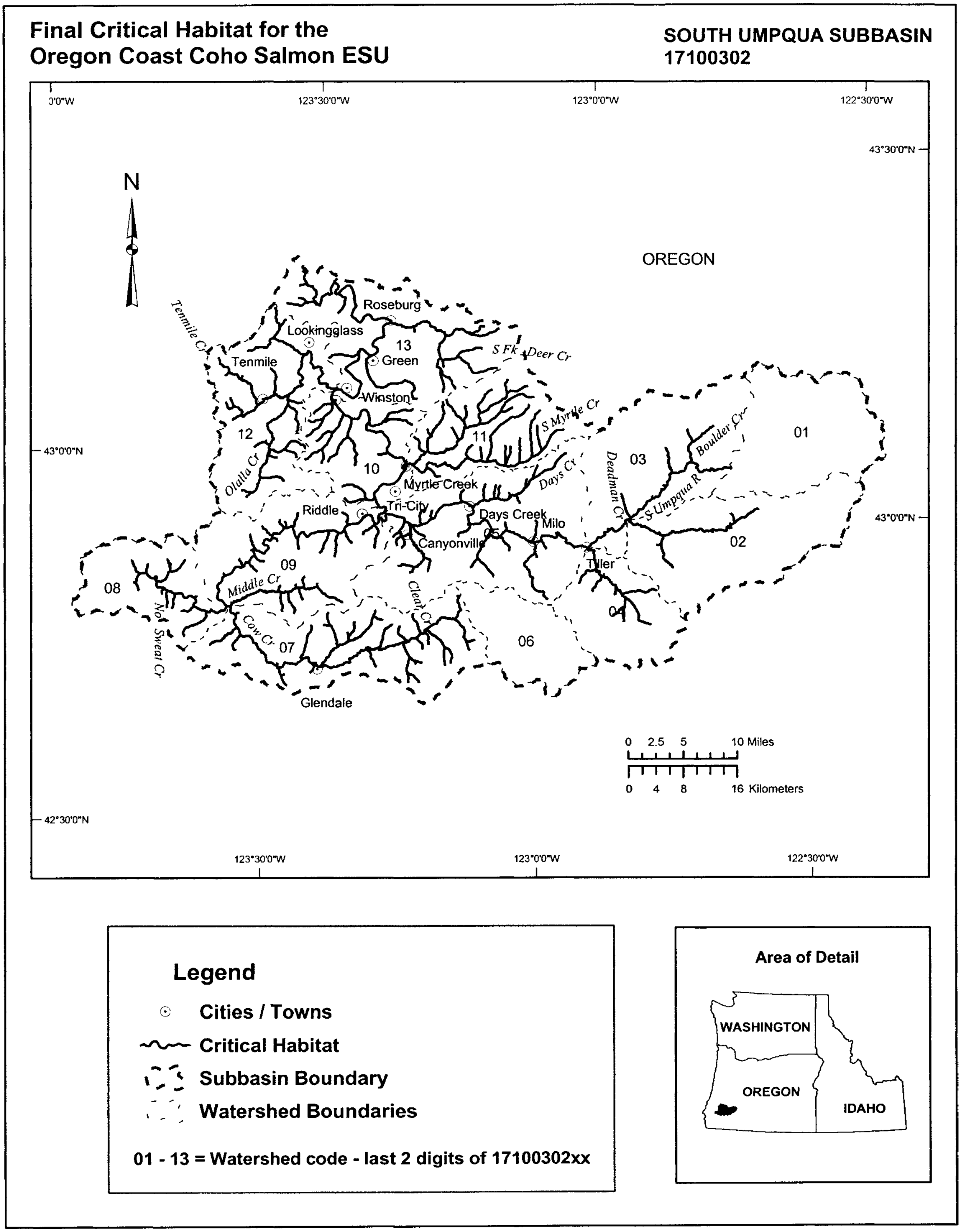

Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
ALSEA SUBBASIN
17100205
124°0'0"W
123°30'0"W
44°30'0"N
44°0'0"N
OREGON
N
Thiel Cr
Seal Rock
Waldport
Yachats R
Yachats
Cummins Cr
Bob Cr
Rock Cr
Big Cr
Cape Cr
Berry Cr
Sutton Cr
N Fk Beaver Cr
Drift Cr
Bull Run Cr
Parker Cr
Fall Cr
Tidewater
Darkey Cr
Alsea
Seeley Cr
S Fk Alsea R
Bummer Cr
Lobster Cr
Five Rivers
01
02
03
04
05
06
07
08
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 08 = Watershed code - last 2 digits of 17100205xx
Area of Detail
WASHINGTON
OREGON
IDAHO

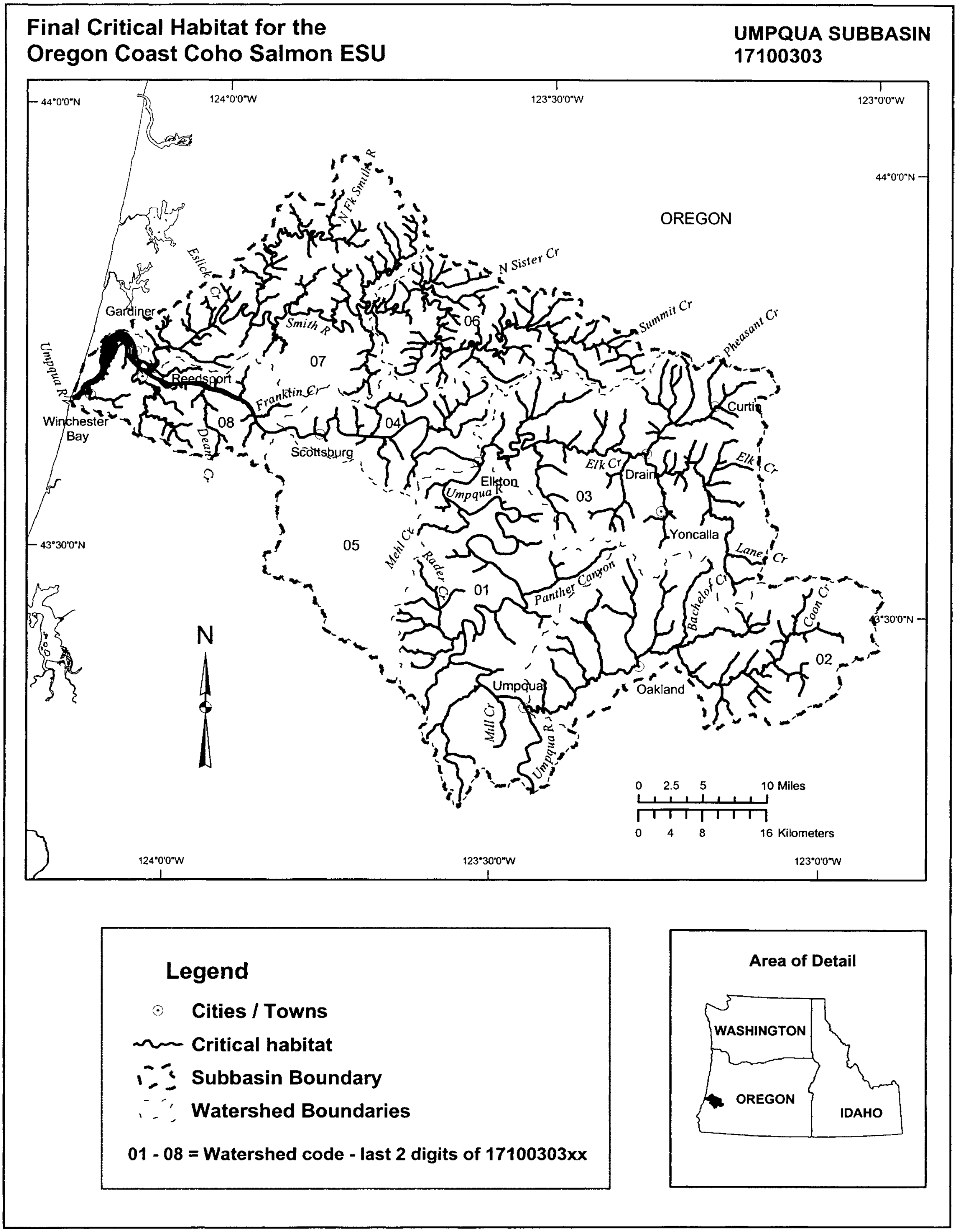


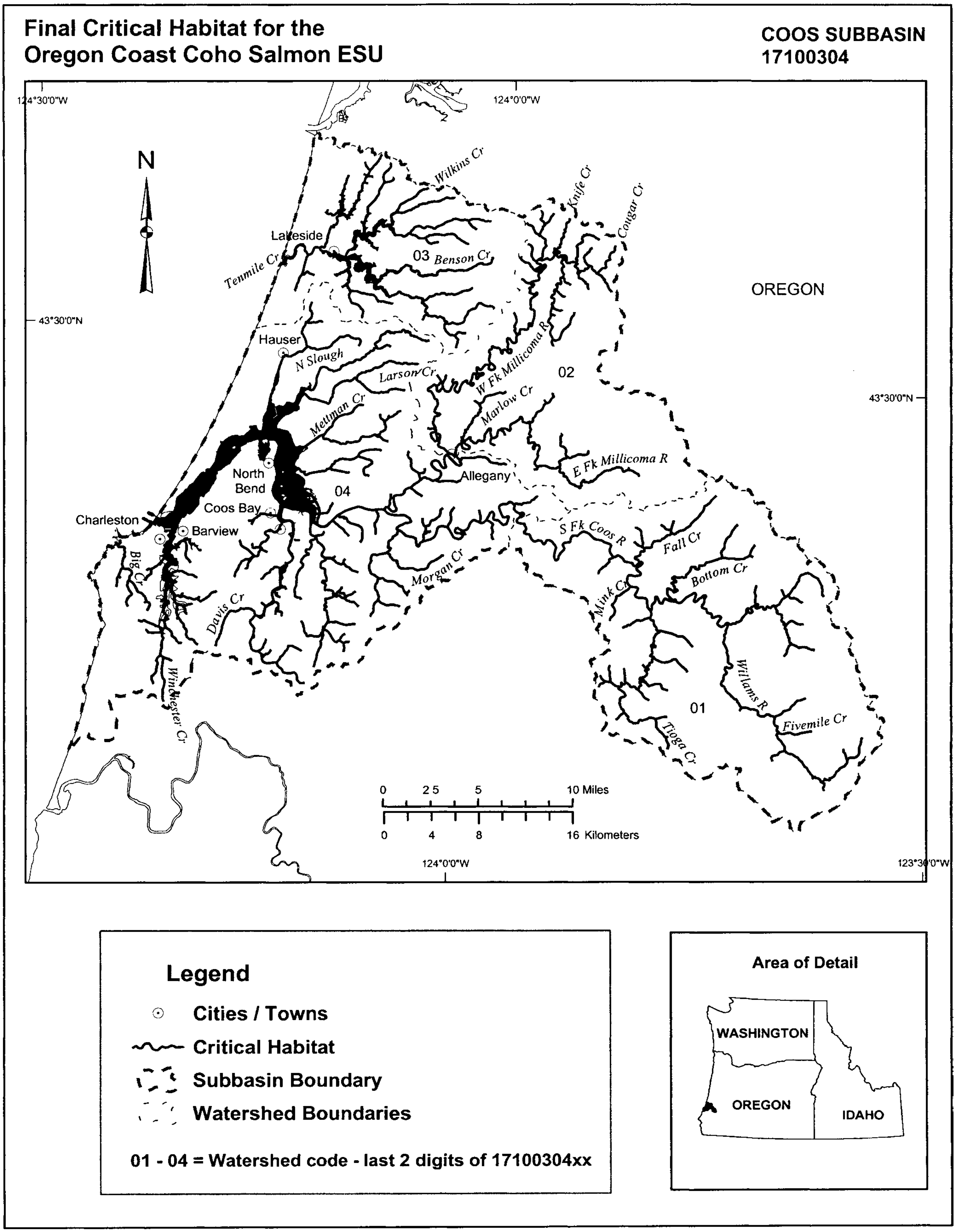
Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
SIUSLAW SUBBASIN
17100206
124°0'0"W
123°30'0"W
44°0'0"N
Indian Cr
Wilhelm Cr
Deadwood Cr
Lake Cr
Nelson Cr
Siuslaw R
Munsel Cr
Cushman
Florence
Mapleton
Swisshome
Knowles Cr
Hoffman Cr
Wildcat Cr
Wolf Crk
Haight Cr
Doe Cr
Kelly Cr
01
02
03
04
05
06
07
08
N
OREGON
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 08 = Watershed code - last 2 digits of 17100206xx
Area of Detail
WASHINGTON
OREGON
IDAHO

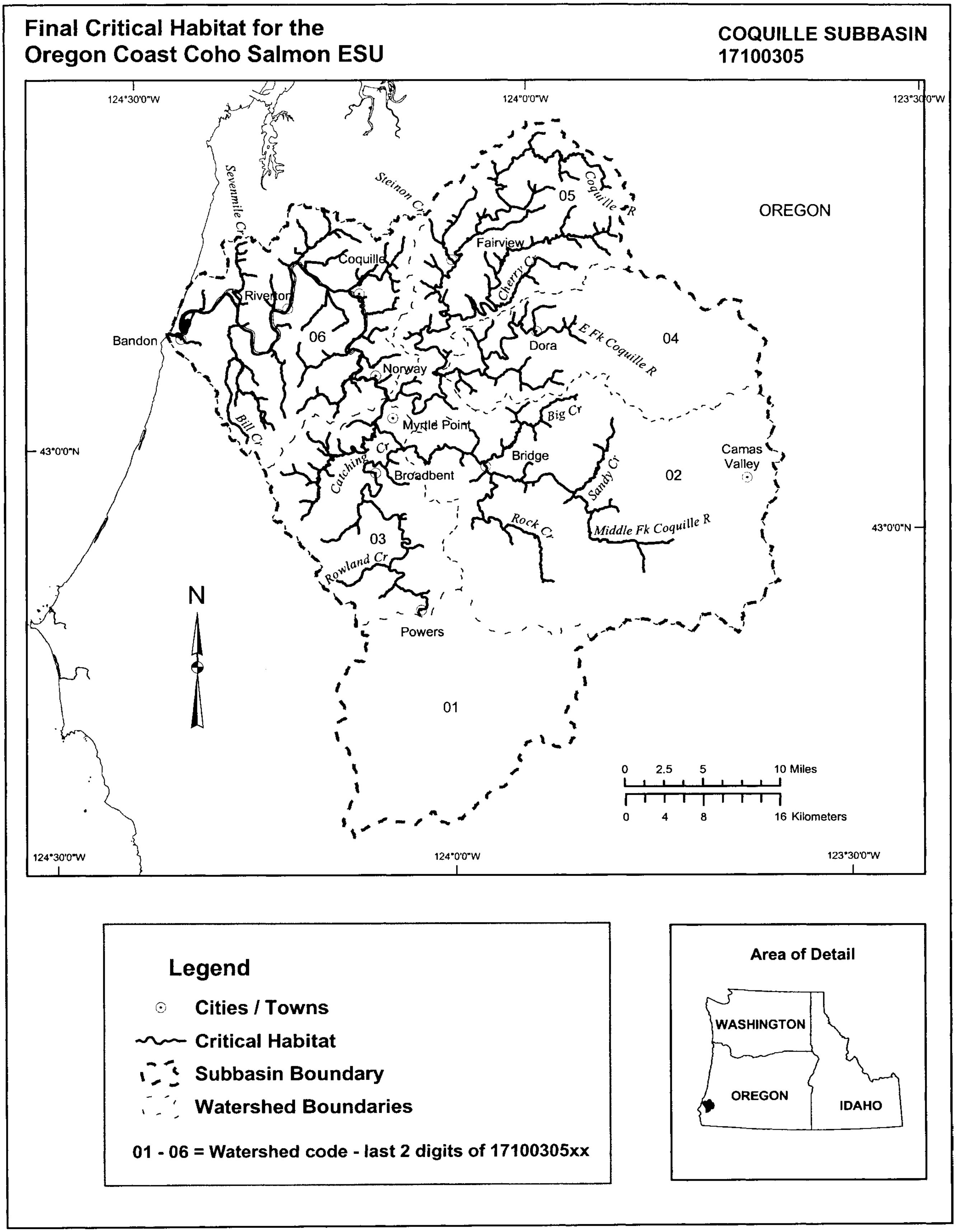

Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
SILTCOOS SUBBASIN
17100207
124°0'0"W
44°0'0"N
44°0'0"N
N
Woahink Lake
Woahink Cr
Dunes City
Maple Cr
Roache Cr
Bear Cr
Fiddle Cr
Siltcoos
Siltcoos R
Siltcoos Lake
01
Bell Cr
Fivemile Cr
Tahkenitch Lake
Tahkenitch Cr
Leitel Cr
OREGON
0 1.25 2.5 5 Miles
0 2 4 8 Kilometers
124°0'0"W
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 = Watershed code - last 2 digits of 17100207xx
Area of Detail
WASHINGTON
OREGON
IDAHO


Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
NORTH UMPQUA SUBBASIN
17100301
123°30'0"W
123°0'0"W
122°30'0"W
122°0'0"W
43°30'0"N
43°0'0"N
N
OREGON
Sutherlin
Sutherlin Cr
12
Winchester
Oak Cr
Glide
Idleyld Park
Rock Ck
N Umpqua R
Little R
Cavitt Cr
10
09
08
06
07
11
03
02
04
05
01
Diamond
Lake
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 12 = Watershed code - last 2 digits of 17100301xx
Area of Detail
WASHINGTON
OREGON
IDAHO

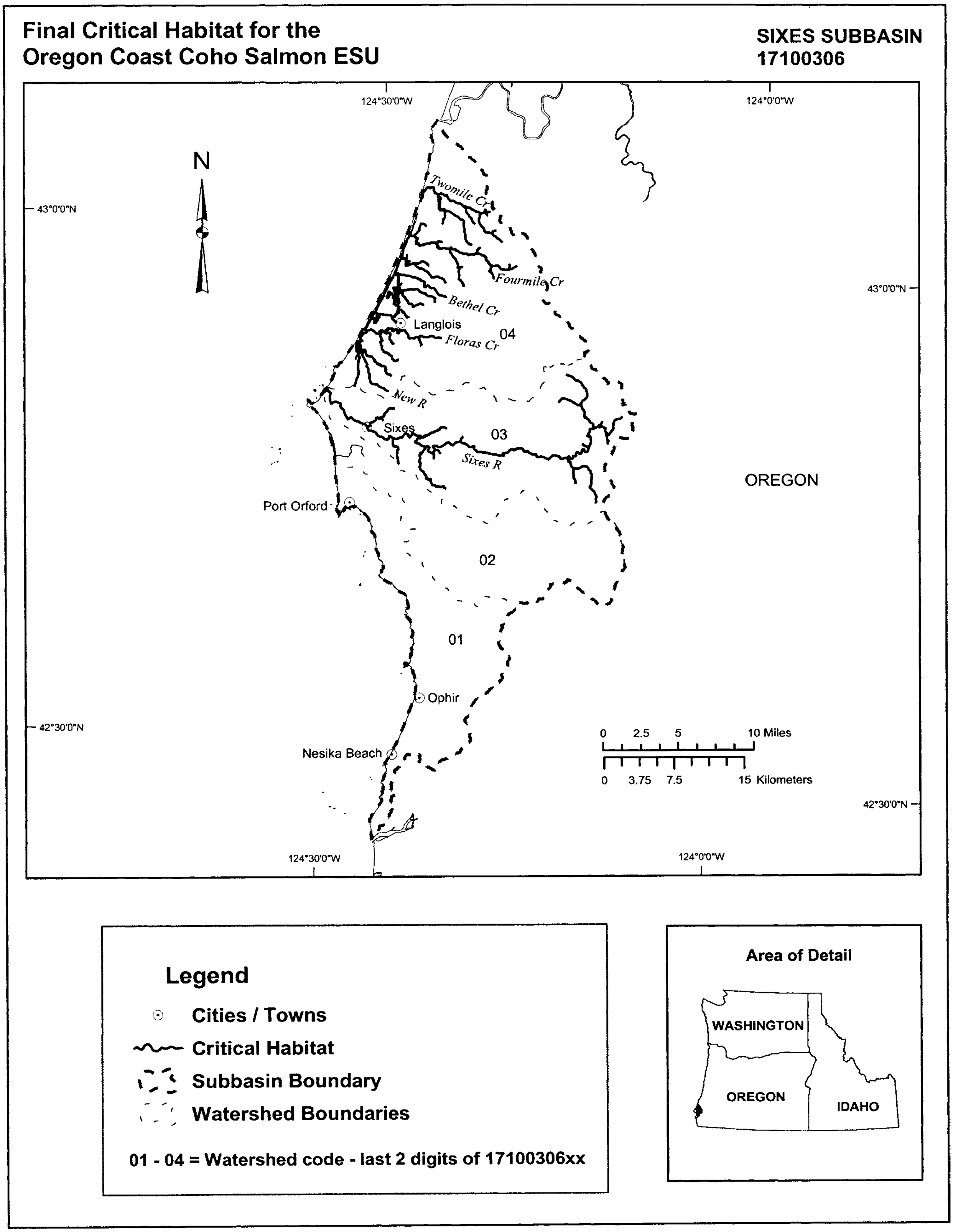

Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
SOUTH UMPQUA SUBBASIN
17100302
123°30'0"W
123°0'0"W
122°30'0"W
43°30'0"N
43°0'0"N
42°30'0"N
N
OREGON
Roseburg
Lookingglass
Green
Tenmile
Winston
Myrtle Creek
Tri-City
Riddle
Canyonville
Days Creek
Milo
Tiller
Glendale
Tenmile Cr
S Fk Deer Cr
S Myrtle Cr
Olalla Cr
Days Cr
Deadman Cr
Boulder Cr
S Umpqua R
Middle Cr
Cow Cr
Clear Cr
Cr
Sweat Cr
01
02
03
04
05
06
07
08
09
10
11
12
13
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 13 = Watershed code - last 2 digits of 17100302xx
Area of Detail
WASHINGTON
OREGON
IDAHO


Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
UMPQUA SUBBASIN
17100303
44°0'0"N
124°0'0"W
123°30'0"W
123°0'0"W
43°30'0"N
OREGON
N Fk Smith R
N Sister Cr
Eslick Cr
Gardiner
Smith R
06
07
Summit Cr
Pheasant Cr
Umpqua R
Reedsport
Franklin Cr
Winchester
Bay
08
04
Scottsburg
Dean Cr
Curtin
Elk Cr
Drain
Elkton
Umpqua R
03
Yoncalla
05
Mehl Cr
Rader Cr
Lane Cr
01
Panther Canyon
Bachelor Cr
Coon Cr
N
02
Oakland
Umpqua
Mill Cr
Umpqua R
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical habitat
Subbasin Boundary
Watershed Boundaries
01 - 08 = Watershed code - last 2 digits of 17100303xx
Area of Detail
WASHINGTON
OREGON
IDAHO


Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
COOS SUBBASIN
17100304
124°30'0"W
124°0'0"W
43°30'0"N
N
OREGON
Lakeside
Tenmile Cr
03
Benson Cr
Wilkins Cr
Knife Cr
Cougar Cr
Hauser
N Slough
Larson Cr
W Fk Millicoma R
02
Marlow Cr
Mettman Cr
Allegany
E Fk Millicoma R
North
Bend
04
Coos Bay
Charleston
Barview
Big Cr
S Fk Coos R
Fall Cr
Morgan Cr
Bottom Cr
Mink Cr
Davis Cr
Williams R
01
Fivemile Cr
Tioga Cr
Winchester Cr
0 2.5 5 10 Miles
0 4 8 16 Kilometers
123°30'0"W
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 04 = Watershed code - last 2 digits of 17100304xx
Area of Detail
WASHINGTON
OREGON
IDAHO



Final Critical Habitat for the
Oregon Coast Coho Salmon ESU
COQUILLE SUBBASIN
17100305
124°30'0"W
124°0'0"W
123°30'0"W
43°0'0"N
OREGON
Sevenmile Cr
Steinon Cr
Coquille R
05
Fairview
Coquille
Cherry Cr
Riverton
Bandon
06
E Fk Coquille R
04
Dora
Norway
Big Cr
Myrtle Point
Bill Cr
Bridge
Camas Valley
Catching Cr
Broadbent
Sandy Cr
02
Rock Cr
Middle Fk Coquille R
03
Rowland Cr
N
Powers
01
0 2.5 5 10 Miles
0 4 8 16 Kilometers
Legend
Cities / Towns
Critical Habitat
Subbasin Boundary
Watershed Boundaries
01 - 06 = Watershed code - last 2 digits of 17100305xx
Area of Detail
WASHINGTON
OREGON
IDAHO




[FR Doc. 08–552 Filed 2–4–08; 3:24 pm]

BILLING CODE 3510–22–C

Federal Register

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
LITTERA SCRIPTA MANET
1985

**Thursday,**

**April 8, 2004**

# Part V

# Department of the Interior

## Fish and Wildlife Service

**50 CFR Part 17**

**Endangered and Threatened Wildlife and Plants; 12-month Finding for a Petition To List the West Coast Distinct Population Segment of the Fisher (*Martes pennanti*); Proposed Rule**

**DEPARTMENT OF THE INTERIOR**

**Fish and Wildlife Service**

**50 CFR Part 17**

## Endangered and Threatened Wildlife and Plants; 12-month Finding for a Petition to List the West Coast Distinct Population Segment of the Fisher (*Martes pennanti*)

**AGENCY:** Fish and Wildlife Service, Interior.

**ACTION:** Notice of 12-month petition finding.

**SUMMARY:** We, the U.S. Fish and Wildlife Service (Service), announce a 12-month finding for a petition to list the West Coast distinct population segment of the fisher (*Martes pennanti*) under the Endangered Species Act of 1973, as amended. After review of all available scientific and commercial information, we find that the petitioned action is warranted, but precluded by higher priority actions to amend the Lists of Endangered and Threatened Wildlife and Plants. Upon publication of this 12-month petition finding, this species will be added to our candidate species list. We will develop a proposed rule to list this population pursuant to our Listing Priority System.

**DATES:** The finding announced in this document was made on April 2, 2004. Comments and information may be submitted until further notice.

**ADDRESSES:** You may send data, information, comments, or questions concerning this finding to the Field Supervisor (Attn: FISHER), Sacramento Fish and Wildlife Office, U.S. Fish and Wildlife Service, 2800 Cottage Way, Room W–2605, Sacramento, CA 95825 or via fax at 916/414–6710. You may inspect the petition, administrative finding, supporting information, and comments received during normal business hours by appointment at the above address.

**FOR FURTHER INFORMATION CONTACT:** Jesse Wild or Arnold Roessler at the above address (telephone: 916/414–6600; fax: 916/414–6710; electronic mail: *fisher@fws.gov*). In the event that our Internet connection is not functional, please submit your comments by the alternate methods mentioned above.

**SUPPLEMENTARY INFORMATION:**

### Background

Section 4(b)(3)(B) of the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq.*), requires that, for any petition to revise the List of Threatened and Endangered Species that contains substantial scientific and commercial information that listing may be warranted, we make a finding within 12 months of the date of the receipt of the petition on whether the petitioned action is: (a) Not warranted, or (b) warranted, or (c) warranted but that the immediate proposal of a regulation implementing the petitioned action is precluded by other pending proposals to determine whether any species is threatened or endangered, and expeditious progress is being made to add or remove qualified species from the List of Threatened and Endangered Species. Section 4(b)(3)(C) of the Act requires that a petition for which the requested action is found to be warranted but precluded shall be treated as though resubmitted on the date of such finding, *i.e.*, requiring a subsequent finding to be made within 12 months. Such 12-month findings are to be published promptly in the **Federal Register**.

On December 5, 2000, we received a petition dated November 28, 2000, to list a distinct population segment (DPS) of the fisher, including portions of California, Oregon, and Washington, as endangered pursuant to the Act, and to concurrently designate critical habitat for this distinct population segment. A court order was issued on April 4, 2003, by the U.S. District Court, Northern District of California, that required us to submit for publication in the **Federal Register** a 90-day finding on the November 2000 petition (*Center for Biological Diversity, et al.* v. *Norton, et al.*, No. C 01–2950 SC). On July 10, 2003, we published a 90-day petition finding (68 FR 41169) that the petition provided substantial information that listing may be warranted and initiated a 12-month status review. Through a stipulated order, the court set a deadline of April 3, 2004, for the Service to make a 12-month finding under 16 U.S.C. 1533 (b)(3)(B).

### Taxonomy

The fisher is classified in the order Carnivora, family Mustelidae, subfamily Mustelinae, and is the largest member of the genus *Martes* (Anderson 1994). The only other North American member of the genus *Martes* is the American marten (*M. americana*). The fisher (*Martes pennanti* Erxleben 1777) is the only extant species in its subgenus *Pekania.*

Goldman (1935) recognized three subspecies of fisher, although he stated they were difficult to distinguish. Both Grinnell *et al.* (1937) and Hagmeier (1959) examined specimens from across the range of the fisher and concluded that differences in skull morphology or pelage were not sufficient to support recognition of separate subspecies. Hall (1981) retained all three subspecies in his compilation of North American mammals, as did Anderson (1994), but neither addressed Hagmeier's conclusion that the subspecies should not be recognized (Powell 1993). Several authors address genetic variation in fisher populations in their northern and eastern ranges (Williams *et al.* 1999, 2000; Kyle *et al.* 2001) and in the west (Drew *et al.* 2003; Aubry and Lewis 2003; Wisely *et al.* in litt. 2003). These analyses found patterns of population subdivision similar to the earlier described subspecies (Drew *et al.* 2003). Drew *et al.* (2003) stated that, although it is not clear whether Goldman's (1935) subspecific designations are taxonomically valid, ''* * * it is clear (based on genetic results) that population subdivision is occurring within the species, especially among populations in the western USA and Canada.''

### Description

The fisher is light brown to dark blackish brown with the face, neck, and shoulders sometimes being slightly gray. The chest and underside often has irregular white patches. The fisher has a long body with short legs and a long bushy tail. At 6.6 to 13.2 pounds (lbs) (3 to 6 kilograms (kg)), male fishers weigh about twice as much as females (3.3 to 5.5 lbs; 1.5 to 2.5 kg). Males range in length from 35 to 47 inches (in) (90 to 120 centimeters (cm)) while females range from 29 to 37 in (75 to 95 cm) in length. The fishers from the Pacific States may weigh less than fishers in the eastern United States (Seglund 1995; Dark 1997; Golightly 1997; Aubry and Lewis 2003). Fishers are estimated to live up to 10 years (Powell 1993).

### Distribution and Status

Fishers occur in the northern coniferous and mixed forests of Canada and the northern United States, from the mountainous areas in the southern Yukon and Labrador Provinces in Canada southward to central California and Wyoming, the Great Lakes and Appalachian regions, and New England (Graham and Graham 1994; Powell 1994). The fisher's range was reduced dramatically in the 1800s and early 1900s through overtrapping, predator and pest control, and alterations of forested habitats by logging, fire, and farming (Douglas and Strickland 1987; Powell 1993; Powell and Zielinski 1994; Lewis and Stinson 1998). Since the 1950s, fishers have recovered in some of the central and eastern portions of their historic range in the United States as a result of trapping closures, changes in forested habitats (*e.g.*, forest regrowth in abandoned farmland), and reintroductions (Brander and Books 1973; Powell and Zielinski 1994). However, fishers are still absent from their former range southeast of the Great Lakes (Gibilisco 1994). Grinnell *et al.* (1937) estimated extremely low population numbers for the fisher in California at a time when trapping for the fur trade had greatly reduced populations of furbearing animals. Although it is possible that fisher populations recovered somewhat immediately following the trapping prohibitions in the 1930s and 40s, Powell and Zielinski (1994) more recently note population declines for fisher populations in the west. Fishers are believed to be extirpated from the lower mainland of British Columbia; however, they may still occupy the higher elevations of these areas in low densities (BC Species and Ecosystems Explorer 2003). In the Pacific States, fishers were historically more likely to be found in low to mid-elevation forests up to 8,200 feet (ft) (2,500 meters (m)) (Grinnell *et al.* 1937; Schempf and White 1977; Aubry and Houston 1992). In recent decades, the scarcity of detections in Washington, Oregon, and the northern Sierra Nevada indicates that the fisher may be extirpated or reduced to very low numbers in much of this area (Aubry and Houston 1992; Zielinski *et al.* 1995; Aubry and Lewis 2003).

**Washington**

The fisher historically occurred both east and west of the Cascade Crest in Washington (Scheffer 1938; Aubry and Houston 1992). Lewis and Stinson (1998) conclude that, "Based on habitat, the historical range of fishers in Washington probably included all the wet and mesic forest habitats at low to mid-elevations. The distribution of trapping reports and fisher specimens collected in Washington confirms that fishers occurred throughout the Cascades, Olympic Peninsula, and probably southwestern and northeastern Washington.'' Aubry and Houston (1992) compared current and historical records of fishers in Washington to determine their distribution in relation to major vegetation and elevation zones. In total, they found 88 reliable records, dating from 1955 to 1991. West of the Cascades, fishers occurred from 328 to 5,900 ft (100 to 1800 m), with most records from below 3,280 ft (1,000 m). On the east slope of the Cascades where precipitation is lower, fishers were recorded from 1,970 to 7,200 ft (600 to 2,200 m) (Aubry and Houston 1992). Similar to elsewhere in the range, the upper elevational limit may be determined by snow depth (Krohn *et al.* 1997). Based on a lack of recent sightings or trapping reports, the fisher is considered to be extirpated or reduced to scattered individuals in Washington (Aubry and Houston 1992; Lewis and Stinson 1998).

**Oregon**

Aubry and Houston (1992) noted that most fisher records for Washington occurred in the western hemlock and sitka spruce forest zones. Given that these forest zones occupy large portions of northwestern Oregon (Franklin and Dyrness 1988), it is likely that the fisher historically occurred in this part of the State. Based on extensive camera and track plate surveys, Lewis and Stinson (1998) concluded that the fisher is greatly reduced in Oregon. Based on extensive inquiry and review of records, Aubry and Lewis (2003) found that extant fisher populations in Oregon are restricted to two disjunct and genetically isolated populations in the southwestern portion of the State: one in the northern Siskiyou Mountains of southwestern Oregon and one in the southern Cascade Range. The fishers in the Siskiyou Mountains near the California border are probably an extension of the northern California population (Aubry and Lewis 2003). The population in the southern Cascade Range is reintroduced and is descended from fishers that were translocated to Oregon from British Columbia and Minnesota (Aubry and Lewis 2003). The Oregon Cascade Range population is separated from known populations in British Columbia by more than 404 miles (mi) (650 kilometers (km)) (Aubry and Lewis 2003).

**California**

In eastern California, the fisher historically ranged throughout the Sierra Nevada, from Greenhorn Mountain in northern Kern County northward to the southern Cascades at Mount Shasta (Grinnell *et al.* 1937). In western California, it ranged from the Klamath Mountains and north Coast Range near the Oregon border southward to Lake and Marin Counties (Grinnell *et al.* 1937). Krohn *et al.* (1997) note that the map of fisher distributions by Grinnell *et al.* (1937) suggests that fishers may have been less common in the central Sierra Nevada than elsewhere in California during the early 1900s, but it is unknown whether this distribution was the historical condition or reflects human effects on forests and fishers prior to their assessment. The map was based on the trapping records of one 5-year period prior to which there was already concern that trapping had dangerously decreased the population of fisher in California (Grinnell *et al.* 1937).

Substantial efforts have been made in recent years to assess the status of fishers and other forest carnivores in California using systematic grids of baited track and camera stations (Zielinski *et al.* 1995, 1997a, 1997b, 2000; Zielinski and Stauffer 1996; Zielinski 1997). Recent surveys indicate that fishers appear to occupy less than half of the range they did in the early 1900s in California, and this population has divided into two remnant populations that are separated by approximately 260 mi (420 km) (Zielinski *et al.* 1995), almost four times the species' maximum dispersal distance as reported by York (1996) for fishers in Massachusetts. One population is located in northwestern California and the other is in the southern Sierra Nevada Mountains. Since 1990, there have generally been no detections outside these areas except for one in 1995 in Mendocino County and one in 1995 in Plumas County (CDFG 2002, updated November 13, 2003).

Failure to detect fishers in the central and northern Sierra Nevada, despite reports of their presence there by Grinnell *et al.* (1937) and reports from the 1960s collected by Schempf and White (1977), suggests that the fisher population in this region has declined, effectively isolating fishers in the southern Sierra Nevada from fishers in northern California (Truex *et al.* 1998; Lamberson *et al.* 2000). However, prior to the recent development of a rigorous fisher survey protocol, differences in the type and quality of data available over the previous 60-year period make interpretation of distributional changes difficult (Zielinski *et al.* 1995).

**Population Size**

Although reductions in the fisher's distribution in the Pacific States are well documented (Aubry and Lewis 2003; Gibilisco 1994; Powell and Zielinski 1994), accurate information on fisher densities and abundance outside the northeastern United States is very limited. There have been no good population estimates for fisher populations in California, Oregon, and Washington, so it is unknown precisely how many fishers exist. Estimates of fisher abundance and vital rates (*e.g.*, survival, reproduction) are very difficult to obtain (Douglas and Strickland 1987) and may vary widely based on habitat composition and prey availability (York 1996). In addition, the assumptions of many methods for estimating populations (*e.g.*, equal trapability, no learned trap response, sufficient trapability to yield adequate sample sizes) may not be valid for fishers (Powell and Zielinski 1994). Consequently, only a few estimates of local fisher population density are available for the Pacific States and British Columbia, and are summarized here.

In British Columbia, densities of fishers are estimated to be between 1 and 1.54 fishers per 38.6 mi $^2$ (100 km $^2$) in the highest quality habitats in the province (Weir 2003). Using the area of each habitat capability rank within the extent of occurrence of fishers in British Columbia, the late-winter population for the province is estimated to be between 1,113 and 2,759 fishers (Weir 2003). In a preliminary progress report of fisher studies on the Hoopa Valley Indian Reservation in the Klamath mountain range (Humboldt County, California), Higley *et al.* (1998) report high capture numbers and small home ranges, some of which overlap each other, indicating that densities in this 25 mi $^2$ (65 km $^2$) study area may be very high relative to those in the rest of the occupied West Coast range. In their analysis of two fisher studies in California, Zielinski *et al.* (in press 2003a) provided a rough estimate of approximately 5 female fishers per 38.6 mi $^2$ (100 km $^2$) for their 154 mi $^2$ (400 km) north coast study area (in the Six Rivers and Shasta-Trinity National Forests of southeastern Humboldt and southwestern Trinity Counties), whereas they estimated approximately 8 females per 100 km $^2$ in their 108 mi $^2$ (280 km $^2$) southern Sierra Nevada study area (in the Sequoia National Forest in Tulare County). For the purpose of modeling population viability, Lamberson *et al.* (2000) estimated that there were between 100 and 500 individuals in the southern Sierra Nevada fisher population. Based on trapping records from the 1920s, Grinnell and colleagues (1937) provided a dire estimate of 1 fisher per 100 mi $^2$, or 300 in California. However, although Grinnell *et al.* employed accepted methodologies at the time they conducted their research, we believe that their population estimate for California is incorrect by modern standards due to the lack of a significant sample size, survey bias, and inadequate knowledge of the historical baseline.

Despite the lack of precise empirical data on fisher numbers in the western states, the relative reduction in the range of the fisher on the West Coast, the lack of detections or sightings over much of its historical distribution, and the high degree of genetic relatedness within some populations (esp., native fishers in California) (Drew *et al.* 2003), indicate that it is likely extant fisher populations are small.

**Diet**

The fisher is an opportunistic predator with a diverse diet that includes birds, squirrels, mice, shrews, voles, reptiles, insects, carrion, vegetation, and fruit (Powell 1993; Martin 1994; Zielinski *et al.* 1999; Zielinski and Duncan, in press 2003). Fishers hunt exclusively in forested habitats and generally avoid openings (Earle 1978; Rosenberg and Raphael 1986; Powell 1993; Buskirk and Powell 1994; Jones and Garton 1994; Seglund 1995; Dark 1997). Being dietary generalists, fishers tend to forage in areas where prey is both abundant and vulnerable to capture (Powell 1993).

**Reproduction**

Except during the breeding season, fishers are solitary animals. The breeding season for the fisher is generally from late February to the end of April (Leonard 1986; Douglas and Strickland 1987; Powell 1993; Frost and Krohn 1997). Birth occurs nearly 1 year after copulation, due to delayed implantation in which the embryos remain in a state of arrested development for approximately 10 months. Arthur and Krohn (1991) and Powell (1993) speculate that this system allows adults to breed in a time when it is energetically efficient, while still giving kits adequate time to develop before winter. Raised entirely by the female, kits are completely dependent at birth and weaned by 10 weeks (Powell 1993). The mother becomes increasingly active as kits grow in order to provide enough food (Arthur and Krohn 1991; Powell 1993), and females may move their kits periodically to new dens (Arthur and Krohn 1991). At 1 year, kits will have developed their own home ranges (Powell 1993). Fishers have a low annual reproductive capacity, and reproductive rates may fluctuate widely from year to year (Truex *et al.* 1998).

**Home Range Size**

A home range is an area repeatedly traveled by an individual in its normal activities of feeding, drinking, resting, and traveling. Fishers have large home ranges and male home ranges are considerably larger than those of females (Buck *et al.* 1983; Truex *et al.* 1998). Fisher home range sizes across North America vary from 3,954 to 30,147 acres (ac) (16 to 122 km $^2$ for males and from 988 to 13,096 ac (4 to 53 km $^2$ for females (Powell and Zielinski 1994; Lewis and Stinson 1998). However, Beyer and Golightly (1996) reported that male home ranges in northern California may be as large as 31,629 ac (128 km$^2$).

Truex *et al.* (1998) compared fisher home range sizes in three study areas: the Klamath Mountains (Shasta-Trinity National Forest, the North Coast Ranges), Six Rivers National Forest, and the southern Sierra Nevada (Sequoia National Forest). They found the largest home range sizes in the eastern Klamath study area in northern California where habitat quality was generally considered poor. A preliminary summary of an unpublished study conducted in coastal redwood forests in the Coast Ranges of northwestern California indicates female home range sizes of 790 to 2050 ac (3.2 km $^2$ to 8.3 km $^2$) (Joel Thompson unpublished data; Neal Ewald, pers. comm. 2003), which is somewhat larger than range sizes reported by other researchers for the species in North America. Zielinski *et al.* (in press 2003a) found that females had home ranges that were almost three times larger in their northern California study area in the Coast Ranges than in their southern Sierra Nevada study area. They too suggest that this difference in home range size is a result of better quality habitats in the southern Sierra Nevada, which are occupied by a higher density of animals within a smaller area of suitable habitat (Zielinski *et al.*, in press 2003a). Based on northeastern fisher home range sizes, Allen (1983) assumed that a minimum of 62 mi $^2$ (161 km $^2$ of potentially suitable and connected habitat must be present before an area can sustain a population of fishers. However, Allen's estimates of amount of habitat required to support a fisher population may be an underestimate when applied to western forests, where male home ranges have been found to be somewhat larger (Beyer and Golightly 1996).

**Dispersal**

Dispersal (movement away from the natal home range) is the primary mechanism for the spread of a population. Arthur *et al.* (1993) reported an average maximum dispersal distance of 9.3 and 10.7 mi (14.9 and 17.3 km) for females and males, respectively (range = 4.7 to 14.0 mi (7.5 to 22.6 km) for females and 6.8 to 14.3 mi (10.9 to 23.0 km) for males) in a population in Maine with high trapping mortality and low density. In areas with high mortality and low density, young fishers may not have to disperse as far in order to find unoccupied home ranges (Arthur *et al.* 1993). York (1996) reported dispersal distances for juvenile male and female fishers averaging 20 mi (33 km) (range = 6 to 66 mi; 10 to 107 km) for a high-density population in Massachusetts. Based on field observation and microsatellite genotype analyses of the southern Cascades fisher population, Aubry *et al.* (USDA Forest Service, Pacific Northwest Research Station, in press 2003) found empirical evidence of male-biased juvenile dispersal and female philopatry (the drive or tendency of an individual to return to, or stay in, its home area) in fishers, which may have a direct bearing on the rate at which the fisher may be able to colonize formerly occupied areas within its historical range.

**Habitat**

Assessment of habitat relationships of fisher in current western U.S. forests is complicated by broad-scale changes in forest structure and composition over the past century. Grazing, wildfire suppression, and timber harvest have resulted in dramatic changes in forest ecosystems, including reduction of large tree component, increased dominance of shade-tolerant conifer species, increased stand density, and reduced structural diversity (McKelvey and Johnson 1992; Agee 1993; Skinner 1995; Chang 1996; Norman 2003). These effects vary among forest ecosystems, but generally are more pronounced in drier interior forests of the eastern Cascades, Sierra Nevada, and eastern Klamath Mountain ranges. The degree to which currently-described habitat relationships, particularly at broader scales, existed under historical conditions is unknown.

According to Buskirk and Powell (1994), the physical structure of the forest and prey associated with forest structures are thought to be the critical features that explain fisher habitat use, rather than specific forest types. Powell (1993) stated that forest type is probably not as important to fishers as the vegetative and structural aspects that lead to abundant prey populations and reduced fisher vulnerability to predation, and that they may select forests that have low and closed canopies. In the Klamath and north coast regions of California, Carroll *et al.* (1999) also found a strong association with high levels of tree canopy cover, tree size class, and percent conifer. Within a given region, the distribution of fishers is likely limited by elevation and snow depth (Krohn *et al.* 1997), and fisher are unlikely to occupy forest habitats in areas where elevation and snow depth act to limit their movements. However, in mid-elevation areas with intermediate snow depth, fishers may use dense forest patches with large trees because the overstory closure increases snow interception (Weir 1995a).

In a track-plate study conducted on private timberlands in the redwood-Douglas-fir transition zone of the Coast Ranges of northwestern California, Klug (1997) detected fishers on 238 occasions at 26 of 40 (65 percent) survey segments located in second-growth Douglas-fir and redwood. Fishers were detected more frequently than expected (based on availability) in areas at higher elevations, in stands where Douglas-fir was the dominant or co-dominant vegetation type, and with greater amounts of hardwoods. Klug (1997) found no relation between fisher occurrence and stand age or old-growth habitats; however there was less than 2 percent old-growth on his study area. The mean canopy cover for all stations Klug sampled was 94.7 percent, and mean stand age was 42.6 years, an age which, in productive lowland redwood and Douglas-fir habitats, often correlates with large-tree conditions. During subsequent studies in this area (Ewald, pers. comm. 2003), 24 individual fisher were captured (10 males, 14 females). Nine of 11 adult females showed signs of reproduction, and 9 natal and maternal dens were located. In their adjacent study area in Redwood National and State Parks with coastal forests dominated by redwood, Slauson *et al.* (2003) found that redwood was the dominant overstory and understory species where fishers were detected; Douglas-fir was dominant at sites where they were not. This study area had 38 percent old-growth habitat; however, fisher were detected more often in second-growth redwood stands. In contrast to forests further north and further inland, the milder temperature and higher humidity in these coastal areas may create suitable habitat conditions, at least for foraging, in younger forests.

**Fragmentation**

A number of studies have shown that the fisher avoids areas with little forest cover or significant human disturbance and conversely prefers large areas of contiguous interior forest (Coulter 1966; Kelly 1977; Buck 1982; Mullis 1985; Rosenberg and Raphael 1986; Arthur *et al.* 1989a; Powell 1993; Jones and Garton 1994; Seglund 1995; Dark 1997).

Rosenberg and Raphael (1986) assessed forest fragmentation in northwestern California and its effect on fishers. Their study shows a significant positive association with a plot's distance to a clearcut, and significant negative associations with a stand's length of edge, degree of insulation (defined as "the percentage of its perimeter that was clearcut edge''), percent clearcut, and total edge. Rosenberg and Raphael (1986) state, "Among the species suspected of being most sensitive to forest fragmentation in our study, only the fisher and spotted owl were also associated with old-growth forests.'' They show a significant positive association between fisher presence and forest stand area, detecting fishers more frequently in stands over 247 ac (100 ha) (70 percent frequency of occurrence) and stands of 126 to 247 ac (51 to 100 ha) (90 percent frequency of occurrence) than in smaller stands; fishers were detected in 55 percent of stands that were 52 to 124 ac (21 to 50 ha), in 30 percent of stands that were 27 to 49 ac (11 to 20 ha), and in 17 percent of stands under 25 ac (10 ha).

The fisher's need for overhead cover is very well-documented. Many researchers report that fishers select stands with continuous canopy cover to provide security cover from predators (de Vos 1952; Coulter 1966; Kelly 1977; Arthur *et al.* 1989; Weir and Harestad 1997, 2003). Fishers may use forest patches with large trees because the overstory closure increases snow interception (Weir 1995a). Forested areas with higher density overhead cover provide the fisher increased protection from predation and lower the energetic costs of traveling between foraging sites. Fishers probably avoid open areas because in winter open areas have deeper, less supportive snow which inhibits travel (Leonard 1980; Raine 1983; Krohn *et al.* 1997), and because they are more vulnerable to potential predators without forest cover (Powell 1993). Furthermore, preferred prey species may be more abundant or vulnerable in areas with higher canopy closure (Buskirk and Powell 1994).

Several studies have shown that fishers are associated with riparian areas (Buck 1982; Jones 1991; Aubry and Houston 1992; Seglund 1995; Dark 1997; Zielinski *et al.* 1997c; Zielinski *et al.* in press 2003b, in press 2003a). Riparian forests are in some cases protected from logging and are generally more productive, thus having the dense canopy closure, large trees and general structural complexity associated with fisher habitat (Dark 1997). According to Seglund (1995), riparian areas are important to fishers because they provide important rest site elements, such as broken tops, snags, and coarse woody debris.

**Composition of Home Ranges**

Mazzoni (2002) measured habitat composition within the home ranges of 11 fisher in the southern Sierra Nevada. Home range areas averaged 24.8 percent coverage by "late-successional'' (greater than 50 percent canopy cover, greater than 24 in (61 cm) diameter) conifer forest habitat (range 15.0 to 32.1 percent). The mean percent of home range area with dense (greater than 50 percent canopy cover) conifers of all sizes was 53.6 percent (range 34.9 to 76 percent). Also in the southern Sierra Nevada, Zielinski *et al.* (in press 2003a) found that home ranges of 12 fishers consisted of 12.8 percent (SD=10.9) large tree (greater than 24 in (61 cm) ) conditions. Intermediate tree size classes (12–24 in dbh), dense (greater than 60 percent) canopy closure, and Sierran Mixed Conifer forest type composed the greatest proportion of the home ranges studies (60.7, 66.3, and 40.1 percent, respectively).

In the North Coast Range of northern California, Zielinski *et al.* (in press 2003a) found that home ranges of nine fishers were dominated by mid-seral Douglas-fir and white fir (42.8 percent); home ranges included 14 percent (SD=13.36) late-successional Douglas-fir on average and 13.97 percent true fir (SD=10.23), on average.

**Resting and Denning Habitat**

Powell and Zielinski (1994) and Zielinski *et al.* (2003b) suggest that habitat suitable for resting and denning sites may be more limiting for fishers than foraging habitat. Numerous studies have documented that fishers in the western United States utilize stands with certain forest characteristics for resting and denning such as large trees and snags, coarse woody-debris, dense canopy closure and multiple-canopy layers, large diameter hardwoods, and steep slopes near water (Powell and Zielinski 1994; Seglund 1995; Dark 1997; Truex *et al.* 1998; Self and Kerns 2001; Aubry *et al.* 2002; Carroll *et al.* 1999; Mazzoni 2002; Zielinski *et al.* in press 2003b).

Rest sites have structures that provide protection from unfavorable weather and predators. Fishers also use rest sites as protected locations to consume prey following a successful foraging bout (Zielinski, pers. comm.). Re-use of rest sites is relatively low (14 percent: Zielinski *et al.* in press 2003b), indicating that habitats providing suitable resting structures need to be widely distributed throughout home ranges of fishers (Powell and Zielinski 1994; Truex *et al.* 1998), and spatially interconnected with foraging habitats.

**Rest Site—Stand Characteristics**

The most influential variables affecting rest site selection in California fisher populations include maximum tree sizes and dense canopy closure, but other features are important to rest site choice as well, such as large diameter hardwoods, large conifer snags, and steep slopes near water (Zielinski *et al.* in press 2003b). Fishers select areas as rest sites where structural features are most variable but where canopy cover is least variable, suggesting that resting fishers place a premium on continuous overhead cover but prefer resting locations that also have a diversity of sizes and types of structural elements (Zielinski *et al.* in press 2003b). Seglund (1995) found that a majority of fisher rest sites (83 percent) were further than 328 ft (100 m) from human disturbance and Dark (1997) found that fishers used and rested in areas with less habitat fragmentation and less human activity. Characteristics of forest stands containing rest sites on industrial timberlands were similar to those reported elsewhere in northern California. Fishers in Shasta County used rest sites in stands of the largest tree size classes available, with mean canopy closure of 71 percent (Self and Kerns 2001).

**Rest Site Structure Type and Size**

Rest site structures used by fishers include: cavities in live trees, snags, hollow logs, fallen trees, canopies of live trees, platforms formed by mistletoe ("witches brooms'') or large or deformed branches, and to a lesser extent stick nests, rocks, ground cavities, and slash and brush piles (Heinemeyer and Jones 1994; Higley *et al.* 1998; Mazzoni 2002; Zielinski *et al.* 2003b). Tree size, age, and structural features are important characteristics of a rest structure. Zielinski *et al.* (in press 2003b) stated that rest structures in their study areas in the North Coast and the southern Sierra Nevada were among the largest diameter trees available, averaging 46.2, 47.2, and 27.2 in (117.3, 119.8, and 69.0 cm) for live conifers, conifer snags, and hardwoods, respectively. Most rest locations in the study areas of Zielinski *et al.* (2003b) were in cavities or broken tops of standing trees. Trees must be large and old enough to bear the type of stresses that initiate cavities, and the type of ecological processes (*e.g.*, decay, woodpecker activity) that form cavities of sufficient size to be useful to fishers; tree species that typically decay to form cavities in the bole are more important than those that do not (Zielinski *et al.* 2003b). Cavities in hardwoods were the most frequently used rest structure in the southern Sierra Nevada study area where Douglas-fir is absent (37.5 percent of rest structures were in black oaks); and in the North Coast study area, Douglas-firs were the most frequently used species (65.6 percent) and black oaks were used less frequently (11.4 percent) (Zielinski *et al.* 2003b). Higley *et al.* (1998) found that fishers in their Klamath study area use live hardwood trees most frequently for resting (57.14 percent) followed by live conifer trees (26.29 percent), snags and logs (14.86 percent—hardwoods and conifers combined) and the ground (1.71 percent). On managed industrial timberlands in northwestern California, fisher resting sites (N=35) were predominantly located on dwarf mistletoe in western hemlocks, large lateral branches and mammal nests in Douglas-firs, and cavities in cedars (Simpson Resource Company 2003). The majority of 34 rest sites described by Self and Kerns (2001) were located in mistletoe brooms in live Douglas-firs, whereas only 20 percent were in snags or hardwoods.

**Natal and Maternal Dens**

Most dens are found in live trees, and there is little evidence that den sites are reused over time (Campbell *et al.* 2000). The trees must be large enough for cavities that can be used for natal and maternal dens. Of 19 tree dens documented by Truex *et al.* (1998) across three study areas in California, the average diameter was 45 in (115 cm) for conifers and 25 in (63 cm) for hardwoods. Of 16 maternal and natal dens located on managed timberlands in northwestern California, nine were in cavities in hardwoods and seven were in conifer snags: diameters of den trees ranged from 24.6 in (62.5 cm) to 116 in (295 cm) (Simpson Resource Company 2003). According to Lewis and Stinson (1998), natal dens are most commonly found in tree cavities at heights of greater than 20 ft (6 m), while maternal dens may be in cavities closer to the ground so active kits can avoid injury in the event of a fall from the den. The mean height of natal and maternal dens found in British Columbia was 99 ft (26 m) above ground (Weir and Harestad 2003). The height of these dens may help prevent predation by the larger male fishers or by other species.

**Foraging Habitats**

Fishers in the Pacific States appear to be dietary generalists, and therefore, they may be flexible in their requirements for foraging habitat. Selection of foraging habitat may be driven by habitat relationships of primary prey species.

Several studies have characterized foraging habitat which, similar to resting habitat, is often typified by characteristics associated with mature and late-successional forests (Jones and Garton 1994; Zielinski *et al.* 1997c).

However, fishers have been found to use a broader range of successional stages for hunting than for resting (Jones 1991; Heinemeyer 1993; Jones and Garton 1994). Jones (1991) found that younger-aged forests appeared suitable for hunting but were rarely used for summer resting; more structurally complex forests seemed to have been preferred for both activities, but simpler stand structures were used for hunting. In their use of younger forests, fishers in Idaho still appeared to select localities with higher availability of large-diameter trees, snags, and logs (trees over 18 in (47 cm) diameter, snags over 20 in (52 cm) diameter, and logs over 18 in (47 cm)) relative to randomly-located plots in the home range (Jones 1991).

Complex down woody material including large down logs, and multi-layered vegetative cover are important habitat elements for fishers. Fishers are often detected at sites with higher amounts of downed logs than at random sites (Klug 1997; Slauson *et al.* 2003), and high volumes of coarse woody debris and structural complexity near the forest floor (Weir and Harestad 2003), at least in part because high structural diversity is associated with prey species richness and abundance (Slauson *et al.* 2003) and greater prey vulnerability to capture (Buskirk and Powell 1994). Shrubs also provide food for prey and for fishers in the form of fruits and berries. Slauson *et al.* (2003) found that sites in their study area where fishers were detected had higher shrub cover (40–60 percent) than sites where they were not detected. Fishers may also avoid areas with too much low shrub cover because it may adversely affect the hunting success of fishers (Weir and Harestad 2003).

**Conclusion**

The key aspects of fisher habitat are best expressed in forest stands with late-successional characteristics. Fishers use habitat with high canopy closure, large trees and snags, large woody debris, large hardwoods, multiple canopy layers, and avoidance of areas lacking overhead canopy cover (Aubry and Houston 1992; Buskirk and Powell 1994; Buck *et al.* 1994; Seglund 1995; Klug 1996; Dark 1997; Truex *et al.* 1998; Mazzoni 2002; Weir and Harestad 2003; Zielinski *et al.* in press 2003b, in press 2003a). Fisher also occupy and reproduce in some managed forest landscapes and forest stands not classified as late-successional that provide some of the habitat elements important to fisher, such as relatively large trees, high canopy closure, large legacy trees, and large woody debris, in second-growth forest stands (Klug 1997; Simpson Resource Company 2003). However, intensive management for fiber production on industrial timberlands does not typically provide for retention of these elements. It is unlikely that early and mid-successional forests, especially those that have resulted from timber harvest, will provide the same prey resources, rest sites and den sites as more mature forests (Zielinski and Powell 1994).

Late-successional coniferous or mixed forests provide the most suitable fisher habitat because they provide abundant potential den sites and preferred prey species (Allen 1987). Forest structure of good quality fisher habitat should provide high diversity of dense prey populations, high vulnerability of prey to fishers, and natal and maternal dens and resting sites (Powell and Zielinski 1994). Younger forests in which complex forest structural components such as large logs, snags, and tree cavities are maintained in significant numbers, and which provide a diverse prey base, may be suitable for fisher (Lewis and Stinson 1998).

**Distinct Population Segment**

In a 12-month finding, we must determine if (1) the petitioned action is warranted, in which case we would promptly publish a proposed rule to list the species; (2) the petitioned action is not warranted; or (3) the petitioned action is warranted but precluded by other higher priority listing activities. Under the Act, a species is defined as including any subspecies and any distinct population segment of a vertebrate species. To implement the measures prescribed by the Act and its Congressional guidance, we and the National Marine Fisheries Service (National Oceanic and Atmospheric Administration—Fisheries), developed a joint policy that addresses the recognition of DPSs of vertebrate species for potential listing actions (61 FR 4722). The policy allows for a more refined application of the Act that better reflects the biological needs of the taxon being considered, and avoids the inclusion of entities that do not require its protective measures. The DPS policy specifies that we are to use three elements to assess whether a population segment under consideration for listing may be recognized as a DPS: (1) the population segment's discreteness from the remainder of the species to which it belongs and (2) the significance of the population segment to the species to which it belongs. Our evaluation of significance is made in light of Congressional guidance that the authority to list DPSs be used "sparingly'' while encouraging the conservation of genetic diversity. If we determine that a population segment meets the discreteness and significance standards, then the level of threat to that population segment is evaluated based on the five listing factors established by the Act to determine whether listing the DPS as either threatened or endangered is warranted.

Below, we address under our DPS policy the population segment of the fisher that occurs in the western United States in Washington, Oregon and California. The area for this DPS includes the Cascade Mountains and all areas west, to the coast in Oregon and Washington; and in California, the North Coast from Mendocino County north to Oregon, east across the Klamath (Siskiyou, Trinity, and Marble) Mountains, across the southern Cascade Mountains and south through the Sierra Nevada Mountains. The mountainous areas east of the Okanogan River in Washington and the Blue Mountains west to the Ochoco National Forest in eastern Oregon are not included in this DPS due to their geographical isolation from the remainder of the DPS.

**Discreteness**

Under our DPS policy, a population segment of a vertebrate species may be considered discrete if it satisfies either one of the following two conditions: (1) it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (quantitative measures of genetic or morphological discontinuity may provide evidence of this separation); or (2) it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant with regard to conservation of the taxon in light of section 4(a)(1)(D) of the Act.

The proposed DPS is markedly separated from other fisher populations as a result of several factors. Native populations of the fisher in California and the reintroduced population in the southern Cascade Mountains of Oregon are physically isolated from the Canadian populations by over 200 miles (Weir 2003), given the northward contraction of the British Columbia population (Weir 2003) in Canada. Substantial information is available indicating the West Coast population is also physically separated from known populations of the fisher to the east.

The range of the fisher in Washington, Oregon, and California is separated from the Rocky Mountains and the rest of the taxon in the central and eastern United

States by natural physical barriers including the non-forested high desert areas of the Great Basin in Nevada and eastern Oregon, and the Okanogan Valley in eastern Washington. At its extreme northern (unoccupied) extent in northern Washington, the DPS is separated from the western extension of the Rocky Mountains and associated ranges by the Okanogan Valley, a distance of approximately 93 to 124 mi (150 to 200 km), which is well beyond the dispersal range for the species. Other physical barriers that separate the West Coast population from Rocky Mountain and eastern U.S. fisher populations include major highways, urban and rural open-canopied areas, agricultural development, and other nonforested areas. Fishers have a strong aversion to areas lacking in forest cover or to crossing large rivers that do not freeze in the winter (Powell 1993; Powell and Zielinski 1994; Aubry and Lewis 2003); these behavioral factors, along with the other numerous barriers identified above, represent a significant impediment to eastward or westward movement for the fisher.

We currently have limited information on dispersal distances of fishers in the western United States. However, studies conducted on fisher dispersal in the northeastern United States indicate that dispersal distances are relatively short (Arthur *et al.* 1993; York 1996). There is no evidence that fishers are successfully dispersing outside of known population areas in California and Oregon. This is possibly due to the extent of habitat fragmentation, developed or disturbed landscapes, and highways and interstate corridors (see dispersal section above).

Genetic information (Drew *et al.* 2003) indicates that the West Coast population of fisher originally colonized the Pacific states from British Columbia. The current range of fisher in British Columbia has been reduced and connection to fisher populations in the continental United States no longer exists (Weir 2003, BC Species and Ecosystems Explorer 2003). The fisher's present range in British Columbia has contracted northward from the international boundary by about 200 kilometers. (Weir 2003). Movement of fisher from British Columbia southward to areas occupied by the West Coast population is not possible based on lack of available habitat, habitat preferences, and dispersal behavior of the fisher.

The West Coast population also appears to be separated from other populations as a result of ecological factors, as they use forest types that differ in species composition, tree size, and habitat structure as compared to those used by fishers in other populations. The fisher is regarded as a habitat specialist in the western United States (Buskirk and Powell 1994), occurring only at mid to lower elevation in mature conifer and mixed conifer/hardwood forests characterized by dense canopies and abundant large trees, snags, and logs (Powell and Zielinski 1994). In contrast, fishers in the northeastern United States and the Great Lakes region inhabit areas with a large component of deciduous hardwood forest containing American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and other broadleaf species (Powell and Zielinski 1994). The majority of conifer forest habitat in Canada is characterized as boreal forest, which is different from the relatively dryer environmental conditions associated with Washington, Oregon, and California. In the Rocky Mountains of north central Idaho, certain all-conifer habitat types which include grand fir and Engelmann spruce appear to be important to, and preferentially selected by fishers (Jones 1991).

With regard to physiological differences, the fishers in the native northern California population are significantly smaller in size (based on condylobasal length) than fishers from western and central Canada (Hagmeier 1959; Zielinski *et al.* 1995; Aubry and Lewis 2003.

The West Coast population of the fisher is also delimited to the north by the international governmental boundary between the United States and Canada because of differences in control of exploitation, management of habitat, conservation status, and regulatory mechanisms that may be significant with respect to section 4(a)(1)(D) of the Act. Canada has no overarching forest practices laws governing management of its national lands. In contrast, lands within the National Forest System in the United States are considered under the National Forest Management Act of 1976, as amended (16 U.S.C. 1600), and associated planning regulations. The fisher is covered by British Columbia's Wildlife Act which protects virtually all vertebrate animals from direct harm, except as allowed by regulation (*e.g.*, hunting or trapping). The fisher is designated as a Class 2 furbearer in British Columbia and, as such, can be legally harvested by licensed trappers under regional regulations. However, the fisher was reclassified to the Red List in British Columbia in 2003 with a provincial conservation ranking of "S2,'' as assigned by the British Columbia Conservation Data Centre to "score'' the risk of extinction or extirpation (BC Species and Ecosystems Explorer 2003). The Red List designation means that the species is considered imperiled at the provincial level. The change in the fisher designation was the result of an estimated provincial population of fewer than 3,000 individuals and habitat loss due to logging, hydro-electric development and other land use changes (BC Species and Ecosystems Explorer 2003). Although the change in Red List designation for the fisher in British Columbia carries no legal implications, trapping seasons for it have been closed until new information is collected that indicates the population is secure (BC Ministry of Land, Water, and Air Protection 2003). Beyond this voluntary closure of the trapping season, the fisher carries no protected status in British Columbia. Trapping the species has been prohibited for decades in Washington, Oregon, and California (Lewis and Stinson 1998). For the reasons stated above, we believe that these factors collectively play a role in delimiting the northern DPS boundary along the international border with Canada from the Cascade Mountains west to the Pacific Ocean.

Based on the available information on fisher range and distribution, we conclude that the West Coast population of fisher is distinct and separate from other fisher populations in the United States and meets the requirements of our DPS policy for discreteness. The West Coast population of fisher is separated from fisher populations to the east by geographical barriers and to the north by habitat availability; it is further delineated by the international boundary with Canada, within which there are differences in control of exploitation, conservation status, and regulatory mechanisms that are significant to its conservation.

**Significance to the Species**

Under our DPS policy, once we have determined that a population segment is discrete, we consider its biological and ecological significance to the larger taxon to which it belongs. This consideration may include, but is not limited to, the following factors: (1) Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; (2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon; (3) evidence that the population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range; and (4) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics. Significance is not determined by a quantitative analysis, but instead by a qualitative finding. We have found substantial evidence that the West Coast DPS of the fisher meets two of the significance factors and is supported by a third significance factor, and we have described them below.

Fishers in the West Coast population persist in an ecological setting that is unusual in comparison to the rest of the taxon, with a different climate, topography, and habitat than that found in the majority of its range. The forests inhabited by fishers on the west coast lack the extensive broadleaf hardwood component that is common in the eastern portions of the species' range. The Pacific coast's wet winter followed by a dry summer is unique in comparison to climate types in the east and Canada, and produces distinctive sclerophyll forests of hardleaved evergreen trees and shrubs (Smith *et al.* 2001). This climate is characterized by mild, wet winters and warm, dry summers (Bailey 1995), while the climate in the animal's range in the Rocky Mountains consists of cold winters and cool, dry summers, and in the Great Lake States, eastern Canada, and the northeast United States it is characterized by cold winters, and warm, wet summers. Fishers on the west coast primarily occur in habitat in steep, mountainous terrain, while those in the Great Lakes region, eastern Canada, and the northeastern United States inhabit level terrain or low lying glaciated mountains. Releases of eastern fishers into western forests have generally been unsuccessful; Powell and Zielinski (1994) state that, "Roy's (1991) results [unsuccessful attempts to reintroduce Minnesota fishers to Montana] indicate that many fishers from eastern North America may lack behaviors, and perhaps genetic background, to survive in western ecological settings.'' The repeated introductions of fishers from British Columbia and Minnesota to the southern Cascade Mountains of Oregon (from 1960s to 1980s) have resulted in an apparently stable, but small population there; however, the species is not expanding and dispersing from the areas into which it was introduced.

The loss of the West Coast DPS of the fisher would eliminate the entire southwest portion of the fisher's North American range. Additionally, the West Coast DPS of the fisher represents the southernmost range of the *Martes* genus. The West Coast populations represent three of the known remaining four populations in the western United States (fourth being the Rocky Mountain population), and a significant portion of the western range of fishers in North America. Based on figures from Weir (2003), the total range of the fisher in North America has been reduced approximately 33 percent in geographical area since the 1600s. This reduction is most apparent in the fishers southern and western range—largely in the United States. Based on our review of Lewis and Stinson's (1998) maps (modified from Gibilisco 1994), these are three of only six or seven remaining areas occupied by fishers in the United States. Although these maps consider a large area of Canada to be within the 1994 range of the fisher, distribution has diminished in some areas of southeastern Ontario and Quebec, in the prairie provinces (Alberta, Saskatchewan, and Manitoba), and in the western United States (Gibilisco 1994); and because of the lack of inventories for the species in Canada, it is not known to what extent the range in Canada is occupied. Additionally, the populations in the southern Sierra Nevada and northern California/southern Oregon appear to be the only native populations of the fisher remaining in the west (Truex *et al.* 1998; Aubry *et al.* in press 2003; Drew *et al.* 2003), and are "the only populations that have not been augmented with individuals (and genes) from other regions'' (Zielinski *et al.* 2003b).

As stated earlier (see distribution section), the extent of area known to be currently occupied by fishers in Washington, Oregon, and California is roughly 20 percent of their historical extent in these States. The loss of the species from the United States west of the Rocky Mountains and south of British Columbia would result in a significant gap in the range of the species as a whole and represent the loss of a major geographical area of the range of the taxon. It would represent a loss of the species from about 20 percent of its historical range in the United States, a significant portion of its North American range, recognizing that the historical range was not continuously occupied spatially or temporally, and that the present range we identify is also not occupied continuously nor is all of the historical habitat still available, especially in the midwest and east.

The extinction of fishers in their west coast range would also result in the loss of a significant genetic entity, since they have been described as being genetically distinct from fishers in the remainder of North America. More specifically, native fishers in California have reduced genetic diversity compared to other populations (Drew *et al.* 2003). Additionally, the extant native populations in California share one haplotype that is not found in any other populations (Drew *et al.* 2003).

Quantitative measures of genetic discontinuity indicate that there is no naturally occurring genetic interchange with the California fisher populations. Based on genetic evidence, and supported by paleontological and archeological evidence, Wisely *et al.* (in litt. 2003) theorize that fishers probably colonized the Pacific peninsula from the north, not the east. The fisher was once distributed throughout much of the dense coniferous forests in British Columbia, Washington, Oregon, and California (Drew *et al.* 2003). This historical connectivity among populations along the Pacific Coast is evidenced by the presence of British Columbia haplotypes in museum specimens from California and Washington (Drew *et al.* 2003). The historical continuity in fisher distribution no longer exists, as discussed above. Genetic variation shows the Oregon southern Cascade population is a reintroduced population descended from fishers translocated to Oregon from British Columbia and Minnesota (Drew *et al.* 2003). There is evidence that there has been no genetic interchange between the native northern California/southwestern Oregon Siskiyou population and the reintroduced southern Cascade Oregon population (Aubry *et al.* in press 2003).

**Conclusion**

We have evaluated as a DPS the population of fishers in the West Coast range and have addressed the elements our policy requires us to consider in deciding whether a vertebrate population may be recognized as a DPS and considered for listing under the Act. In assessing the population segment's discreteness from the remainder of the taxon, we have described the factors separating it from other populations. We considered distributional, ecological, behavioral, morphological, and genetic information, information from status surveys, and geographical and biogeographical patterns, and have concluded that this population segment is discrete under our DPS policy. In assessing the population segment's significance to the taxon to which it belongs, we have considered the geographical area represented by the western DPS, its genetic distinctness from fisher populations in the central and eastern United States, its unique ecological setting, and other considerations and factors as they relate to the species as a whole. We conclude that loss of the species from the west coast range in the United States would represent (1) a significant gap in the species' range, (2) the loss of genetic differences from fisher in the central and eastern United States, and (3) the loss of the species from a unique ecological setting. Therefore, as the population segment meets both the discreteness and significance criteria of our DPS policy, it qualifies as an entity that may be considered for listing. We now evaluate its status as endangered or threatened. In making this determination, we evaluate the factors enumerated in section 4(a)(1) of the Act (16 U.S.C. 1533 (a)(1)).

**Summary of Factors Affecting the Species**

Section 4 of the Act (16 U.S.C. 1533), and implementing regulations at 50 CFR 424, set forth procedures for adding species to the Federal endangered and threatened species list. In making this finding, information regarding the status and threats to this species in relation to the five factors in section 4 of the Act is summarized below.

*Factor A. The Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range.* Vegetation management activities such as timber harvest and fuels reduction treatments, stand-replacing fire, large-scale forest disease outbreaks or insect infestations (*e.g.*, pine beetle), and development can destroy, alter, or fragment forest habitat suitable for fishers.

*Timber Harvest*

The extent of past timber harvest is one of the primary causes of fisher decline across the United States (Powell 1993), and may be one of the main reasons fishers have not recovered in Washington, Oregon, and portions of California as compared to the northeastern United States (Aubry and Houston 1992; Powell and Zielinski 1994; Lewis and Stinson 1998; Truex *et al.* 1998). Timber harvest can fragment fisher habitat, reduce it in size, or change the forest structure to be unsuitable for fishers.

Habitat fragmentation has contributed to the decline of fisher populations because they have limited dispersal distances and are reluctant to cross open areas to recolonize historical habitat. Based on northeastern fisher home range sizes, Allen (1983) estimated that a minimum of 161 $km^2$ (39,780 ac) of potentially suitable and contiguous habitat must be present before an area can sustain a population of fishers. However, fisher populations in western forests may need even larger areas because male home ranges in northern California have been reported to be as large as 128 $km^2$ (Beyer and Golightly 1996). A habitat suitability model developed in British Columbia figures that a minimum of 259 $km^5$ of contiguous habitat is required for fisher transplant attempts (Apps 1996 as cited in Craighead *et al.* 1999).

Fishers use large areas of primarily coniferous forests with fairly dense canopies and large trees, snags, and down logs; vegetated understory and large woody debris appear important for their prey species. Fishers in the Pacific Northwest use late-successional forest more frequently than the early to mid-successional forests that result from timber harvest (Aubry and Houston 1992; Buck *et al.* 1994; Rosenberg and Raphael 1986). Elimination of late-successional forest from large portions of the Sierra Nevada and Pacific Northwest (Morrison *et al.* 1991; Aubry and Houston 1992; McKelvey and Johnston 1992; Franklin and Fites-Kauffman 1996) has probably significantly diminished the fisher's historical range on the west coast (Lewis and Stinson 1998).

Several studies have found sharp declines in late-successional/old-growth forests (Beardsley *et al.* 1999, Bolsinger and Waddell 1993, the Report of the Forest Ecosystem Management Assessment Team (FEMAT) 1993, Franklin and Fites-Kaufmann 1996, Morrison *et al.* 1991, Service 1990). Old growth comprised about 50 percent of the forests of Washington, Oregon, and California in the 1930s and 1940s, but made up less than 20 percent of those forests in 1992 (about 10.3 million ac; 41,683 $km^2$) (Bolsinger and Waddell 1993).

Franklin and Fites-Kaufman (1996) find that forests with high late successional/old-growth structural rankings are now uncommon in the Sierra Nevada of California (8 percent of mapped area). Mixed conifer forests are a particularly poorly represented forest type as a result of past timber harvesting, and key structural features of late successional/old-growth forests, such as large-diameter trees, snags, and logs, are generally at low levels (Franklin and Fites-Kaufman 1996). The loss of structurally complex forest and the loss and fragmentation of suitable habitat by roads and residential development have likely played significant roles in both the loss of fishers from the central and northern Sierra Nevada and the fisher's failure to recolonize these areas (USDA Forest Service 2000).

Within the Northwest Forest Plan area, 60 to 70 percent of the forested area of the region was historically dominated by late-successional and old-growth forest conditions. Most of the forest (perhaps 80 percent) probably occurred in relatively large contiguous areas (greater than 1000 ac; 4 $km^2$) (Bolsinger and Waddell 1993, USDA Forest Service and U.S. Department of Interior Bureau of Land Management (USDI BLM) 1994a). Franklin and Spies (1986) estimated that 15 million ac (60,703 $km^2$) of old-growth forest existed west of the Cascade Mountains in Oregon and Washington in the 1800s, and only about 5 million ac (20,234 $km^2$; 33 percent) remain. FEMAT (1993) reports the status of forests in several regions: private and State lands within western Washington and western Oregon Cascades have mostly been harvested, whereas Forest Service and Bureau of Land Management lands (BLM) still include significant areas (albeit highly fragmented) of late successional/old-growth forest; the Klamath Provinces of southwestern Oregon and northwestern California have forests that are highly fragmented by timber harvest and natural factors (poor soils, dry climate, wildfires); the southern end of the Cascades Range in Oregon extending into California has forests that are highly fragmented due to harvest activities and natural factors.

The NWFP states that fisher populations are believed to have declined on Federal lands in old-growth habitat for two primary reasons: (1) Loss of habitat due to forest fragmentation resulting from clearcutting, and (2) the removal of large down coarse woody debris and snags from the cutting units (USDA Forest Service and USDI BLM 1994). Fishers in the eastern Klamath area of northern California have lower population densities, larger home ranges, lower capture rates, and a higher proportion of juveniles than other populations studied, possibly due in part to timber harvest having decreased habitat quality for the fisher in this area (Truex *et al.* 1998).

The conversion of low-elevation forests in western Washington to plantations and non-forest uses may have eliminated a large portion of the fisher habitat in the state (Powell and Zielinski 1994). There were historically many mature and old-growth stands (Aubry and Houston 1992). Over 60 percent of the 24.7 million ac (100,000 $km^2$) of forest believed to be present in Washington when white settlers first arrived were potential fisher habitat (Lewis and Stinson 1998). By 1992, the area of old-growth forest was reduced to 2.7 million ac (10,927 $km^2$) (Bolsinger and Waddell 1993). During the last 50 years, the structure, composition, and landscape context of much of

Washington's 16,803,100 ac (68,000 $km^2$) of commercial timberland has significantly changed because of intensive timber harvesting activities (Morrison 1988). Most of the remaining younger low and mid-elevation forest is fragmented and has reduced amounts of large snags and coarse woody debris, and may not be able to sustain fisher populations (Rosenberg and Raphael 1986; Lyon *et al.* 1994; Powell and Zielinski 1994). The higher elevation forests are less suitable for fishers because of deep snowpacks (Aubry and Houston 1992; FEMAT 1993).

Some forest management practices change the dominance of certain forest subtypes in western states (Lewis and Stinson 1998, Bouldin 1999). This change in forest structure is important because certain habitat types or tree species are suitable for fishers. In addition, logging and fire suppression have created higher densities of small trees which have led to higher insect and pathogen-induced mortality and the loss of structural diversity, and increased chances for stand-destroying fires (Bouldin 1999), the effects of which are discussed below.

Mazzoni (2002) found that timber harvest, fire, and succession resulted in fisher habitat fragmentation in the southern Sierra Nevada from 1958 to 1997. Rosenberg and Raphael (1986) emphasize that the fragmentation of northwestern California Douglas-fir forests is relatively recent in comparison with forests of other regions, and that the true long-term responses of species to the break-up of their habitat cannot yet be discerned.

The effects of timber harvest on fisher habitat depend on the silvicultural prescriptions used and the condition of the habitat prior to harvest. Habitat fragmentation is a concern. Clearcutting, selective logging, and thinning change the suitability of fisher habitat by removing overhead cover and insulating canopy, exposing the site to the drying effects of sun and wind (Buck *et al.* 1994) or to increased snow deposition, removing prime resting and denning trees, and increasing exposure of the fisher to predators.

*Fuels Reduction and Loss of Habitat From Fire*

Mechanical thinning or prescribed fire negatively affect fishers if it impacts habitat quality by reducing canopy cover and coarse woody debris over large areas or fragment habitat. Fuels reduction treatments, including thinning and the removal of down woody debris, dense understory, snags, and low overstory tree crowns may significantly affect fishers in the immediate area. Prescribed burning generally promotes forest health, and can enhance suitability for wildlife, but may vary in its effect on fishers. Small fires should not be detrimental to fishers because of the fishers' large home ranges (unless they impact natal dens during breeding season); however, hotter or more widespread fires may displace fishers or destroy habitat. Prescribed fire can also consume habitat structural elements such as snags and downed logs that are important to fishers.

The potential for stand-replacing wildfire has increased in areas where fire suppression has played a role in raising fuel load to levels that place late successional forest-dependent species at a higher risk of habitat loss (USDA Forest Service and USDI BLM 1994b). Stand replacing fires can impact large areas and render them unsuitable for fisher for several decades (Lewis and Stinson 1998). The combination of increased tree density and standing tree mortality (with associated increased surface/ground fuel loads) over the past century presents the greatest single threat to the integrity of Sierra Nevada forest ecosystems (McKelvey *et al.* 1996, USDA Forest Service 2000). On the other hand, while increased density of trees and woody debris (“fuel loading'') increases the risk of stand-replacing fire, they may also enhance habitat for the fisher in the short term.

*Forest Disease and Insect Outbreaks*

Although large area epidemics may displace fishers if canopy cover is lost, the usual pattern of localized outbreaks and low density of insect and disease damage is probably not a great threat to fisher habitat. In some cases, the diseased trees are beneficial, providing structures conducive to resting and denning. However, timber removal and thinning prescriptions in response to outbreaks may fragment or degrade habitat in the short term in order to prevent catastrophic fire that will eliminate habitat altogether for decades (see previous discussion). In addressing outbreaks of the mountain pine beetle (*Dendroctonus ponderosae*) and other insects in British Columbia, Weir (2003) states that reduction in overhead cover may be detrimental to fishers and that wide-scale salvage operations may substantially reduce the availability and suitability of fisher habitat.

Sudden Oak Death Phytophthora affects oaks and redwoods and may affect tanoak, evergreen huckleberry, and Pacific rhododendron (*Rhododendron macrophyllum*). Four sites on Federal, private industrial, and private nonindustrial forestlands in Oregon (near Brookings) have been confirmed as having Sudden Oak Death. The outbreaks at these sites affect from less than 1 ac (0.4 ha) to approximately 8 ac (3 ha) in size. Chances of continued introductions and establishment of the disease appear high in southwestern Oregon and northwestern California because these areas have the hosts, the climatic conditions preferred by the pathogen, and many potential pathways for its movement. It is a potentially significant threat if it spreads into areas in which oaks are the primary trees used for fisher denning.

*Development, Recreation, and Roads*

Urban Development and Recreation

Forested area in the Pacific coast region decreased by about 8.5 million ac (34,400 $km^2$) between 1953 and 1997 (Smith *et al.* 2001). Alig *et al.* (2003) state that “Forest cover area [in the Pacific coast states] is projected to continue to decrease through 2050, with timberland area projected to be about 6 percent smaller in 2050 than in 1997. Forest area is projected to decline in all three subregions [Washington, Oregon, and California]. Population and income are expected to further fuel development in the region, as population is projected to increase at rates above the national average, leading to more conversion of forest to nonforest uses.''

Rural and recreational development, such as campgrounds, recreation areas, and hiking, biking, off-road vehicle and snowmobile trails, may adversely affect fishers. Recreational activities can alter wildlife behavior, cause displacement from preferred habitat, and decrease reproductive success and individual vigor (USDA Forest Service 2000). A study of fisher habitat use on the Shasta-Trinity National Forest indicates that fishers use landscapes with more contiguous, unfragmented Douglas-fir forest and less human activity (Dark 1997).

Roads

Highways and associated developments can substantially influence movement patterns of wildlife (Bier 1995). The adverse effects of roads include direct loss of habitat, displacement from noise and human activity, direct mortality, secondary loss of habitat due to the spread of human development, increased exotic species invasion, and creation of barriers to fisher dispersal. The impacts of these effects on low density carnivores like fishers are more severe than most other wildlife species due to their large home ranges, relatively low fecundity, and low natural population density

(Ruediger *et al.* 1999), and their general avoidance of non-forested habitats. Disruption of movement can contribute to a loss of available habitat (Mansergh and Scotts 1989), isolate populations, and increase the probability of local extinctions (Mader 1984). The loss of structurally complex forest (Beesley 1996) and the loss and fragmentation of suitable habitat by roads and residential development (Duane 1996) has likely played a significant role in both the loss of fishers from the central and northern Sierra Nevada and its failure to recolonize these areas.

Areas with more roads may have increased fisher mortality due to road kill (Heinemeyer and Jones 1994). Given patterns of human population growth in areas near and within fisher habitat, road development and traffic, and associated mortality, can be expected to increase. Campbell *et al.* (2000) stated that many records of fisher locations come from roadkills; for example, Yosemite National Park reported four fishers killed by automobiles between 1992 and 1998. Proulx *et al.* (1994), York (1996), and Zielinski *et al.* (1995, 1997a) all cite the risk of fishers being struck and killed by vehicles as a potential threat to populations. The potential for vehicle collisions increases with the density of open roads in suitable habitat. Vehicles caused the death of two of the 50 radio-collared fishers in a 5-year Maine study (Krohn *et al.* 1994), and three of 97 fishers in a 3-year study in Massachusetts (York 1996). Vehicle collisions could be a significant mortality factor, especially for small fisher populations. Off-highway and over-snow vehicles are used throughout the range of the fisher, and can also directly kill fishers or cause behavioral changes due to disturbance.

Vehicle traffic during the breeding season in suitable habitat may impact foraging and breeding activity. Dark (1997) found that fishers more often used areas with a greater than average density of low use roads, and may not have used areas that were dissected by moderate to high use roads. Campbell (2004) found that sample units within the central and southern Sierra Nevada region occupied by fishers were negatively associated with road density. This relationship was significant at multiple spatial scales (from 494 to 7,413 ac (2 to 30 $km^2$). In a stand-scale level study, Robitaille and Aubry (2000) found that martens, close relatives of fishers, were less active near roads. Paved roads are expected to cause more mortality than unpaved roads because of the higher use and speeds associated.

The access to forest areas provided by roads leads to increased human disturbances from resource use and extractive activities. These disturbances result in an overall degradation of habitat. Because fishers occur at relatively low elevations, they are likely to be directly affected by human activities (Campbell *et al.* 2000). Roads also provide access for trappers who target other species, but might incidentally trap fishers (Lewis and Zielinski 1996).

In conclusion, habitat loss and fragmentation appear to be significant threats to the fisher. Forested habitat in the Pacific coast region decreased by about 8.5 million ac (34,400 $km^2$) between 1953 and 1997 (Smith *et al.* 2001). Forest cover in the Pacific coast is projected to continue to decrease through 2050, with timberland area projected to be about 6 percent smaller in 2050 than in 1997 (Alig *et al.* 2003). Thus fisher habitat is projected to decline in Washington, Oregon, and California in the foreseeable future.

*Factor B. Overutilization for commercial, recreational, scientific, or educational purposes.* The fisher has been commercially trapped since the early-1800s. Although exact numbers are unknown, trapping caused a severe decline in fisher populations. Aubry and Lewis (2003) state that overtrapping appears to have been the primary initial cause of fisher population losses in southwestern Oregon. The high value of the skins, the ease of trapping fishers (Powell 1993), year-round accessibility in the low to mid-elevation coniferous forests, and the lack of trapping regulations resulted in heavy trapping pressure on fishers in the late 1800s and early 1900s (Aubry and Lewis 2003).

In 1936, the Chief of the U.S. Biological Survey urged closing the hunting/trapping season for 5 years to save fisher and other furbearers from joining the list of extinct wild animals, noting that these species had disappeared from much of their former range in Oregon, Washington, and other states (USDA 1936). Commercial trapping of fishers has been prohibited in Oregon since 1937, in California since 1946 (Aubry and Lewis 2003), and in Washington since 1933 (Lewis and Stinson 1998). Where trapping is legal in other states and in Canada, it is a significant source of mortality. Krohn *et al.* (1994), for example, found that over a 5-year period, trapping was responsible for 94 percent of all mortality for a population of the fisher in Maine. In British Columbia, the fisher is classified as a furbearing mammal that may be legally harvested; however, due to a recent change in conservation status, the trapping season has been closed until it can be determined that the populations can withstand trapping pressure.

Although it is currently not legal to trap fishers intentionally in California, Oregon and Washington, they are often incidentally captured in traps set for other species (Earle 1978; Luque 1983; Lewis and Zielinski 1996). It is legal to harvest many mammals that are found in fisher habitat, including bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), mink (*Mustela vison*) and other furbearers. Red fox (*Vulpes vulpes*) and marten (*Martes americana*) may also be trapped in Oregon and Washington. Incidental captures often result in crippling injury or mortality (Luque 1983; Strickland and Douglas 1984; Cole and Proulx 1994). Lewis and Zielinski (1996) estimated an incidental capture of 1 per 407 trap set-nights (number of set locations—where usually 1 or 2 leg-hold traps were set—multiplied by the number of nights when traps were set) and an average mortality-injury rate of 24 percent, based on reports from five practicing trappers in California (72 incidental fisher captures over 50,908 set-nights).

Even low rates of additive mortality from trapping have been predicted to affect fisher population stability (Powell 1979, Lewis and Stinson 1998), and may slow or negate population responses to habitat improvement (Powell and Zielinski 1994). Powell (1979) reported that as few as one to four additional mortalities per year due to trapping over a 100 $km^2$ (39 $mi^2$) area could cause a significant decline in a reduced fisher population. The potential effects on fishers of legal trapping of other species may be significant when considered in conjunction with habitat loss and other sources of mortality.

In summary, information available suggests that historical trapping caused a severe population decline, and current mortalities and injuries from incidental captures of fishers could be frequent and widespread enough to prevent local recovery of populations, or prevent the re-occupation of suitable habitat.

*Factor C. Disease or Predation.* Fishers are susceptible to many viral-borne diseases, including rabies (Family *Rhabdoviridae*), canine and feline distemper (*Mobillivirus* sp.), and plague (*Yersinia pestis*). Contact between fishers and domesticated dogs and cats and other wild animals susceptible to such diseases (raccoons, coyotes, martens, bobcats, chipmunks, squirrels, *etc.*) may lead to infection in fishers. Although specific information on fisher diseases is limited, populations of three other mustelids, the black-footed ferret (*Mustela nigripes*), the marten, and the sea otter (*Enhydra lutris*), have experienced outbreaks of various parasitic, fungal, or bacterial diseases. An epidemic of canine distemper in black-footed ferret in 1985 led to the extirpation of the species from the wild (Thorne and Williams 1988). Evidence of plague was found in martens in California through detection of plague antibodies and host fleas (Zielinski 1984). In a study on sea otter, it was determined that infectious disease caused the deaths of 38.5 percent of the sea otters examined at the National Wildlife Health Center collected in California from 1992–1995 (Thomas and Cole 1996).

Studies in the urban-wildland interface suggest a correlation between the prevalence of disease in wild populations and contact with domestic animals, however fisher populations do not currently appear to be at risk.

Mortality from predation could be a significant threat to fishers. Potential predators include mountain lions (*Puma concolor*), bobcats, coyotes, and large raptors (Powell 1993; Powell and Zielinski 1994; Truex *et al.* 1998). Although generalist predators such as bobcats and mountain lions are not common in dense forest environments, they can invade disturbed habitat. Healthy adult fishers are apparently not usually subject to predation, except for those that have been translocated (Powell and Zielinski 1994) to an unfamiliar area, or those in areas with less canopy cover and forest structure (Buck *et al.* 1994). However, Powell and Zielinski (1994) and Truex *et al.* (1998), report that predation as well as human-caused death are significant sources of mortality. Of mortalities recorded by Truex *et al.* (1998), nine were suspected to be from predation and five were suspected to be human-caused, including two vehicle collisions, two cases where the collar was cut (indicating poaching), and one fisher that died after being trapped in a water tank. Four fishers out of seven that died during a study by Buck *et al.* (1994) were killed by other carnivores; the death of one juvenile was suspected to have been caused by another fisher.

In conclusion, mortality from disease and predation does not appear to be a significant threat unless populations are extremely small as is the case of the West Coast population of the fisher. Diseases in other mustelids affect this species and there is the potential for such disease outbreaks to occur in fisher populations.

*Factor D. The Inadequacy of Existing Regulatory Mechanisms.* Existing regulatory mechanisms that could provide some protection for the fisher include: (1) Federal laws and regulations; (2) State laws and regulations; and (3) local land use processes and ordinances. However, these regulatory mechanisms have not prevented continued habitat fragmentation and modification, incidental trapping, and predator control programs all of which result in population declines of fisher in the west. Although many States, Tribes, and Federal agencies recognize the fisher as a species which has declined substantially, their use of available regulatory mechanisms to conserve the species is limited. There are no regulatory mechanisms that specifically address the management or conservation of functional fisher habitat. However, the states in the petitioned area provide the fisher with protections from hunting and trapping, and regulatory mechanisms governing timber harvests incidentally provide conservation benefits for the fisher. The fisher is regulated under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a treaty established to prevent international trade that may be detrimental to the survival of wild plants and animals.

*Federal Regulations*

National Forests

Federal activities on National Forest lands are subject to compliance with Federal environmental laws including the Multiple-Use Sustained-Yield Act of 1960 (16 U.S.C. 528 *et seq.*), National Environmental Policy Act of 1969 (42 U.S.C. 4321 *et seq.*), and Clean Water Act of 1972 as amended (33 U.S.C. 1251 *et seq.* 1323 *et seq.*), as well as the National Forest Management Act of 1976 (90 Stat. 2949 *et seq.*; 16 U.S.C. 1601–1614) (NFMA).

The 1982 NFMA planning rules currently in effect require the Forest Service to “maintain viable populations of existing native and desired non-native vertebrates in the planning area [National Forests System lands]’’ (30 CFR 219.19). The 2000 planning rule shifted the emphasis from maintaining viable populations of individual vertebrate species to providing ecological conditions that provide a high likelihood of supporting the viability of native and desired non-native species well distributed throughout their ranges within the plan area (§ 219.20). The viable population mandate, with associated monitoring requirements, could serve as the basis for forest management consistent with maintaining fishers. The viability requirement was integral in guiding the protection and management of late successional forest through the NWFP process, and through the SNFPA amendment process; the regulatory contributions of both plans to fisher conservation is discussed below.

The Forest Service’s Sensitive Species Policy (Forest Service Manual 2670.32) calls National Forests to assist and coordinate with states, the Service, and NOAA Fisheries in conserving species with viability concerns. The fisher has been identified as a sensitive species by the Region 5 (Pacific Southwest Region) Regional Forester. The Forest Service defines Sensitive Species as “those plant and animal species identified by a Regional Forester for which population viability is a concern as evidenced by significant current or predicted downward trend in numbers or density.’’

On December 6, 2002, the Forest Service published a proposed rule to revise the 2000 NFMA planning rule. It is uncertain how the proposed rule, if and when implemented, will affect the interpretation of viability and the implementation of management for species viability.

National Environmental Policy Act

The National Environmental Policy Act of 1969, as amended (NEPA), requires all Federal agencies to formally document, consider, and publicly disclose the environmental impacts of major federal actions and management decisions significantly affecting the human environment. The resulting documents are primarily disclosure documents, and NEPA does not require or guide mitigation for impacts.

Projects that are covered by certain “categorical exclusions’’ are exempt from NEPA biological evaluation. The Forest Service and the Department of Interior have recently revised their internal implementing procedures describing categorical exclusions under NEPA 68 FR 33813 (June 5, 2003). The joint notice of NEPA implementing procedures adds two categories of actions to the agency lists of categorical exclusions: (1) Hazardous fuels reduction activities; and (2) rehabilitation activities for lands and infrastructure impacted by fires or fire suppression. These exclusions apply only to activities meeting certain criteria: mechanical hazardous fuels reduction projects up to 1,000 ac (4 $km^2$) in size can be exempt, and hazardous fuels reduction projects using fire can be exempt if less than 4,500 ac (18.2 $km^2$). See 68 FR 33814 for other applicable criteria. Exempt post-fire rehabilitation activities may affect up to 4,200 ac (17 km²). As stated above under Factor A, fuels reduction activities can reduce key fisher habitat elements such as large down logs and woody debris, large snags, but have counter-balancing benefits of reducing fire probability and brushy undergrowth which is not favored by fishers.

On July 29, 2003, the Forest Service published a notice of final interim directive (68 FR 44597) that adds three categories of small timber harvesting actions to the Forest Service's list of NEPA categorical exclusions: (1) The harvest of up to 70 ac (28 ha) of live trees with no more than 0.5 mi (.8 km) of temporary road construction; (2) the salvage of dead and/or dying trees not to exceed 250 ac (101 ha) with no more than 0.5 mi (.8 km) of temporary road construction; and (3) felling and removal of any trees necessary to control the spread of insects and disease on not more than 250 ac (101 ha) with no more than 0.5 mi (.8 km) of temporary road construction. Again, as stated above under Factor A, timber harvest and road construction can reduce key habitat elements for the fisher such as dense canopy cover and large trees, and results in at least temporary habitat fragmentation, but have corresponding long-term benefits.

Northwest Forest Plan

The NWFP was adopted in 1994 to guide the management of 24 million ac (97,125 km²) of Federal lands in portions of western Washington, Oregon, and northwestern California. The NWFP represents a 100-year strategy intended to provide the basis for conservation of the northern spotted owl (spotted owl) and other late-successional and old-growth forest-associated species on Federal lands (USDA *et al.* 1993).

Implementation of the NWFP (November 2003) would over time provide a network of connected reserves of late successional forest habitat surrounded by younger forest. Implementation of the plan will lead to a substantial improvement in current habitat conditions for the fisher on Federal lands. However, the assessment of NWFP implementation on the fisher projected a 63 percent likelihood of achieving an outcome in which habitat is of sufficient quality, distribution, and abundance to allow the fisher population to stabilize and be well distributed across Federal lands. We will need to reassess this prediction as the NWFP is implemented and other fisher conservation efforts (*e.g.*, reintroductions) are initiated.

Sierra Nevada Forest Plan Amendment (SNFPA)

The SNFPA was adopted in January 2001 as a guidance and policy document for managing 11 national forests and about 11 million ac (44,516 km²) of California's National Forest lands in the Sierra Nevada and Modoc Plateau. The SNFPA includes measures expected to lead to an increase over time of late-successional forest; these measures include requirements to retain conifers greater than 30 in (76.2 cm) DBH and hardwoods greater than 12 in (30.5 cm) DBH in westside forests, retention of important wildlife structures such as large diameter snags and coarse downed wood, and management of about 40 percent of the plan area as old forest emphasis areas (USDA Forest Service 2001). The SNFPA also established a Southern Sierra Fisher Conservation Area with additional requirements intended to maintain and expand the fisher population of the southern Sierra Nevada. Conservation measures for the fisher conservation area include maintaining at least 60 percent of each watershed in mid-to-late successional forest (11 to 24 in (28 to 61 cm) dbh and greater) with forest canopy closure of 50 percent or more. The plan also includes protections for den sites; as discussed elsewhere in this document, this tends to provide limited conservation value. Implementation of the 2001 plan was expected to maintain and restore fisher habitat in Southern Sierra Fisher Conservation Area, and encourage recovery to its historic range (USDA Forest Service 2001).

In response to appeals to the adoption of the SNFPA, the Regional Forester assembled a review team to evaluate specific plan elements, including the fuels treatment strategy, consistency with the National Fire Plan, and agreement with the Herger-Feinstein Quincy Library Group Recovery Act. The review was completed in March 2003 (USDA Forest Service 2003b), and in June 2003, the Forest Service issued a Draft Supplemental Environmental Impact Statement (DSEIS) for proposed changes to the SNFPA (USDA Forest Service 2003a). The Final Supplemental Environmental Impact Statement (FSEIS) was issued in January 2004, and the new Record of Decision was issued on January 21, 2004 (USDA Forest Service 2004).

The preferred alternative in the FSEIS, Alternative S2, was chosen in the final Record of Decision. This alternative includes an objective to retain 30 in (76.2 cm) and larger trees (with exceptions allowed to meet needs for equipment operability) and a desired condition for the Southern Sierra Conservation Area which states that outside of any Wildland Urban Interface areas, a minimum of 50 percent of the forested area has at least 60 percent canopy cover for known or estimated female fisher home ranges (USDA Forest Service 2004, Record of Decision p. 41). Furthermore, it directs that where home range information is lacking, the watershed mapped at the Hydrologic Unit Code 6 level be used as the analysis area for this desired condition. The Record of Decision also states that if fishers are detected outside of the Southern Fisher Conservation Area, habitat conditions should be evaluated and appropriate mitigation measures implemented to retain suitable habitat within the estimated home range.

The FSEIS preferred alternative includes standards and guidelines which apply to fishers and provide protections for verified fisher den sites, including a 700 ac (2.8 km²) buffer around confirmed fisher birthing and rearing dens during March 1 through June 30. However, the guidelines would provide little protection to fishers or their habitat, because: (1) Den sites are difficult to detect even in studies using radio-collared fishers (fewer than 10 den sites have been found to date) and project-level surveys are unlikely to locate dens (USDA Forest Service 2000); (2) there is little evidence that den sites are reused over time (Campbell *et al.* 2000), limiting the value of protecting past den sites; (3) some restrictions can be waived, including the limited operating period for vegetation treatments; and (4) it is unclear how and to what extent the impacts of roads, off highway vehicles, and recreation would be minimized.

National Forest Land and Resource Management Plans

Each National Forest is operated under a Land and Resource Management Plan (LRMP). The NWFP standards and guidelines apply for National Forests within the range of the northern spotted owl except when the standards and guidelines of LRMPs are more restrictive or provide greater benefits to late-successional forest species. Most National Forests within the range of the fisher in its west coast range have LRMPs that incorporate the provisions of the NWFP or are amended by the SNFPA, and therefore implement the standards and guidelines of the applicable plan. Most individual Forest LRMPs do not provide any additional protections to fisher or fisher habitat; therefore, the above discussion regarding the NWFP and SNFPA summarizes the primary regulatory mechanisms in place on National Forest lands within the DPS area.

In California, the Humboldt-Toiyabe, Modoc, Lassen, Plumas, Tahoe, Eldorado, Stanislaus, Sierra, Inyo, and Sequoia National Forests and the Lake Tahoe Basin Management Unit are within the area covered by the SNFPA.

In Oregon, National Forests located on the west side of the Cascade Mountains (Mt. Hood, Willamette, Umpqua, Rogue, Siuslaw, Siskiyou National Forests) are within the boundaries of the NWFP.

Forests on the east side of the Cascade Mountains (Winema, Deschutes, Fremont National Forests) only partially overlap the NWFP area. Outside of the NWFP boundaries, the Inland Native Fish Strategy (INFISH) and Interim Management Direction Establishing Riparian, Ecosystem, and Wildlife Standards for Timber Sales (Eastside Screens) amend the LRMPs for the eastern portion of the Winema National Forest and all of the Fremont National Forest. The guidelines, developed to protect fish habitat, may also provide benefits to fisher by protecting riparian corridors; establishing large woody debris requirements (greater than 20 pieces per mi (12.4 pieces per km); greater than 12 in (30.5 cm) diameter; greater than 35 ft (10.7 m) long); and delineating Riparian Habitat Conservation Areas (RHCAs), which would prohibit timber harvests within them in most situations. Minimum widths for RHCAs range from a minimum of 300 ft (91 m) slope distance on either side of fish-bearing streams to 150 ft (46 m) on either side of perennial non-fish-bearing streams and around most lakes, ponds, reservoirs and wetlands. Seasonally flowing or intermittent streams, wetlands less than an acre, landslides, and landslide-prone areas would have protections ranging from about 50 to 100 ft (15 m to 30 m) or one site-potential tree height, depending on watershed priority.

The Eastside Screens provide interim direction for timber harvest associated with forest health and prohibit the harvest of large diameter trees (21 in (53 cm) DBH or larger) and protect snags and large woody debris for wildlife. Both INFISH and the Eastside Screens were expected to be short-term strategies to be replaced once LRMPs are amended by other guidance, such as the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

At this time, a decision notice for ICBEMP has not been issued, although a Memorandum of Understanding (MOU) has been signed which implements the associated Interior Columbia Basin Strategy (Strategy). The purpose of the MOU is to cooperatively implement the Interior Columbia Basin Strategy guiding the amendment and revision of Forest Service National Forest and BLM LRMPs and project implementation on public lands. The plans and MOU currently being implemented could maintain or enhance fisher habitat by preventing the loss of old-growth forests and promoting long-term sustainability of old forest habitat, although short-term adverse impacts may occur as a result of activities including thinning and silvicultural treatments. Maintaining wildlife movement corridors primarily associated with deer and elk are usually included as part of project designs and may also benefit fishers.

Potential fisher habitat in Washington State is located on the Olympic, Mount Baker-Snoqualmie, Gifford Pinchot, Wenatchee, and Okanogan National Forests. There are approximately 1,479,749 ac (5,987 $km^2$) of fisher habitat on Federal lands in Washington State, of which 1,108,994 ac (4,489 $km^2$; 75 percent) are in National Forests and the remainder is in National Parks.

Most of the potential fisher habitat in Washington State is within the range of the northern spotted owl and thus also within the NWFP Area. Over 80 percent of the habitat is in areas that are designated as reserves (Congressionally withdrawn, LSRs, or natural areas). Logging within these areas is restricted and limited to thinning or individual tree removal. The WDFW recently conducted a feasibility analysis to determine areas for potential reintroduction of the fisher. Based on this analysis, the largest blocks of suitable habitat are located in the Olympic NF, areas around the Goat Rocks and Indian Heaven Wilderness on the Gifford Pinchot NF, portions of the Wenatchee NF east of Mount Rainier National Park, and the foothills to the west of the Alpine Lakes and Glacier Peak Wilderness Areas on the Mount Baker-Snoqualmie NF. Approximately 81 percent of the Olympic, 75 percent of the Gifford Pinchot, 63 percent of the Mount Baker-Snoqualmie, 40 percent of the Wenatchee, and 22 percent of the Okanogan National Forests are below 4000 ft (1,220 m) in elevation. Although most of the remaining fisher habitat will be protected as long as the NWFP remains in effect, the landscape remains fragmented.

Bureau of Land Management (BLM) Lands

The NWFP standards and guidelines apply to BLM lands within the range of the northern spotted owl except when the standards and guidelines of Resource Management Plans (RMPs) are more restrictive or provide greater benefits to late-successional forest species. The BLM's Alturas District in northern California is currently in the process of rewriting its RMP. However, the District has very little land with potential fisher habitat. Neither fishers nor their potential habitat are mentioned in the RMP, and the RMP is not affected by the SNFPA or NWFP. The RMPs for the Arcata, Redding, and Ukiah Field Offices also do not contain any protective measures for fisher or require pre-project surveys. In Oregon, BLM Resource Management Plans were amended by the NWFP in the west Cascades, and by INFISH and Eastside Screen interim guidance in the east Cascades. Therefore, management would be similar to that described above for the National Forests. The BLM and U.S. Timberlands (private landowner) are working together, where their land ownerships are checkerboarded, to reduce wildlife impacts by restricting access and closing roads. BLM lands are limited in Washington state and do not contribute to fisher habitat.

National Park Lands

The land management plan for Redwood National Park does not contain any protective measures for fishers and does not require pre-project surveys. Undeveloped areas of Crater Lake National Park are managed toward natural processes and are expected to maintain fisher habitat. Hunting and trapping are not allowed in the park, and park facilities are currently confined to certain areas, primarily in the higher elevations above fisher habitat. Studies are planned to evaluate snowmobile use in the park.

The Columbia River Gorge National Scenic Area in Oregon (and Washington) encompasses about 292,500 ac (1,184 $km^2$) and is operated under a land use management plan that provides protection to all lands in the gorge. About half of the land in the Gorge is state or federally owned and has special management area guidelines dedicated to scenic and natural values. The remainder of the Gorge is private lands managed under general guidelines that are currently being revised. The fisher is a protected species within the area covered by the Columbia River Gorge management plan. On Federal lands, the restriction against removal of old-growth forests and clearcut logging would protect fisher habitat. After the Gorge forest practices guidelines are revised it is expected that habitat conditions will be retained for fisher because of the priority concept of retaining old growth, scenic, and natural values in the Gorge.

Fisher habitat occurs in the Olympic, North Cascades and Mount Rainier National Parks. However, the interiors of all three parks are classified as alpine and are too steep and rugged to be suitable for fishers. Approximately 33 percent of the 1 million ac (4,047 $km^2$) Olympic National Park, 30 percent of the North Cascades NP and Ross Lake National Recreation Area (just over 500,000 ac (2,023 $km^2$), combined), and less than 15 percent of Mount Rainier National Park (235,500 ac; 953 $km^2$) is typed as fisher habitat. The largest blocks of habitat occur in a ring around the mountainous interior of the Olympic Peninsula, in areas to the south and east of Mount Rainier National Park, in the Ross Lake National Recreation Area, and in river valleys on the west side of the North Cascades National Park.

Because the interior of the Cascades and Olympic Peninsula are alpine, fisher habitat is limited to a relatively narrow band along the foothills. In addition, most of the low elevation passes are bisected by major transportation corridors. Efforts are currently under way to provide wildlife corridors (under or overpasses) along Interstate 90 to facilitate north-south movement of wildlife through the Washington Cascades.

National Resource Conservation Service (NRCS)

The NRCS does not manage lands, and has not been involved with forest related work, but plans to develop forest-related projects in the near future. Initial projects will likely be east of the NWFP boundary, along the Sprague River in Oregon and elsewhere. Focus would be on thinning projects to enhance wildlife habitat and could enhance potential fisher habitat where it exists. The NRCS would be subject to NEPA and other existing regulatory mechanisms discussed elsewhere.

Tribal

In California, the Hoopa Valley Indian Reservation forest management plan (Tribal Forestry 1994) addresses the 88,958 ac (360 $km^2$) where fishers are known to be present, and which contains about 75,000 ac (303.5 $km^2$) of commercial timberland. The forest management plan also recognizes the fisher as a traditional and culturally important species and designates the fisher as a species of special concern, and forest management activities are not allowed to knowingly result in "take'' of species of concern unless approved by the Tribal Council. The plan contains some protective measures for fisher such as setting aside three to seven habitat reserves (each 50 ac (20 ha) or less in size) for pileated woodpeckers, mink, and fishers. Intensive timber harvest will not occur within the reserves. The plan establishes 32 no-harvest reserves (minimum of 60 ac (24 ha) each) for late-seral, cultural, sensitive, and listed species.

The Yurok Tribe manages roughly 4,000 ac (16 $km^2$) of collective Tribal land holdings, held in trust by the Department of the Interior. Tribal lands include about 1,000 ac (4 $km^2$) of late-seral redwood forest. The land management plan for the Yurok Tribe does not contain specific protective measures for fishers and does not require pre-project surveys. It is unclear to what extent this plan will help to maintain appropriate habitat elements for the fisher.

The Tule River Reservation in the southern Sierra Nevada includes about 56,000 ac (227 $km^2$) of lands, which includes forest lands managed for timber and firewood. Information is not available regarding regulatory mechanisms for these Tribal lands.

The Warm Springs Reservation of Oregon encompasses almost 1,000 $mi^2$ (2,590 $km^2$) on the western slope of the Cascade Range. The Integrated Resource Management Plan (IRMP) for forested areas of the Warm Springs Reservation of the Confederated Tribes includes guidelines that ensure buffers of 30 to 100 ft (9 to 30 m) (depending on the size of the feature) for riparian features such streams, wetlands, seeps, springs, or bogs. Standards to protect wildlife habitats and species include protection of at least four overstory trees per acre, retaining a minimum of ten class 1–3 logs per ac (12 in (30 cm)) diameter and 20 ft (6 m) long), and a 60:40 forage to cover ratio in wildlife management zones. The IRMP identifies conditional use areas that are not part of the commercial forest base although these areas could be harvested at some point in the future. These areas typically have cultural value and comprise about five percent of the Reservation. There are 14 spotted owl activity centers on the reservation.

For the Klamath Tribes in Oregon, the only activity identified that may impact the fisher is bobcat trapping. According to Rick Ward (Klamath Tribe biologist), trapping activity is currently very low due to presently low pelt prices. However, as reported in the Klamath News, an official publication of the Klamath Tribe (2003), there is a current effort to return approximately 690,000 ac (2,792 $km^2$) of the former reservation from the Fremont-Winema National Forest to the Klamath Tribes. This includes areas where fisher have been documented. If the land ownership changes, that would likely alter management of fisher habitat.

The Coquille Tribe of Oregon manages their land according to the guidelines of the NWFP. The Coquille lands were formerly managed by the BLM. When the lands were transferred from the BLM to the Tribe, the Tribe agreed to manage their lands according to the guidelines in the NWFP and the Coos Bay BLM Resource Management Plan. Their land holdings in southwest Oregon are all in NWFP "matrix'' designation (*i.e.*, areas contemplated for timber harvest) which does not provide any benefits to fisher conservation.

There are 19 Tribes with forest lands within the range of the fisher in Washington State. The majority of those Tribes do not have any suitable fisher habitat or do not have sufficient acreage. The Tribal lands of the Makah, Quinault, and Yakama Indian Nations may have suitable fisher habitat, but only the Quinault and Yakama Tribes have management plans that protect enough habitat for the northern spotted owl (a late-successional associate) that the plans likely incidentally also provide habitat for fishers.

The Confederated Tribes and Bands of the Yakama Nation reservation is located in south central Washington State, east of the Cascade crest, and contains about 526,000 ac (2,129 $km^2$) of forests. In 1998, 144,559 ac (585 $km^2$) of reservation forest were typed as suitable habitat for spotted owls (Yakama Nation 2003). Of these, about 43 percent (62,266 ac; 252 $km^2$) are currently not managed for commercial timber production, while the remaining 57 percent will receive some level of stand management. Timber harvest is generally conducted using uneven-aged management prescriptions (King *et al.* 1997), in which up to 30 percent of the volume may be removed during an entry. Based on the Tribe's forest management practices and the distribution of spotted owl habitat, Yakama lands may widely provide suitable foraging habitat for fishers, and sufficient habitat elements including snags and downed logs to provide some denning/resting habitat, particularly in the areas reserved from harvest. Owl habitat may be a rough surrogate for fisher habitat, since both require late successional forests.

The North Boundary Area of the Quinault Tribe Reservation is contiguous with Forest Service Late Successional Reserves to the north and southeast, and National Park Service lands to the east, and is the only area on the reservation that has potential habitat for the fisher. Negotiations are currently under way with the Tribe to protect habitat around occupied owl and murrelet sites, which may incidentally protect potential fisher habitat.

*State*

Washington

The Washington Department of Natural Resources (WDNR) manages the State lands in Washington. State lands occupy a substantial portion of the fisher's historic range in the State, consisting of roughly 1.6 million ac (6,475 km$^2$) of forest within the range of the northern spotted owl (primarily lands west of the crest of the Cascade Mountains). Because these lands generally occur at lower elevations than National Forest lands, a higher proportion is within the elevation range preferred by the fisher (Aubry and Houston 1992; WDNR 1997). Thus, State lands are important to the conservation of the fisher. However, over half of all WDNR forests are less than 60 years in age and less than 150,000 ac (607 km$^2$, about 9 percent) are over 150 years, indicating that most old growth on Washington State lands has been liquidated (WDNR 1997).

Several State Parks in Washington contain remnant stands of mature and late-successional forest and may have suitable habitat for the fisher. Like elsewhere, these parks are widely scattered and isolated by large areas that are unsuitable for fishers. There are approximately 18,858 ac (76 km$^2$) of mature or old-growth forests within State Parks in Washington. Unfortunately, many of the larger parks are on islands and would not contribute to the recovery of the fisher. A few state parks and forests, such as Mount Pilchuck State Forest, and Rockport, Ollalie, Hamilton Mountain/Beacon Rock, Twin Falls, and Wallace Falls State Parks have limited habitat which may provide some foraging opportunities for dispersing fishers and extend the habitat on Federal lands in the Cascades. Trapping of fishers has been prohibited in Washington since 1933, but fishers have been caught incidentally in traps set for other species, and the impact of incidental captures in Washington is unknown (Lewis and Stinson 1998).

In October 1998, the State of Washington listed the fisher as Endangered (WAC 232–12–297), which provides additional protections in the form of more stringent fines for poaching and a process for environmental analysis of projects affecting the species. There are no special regulations to protect habitat for the fisher or to conduct surveys for this species prior to obtaining forest activity permits. Although a few individuals may still reside in remote areas, the species is believed to be extirpated from Washington and the State is currently in the process of completing a feasibility report to determine suitable areas for reintroduction.

About 7 million ac (28,330 km$^2$) of non-Federal forest lands exist within the possible range of the fisher in the Olympic Peninsula and Cascades in Washington. A geographic information system (GIS) analysis of general habitat suitability typed about 2 percent (approximately 152,300 ac (616 km$^2$)) as suitable habitat for fisher. This analysis included mature/old-growth, northern spotted owl habitat, and habitat meeting other criteria as suitable fisher habitat. Because the remnant patches of mature forest are widely scattered and isolated, it is unlikely that there is sufficient habitat on non-Federal lands to support resident fishers. However, if proposed fisher reintroduction efforts occur and are successful, private lands may be important to maintain habitat in key linkage areas across the Puget Trough lowlands to provide connectivity between the Olympic Peninsula and the Cascades.

The primary regulatory mechanism on non-Federal forest lands in western Washington is the Washington State Forest Practice Rules, Title 222 of the Washington Administrative Code. These rules apply to all commercial timber growing, harvesting, or processing activities on non-Federal lands, and give direction on how to implement the Forest Practice Act (Title 76.09 Revised Code of Washington), and Stewardship of Non-Industrial Forests and Woodlands (Title 76.13 RCW). The rules are administered by the WDNR, and related habitat assessments and surveys are coordinated with the Washington Department of Fish and Wildlife (WDFW).

Washington's forest practice rules are more protective of riparian and aquatic habitats, and require more trees to be left than Oregon's forest practice rules. Clearcuts are limited to 120 ac (49 ha) in size with exceptions given up to 240 ac (97 ha). In all cutting units, three wildlife reserve trees (over 12 in (30)) in diameter), two green recruitment trees (over 10 in (25 cm) diameter, 30 ft (9 m) in height, and ⅓ of height in live crown) and two logs (small end diameter over 12 in (30 cm), over 20 ft (6 m) in length) must be retained per acre of harvest. These trees may be counted from those left in the "riparian management zones,'' which range in size from 80 to 200 ft (25 to 62 m) for fish-bearing streams, depending on the size of the stream, the class of site characteristics, and whether the harvest activity is east or west of the Cascade crest (Washington Administrative Code 222–30). Riparian management zones for non fish-bearing streams are 50 ft (15 m), applied to specified areas along the streams. Seventy acres (28 ha) of habitat must be protected around all known spotted owl activity centers during the nesting season, outside of which logging can occur. Washington's forest practices rules do not specifically preserve key components of fisher habitat.

Riparian buffers may provide some habitat for fishers, primarily along perennial fish-bearing streams where the riparian buffer requirements are widest. In western Washington—the majority of the State area addressed by the petition, the Forest Practice Rules require 90 to 200 ft (27 to 61 m) buffers on fish-bearing streams, depending on site class (site potential for tree growth). The riparian buffer of fish-bearing streams is divided into three zones, including a 50-ft (15-m) "core zone'' where no timber cutting is permitted. The remainder of the buffer is divided into an "inner zone'' where partial harvest is permitted consistent with achieving stand basal area requirements, and an outer zone where logging must generally leave at least 20 conifers per acre, of 12 inches DBH or greater. For parcels of 20 contiguous acres or less, landowners with total parcel ownership of less than 80 forested acres are exempt from the riparian buffer requirements described above; less stringent rules apply to those parcels.

While it has been noted that the Washington State Forest Practice Rules do not specifically address the fisher and its habitat requirements, some habitat components important to the fisher, like snags, canopy cover, *etc.*, are likely to be retained as a result of the rules.

Oregon

In Oregon, two final forest management plans for state forests in northwest and southwest Oregon were approved by the Oregon Board of Forestry in January 2001: the Northwest Oregon State Forests Plan and the Southwest Oregon State Forests Plan. The Elliott State Forest Management Plan was approved in 1994 and the Elliott State Forest Habitat Conservation Plan for northern spotted owls and marbled murrelets was approved in 1995, however, both the management plan and HCP are now being revised. Additionally, Oregon has proposed to develop the Western Oregon State

Forests Habitat Conservation Plan for threatened and endangered species and other species of concern on western Oregon state forests in 2004–2005.

The management plans for Oregon's State Forests generally appear to be of little benefit to the fisher. The 18,074 ac (73 $km^2$) of State forest lands in the Southwest Oregon State Forests Plan area consists of generally small parcels that range in size from 40 ac to 3,500 ac (0.16 $km^2$ to 14 $km^2$) and are widely scattered. There are no specific measures for or mention of the fisher in the plan. The Northwest Oregon State Forests Management Plan provides management direction for 615,680 ac (2,491 $km^2$) of state forest land, located in twelve northwest Oregon counties, but has no specific provisions for fishers. Both plans include provisions to protect some forest reserves, but these are not likely to benefit the fisher because of the fragmented nature of the lands. In Oregon, the fisher is designated a protected non-game species, and is listed as a "Sensitive Species—Critical Category.'' The Oregon Department of Fish and Wildlife (ODFW) does not allow take of fisher in Oregon, but some fishers may be injured and killed by traps set for other species. Training and testing is required of applicants for trapping licenses in order to minimize the potential take of non-target species such as fisher.

The Oregon Department of Forestry (ODF) implements the Forest Practice Administrative Rules and Forest Practices Act (ODF 2000). Interim procedures (section 629–605–0180, Oregon Forest Practice Rules) exist for protecting sensitive resource sites on all State, county, and private lands in Oregon. These procedures apply only to threatened and endangered species, and to bird species listed as "sensitive'' in the rules, and currently do not apply to the fisher. Prior approval from the State Forester is also required before operating near or within critical wildlife habitat sites (629–605–0190), including habitat of species classified by ODFW as threatened or endangered, or any federally listed species, but fisher does not currently benefit from this status.

Although Oregon's rules governing forest management on State, county and private lands do not directly protect the fisher or its habitat, the rules may provide some fisher habitat elements. In clearcut harvest units that exceed 25 ac (10 ha), operations must retain two snags or two green trees, and two downed logs per acre. Green trees must be over 11 in (28 cm) DBH and 30 ft (9m) in height, and down logs must be over 6 feet long and 10 cubic feet in volume. Riparian management areas (RMAs) provide for vegetation retention along fish-bearing (Type F) and domestic-use streams without fish (Type D), in a band of 20 to 100 ft (6 to 30 m) width, depending on stream size and type. In general, RMAs for fish-bearing and domestic-use streams require no tree harvesting within 20 ft (6 m) of the stream, and, within the entire RMA, retention of a minimum basal area of conifer trees (40 trees per 1000 ft of stream for thinning operations). Along fish-bearing streams, the RMAs are intended to become similar to mature streamside stands, dominated by conifers; streams lacking fish will have sufficient streamside vegetation to support the functions and processes important to downstream fisheries, domestic water use, and wildlife habitat. Similar guidelines retain vegetation around wetlands, lakes, seeps and springs. No RMA is required for streams that do not provide for domestic water use or bear fish, for small wetlands, or for lakes 0.5 ac (.2 ha) or less.

California

The State of California manages relatively little forested lands. California has eight Demonstration State Forests totaling 71,000 ac (287 $km^2$), of which less than 20,000 ac (81 $km^2$) are within the current range of the fisher. These forests are managed primarily to achieve maximum sustained production of forest products, not for late-successional characteristics, and appear to provide little habitat for the fisher. California has about 270 State Park units and 1.3 million ac (5260 $km^2$), which are mostly outside the historic range of the fisher and appear to provide little habitat for fishers. The largest state park in the fisher's historic range, Humboldt Redwoods State Park, includes about 53,000 ac (214 $km^2$) in southern Humboldt County and has a Preliminary General Plan (June 2001) with a stated goal of protecting California species of concern. Although it does not include specific measures for fisher management, the general emphasis on retention of some habitat components (snags, canopy cover, *etc.*) will provide incidental benefits to the fisher.

The State of California classifies the fisher as a furbearing mammal that is protected from commercial harvest, which provides protection to the fisher in the form of minor fines for illegal trapping; trapping is discussed further under Factor B. The fisher is not listed under the California Endangered Species Act or as a State "fully protected'' species and thus does not receive protections available under those statutory provisions. The California Department of Fish and Game (CDFG) has identified the fisher as a Species of Special Concern (CDFG 1986). This status is applied to animals not listed under the Federal or the State endangered species acts, but judged vulnerable to extinction.

The California Environmental Quality Act (CEQA) requires disclosure of potential environmental impacts of public or private projects carried out or authorized by all non-Federal agencies in California. CEQA guidelines require a finding of significance if the project has the potential to "reduce the number or restrict the range of an endangered, rare or threatened species'' (CEQA Guidelines 15065). The lead agency can either require mitigation for unavoidable significant effects, or decide that overriding considerations make mitigation infeasible (CEQA 21002), although such overrides are rare. CEQA can provide protections for a species that, although not listed as threatened or endangered, meet one of several criteria for rarity (CEQA 15380).

Regulatory Mechanisms for Private and State Timberlands

In California, logging activities on commercial (private and State) forestlands are regulated through a process that is separate from but parallel to CEQA. Under CEQA provisions, the State has established an independent regulatory program to oversee timber management activities on commercial forestlands, under the Z'berg-Nejedly Forest Practice Act of 1973 and the California Forest Practice Rules (FPRs) (CDF 2003). The California FPRs are administered by the California Department of Forestry and Fire Protection (CDF), and apply to commercial harvesting operation for non-Federal, non-Tribal landowners of all sizes.

While the FPRs may incidentally protect some habitat or habitat elements used by the fisher, the rules do not require fisher surveys, protection of fisher or fisher den sites, or a mechanism for identifying individual or cumulative impacts to the fisher or its habitat.

The California FPRs provide specific, enforceable protections for species listed as threatened or endangered under CESA or the ESA, and for species identified by the California Board of Forestry as "sensitive species'' (CDF 2003); however, the fisher is not currently on any of these lists. The FPRs also include intent language about reducing significant impacts to non-listed species (FPR § 919.4, 939.4, 959.4) and maintaining functional wildlife habitat (FPR § 897(b)(1)), however, implementation of these measures to provide protection to the fisher is not documented or tracked.

Some California FPR provisions could incidentally contribute to protection of important elements of fisher habitat, such as late seral forests and snags, downed wood, and large live trees containing the structural attributes that are used by fishers for resting and denning sites and contribute to the diversity and abundance of prey species. These are discussed below.

While the California FPRs generally require that snags within a logged area be retained to provide wildlife habitat, they also allow exceptions to this requirement. The FPRs do not require the retention of downed woody material, decadent or other large trees with structural features such as platforms, cavities, and basal hollows, which appear to be important components of fisher habitat. Some timber operations, such as salvage, fuelwood harvest, powerline right-of-way clearing, and fire hazard reduction are exempt from timber harvest plan preparation and submission requirements. In 2002, new rules were passed that prohibit the harvest of large old trees under exemptions, although harvest is still allowed in cases of safety, building construction, or when the tree is dead or will be dead within the year. Overall retention of habitat features important to fishers does occur to some degree but is specific to fishers.

California's FPRs provide for disclosure of impacts to late successional forest stands, in some cases. The rules require that information about late successional stands be included in a timber harvest plan when late successional stands over 20 ac (8 ha) in size are proposed for harvesting and such harvest will "significantly reduce the amount and distribution of late succession forest stands'' (FPR § 919.16, 939.16, 959.16). If the harvest is found to be "significant,'' FPR § 919.16 requires mitigation of impacts where it is feasible. In practice, such a finding during plan review can be challenged by the landowner.

The California FPRs require retention of trees within riparian buffers to maintain a minimum canopy cover, dependent on stream classification and slope. The rules currently mandate retention of large trees in watersheds identified as having "threatened or impaired'' values (watersheds with listed anadromous fish). For Class I (fish-bearing) streams, the 10 largest conifer trees per 330 ft (133 m) of stream channel must be retained along qualifying watercourses. These trees are retained within the first 50 ft (15 m) of permanent woody vegetation measured out from the stream channel; this provides about 26 trees per acre within that zone. The threatened and impaired provision applies to many streams within the fisher's range in northern California, but not to most of the Sierra Nevada nor to most of the upper Trinity River basin (where fishers still occur), and is set to expire in 3 years. Where applied, the threatened and impaired rules should result in the retention of some large trees of value to fishers, but the value may be limited, as it applies to only a small part of any affected watershed and in a fragmentary pattern. Averaged over the landscape, the measure provides on average less than one retained tree per forested acre in qualifying watersheds, based on an evaluation of a sample of timber harvest plans (Scott Osborn, CDFG, pers. comm. 2003). Over time, the retained trees may develop late seral and decadent characteristics, but this is likely to take place over time scales of decades and centuries.

Outside of "threatened and impaired'' watersheds, watercourse protection measures are limited. Class I streams must retain at least 50 percent of the overstory and 50 percent of the understory. No minimum canopy closure requirements are specified for Class II and Class III streams. Harvest plans are required to leave 50 percent of the existing total canopy including understory, and provide no protection for large trees or other late-seral habitat elements.

Regulations Providing Protections for Other Listed Species

Regulatory protections for habitat of the federally-listed northern spotted owl, marbled murrelet, and anadromous salmonids may provide some elements that benefit the fisher, but because these protections are not implemented consistent with specific life history requirements of the fisher (wide ranging, avoids open areas, *etc.*), these measures may be of limited conservation value for fishers. For example, fishers are likely to require larger habitat blocks in contiguous spacing (Lewis and Stinson 1998). Finally, a large part of the current and historic west coast range of the fisher is outside the range of the listed owl, murrelet and salmonids.

Regulatory Mechanisms for Private and State Timberlands

In California, logging activities on commercial (private and State) forestlands are regulated through a process that is separate from but parallel to CEQA. Under CEQA provisions, the State has established an independent regulatory program to oversee timber management activities on commercial forestlands, under the Z'berg-Nejedly Forest Practice Act of 1973 and the California Forest Practice Rules (FPRs) (CDF 2003). The California FPRs are administered by the California Department of Forestry and Fire Protection (CDF), and apply to commercial harvesting operation for non-Federal, non-Tribal landowners of all sizes.

Based on the best available information on fisher habitat, fishers can use areas of younger (non-old-growth) forest, but the presence of late seral elements within those forests is important in providing resting/denning sites and adding to increased foraging opportunities and prey base.

The California FPRs provide specific, enforceable protections for species listed as threatened or endangered under CESA or the ESA, and for species identified by the California Board of Forestry as "sensitive species'' (CDF 2003); however, the fisher is not currently on any of these lists. The FPRs also include intent language about reducing significant impacts to non-listed species (FPR § 919.4, 939.4, 959.4) and maintaining functional wildlife habitat (FPR § 897(b)(1)). However, this language has not been effective in securing protections for the species, due to the lack of specific enforceable measures in the rules. Moreover, FPR language (§ 1037.5(f)) makes it difficult for CDF to adopt mitigation measures above those specified in the California FPRs, unless the landowner agrees to them. In comments to CDF on timber harvest plans in northwestern California, CDFG has raised concerns regarding adverse effects on fishers and other species associated with the loss of late seral habitat elements and has recommended retention of such elements. These efforts have generally not been successful in effecting mitigation measures for the fisher and other late-seral species (Ken Moore, CDFG, Yreka, pers. comm., 2003; Scott Osborn, CDFG, pers. comm., 2003).

Some California FPR provisions could incidentally contribute to protection of important elements of fisher habitat, such as late seral forests and snags, downed wood, and large live trees containing the structural attributes that are used by fishers for resting and denning sites and contribute to the diversity and abundance of prey species. These are discussed below.

While the California FPRs generally require that all snags within a logged area be retained to provide wildlife habitat, they also allow broad discretionary exceptions to this requirement, which greatly reduce the effectiveness of the snag retention requirement. The FPRs do not require the retention of downed woody material, making retention of these structural elements voluntary. Similarly, the California FPRs do not contain enforceable and/or effective measures for protection of decadent or other large trees with structural features such as platforms, cavities, and basal hollows, which appear to be important components of fisher habitat. Some timber operations, such as salvage, fuelwood harvest, powerline right-of-way clearing, and fire hazard reduction are exempt from timber harvest plan preparation and submission requirements. CDF considers applications for exemptions as ministerial in nature, and therefore exemptions receive minimal review by CDF. In 2002, new rules were passed that prohibit the harvest of large old trees under exemptions, although harvest is still allowed in cases of safety, building construction, or when the tree is dead or will be dead within the year.

California's FPRs provide for disclosure of impacts to late successional forest stands, in some cases. The rules require that information about late successional stands be included in a timber harvest plan when late successional stands over 20 ac (8 ha) in size are proposed for harvesting and such harvest will "significantly reduce the amount and distribution of late succession forest stands'' (FPR § 919.16, 939.16, 959.16). If the harvest is found to be "significant,'' FPR § 919.16 requires mitigation of impacts where it is feasible. In practice, such a finding during plan review is very rare and likely to be challenged by the landowner. Also, few proposed harvests trigger the late successional analysis because very little forest on commercial timberlands meets the definition of late successional forest, due to past logging history (Curt Babcock, CDFG, pers. comm. 2003).

The California FPRs require retention of trees within riparian buffers to maintain a minimum canopy cover, dependent on stream classification and slope. The FPR prescriptions are not designed or intended to protect late seral habitat, but this may occur at times. The rules currently mandate retention of large trees in watersheds identified as having "threatened or impaired'' values (watersheds with listed anadromous fish). For Class I (fish-bearing) streams, the 10 largest conifer trees per 330 ft (133 m) of stream channel must be retained along qualifying watercourses. These trees are retained within the first 50 ft (15 m) of permanent woody vegetation measured out from the stream channel; this provides about 26 trees per acre within that zone. There are no additional protection measures required for non-fish-bearing streams (classes II and III) within "threatened or impaired'' watersheds. The threatened and impaired provision applies to many streams within the fisher's range in northern California, but not to most of the Sierra Nevada nor to most of the upper Trinity River basin (where fishers still occur), and is set to expire in 3 years. Where applied, the threatened and impaired rules should result in the retention of some large trees of value to fishers, although the protective value is limited, as it applies to only a small part of any affected watershed and in a fragmentary pattern. Averaged over the landscape, the measure provides on average less than one retained tree per forested acre in qualifying watersheds, based on an evaluation of a sample of timber harvest plans (Scott Osborn, CDFG, pers. comm. 2003), and on Arcata FWO calculations on watercourse density on commercial timberland ownerships in northwestern California. Also, in many watersheds, few large trees remain along watercourses, thus most of the trees retained under this measure are likely to be of a size and age that provide little current value as late seral elements commonly used by fishers. Over time, the retained trees may develop late seral and decadent characteristics, but this is likely to take place over time scales of decades and centuries.

Outside of "threatened and impaired'' watersheds, watercourse protection measures are limited. Class I streams must retain at least 50 percent of the overstory and 50 percent of the understory. No minimum canopy closure requirements are specified for Class II and Class III streams. Harvest plans are required to leave 50 percent of the existing total canopy including understory, and provide no protection for large trees or other late-seral habitat elements.

*Habitat Conservation Plans (HCPs)*

Some non-Federal lands are managed under HCPs with strategies that conserve habitat. These HCPs may provide some incidental benefit to fishers and some have fisher-specific protection measures. Habitat conservation plans cover large areas within the historic range of the fisher, particularly in western Washington and northwestern California. Although the fisher is a covered species in seven HCPs within Washington and California, the species is currently known to be present only on lands under two California HCPs. In most HCPs, the areas where late successional habitat will be protected or allowed to develop are mostly in riparian buffers and smaller blocks of remnant old forest. The HCP conservation strategies generally do not provide the large blocks of forest with late seral structure that appear to be important for sustaining resident fisher populations, particularly for providing denning and resting sites.

In conclusion, the primary threats are the loss and fragmentation of habitat and further decline and isolation of the remaining small populations. Any of the key elements of fisher habitat (*see* Habitat section) may be affected by Federal and State management activities. Reduction of any of these elements could pose a risk to the fishers. Activities under Federal regulatory control that result in fisher habitat fragmentation or population isolation pose a risk to the persistence of fishers. A large proportion of forests within the range of the West Coast DPS for the fisher are managed under the NWFP or SNFPA. These regional planning efforts provide for retention and recruitment of older forests, and provide for spatial distribution of this type of habitat that will benefit late successional forest dependent species such as the fisher. The adequacy of these plans, however is uncertain, as evidenced in the FEMAT's own assessment of fisher viability under the NWFP.

Proposed changes to both the NWFP and SNFPA are in progress, which could weaken habitat measures that benefit the fisher. Even with these plans in place, timber harvest, fuels reduction treatments, and road construction may continue to result in the loss of habitat and habitat connectivity in areas, resulting in a negative impact on fisher distribution, abundance and recovery/recolonization potential.

The same potential risks apply to non-Federal forested lands as discussed for lands under Federal regulatory control. Protections provided under state regulation of forest practices are less than provided on Federal lands, where the NWFP and SNFPA provide greater consideration of late-successional forest and dependent species, and of forest management at larger geographic scales. Existing regulatory processes for non-Federal, non-Tribal timberlands in California and Washington do not include specific measures for management and conservation of fishers or fisher habitat. Regulations regarding late successional forest rarely provide protection of these forests on commercial timberlands. This is largely because the regulations lack specific and enforceable conservation measures for these forests, and for most unlisted wildlife species, including the fisher. While the State regulatory process for these lands in all three States incidentally protects some fisher habitat via the Forest Practice Rules, the benefits are limited and do not include strategies which target either the fisher or key fisher habitat requirements. Existing habitat conservation plans for non-Federal timberlands provide some additional benefits to the fisher. These plans are focused on providing some level of protection for the habitat of spotted owls, marbled murrelets, and listed salmonids, which can protect important habitat elements for the fisher where habitat overlaps. However, many of these plans only protect occupied habitat, and harvest deferrals may be lifted if the mature stands no longer support listed species. Thus, benefits to the fisher from these HCPs may be ephemeral, especially in the case of listed species decline, like that of the spotted owl population occurring in Washington. HCPs only apply to a small part of the fisher's currently occupied range on non-Federal lands in California and Oregon, and the adequacy of the measures in these plans is uncertain. Because of the loss and fragmentation of low-elevation habitat, large geographic areas that were once occupied have become unsuitable, which poses a significant challenge for fisher genetic exchange across isolated patches of habitat.

In addition to the inadequacy of regulations to address fisher habitat requirements, current trapping regulations in Washington, Oregon, and California, while prohibiting intentional trapping of fishers, do not provide accurate reporting of the numbers of incidental captures of fishers, and appear inadequate to control such incidental trapping where fishers are present. Any source of additional mortality in small fisher populations could prevent recovery or reoccupation of suitable habitat (Lewis and Stinson 1998; Lewis and Zielinksi 1996).

It is uncertain whether current regulations will be effective in reducing the level of threat to the fisher. We therefore believe that existing regulatory mechanisms are not sufficient to protect the DPS as a whole from the acknowledged habitat pressures discussed under Factors A and E.

*Factor E. Other natural or manmade factors affecting the continued existence of the species.* Fisher populations in the West Coast DPS are small and isolated and may be threatened by numerous factors including inbreeding depression and unpredictable variation (stochasticity) in demographic or environmental characteristics. Other natural or anthropogenically-influenced factors, including urban development, barriers to dispersal, contaminants, pest control programs, non-target poisoning, stand-replacing fire, timber harvest, accidental trapping in manmade structures, decrease in prey base, and climate change may cause additional fisher declines. Because of small population size, accidental death is a threat.

*Other Causes of Mortality*

There have been several incidents of fishers being found dead in open water tanks. The remains of eight fishers were discovered in an abandoned water tank near a logging road in the northwestern California Coast Ranges (Folliard 1997). The tank had been used to store water for transferring into tank trucks to spread on roads for dust abatement during summer months. The fishers had entered the cylindrical 13-foot-long, 7.5-foot-deep tank from a lidless, 1.5-foot opening in the top. Fisher remains were the only species found inside. It was apparent from the carcasses' different stages of decay that the fishers had been trapped over a period of several years. In another instance of a manmade structure trapping fishers, Truex *et al.* (1998) reported that a 5-year-old female fisher died in the southern Sierra Nevada study area due to a combination of starvation and exposure after becoming entrapped in an uncovered, empty water storage tank. This source of mortality is cause for concern.

*Population Size and Isolation*

Preliminary analyses indicate West Coast fisher populations, particularly in the southern Sierra, may be at significant risk of extinction because of small population size and factors consequent to small population size such as isolation, low reproductive capacity, demographic and environmental stochasticity. A scarcity of sightings in Washington, Oregon, and the northern and central Sierra Nevada of California suggests that fisher is extirpated from most of its historical range in Washington, Oregon, and California (Zielinski *et al.* 1997b; Carroll *et al.* 1999; Aubry *et al.* 2000). The southern Sierra Nevada and northern California/Oregon Siskiyou populations are the only naturally-occurring, known breeding populations of fishers in the Pacific region from southern British Columbia to California that we have been able to identify (Zielinski *et al.* 1997b).

The current rarity of fishers in Washington brings their continued existence there into question. Eleven years ago, Thomas *et al.* (1993) stated that existing fisher populations in northern Oregon and Washington were at a medium to high risk of extirpation on National Forest lands within the next 50 years. According to FEMAT (1993), it was unknown whether the individual fishers that may exist in Washington could repopulate the State in the future. Recovery of the fisher in Washington will probably not occur without reintroductions (Lewis and Stinson 1998). Immigration of fishers into Washington from British Columbia, Idaho, or Montana is unlikely to provide significant demographic support to Washington's fisher population; fisher populations in adjacent parts of Idaho and British Columbia are small, the number of dispersing individuals is probably very low (Heinemeyer 1993), and the geographical separation is large. Reintroductions have apparently been successful in some, but not all other parts of the fisher's national range.

The introduced population in the southern Cascades of Oregon is small and isolated. It stems from the release of 28 fishers from British Columbia between 1961 and 1980, and an additional release of 13 fishers from Minnesota in 1981 (Aubry *et al.* 2002; Drew *et al.* 2003). Aubry *et al.* (in press 2003) concluded, "The high degree of relatedness among fishers in the southern Cascade Range (R = .56) is consistent with the hypothesis that this population is small and isolated.'' This reintroduced population is separated from the northwestern California/southwestern Oregon population by large expanses of non-forested areas, an interstate highway (Interstate 5), recreational developments, and densely populated areas. The isolation of these populations from each other in Oregon is further demonstrated by evidence indicating that there has been no genetic exchange between fishers in the northern Siskiyou Mountains and those in the southern Cascade Range (Aubry *et al.* in press 2003). Small size and isolation make the Oregon populations vulnerable to extirpation.

Because of the apparent loss of viable fisher populations from most of Oregon and Washington, and the northern contraction in the British Columbia populations, fishers in California are reproductively isolated from fishers in the rest of North America. This isolation precludes both immigration and associated genetic interchange, increasing the vulnerability of the California/southern Oregon populations to the adverse effects of deterministic and stochastic factors. Wisely *et al.* (in litt. 2003) documented that fishers in northern California already have lower genetic diversity than other populations in North America. Drew *et al.* (2003) cite evidence of genetic divergence between the California and British Columbia fisher populations; since becoming isolated, the California populations have lost a genetic haplotype still found in British Columbia fishers. The genetic divergence of California populations from each other and from British Columbia fishers could be associated with adaptation to local conditions, but is more likely the result of reduction of population numbers with habitat loss (Drew *et al.* 2003). Isolation makes it unlikely that in the event of population decline, immigration from other populations could temporarily augment the population, rescuing it from extinction.

Genetic studies using mitochondrial and nuclear DNA sequencing indicate that California populations, in particular, differ strongly in haplotype frequencies from each other and from all other populations (Drew *et al.* 2003). These results are consistent with the conclusions of Aubry and Lewis (2003) that native populations in California and the reintroduced population in southwestern Oregon have become isolated from the main body of the species' range due to the apparent extirpation of fishers in Washington and northern Oregon. According to Drew *et al.* (2003), their findings suggest that gene flow once occurred between fisher populations in British Columbia and those in the Pacific states, but extant populations in these regions are now genetically isolated. The southern Sierra Nevada population is geographically isolated from others by approximately 420 km (260 mi) (Zielinski *et al.* 1995, 1997b). There is a low probability that it could be rescued through migration of individuals from other populations were it to decline, since the distance to the nearest population is almost four times the species' maximum dispersal distance of 66 mi (107 km) as reported by York (1996). The unexpected magnitude of Pacific states fishers' genetic structure and lack of gene flow indicates that intermediate distances may represent evolutionarily important barriers to movement that can facilitate rapid genetic divergence (Wisely *et al.* in litt. 2003). Truex *et al.* (1998) concluded that, "Recolonization of the central and northern Sierra Nevada may be the only way to prevent fisher extinction in the isolated southern Sierra Nevada population.''

Indications that extant fisher populations are small in size include the apparent reduction in the range of the fisher on the west coast, the lack of detections or sightings over much of its historical distribution, and the apparently high degree of genetic relatedness within some populations. Small fisher population sizes are cause for concern, particularly considering that the West Coast populations are isolated from the larger continental populations and may have high female mortality (Truex *et al.* 1998). Small populations are at risk of extinction solely from demographic and environmental stochasticity, independent of deterministic factors such as anthropogenic habitat loss (Lande and Barrowclough 1987; Lande 1993). Random fluctuations in gender ratio, fecundity, mortality, droughts, cold weather, heavy snow years and other temporal environmental changes can lead to declines that, in small populations, result in rapid extinction. These factors present threats to the long-term survival of isolated populations such as the southern Sierra Nevada population (Lamberson *et al.* 2000). Catastrophes, such as stand-replacing fire or severe storms, magnify risk of extinction further (Shaffer 1987; Lande 1993).

According to Heinemeyer and Jones (1994), the greatest long-term risk to the fisher in the western United States is probably population extinction due to isolation of small populations. Fishers are known to be solitary and territorial with large home ranges. This results in low population densities as the population requires a large amount of quality habitat for survival and proliferation. Additionally, fishers are long-lived, have low reproductive rates, and small dispersal distances. Given the apparent reluctance of fishers to cross open areas (Coulter 1966; Kelly 1977; Powell 1977; Buck *et al.* 1994; Jones and Garton 1994), it is more difficult for fishers to locate and occupy distant, but suitable, habitat. These factors together imply that fishers are highly prone to localized extirpation, their colonizing ability is somewhat limited, and their populations are slow to recover from deleterious impacts. Isolated populations are therefore unlikely to persist.

Some fisher populations in northeastern North America have shown patterns of rapid density fluctuation consistent with those following cycles in prey numbers (deVos 1952; Rand 1944), or with changes expected for animals whose density-dependent feedback comes through changes in mortality rather than in reproduction, allowing them to recover into areas from which they had been extirpated. Western populations, however, do not appear to be recovering from early overtrapping and habitat degradation. Powell and Zielinski (1994) state:

> This pattern of rapid population increase has not been observed in western populations, many of which have failed to recover despite decades of protection from trapping (*e.g.*, northern Sierra Nevada, Olympic Peninsula), reintroductions (*e.g.*, Oregon), or both. Therefore, one or more major life requisites must be missing. Suitable habitat may be limited, colonization of suitable habitat may be limited due to habitat fragmentation, or some other factor or combination of factors may be involved.

Low fecundity retards the recovery of populations from declines, further increasing their vulnerability. As stated above, fishers have very low reproductive capacity. After 2 years of age, they generally produce only one to four kits per year, and only a portion of all females breed (Powell 1993; Truex *et al.* 1998; Lamberson *et al.* 2000). Truex *et al.* (1998) documented that of the females in the southern Sierra Nevada study area (one of three study areas that they analyzed in California), about 50 to 60 percent successfully gave birth to young. In the study area they analyzed on the North Coast, however, 73 percent of females gave birth to young in 1995, but only 14 percent (one of seven) did so in 1996, indicating fisher reproductive rates may fluctuate widely. Low survival rates for kits, coupled with low reproductive rates, would result in very low reproductive success rates. In their study on the west slope of the Cascade Range in southern Oregon, Aubry *et al.* (2002) radio-collared 13 females and monitored two to four adult females each year from 1995 to 2001. Although their data are preliminary at this point, they found that the average annual reproductive success was only 44 percent.

Female survival has been shown to be the most important single demographic parameter determining fisher population stability (Truex *et al.* 1998; Lamberson *et al.* 2000). Truex *et al.* (1998) documented a low annual survival rate, pooled across years, of 61.2 percent of adult female fishers in the southern Sierra Nevada from 1994 to 1996, 72.9 percent for females and 85.5 percent for males in their eastern Klamath study area, and 83.8 percent for both females and males in their North Coast study area. Addressing the southern Sierra Nevada population, Truex *et al.* (1998) conclude that, "High annual mortality rates raise concerns about the long-term viability of this population.'' Lamberson *et al.* (2000) used a model (deterministic, Leslie stage-based matrix) to gauge risk of extinction for the southern Sierra Nevada population of the fisher and found that the population has a very high likelihood of extinction given reasonable assumptions with respect to demographic parameters. They concluded, "In our model population, growth only occurs when parameter combinations are extremely optimistic and likely unrealistic: if female survival and fecundity are high, other parameters can be relaxed to medium or low values. If female survival and fecundity are medium and all other parameters high, a steady decline toward extinction occurs.''

As with any small, isolated population, risks of extinction are enhanced by stochastic factors (Lamberson *et al.* 2000). Demographic stochasticity, the chance events associated with annual survival and reproduction, and environmental stochasticity, temporal fluctuations in environmental conditions, tend to reduce population persistence (Shaffer 1981; Boyce 1992). Habitat specificity coupled with human-induced habitat fragmentation may also contribute to the exceptionally low levels of gene flow (migrants per generation) estimated among populations of fishers (Wisely *et al.* in litt. 2003). Wisely *et al.* (in litt. 2003) found that populations of the fisher exhibit high genetic structure (FST = 0.45, SE = 0.07) and limited gene flow (Nm < 1) within their 994 mi (1,600 km) long peninsular distribution down through Washington, Oregon, and California. They state concerns about the future viability of the western fisher: * * * we found that * * * genetic diversity decreases from the base [British Columbia] to the tip [southern Sierra Nevada] of the peninsula, and that populations do not show an equilibrium pattern of isolation-by-distance. Genetic structure was greater at the periphery than at the core of the distribution and our data fit a one-dimensional model of stepping-stone range expansion. Multiple lines of paleontological and genetic evidence suggest that the fisher recently (<5000 ybp) expanded into the mountain forests of the Pacific coast. The reduced dimensionality of the distribution of the fisher in the West appears to have contributed to the high levels of structure and decreasing diversity from north to south. These effects were likely exacerbated by human-caused changes to the environment. The low genetic diversity and high genetic structure of populations in the southern Sierra Nevada suggest that populations in this part of the geographic range are vulnerable to extinction.

It is difficult for subpopulations to rescue each other when distributed in such a narrow, linear fashion north-south peninsular distribution. Even isolated from other threats, the north-south peninsular distribution of fishers in the Sierra Nevada is a risk factor for the southern Sierra Nevada population. Being at the southernmost extent of the genus' distribution, the population already exists at the edge of environmental tolerances. The loss of remaining genetic diversity may lead to inbreeding and inbreeding depression. Given the recent evidence for elevated extinction rates of inbred populations, inbreeding may be a greater general threat to population persistence than is generally recognized (Vucetich and Waite 1999).

Combinations of factors can interact to produce significant cumulative risk. Lamberson *et al.* (2000) give the following example: if demographic stochasticity results in lower than average recruitment of female kits into a population for three consecutive years, and this is followed by two heavy-snow winters and one large fire, the population may quickly become in jeopardy of local extinction. Wisely and others (in litt. 2003) "have demonstrated isolation among populations with limited exchange suggesting that populations on the Pacific coast have little demographic buffer from variation in the population growth rate. Immediate conservation action may be needed to limit further erosion of the unique genetic architecture found in this one-dimensional metapopulation.''

In summary, unregulated trapping for furs began in the 1700s; predator bounties began in the 1800s and extended to 1960; extensive, lethal predator control programs were used until the mid-1970s. These factors have likely impacted fishers for nearly two centuries and were exacerbated by loss and fragmentation of habitat from urban growth and development, forest management activities, and road construction. The remaining two populations are threatened with extirpation due to their size and isolation. There is substantial information indicating that the interaction of all the factors above may cause the populations of fishers in their west coast range to become significantly at risk of extirpation.

## Conservation Activities

This fiscal year, the Pacific Region (Region 5) of the U.S. Forest Service is due to complete a conservation assessment for the fisher in the Sierra Nevada Mountains. This effort is part of the Sierra Nevada Framework planning document and is a collaborative effort including scientists from the State and Federal agencies. The assessment may be used to develop a conservation strategy for the Sierra Nevada fisher populations in California.

The timber industry and their representatives, including Sierra Pacific Industries, Simpson Timber Company and the California Forestry Association have indicated willingness to develop a conservation strategy to, if appropriate, conduct a reintroduction and/or relocation strategy in California. Their participation could include funding, staffing, and assistance with analysis and planning.

The State of Washington has completed a reintroduction feasibility study and has identified several sites in the Washington Cascades and the Olympic peninsula where sufficient potential habitat exists to support a fisher population. Reintroduction efforts and evaluation by the State are ongoing and would potentially compliment efforts to establish additional populations throughout the range of the fisher.

## Finding

We have carefully assessed the best scientific and commercial information available regarding the past, present, and future threats faced by this species. We reviewed the petition, available published and unpublished scientific and commercial information, and information submitted to us during the public comment period following our 90-day petition finding. This finding reflects and incorporates information we received during the public comment period and responds to significant issues. We also consulted with recognized fisher experts and Federal and State resource agencies. On the basis of this review, we find that the West Coast population of the fisher constitutes a valid DPS, which is both discrete and significant under our DPS policy, and that listing the fisher in its west coast range is warranted but precluded by pending proposals for other species with higher listing priorities.

In making this finding, we recognize that there have been declines in the distribution and abundance of the fisher in its west coast range, primarily attributed to historical overtrapping and habitat alteration. Much of the fisher's historical habitat and range has been lost. There is substantial information indicating that the habitat of fishers continues to be threatened with further loss and fragmentation resulting in a negative impact on fisher distribution and abundance. Mortalities and injuries from incidental captures of fishers may be frequent enough to prevent local recovery of populations, or prevent the re-occupation of suitable habitat. Removing important habitat elements such as cover could allow predation to become a significant threat. Other factors considered to be threats to the fisher include mortality from vehicle collisions, a decrease in the prey base, and increased human disturbance. Fisher populations are low or absent throughout most of their historical range in Washington, Oregon, and California. Because of small population sizes and isolation, fisher populations on the West Coast may be in danger of extirpation.

Federal, State, and private land management activities may affect key elements of fisher habitat; reduction of any of these key habitat elements could pose a risk to the fisher. Current regulations provide insufficient certainty that conservation efforts will be implemented or that they will be effective in reducing the level of threat to the fisher. We, therefore, believe that existing regulatory mechanisms are not sufficient to protect the DPS as a whole from habitat pressures.

We conclude that the overall magnitude of threats to the West Coast DPS of the fisher is high, and that the overall immediacy of these threats is non-imminent. Pursuant to our Listing Priority System (64 FR 7114), a DPS of a species for which threats are high and non-imminent is assigned a Listing Priority Number of 6. The threats occur across the range of the DPS resulting in a negative impact on fisher distribution and abundance. The threats are non-imminent as the greatest long-term risks to the fisher in its west coast range are the subsequent ramifications of the isolation of few, small populations. While we conclude that listing the West Coast DPS of the fisher is warranted, an immediate proposal to list is precluded by other higher priority listing actions. During Fiscal Year 2004 we must spend nearly all of our Listing Program funding to comply with listing actions required by court orders and judicially approved settlement agreements, which are now our highest priority actions. To the extent that we have discretionary funds, we will give priority to using them to address emergency listings and listing actions for other species with a higher priority. We expect that our discretionary listing activity in Fiscal Year 2004 will focus on addressing our highest priority listing actions.

There are currently efforts underway to implement a conservation strategy to reintroduce the fisher into its former range along the Pacific Coast. Additional populations of fishers will reduce the probability that a stochastic event would result in extirpation of these species. We will evaluate a completed conservation strategy in accordance with our Policy on Evaluating Conservation Efforts (68 FR 15100, March 28 2003) to determine whether it sufficiently removes threats to the fisher so that it no longer meets the definition of threatened under the Act.

We will add the West Coast DPS of the fisher to the list of candidate species upon publication of this notice of 12-month finding. We request that you submit any new information, whenever it becomes available, for this species concerning status and threats. This information will help us monitor and encourage the conservation of this species. Should an emergency situation develop with this or any of the candidate species, we will act to provide immediate protection, if warranted.

We intend that any proposed listing action for the West Coast DPS of the fisher will be as accurate as possible. Therefore, we will continue to accept additional information and comments from all concerned governmental agencies, the scientific community, industry, or any other interested party concerning this finding.

## References Cited

A complete list of all references cited is available on request from the Sacramento Fish and Wildlife Office (see **ADDRESSES** section, above).

## Author(s)

The primary author of this document is the Sacramento Fish and Wildlife Office (see **FOR FURTHER INFORMATION CONTACT** section).

## Authority

The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Dated: April 2, 2004.

**Steve Williams,**

*Director, Fish and Wildlife Service.*

[FR Doc. 04–7941 Filed 4–7–04; 8:45 am]

**BILLING CODE 4310–55–P**

# JCEP LNG TERMINAL PROJECT

## Resource Report 3- Fish, Wildlife and Vegetation

| To Verify Compliance with this Minimum FERC Filing Requirement: | | See the Following Resource Report Section: |
|---|---|---|
| 1. | Describe commercial and recreational warmwater, coldwater, and saltwater fisheries in the affected area and associated significant habitats such as spawning or rearing areas and estuaries. | Section 3.3 |
| **2.** | Describe terrestrial habitats, including wetlands, typical wildlife habitats, and rare, unique, or otherwise significant habitats that might be affected by the proposed action. Describe typical species with commercial, recreational or aesthetic value. | Section 3.1<br>Section 3.2<br>Section 3.4 |
| **3.** | Describe and provide the acreage of vegetation cover types that would be affected, including unique ecosystems or communities such as remnant prairie or old-growth forest, or significant individual plants, such as old-growth specimen trees. | Section 3.1<br>Section 3.2 |
| **4.** | Describe the impact of construction and operation on aquatic and terrestrial species and their habitats, including the possibility of a major alteration to ecosystems or biodiversity, and any potential impact on state-listed endangered or threatened species. Describe the impact of maintenance, clearing and treatment of the project area on fish, wildlife and vegetation. Surveys may be required to determine specific areas of significant habitats or communities of species of special concern to state or local agencies. | Section 3.1<br>Section 3.2<br>Section 3.3<br>Section 3.4 |
| **5.** | Identify all federally listed or proposed endangered or threatened species and critical habitat that potentially occur in the vicinity of the project. Discuss the results of the consultation requirements listed in §380.13(b) at least through §380.13(b)(5)(i) and include any written correspondence that resulted from the consultation. The initial application must include the results of any required surveys unless seasonal considerations make this impractical. If species surveys are impractical, there must be field surveys to determine the presence of suitable habitat unless the entire project area is suitable habitat. | Section 3.4 |
| **6.** | Identify all federally listed essential fish habitat (EFH) that potentially occurs in the vicinity of the project. Provide information on all EFH as identified by the pertinent Federal fishery management plans that may be adversely affected by the project, and the results of abbreviated consultations with NMFS, and any resulting EFH assessments. | Section 3.3 |
| **7.** | Describe site-specific mitigation measures to minimize impacts on fisheries, wildlife, and vegetation. | Section 3.1<br>Section 3.2<br>Section 3.3 |
| **8.** | Include copies of correspondence not provided pursuant to paragraph (e)(5) of this section, containing recommendations from appropriate Federal and state fish and wildlife agencies to avoid or limit impact on wildlife, fisheries, and vegetation, and the applicant's, along with response to the recommendations. | Appendix A.3 |

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## CONTENTS

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

### TABLES



### FIGURES

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)



## APPENDICES

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## ACRONYMS

| | |
|---|---|
| BiOP | Biological Opinion |
| BLM | Bureau of Land Management |
| BWE | Ballast Water Exchange |
| BMPs | Best Management Practices |
| BOG | Boil-off Gas |
| BRT | Biological Review Team |
| Btu | British Thermal Unit |
| BWM | Ballast Water Management |
| CFR | Code of Federal Regulations |
| CM | Channel Mile |
| cy | Cubic Yards |
| DPS | Distinct Population Segment |
| EEZ | Economic Exclusion Zone |
| EFH | Essential Fish Habitat |
| ESA | Endangered Species Act |
| ESCP | Erosion and Sedimentation Control Plan |
| ESU | Environmentally Sensitive Unit |
| FERC | Federal Energy Regulatory Commission |
| FMP | Fishery Management Plan |
| FR | Federal Register |
| ft/sec | Feet Per Second |
| gpm | Gallons Per Minute |
| HRSG | Heat Recovery Steam Generator |
| JCEP | Jordan Cove Energy Project, L.P. |
| LNG | Liquefied Natural Gas |
| $m^3$ | Cubic Meter |
| $m^3$/hr | Cubic Meters Per Hour |
| MBTA | Migratory Bird Treaty Act |
| mm | Millimeters |
| MMBtu | Million British Thermal Units |
| MMTPA | Million Metric Tons Per Annum |
| MSL | Mean Sea Level |
| mt | Metric Ton |
| MW | Megawatt |
| NAS | National Audubon Society |
| NGA | Natural Gas Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| OAR | Oregon Administrative Rule |
| ODA | Oregon Department of Agriculture |
| ODFW | Oregon Department of Fish and Wildlife |
| OISC | Oregon Invasive Species Council |

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## ACRONYMS (Continued)

| | |
|---|---|
| ORBIC | Oregon Biodiversity Information Center |
| ORNHIC | Oregon Natural Heritage Program Information Center |
| OPRD | Oregon Parks and Recreation Department |
| OSWB | Oregon State Weed Board |
| PCGP | Pacific Connector Gas Pipeline |
| PFMC | Pacific Fishery Management Council |
| POC | Port Orford Cedar |
| SAV | Submerged Aquatic Vegetation |
| SPCCP | Spill Prevention, Containment, and Countermeasure Plan |
| SORSC | Southwest Oregon Regional Safety Center |
| SSNERR | South Slough National Estuarine Research Reserve |
| U.S. | United States |
| USC | United States Code |
| USCG | U.S. Coast Guard |
| USFWS | U. S. Fish and Wildlife Service |
| USFS | U. S. Forest Service |

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## 3. INTRODUCTION

Jordan Cove Energy Project, L.P. (JCEP) is requesting authorization from the Federal Energy Regulatory Commission (FERC) to site, construct, and operate a natural gas liquefaction and export facility (LNG Terminal or Project), located on the bay side of the North Spit of Coos Bay, Oregon. The Project will provide a facility capable of liquefying natural gas and storing the liquefied natural gas (LNG) for export. Once the Project facilities are completed and placed in service, natural gas will be delivered to the LNG Terminal via the proposed Pacific Connector Gas Pipeline (PCGP), which will connect the Project with existing interstate natural gas pipeline systems. The authorization required for the PCGP will be addressed in a separate application filed by PCGP pursuant to Section 7(c) of the Natural Gas Act (NGA).

Natural gas received at the LNG Terminal will be cooled into liquid form and stored in two 160,000 cubic meter ($m^3$) full-containment LNG storage tanks. The proposed Project facilities will have the capability to allow export of six million metric tons per annum (MMTPA). Approximately 90 LNG carriers per year will be required to transport the LNG to locations in the United States (U.S.) and around the world.

The following facilities will be constructed for the Project:

- A pipeline gas conditioning facility consisting of two feed gas cleaning and dehydration trains with a combined natural gas throughput of approximately 1 Bscf/d;
- Four natural gas liquefaction trains, each with the export capacity of 1.5 MMTPA;
- A refrigerant storage and resupply system;
- An Aerial Cooling System (Fin-Fan);
- An LNG storage system consisting of two full-containment LNG storage tanks, each with a net capacity of 160,000 $m^3$ (1,006,000 barrels), and each equipped with three fully submerged LNG in-tank pumps sized for approximately 11,600 gallons per minute (gpm) each;
- An LNG transfer line consisting of one 2,300-foot-long, 36-inch-diameter line that will connect the shore based storage system with the LNG loading system;
- An LNG carrier cargo loading system designed to load LNG at a rate of 10,000 $m^3$ per hour ($m^3$/hr) with a peak capacity of 12,000 $m^3$/hr, consisting of three 16-inch loading arms and one 16-inch vapor return arm;
- A protected LNG carrier loading berth constructed on an Open Cell® technology sheet pile slip wall and capable of accommodating LNG carriers with a range of capacities;
- The improvement of an existing, on-site unimproved road and utility corridor to become the primary roadway and utility interconnection between the LNG Terminal and South Dunes sites, including between the pipeline gas conditioning units on the South Dunes Power Plant site and the liquefaction trains on the LNG Terminal site;
- A boil off gas (BOG) recovery system used to control the pressure in the LNG storage tanks;

- Electrical, nitrogen, fuel gas, lighting, instrument/plant air and service water facility systems;
- An emergency vent system (ground flare);
- An LNG spill containment system, a fire water system and various other hazard detection, control, and prevention systems; and
- Utilities, buildings and support facilities.

The following facility, although not jurisdictional to FERC, will also be constructed to support the Project:

- The South Dunes Power Plant, a 420 megawatt (MW) natural gas fired combined-cycle electric power plant inclusive of heat recovery steam generator (HRSG) units for the purpose of powering the refrigeration systems in the natural gas liquefaction process and supplying steam to the conditioning units.

**Purpose of Report**

The purpose of this Resource Report is to review and characterize existing scientific information for vegetation, wildlife, fish, and aquatic resources, and to identify potential direct, indirect, and cumulative effects to these resources from the construction and operation of the Project. This report also identifies mitigation, enhancement, and protection measures that can be implemented to avoid or minimize potential adverse impacts to these resources and their associated habitats.

The goal of this report is to provide a comprehensive reference document utilizing the best scientific information available for use in making sound decisions with respect to Project planning, environmental reviews, and permitting. It is intended for use by federal and state resource managers, permitting agencies, professionals engaged in habitat assessment activities, the regulatory community, and the public.

**Agency Communications**

In the preparation of this Resource Report, communications have occurred with the U. S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA) - National Marine Fisheries Service (NMFS), the Oregon Department of Fish and Wildlife (ODFW), the Oregon Biodiversity Information Center (ORBIC), and the Oregon Department of Agriculture (ODA) to identify significant terrestrial and marine biological resources, including significant habitats, federally-listed species, state-listed species, and the occurrence of Essential Fish Habitat (EFH) within the Project area. A summary of key agency contacts is presented in Table 1.8-1 (Resource Report 1 - General Project Description). Coordination and consultation with these agencies, along with surveys and assessments conducted, is documented in the attached botanical, wildlife, and fisheries reports completed for the Project.

**Report Organization**

This Resource Report is organized into five major sections and a references section. Section 3.1 discusses Vegetation, Section 3.2 Wildlife, Section 3.3 Fisheries and Marine Resources, and Section 3.4 Federal and State Threatened and Endangered Species (including proposed species and Critical Habitat). Section 3.5 briefly summarizes the overall impacts of the proposed Project, and overall mitigation, enhancement, and protection measures to address the primary impacts. References used in the development of this Resource Report are presented in Section 3.6.

**Project Area Characterization**

As discussed in Resource Report 1 – General Project Description and shown in Figure 1.1-1, the Project is located across two parcels of land on the bay side of the North spit of Coos Bay. All jurisdictional facilities except the pipeline gas conditioning facilities will be located on the western parcel (LNG Terminal site), the South Dunes Power Plant and the pipeline gas conditioning facilities will be located on the eastern parcel (South Dunes Power Plant site). The two sites will be connected by the utility and access corridor (in the aggregate, the Project site). It will include a temporary construction worker camp and compensatory mitigation sites, including the Kentuck site for wetland and estuarine resources; the Panhandle mitigation site for wetland and wildlife habitat impacts; and an eelgrass mitigation site southwest of the Southwest Oregon Regional Airport in North Bend.

## 3.1 VEGETATION

The Project will encompass a number of ecological systems that support diverse vegetation communities. The overall location was selected on the basis of avoiding, to the extent practical, unique vegetation communities and higher value wetlands. Selection of temporary construction areas was purposely restricted to upland areas to avoid impacting wetlands. Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project vicinity are included in the description of vegetation associations presented below, as applicable, and are discussed further in Section 3.4.

### 3.1.1 Existing Resources

Extensive surveys have been conducted at the Project site for botanical resources. The Project site was initially surveyed and evaluated extensively in 2005 and 2006 for the previously proposed LNG import facility. Additional surveys were conducted in 2012 and 2013 to supplement the previous surveys and ensure that all existing botanical resources are included in this evaluation. A preliminary botanical survey of the construction worker camp site across the bay was conducted in April 2013.

Vegetation in the area to be affected by construction of the Project is generally typical of vegetation and associated habitats found on the North Spit of Coos Bay. The site consists of a number of different plant associations, as well as disturbed areas resulting from the placement of fill from historical dredging operations and previous industrial use.

The proposed Kentuck and Panhandle wetland mitigation sites are also included in the discussion of the various plant communities that occur for the Project. The Kentuck site is addressed in more detail in Resource Report 2 – Water Use and Quality, which evaluates the site for use as mitigation for impacts to wetlands by the Project. The Panhandle mitigation site will be evaluated further as the use of the site for wildlife habitat and wetland mitigation moves forward.

Vegetation associations have been grouped into four main categories: forest, woodland, shrubland, and herbaceous associations (Figure 3.1-1). These classifications are based on the National Vegetation Classification System (NVCS) used for *Plant Associations of the Oregon Dunes National Recreation Area* (Christy et al. 1998), a U.S. Department of Agriculture (USDA) publication. Forests are defined as associations where tree species make up at least 60 percent of the vegetation cover. Woodland associations are defined as open stands, usually without crowns touching, and cover varies from 25 to 60 percent. Communities that generally consist of at least 25 percent shrub cover are classified as shrubland associations. Conversely, communities that generally have less than 25 percent shrub cover are defined as herbaceous associations. These associations are discussed in Section 3.1.2.

In addition to the above vegetation associations, dune forests that occur within these associations at the Project site have been classified as A through E. Dune Forest B is the largest and is slated for removal to create the access channel and slip for the LNG facility. Dune Forest C is smaller and is located north of Dune Forest B, immediately south of the Trans-Pacific Parkway. There is a sand trail that separates the two. Dune Forest A, the highest in dune forest habitat value, is located west of Jordan Lake and runs approximately 800 feet down from the utility corridor. It consists of Port Orford cedar and shore pine-Sitka spruce communities.

Additional dune forests D and E occur in shore pine/Douglas fir associations. Dune Forest D is located on the northwestern tip of the overall site, immediately south of the Trans-Pacific Parkway. Dune Forest E is located in the western portion of the South Dunes Power Plant site, immediately east of Jordan Cove Road.

Dune forests also occur in areas that will not be impacted by the Project, including in the forested wetland mosaic complex (east of Dune Forest C and north of the Roseburg Forest Products wood chip export facility) and in upland forest sites along the ridgelines throughout the complex. These dune forests are interspersed among the wetlands and consist of shore pine-Sitka spruce, shore pine-Douglas fir, and shore pine/slough sedge.

### 3.1.2 Associations

#### 3.1.2.1 Forest Associations

Forest associations are defined as trees with crowns overlapping and generally a cover of 60 to 100 percent. Evergreen forests in this association have greater than 75 percent tree cover. Forest associations within the Project site are dominated by coniferous species with scattered hardwoods that occur generally along ridges and the toe of slopes. Forests vary in seral (intermediate ecological) and mature stand stages. The youngest forests are generally located along the northern perimeter of the developed portions of the LNG Terminal site and adjacent to the Trans-Pacific Parkway. The more successionally mature forests are located in the interior portions of the site, on stabilized dune ridges, troughs, and dry deflation basins. Forest types included in this association that occur at the Project site are described below.

**Shore Pine-Douglas Fir/Wax Myrtle-Evergreen Huckleberry (Evergreen, Upland)**

Shore pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*) forests in this association occur near previously developed areas such as roads, fill sites, or industrial sites. They have been noted to occur most frequently on warm, dry ridges, and slopes on the dunes; primarily with south to west facing aspects (Christy et al. 1998). This association is characteristic of younger forest sites north of Jordan Cove. They occur in areas where dune stabilization has been achieved through recruitment of vegetation, most notably European beachgrass (*Ammophila arenaria*) and Scotch broom (*Cytisus scoparius*). This association has an open overstory dominated by shore pine with scattered Douglas fir. The shrub layer is dominated by Scotch broom and coyote bush (*Baccharis pilularis*), with scattered hairy manzanita (*Arctostaphylos columbiana*), wax myrtle (*Myrica californica*), and evergreen huckleberry (*Vaccinium ovatum*). Dominant herbaceous species include European beachgrass, silver hairgrass (*Aira caryophyllea*), little hairgrass (*A. praecox*), hairy cat's ear (*Hypochaeris radicata*), braken fern (*Pteridium aquilinum*), and sheep sorrel (*Rumex acetosella*).

Shore pine and Douglas fir forests were observed in portions of Dune Forests A, B, and C where adjacent landscapes have been altered by human or natural influences.

**Shore Pine-Sitka Spruce/Evergreen-Huckleberry (Evergreen, Upland)**

This association is common in more successionally mature forests. Stands are generally dominated by shore pine and Douglas fir, but also include Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and scattered Port Orford cedar (*Chamaecyparis lawsoniana*). The shrub understory layer ranges from dense to nearly impenetrable and is dominated with evergreen huckleberry, salal (*Gaultheria shallon*), and wax myrtle, with scattered Pacific rhododendron (*Rhododendron macrophyllum*). The herbaceous layer varies from being depauperate (diminished) to moderately covered with candy-stick (*Allotropa virgata*), rattlesnake plantain (*Goodyera oblongifolia*), and bracken fern along edges or gaps in the overstory. Dune Forest B, the largest dune forest identified within the LNG Terminal site**,** occurs within this association and consists of a mix of shore pine, Sitka spruce, and Douglas fir.

Forests within the Panhandle mitigation site are dominated by coniferous species, generally along the toe of slopes and low lying areas adjacent to shrublands, and most closely fit this association. Forests found in the site are dominated by shore pine, with scattered Sitka spruce, and western hemlock. The shrub layer in the wetland forest sites ranges from dense to nearly impenetrable and is dominated with evergreen huckleberry, salal, and wax myrtle, with scattered Pacific rhododendron. The herbaceous layer is dominated by slough sedge (*Carex obnupta*), which is found along the edge of the tree line throughout the Panhandle mitigation site area.

**Shore Pine/Scotch Broom/European Beachgrass (Evergreen, Upland)**

Although this association at the Project site contains shore pine, it is usually observed as a shrubland due to the high density of shrubby species, including Scotch broom, with limited distribution of shore pine due to the abundance of non-native species. This association is relatively widespread throughout the LNG Terminal site of the Project area and is associated with roads and other disturbed areas. The overstory within this association is generally open, averaging less than 50 percent cover of shore pine in most areas. Scotch broom cover varies from moderately dense to very dense in areas that lack a substantial canopy cover.

The herbaceous layer varies from depauperate, where there is a significant cover of Scotch broom, to moderately vegetated in areas that lack dense shrub cover. Dominant herbaceous species include European beachgrass, red fescue (*Festuca rubra*), tall fescue (*Festuca arundinaceae*), silver hairgrass, hairy cat's ear, and sheep sorrel*.* This association occurs west of the South Dunes Power Plant, north of the Roseburg Forest Products wood chip export terminal, along previous road cuts for the Trans-Pacific Parkway, and at the temporary construction worker camp site.

**Port Orford Cedar/Evergreen-Huckleberry (Evergreen, Upland)**

The Port Orford cedar and evergreen huckleberry association is described by Christy et al. (1998) as unique. It occurs in all aspects and slopes on narrow, dry stabilized dune ridges, troughs, and seasonally dry deflation basins at the southern end of the Oregon Dunes National Recreation Area immediately north of the Project site.

Port-Orford-cedar (POC) root rot disease is caused by the fungus *Phytophthora lateralis*. The disease was first discovered in POC's natural range in 1952 and since has spread throughout the POC's (host) range. The fungus invades the roots of POC and eventually colonizes the entire root system until the tree eventually dies from girdling. POC root rot disease affects both seedlings and mature trees. Evidence of infected trees includes lighter colored foliage that eventually turns red to brown. It also dyes and discolors the inner bark. The spores live in the soil and are spread through contact with contaminated soil or via free water. The disease is primarily spread through soil disturbance and spread of the disease may occur over long distances.

A small component of a well-developed Port Orford cedar/evergreen huckleberry association is located upslope from the southwestern shore of Jordan Lake, in the center of the Project site. Port Orford cedar observed at this location includes two trees upslope from the existing access trail that travels from the Roseburg Forest Products facility to Jordan Lake. Additionally, 23 Port Orford cedars were observed at sites located adjacent to Jordan Lake, in areas that will be preserved as part of the Project. Dune Forest A occurs partially within this association. Of note, the plot plan for the Project is different from that of the previously proposed LNG import terminal. The area to be disturbed by the Project now avoids this plant association.

**Shore Pine/Slough Sedge (Evergreen, Seasonally Flooded)**

This wetland forest association occurs in depressions on deflation plains and on ancient marine terraces. It was observed in the north central wetland mosaic north of the Roseburg Forest Products wood chip export terminal and is the predominant wetland type observed in the wetland forested sites found scattered throughout the Panhandle mitigation site. The understory on mounds in and around depressions is dominated by shrub species, including wax myrtle, salal, and evergreen huckleberry. Slough sedge is the single dominant herbaceous species and was observed growing in depressions and open water habitats throughout the North Spit locations of the Project.

**Red Alder/Salmonberry/Slough Sedge-Skunk Cabbage (Deciduous, Saturated)**

Red alder/salmonberry/skunk cabbage forests occur in wetland habitats adjacent to upland forested habitats, and in low flat areas adjacent to inundated wetlands. In this association, the overstory consists entirely of red alder (*Alnus rubra*) around wet areas, but transitions to shore pine in adjacent areas. Canopy cover varies from moderate to closed (more than 50 percent). Scattered clusters of dense shrubs that include salmonberry (*Rubus spectabilis*) and Hooker willow (*Salix hookeriana*) are located under the canopy. Herbaceous coverage is generally found in wet areas and consists almost entirely of slough sedge, with scattered skunk cabbage (*Lysichiton americanus*). This association has been documented in low spots in forests east of Jordan Cove Road and along the southern edge of the wetland mosaic located in the northwest part of the LNG Terminal site.

### 3.1.2.2 Woodland Associations

Woodland associations are defined as open stands, usually without crowns touching, and generally form 25 to 60 percent cover (sometimes less). They occur on all aspects of dry, well-drained, partially stabilized dune ridges, slopes, and flats between the sand and the forest edge (Christy et al. 1998). Three woodland associations occur within the LNG Terminal site, but are not well represented. They are described below.

**Shore Pine/Bearberry (Evergreen, Upland)**

The overstory for this association consists entirely of shore pine. The shrub layer is dominated by the low growing shrub bearberry (*Arctostaphylos uva-ursi*), with hairy Manzanita in scattered patches. The shore pine/bearberry association has small portions scattered throughout the

Project site, with the most substantial occurrence on the stabilized dune ridge northwest of the Roseburg Forest Products wood chip export terminal between Dune Forests B and C.

**Shore Pine/Hairy Manzanita (Evergreen, Upland)**

The shore pine/hairy manzanita association successionally replaces the shore pine/bearberry association. The overstory is moderately open and is dominated by shore pine with scattered Douglas fir trees. The shrub layer varies from moderately dense to dense in areas where the canopy is patchy. Hairy manzanita is the dominant shrub species with scattered evergreen huckleberry and bearberry along the edges. A small area of this association can be found along the eastern boundary of Dune Forest B.

#### 3.1.2.3 Shrubland Associations

Communities that consist of shrubs greater than 0.5 meter tall with generally greater than 25 percent cover and generally less than 25 percent tree cover are classified as shrubland associations. Deciduous shrubland generally has greater than 75 percent deciduous species shrub cover. The density and distribution of the shrubland association is correlated to hydrology and topography. One of the major characteristics of the shrubland association is minor variation in topography, which affects the distribution of herbs and shrubs. The lowest lying areas are frequently inundated with water and, depending on the frequency and duration of inundation, they may be dominated with emergent hydrophyte species that generally grow partly or totally submerged in water.

Shrublands within the Panhandle mitigation site are referred to as scrub-shrub wetlands, with variations in species composition and abundance throughout the site. Extensive shrublands were observed in the areas bordering open water throughout the Panhandle mitigation site and were observed dominating the landscape from the edge of the forest community to emergent wetland sites. The overstory within this shrubland varies from patchy to dense and is dominated by Hooker willow, Sitka willow (*S. sitchensis*), and Douglas spiraea (*Spiraea douglasii*), with scattered twinberry (*Lonicera involucrata*). Coniferous trees are for the most part absent in the shrubland community but may include scattered shore pine and Sitka spruce. Slough sedge is the most abundant herbaceous species.

**Hooker Willow-Crabapple/Slough Sedge-Skunk Cabbage (Deciduous, Saturated)**

Scrub-shrub communities identified for the Project site most closely resemble Hooker willow-crabapple/slough sedge-skunk cabbage association, minus the skunk cabbage. Minor variations in hydrology and topography may change the species composition drastically. This association is further described as having dwarf shrubland with shrubs less than two feet tall that provide generally greater than 25 percent cover. Tree cover is generally less than 25 percent.

The overstory within this association varies from patchy to dense and is dominated by Hooker willow, Sitka willow, and Douglas spiraea, with scattered twinberry. Evergreen (coniferous) trees are for the most part absent in the shrubland community, but may include scattered shore pine and Sitka spruce. Slough sedge is the most abundant herbaceous species. Other species include spreading rush (*Juncus effuses*), dagger-leaved rush (*Juncus ensifolius*), toad rush (*J. bufonius*), western bent-grass (*Agrostis exarata*), creeping bent-grass (*A. stolonifera*), reed canary grass (*Phalaris arundinacea),* northern willowherb (*Epilobium ciliatum*), tall mannagrass (*Glyceria elata*), and lowland cudweed (*Gnaphalium palustre*).

Hooker willow/slough sedge shrubland and Douglas spiraea saturated shrubland were observed extensively throughout wetlands west of Jordan Cove Road and southwest of Jordan Lake. In addition, this alliance is the dominant vegetation association observed in the scrub-shrub wetland habitat located in the Panhandle mitigation site.

#### 3.1.2.4 Herbaceous Associations

Communities that have generally less than 25 percent tree and shrub cover with generally greater than 25 percent herbaceous vegetation (graminoids, forbs, and ferns) are defined as herbaceous associations. Perennial vegetation for this association generally has greater than 50 percent of total herbaceous cover.

Herbaceous associations are the most variable of all the vegetation associations located in the Project site. They range from being dominated by plants that are adapted for sand burial and desiccating winds, to species that are emergent or submergent hydrophytes. They are widespread throughout the Project site, including areas that have some active sand movement and/or anthropogenic (human) disturbance. Effects from anthropogenic disturbances are reflected in the nonnative herbaceous species composition. Vegetation communities occurring in sand dune areas of the Project site are composed almost entirely of herbaceous species of plants, with no persistent woody stems above ground.

Numerous special status plant species are known to occur in herbaceous associations and are included Section 3.1.4 for unique and special status species. Federal and state-listed threatened and endangered plant species known to occur in herbaceous associations found in coastal habitats include: pink sand verbena (*Abronia umbellate,* ssp. *breviflora*), Point Reyes bird's-beak (*Cordylanthus maritimus,* ssp. *palustris*), silvery phacelia *(Phacelia argentea)*, western lily (*Lilium occidentale*), and Wolf's evening primrose *(Oenothera wolfii).* These species and their potential to occur in or near the Project are discussed further in Section 3.4.

Plant communities that occur in herbaceous associations at the Project site are described below.

**European Beachgrass (Perennial, Upland)**

Vegetation located on the active to semi-stable sand dunes is consistent with common herbaceous dune species. Dominant dune species include European beachgrass, red fescue, silver burweed (*Ambrosia chamissonis*), sand pea (*Lathyrus japonicus*), seashore lupine (*Lupinus littoralis*), beach silvertop (*Glehnia littoralis*), and beach evening primrose (*Camissonia cheiranthifolia*).

In degraded habitats such as where fill material has been deposited in the past, and near roadsides or other industrial sites, this association includes patchy non-native shrubs species, including Scotch broom. It can begin to resemble the shore pine/Scotch broom/European beachgrass association. At these sites the herbaceous vegetation is being displaced by encroaching invasive species, including European beachgrass and Scotch broom.

This association was observed in the western part of the LNG Terminal site in the dredge spoils fill site (also known as Ingram Yard) where the slip will be located and at the construction worker camp site. It was also observed in patchy distribution throughout open dune lands located north of Jordan Lake where the access/utility corridor is proposed.

#### Red Fescue-Salt Rush (Perennial, Upland)

In grasslands found on sand or fill material, red fescue is the single dominant species. Scattered red fescue was observed west of the South Dunes Power Plant site (on fill) and north of the Roseburg Forest Products export facility (on sand). At the South Dunes Power Plant site, in an area surrounded by scattered red fescue, a portion of a small dune contained the single dominant species salt rush (*Juncus lesuerii*). Red fescue-salt rush was also observed at sites where sand burial by wind driven forces limits species diversity, including in the Ingram Yard east of Henderson Marsh (western part of the LNG Terminal site).

#### American Dunegrass (Perennial, Upland)

This association includes dune lands with the single dominant species American dunegrass (*Leymus mollis*). It can be found on beaches and in foredunes, and to a lesser extent on open deflation plains and in upper estuaries. Continual sand burial and inputs of salt spray seem necessary for American dunegrass to thrive. Stands in most locations have been overrun by European beachgrass, but American dunegrass often persists in patches among the European beachgrass, which is the case of the grasses occurring on the western half of the construction worker camp site. Scattered American dunegrass was also observed west of Dune Forest B, in the Ingram Yard grassland habitat east of Henderson Marsh on previous fill deposits. Continual sand burial at this site limits competing vegetation and inputs of salt spray create the conditions necessary for this species to thrive.

#### Pond Lily (Perennial, Semi-permanently Flooded)

Other herbaceous associations are dominated by emergent hydrophytes, as described in the shrubland association section. Dominant species in semi-permanently flooded areas include yellow pond lily (*Nuphar lutea ssp. polysepala),* floating water-pennywort *(Hydrocotyle ranunculoides),* floating-leaved pondweed (*Potamogeton natans*), parrotfeather (*Myriophyllum aquaticum*), water shield (*Brasenia schreberi*), and common bladderwort (*Utricularia macrorhiza*). Pond lily habitat was observed in deep freshwater wetlands located in the Project site. This includes wetlands immediately west of Jordan Cove Road where the access/utility corridor is proposed (Wetland 2012-2 and 2013-6) and in the southern portion of Wetland E.

### 3.1.2.5 Other Plant Associations

#### Maintained Grasslands

Maintained grassland habitats observed throughout the Kentuck wetland mitigation site include native and non-native grasses and other herbaceous species associated with manicured grasslands. This site is dominated by red fescue, Kentucky bluegrass (Poa pratensis), reed canary grass (*Phalaris arundinacea*), common rush (*Juncus effuses*), and orchard grass (*Dactylis glomerata*). Wetland habitats were observed in the drainage that flows out of the levee situated along East Bay Drive at the western edge of the site. Dominant species include common rush and common cattail (*typha latifolia*). Reed canary grass, an invasive plant species, was observed in patchy distribution in areas that bordered forest sites. Tree species were planted throughout the site and include ornamental species such as blue spruce (*Picea pungens*) and poplar (*Populus trichocarpa*), as well as native tree species such as western hemlock, Sitka spruce, and Douglas fir.

#### Common Cattail/Open Water

This association includes wetland fringe sites observed adjacent to open bodies of water. These sites are limited in species diversity due to competition from common cattail which displaces other emergent vegetation. This association was observed in wetlands surrounding the existing sludge ponds at the South Dunes Power Plant site and the wetlands observed south of the Trans-Pacific Parkway in the eastern portion of the Project site.

Wetlands that occur in the Project area include emergent, scrub-shrub, forested, and estuarine intertidal, as described briefly below. A more detailed analysis is included in Resource Report 2 – Water Use and Quality, including potential effects to wetlands and proposed mitigation.

- Herbaceous emergent wetland habitat is located in low lying areas throughout the Project area. Vegetation is typically dominated by sedges, rushes, and grasses, with wetter portions of this habitat type consisting of aquatic floating and emergent plants in relatively shallow seasonally or perennially inundated areas.
- Scrub-shrub wetland habitat is commonly dominated by Hooker willow, with salmonberry and other common coastal wetland species such as slough sedge and skunk cabbage.
- Forested wetland habitat consists of wetlands that have remained undisturbed long enough to develop a consistent tree canopy. It is dominated primarily by red alder, with some areas of tree-size Hooker willow. The shrub layer is dominated by common coastal wetland species.
- Estuarine intertidal wetlands occur along the shore of Coos Bay at the mouth of the proposed slip and in an intertidal mudflat area associated with Wetland H.

**Salt Marsh Species**

Salt marshes are located along the vegetated shoreline adjacent to Jordan Cove, towards the western end of the Kentuck wetland mitigation site in areas where tidal influence occurs, and at the construction worker camp site. Dominant species include pickleweed (Salicornia virginiana), Lyngby sedge (*Carex lyngby*), salt grass (*Distichlis spicata*), and hairgrass (*Deschampsia caespitosa*). A small occurrence of salt marsh species was observed in a portion of Henderson Marsh which is located to the west and outside of the Project site, as well as in the lightly vegetated mudflat area associated with Wetland H (see Resource Report 2) that drains from the South Dunes Power Plant site into the bay.

### 3.1.3 Noxious Weeds

Noxious weeds are non-native, aggressive, and invasive plants. Species such as European beachgrass and Scotch broom are replacing native vegetation and opportunistically becoming established on sites otherwise unoccupied by grass or shrub species. The spread of noxious weeds is altering habitats and interfering with natural succession. Resource and vegetation management is necessary to maintain natural communities, successional processes, biodiversity, and ecosystem health.

Noxious weeds are classified by the Oregon State Weed Board (OSWB) as any plant that is injurious to public health, agriculture, recreation, wildlife, or any public or private property. They have become so thoroughly established and are spreading so rapidly on private, state, county, and federally owned lands in Oregon that they have been declared by Oregon Revised Statutes (ORS) 569-350 to be a menace to public welfare.

Noxious weeds have the potential to be eradicated or controlled in the state; however, steps leading to eradication and intensive control are necessary. Eradication and intensive control rests not only on private landowners and operators, but on the county, state, and federal government. To assist in control, the Oregon Department of Agriculture (ODA) Noxious Weed

Control Program and the OSWB maintain the state noxious weed list, which covers all lands within the State of Oregon.

#### 3.1.3.1 Classification of Noxious Weeds

The Noxious Weed Policy and Classification System (ODA 2013) establishes three categories for weeds within or having potential habitat in Oregon. Noxious weeds are listed as either A or B, and may be added to the T list, as directed by the OSWB, to receive priority in implementing noxious weed control projects. These classifications are defined below.

- Class "A" weeds—a weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent.
- Class "B" weeds—a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties.
- Class "T" weeds—a priority noxious weed designated by the OSWB as a target on which the Oregon Department of Agriculture (ODA) will develop and implement a statewide management plan. "T" designated noxious weeds are species selected from either the "A" or "B" list.

The Coos County Weed Board utilizes ODA's classification system; however, it distinguishes "A" weeds as those not known to occur in Coos County but its presence in neighboring counties make future occurrence in Coos County seem imminent. "T" weeds are listed as designated priority noxious weeds for the county.

#### 3.1.3.2 Noxious Weeds Sites

The current list of noxious weeds for Coos County, including their potential to occur at the Project site, is presented as Table 3.1-1. Of those species, 14 were encountered during field surveys conducted for the Project. Eight noxious weed species have been mapped for the LNG Terminal, South Dunes Power Plant, and construction worker camp sites in Figure 3.1-2. The mapped species include: Scotch broom, Himilayan blackberry *(Rubus discolor),* European beachgrass, gorse (*Ulex europaeus*), sweet fennel (*Foeniculum vulgare*), poison hemlock (*Conium maculatum*), pampas grass (*Cortaderia jubata*), English ivy (*Hedera helix*), parrotfeather, and Italian thistle (*Carduus pycnocephalus*). Gorse and parrotfeather are listed as target "T" species by both the county and State to receive priority for prevention and control.

**Project Site**

Scotch broom, Himilayan blackberry, and European beachgrass have been observed throughout the Project site. All three species in this association are dominant species in the disturbed habitats associated with the South Dunes Power Plant site and the Roseburg Forest Products wood chip export terminal site. This association was also noted to occur in the active dune lands north of Jordan Lake. Additional species include: poison hemlock, observed in the South Dunes Power Plant site along a stretch of Jordan Cove Road; pampas grass, observed scattered throughout the South Dunes Power Plant site, with additional sporadic pockets occurring along the north-south rail line westerly to, and including, the easterly side of Jordan Cove Road; and English ivy, observed along the southern South Dunes Power Plant access road to Jordan Cove Road.

The LNG Terminal site has pockets of gorse scattered throughout the lower half of the fill area at the slip site, beginning approximately 150 feet north of the gravel access road along the Coos Bay shoreline and extending approximately 1,800 feet to the north. At the northern reach, the gorse appears to have spread in a southeasterly direction to the forested dune. Gorse is also present along the eastern edge of Henderson Marsh and along the forested dune tree line to the southern gate for the site. There are a few gorse plants at the South Dunes Power Plant site, with the majority located just south of the existing power substation. Gorse has been sprayed within the past year at the sites discussed above as part of an ongoing control program recently implemented. All visible gorse is dead.

**Construction Worker Camp**

The eastern portion of the construction worker camp site contains an infestation of Scotch broom, Himalayan blackberry, and European beachgrass. This area is an abandoned industrial site created on dredge spoils that was most recently utilized as a log deck. Noxious weeds are the dominant vegetation cover at this site. Immediately west is another former dredge spoils site separated by lowlands and tidal influence that has created a separate peninsula resembling an island. This site is covered with the singular dominant species European beachgrass. Both sites are adjacent to high quality estuarine marshlands that necessitate protection from herbicide applications for the control of noxious weeds.

### 3.1.3.3 State and Federal Action Plans

At the state level, the Oregon Invasive Species Council (OISC) was created by the Oregon legislature (ORS 561.685) to conduct a coordinated and comprehensive effort to keep invasive species out of Oregon and to eliminate, reduce, or mitigate the impacts of invasive species already established in Oregon. The council began official business on January 1, 2002. Four main functions identified by the statute for the council include: 1) creating and publicizing a system for reporting sightings of invasive species and referring those reports to the appropriate agencies, 2) undertaking educational activities to increase awareness of invasive species issues, 3) developing a statewide plan for dealing with invasive species, and 4) funding eradication and education projects.

The OISC Action Plan for 2012-2016 (Appendix H.3) includes the mission, vision, and core values of the council, as well as key strategic actions the OISC seeks to engage in during that period. The action plan is the result of a planning effort following a statewide invasive species summit in 2011 and the completion of a management assessment of invasive species in Oregon. Each year the OISC provides an updated list of the 100 most dangerous invaders to keep out of Oregon. The list is comprised or micro-organisms, aquatic plants, land plants, aquatic invertebrates, land invertebrates, and fish species.

At the federal level, the U.S. Department of Interior's Bureau of Land Management (BLM), Coos Bay District, oversees lands in the vicinity of the Project and has lists of noxious weeds of concern described in its various resource management plans, including its *Final North Spit Plan* (2006). The BLM objective for weeds is to contain and/or reduce noxious weed infestations with an integrated pest management approach (e.g., chemical, mechanical, manual, and/or biological) and to avoid introducing or spreading noxious weed infestations in any areas. This is outlined in the BLM's multi-state environmental impact statement *Northwest Area Noxious Weed Control Program* (1985) and its supplements.

### 3.1.4 Unique and Special Status Species

Special status native vegetation classifications used for this analysis are based on the Oregon Wetland Explorer At Risk Wetland Associations Database (ORBIC 2009) and the Classifications of Native Vegetation of Oregon (ORBIC 2004). Rare vegetation classifications include both state rank (S) and global rank (G) for ORBIC Natural Heritage Ranking and are given the following numerical codes:

1. Critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation (gone from a portion of its former range), typically with 5 or fewer occurrences.
2. Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction or extirpation, typically with 6-20 occurrences.
3. Rare, uncommon, or threatened; but not immediately imperiled, typically with 21-100 occurrences.

Rare forest associations observed in the Project area include the shore pine-Douglas fir/wax myrtle-evergreen huckleberry (G3S3), shore pine-Sitka spruce/evergreen huckleberry (G3S3), and critically imperiled Port Orford cedar/evergreen huckleberry (G1S1). As previously noted, two Port Orford cedars are known to occur within the Project site that would be impacted. The Port Orford cedar/evergreen huckleberry forest association is sensitive because it is being decimated throughout its limited range by the POC root rot disease. In addition, the forested wetland (shore pine/slough sedge) east of Dune Forest C and the northern portion of Dune Forest B is considered rare/uncommon in ORBIC.

The shore pine/bearberry woodland association is sensitive due to its limited distribution, which is restricted to a thin band adjacent to the coastline, and the fact that it is easily damaged by human disturbances. Rare woodland associations include shore pine/bearberry (G1S1) and shore pine/hairy manzanita (G1S1). Both associations are found in limited distribution at sites associated with Dune Forest B where openings occur within the forest canopy. These associations were also observed in the Panhandle mitigation site, most notably at the interface between dune and forest habitats.

Rare herbaceous associations include red fescue-salt rush (G3S3) and American dunegrass (G1S1). Both of these rare associations were observed on significantly disturbed habitat associated with the dredge spoils fill site located east of the Henderson Marsh.

A list of the individual special status botanical species that have the potential to occur within forested, woodland, shrubland, and herbaceous associations referred to above is included in Table 3.1-2, including numerous lichen species. The list includes BLM special rankings and ORBIC state and global rankings. Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project site are not included in the list, as they discussed in detail in Section 3.4.

### 3.1.5 Along the Waterway

Vegetative communities along the route of the LNG carriers are typical of the Coos Bay region for estuaries and shorelines. Vegetated areas within the Zones of Concern consist of forest, woodland, shrubland, and herbaceous plant associations with a component of wetland areas (salt and freshwater marshes). The most prominent vegetation within this area includes a mix of herbaceous sand dunes, shore pine forests, Sitka spruce forests, salt marshes, and freshwater marshes. Marine, estuarine, lacustrine, and palustrine wetlands occur along the LNG carrier transit route. The southeastern side of the bay is urbanized and native vegetation has been modified by residential and commercial developments.

### 3.1.6 Environmental Consequences (Construction and Operation)

The majority of vegetation that will be impacted by the Project is forested associations, with minor impacts to shrublands and herbaceous wetland associations. Direct impacts are expected to include removal of a portion of the overall habitat. The most substantial direct impact to botanical resources within the study area is a reduction in the quantity of plant species (including trees) that occur in the dune forests and adjacent areas impacted. In addition, the Project would result in impacts to natural resources within the intertidal and shallow subtidal zone of Coos Bay, and a small area of freshwater emergent wetland would also be impacted. These resources provide important ecological functions to the greater Coos Bay ecosystem. Table 3.1-3 includes details on the types and amount of vegetation that will be impacted by the Project, including the acreage volumes, per 18 CFR Part 380.12(e)(3).

The Project is not expected to have a long-term significant impact to vegetation resources, as the areas that will be graded and cleared for construction are relatively common and widespread throughout the North Spit and the Project vicinity. The Project footprint was selected on the basis of avoiding, to the extent practical, unique vegetation communities and higher value wetlands. Selection of temporary construction sites was purposely restricted to upland areas to avoid impacting wetlands.

The Project will affect approximately 1.74 acres of forested wetlands and approximately 35 acres of non-forested wetlands during construction and 1.73 acres of forested wetlands and 34.34 acres of non-forested wetlands during operation (Table 2.2-1 of Resource Report 2 – Water Use and Quality). This is the total wetland area of wetlands affected, both terrestrial and non-terrestrial, and includes those wetlands that will require mitigation as well as those that do not, as described further below. In addition to the total area of wetlands affected, totals are presented in Table 2.2-1 for affected terrestrial and non-terrestrial wetlands, and for terrestrial and non-terrestrial wetlands that will require mitigation.

The approximately 35 acres of non-forested wetlands affected by construction and approximately 34 acres affected by operation include 13.07 acres of intertidal and shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass affected by the slip and access channel and the construction dock. Acreage-based mitigation for impacts to the 15.24 acres of deep subtidal habitat by creating new deep subtidal habitat is not proposed. Dredging the access channel will deepen existing deep subtidal habitat. Also, new deep subtidal habitat will be created as a product of excavating the slip, but this is not viewed as mitigation.

Approximately 1.75 acres of wetlands F and G are associated with the waste treatment ponds remaining from the remedial action at the now demolished Weyerhaeuser linerboard mill. While these wetlands are considered jurisdictional under Section 404, mitigation for the 1.75 acres will not be required as the filling of these wetlands has been authorized in the ODEQ site closure plan.

The Project site also includes approximately 45.4 acres of land with 32.3 acres of delineated wetlands that will not be disturbed by the Project and will in fact be preserved as a result of the Project. Approximately 10.9 acres (Area E3 on Figure 1.2-1 in Resource Report 1 – General Project Description) of these 45.4 acres of preserved wetlands include Henderson Marsh and are included as part of the Project site property simply to provide sufficient property under the direct control of JCEP for the thermal radiation exclusion zones. The thermal radiation exclusion zone is a modeled indication of an area that could be affected in the highly unlikely event of an LNG spill or fire at the Project site. There are no thermal radiation or vapor effects from the Project that would have an adverse effect on the wetlands during the normal operation of the Project.

The liquefaction facilities and the access/utility corridor will affect approximately 2.58 acres of forested, scrub shrub, emergent and ponded wetlands during construction and approximately 1.51 acres during operation (as indicated in Table 2.2-1). The loss of these wetlands will be mitigated by the preservation and enhancement of areas owned by JCEP and located to the north of the Project site and the Trans-Pacific Parkway. This area is referred to as the Panhandle mitigation site and will be described in detail in the mitigation plan referenced below.

The loss of 9.69 acres of intertidal and 3.38 acres of shallow subtidal wetlands, due to the construction of the slip and access channel and the construction dock, will be mitigated by the restoration of wetlands at a former golf course. This area is now known as the Kentuck wetland mitigation site. The loss of approximately 2.49 acres of eelgrass will be mitigated at a proposed eelgrass mitigation site south of the west end of the Southwest Oregon Regional Airport. Alternative eelgrass mitigation sites are currently being evaluated, with one of those areas being in Jordan Cove.

Specific impacts to dune forests occurring at the Project site and the potential for root rot disease to occur in Port Orford cedar are discussed below.

#### 3.1.6.1 Dune Forests

Dune Forest A will be impacted with the construction of the access/utility corridor and the control building/plant warehouse/maintenance building. The majority of this dune forest will be unaffected by the development of the Project. Impacts will include the removal of 1.8 acres of shore pine-Sitka spruce/evergreen huckleberry forest, 0.3 acres of shore pine-douglas fir/wax myrtle-evergreen huckleberry, and 1.9 acres of Port Orford cedar/evergreen huckleberry, including two Port Orford cedars observed northwest of Jordan Lake.

Dune Forest B will be impacted by the development of the slip, LNG loading berth, liquefaction process area, LNG storage tank area, refrigerant storage area, flare area, and laydown area. Dune Forest B includes approximately 61.4 acres of shore pine/Sitka spruce/evergreen huckleberry forest.

Nearly half of Dune Forest C is located in the sand dune area (E2), which will be partially impacted by fill during construction. A total of 5.8 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest is located in this area and has the potential to be impacted. Permanent impacts to the site are proposed to affect 6.3 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest with the development of the laydown area.

The LNG Terminal site access and fill area will impact 3.4 acres of Dune Forest D, including shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest.

Dune Forest E will be affected by the construction of the access/utility corridor and the ancillary Southern Oregon Regional Safety Center (SORSC) just east of Jordan Cove Road. The affected area includes 4.5 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest and 0.6 acres of red alder/salmonberry/slough sedge-skunk cabbage forest.

#### 3.1.6.2 Port Orford Cedar

Spread of the POC root rot disease has the potential to occur at the Project site from contaminated equipment. Surveys for POC root rot disease were not conducted in the Project area, but based on what is known about the disease, it is likely to be present in the Coos Bay area, regardless of whether infected trees have been identified.

### 3.1.7 Mitigation, Enhancement, and Protection Measures

Site areas that are disturbed by construction of the Project will be stabilized by applying Best Management Practices (BMPs) for temporary sediment and erosion control measures until construction is complete, unless covered by equipment, gravel, or other covering. Site areas that are disturbed only by temporary construction activities (i.e., will not be permanently affected by a Project component) will be restored using non-invasive native plant species, to the extent practicable, to achieve stabilization of the sites and to prevent erosion of the areas disturbed.

Environmental monitoring would be conducted in all of the areas disturbed and would focus upon stabilization and prevention of erosion. This would be an ongoing activity on the Project site. In areas temporarily disturbed by construction, environmental monitoring will continue until a sufficient vegetative cover has become established. All construction activities and the operation of the facility will meet the requirements of JCEP's Upland Erosion Control, Revegetation, and Maintenance Plan (Plan) and JCEP's Wetland and Waterbody Construction and Mitigation Procedures (Procedures), including the implementation of Project-specific plans and procedures.

In addition, following the dredging activities to create the slip, all disturbed areas will be stabilized immediately with a dunegrass seed mixture compatible with Natural Resources Conservation Service (NRCS) criteria as being capable of surviving in highly permeable substrates in order to withstand seasonal soil moisture changes, loose sand, and burial and deflation from aeolian (wind) processes. Wind may erode, transport, and deposit materials, and particularly needs to be addressed in areas of the Project site with sparse vegetation and a large supply of unconsolidated sediments.

Native species will be used and if any non-native species are required for specific problem areas, species will be selected that will not become nuisance species to the surrounding areas. Should there be any areas disturbed by the excavated material haul truck road, the heavy equipment haul road, or the hydraulic slurry/decant water return pipelines that do not become part of the access and utility corridor for the LNG Terminal, they will be restored to pre-construction condition.

Impacts to wetlands will be mitigated through the implementation of an approved compensatory wetland mitigation plan. Compensatory mitigation is a method of offsetting adverse effects and is considered only after all measures to avoid and minimize impacts have been exhausted. A compensatory wetland mitigation plan has been prepared in accordance with the Oregon Department of State Lands administrative rules to address impacts to wetlands. It is provided as Appendix M.2 in Resource Report 2 – Water Use and Quality.

#### 3.1.7.1 Control of Exotic, Invasive Species

JCEP will implement treatments to remove exotic and noxious species. In addition, to avoid introducing or spreading noxious weeds or invasive species, JCEP will conduct a pre-construction survey of the Project site to identify noxious species listed by the ODA that persist despite recent and previous control efforts. Following the survey, JCEP will employ standard removal practices as approved by the BLM for the species identified on the Project site. Methods for removal that would not aid in the dispersal of these species will be used and will include the use of integrated BMPs such as fire, mechanical or manual removal, and herbicide application, as appropriate. Treated areas would be restored by spreading native seed and planting native plants. BMPs would also be implemented to prevent the further spread of noxious weeds.

JCEP will follow the BLM's existing policy and procedures for ongoing noxious weed control. Construction equipment that will be used off the Project site will be cleaned to prevent the export and spread of noxious weed species and seeds. JCEP will also use herbaceous and native dune seed mixes to limit germination of noxious weeds during the stabilization and restoration of the Project during and following construction. Once the overall Project site is stabilized and in operation, the site will be checked for noxious weed infestations and control measures will be implemented that are consistent with ODA, OISC, and BLM noxious weed control plans and policies, as applicable.

#### 3.1.7.2 Control of Diseases

JCEP will take precautions during the construction of the Project to minimize the introduction or spread of POC root rot disease from contaminated earth moving equipment. Surveys will be conducted prior to construction to identify whether the disease occurs on site and if so, measures will be taken to decontaminate equipment before leaving the site and to prevent cross contamination between soil and water. In addition, all equipment will be decontaminated before beginning work on the site. If the disease is found during pre-construction surveys, maps with precise locations will be provided to all contractors and site construction personnel to minimize and help prevent the spread of the disease to off-site locations. To ensure adequate conservation measures to address POC root rot disease are in place and implemented, JCEP will follow the BLM's existing policies and procedures.

## 3.2 WILDLIFE

A number of habitats exist on the Project site that support a variety of wildlife species as temporary or permanent residents. Approximately 178 tetrapod species (amphibians, reptiles, birds, and mammals) were recorded on or adjacent to the Project site during surveys conducted in October 2012 and during previous surveys from June to December 2005 and in early 2006 (Table 3.2-1). Terrestrial species include approximately 115 species. Approximately 151 seasonal or year-round resident bird species occur in the Project site area, and a variety of habitats suitable for migratory birds exists within the Project site boundaries. Also, as would be expected for the area, species utilizing aquatic habitats comprise the greatest occurrence by an individual species or by the number of individuals within a species. Species types and densities are directly related to season of year, preferred habitats, food resources, and protective cover.

The Project also includes compensatory mitigation sites outside of the Project footprint at Kentuck and the Panhandle for wetlands, wildlife, and estuarine habitat impacted by the Project. Although no degradation in the quality of the habitat at the mitigation sites is anticipated, they are included in this review to determine a baseline habitat.

Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project vicinity are presented in this section and discussed in detail in Section 3.4.

### 3.2.1 Wildlife Habitat Characterizations

Characterizations of wildlife habitats potentially affected by construction of the Project were based on resource agency consultation, habitat surveys, and published reports, in accordance with the habitat categories described in the Oregon Department of Fish and Wildlife (ODFW) Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0025). The ODFW has established the following six classifications for habitats, based on dominant plant, soil, and water associations of value to the support and use of fish and wildlife:

Category 1 – irreplaceable, essential habitat

Category 2 - essential habitat

Category 3 - essential or important habitat

Category 4 - important habitat

Category 5 - habitat having a high potential to become essential or important habitat

Category 6 - habitat that has a low potential to become essential or important habitat

The ODFW habitat categories have been used to characterize wildlife habitats occurring on the Project site (Table 3.2-2). Habitat classifications for the Project site were qualified with ODFW personnel concurrence following field reconnaissance beginning in November 2006. Approved wildlife habitat categories were memorialized in November 2012 (DEA 2012). For the Project, Category 2 habitat occurs in open water, emergent wetland, forested/shrub wetland, and algae/mud/sand subtypes for surface water. The accepted ODFW wildlife habitat types and assigned categories for the Project site are shown in Figure 3.2-1 and summarized below. The Project does not have any Category 1 habitat.

#### 3.2.1.1 Upland Habitat

Upland wildlife habitat types found in the Project site are typical of the North Spit area of Coos Bay. Shore pine and Sitka spruce forests constitute the habitat with the greatest structural complexity on the North Spit and support the greatest diversity of wildlife species. The trees, snags, and down logs not found in other plant communities provide important breeding, foraging, and cover habitat for a variety of wildlife species. Upland amphibians seek cover in down logs, and many bird species (including raptors, woodpeckers, and songbirds) nest and forage in these habitats.

Emergent, shrub, and forested wetlands occurring in upland habitat are classified as Category 2 as essential wildlife habitat that is limited, but is replaceable through mitigation. Coastal dune forest and riparian forest habitats are classified as Category 3 because they are essential to wildlife but not limited. Although the unvegetated sand upland habitat formed by dunes is generally devoid of vegetation, it still provides important and essential, though not limited, habitat for a variety of wildlife and is therefore classified as important in Category 4. Upland grasslands and shrublands are also classified as Category 4.

#### 3.2.1.2 Open Water/Wetland Habitat

Open water habitats on the Project site and adjacent land are comprised of several freshwater lakes, ponds, and tidally influenced marshes on the terrestrial side of the shoreline. The marine open water environment consists of the Coos Bay estuary to the mouth of the bay, continuing westward into the open sea along the Pacific coast, and is discussed further in Section 3.3 for fisheries and marine resources. Habitats found in this environment support a rich wildlife community.

Herbaceous emergent wetland, scrub-shrub, and forested wetland habitat are all classified as Category 2 because they are essential for wildlife and limited, but can be replaced through mitigation. These habitats are used by various amphibians, birds, and invertebrates. The amount of cover and available prey or plant foods determine which species occur in these habitats. Black-tailed deer and rabbits occur throughout these communities, and songbird species feeding on plant seeds and insects take cover in the dense shrubbery. Mammalian predators such as skunks, foxes, coyotes, raccoons, mink, and bobcats prey on small mammals, birds, eggs, reptiles, and insects occurring in these habitats.

Flora and fauna usage of open water habitats occurring at the Project site (wetlands, estuarine, or marine) are generally specialized, or show strong preference for one habitat type over another. However, there are dozens of species associated with the Project area that are very well adapted to utilizing one, two, or all three of these open water habitats, as seasonal conditions warrant. Mudflats and sandflats found on the North Spit’s bay side are tidally-inundated and provide foraging habitat for a variety of birds and mammals. Resident and migrant shorebirds congregate there, especially during low tides, to forage on the invertebrates in the shallow waters and exposed mudflats. The concentration of shorebirds and wading birds in these habitats provide prey for bald eagles, northern harriers, and peregrine falcons. Ravens, gulls, raccoons, mink, and skunks forage in these areas for shellfish and invertebrates. The portion of the open water habitat that will be impacted by the construction and operation of the Project is classified as Category 2 because it is essential for wildlife, and limited, but can be replaced through mitigation.

#### 3.2.1.3 Developed Habitat

Developed areas include portions of the Project site that have been significantly disturbed by previous development and industrial use, including land use activities such as demolished mill foundations/concrete pad, roads, unvegetated cut slopes, rocked yards, and maintenance building footprints. This includes paved roads, parking lots, gravel roads, concrete lay down areas, log deck storage areas, and sandy roadside areas. They have limited potential to become important or essential in the foreseeable future and are therefore classified as Category 6.

#### 3.2.1.4 Regional Wildlife Management Areas

The North Spit Area of Critical Environmental Concern is approximately 5 miles southwest of the Project site and is administered by the BLM. No other federal wildlife refuges, state game, or wildlife management areas exist in the immediate Project vicinity. Marine reserves, wildlife refuges, and coastal management areas are discussed further in Section 3.3.

### 3.2.2 Existing Resources

The proposed Project site provides suitable habitat for a number of wildlife species associated with the coastal, mid-coastal, interior foothills, and mountain terrains that construction and operation of the proposed Project could affect. The majority of wildlife species detected on or adjacent to the Project site during the 2005/2006 and 2012 surveys were birds. Approximately 107 out of 151 bird species recorded were located within the Project area. Project areas surveyed and assessed in 2012 are shown in Figure 3.2-3.

#### 3.2.2.1 Amphibians and Reptiles

The BLM recognizes 11 species of amphibians (8 salamanders, 3 frogs) occurring on the North Spit (BLM 2005). Despite the presence and continual threat of invasion by non-native bullfrogs

(*Rana catesbeiana*), native amphibians were observed within suitable habitat during the wildlife surveys conducted in 2005 and 2006 for the LNG Terminal site. Northern red-legged frogs (*Rana aurora aurora*) and northwestern salamanders (*Ambystoma gracile*) are abundant within some wetlands within the Project site. It is likely that where bullfrog have not been introduced or invaded, native amphibians are present.

The BLM has observed at least 10 species of reptiles on the North Spit (BLM 2005), including the northwestern pond turtle (*Clemmys marmorata marmorata*). However, northwestern pond turtle was not observed during limited pre-construction wildlife surveys of the Project site area (LBJ 2006). Palustrine wetlands are relatively common on the North Spit so it is likely that a substantial amphibian and reptile assemblage exists. With the exception of sea turtles, amphibians and reptiles would likely occur in terrestrial habitats along the LNG carrier transit route.

#### 3.2.2.2 Birds

The Project is located in the statewide Pacific Flyway path for migratory birds. The Southern Oregon coast provides wintering and migratory habitat for birds and Coos Bay is one of a number of important areas for shorebirds between San Francisco Bay and British Columbia. Key areas for migrating shorebirds include the bay and shoreline, along with wetlands and deflation plains found throughout the North Spit. Coos Bay's extensive eelgrass beds, productive sloughs, intertidal algal flats, and substantial tidal marshes (1,726 acres) provide valuable habitat for thousands of shorebirds.

The BLM has documented 275 avian species using habitats on or near the North Spit of Coos Bay (BLM 2005). In addition, LBJ Enterprises (2006) documented 151 avian species during pre-construction surveys of the Project site, including two additional species not documented by the BLM. A mosaic of habitat types occurs within and near Coos Bay within the LNG carrier transit route zones. Some of the most important habitat types for birds include nearshore rocks and islands, beaches, dunes, coastal forests, and Palustrine and estuarine wetlands. The location of migratory bird habitat occurring within the zones of the LNG carrier transit route is shown in Figure 3.3-7, which also includes marine mammals.

Federal and state-listed threatened, endangered, or proposed species, including the brown pelican, bald eagle, short-tailed albatross, streaked horned lark, and western snowy plover are discussed in Section 3.4. Forests further inland from the Project provide habitat for the northern spotted owl and the marbled murrelet and these two species are also discussed in Section 3.4.

**Shorebirds**

Foraging habitat for shorebirds includes intertidal mudflats, rocky intertidal, estuaries, salt marshes, and beaches. Shorebirds are most often associated with exposed mudflats for foraging and salt marshes for resting and preening. The vast majority of shorebirds are migratory and non-breeders in Coos Bay. An important exception would be the western snowy plover (*Charadrius alexandrinus nivosus*), which nests on upper beaches on the North Spit of Coos Bay. Shorebirds are most likely to be encountered along the beaches of the North Spit and within the bay along tidal mudflats, salt marshes, and other exposed estuarine habitat in the 0.3 and 1.0 mile zones.

**Waterfowl**

Waterfowl habitat is as diverse as the birds themselves, varying from ocean surf to fields and open meadows to upland streams (USFWS 2007a). Coos Bay has long been recognized as an important migration and wintering waterfowl location. Waterfowl are most likely to be encountered within Coos Bay and the immediate nearshore habitat within the LNG carrier transit route zones.

**Passerines (Song Birds)**

Breeding and feeding habitat for migratory passerines is associated with terrestrial and wetland habitat within Coos Bay. Important habitat includes coastal scrub-shrub, coastal dune forest and Palustrine wetlands. In the case of swallows, human-made structures can be important structures for nesting colonies. Passerines are most likely encountered in suitable terrestrial habitats along the LNG carrier transit route 2.2 mile zone.

**Wading Birds**

Several wading bird species are residents within the Coos Bay area and the North Spit. Wading birds are typically colonial when nesting and therefore are sensitive to human disturbance. Wading birds hunt in a variety of habitat types from fields and meadows to Palustrine and estuarine wetlands. At least two historic great blue heron (*Ardea herodias*) rookeries occur within close proximity to the Project site LBJ 2006) and are discussed in Section 3.4.2 for unique and special status species. Recent field surveys have indicated that the rookeries are currently not occupied by species. Wading birds are most likely to be encountered along the LNG carrier transit route zone. A discussion of the current status of these historic rookeries is provided below.

**Birds of Prey**

Predatory birds are abundant year round residents in Coos Bay. The BLM has observed 14 species (BLM 2005), and surveys conducted by LBJ (2006) detected both peregrine falcons (*Falco peregrinus*) and bald eagles (*Haliaeetus leucocephalus*) near the Project area. Coos Bay and the North Spit provide a mosaic of habitat types with abundant prey for raptors. White-tailed kites (*Elanus leucurus*) were regularly observed during 2005 surveys, especially near Henderson Marsh. Osprey (*Pandion haliaetus*) are relatively common near river estuaries and bays and nest on human-made structures including the Roseburg Forest Products facility lights.

Predatory birds (i.e., hawks and owls) are most likely to be encountered within Coos Bay in terrestrial habitats. Osprey, falcons, and eagles may be encountered in nearshore habitats along the LNG carrier transit route. Falcons in particular are likely to be associated with salt marsh and tidal mudflats where shorebirds are likely to be abundant.

**Sea Birds**

Although the length of the Oregon coast is less than a quarter of the entire Washington, Oregon, and California coastline, over one-half of the nesting seabirds of this coastline are found along the Oregon coast (Oregon Ocean Resources Management Task Force 1991). Thirteen sea bird species breed along Oregon's coast, with offshore rocks and islands providing critical nesting habitat and important rest-over locations. Seabirds depend on relatively undisturbed coastal nesting habitats and on the rich coastal waters for food. Foraging habitat can differ by species; some species such as the sooty shearwater (*Puffinus griseus*) and the northern fulmar (*Fulmarus glacialis*) are found primarily along the mid and outer shelf, while California and western gull (*Larus californicus, L. occidentalis*) occur only in the nearshore (Oregon Ocean Resources Management Task Force 1991). Foraging sea birds can be encountered along the entire LNG carrier transit route in the 0.3 and 1.0 mile zones. Nearshore rocks and islands are of greatest importance to sea birds for nesting habitat.

**Migratory Bird Treat Act**

The Migratory Bird Treaty Act (MBTA) of 1918, as amended, provides federal protection for migratory birds, their nests, eggs, and body parts from harm, sale, or other injurious actions. The MBTA protects nearly all of the native species of birds. The only exceptions are introduced species, including English (house) sparrow, starlings, and rock dove (commonly known as park pigeons). There is no federal protection for upland game species (chuckar, pheasant, quail, and grouse), but most states protect these species. U.S. Fish and Wildlife Service (USFWS) permits are required to take, capture, relocate, or possess any of the protected species of birds or their parts, nests, or eggs. The MBTA includes a 'no take' provision and consultation with the USFWS is required if an action is determined to cause a potential take of migratory birds. The consultation determines measures to minimize or avoid these impacts.

Birds and nests are protected under MBTA, but habitat is not. Habitat is only protected when there is an active nest (a nest with chicks or eggs being tended by an adult). Empty/abandoned nests and nonviable eggs are not protected, but cannot be taken into possession without a permit during the nesting season. Outside of the nesting season, permits are not required to remove an empty or abandoned nest, or to remove or alter the structure the nest is built in or on. The MBTA policy excludes eagle nests and nest trees, which are protected under the Bald and Golden Eagle Protection Act, as amended in 1962, and threatened or endangered species, which are protected under the Endangered Species Act.

The USFWS advises that large clearing projects be conducted prior to March 1 or after August 31 to ensure most nesting birds have fledged. If construction activities occur during the nesting season, trees should be surveyed for the presence of any active nests. If there are none in the trees or the immediate area, and there are no active nests close enough for the activity of taking down trees to disturb the nesting birds, they can be removed without permits. If there should be a nest in one tree, the tree should be marked and activity limited around that area until the birds fledge, perhaps leaving that tree for the last of the project.

Unless the nests are in a location to pose a risk to human safety or the birds, there is no permit the USFWS can issue. Examples of human safety issues are permits issued to airports to protect air traffic and nests built on active power equipment which pose a fire hazard. There are no 'incidental take' permits under the MBTA. Any activity that involves habitat destruction during nesting season should proceed with caution.

### 3.2.2.3 Mammals

The BLM has documented 58 mammal species on the North Spit (BLM 2005). Pre-construction wildlife surveys conducted in the area of the Project site in 2005 and 2006 documented 16 mammal species (LBJ 2006). The Coos Bay area and North Spit provide a substantial amount of high quality habitat allowing for a diverse assemblage of mammals. For example, nine species of bats are known to occur on the North Spit (BLM 2005). While bat specific surveys were not completed during the pre-construction wildlife surveys, the mosaic of habitat types and abundant over-water foraging habitat present within the Coos Bay area suggest bat presence is high. The Pacific fisher (*Martes pennant pacificus*) and American marten (*Martes Americana*), as well as large mammals such as mountain lion (*Felis concolor*), Roosevelt elk (*Cervis elaphus roosevelti*), and black bear (*Ursus americanus*) have been documented on the North Spit (BLM 2005).

With the exception of pinnipeds (i.e., seals, sea lions) and unlikely but possible whale occurrences, all mammals encountered along the proposed LNG carrier transit route would be in terrestrial habitat types on the North Spit and the southwestern side of the bay. Bats may be encountered at any point along the proposed transit route within Coos Bay itself.

### 3.2.3 Wildlife Occurring in Project-Specific Sites

Wildlife that has the potential to occur in each major component of the Project is described below.

#### 3.2.3.1 Project Site

The natural habitat in the immediate area of the LNG Terminal has been altered by the historic use of this property, including the area east of Henderson Marsh (referred to as the Ingram Yard) that has been altered by the historical Henderson Ranch settlement and past placement of dredged material; the current Roseburg Forest Products wood chip export terminal; and the former Weyerhaeuser linerboard (paper) mill site (South Dunes Power Plant site). East of Ingram Yard, the Project site includes a dune forest where the majority of the site's natural habitats, as described in Section 3.1, remain unaltered by industrial activity. Structures located immediately adjacent to the Project site include two large buildings (Roseburg Forest Products Company north and south buildings), a few small outbuildings, and a substantial concrete lay down area east and south of the two buildings. Additionally, there are two large water tanks on the Project site within Dune Forest B along the ridgeline (see Figure 3.1-1). A dirt road provides access to the water tanks from the developed area.

East of Dune Forest B and north of the Roseburg Forest Products facility, the Project site includes an access/utility corridor that crosses along the northern boundary of the Roseburg Forest Products property and includes mature dune forests and an area of active dune. This corridor includes utilities supporting the disposal of industrial wastewater from the landfills located on the South Dunes Power Plant site. The South Dunes Power Plant site includes asphalt surfacing, gravel access roads, and previously disturbed grassland habitats. Immediately west, a mosaic of emergent and scrub-shrub wetlands interspersed in coastal dune forests occurs. This area also includes a portion of Jordan Cove Road. With the exception of the access/utility corridor, the entire Project site is bordered by the Trans-Pacific Parkway on the northern perimeter.

#### 3.2.3.2 Construction Worker Camp

The temporary construction worker camp site includes two distinct areas (eastern and western) intersected by North Point Slough. The eastern half of the site includes an abandoned industrial area that is the remains of a logging deck used to store logs until recently. The western half of the site includes a historical dredge spoils site. The highly disturbed eastern half has been filled and road prisms (gravel) have been built throughout the majority of the site. The former dredge spoils site on the western half lacks infrastructure and is occupied with an abundance of non-native weedy species, including dominant species European beachgrass and Scotch broom. High quality estuarine habitat was observed in the North Point Slough that intersects the site.

Wildlife habitat observed at the construction worker camp site includes foraging habitat for numerous species that can exist without tree cover. Breeding habitat is limited to species adapted to breeding in disturbed habitats that lack a significant tree cover. Wildlife observed (including sign) at the site include American robin (*Turdus migratorius)*, common raven (*Corvus corax*), western gull (*Larus occidentalis*), turkey vulture (*Cathartes aura*), and black-tailed deer (*Odocoileus hemionus*). Typical bird species that have potential to use the site include common species associated or adapted to disturbed habitat types, including but not limited to, common raven, American robin, foraging peregrine falcon, white-tailed kite (*Elanus leucurus*), American goldfinch (*Carduelis tristis)*, and western gull. Mammals likely to use the site include, but are not limited to, opossum (*Didelphis virginiana*), black-tailed deer, striped skunk (*Mephitis mephitis*), and raccoon (*Procyon lotor*).

### 3.2.3.3 Compensatory Mitigation Sites

The eelgrass mitigation site is discussed under Section 3.3 for fisheries and marine resources.

**Kentuck Wetland Mitigation Site**

Kentuck Slough has been identified as an estuarine and wetland mitigation site for the Project. This site includes a previously maintained golf course that closed down several years ago and is currently being used sporadically for cattle grazing. The area consists of former golf course infrastructure that includes roads, trails, fencing, and landscaping and is surrounded by semi-rural housing.

Wildlife species observed at the site include numerous wading, ground foraging, and aerial foraging species. The diversity in habitat types present (wetland, grassland, and patchy forest sites) makes this area ideal habitat for many local species. Species observed include American crow (*Corvus brachyrhynchos)*, barn swallow (*Hirundo rustica)*, great egret (*Ardea alba)*, mallard duck (*Anas platyrhynchos)*, marsh wren (*Cistothorus palustris)*, and song sparrow (*Melospiza molodia)*. Wildlife species with potential to use the site include numerous species, including common mammal species associated with rural residential areas such as black-tailed deer, black bear (*Ursus americanus*), striped skunk, and raccoon. Numerous bird species with potential to use the site for foraging include Canada goose, great egrets, waterfowl, shorebirds, wading birds, and many more. Potential nesting habitat for raptors and other breeding birds was observed in forest sites bordering Kentuck to the south and southwest, and includes potential nesting habitat for osprey, bald eagles, and red-shouldered hawks.

On any given morning or evening, numerous bird species can be observed foraging in the Kentuck Slough immediately west of East Bay Drive that separates the estuary from the site. It is not uncommon to see numerous great egrets, geese, ducks, smaller shorebirds, and occasional great blue herons in this area. The former golf course, with its grasslands still mowed and maintained, often sits empty in comparison. If opened up to expand the estuarine and subtidal area at the site, the now marginal Kentuck site inland has the potential to become an extremely productive site where even more amphibian, bird, and mammal species would seek its shelter and prime foraging and nesting habitat.

**Panhandle Mitigation Site**

The Panhandle is a proposed wildlife and wetland mitigation site for the Project and contains habitat types typical of deflation plains found throughout the North Spit. Habitats observed at the site include forest, shrubland, and herbaceous communities.

Wildlife species with potential to occur in the Panhandle include species that require or utilize forests, shrubland, open water, and/or sand dune habitats. This habitat is exceptional for amphibian species such as northern red-legged frogs and Northwestern salamander. Bird species expected to occur include waterfowl species such as wood duck (*Aix sponsa*), Eurasian wigeon (*Anas platyrhynchos*), herons and egrets such as great egret (*Ardea alba*), and great blue heron (*Ardea herodias*), as well as numerous song birds including brown creeper (*Certhia americana*), and marsh wren (*Cistothorus palustris*). This habitat has the potential to provide nesting and foraging habitat for raptor species such as Cooper's hawk (*Accipiter cooperii*) and sharp-shinned hawk (*Accipiter striatus*). Mammal species with the potential to occur in the

Panhandle mitigation area include black bear and American beaver (*Castor Canadensis*), to name a few.

### 3.2.4 Unique and Special Status Species

Special status wildlife species occurring in Coos County are listed in Table 3.2-3, along with their rankings for local, state, national, and global occurrences. In addition, Table 3.2-4 lists the potential for occurrence of these species at various sites for the Project, including general habitat requirements.

#### 3.2.4.1 Amphibians and Reptiles

**Clouded Salamander**

The clouded salamander (*Aneides ferreus*), known to occur on the North Spit and listed as state sensitive-vulnerable, was not found during site surveys, but the dune forests in the Project area could support this species.

**Northern Red-legged Frog**

The northern red-legged frog is a federal species of concern. Habitat for the northern red-legged frog includes the vicinity of permanent waters of marshes, ponds, and other quiet bodies of water. This frog regularly occurs in damp woods and meadows some distance from water, especially during wet weather. All age classes of this species were observed at the eastern edge of Henderson Marsh and high concentrations of northern red-legged frogs were observed in multiple freshwater wetland sites throughout the Project site (LBJ 2006, SHN 2012). American bullfrogs, a known predator of the northern red-legged frog, were observed during surveys in wetlands conducted in 2005-2006, but were not observed in 2012. Though not observed, this species is a long-lived and highly adaptive species that is an opportunistic predator of small animals, including other amphibians.

**Northwestern Pond Turtle**

The northwestern pond turtle is listed as a federal species of concern and state sensitive–critical. Even though this species was not found on the Project site, it is known to occur on the North Spit. Jordan Lake and other wetlands and adjacent dunes on the Project site seem to be suitable for this turtle, although the soil may be too sandy to allow turtles to nest.

**Western Toad**

This species (state sensitive–vulnerable) was not found on the Project site and is not listed by the BLM as occurring on the North Spit.

#### 3.2.4.2 Birds

Fifteen special status bird species were observed throughout the Project area during wildlife surveys conducted in 2005-2006 and in 2012 (Figure 3.2-4). Detections of special status birds during surveys include species of grebes, waterfowl, hawks, nightjars, pigeons, flycatchers, and swallows. Special status waterfowl and grebes observed in Coos Bay and associated wetland and grassland habitats include the following species: Clark's grebe (*Aechmophorus clarkia*) and western grebe (*Aechmophorus occidentalis*), observed at sites near the bay adjacent to the Project; Aleutian cackling goose (*Branta hutchinsii leucopareia*), federally delisted, observed foraging near the airport and flying over the Project site; bufflehead (*Bucephala albeola*), observed just offshore of the Project site; horned grebe (*Podiceps auritus*), common in Coos Bay and observed offshore near the Project site; and red-necked grebe (*Podiceps grisegena*), state critical, observed offshore near the Project site.

Special status hawk and nightjar were observed at several locations at or near the Project area and were recorded as flying over or foraging. They include the following species: common nighthawk (*Chordeiles minor*), a single occurrence observed as a fly-over at the Project site; American peregrine falcon (*Falco peregrinus anatum*), federally delisted and state vulnerable, observed foraging above the southwest edge of Henderson Marsh and at the Project site; and white-tailed kite (*Elanus leucurus*), observed over Henderson Marsh and the Jordan Cove area multiple times. In addition, the Arctic peregrine falcon (*Falco peregrinus tundrius*), state sensitive–vulnerable, is reported as a rare visitor to the Oregon Coast and Coos County.

Additional special status birds include pigeon, passerine, quail, and meadow lark. They include the following species: band-tailed pigeon (*Patagioenas fasciata*), federal species of concern, recorded once at the Project site; purple martin (*Progne subis*), federal species of concern and state critical, observed multiple times during the breeding season, with active nests within view of the Project site; olive-sided flycatcher (*Contopus cooperi*), federal species of concern and state vulnerable, recorded singing near the LNG Terminal site; little willow flycatcher (*Empidonax traillii brewsteri*), state vulnerable, recorded near the South Dunes Power Plant site, mountain quail (*Oreortyx pictus*), federal species of concern and state vulnerable, observed in Dune Forest B near the water tanks; and western meadowlark (Sturnella neglecta), state critical, observed once at the Project site.

Special status bird species that are considered likely to occur (moderate to high potential for occurrence) in the Project area but have not been detected include the following: upland sandpiper (*Bartramia longicauda*), federal species of concern and state critical; black oystercatcher (*Haematopus bachmani*), federal species of concern and state vulnerable; yellow-breasted chat (*Icteria virens*), federal species of concern and state critical; acorn woodpecker (*Melanerpes formicivorus*), federal species of concern and state vulnerable; Oregon vesper sparrow (*Peoecetes gramineus affinis*), federal species of concern and state critical; western bluebird (*Sialia mexicana*), state vulnerable; Arctic peregrine falcon (*Falco peregrines tundris*), BLM sensitive; bobolink (*Dolichonyx oryzivorus*), BLM sensitive; dusky Canada goose (*Branta canadensis occidentails*), BLM sensitive; pileated woodpecker (Dryocopus pileatus), state vulnerable; and trumpeter swan (*Cygnus buccinators*), BLM sensitive.

Special status bird species considered likely to occur (moderate to high potential for occurrence) along the waterway where vessels will be traveling include the following species: Cassin's auklet (*Ptychoramphus aleuticus*), state vulnerable; rhinoceros auklet (*Cerorhinca monocerata*), state vulnerable; and tufted puffin (*Fratercula cirrhata*), state vulnerable.

In addition to the unique and special status birds discussed above, the American peregrine falcon and great blue heron warrant additional analysis, as discussed below.

**American Peregrine Falcon (Federal Delisted and State Sensitive–Vulnerable)**

The American peregrine falcon nests widely in coastal and montane areas throughout Oregon, possibly including the Coos Bay area (Adamus et al 2001). Nesting has been confirmed in the Bandon area (Adamus et al. 2001). The BLM reported it to be an uncommon, year-round resident of the North Spit (USDI 2005), while observations by local birders and ODFW local wildlife biologists indicate that it is common on the North Spit. Its habitat is difficult to characterize, as it may occur virtually anywhere and is quite variable and adaptable in its nesting and feeding habits. The American peregrine falcon requires concentrations of prey such as shorebirds, starlings, pigeons, and small ducks; elevated perch sites; and for nesting, a relatively secluded ledge on a bridge or cliff (Henny and Pagel 2003).

Ample food and nest sites occur around Coos Bay, and the McCullough Bridge could be considered a potential nest site. The Project site area itself probably does not offer any suitable nest sites, but peregrine territories are large and the site is used regularly by many prey species. There were seven sightings of this species during field surveys, including several in the Project site, and no seasonality was apparent.

**Great Blue Heron**

There is a historic great blue heron (*Ardea herodias*) rookery approximately 300 feet from Jordan Cove Road near the beginning of the road, situated approximately 2,000 feet to the east of the LNG Terminal site. This rookery was visited on November 1, 2006, during a site visit with ODFW and BLM biologists and was found to be inactive, but it still contained some nests. At that time, the BLM biologist noted that it had been inactive the previous two breeding seasons. The location of the rookery is in an area that will not be affected by the construction of the Project; however, it would be subject to construction traffic noise. It is currently subject to truck and railroad car traffic delivering chips to the Roseburg Forest Products wood chip export facility. If it were to become active again, the nesting birds could be disturbed by the existing Roseburg Forest Products traffic, as well as construction traffic for the Project.

Another historic rookery is located adjacent to the Project site on the south side of Henderson Marsh. It has not been active for several years (BLM biologist, pers comm.). Great blue herons have been observed foraging at this site during pre-construction surveys in 2005/2006 and in 2012, although no evidence of breeding in the area has been observed.

Surveys for nests were conducted on April 11, 2013, to determine if historic rookeries are being utilized this breeding season. It was determined during the survey that the rookeries are not active at this time. No nests or nest building activities were observed, although numerous detections of the great blue herons were noted foraging along the tidal flats and flying north past Jordan Cove.

### 3.2.4.3 Mammals

Special status mammals that are considered likely to occur (moderate to high potential for occurrence) include terrestrial and arboreal rodents, bats, and weasel species, the majority of which are associated with mature forest sites with sources of water.

Special status rodents with the potential to occur in the Project area include white-footed vole (*Arborimus albipes*), federal species of concern, and red tree vole (*Arborimus longicudus*), federal species of concern and state vulnerable. White footed voles are associated with stands of alders generally found in riparian areas. Red tree voles occur in old-growth stands of Douglas fir and various other mesic forest sites (i.e., that require a moderate amount of moisture).

Special status bats include the following species: Townsend's western big-eared bat (*Corynorhinus townsendii townsendii*), federal species of concern and state critical; silver haired bat (*Lasionycteris noctivagans*), federal species of concern and state vulnerable; California myotis (*Myotis californicus*), state vulnerable; long-eared myotis bat (*Myotis evotis*), federal species of concern; and Yuma myotis bat (*Myotis yumanensis*), federal species of concern. Bats are generally associated with a variety of habitat types, including caves, forests, open grasslands, and water. Due to the prevalence of freshwater habitats and forests, it is likely that special status bat species exist at the Project site.

Special status weasels include the American marten (*Martes Americana*), state vulnerable, and fisher (*Martes pennanti*),candidate for federal listing and state as sensitive–critical. The American marten is associated with large tracks of mature forests and has a habitat range that overlaps that of fishers. Dune Forest B and the Panhandle are noted to contain potential American marten habitat. The fisher is discussed in further detail below.

**Fisher (Federal Candidate Species, State Sensitive-Critical)**

The fisher is a large weasel which inhabits forests with high canopy closure, large trees and snags, large woody debris, large hardwoods, and multiple canopy layers (USFWS 2004). Fishers are known to have very large home ranges and to wander widely. They avoid areas lacking overhead canopy cover and disturbance by humans. Fishers also occupy and reproduce in some managed forest landscapes and forest stands not classified as late-successional that provide some of the habitat elements important to the species.

The fisher was nearly extirpated from Oregon by logging and trapping and is now very rare. Reintroductions have been attempted in several inland counties and there have been recent sightings in the mountains east and west of the Willamette Valley (Csuti et al. 2001). The BLM Coos Bay District wildlife sightings database contains several fisher observations in Coos County. None of these sightings were in the vicinity of the North Spit. An adult was seen near Daniels Creek just below Wren Smith Creek (about 10 miles from the Project area) in 1991 (ORNHIC). The presence of the fisher on the North Spit is unlikely given the rarity of the species and the lack of large, well-connected tracts of mature forest with continuous canopies (BLM 2006). Most forested areas on the North Spit are interspersed with areas of open sand and research indicates that fishers are reluctant to cross openings greater than 25 meters (Powell and Zielinski 1994). Furthermore, fishers on the North Spit would be separated from Coast Range populations by Highway 101, human developments, and fragmentation of mature forest. It is uncertain the extent to which fishers can recover from extirpation given that their populations are isolated and their apparent inability to colonize unoccupied areas (Aubry and Lewis 2003).

Although the species is considered of potential occurrence on the North Spit (ODFW 2012 pers comm.), and porcupines, one of the fisher's preferred prey items, are present in the Project area, there are no records of its presence and no fisher was observed during focused Project surveys. Moderate habitat for this species was found in the forested hillside and riparian areas within the Project study area; however, it is assumed that there is too much disturbance and that the forest is too immature and fragmented for the site to be used by fishers.

### 3.2.5 Environmental Consequences (Construction and Operation)

The overall area affected by the construction of the Project encompasses a total of approximately 406.8 acres, including the 251.9 acres for the Project facilities, 64.0 acres for the non-jurisdictional facilities, and 90.9 acres of temporary construction areas (Table 1.2-1, Resource Report 1, General Project Description). An additional 45.4 acres of adjacent emergent and forested wetlands (including a portion of Henderson Marsh) will not be impacted and will be avoided and preserved. These avoided habitats do not require mitigation and are not considered further. Some wildlife currently inhabiting the upland habitats on the Project site will most likely be displaced or experience some direct mortality during construction. Several areas of the Project site will remain open and can be restored to higher value habitat by contouring, landscaping, and vegetation plantings typical of the coastal dune setting of the North Spit. Restored construction areas will be converted to ODFW Habitat Category 4. A summary of habitat lost and post-construction habitat categories is listed in Table 3.2-5 and shown in Figure 3.2-2.

Direct effects to animals in terrestrial habitats along the waterway for LNG carrier traffic could include direct mortality if they were not able to flee from a spill, or the loss and/or modification of habitat in the event of an accident. It is possible that an oil or fuel leak from the LNG carriers in transit to or from the LNG Terminal could affect either aquatic or terrestrial wildlife, with the level of intensity dependent on the scope and size of the spill. These potential environmental consequences are discussed further in Section 3.5.

### 3.2.5.1 Amphibians and Reptiles

Amphibians and reptiles, including special status species, are likely to be impacted by fill activity in 2.58 acres (LNG Terminal site, access/utility corridor, and construction worker camp) of low to mid quality wetlands impacted by fill activities. Removal of dune forest for the Project will reduce habitat for the clouded salamander, should this species occur in these areas. The sand dunes adjacent to Jordan Lake and other wetlands on the Project site will not be affected by the construction of the Project. Hence, the northwestern pond turtle should not be affected and no mitigation is proposed for this species. Jordan Lake and nearby wetlands on the east side of the Project site area may offer suitable breeding habitat for the western toad, although the species was not found on the Project site. None of these areas will be affected by the Project and no mitigation is proposed.

### 3.2.5.2 Birds

#### American Peregrine Falcon

Potential effects to American peregrine falcon populations will be minimal. The species may lose some foraging habitat with the removal of the tidal flat during slip construction, but the species is adaptable in its feeding habits. The Project site does not offer any suitable nest sites.

#### Sensitive Breeding Birds

Ospreys nest on one of the tall lights in the Roseburg Forest Products Company yard on the east side of the Project site area. This nest is in a highly disturbed area and the birds are habituated to a high level of disturbance. It is likely that Project construction activity will agitate the birds initially, but it is expected that they will become habituated to it as well.

The forested portions of the Project site area are suitable breeding habitat for the olive-sided flycatcher, a federal species of concern, and this bird was detected regularly in small numbers during summer surveys. Some suitable nesting habitat may be lost as a result of Project construction. Specific mitigation is not proposed for this species.

#### Wading Birds and Shorebirds

The impact of the construction of the slip and access channel on wetlands will be the permanent loss of approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, and 2.49 acres of eelgrass. These are all habitat for wading birds and shorebirds. The loss of this habitat will be offset by the construction of in-kind mitigation (intertidal algal flats and intertidal unvegetated mud flats) proposed by the JCEP at the Kentuck estuarine and wetland mitigation site.

#### Migratory Bird Treaty Act

Nesting habitat for migratory birds occurs within areas that will be cleared for the Project. The Project would alter and disturb breeding and non-breeding habitat and could affect food fish populations. To a certain extent the Project has the potential to contribute to pollution levels or contamination of marine waters. Focused pre-construction surveys will allow JCEP to comply with the MBTA by ensuring that impacts to nesting birds are avoided. The loss of the approximately 9.69 acres of intertidal and 3.38 acres of shallow subtidal habitat may reduce the migratory bird feeding opportunities, although the mitigation of these losses at compensatory mitigation sites should minimize the losses and reduce the overall impact.

#### 3.2.5.3 Mammals

**American Marten**

The American marten (state sensitive–vulnerable) occurs in mature, closed-canopy forests and travels through openings if sufficient cover exists. Although unlikely, occasional dispersing individuals could wander into forested portions of the Project site. Thus, loss of dune forest for the Project could potentially reduce this species' habitat should this species occur in these areas. If potential occurrence is detected during pre-construction surveys, coordination with resource agencies and monitoring of American marten would be conducted, likely following the protocol developed by the U.S. Forest Service (USFS) for detecting carnivores (USDA 1995).

**Bats**

Specific bat surveys have not been conducted, but potentially suitable foraging habitat for many species occurs in the Project area, particularly around wetlands where insect prey is probably most numerous. Unidentified bats were observed in one of the buildings on the Roseburg Forest Products Company property on July 21, 2005. Breeding and roosting sites are likely very limited due to the existing high level of industrial activity and disturbance in the Project area, as well as the absence of more typical bat habitat such as cliffs, rock outcrops, bridges, caves, mines and large snags. Habitat for those species that nest under bark is available in the Project area.

**Fisher**

Potential adverse effects to fisher populations would be unlikely. There are no records of its occurrence on the North Spit, the site is separated by U.S. Highway 101 from inland forested habitat, there is too much disturbance from previous fill deposits and industrial use of the site, the forest is too immature and fragmented, and the species is too rare in the region for Project site use to be likely.

**Big Game**

Black bear and Roosevelt elk are fairly common on the North Spit and both have been sighted in the Project area. Black-tailed deer are also numerous in the Project area and use the site regularly. The development of the Project will reduce the amount of habitat for big game species and increased vehicle traffic during construction will increase the potential for collisions. However, due to the already disturbed nature of the Project site and existing industrial activities, it is not anticipated that the Project will have any significant adverse effects on these species.

### 3.2.6 Mitigation, Enhancement, and Protection Measures

Mitigation, enhancement, and protection measures for wildlife species that have been observed or are likely to utilize habitats in the Project area include specific measures, as defined below. These measures have been developed to avoid or limit potential impacts. As defined in the Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0010), the ODFW requires or recommends, depending upon the habitat protection and mitigation opportunities provided by specific statutes, mitigation for losses of fish and wildlife habitat resulting from development actions. Pursuant to the Fish and Wildlife Habitat Mitigation Policy, the Project will provide mitigation for lost fish and wildlife habitat by developing compensatory mitigation plans, including the Kentuck and Panhandle mitigation sites for wildlife species. Wildlife mitigation will be carried out at ratios agreed upon with the ODFW.

#### 3.2.6.1 Amphibians and Reptiles

The mitigation measures below will be implemented for construction and vegetation removal activities that may impact freshwater wetlands, including ponds, ditches, and other freshwater habitats that provide habitat for these species.

1. Suitable habitat that will be impacted by construction activities has been identified for further pre-construction surveys. A qualified biologist will survey the Project site 30 days prior to construction activities to determine if the northern Pacific pond turtle, northern red-legged frog, or the clouded salamander are in or near the action area and could be impacted by construction activities. Surveys will be in accordance with current species protocols. Areas that do not contain suitable habitat for these species will be released for construction without additional requirements.
2. The JCEP and ODFW will consult regarding the location of freshwater habitats for the relocation of amphibians or reptiles discovered during pre-construction surveys at the Project site. These habitats will provide areas for species relocation outside of construction areas where habitats are either being removed, modified, or managed for Project needs. Areas identified will be mapped and agreed to prior to construction.
3. Immediately prior to construction (within 4 hours) in areas identified as potential habitat, a qualified biologist will conduct surveys for the northern Pacific pond turtle, northern red-legged frog, and the clouded salamander. Species that are found during the survey will be captured and transported to suitable habitats outside of the construction areas, as pre-determined in consultation with the ODFW. Appropriate authorizations for capture and collection will be secured by the biologist prior to pre-construction surveys.

#### 3.2.6.2 Birds

To ensure compliance with the MBTA, clearing of Project area and any activity that involves habitat destruction, including staging and grading areas, if the construction schedule allows, will be conducted prior to March 1 or after August 31 to ensure most nesting birds have fledged. If construction activities must occur during the nesting season, JCEP will conduct focused pre-construction surveys to determine if there are active migratory bird nests present to ensure that impacts to nesting birds are avoided. The surveys will be conducted within the construction limits and within 100 feet (200 feet for raptors) of the construction limits. If active nests are encountered within the limits of the survey, construction and vegetation removal activities will be halted in the immediate vicinity until a qualified biologist has determined that the individuals have fledged from the nest (evacuated). JCEP will coordinate with the USFWS prior to proceeding with construction and any consultation exchange with the USFWS will be provided to FERC.

For construction activities during the nesting season, if no active nest is encountered within the limits of the survey, construction and vegetation removal will proceed with caution with an eye out for active bird nests. Empty or abandoned nests will not be taken into possession without a permit. During the non-nesting season, permits are not required to remove an empty or abandoned nest, or to remove or alter the structure the nest is built in or on.

Structures associated with the proposed Project would be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the MBTA.

LNG carriers along the transit route could affect migratory birds should an LNG spill occur while birds are flying directly through the spill area if the birds come in direct contact with either the unignited or ignited spill, or should an ignited spill affect the habitat of the migratory birds. In order for an unignited spill to affect a bird species flying through the vapor cloud, the bird would have to be flying at a level close to the spill where the vapor concentrations would be high enough to cause asphyxiation. This is unlikely unless the spill occurs in the route to the habitat to which the bird was descending and no other habitat was available. Given the amount of migratory bird habitat along the LNG carrier transit route, this would be an unlikely scenario. If the spill was ignited, it is likely that the birds would avoid the heat and smoke of the fire. The way that an effect could occur is if the vapor cloud ignited at the exact same time that the bird flew through it. The probability of this occurring is extremely remote.

If the release of LNG near a migratory bird habitat was in the presence of an ignition source, the resulting fire could injure the habitat within the 0.3 mile zone depending on the time of the year and conditions existing at the time of the fire. Heat from such a fire would have less of an effect on habitat vegetation within the 1.0 mile zone, and no effect from a pool fire is anticipated on wetland vegetation in the 2.2 mile zone. Even if vegetation is impacted by the fire, root structures would remain and allow the plants to become re-established.

The maximum flammable range for a vapor cloud could extend to the outer limits of the 2.2 mile zone and if an ignition source were present, the resulting fire could burn back to the source of the spill, directly injuring any habitat in the path. Again, this could result in injury to parts of the habitat plants, but would not result in long term damage to the plant or the plant community. The probability of these scenarios occurring is low given the marine transit safety and security measures employed and the unlikelihood of a spill of LNG cargo due to collisions and potential terrorist attacks.

**Great Blue Heron Rookery**

Ongoing surveys of the two (currently abandoned) great blue heron rookery sites near the Project site would be conducted prior to construction. Although both rookeries have been documented to be abandoned, reuse by this species can occur. Pre-construction surveys will be conducted during seasonally appropriate nesting periods. If coordination with the ODFW and BLM determines that these agencies are conducting rookery surveys, JCEP may suspend surveys and use the results of these agency surveys. In the event that a rookery becomes active, JCEP, in consultation with ODFW biologists, will develop an appropriate mitigation plan depending on the status of construction and the potential for indirect effects. No mitigation for potential impacts will be required as long as the rookery is inactive.

### 3.2.6.3 Mammals

Relocation of mammals ranging from small to big game species will occur as these species typically relocate from sites impacted by construction. To avoid inadvertent return of these species to the construction site, vegetation clearing will occur in a progressive manner, to encourage species to move out of the Project site to more natural lands managed by the USFS. As areas of the Project site are cleared, fencing will be installed to discourage foraging activities back onto the construction site.

#### 3.2.6.4 ODFW Wildlife Habitat

On the basis of the Oregon Administrative Rules habitat categorization scheme (OAR 635-415-0025), ODFW Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0000), and coordination with the ODFW, habitat values lost to the construction of the Project will be replaced in-kind. Replacement of the lost habitat will include the following;

- Approximately 2.49 acres of eelgrass (Habitat Category 2) will be replaced by constructing eelgrass across the bay south of the runway for the Southwest Oregon Regional Airport.
- Approximately 13.9 acres of estuarine resources (Habitat Category 2), including intertidal unvegetated sand, shallow intertidal and algal/mud/sand flats, will be mitigated by the construction of mud flat estuarine wetlands in the Kentuck wetland mitigation site.
- Approximately 2.4 acres of additional Habitat Category 2 impacted by the construction of the Project will be mitigated in accordance with Oregon Division of State Lands Wetland Mitigation requirements (OAR Division 85 and Division 90) on neighboring North Spit property owned by JCEP.
- The loss of approximately 80.8 acres of terrestrial habitat (predominately coastal dune and riparian forests) classified as Habitat Category 3 will be mitigated by in-kind habitat replacement on neighboring North Spit property. Neighboring property to be used for in-kind replacement for lost habitat will be valued in accordance with OAR 635-415-0025 as agreed upon by consultation with the ODFW.
- The loss of approximately 62.9 acres of terrestrial habitat (Habitat Category 4; predominantly grassland, shrub, herbaceous, and herbaceous shrub upland) will be mitigated by in-kind or better habitat replacement on neighboring North Spit property. Neighboring property to be used for in-kind replacement of lost habitat will be valued in accordance with OAR 635-415-0025 as agreed upon by consultation with the ODFW.

## 3.3 FISHERIES AND MARINE RESOURCES

The Coos Bay estuary is the second largest estuary in Oregon and covers approximately 54 square miles of open channels and periodically inundated tidal flats. It ranges from a mile to a mile and a half wide by 15 miles long and has approximately 30 tributaries. The major tributary flowing into Coos Bay is the Coos River. Coos Bay and its connecting waterways provide foraging, migratory, spawning, and juvenile nursery habitat to numerous species of fish and invertebrates. This area also contains important crab, clam and salmon resources, as well as marine fish such as flatfish and rockfish. It is a major migration corridor for salmon and steelhead that spawn and rear in the Coos River systems.

The fish community consists of species that are adapted to salinity fluctuations characteristic of the Coos Bay estuary, with the number of species increasing down river through the estuary towards the ocean. Some estuarine fish such as kelp greenling and starry flounder spend their entire lives within the estuary, whereas other species are seasonal. Anadromous fish species occurring in the Project area include Chinook salmon, coho salmon, chum salmon, steelhead, and coastal cutthroat trout. Anadromous salmon are generally transitory, passing through the bay in the fall as adults to Coos River, while juveniles primarily outmigrate in the spring and summer. Other seasonal inhabitants include white and green sturgeon, American shad, Pacific lamprey, surfperch, lingcod, rock greenling, sculpin, surf smelt, Pacific herring, English sole, eulachon, longfin smelt, Pacific tomcod, sand sole, and topsmelt. In addition, clams, crabs, oysters, and shrimp make up important invertebrate components of the bay. Table 3.3-1 provides a list of commonly occurring fish and invertebrate species in Coos Bay.

Historically, dredged materials have been deposited in Coos Bay in the bay, marshes, and flats to provide fill for development or to store it outside of the navigational channels. Major historical alterations of Coos Bay include dredging and in-bay spoil disposal located at approximate CM 3.0, between CM 4.0 and 5.0, below CM 6.0, and between CM 8.0 and 9.0. Jefferts (1977) reported that dredging has a relatively minor influence on the fauna of the lower reaches of the estuary, which primarily consists of coarse sediment type. The marine habitats affected by the construction of the slip and access channel and the construction dock will be approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass.

Along the western shore of the bay from CM 6.0 to CM 8.0 (including Jordan Cove) the narrow sandy shore drops off quickly into the subtidal zone and the deeper navigational channel. Ebb and flow currents through the deeper portion of the bay are swift and scour the shores so that attached vegetation is absent. Five pile dikes have been installed along the shore to retard erosion (USACE 1973). This area is an important feeding area for English sole, topsmelt, surfsmelt, herring, anchovy, coho salmon, and Chinook salmon. Fish feed on material in the water column from adjacent productive areas. Closer to shore, herring spawn at the Roseburg Forest Products Co. dock and on eelgrass beds in Jordan Cove. In addition, west of the railroad bridge at Jordan Point is a sandy area where the ODFW seines and samples large numbers of fish.

A total of over 14,000 acres of habitat is present in Coos Bay, including some 1,500 acres of eelgrass beds, an important habitat component for major estuarine resources. The flat inner portions of the bay are used by most species found in the bay. These regions are where most eelgrass beds are found.

Eelgrass habitats are common in the lower bay subsystem. These submerged aquatic vegetation (SAV) areas appear to exhibit great species diversity and are preferred by many aquatic species. Most fish species within Coos Bay utilize the flats of the lower bay at some time during the year, where a majority of the eelgrass beds exist. Color infrared aerial photographs taken near the Project site area reveal a narrow band of sparsely populated SAV near the low tide line and partially submerged along the beach west of the Roseburg dock. Field surveys indicated that approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass occur at the slip and access channel and the construction dock site (Figure 3.3-1). It is recognized that eelgrass is an annual aquatic plant and production can vary widely from year to year. However, the aerial photography and field verification provides an indication of the extent of the eelgrass within the Project area.

Salinity and other water quality characteristics vary with proximity to the estuary mouth and with the volume of freshwater entering sloughs. In general, the lower bay (below CM 9.0) is dominated by higher salinity from ocean water while the upper bay water is affected by freshwater influx that varies seasonally. Tidal flux constantly changes the salinity of the water in the channel. South Slough, at CM 1.3, is relatively saline whereas Catching Slough at approximate CM 15.5 is brackish with a much lower salinity. The abundance of fish in the lower bay increases in the summer due to higher salinity.

The Fish and Wildlife Coordination Act (FWCA) was enacted to protect fish and wildlife when federal actions result in the control or modification of a natural stream or body of water. JCEP consulted with the ODFW, USFWS, and NMFS regarding potential impacts to fish and wildlife as part of the overall state and federal permitting and authorization process for the Project.

The Oregon Parks and Recreation Department (OPRD) has statutory authority for managing Oregon's ocean shore, which includes public beaches and other intertidal areas along the entire coast. The ocean shore is defined as the land lying between extreme low tide of the Pacific Ocean and the statutory vegetation line or the line of established upland shore vegetation, whichever is farther inland (ORS 390.605). The ocean shore does not include estuaries.

### 3.3.1 Existing Habitat

#### 3.3.1.1 Coos Bay Estuarine Habitat

Much of the Coos Bay shoreline and subtidal habitat consists of unvegetated mud and sand, mixed with areas of various algae species. Algae/mud/sand flat habitat is inundated with water more frequently and for a longer duration than intertidal unvegetated sand habitat and is therefore more likely to support aquatic organisms. Clam and/or burrowing shrimp holes occur within this habitat, with varied abundance and diversity. The habitat is classified as Category 2 by the ODFW because it is essential for fish and marine species, and limited, but can be replaced through mitigation. Based on conversations with ODFW personnel, habitat at the site is limited due to its location within the Coos Bay ecosystem.

Many of the managed groundfish species occur in estuarine waters and are included under Essential Fish Habitat. Juvenile and adult life stages of cabezon can be found in shallow water bays and estuarine areas. All life stages of kelp greenling and starry flounder are found in estuarine areas. Several species of rockfish occur in estuarine areas during their juvenile and adult life stages. These include black, brown, copper, and quillback rockfish that are usually found near kelp beds off the coast in later stages. Other groundfish species that may be found in estuarine and coastal areas include Pacific cod, Pacific whiting, sablefish, bocaccio, English sole, Pacific sand dab, and rex sole which utilize nearshore nursery areas.

Salt marshes exist on the transition zone between the land and the sea in protected low-energy areas such as estuaries, lagoons, bays, and river mouths. Marsh ecosystems, like all wetlands, are a function of hydrology, soil, and biota. Tidal cycles allow salty and brackish water to inundate and drain the salt marsh, circulating organic and inorganic nutrients throughout the marsh. Water is also the medium in which most organisms live. The marshes are strongly influenced by tidal flushing and stream flow, which affect the inundation and salinity regimes of salt marsh soils. In areas with enough runoff, salt marshes transition into brackish and freshwater marshes.

Sand- and mudflats occur at extreme low water, whereas salt marsh vegetation develops where soils are more exposed to the air than inundated by tides, usually above mean sea level. Sedges, salt grasses, beach grasses, and eelgrasses dominate the shallow intertidal and subtidal habitats. Salt marshes are of paramount ecological importance because they 1) export vital nutrients to adjacent waters; 2) improve water quality through the removal and recycling of inorganic nutrients; 3) absorb wave energy from storms and act as a water reservoir to reduce damage further inland; and 4) serve an important role in nitrogen and sulfur cycling (Mitsch and Gosselink 1993, Thayer et al. 1981).

Marshes and sloughs in Coos Bay provide rearing habitat for coho salmon and brackish-water estuarine areas may also be used by juvenile coho. The Coos estuary is estimated to contain less than 10 percent of its original salt marsh habitat, due to filling, dredging, and other development. Significant portions of the salt marshes remaining are in the South Slough National Estuarine Research Reserve, a 5,000 acre natural area near Charleston, which has approximately 550 acres of intertidal habitat and contains large expanses of eelgrass beds alongside its meandering, shallow channels, providing essential habitat for many fish and shellfish species, including Dungeness crab.

The LNG carrier transit route zones within Coos Bay overlap South Slough, Pony Slough, and North Slough/Haynes Inlet. Slough habitat varies depending on the location and amount of freshwater inputs. For example, salinity and other characteristics vary with proximity to the estuary mouth and the volume of freshwater entering sloughs. In general, sloughs provide habitat for a number of estuarine fishes, commercial shellfish, and invertebrates, many of which are important food sources for salmonids. Many marshes bordering sloughs have been diked, restricting tidal flush and flow of nutrient-rich organic material into the estuary.

South Slough enters the main channel of Coos Bay less than two miles from the estuary mouth and has a high shoreline to surface area ratio resulting in diverse habitats. The upper reaches of South Slough have been set aside as a research sanctuary. Because of its proximity to the ocean, it receives more marine influence than the other slough subsystems and its north-south orientation makes it susceptible to strong north-northwest winds. South Slough is an area of sediment deposition. The marine influence, coarse sediments, and relatively undisturbed nature of the upper portion provide habitat for more species of invertebrates and fish than are found in other slough subsystems in Coos Bay. Commercial oyster culture is a major commercial use in South Slough.

Pony Slough, across the bay from Jordan Cove (near CM 9), has subtidal areas with unconsolidated bottoms, intertidal mud flats, sand-mud flats, eelgrass beds, algal beds and marshes. Eelgrass is distributed along the intertidal areas near the slough entrance and through part of the main channel. Mud flats are populated by burrowing mudflat organisms including *Corophium spinicorn,* an important amphipod in the diet of juvenile salmonids. Tide flat users harvest soft shell clams and ghost shrimp.

The North Slough subsystem extends approximately three miles north from the main body of Coos Bay at CM 9, near Jordan Cove. The Trans-Pacific Parkway separates the slough from full exposure to the main bay, and the diked system reduces tidal circulation. Water quality sampling has shown high temperatures, high coliform counts, and excessive turbidity. Low summer stream flows, incomplete mixing, livestock, log storage, and waste are thought to contribute to degraded water quality. Ghost shrimp, lugworms, American shad, shiner perch, staghorn sculpin, and starry flounder have been documented in the slough (Cummings and Schwartz 1971). Coho salmon spawn in North Creek, a tributary to the North Slough.

Eelgrass habitats are common in the lower bay subsystem and they appear to exhibit great species diversity and are preferred by many aquatic species. Previous studies (Akins and Jefferson 1973) reported that Coos Bay has 1,400 acres of lower intertidal and shallow subtidal tide flats covered by eelgrass meadows. In 1979, the ODFW conducted habitat mapping in Coos Bay and documented intertidal and subtidal aquatic beds, including documentation of SAV in Jordan Cove and across the bay from the proposed LNG Terminal in and near the mouth of Pony Slough. The largest and most contiguous beds of submerged grasses are located in both the lower and upper bay, in the North and South Sloughs, and in Haynes Inlet. Eelgrass in

Pony Slough is distributed along the intertidal areas near the slough entrance and through part of the main channel. In the fall and winter, as much as 75 percent of the eelgrass blades die back and decompose, supplying estuarine food webs with essential nutrients. In spring and summer, eelgrass beds sprout and grow, renewing the annual cycle of production.

Submerged grass meadows provide cover and food for a large number of organisms including burrowing, bottom-dwelling invertebrates; diatoms and algae; herring that deposit egg clusters on leaves; tiny crustaceans and fish that hide and feed among the blades; and larger fish, crabs, and wading birds that forage in the meadows at various tides. Eelgrass in Coos Bay provides shelter for a variety of fish and may lower predation, allowing more opportunity for foraging. The protective structure attribute of eelgrass is primarily for smaller organisms and juvenile life history stages of fishes. Orth et al. (1984) reported that shoot density, patchiness, leaf area, leaf morphology, along with the thickness, structure, and proximity of the rhizome layer to the sediment surface are the primary characteristics that affect predation rates. Structural complexity is related to fish abundance and species richness. Fish diversity and eelgrass biomass were also significantly correlated in surveys conducted in Craig, Alaska (Murphy et al. 2000).

Field surveys of the Project site conducted in September 2006 verified the extent and species composition of SAV previously identified from aerial photography as occurring in the area of the slip and access channel and construction dock. The narrow strip of SAV was found to be comprised of eelgrass (*Zostera marina*) and algae. It is recognized that eelgrass is an annual aquatic plant and production can vary widely from year to year. However, the aerial photography and field verification provides an indication of the areal extent.

#### 3.3.1.2 Along the LNG Marine Transit Route

Oregon, along with nearly every other coastal state, has jurisdiction over the seabed and its resources out to three geographical (or nautical) miles. First proposed in 1793 by then-Secretary of State Thomas Jefferson as a "temporary" seaward boundary for the United States, state jurisdiction over the "territorial sea" was finally established by Congress in the 1953 Submerged Lands Act (43 USC 1301-1315). Where offshore islands occur within the three miles, the Territorial Sea extends another three miles beyond. The Oregon Territorial Sea is 950 square nautical miles. In 1991, the Oregon Legislature required that the Territorial Sea also include the ocean shore, which is defined in state law (ORS 390.605) as the land lying between extreme low tide of the Pacific Ocean and the line of vegetation (also known as the beach zone line).

**Riparian Zones and Streams**

The LNG carrier transit route zones within Coos Bay overlap tributaries and riparian zones draining into Coos Bay. An abundance of streams drain into Coos Bay from mixed-conifer forests and developed areas. Chinook and coho salmon spawn in freshwater tributaries of Coos Bay in select areas such as pool tailouts, runs, and riffles during the fall or winter (Vronskiy 1972, Burger et al. 1985, Healey 1991). Riparian zones are typically lined with red alder, willows, and ferns. The transit route zones within Coos Bay overlap multiple small freshwater tributaries flowing into South Slough within lower Coos Bay including Hayward Creek, Day Creek, Elliot Creek, and Joe Ney Creek. In addition, lower Pony Creek is within the transit route zones that reach into the upper bay. Miner Creek and Big Creek are within the LNG carrier transit route zones along the coast, and drain directly into the Pacific Ocean near Gregory Point just north of Sunset Bay.

**Shoreline Habitat**

Sandy beaches are transitional areas between subtidal soft sediments and the terrestrial dunes or sedimentary bluffs. Ecotypes include high intertidal and mid to low intertidal areas. Fauna of sandy beach habitat are transitory and move up and down with the tides. Fish use these areas for foraging and invertebrates burrow in sand during periods of exposure. Fish utilizing submerged sandy beach habitat include surf smelt, English sole, night smelt, roughback sculpin, Pacific sand lance, and Pacific staghorn sculpin. Species utilizing the mid to low intertidal zones along sandy beaches include Dungeness and red rock crab, various species of clams, Pacific sand lance, surfperch, night smelt, and bay rays.

The shoreline in the vicinity of Coos Bay is dominated by geological features distinctive of the Klamath Mountain metamorphic province, as well as rocky shores of uplifted and tilted marine sediments. Rocky shore habitat exists south of Coos Bay, including diverse intertidal habitat, shore-associated reefs, offshore reefs, offshore rocks, and islands. Cape Arago and Gregory Point research reserves provide coastal intertidal and kelp forest habitats. The coastline just north of Coos Bay is sandy beach habitat. Nearshore environments vary from low-energy sheltered environments to more exposed coastline, subjected to high-energy wave and tidal action. Numerous groundfish species, salmon, and a number of coastal pelagic species are found in nearshore habitat. These include juvenile and adult life stages of Pacific mackerel, which occur off sandy beaches. In open bays, eggs and paralarvae of market squid are found in shallow, semi-protected nearshore areas (PFMC 1998a).

The transit route also overlaps soft bottom subtidal areas off of Coos Bay, which have primarily sandy substrates. Communities are dominated by burrowing invertebrates such as worms with shrimp, crabs, snails, bivalves, sea cucumbers, and sand dollars living on the sediment surface. Common fish include flatfish, sand lance, and burrowing sandfish.

**Rocky Shore Habitat**

The LNG carrier transit route zones overlap rocky shore habitat south of the entrance to Coos Bay. Rocky shore habitat includes all hard substrate areas along the shoreline that are alternately exposed and covered by the tides. Rocky shores contain the following ecotypes: high intertidal, mid-intertidal, low intertidal, and intertidal artificial substrates (jetties, etc.). The physical characteristics of nearshore rocky reefs reflect local shoreline geology, exposure, and currents as well as biological influences. South of Coos Bay, the coastal geology produces the complex of cliffs, reefs, and rocks of Cape Arago, which are tilted layers of sedimentary rocks. The physical environment of intertidal areas changes dramatically as the tide rises and falls, and habitat is either covered by salt water or exposed to air and the sun. Rocky intertidal habitats have an abundant and diverse biological community, including algae and other marine plants (surfgrass), attached and mobile invertebrates (sponges, anemones, barnacles, bryozoans, tunicates, mussels, crabs, snails, sea stars, urchins, brittle stars, nudibranchs, chitons, worms), fish (sculpins, gunnels, pricklebacks), marine mammals, and sea birds. Rocky shore habitat fish species include cabezon, black rockfish, and other species of rockfish.

**Rocky Reef Habitat**

The ODFW has studied a modest number of reefs along the Oregon coast. Many species are principally associated with rocky reefs and these areas are a focal point for commercial and recreational fishing. The LNG carrier transit route zones overlap portions of submerged rocky reef habitat south and north of Coos Bay, including nearshore rocky reefs near Cape Arago and deeper subtidal reefs offshore of this area, as well as a subtidal rocky reef north of Coos Bay.

Rocky subtidal habitat includes all hard substrate areas that are never exposed at low tide, including reefs, rocky reefs, rocky banks, pinnacles, and hard bottoms. Ecotypes include shallow rocky reefs with kelp beds, shallow rocky reefs without kelp beds, deep rocky reefs, and subtidal artificial substrates. Subtidal rocky reefs have a variety of microhabitats and an abundant and diverse biological community. Species utilizing shallow rocky reefs include numerous species of rockfish, greenling, sculpin, gunnel, flounder, perch, and smelt. Invertebrates include mussels, crabs, abalone, limpets, anemones, snails, sea stars, sea urchins, chitons, barnacles, and scallops. Deep rocky reefs have a rich invertebrate and fish community, with little algae. Invertebrates include sponges, anemones, snails, sea stars, and crabs. Deep nearshore reefs tend to have a higher diversity of rockfish as well as perch, lingcod, Irish lord, sole, and dogfish sharks.

**Kelp Forests**

Kelp forests are associated with rocky reefs and include subtidal marine communities that form floating canopies on the surface of the sea. Kelp forests are highly productive and create a three-dimensional aspect to the nearshore environment, providing habitat and food for hundreds of other species of plants (algae) and animals. Kelp forest ecosystems include structure-producing kelps and their myriad of associated biota such as marine mammals, fishes, crabs, sea urchins, mollusks, other algae, and epibiota (organisms living on its surface), which collectively make this one of the most diverse and productive ecosystems in the world (Steneck et al. 2002).

Kelp forests are included as SAV in subtidal marine habitat, occurring across a wide depth range, from rocky intertidal habitats to depths of 40 meters, and for some species, broad latitudinal ranges. Kelp grows on many of Oregon’s shallow rocky reefs on rocky substrates between 5 and 20 meters of water, with some extending to 25 meters (ODFW 2005b). While rocky reefs of this depth range exist all along the Oregon coast, the strip of coast from Cape Arago south contains approximately 92 percent of the state’s kelp beds (ODFW 2005b).

Distribution patterns of kelp are influenced by light, salinity, temperature, substrate type, and currents. Kelp forests supply many habitat functions, including: 1) supporting of large numbers of non-parasitic epiphytic organisms that live on them; 2) damping of waves and slowing of currents which enhances sediment stability and increases the accumulation of organic and inorganic material; 3) binding sediments with their holdfasts (roots), thus reducing erosion and preserving sediment microflora; and, 4) holdfasts and blades (leaves) provide horizontal and vertical complexity to habitat, which, together with abundant and varied food sources, support densities of fauna generally exceeding those in unvegetated habitats.

### 3.3.2 Existing Fish and Marine Species

#### 3.3.2.1 Fish

ODFW (2005) seining data at stations near Jordan Cove give a snapshot of the diversity of species that utilize habitat near the proposed slip location. Species seined in September and July of 2005 at McCullough Bridge (upper bay from the Project area) included Chinook salmon, shiner perch, walleye perch, northern anchovy, starry flounder, staghorn sculpin, speckled sand dab, and saddleback gunnel. Species seined in July 2005 from the Trestle station (just upbay from the Project site area) included coho salmon, Chinook salmon, shiner perch, staghorn sculpin, sand sole, white sea perch, surf smelt, and American shad. Species seined from the Pony Creek station (across and upbay from the Project site area) in July 2005 included coho salmon, Chinook salmon, shiner perch, staghorn sculpin, sand sole, white sea perch, surf smelt, jack smelt, and bay pipefish.

**Salmon**

The Coos Bay system provides migration, rearing, and feeding habitat for the following environmentally sensitive units (ESUs) of Pacific salmonids: federal species of concern Oregon Coast (OC) coastal cutthroat trout (*O. clarki clarki*); OC Chinook salmon (*Oncorhynchus tshawytscha*), state sensitive-critical; Pacific Coast chum salmon (*O. keta*), state sensitive-critical; OC steelhead (*O. mykiss*), state sensitive-vulnerable, which is also a federal species of concern; and OC coho salmon (*O. kisutch*), federally-listed as threatened under the Endangered Species Act (ESA) in February 2008.

### 3.3.2.2 Invertebrates

As one of Oregon's largest estuaries, Coos Bay provides habitat and rearing value for clams, crabs, and shrimp, which are of significant economic importance to the area, including Oregon's economically productive Dungeness crab fishery. Many invertebrates have not been thoroughly studied and updated population and distribution information is not available. Variations in substrate, attachment sites, sediments, salinities, temperatures, dissolved oxygen, and other physical factors in Coos Bay affect shellfish distribution. Shellfish distribution varies along the route from the proposed LNG Terminal to the Coos Bay harbor entrance, with principal subtidal clam beds and crab species found in the lower bay along the route.

Mapped clam and crab distributions shown on Figure 3.3-2 are based on the Shellfish and Estuarine Assessment of Coastal Oregon: Coos Bay (SEACOR) conducted in 2008 by the ODFW. Butter (Martha Washington, beefstake, quahog) and gaper (horse, horseneck, blue, Empire) clams are considered the most numerous in Coos Bay and studies conducted from the 1970s to 2009 have shown increased populations. Cockles and littlenecks (steamers) are less common and studies show their populations have been dropping since the 1970s. Softshell clams (non-native) are typically found further inland along the bay.

Oysters and shrimp distributions are mapped in Figures 3.3-3 and 3.3-4, respectively, and are based on distributions contained in Coos Bay by the Oregon Geographic Response Plan (U.S. Coast Guard 2004). There are two species of oysters in Coos Bay: the native or Olympia oyster (*Ostrea lurida*) and the commercially grown Pacific oyster (*Crassostrea gigas*). The Olympia oyster is the only oyster native to Oregon and Coos Bay is one of only a few bays where they exist in Oregon. Neither species is legal for recreational harvest. Native oyster populations are protected to encourage their recovery, but since Pacific oysters are only commercially grown they are private property.

Bringing the Olympia oyster back to Oregon's coastal waters has become a priority for natural resource managers, scientists, shellfish farmers, and recreationists. A team led by the South Slough National Estuarine Research Reserve in lower Coos Bay is conducting the science and forming the relationships necessary to make Coos Bay the epicenter of the state's restoration efforts. In 2010, the reserve received a federal start-up grant for a pilot restoration project. Since then they have re-introduced about 4 million juvenile oysters to South Slough. The project aims to build on existing research and relationships to establish a community stakeholder group committed to working collaboratively to bring the Olympia oyster back to Coos Bay.

### 3.3.2.3 Marine Mammals

The Marine Mammal Protection Act (MMPA) was enacted on October 21, 1972, and prohibits killing, harming, or harassing any marine mammal. It is based on the finding that some marine mammal species or stocks may be in danger of extinction or depletion as a result of human activities and that these populations must not be permitted to fall below their optimum sustainable population level. The MMPA was amended substantially in 1994 to provide certain exceptions to the take prohibition, including: 1) for small takes incidental to specified activities; 2) permits and authorizations for scientific research; and 3) access by Alaska Natives to marine mammal subsistence resources. The amended act also included a program to authorize and control the taking of marine mammals incidental to commercial fishing operations, the preparation of stock assessments for all marine mammal stocks in waters under U.S. jurisdiction, and studies of pinniped-fishery interactions.

In addition to the marine mammals listed below, other threatened or endangered marine mammals that may occur in the LNG carrier transit route zones are described in Section 3.4 and include whales and Steller sea lions.

**California Sea Lion**

California sea lions (*Zalophus* californianus) occur in nearshore waters along the Pacific coast from Vancouver Island, British Columbia, to Baja Mexico. North of southern California, the haulout grounds are occupied by males only who migrate north for the winter following the breeding season, which ends in mid-July (Maser et al. 1981) after the pups are born. Females and their pups remain in California all year. Males may often reach 850 pounds and 7 feet in length. Males develop a bony bump on top of their skull, which is called a sagittal crest. Females can weigh up to 220 pounds and reach 6 feet in length; females are lighter in color than the males. California sea lions are very social animals and rest together in tightly packed groups on haulout sites. The main haulout sites along the Oregon coast include Shell Island at the Simpson Reef. California sea lions forage within Coos Bay throughout the year and use dredge material islands as haul-out sites (BLM 2005). Occasionally they may be found on the North Spit's beaches (BLM 2005). The California sea lion may occur in the LNG carrier transit route zones.

**Harbor Porpoise**

The harbor porpoise (*Phocoena phoceoena*) is circumboreal in the northern hemisphere and occurs in ice-free waters. In the eastern Pacific Ocean, this species ranges from Point Barrow, Alaska, to San Diego, California. This species is the smallest cetacean in the eastern North Pacific Ocean and is considered abundant in waters off Washington and western Canada. Adult males reach up to 1.7 meters in length and females reach 1.8 meters. Adult harbor porpoises weigh up to 90 kilograms. In the Pacific, harbor porpoises feed on bottomfish, cod, herring, squid, clams, and occasionally crustaceans. Harbor porpoise could be found within the LNG carrier transit route zones.

**Harbor Seal**

Harbor seals (*Phoca vitulina*) occur in both the Pacific and Atlantic oceans north of the equator. In the Pacific, they range from Alaska to Baja Mexico and can often be seen in nearshore coastal waters, bays, estuaries, and on sandy beaches and mudflats. Harbor seals have spotted coats in a variety of colors, ranging from silver to dark brown or black. Males are slightly larger than females and the species reaches 5-6 feet in length and weigh up to 300 pounds. In Oregon, pups are born in April and May. Harbor seals are opportunistic feeders and take a variety of bottom fishes and rockfishes, small schooling fish such as herring, some salmon, and lamprey (Maser et al. 1981). Harbor seals spend half their time on land and half in the water, occasionally sleeping in the water. Harbor seals are year-round residents on the Oregon coast and can be found at Cape Arago. Harbor seals forage within Coos Bay throughout the year and use dredge material islands as haul-out sites (BLM 2005). Occasionally they may be found on the North Spit's beaches and are very sensitive to disturbance (BLM 2005). Harbor seals could occur within the LNG carrier transit route zones.

**Northern Elephant Seal**

Northern elephant seals (*Mirounga angustirostris*) occur in the North Pacific, from Baja Mexico to the Gulf of Alaska and Aleutian Islands. The elephant seal was almost extinct by the late 19$^{th}$ century but has repopulated throughout its range, having once received protection. During the breeding season, they live on offshore island beaches and a few remote locations on the mainland. The rest of the year elephant seals live offshore. Adult males reach up to 13 feet in length and weigh up to 5,000 pounds. The females are smaller at 10 feet in length and weighing less than 1,000 pounds. This species is the second largest seal in the world, after the southern elephant seal, and can dive to depths of 5,000 feet. Elephant seals breed in the winter and male elephant seals arrive first at their breeding beaches in Mexico and California to establish territories. Pups cannot survive in the water until eight to ten weeks after birth. The northernmost breeding site on the Pacific coast is Shell Island at Cape Arago, which is also the largest marine mammal haulout area on the Oregon Coast (USFWS 2007b). Elephant seals may occur in the LNG carrier transit route zones.

**Sea Otter**

The sea otter (*Enhydra lutris*) was extirpated from Oregon by the early 20$^{th}$ century; however, translocation attempts were made in Cape Arago in 1971 where 41 otters were released (Jameson 2007). The translocated populations failed and the last sea otter observation at Cape Arago was in 1991 (Jameson 2007). This species is currently extirpated in Oregon and will not be affected by the LNG carrier transit route zones.

### 3.3.3 Commercial and Recreational Fisheries

Commercial and recreational fish and invertebrates species found in Coos Bay are listed in Table 3.3-3.

#### 3.3.3.1 Commercial Fishing

Commercial fisheries in the Coos Bay estuary includes clams, bait fish, and ghost and mud shrimp (used for fishing bait), along with limited crabbing from September through December. Only 15 permits for commercial clam harvesting are issued per year for the entire state of Oregon. A company called West Coast Clams began regularly harvesting clams commercially in Coos Bay in March 2012 and has since opened up new markets for clams from Coos Bay.

Commercial ocean fisheries include boats (trollers and trawlers) targeting tuna, sablefish, salmon, groundfish, Dungeness crab, clams, and pink shrimp. Most vessels fishing offshore dock and sell their products in Coos Bay and a fisherman's market cooperative and a small commercial salmon fleet are located in Charleston. Shellfish fisheries (predominantly crab, shrimp, and clams) are of significant economic importance to the Coos Bay area.

In 2011, the total value of the catch at the fisherman's level reported by the ODFW at Charleston was $35.7 million. This was comprised of $12.7 million for fish, $23.1 million for crab and shrimp, $8,312 for clams, and $700 for other invertebrates. Within the fish category, albacore tuna, sablefish, and Chinook salmon were the highest valued catch of all the fish caught, at $4.2, $3.7, and $1.3 million, respectively. In 2011, the ODFW reported that Dungeness crab harvested from the ocean had a total value of $11.8 million at the fishermen's level. Pink shrimp had a value of $10.9 million, and spot shrimp, $182,264. Cockle and gaper clams, combined, account for only $7,069.

Although many shrimp species are found in waters off Oregon, the pink shrimp (*Pandalus jordani*), also known as the ocean shrimp, is the only one found in quantities large enough to be commercially harvested. The pink shrimp is a small shrimp in comparison to many shrimp and prawns seen in supermarkets and restaurants, and is often referred to as cocktail shrimp or salad shrimp. Pink shrimp have been harvested in Oregon since 1957 and are caught by trawl boats which generally fish between 450 to 750 feet deep on mud and muddy-sand substrates off the coast. Populations vary widely from year to year, which is common for many short-lived crustaceans. Landings in 2005 were 15 million pounds and have averaged 26 million pounds per year over the last 31 years.

The Oregon Division of State Lands (DSL) oversees six oyster claims in Coos Bay and leases for commercial operations are issued by the Port of Coos Bay and Coos County. There are four commercial growers that cultivate about 1,500 acres of non-native Pacific oysters, worth about $10 million each year. No oysters are allowed to be recreationally harvested in the bay. The closest commercial oyster lease occurs east of the Project, as mapped in Figure 3.3-3.

### 3.3.3.2 Recreational Fishing

The main recreational catch species of fish include coho and Chinook salmon. Other recreational catch species include American shad, shiner perch, redtail surf perch, striped sea perch, white sea perch, pile perch, black rockfish, lingcod, Cabezon, red Irish lord, Pacific staghorn sculpin, surf smelt, Pacific herring, Pacific tomcod, kelp and rock greenling, blue and cooper rockfish, California halibut, and white sturgeon.

Much of the recreational angling for salmon in Coos Bay occurs in late summer and fall. It usually begins in late summer at jetty areas and moves up the bay as fish move upstream. Bank angler access on the North Spit is limited. Boat angling occurs throughout the bay, but angling is limited in some areas at times by exposure to winds. For example, the Roseburg Forest Products Co. dock area in Jordan Cove gets less boat angling use due to exposure to wind and tidal action. Other areas of concentrated angling for fall salmon are further up the bay, beginning at the railroad bridge and extending through the Marshfield and Coos River channels.

Perch fishing begins in Coos Bay in late February to early March, depending on freshwater runoff into the bay, and can continue through July. Rocks around bridge abutments and the north jetty are targeted by anglers on the outgoing tide.

Recreational fishing for sturgeon occurs between the railroad bridge and McCullough Bridge and also above the McCullough Bridge. Green sturgeon are illegal to retain and are listed as threatened under the ESA. White sturgeon can be taken year round, but the best angling is during December through March when there is a heavy freshwater plume in Coos Bay. Sturgeon anglers target areas upstream of the McCullough Bridge away from the Project site area.

The west shore of the bay at Jordan Cove contains sand-mud flats, eelgrass beds, and a fringe of estuarine wetlands that provide habitat for recreationally important ghost shrimp and mud shrimp. These shrimp are recreationally harvested at a number of locations throughout the bay

(Figure 3.3-4) and are popular among fishermen for use as bait for species such as perch, rockfish, and various groundfish species that occur in the bay.

Recreational crabbing and clamming brings year-round tourist income to the region. Crabbing occurs in the main channel areas, largely from the BLM boat ramp on the North Spit (west of the Project) to the mouth of the bay and typically is done around slack tides. Crab harvesting by boats is very productive along the western side of the lower bay west/southwest of the BLM boat dock on the North Spit. Along the eastern side of the lower bay from the Empire area south are sand and mud flats that provide some of the highest recreational effort for clams.

Six main areas for recreational shellfish are described below (ODFW 2013):

**Area 1** (South Slough) can be reached from several access points along the west side of South Slough within Charleston. This area is a large sand/mud flat that is firm enough to walk on easily in most places. Many clam species can be found in this highly marine influenced area. In sandy areas, such as those just south of the Charleston bridge, cockle raking is popular. In muddier areas, such as the "Charleston Triangle" (between the commercial docks and the bridge), gaper clams can be found readily at good tides. In areas further up South Slough soft shell clams can be found sparingly. Other clams, such as butter and littleneck clams, are found mixed throughout.

**Area 2** (North Spit) requires a boat or 4x4 vehicle for access other than hiking. This area supports several large and productive clam beds. All species common to lower bays can be found here, including gapers, butters, cockles, and littlenecks.

**Area 3** (Fossil Point and Pigeon Point) can be accessed by many points along Cape Arago Highway from Empire to Charleston. Substrate in the area varies from sand/mud to sandstone/ gravel. In the sandier areas of Pigeon Point, gapers and cockles are easily found. In gravelly areas, such as Fossil Point, butter and littleneck clams are more common.

**Area 4** (Haynes Inlet, North Slough, and Glasgow) can be reached by the nearby banks, from Highway 101 or East Bay Drive. Soft shell clams are common throughout the intertidal areas. Ghost shrimp are common in the area. Commercial oyster operations are also nearby. The oysters are private property and cannot be harvested recreationally.

**Area 5** requires a boat for crabbing. Large sandy flats in depths of 20-30 feet provide excellent bay crabbing year round. Pots may be set anywhere within this area, using caution to avoid direct placement in navigation channels.

**Area 6** includes areas for dock crabbing. In Charleston, the primary areas for dock crabbing are the commercial docks, public crab dock, and "T" docks just south of the bridge. Another popular spot is on the docks adjacent to the Empire boat ramp. Dock crabbing is often fruitful year round, but less so than boat crabbing.

### 3.3.4 Unique and Special Status Fisheries and Marine Resources

Additional species not federally or state-listed as threatened or endangered but designated as protected or sensitive by an environmental division of the local, state, or federal government are described below.

#### 3.3.4.1 Essential Fish Habitat (federal) and Essential Salmonid Habitat (State)

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1976, as amended, was enacted, along with other goals, to promote the protection of Essential Fish Habitat (EFH) in the review of projects conducted under Federal permits, licenses, or other authorities that affect or have the potential to affect EFH. The MSA requires all federal agencies to protect fisheries habitat from being lost due to disturbance and degradation and to consult with the National Marine Fisheries Service (NMFS) when an action has the potential to adversely affect EFH. EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” [16 USC § 1801(10)]. The EFH interim final rule, summarizing EFH regulations (62 FR 66531-66559), outlines additional interpretations of the EFH definition.

For the purpose of interpreting the definition of EFH, “waters” include aquatic areas that are used by fish and their associated physical, chemical, and biological properties, and may include areas historically used by fish where appropriate; “substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” means the habitat required to support a sustainable fishery and a healthy ecosystem; “fish” includes finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds; and “spawning, breeding, feeding, or growth to maturity” covers a species’ entire lifecycle.

The MSA established regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to identify and describe the habitat areas of particular concern within the EFH. When Congress reauthorized this act in 1996 as the Sustainable Fisheries Act, several reforms and changes were made. One change was to charge the NMFS with designating and conserving EFH for species managed under existing FMPs. This was intended to minimize, to the extent practicable, any adverse effects on habitat caused by fishing or non-fishing activities, and to identify other actions to encourage the conservation and enhancement of such habitat.

The Pacific Fishery Management Council (PFMC) has authority over the fisheries in the Pacific Ocean seaward of the states of California, Oregon, Washington, and Idaho. The individual FMPs addressing EFH for managed species in these areas represent the PFMC’s response to those requirements stated in Section 303(a)(7) of the MSA (16 USC §1801 et seq.). Four FMPs have been established by the PFMC, including: FMP for the groundfish in the Pacific; FMP for coastal pelagic species in the Pacific, FMP for salmon in the Pacific, and FMP for highly migratory species (tuna, sharks, and billfish). Tuna and billfish do not occur in Coos Bay but may be found seasonally offshore when the ocean’s temperature warms up.

For the Pacific salmon fishery, the PFMC identified EFH using U.S. Geological Survey hydrologic units, as well as habitat association tables and life history descriptions for each life stage. These areas encompass all streams, lakes, ponds, wetlands, and other currently viable water bodies and most of the habitat historically accessible to salmon in Washington, Oregon, Idaho, and California. In estuarine and marine areas, EFH for Pacific salmon extends from the nearshore and tidal submerged environments within state waters out to the full extent of the Exclusive Economic Zone (EEZ; 200 nautical miles).

EFH is described and identified as everywhere that species managed by the PFMC occur. Specifically, EFH is identified and described based on areas where various life stages of 90 managed species commonly occur. These include 82 species of groundfish, five coastal pelagic species (four finfish: Pacific sardine; Pacific (chub) mackerel; northern anchovy; jack mackerel and one invertebrate: market squid); and three species of salmon (Chinook, coho, and pink salmon). Table 3.3-2 lists species with designated EFH in Oregon. EFH species in Coos Bay include Chinook and coho salmon, northern anchovy, Pacific sardine, and a variety of rock and groundfish. The ODFW reports that adult and juvenile black, blue, and copper rockfish, lingcod, rock greenling, and starry flounder are found in Coos Bay year-round. It also reports that recent genetic work points to the possibility of resident copper rockfish. All habitat accessible to these managed species in the Coos Bay system is considered EFH. This includes estuarine habitat, shore environments, marsh habitat, SAV, and kelp beds. The locations of EFH within Coos Bay and the zones of the LNG carrier transit route are shown in Figure 3.3-5.

Approximately 31.5 acres of potential EFH within Coos Bay will be removed by the dredging and construction that will occur for the Project, including 29.1 acres for the slip, 1.7 acres for the construction dock, and 0.7 acre for the gas processing area. This includes approximately 9.69 acres of intertidal (unvegetated sand), 3.38 acres of shallow intertidal habitat (algae, mud, and sand), 2.49 acres of eelgrass, and 15.24 acres of deep subtidal habitat (Figure 3.3-1).

No habitat designated as EFH for species under federal management plans will be affected by the construction of the land-based elements of the Project; however, it is likely that EFH will be affected by the construction of the slip. The normal transit of LNG carriers to and from the Project will have no direct physical effect on EFH, although maintenance dredging for the access channel to the LNG Terminal ship berth will affect EFH that develops between maintenance dredging periods. Development and maintenance of the slip will temporarily affect the subtidal mudflats in the Project area; however, it will result in the production of a zone of deepwater habitat that will likely be utilized by a myriad of fish species, including the green and white sturgeon. The conversion of shore lands, grassland, and dune forest to open water for the slip will also create additional underwater habitat, which should be considered ODFW Habitat Category 3.

**Prey Dependence on EFH**

Habitat for prey items of species for which EFH has been identified in Coos Bay is essentially the same as that required by those managed species (i.e., estuarine and marine habitats). Shrimp larvae feed on phytoplankton and zooplankton. Postlarvae feed on epiphytes, phytoplankton, and detritus. Juveniles and adults prey on polychaetes, amphipods, and chironomid larvae, but also on detritus and algae (Pattillo et al. 1997). Submerged grasses are important habitat for small prey species of adult lingcod (EFH Core Team 1998).

Forage habitat components for the managed species depend to some extent on estuarine systems. Many species of groundfish and salmonids occupy inshore areas of the lower bay during juvenile stages (e.g., Chinook salmon, coho salmon, English sole, eulachon) where they feed on estuarine dependent prey, including shrimp, small fishes, and crabs. As they mature and move offshore, their diets in many cases change to include fish, although estuarine-dependent species (e.g., shrimp, crabs) can still constitute an important dietary component.

**Essential Salmonid Habitat (State)**

Pursuant to Oregon Revised Statutes (ORS) 196.810(1)(b), the Oregon Department of State Lands (DSL), in consultation with the ODFW, designates Essential Indigenous Anadromous Salmonid Habitat (ESH) areas based on field surveys and/or the professional judgment of ODFW´s district biologists. ESH is defined as the habitat necessary to prevent the depletion of native salmon species (chum, sockeye, Chinook, and Coho salmon; and steelhead and cutthroat trout) during their life history stages of spawning and rearing. The designation applies only to those species that have been listed as sensitive, threatened, or endangered by a state or federal authority, and designations are periodically reviewed and updated.

All projects proposed in ESH must be reviewed pursuant to the standards set forth in the State's Removal-Fill Law (ORS 196.600 to 196.990) and rules (OAR 141-085). An authorization from

DSL for activities involving the fill or removal of any amount of material in ESH is required unless the activity is exempt. This authorization is included in the permit issued by the DSL as part of the Joint Permit Application process with the U.S. Army Corps of Engineers. The DSL Permit for the slip and access channel has been issued to the Port. A copy is provided in Appendix O.2 of Resource Report 2 – Water use and Quality.

#### 3.3.4.2 Native American Fisheries

Historically, an essential resource for the Native Americans in Coos Bay was fish. The extensive tidal channels of the bay were habitat for dozens of species of fish. Massive spawning runs occurred in all seasons of the year, bringing salmon, herring, smelt, and other fishes in vast numbers. One of the most effective systems the local Native Americans used to harvest these fish involved weirs and traps of wooden stakes and woven lattice or basketry, often built across the mouths of tidal channels. They were typically designed to allow fish passage upstream as the tide rose, then trap the fish as the tide receded. In the mid-1900s, the stakes forming these weirs could still be observed at various sloughs in the bay. This is no longer the case, although, remnants of fishing weirs are occasionally reported by those familiar with identifying such weirs.

Modern Native Americans living in Coos Bay do fish, both recreationally and commercially, but these practices are not conducted as tribal fisheries as they are done at certain locations along the Columbia and Klamath Rivers. There is no land that is currently owned by Native American tribes in or adjacent to the Project site area. The tribes in Coos Bay currently do not have policies that regulate fishing separately from state and federal fisheries management. No information about traditional fishing sites still in use in the Project vicinity was identified during the cultural resource investigations which included consultation with tribal representatives. A more detailed discussion of the Native American fisheries is provided in the Cultural Resources Survey Report, filed as “Privileged and Confidential” (Appendix A.4 to Resource Report 4 – Cultural Resources).

#### 3.3.4.3 Marine Sanctuaries, Reserves, and Management Areas

The location of marine research reserves, reefs, and management areas along Coos Bay and within the zones of the LNG carrier transit route are shown in Figure 3.3-6 and described in the following sections. In addition, migratory marine mammal feeding and breeding grounds and bird habitat along the entire route are shown in Figure 3.3-7.

Within state waters along the coast, 1,400 offshore rocks and islands are classified as Rocks and Islands National Wildlife Refuge System, which is administered by the USFWS. There are no rocks or islands in this refuge that fall within the LNG carrier transit route zones. Shell Island which is part of the Oregon Islands National Wildlife Refuge is approximately three miles from the LNG carrier transit route and is outside of the 2.2 mile zone.

The Cape Arago headland encompasses the coastline of three OPRD parks: Sunset Bay, Shore Acres, and Cape Arago. It contains extensive, rich, and diverse intertidal and subtidal habitat, including Oregon’s largest giant kelp bed, seabird nesting sites, and large marine mammal haulouts (including threatened Steller sea lions and the only year-round elephant seal haulout in the state). Within these parks, some areas get high visitor use. More than 600,000 people visit at Sunset Bay and more than 450,000 people visit Cape Arago each year.

**Cape Arago Intertidal Research Reserve**

Marine reserves are defined by the ODFW (2006) as "areas designated to meet specific goals and are regulated to protect resources or uses from activities that may conflict with these goals." The Cape Arago Research Reserve is located just south of the mouth of Coos Bay and forms the only major rocky shoreline between Heceta Head, 55 miles to the north, and Cape Blanco, 32 miles to the south. The Reserve extends along approximately 2.5 miles of shoreline and includes North Cove, Middle Cove, South Cove and Squaw Island. Shoreline features include steep cliffs, numerous offshore rocks, extensive rocky intertidal and subtidal reefs, and small sand beaches. Sloping bedrock platforms with small surge channels are common at Sunset Bay and portions of North Cove. Steeper sloped platforms with deep surge channels are common at Middle Cove, Simpson Reef, Squaw Island, and most of North Cove. The site supports a rich and diverse community of intertidal wildlife. Several species of pinnipeds and seabirds utilize the area.

The Reserve has several prominent features. Nearshore rocks provide nesting and roosting habitat for seabirds. Squaw Island is surrounded by an extensive intertidal area. Simpson Reef, located just beyond the Reserve, provides shelter from wave energy which has resulted in a rich and extensive intertidal community. The wide variety of habitat types at Cape Arago has created a very diverse intertidal community. Cape Arago is the southernmost site in Oregon to support high densities of intertidal and subtidal purple sea urchins. Red sea urchins are also abundant here. A commercial offshore fishery exists for both urchin species but has been in decline in recent years. High diversity and abundance of algal species occur in North Cove, behind the protection of Simpson Reef. Simpson Reef is the only site in Oregon where significant kelp beds of giant kelp (*macrocystis integrifolia*) are found and kelp is extensive along much of the shoreline. Shell Island in North Cove is another unique feature, as it is entirely covered with shell fragments.

Four species of pinnipeds haulout in the reserve. Shell Island, Squaw Island, Simpson Reef and South Cove support harbor seals, California sea lions, and Steller sea lions. Shell Island has the only breeding population of elephant seals in Oregon. Peregrine falcons are also residents at the site.

According to the USFWS Oregon Islands National Wildlife Refuge website, Simpson Reef at Cape Arago is the world's northernmost pupping site for northern elephant seals, and is the largest marine mammal haulout site on the Oregon coast. Shell Island in Simpson Reef is the largest rock in the reef and is habitat for marine mammals, including the federally threatened Steller sea lion. Simpson Reef and Shell Island are located outside of the LNG carrier transit route zones, but due to their close vicinity and significant marine mammal habitat, they were included in the discussion.

**Gregory Point Subtidal Research Reserve**

Gregory Point Subtidal Research Reserve includes 57 acres of subtidal areas at Gregory Point, Lighthouse Island, and nearby Squaw Island. It is located northwest of the mouth of Sunset Bay State Park and includes all areas seaward of extreme low tide in the area. The rocky intertidal area at the site (3.5 acres) is part of the Cape Arago Research Reserve. Formations at Gregory Point are remnants of steeply upturned sedimentary rocks that underlie the Cape Arago region. Key resources of this site include seabird nesting sites on Lighthouse Island and extensive intertidal and subtidal rocky habitat between Lighthouse Island and Squaw Island. Harbor seals also use the area as a haulout. Because of its isolation, the area has been used for many years for study and research by staff and students at the nearby University of Oregon Institute of Marine Biology in Charleston.

**Marine Protected Areas**

The state of Oregon and NOAA designated the South Slough National Estuarine Research Reserve (SSNERR) as the nation's first estuarine reserve in 1974. The SSNERR is administered by the Oregon DSL, which is under the jurisdiction of State Land Board. The SSNERR is the southern extension of the Coos Bay estuary and South Slough is one of the seven inlets that combine to form the Coos Bay estuary. The SSNERR encompasses 4,765 acres and is approximately one-quarter of the South Slough watershed. The reserve includes approximately 800 acres of water and tidally influenced habitat, 115 acres of riparian habitat, and 3,850 acres of upland forest. The mixture of open water channels, tidal and freshwater wetlands, riparian areas, and forested uplands provides a diverse and biologically rich area. Several threatened and endangered and special status species occur at the reserve, including bald eagle, peregrine falcon, brown pelican, cutthroat trout, coho salmon, California pitcher plant, sea lavender, and Point Reyes bird's-beak. Management and administration at the SSNERR supports and coordinates research, education, and stewardship programs which serve to enhance a scientific and public understanding of estuaries and contribute to improved estuarine management. The SSNERR is located to the south of LNG carrier transit route 2.2 mile zone.

### 3.3.5 Environmental Consequences (Construction and Operation)

#### 3.3.5.1 Fish and Marine Species (including EFH)

Potential effects to fish and marine species are discussed below, and also in Section 3.3.5.2 for aquatic habitats and Section 3.3.5.3 for water quality. Discussion of potential effects to marine mammals is primarily included under Section 3.4.4 for environmental consequences to threatened and endangered species, as the Steller sea lion and nine species of whales are addressed in Section 3.4.

**Acoustic Effects**

All piles required for the LNG carrier berth, including docks and mooring dolphins, will be driven prior to or concurrent with the dredging of the slip on dry land. No open water pile driving will be required, thereby eliminating potential affects to fish and marine organisms from higher intensity sound waves in the water column. It is currently assumed that piles will be driven on dry land in isolation from the Bay, and soils would subsequently be removed from around them, eliminating the majority of potential land-based noise impacts.

**Impingement or Entrainment**

As discussed in Resource Report 2 – Water use and Quality, LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is likely that some organisms small enough to pass through the screens covering the carrier's intake port will be drawn in with the cooling water and will be lost from the population in the slip area; however, it is anticipated that the effect associated with the intake of cooling water will be minimal. Juvenile fish would need to be present in the slip area near the carrier's intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen. Generally the total water intake would occur over a 24-hour period during each loading period, about 90 times per year.

**Temperature**

Temperature effects are discussed in Resource Report 2 – Water Use and Quality. LNG vessels would re-circulate water for engine cooling while loading LNG at the berth to provide power for standard hoteling activities as well as running the ballast water pumps. Using conservative assumptions, the maximum heating of cooling water at the time of discharge is estimated to be approximately 3$^{o}$C (5.4$^{o}$F) above ambient temperature for a distance of 50 feet from the discharge point on the LNG vessel, with the difference decreasing with further distance. The creation of the slip results in the addition of approximately 40 acres of water surface to the Coos Bay estuary. This additional water surface will increase the amount of evaporative cooling, further decreasing the water temperature in the slip area. Considering the volume of Coos Bay, virtually no change in bay temperature would occur from heated water discharge. The tides would be continually exchanging the water and the cooling water would be discharged in the same localized area (the northeast corner of the slip). The warmer engine cooling water is not anticipated to have a significant adverse impact on the water temperature in Coos Bay because of mixing and other factors.

**Localized Changes in the Light Regime**

Localized changes in light regime have been shown to affect fish species behavior in a variety of ways. Disorientation may cause delays in migration, while avoidance responses may cause diversion of migratory routes into deeper, less protected waters. In some cases, increased light may attract both predators and potential prey species.

Lighting at the LNG Terminal and onshore facilities would likely include a mixture of low-power fluorescent lighting and higher intensity security lighting that would primarily be located on shore, in and adjacent to the slip. When an LNG carrier is not in the berth, the lighting would be reduced to that required for security. It would be focused upon the structures and not be in proximity to the water so as to serve as an attractant or deterrent to fish species. When an LNG carrier is at the berth, it would physically block the lighting on the berth from the slip waters and, due to its proximity to the slip wall, would block the fish from getting too close to the lighting on the berth. Lighting used would be similar to that already in place at other Coos Bay facilities.

Lighting on the tug dock would be low intensity lighting for safety, providing sufficient light for personnel movements on the trestle out to the tug berth and for movement on the berth itself. There is no intention to provide lighting near the water line or high intensity lighting that would be associated with activities other than the simple berthing of the tugs at this location. The reduced lighting levels near the water would reduce or eliminate any behavioral effects to fish in the Project vicinity. The final details of the lighting arrangement will be determined through consultation with NMFS in the Biological Opinion (BiOp) and other resource agencies to reduce these potential adverse effects.

**Ship Wake and Propeller Wash**

Shoreline erosion, wave heights and shoreline changes, and propwash scour are all discussed in Resource Report 2 – Water Use and Quality. Propeller wash from LNG vessels and tug boat propellers associated with the Project, as well as ship wakes breaking on shore, could cause increased erosion along the shoreline and re-suspend the eroded material within the water column. This may affect the diversity and health of the benthic community regarding food availability and feeding conditions for foraging and migrating fish species. At high concentrations, suspended sediments can affect oxygen exchange over the gills, resulting in weakened individuals or mortality. However, ship wakes associated with the operation of the slip are not expected to result in significant bank erosion or effects due to the low speed at which carriers would traverse the lower bay when approaching or departing the slip and the limited number of trips (approximately 90 round trips per year).

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds have been observed to cause occasional stranding of juvenile salmon (Pearson et al. 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al.) to cause stranding. In models and research conducted by the JCEP, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute to fish stranding within Coos Bay.

**Marine Sanctuaries, Reserves, and Management Areas**

LNG spills from LNG carriers in the transit route from the LNG Terminal should not have any effect on wildlife refuges as the closest refuge is the islands near Cape Arago that are part of the Oregon Island National Wildlife Refuge which extends down the coast south of the Coos Bay harbor entrance. This area is approximately three miles from the transit route and outside of the 2.2 mile zone. The likelihood of a vapor cloud from an LNG spill moving down to the refuge and then being ignited from an ignition source is very low since boats, aircraft, and humans are prohibited from the area and there are no ignition sources.

There is little likelihood of an LNG carrier losing steerage, running into the islands or reefs of the wildlife refuges, and either physically damaging the wildlife refuge areas or spilling LNG cargo. The LNG carriers are double hulled and in previous and similar incidents no LNG cargo has been spilled. In addition, LNG carriers will always be under tug escort when in proximity to the islands and reefs of the refuge and the tugs will keep the carriers under control in the event of a steering or other control failure.

The effect of the additional LNG carriers on refuges due to wakes disturbing mammals in haulout areas is not considered to be an issue due to the distance of the LNG carrier transit route from the refuges and the fact that the LNG carriers will be traveling at reduced speeds while in the bay. As previously described, the additional number of carriers will logically increase the chances of contact between carriers and marine mammals frequenting the refuges. However, the distance between the LNG carrier transit route and the refuges will help reduce these potential contacts to a minimum.

### 3.3.5.2 Aquatic Habitat

**Loss of Benthic and Shoreline Habitat (including EFH)**

The impact of the construction of the slip and access channel on wetlands will be the permanent loss of approximately 8.1 acres of intertidal, 3.3 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.5 acres of eelgrass. The construction dock will affect 1.6 acres of intertidal and 0.1 acre of shallow subtidal habitat and the gas processing area will affect an additional 0.7 acre of intertidal habitat.

Macroinvertebrates move, rest, find shelter, and feed on the substrate and organic material, as well as live within the substrate in these areas. The Project would physically disturb and reduce shoreline aquatic habitat, including eliminating or displacing established benthic communities and reducing prey availability in the vicinity.

Based on air photo interpretation, the distribution and spatial extent of SAV within the area to be dredged for the slip is patchy and sparse. Due to the low density and narrow extent of distribution of SAV in this area, habitat value is expected to be lower relative to the more extensive and contiguous SAV beds located elsewhere in Coos Bay. While the construction of the slip would adversely impact EFH through loss of this narrow band of SAV, the potential adverse impacts to EFH will not be substantial and dredging of the slip will create approximately 36.7 acres of new marine habitat by converting upland to subtidal habitat.

### 3.3.5.3 Water Quality

**Turbidity Levels**

Elevated turbidity levels will result from actions taken to construct the slip and the Kentuck mitigation site for estuarine habitat mitigation and south of the airport for eelgrass mitigation. Dry season construction will equate to less opportunity for precipitation-generated turbidity and will reduce the chances of juvenile fish entering the work area. Elevated turbidity from construction is expected to be localized, but would develop cumulatively for the aquatic environment affected. Turbidity plume direction movement and disbursement will be dependent on current flow. Construction during outgoing tidal flows, combined with outgoing river flows, will carry turbidity downstream. During the incoming tide, turbidity is not expected to be detectable beyond the immediate area, as tidal fluctuations and wind will drive the currents and disperse the suspended sediments into the navigation channel. Elevated turbidity levels will occur over a short time, lasting a few hours immediately after the work area is inundated by the incoming tide. The elevated turbidity levels will occur over the construction in-water work period, twice each day in relation to the high tide cycle. Turbidity is also discussed in Section 3.3.5. for slip construction and Section 3.3.5.5 for the effects of dredging on fisheries.

**Chemical Contamination**

As with all construction activities, accidental release of fuel, oil, and other contaminants may occur as the presence of construction equipment near sensitive habitats creates the potential for introduction of toxic materials from accidental spills, improper storage of petrochemicals, or mechanical failure. Operation of back-hoes, excavators, and other equipment requires the use of fuel, lubricants, etc., which, if spilled into the bay or adjacent intertidal zone, can injure or kill aquatic organisms.

Potential affects from a fuel spill, equipment malfunction, or accident is likely to be a short-term effect, but could be detrimental to aquatic habitat within the action area. Petroleum-based contaminants such as fuel, oil, and some hydraulic fluids contain poly-cyclic aromatic hydrocarbons (PAHs) which can be acutely toxic to the aquatic environment for fishes and can also cause lethal and chronic sublethal effects to aquatic organisms (Neff 1985).

Accidental spills may allow chemicals to reach Coos Bay, resulting in impacted water quality and reduced feeding opportunities for aquatic species within the action area. The large volume of water in the bay, the strong water currents and wind action, and the conservation measures proposed to minimize the amount and distance of a toxicant material spread will result in the dilution of any spill to undetectable levels in a few hours. Potential water contamination from construction activities will be controlled by the implementation of spill containment measures as specified through the permitting and approval process for the Project. However, depending on the timing, weather conditions, and response and clean-up efficiency, adverse impacts may still occur due to the proximity to aquatic habitat.

#### 3.3.5.4 Slip Construction

The construction of the slip will require the excavation of 2.3 million cubic yards (cy) of material and the dredging of 2.0 million cy of material from the slip area and dredging of 1.3 million cy from the access channel for a total of approximately 5.6 million cy. During the dredging of the slip, the water used to hydraulically convey the material dredged to the placement site will be recycled back to the dredge area as it will not be connected to the bay. Throughout this phase of the construction activity, there will be no discharges (water or turbidity) to Coos Bay. During the dredging of the access channel and removal of the berm separating the slip from the bay, the water used to hydraulically convey the material dredged to the placement site will be returned to the north side of the slip where it will mix with the water in the slip allowing any remaining turbidity to settle before mixing with water in the bay.

Much attention has been given to turbidity effects from dredging in estuaries, embayments, and enclosed waters. Turbidity from dredging can elicit a variety of benthic responses primarily because attributes of the physical environment are affected (Wiber and Clarke 2001). Large quantities of bottom material placed in suspension decrease light penetration and change the proportion of wavelengths of light reaching the bottom, leading to decreases in photosynthesis and primary productivity of benthic algae and submerged grasses. Suspended materials can prevent growth of benthic organisms, plants that provide habitat complexity, and biological structures used by some faunal species for shelter and egg attachment.

Coast and Harbor Engineering (C&H) prepared an analysis of the turbidity generated by the dredging operation at the slip and concluded that the proposed dredging activities for the slip are unlikely to have extensive adverse effects on Coos Bay. The model was developed on the basis of a sediment analysis conducted at the site of the dredging and took into consideration wind, tidal currents, seasonal flows, etc. The model approach was conservative in that it predicted turbidity levels based on dredging the entire slip while still connected to the bay, rather than the approach that is proposed by JCEP in which the majority of the slip construction will be kept isolated from the bay by a berm. Only the dredging of the berm and the access channel would occur while connected to the bay. Dredging activity would be restricted to the in-water work window of October 1 through February 15 when salmonid species are not likely present. The ambient turbidity levels in the water (generated by flows, waves, wind, and vessel traffic) create a background level of turbidity, ranging by season from 3.7 to 18.1 nephelometric turbidity units, thereby reducing the relative impact of dredging-related turbidity.

The proposed area for dredging is adjacent to the existing shipping channel, which is subject to periodic maintenance dredging. It is reported (Newell et al. 1998) that benthic communities on mud substrates in Coos Bay when disturbed by dredging recovered to pre-dredging conditions in four weeks. Thus, it is anticipated that the benthic communities in the areas to be dredged in connection with the Project will recover in the same time period, resulting in short-term effects to benthic populations on mud substrate. The dredged areas will also be subject to periodic maintenance dredging and the same cycle of disturbance and re-colonization (to an unknown extent) will likely occur. Direct mortality or injury to fish from construction equipment is not expected to occur due to mobility of the fish. Turbidity as a result of sediment re-suspension is likely to be localized and short term and is not expected to be transported up or downstream to an extent that it will kill or injure shellfish populations. Dredge operations are expected to result in effects similar to annual winter storm events, with possible higher concentrations of suspended sediments concentrated in the area of the dredging. Sessile benthic organisms (those permanently attached to a base and unable to move), shellfish, clams, and crustaceans could be injured or killed during dredging operations. Implementation of a spill plan will minimize the potential for a fuel spill and adverse effects to aquatic life and habitat during dredging.

Sedimentation and maintenance dredging requirements would likely be reduced at the access channel area over time due to natural stabilization and adjustment processes. Predicted volumes for maintenance dredging in the access channel are 26,100 cy per year after 10 years, 21,900 cy per year after 25 years, and 14,800 cy per year after 50 years.

Approximately 37,700 cy is the total maintenance dredging volume expected at year 1 and 34,600 cy is the total maintenance dredging volume expected at year 10. In the first 10 years, an approximate total of 360,000 cy would be removed and in the next 10 years approximately 330,000 cy would be removed for an approximate total of 690,000 cy in comparison to the prediction of 1.75 million cy for the previously proposed import terminal project. This is a substantial reduction in volume which in turn will reduce the demand for disposal space and the amount of turbidity associated with the dredging and disposal.

The operation of the LNG Terminal does not require or produce large quantities of hazardous materials. Solvents and paints are used during normal maintenance activities and are kept in specialized containers with secondary containment to prevent spills on the ground. Stormwater collected in areas that have no potential for contamination will be allowed to flow or be pumped directly to a system of stormwater bio-swales and ditches, which will ultimately drain to the slip. Stormwater collected in areas that are potentially contaminated with oil or grease will be pumped or will flow to oily water collection sumps. Collected stormwater from these sumps will flow though engineered oily water separator packages before discharging to the industrial wastewater pipeline. Industrial wastewater will be conveyed to the Port of Coos Bay’s existing ocean outfall pursuant to the NPDES permit. No untreated stormwater will be allowed to enter waters of the state.

During the operation of the Project, LNG carriers calling on the LNG Terminal could have accidental releases of fuels or other contaminants found on all ships. In the unlikely event that there is an accidental spill of LNG, no effects on marine life are anticipated. LNG is not toxic and if spilled on water would vaporize as it is warmed by the heat in the water. LNG is not absorbed into the water, resulting in no effects on marine life.

#### 3.3.5.5 Effects of Dredging on Fisheries

Effects of dredging on fisheries will be limited to those species found along the edge of Coos Bay where the new slip will be formed. Fish will relocate from the area of the dredging activity, with the duration of the relocation dependent on the length of time for re-colonization of food sources and habitat. Turbidity would be increased in the short-term in localized work areas and up or downstream depending on tidal action and currents. Dredging would likely create localized areas of increased (above background levels) turbidity and plumes of turbid water flowing away from the work areas in the direction of tides and currents. It is expected that sediments will settle out near work areas.

If salmonids are exposed to moderate to high levels of turbidity for prolonged periods, a number of adverse effects could occur including behavioral changes, sub-lethal effects and increased mortality from predators. Dredging is expected to create spikes of high to moderate turbidity in a localized area. Effects are not expected to be significant or measurable due to the limited area affected, timing (season) of dredging activity, and due to the short duration of proposed dredging operations. Though not anticipated to be present during the in-water work period, rearing and migrating salmonids would likely avoid active work areas.

Increased suspended sediment would affect filter-feeding organisms, including shellfish, through clogging and damaging feeding and breathing organs (Brehmer 1965, Parr et al. 1998). However, sediment re-suspension is likely to be localized and short term and is not expected to be transported up or downstream to an extent that it would kill or injure shellfish populations. There are no commercial oyster beds in the immediate vicinity of the proposed dredging areas. Sessile benthic organisms within areas to be dredged will be removed and killed. Other benthic organisms living immediately adjacent to dredge areas will be subjected to periods of high turbidity, and settling of suspended sediments, which could bury, injure or kill these organisms.

Aquatic organisms in Coos Bay are adapted to and exposed to periods of high to moderate turbidity during winter months. Dredge operations are expected to result in similar effects, possibly with higher concentrations of suspended sediments concentrated in the immediate area of the dredging.

Increases in turbidity can also reduce the depth that light penetrates in the water column, which may affect submerged plants, such as eelgrass, and temporarily reduce productivity and growth rates (Parr et al.,1998). In many bays and estuaries, and seasonally, background turbidity levels are high and organisms are able to tolerate continuous exposure to high suspended sediment concentrations for much longer than would occur during dredging operations (Peddicord and McFarland, 1978). Species living in areas where waters are normally clear, such as along a rocky coast, may be especially vulnerable to the effects of increased suspended sediments. The turbidity levels predicted to occur by conservative modeling in the area of the SAV will be well below the levels reported in the literature as resulting in adverse effects on SAV and due to the relatively short duration of the dredging (approximately 4-6 months), there are no anticipated adverse effects on SAV due to turbidity from dredging. Since the predicted turbidity levels were based on the dredging of the entire slip and not just the area inside the berm that will be left to isolate the majority of the slip construction from the waters of Coos Bay, the actual turbidity levels will be lower than what was originally predicted.

The release of organic rich sediments during dredging or disposal can result in localized removal of oxygen from the water column, which can adversely affect aquatic organisms. This effect would be temporary and tidal exchange would be expected to replenish oxygen. In most cases, where dredging and disposal occurs in open coastal waters, estuaries and bays, localized removal of oxygen has little, if any, effect on aquatic organisms (Bray et al. 1997).

The re-suspension of sediments during dredging and disposal may result in an increase in the levels of organic matter and nutrients available to aquatic organisms. The potential for algal blooms in estuarine waters is limited by turbidity and tidal flushing. Increased organic materials could increase productivity in a localized area as food for zooplankton and higher organisms is increased. This effect is expected to be insignificant based on the limited area to be affected.

Salmonids, green sturgeon, juvenile eulachon (if present), mollusks, crustaceans and other aquatic species have the potential to be adversely affected by the dredging. Neither the eulachon, green sturgeon nor the salmonids spawn near the slip site, but the eelgrass beds may provide important feeding grounds for these species, and mollusks and crustaceans utilize the intertidal zone throughout Coos Bay. However, as the amount of SAV and intertidal habitat is minimal at the slip site, impacts to fish resulting from dredging operations are expected to be short term and minimal.

#### 3.3.5.6 Ballast Water Discharge

Ballast water is discussed in depth in Resource Report 2 – Water Use and Quality. The role of ballast water as a vector for transportation and introduction of various nuisance marine species to U.S. waters has become a critical issue for many international ports in recent years. The Oregon International Port of Coos Bay is no exception to this national concern and all ships utilizing this port will be subject to the 2012 U.S. Coast Guard (USCG) Final Rule on Ballast Water Discharges. (See Final Rule on Ballast Water Discharge Standard - Standards for Living Organisms in Ships Ballast Water Discharged in U.S. Waters).

Pursuant to this Final Rule, all LNG carriers will have been required to flush their ballast tanks at least once while in the open ocean or utilize one of several USCG approved Ballast Water Management (BWM) methods in order to discharge their ballast water into the slip area while concurrently loading their LNG cargo. Because taking on ballast water would only occur at sea and the discharge of ballast water will comply with the 2012 Ballast Water Discharge Standards, the potential impact for ballast water to introduce invasive species of interest in Coos Bay will be negligible. The JCEP will continue to require that the ballast water of all LNG carriers be discharged in accordance with federal oversight and existing regulations.

#### 3.3.5.6 Emissions

Some concern has been raised as to the potential impacts to wildlife of carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), and sulfur dioxide ($SO_2$) emissions from the LNG Terminal. Since the refrigerant compressors will be driven by electric motors, the $NO_2$ emissions will be minimal. Based on data from another LNG plant, emission levels more than a very short distance from their sources will be negligible. The typically windy nature of the site will disperse these emissions quickly and it is not expected that these emissions will be a threat to wildlife.

### 3.3.6 Mitigation, Enhancement, and Protection Measures

#### 3.3.6.1 Submerged Aquatic Vegetation and Intertidal Habitat

The impact of the construction of the slip and access channel and construction dock on wetlands will be the permanent loss of approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass.

The proposed mitigation strategy for offsetting impacts to 3.38 acres of intertidal unvegetated sand and 9.69 acres of algal/mud/sand flats is to restore mud flats at the Kentuck wetland mitigation site. In addition, to mitigate for impacts on approximately 2.49 acres of eelgrass, JCEP will create new eelgrass habitat in an area due south of the west end of the Southern Oregon Regional Airport runway.

The airport eelgrass mitigation site appears to contain areas that are protected from wind, waves and excessive current velocities. Water clarity is fairly good compared to upper reaches of the bay. Dense patches of eelgrass scattered about the general area of the airport site were noted during the September 14, 2006, field reconnaissance (DEA). Opportunities exist to either lower high spots or build up low spots that are currently either too shallow or deep to support eelgrass. The resulting habitat increase from the mitigation site will provide benefits to the population overall by increasing the natural cover and forage production in Coos Bay. It is likely the increased quantity of habitat will offset the losses from the LNG Terminal site.

#### 3.3.6.2 EFH/ESH

To minimize impacts to EFH and ESH, the bulk of the slip construction will take place in isolation from Coos Bay by maintaining a portion of the existing shore line as a berm. Construction activity to remove the remaining portion of the existing shoreline and connect the slip with Coos Bay will be planned during the ODFW preferred work windows (October 1 through February 15) to minimize effects on vulnerable life stages of important fish species. Monitoring will be conducted before, during, and after slip construction to ensure compliance with the design and BMPs to control the release of sediments and/or inadvertent spills will be implemented. Mitigation for habitats removed or disturbed will be conducted as previously described.

#### 3.3.6.3 Shellfish Nurseries

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the shellfish species are located, the LNG will remain on the surface of the water until it vaporizes and will not have an adverse effect on the shellfish. Some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting the shellfish, given the ambient water temperatures in the transit route. If the vapor from an LNG spill were to come in contact with an ignition source the resulting fire would burn back to the spill source and would affect things on the water or in the area that came in direct contact with the fire. Shellfish nursery areas and shellfish in the water would not be affected as the fire would be above the water in the area of the spill where the vaporized LNG is at flammable levels. In either case of lower or higher water temperatures based on the spill scenario, mobile species will move out of the area until the water temperatures return to normal. LNG spills directly on shellfish nursery areas when exposed at low tide are unlikely as the LNG carriers will routinely exit the Port at slack high tide.

There is little likelihood of an LNG carrier losing steerage, running aground, and physically damaging shellfish areas as the channel geometry will serve to keep the LNG carrier within the confines of the channel. In addition the LNG carrier will always be under tug escort when in the channel. The tugs will keep the LNG carrier under control and not allow it to run aground in the event of a steering or other control failure.

#### 3.3.6.4 Import of Exotic Marine Species

Ballast water is held in the ballast tanks and cargo holds of LNG carriers to provide stability and maneuverability during a voyage when carriers are not carrying cargo, are not carrying enough cargo, or require more stability due to rough seas. LNG carriers will need to discharge their ballast water at the LNG Terminal in conjunction with the cargo loading process. Any ship originating from a foreign port of call (LNG or otherwise) has the potential to import an exotic species that could impact the habitat associated with the slip. In recent years the impacts of these effects have become critically manifested in almost all U.S. ports of call. A study by Carlton and Geller has identified 638 taxa of exotic species that have already been introduced into the Coos Bay environment. For years now, all vessels entering U.S. ports have been required to comply with ballast water management protocols, U.S. law (e.g., Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990; 1996 National Invasive Species Act), and agency programs (Department of Defense/U.S. Environmental Protection Agency regulations at 40 CFR Part 1700, which implement Section 312(n) of the Clean Water Act), and establish discharge standards for vessel ballast water.

On March 23, 2012, the USCG issued its Rule regarding Standards for Living Organisms in Ships' Ballast Water Management Discharged in U.S. Waters, which amends the existing BWM regulations and creates a standard for the allowable concentration of living organisms in ballast water discharged in U.S. waters consistent with the International Maritime Organization's International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM Conventions). This Rule will require all vessels equipped with ballast tanks bound for (or departing) U.S. ports to utilize at least one BWM method described in the Rule (77 FR 17254). The most likely convention given the advanced technologies used by LNG carriers will involve a complete ballast water exchange (BWE) in an area 200 nautical miles from any shore prior to discharging ballast water.

JCEP has assumed that the provisions of this Act and the new Rule will apply to both the import and export of nuisance species, and by compliance with this Act and Rule, the LNG carriers will neither cause nuisance species to be introduced from the discharge of ballast water into the Project site within Coos Bay or the ports of delivery for the LNG cargo.

#### 3.3.6.5 Marine Mammals

All marine mammals are protected under the Marine Mammal Protection Act of 1972. The estuarine and open ocean habitats (out to the EEZ) of the Project area could support a variety of protected marine mammals. Only the harbor seal, Steller sea lion, gray whale, and killer whale exhibit any potential to enter the bay and only the harbor seal was observed at the slip site during field surveys. Gray whales and killer whales enter Coos Bay only on an occasional basis. The Steller sea lion is expected to occur more frequently at the bay mouth, near the Charleston harbor where it is attracted to fishing-related activities, or offshore. All four species could be affected by increased shipping traffic. However, Coos Bay has historically experienced higher levels of deep draft vessel traffic (on the order of 200 ships per year versus the current rate of 50 ships plus the additional 90 LNG carriers). Accordingly, while the increase in the number of ships may result in an increased probability of ship strikes, ship strikes should still be less than what occurred a number of years ago.

In October of 2008, NMFS established its Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales on the premise that slower speeds result in reduced potential for whale/ship strike interactions. This Rule does not apply to shipping traffic (LNG carriers) within the Pacific Ocean. Likewise, the Port of Coos Bay does not have regulatory authority over ships in the open sea. However, once an LNG carrier enters U.S. waters and approaches the harbor coastline, a mandatory reduction in speed is required. Each carrier will also be assisted into the bay by pilot and tug vessels; therefore, transit to and from the slip will already be at slow speeds due to in-place operating protocols. Slower speeds will result in reduced potential for LNG carrier strikes and yield minimal wakes inside the bay, such that marine mammals will not be affected by the wakes of passing LNG carriers.

Recent research into whale/ship strike interactions has identified a “sound shadow” that is created by the vessel’s hull by blocking the engine noise generated at the stern from being projected forward toward the bow. This sound shadow essentially veils the engine noise thus catching whales unaware of the vessel’s presence until it is often too late to avoid the vessel or its propellers. Technology has been developed in the form of a submerged directional array that can be deployed at the vessel’s bow to fill the acoustical shadow with sounds detectible by marine mammals and thus avoid a ship strike. The use of sound projection within the bow shadow is currently not required.

JCEP will provide measures proposed by NMFS for avoidance of marine mammals to carriers transporting LNG cargo from the Project to further reduce the likelihood of adverse effects on these species. Some of the suggested measures could include the following:

- Provide training to LNG carrier crews that would include the use of a reference guide such as the “Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska” by Pieter Folkens. This is a pamphlet that could be carried on the LNG carriers.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the carrier to avoid striking protected species.
- When whales are sighted, maintain a distance of 90 meters or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce vessel speed when pods or large assemblages of cetaceans are observed near a vessel underway.
- When whales are sighted in a vessel’s path or in close proximity to a moving vessel, reduce speed or shift the engine to neutral until the whales are clear of the area or path.
- LNG crews will be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the vessel. If the injury or death is caused by a collision with the vessel, appropriate regulatory agencies (FERC or NMFS) will be notified within 24 hours of the incident. Information to be provided will include the date and location (latitude/longitude) of the strike, the vessel name, and the species or a description of the animal, if possible.

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas used as migratory routes by marine mammals, the LNG will float on the water until it vaporizes and will not have an adverse effect on the mammals unless they come in direct contact with the LNG.

#### 3.3.6.6 Project Construction

Land disturbing activities required for the construction of the Project will be confined to the existing property. During construction of the LNG storage tanks and other facilities, disturbed soils will be exposed to potential erosion. To minimize the impacts of erosion and sedimentation on surface waters, land disturbing and construction activities will be conducted in compliance with the National Pollution Discharge Elimination System (NPDES) Permit

Number 1200-C for stormwater discharges during construction activities. Stormwater runoff from the disturbed portions of the Project site will be managed in accordance with a site-specific Erosion and Sedimentation Control Plan (ESCP) included in the NPDES permit, which incorporates stormwater pollution prevention. JCEP will install all necessary erosion and sedimentation control structures in compliance with its ESCP, as well as the provisions of FERC's Plan and FERC's Procedures, both as modified. Following appropriate treatment, all construction stormwater from the Project site will be directed towards the slip.

Spills, leaks, or other releases of hazardous materials during construction of the Project could adversely impact water quality. Hazardous materials entering Coos Bay resulting from material spills being flushed into waterbodies with stormwater runoff or entering Coos Bay directly from leaks or spills at the LNG loading berth could have an adverse impact on water quality and aquatic organisms. A site-specific preliminary spill plan for the construction phase of the Project will be included as part of the NPDES permit to minimize the potential for accidental releases of hazardous materials and to establish proper protocols concerning minimization of, containment of, remediation of, and reporting of any releases which occur.

A Spill Prevention, Containment and Countermeasure Plan (SPCCP) will be prepared for the operational phase of the Project under the NPDES permit to minimize the potential for accidental releases of hazardous materials and to establish proper protocol concerning minimization, containment, remediation, and reporting of any releases which occur. This Plan will meet the requirements of 40 CFR Part 112.

## 3.4 FEDERAL AND STATE LISTED THREATENED AND ENDANGERED SPECIES

Federal agencies are required by Section 7 of the Endangered Species Act (ESA) of 1973, as amended, to ensure that any actions authorized, funded, or carried out by a federal agency do not jeopardize the continued existence of a federally-listed threatened, endangered, or proposed species, or result in the destruction or adverse modification of designated Critical Habitat of a federally-listed species. In addition, Oregon has its own ESA that requires state agencies to protect and promote the recovery of state-listed threatened and endangered species.

For the Project, FERC is required to consult with the USFWS and NMFS for federally-listed threatened and endangered species (or proposed for listing) and Critical Habitat found in the vicinity of the Project and to determine the Project's potential effects on those species or Critical Habitat. Federal candidate species and species of concern do not require federal ESA consultation. JCEP has initiated this consultation (Table 1.8-1, Resource Report 1 – General Project Description). For this report, a list was obtained from the ORBIC on October 19, 2012, for federally-listed species and Critical Habitat occurring within two miles of the Project's action area. At that time, the action area included the LNG export terminal facility, including the South Dunes Power Plant site. The ORBIC database is continually updated and the data received must be updated every six months for compliance with the ESA.

At the state level, consultation is conducted with the ODA for state-listed plant species and the ODFW for fish and wildlife species. However, state regulations pertaining to the protection of botanical resources are limited to ORS 564 and OAR Chapter 603, Division 73. State threatened and endangered plant species that could be present within the Project's boundaries have no legal protective status in Oregon because they would occur on private land and Oregon regulations only apply on all non-federal public lands (state, county, city, etc.). For fish and wildlife species, JCEP is required to coordinate and consult with the ODFW under the Oregon ESA (ORS 496, 506, and 509) and the Oregon Fish and Wildlife Habitat Mitigation Policy (OAR

345-022-0060) regarding state-listed species to ensure conservation of fish and wildlife resources and to develop a fish and wildlife habitat mitigation plan, as appropriate.

A lack of federally-listed species or Critical Habitat for a given area does not necessarily indicate there are no significant elements present, only that there is no information recorded for the site. To ensure there are no significant elements present that may be affected by the Project, the Project site and vicinity, as applicable, have been surveyed during the appropriate season for individual listed species for the county. In addition, JCEP (and its subcontractors) conducted informal consultations with Oregon agencies to determine the presence of state-listed threatened and endangered species that may be affected by the Project, per 18 CFR § 380.12(e)(4) for FERC.

From informal consultation conducted, it appears the Project may affect listed species. In compliance with Section 7 of the ESA, FERC staff is currently preparing a Biological Assessment (BA) for the Project which will be submitted to the USFWS and NMFS with a request to initiate formal consultation. The BA reviews the status of and potential effects by the Project on listed species and Critical Habitat, and includes proposed measures to avoid, minimize, or mitigate impacts on listed species. The BA also identifies and describes EFH that may be adversely affected by the Project, which requires consultation with NMFS under the Magnuson-Stevens Act.

Formal consultation concludes after the USFWS and NMFS each prepare a BiOp that includes analysis of the impact of the Project on listed species or Critical Habitat and determines whether the Project is likely to jeopardize the continued existence of listed species. Jeopardy occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the wild is appreciably reduced. For jeopardy determinations, FERC would be provided with reasonable and prudent measures that would be outlined in an incidental take statement (ITS). The ITS sets forth nondiscretionary terms and conditions, including reporting requirements, that FERC and JCEP must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions would be exempt from the take of ESA-listed species. The BiOp from NMFS would also include conservation recommendations to avoid, minimize or otherwise offset potential adverse effects on EFH, and these recommendations would become a subset of the terms and conditions found in the ITS.

The environmental analysis under this section includes species that are listed by the federal or state government as threatened, endangered, or proposed for listing. Species listed under the Marine Mammal Protection Act and those included as Essential Fish Habitat are described under Section 3.3 for fisheries and marine species.

Twenty-nine federal or state-listed threatened or endangered species, including one proposed species (streaked horned lark), potentially occur in the proposed Project area (Table 3.4-1). The following sections summarize their distributions, habitat requirements, and potential occurrence. Environmental consequences of construction and operation of the Project, including in the LNG carrier transit route, are also discussed, along with proposed mitigation, enhancement, and protection measures.

### 3.4.1 Botanical Species

Five federal and state-listed plant species were identified as having the potential to occur in the Project vicinity. The western lily is the only federally-listed species. State-listed species include the pink sand verbena, Point Reyes bird's-beak, silvery phacelia, western lily, and Wolf's evening primrose. Only one state-listed species (Point Reyes bird's-beak) has been detected within the Project area. The five species are described below.

### 3.4.1.1 Pink Sand Verbena (Federal Species of Concern, State Endangered)

The pink sand verbena (*Abronia umbellata ssp. breviflora*) is the only pinkish-purple-flowered coastal *Abronia* species in Oregon. The historic range of pink sand verbena occurs from California to British Columbia, Canada (USFWS 2006). Its present range is predominantly from Cape Blanco (Curry County) in southern Oregon to Point Reyes National Seashore in Marin County, California; however, they sporadically occur along Oregon's northern and central coast. In the northern portion of its range, most populations occur on broad beaches and/or near the mouths of creeks and rivers. The species usually occurs on beaches in fine sand between the high-tide line and the driftwood zone, and in areas of active sand movement below the foredune. Associate species include sea rocket (*Cakile maritina*), silver burweed, European beachgrass, beach silvertop, and yellow sand verbena (*Abronia latifolia)*.

Suitable habitat for the species was found along the eastern portion of the LNG Terminal site in areas of actively moving dunes and European beachgrass. Surveys conducted on the Project site in 2006 for the majority of the Project site area and in 2012 and 2013 in previously unsurveyed areas for the Project, including the construction worker camp site, did not result in the detection of any individuals (SHN 2006b; SHN 2012). The Project is not expected to affect this species.

### 3.4.1.2 Point Reyes Bird's-Beak (Federal Species of Concern, State Endangered)

Point Reyes bird's-beak (*Chloropyron maritimum ssp. Palustre*, formerly *Cordylanthus maritimus ssp. palustris*) is an annual gray-green and purple-tinged herb that grows 4 to 16 inches tall and has few branched stems. Also referred to as salt marsh bird's beak, it occurs in coastal salt marshes, typically within the zone that is periodically or frequently inundated by high tides (ORBIC 2012b; Brian 2005). Point Reye's bird's-beak inhabits the upper end of maritime salt marshes and its habitat requirements are specific: approximately 7.5 to 8.5 feet above mean lower low water (MLLW), sandy soils with soil salinity of 34 to 55 parts per thousand (ppt), and less than 30 percent bare soil in summer (ODA 2013). It flowers from June to October. Associate species include those that are tolerant of high salinity levels such as salt grass, pickleweed, fleshy jaumea (*Jaumea carnosa*), sea lavender (*Limonium californicum*), and dodder (*Cuscuta salina*). Point Reyes bird's-beak occurs along the Pacific Coast from Tillamook County, Oregon, south to Santa Clara County, California. In Oregon, the species is restricted to Netarts Bay, Yaquina Bay, and Coos Bay, with the majority of known occurrences located in Coos Bay.

Several occurrences of Point Reyes bird's-beak are located in the vicinity of the Project area (ORBIC 2012). Multiple occurrences within Jordan Cove have been observed (ORNHIC 2005; SHN 2012), as shown in Figure 3.4-1. The closest known occurrence to the Project site is located within Jordan Cove along the shoreline east and west of the South Dunes Power Plant site. Potential habitat for this species has also been observed along the shoreline south of the South Dunes Power Plant site. This habitat contains an abundance of the associated species, including pickleweed. Prior to construction, an additional survey for Point Reyes bird's-beak will be conducted during the appropriate blooming period in the area defined as potential habitat for the species.

### 3.4.1.3 Silvery Phacelia (Federal Species of Concern, State Threatened)

Silvery phacelia (*Phacelia argentea*) is a hairy, fleshy perennial herb with thick leaves that are coated in long, straight, silvery hairs. They occupy open sand above the high tide line, open and partly stabilized sand dunes further inland, and coastal bluffs. They flower from late May to early August. Silvery phacelia occurs in Coos and Curry counties along the Oregon coast and Del Norte County in California, from the vicinity of Bandon, Oregon, south to Crescent City, California. There is one historic collection of the species from Clatsop County, Oregon, to the north in 1933, but there have been no reports of it from that area since. The majority of occurrences are in Oregon (ODA 2013).

Suitable habitat for silvery phacelia exists at the Project site in areas with active or semi-stabilized dunes and upper beach habitat where European beachgrass and red fescue-salt rush herbaceous vegetation associations occur. Surveys conducted on the Project site for the majority of the Project area did not result in the detection of silvery phacelia (SHN 2006b; SHN 2012). The Project is not expected to affect this species.

### 3.4.1.4 Western Lily (Federal Endangered, State Endangered)

The western lily (*Lilium occidentale*) is a member of the perennial lily family (Liliaceae) and grows up to 5 feet tall with nodding red (sometimes deep orange) flowers. The species was federally-listed as endangered on August 17, 1994, and a final recovery plan was released four years later (USFWS 1998c). It inhabits 31 small, widely separated populations in freshwater marshes and swamps, coastal scrub and prairie, and openings in coastal coniferous forest (Sitka spruce dominated) along the coast of southern Oregon and northern California. It occurs within four miles of the coast, generally on marine terraces below 300 feet above mean sea level (MSL; CNDDB 2005). The western lily is considered a bog plant and grows in areas with perched water tables which are associated with one or two soil types. Occurrences within the Coos Bay area are reported to occur in Blacklock soils (ORNHIC 2005), which are deep, poorly drained soils high in organic content (Hagen 1989); however, it also grows in soils that are well drained that have a significant layer of organic soil.

The wetlands where Western lilies occur are not what are often associated with wetlands. They are in areas where the marsh is flooded in the winter but is typically very dry in the summer. The species emerges in Oregon in late March or early April and flowers in late June or July (USFWS 1998). Species typically associated with western lily include Sitka spruce, Pacific reed grass, willows, false lily-of-the-valley, and evergreen huckleberry (Imper 2003).

The closest known western lily occurrence to the Project site is approximately 5.5 miles northeast at Hauser Bog (ORNHIC 2005). There are not any records of the western lily north of Hauser and the USFWS typically considers Hauser the northern extent along the Oregon Coast for the species (Vander Heyden pers comm. 2013). Surveys were conducted at the Project site in 2006 for the majority of the Project area and again in 2012. The surveys did not result in the detection of western lily (SHN 2006b, SHN 2012). While suitable habitat is located along the terrestrial portion of the LNG carrier transit route in Coos Bay, LNG carrier traffic is not expected to affect the western lily.

### 3.4.1.5 Wolf's Evening Primrose (Federal Species of Concern, State Threatened)

Wolf's evening primrose (*Oenothera wolfii*) is a rare species of flowering plant in the evening primrose family. It occurs in well-drained sandy soil in coastal strands, roadsides, and coastal bluffs (ODA 2013). This species is associated with a high disturbance regime and several occurrences in California are located along roadsides with sandy soil (CNDDB 2005). Wolf's evening primrose is typically associated with low elevation coastal habitats, but there have been reported occurrences in lower montane coniferous forest in California, at elevations greater than 2,500 feet above MSL (Tibor 2001).

The current range of Wolf's evening primrose is from Curry County in southern Oregon to the northern California coast. The closest known occurrence to the Project site is in Port Orford, Oregon, approximately 60 miles to the south of the Project. The species is included in this analysis as suitable habitat exists within the Project site. Surveys conducted on the Project site did not result in the detection of wolf's evening primrose (SHN 2006b, SHN 2012). The Project is not expected to affect this species.

### 3.4.2 Terrestrial Wildlife Species

#### 3.4.2.1 Reptiles and Amphibian Species

There are no terrestrial federal or state threatened or endangered (or proposed) amphibian or reptile species that occur within the Project site.

#### 3.4.2.2 Birds

Seven bird species that are federal or state-listed as threatened, endangered, or proposed have the potential to occur in the vicinity of the Project, as described below. The locations of federal species detected in the Project site vicinity are shown in Figure 3.3-7.

**Bald Eagle (Federal Delisted, State Threatened)**

The bald eagle (*Haliaeetus leucocephalus*) is a widespread breeder in Oregon, with confirmed nesting in all but four counties. When the bald eagle was delisted on July 9, 2007 (72 FR 37346-37372), legal protections provided to the bald eagle switched to the Bald and Golden Eagle Protection Act and new guidelines were developed (USFWS 2007d). The most substantive change in the guidelines was a reduction in the distance between activities and in occupied nests from 0.5 mile to 660 feet when the activity is visible from the nest (line-of-sight).

Bald eagles are usually associated with large water bodies, including lakes, rivers, and coastal nearshore habitat. Home ranges are usually about 2-3 square miles (Anthony et al. 1990, Garrett et al. 1993). Bald eagle numbers peak in late winter and early spring when breeders, transients, and winter residents are all present (Isaacs and Anthony 2003). They nest on large, prominent trees and snags, usually within a mile of water, and nests are almost always reused (Isaacs and Anthony 2003).

Bald eagles are an uncommon resident of forested habitats near water on the Oregon coast (Eltzroth 1987), including Coos County (Rodenkirk in prep.) and the North Spit (USDI 2005); however, nesting is confirmed in most of Coos County (Adamus et al. 2001). It is not believed that any suitable nest sites exist within the Project site area, but there is ample foraging habitat in and along the bay. During field surveys conducted in 2005, there were five sightings in all seasons. Only one was observed at the Project site, consisting of an incidental sighting of a perched bird, and no nests were found. The rest of the sightings were over or across the bay from the Project site (LBJ 2006). A nest site in the ORBIC database, active at least as recently as 2003, is on Mettman Ridge above Glasgow, roughly three miles from the Project site.

Bald Eagles may be encountered in any of the LNG carrier transit route zones from nearshore coastal waters to the Project site. No nests occur at the Project site and the Project is not expected to affect this species.

**Brown Pelican (Federal Delisted, State Endangered)**

The brown pelican (*Pelecanus occidentalis)*, sometimes referred to as the California brown pelican, is found in nearshore ocean waters, in large bays and river mouths, and on beaches and spits. These birds are rarely seen inland or more than 40 miles from shore and they feed mostly in shallow estuarine waters. Pelicans make extensive use of sand spits, offshore sand bars, and islets for nocturnal roosting and daily loafing, especially by nonbreeders and during the non-nesting season (USFWS 2005).

The brown pelican is considered a common to abundant post-breeding migrant on the North Spit (BLM 2005). It arrives from the south along the Oregon coast in April and becomes abundant by August and September (Eltzroth 1987, Nehls 2003a, Rodenkirk in prep.). Although most brown pelicans have withdrawn to the south by December, small numbers now winter most years in the Coos Bay area (Contreras 1998, Rodenkirk in prep.). Coos Bay adjacent to Jordan Cove is excellent habitat for this species and it was recorded foraging near the Project site more than 500 feet from the shore and loafing across the bay in moderate numbers daily during surveys in October 2012 (SHN 2012). The species was also observed during surveys conducted in 2005-2006 until early September (LBJ 2006). The Project site provides no nesting habitat for the brown pelican.

Brown pelicans may be encountered during any portion of the LNG carrier transit route but are most likely to be encountered in the coastal nearshore waters out to the 0.3 mile zone. They appear unaffected by industrial activity already taking place in and around the bay and no impact to this species is anticipated from the development of the Project.

**Marbled Murrelet (Federal Threatened, State Threatened)**

The marbled murrelet (*Brachyramphus marmoratus*) is a small, chubby seabird that has a very short neck. It was listed as threatened under the ESA on October 1, 1992, for the Pacific region (including Washington, Oregon, and California). Critical Habitat was designated for the marbled murrelet (MAMU) on May 24, 1996 (61 FR 26257-26320). Following a series of proposed revisions in 2006 and 2008, a final rule on revised Critical Habitat was issued on October 5, 2011 (76 FR 61599-61621). MAMUs are not recovering like they should be and they have a high predation rate along the coast.

MAMUs nest primarily in coastal, old growth forests within 50 miles of the coast that are characterized by large conifer trees, multi-storied stands, and moderate-to-high canopy coverage from Alaska to Monterey Bay, California. They are also known to nest in mature forests with old growth characteristics. Nest trees for MAMUs need to be 19.1 inches or greater in diameter breast height (dbh), greater than 107 feet in height, have a least one platform 4 inches or greater in diameter that occurs a minimum of 32.5 feet above the ground (due to the way the birds take off from the platform—dropping down and coming up), and have an access route through the tree canopy that a MAMU could use to approach and land on the platform. It also needs a tree branch or foliage that provides protective cover (Nelson and Wilson 2002). The platform cannot be on a snag with no cover.

MAMUs spend a majority of their life on the ocean (USFWS 2007). Nesting adults make daily foraging trips to shallow, protected, nearshore coastal waters, feeding mostly on small fish but sometimes on euphausiids (small shrimp-like crustaceans). When at sea, MAMUs are rarely found more than a few miles from the shore (Hunter et al. 2005).

The USFWS consults on projects within ¼ mile of Critical Habitat for effects from construction with heavy equipment and one mile for more complex projects such as blasting and large helicopter work (Bridgette Tuerler pers comm. 2013). The USFWS is primarily concerned about removing MAMU habitat or impacting the land or the ability of the land to grow trees. It is also concerned about possible predation to the species due to predators attracted to potential habitat in the vicinity by human activities.

For sites determined to be close to potential MAMU habitat (whether listed as Critical Habitat or not), it is assumed there will be noise associated with the proposed work and, therefore, the Project could potentially affect the species. The extent of that effect would depend on the timing, associated activities and equipment, duration, season, location, etc. If potential Critical Habitat occurs within ¼ mile of the Project, these details would need to be considered and analyzed in a Biological Assessment before the USFWS could provide concurrence, as required under the ESA.

The species is considered uncommon to rare year-round on the Oregon coast (Marshall et al 2003), but Coos Bay is within the zone of highest density (Strong et al 1995). The MAMU nests in the Elliott State Forest northeast of Coos Bay in the Oregon Coast Range, and it probably nests in the Coos Bay area as well (Adamus et al. 2001). It is considered an uncommon, year-round, offshore resident on the North Spit (BLM 2005). One to four MAMUs are observed most years during the annual Coos Bay Christmas bird count (NAS website 2012). Although none were observed during surveys conducted for the Project (LBJ 2006), it is considered possible that MAMUs could occur on the bay within the general Project area and perhaps over the Project site in transit between nesting and feeding sites. MAMUs could be also be encountered along the LNG carrier transit route, as they generally forage in the nearshore region within three miles of the shore (McShane et al. 2004).

**Northern Spotted Owl (Federal and State Threatened)**

The northern spotted owl (*Strix occidentalis caurina*) is dependent on old-growth components in coniferous forests. In Oregon, it is found in low- and mid-elevation coniferous forests in the Coast, Siskiyou, and Cascade ranges (Forsman 2003). There are many spotted owl habitat areas in the forests inland from Coos Bay. The nearest site to the Project site is approximately five miles away in the Kentuck Creek drainage (ORBIC 2012). However, the species is extremely rare on the immediate coast of Oregon (Eltzroth 1987), rare in Coos County (Rodenkirk in prep.), and absent from coastal Coos County (Adamus et al. 2001). The northern spotted owl is absent from the North Spit wildlife list (BLM 2005) and is unlikely to be encountered in any of the terrestrial habitat in or near the Project vicinity or along the LNG carrier transit route. The species is not discussed further in this document.

**Short-tailed Albatross (Federal Endangered, No State Listing)**

The short-tailed albatross (*Phoebastria albatrus*) is the largest pelagic seabird in the North Pacific. Its long, narrow wings are adapted to soaring low over the ocean. It is best distinguished from other albatrosses by its large bubblegum-pink bill. The short-tailed albatross was federally-listed as endangered throughout its range on July 31, 2000. Critical Habitat is not prudent for this species. A recovery plan, drafted in 2005, is not finalized.

Historically, millions of short-tailed albatrosses bred in the western North Pacific on several islands south of the main islands of Japan. Only two breeding colonies remain active today and both are in Japan. Single nests occasionally occur on Midway Island, Hawaii. Eggs hatch in late December through early January and chicks remain near the nest for about five months, fledging in June. After breeding, short-tailed albatrosses move to feeding areas, with juveniles remaining at sea up to ten years before returning to nest. The species is distributed widely throughout its historical foraging range of the temperate and subarctic North Pacific ocean and they are often found close to the U.S. coast. They have been known to forage up to 1,988 miles from their breeding ground (USFWS 2012).

The short-tailed albatross population is estimated to be 1,200. Of these, the total number of breeding age birds is thought to be approximately 600 birds (USFWS 2013). The worldwide population of short-tailed albatrosses continues to be in danger of extinction throughout its range due to natural environmental threats, small population size, and the small number of breeding colonies. Longline fishing, plastics pollution, oil contamination, and airplane strikes are not viewed as threats by the USFWS to the species' survival but are considered threats to the conservation and recovery of the species.

Short-tailed albatross have been documented to occur off the Oregon coast in the vicinity of Coos Bay. ORBIC data reported a number of different occurrences along the coastline that transits the Coos Bay area. In November 2006, a radio-tagged bird moved from Alaskan waters to the mouth of the Columbia River, then down the Oregon coast to Cape Blanco (between Bandon and Port Orford), then out to sea and back to the Aleutian Islands in Alaska (ORBIC 2012). From September 25-29, 2009, another radio-tagged bird moved from Alaskan waters to off the mouth of the Columbia River, then headed down the Oregon coast on September 27 and into California. Other occurrences recorded included a short-tailed albatross observed off the coast of Yachats, between Florence and Newport to the north, on April 8, 2010.

Short-tailed albatross spend much of their time feeding in nutrient-rich waters of ocean upwelling which often occur at continental shelf breaks (USFWS 2005a). The short-tailed albatross could potentially be encountered within the LNG carrier transit route zones within the EEZ.

**Streaked Horned Lark (Federal Proposed, State Sensitive-Critical)**

The streaked horned lark (*Eremophilia alpestris strigata*) is a rare subspecies of the horned lark. It migrates between Oregon and Washington with breeding populations found in the Puget Sound lowlands, Columbia River/coastal Washington, and the Willamette Valley in Oregon from late March to early August. A previous candidate for federal listing, it was proposed for listing as a threatened species under the ESA on October 11, 2012. In addition to the listing, Critical Habitat was proposed for 7 counties in Washington and 11 counties in Oregon, but did not include Coos County. The closest county with Critical Habitat is Lane County to the north.

Some individuals winter in California (Pyle 1997) and occur along the Oregon coast on migration, while a few winter on the coast. The species occurs in bare and sparsely vegetated habitats such as coastal dunes, beaches, gravel roads, airport runways, grazed pastures, and dry mudflats; however, they do not occur on rolling or steep areas at these sites. Where deflation plains occur, streaked horned larks are often behind the foredune (Pearson pers comm. 2013). Larks also occur where dredge spoils have been deposited or in areas where there is accretion (deposition) of sand causing beach areas to become wider, provided the sites are sparsely vegetated and are immediately adjacent to water. For sites not adjacent to water, the area of expanse has to be quite large, likely 300 acres or greater, although further studies are needed (Pearson pers comm. 2013).

During winter surveys conducted in 2004/2005, streaked horned larks were found on dune and beach habitat adjacent to open water with few or no trees and shrubs on the Washington coast. On the lower Columbia River they were primarily found on sparsely vegetated dredge spoils (Pearson et al. 2005). The streaked horned lark has been documented on the North Spit (BLM

2005) and may winter over on the southern Oregon coast (Pearson et al. 2005). They spend the winter in large groups of mixed subspecies of horned larks in the Willamette Valley, and in smaller flocks along the lower Columbia River and Washington Coast (Pearson et al 2005).

When new unvegetated land is created by dredge spoils and accretion, it is not used by larks for the first year or two after deposition. Once the site becomes sparsely vegetated it can be quickly colonized by larks, especially on island spoils where off-road vehicle (ORV) traffic does not occur. If the site becomes colonized by non-native beach grasses (*Ammophila spp.,* including European beachgrass) it is no longer used by streaked horned larks once it becomes densely vegetated (Pearson and Hopey 2004). There is a fairly narrow window of time when the habitat is sparsely vegetated and appropriate for larks. In addition, dredge spoils colonized by Scotch broom (*Cytisus scoparus*) or horsetail (*Equisetum sp.*) are not used by the species (Pearson et al. 2005). As sandy habitats on the coast continue to be colonized with a dense covering of beachgrass, the larks do not use these habitats for breeding or over-wintering.

There appear to be very few streaked horned larks remaining in the world (probably between 500 and 1000 birds) and preliminary genetics work suggests that the remaining birds have little genetic diversity. This result suggests that the streaked horned lark population may already be experiencing the deleterious effects of inbreeding or the results of a small founder population. The remaining populations are vulnerable to all of the threats small populations commonly face (e.g., vulnerability to environmental and demographic variability and to the loss of genetic variability)(Pearson et al. 2005).

A focused field evaluation of the Project site on the North Spit was conducted by SHN Consulting (SHN) staff on April 23, 2013, to assess the potential for streaked horned lark habitat to occur (Figure 3.4-2). One small area approximately 75' by 150' was noted at the South Dunes Power Plant site; however, it is surrounded by the previous mill site industrial footprint and is not adjacent to open water. Along the utility corridor and access road between the South Dunes Power Plant and LNG Terminal sites, sparsely vegetated portions of the rolling (and at times steep) dunes in the area was noted; again, the sites were not adjacent to open water. Small pockets of potential habitat were also noted in the upper half of the slip site, but they are surrounded by and being encroached by European beachgrass, gorse, and Scotch broom (hence making it unlikely habitat). An additional area at the northwest tip of the Project site, immediately south of the Trans-Pacific Parkway, also provides sparsely vegetated sand habitat but is not adjacent to open water.

The "weedy fields between the shoreline and dunes on the Roseburg Forest Products facility" noted in previous surveys as potential habitat (LBJ 2006) were scraped off approximately five years ago and planted with grass that has become dense. When the previous surveys were conducted in 2005 and 2006, the site was likely at the stage between unvegetated landscape and dense covering of grasses. That habitat no longer exists and the site would no longer be considered potential habitat for the streaked horned lark.

Laura Todd, USFWS Newport Field Office, in a telephone conversation with SHN staff on April 29, 2013, said the USFWS has not done long term studies regarding the streaked horned lark to date and they are not sure of the range in coastal Oregon. So far the range has been primarily noted along coastal Washington; however, the USFWS does not discount the possibility that streaked horned lark habitat could exist along the Oregon coast.

Dr. Scott Pearson, Senior Research Scientist for the Washington Department of Fish and Wildlife, has been studying avian ecology for over 20 years and his research has included focused studies on the streaked horned lark. In a telephone conversation with Dr. Pearson by

SHN staff (April 29, 2013), Pearson said he would not be surprised if streaked horned larks were found to breed on the Oregon coast as it seems the habitat is ideal. Portions of the North Spit are well-suited for lark habitat, particularly in areas where there are western snowy plovers and habitat restoration has occurred. It is possible that larks could share the same habitat with plovers. Pearson found a lark nest within 5 meters of a plover nest in Washington. They use very similar habitat, although plovers use more extreme open habitats, whereas the lark needs some vegetation.

Based on the habitat specifications provided by Dr. Pearson in addition to a literature review of reports documenting research on the streaked horned lark, although potential lark habitat appears to exist in pockets of the Project footprint, those areas do not meet the criteria described by Dr. Pearson as essential for lark occurrence. Occurrence of the streaked horned lark is not anticipated at the Project site. They may be encountered within the general Project vicinity or along the LNG carrier transit route; however, the species would likely keep a distance and avoid close interactions.

**Western Snowy Plover (Federal Threatened, State Threatened)**

The western snowy plover (*Charadrius alexandrinus nivosus*) is a small shorebird approximately 6 inches long with a thin dark bill. The Pacific Coast breeding population includes Oregon, with coastal populations typically consisting of resident and migratory birds. The North Spit of Coos Bay supports the most productive snowy plover population segment on the Oregon coast.

The Pacific Coast population of the western snowy plover was listed as a threatened species under the ESA on March 5, 1993. In addition to being listed as threatened under the ESA, Critical Habitat was designated for the Pacific Coast population in 1999 and a recovery plan for the species was developed by the USFWS (USFWS 2007b). Objectives in the recovery plan include: 1) achieving well-distributed increases in numbers and productivity of breeding adult birds, and 2) providing for long-term protection of breeding and wintering plovers and their habitat.

The southwestern portion of the North Spit is designated as Critical Habitat for the western snowy plover from the ocean beach at Horsfall to the Coos Bay north jetty and includes all federal lands at the south end. The Project site is greater than 2.5 miles from the northern extent of Critical Habitat and greater than 4.5 miles from the primary nesting areas. Nesting in Oregon may occur as early as mid-March, with peak nest initiation occurring from mid-April through mid-July. The closest nest is 2.57 miles from the Project (ORBIC 2010). On the coast, it is almost exclusively a bird of open sand beaches. It is unlikely that this species would nest in or around Jordan Cove due to the lack of primary habitat for the species. Its typical coastal nesting habitat is at the upper edge of the beach below the foredunes. It also nests on bare spits at small estuary mouths and, on the North Spit, is most prevalent on restored sand habitat east of the foredune.

Current management activities and use restrictions within the Coos Bay North Spit Recreation Management Area relative to the snowy plover population include predator management, symbolic fencing, habitat restoration, public outreach and education by BLM staff, monitoring of snowy plover populations, and recreational use restrictions in place from March 15 to September 15 of each year. Recreational use restrictions include seasonal re-routing of the foredune road along with prohibiting vehicles, camping, and dogs. Non-prohibited recreational use (i.e., jogging, beach combing, horseback riding) is restricted to the wet sand outside of roped off and signed breeding areas.

USFWS surveys conducted on the North Spit document an increase in adults from 27 in 2005 to 52 in 2012. Total adults surveyed in Oregon have increased from 100 in 2005 to 206 in 2012. The North Spit population accounts for approximately 25 percent of the total adults observed in Oregon. On the Pacific Coast (including Washington, Oregon, and California), California has the highest documented occurrence, with 1621 adults surveyed in 2012; however this number is down from 1680 adults surveyed in 2005.

There does not appear to be any typical habitat in the Project site. While an occasional individual may use the mudflats adjacent to Jordan Cove for foraging, breeding is unlikely. None were detected during field surveys conducted for the Project in 2005 and 2006, and again in 2012. Western snowy plovers may be encountered in the LNG carrier transit route zones from nearshore coastal waters to the Project.

#### 3.4.2.3 Mammal Species (Terrestrial)

**Gray Wolf (Federal Endangered, State Endangered)**

Gray wolves (*Canis lupus*) in Oregon remain listed statewide as endangered under the Oregon ESA. Wolves occurring west of Oregon Highways 395/78/95 continue to be federally protected as endangered under the federal ESA. The USFWS is in the process of evaluating the classification status of gray wolves currently listed in the contiguous U.S. In the federally listed portion of Oregon, the ODFW implements the Oregon Wolf Conservation and Management Plan (OWP) under the guidance of the Federal/State Coordination Strategy (March 2011).

Wolves occurring in Oregon today are part of the Northern Rocky Mountain wolf population. They are descendants of wolves originally captured in Canada and released in Yellowstone National Park and Idaho in the mid-1990s. Wolf numbers fluctuate throughout the year as wolves disperse, pups are born, and new packs are formed. The Oregon wolf population is officially documented at the end of each year. On December 31, 2012, the minimum Oregon population was 53 wolves. This means that at least 53 wolves were documented. It is likely that there are more, as lone wolves can be challenging to document.

Oregon's wolf population continued to increase in distribution and abundance in 2012 and at year-end the minimum wolf population was 46 wolves in six packs. All six packs met the criteria as breeding pairs. All known resident wolves occurred in Wallowa, Umatilla, Union, and Baker counties. This marks the first year that the initial OWP conservation population objective to have four breeding pairs in eastern Oregon was reached.

It is unlikely the gray wolf occurs on the North Spit and the Project vicinity, given current tracking and distribution data available (ODFW 2013). The Project is not anticipated to have any impact to the gray wolf and the gray wolf does not warrant further investigations at this time.

### 3.4.3 Fisheries (Including Marine Species)

There are no threatened or endangered fish species listed by the ODFW or NMFS that spend their entire life cycle within Coos Bay or the area where the Project will be constructed. Three federally-listed anadromous fish species spend a portion of their life cycle within the estuarine environment of Coos Bay, including the area of the access channel and slip site. Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch)*, southern distinct population segment (DPS) green sturgeon (*Acipenser medirostris*), and southern DPS Pacific eulachon (*Thaleichthys pacificus*), were federally-listed (2008, 2006 & 2010, respectively) as threatened under the ESA. These three species have not warranted listing as threatened or endangered by the State of Oregon. Use of the Coos Bay system by eulachon and green sturgeon is sporadic at best (based on various ODFW seining surveys and personal communications) and there is very little habitat available for coho salmon in the Project area.

For analysis under the ESA for fish species, the action area includes all areas to be affected directly or indirectly by the Project and not merely the immediate areas involved in the action. Typically the action area extends 500 feet upstream from the Project site and 1,500 downstream from the downstream end of the Project site in Coos Bay due to potential impacts from stormwater discharge, turbidity, contaminant dispersion, and habitat loss. The action area also incorporates the construction worker camp and the Kentuck and eelgrass bed mitigation sites.

#### 3.4.3.1 Oregon Coast Coho Salmon (Federal Threatened, State Sensitive-Critical)

Oregon Coast (OC) coho salmon are one of several anadromous salmonid species that utilize Coos Bay for migration and rearing habitat for adult and juveniles on their way to and from the ocean between marine and freshwater environments. On February 4, 2008, NMFS listed the naturally spawning populations within the Evolutionary Significant Unit (ESU) of OC coho salmon as a federal threatened species under the ESA. Critical Habitat for this ESU has been designated within several freshwater sub-basins of the Coos Bay system; however, no critical habitat exists within the Project action area.

OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population (Lawson et al. 2007). An independent population is defined as having minimal demographic influence from adjacent populations and is viable-in-isolation. An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations (McElhany et al. 2000). The Coos River population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU.

Annual spawning surveys conducted by the ODFW document the Coos River's population's annual abundance varies considerably from year to year. The 2012 ODFW monitoring report on the status of Oregon stocks of coho salmon for 2011 summarizes the results of status and trend monitoring for Oregon's naturally spawning coho salmon populations through the 2011 run year (October 2011 through February 2012). Monitoring results include:

1. Abundance of naturally spawning coho salmon;
2. Density (fish/mile) of naturally spawning coho salmon;
3. Coho salmon spawn timing and distribution; and
4. Proportion of hatchery (marked) coho salmon in naturally spawning populations.

Surveys conducted at 29 sites for OC coho ESU populations on the Coos River determined fish presence at 83 percent of the sites. Annual abundance estimates of naturally spawning wild adult coho salmon in the OC coho ESU for run years 1990 through 2011 document that the Coos River's population's annual abundance varies considerably from year to year (Table 3.4-2). The 2011 estimates show a recent negative trend in abundance at the ESU level for the average over the past 10 years. The 2011 estimates are more symbolic of estimates from the previous 10 years.

#### 3.4.3.2 Pacific Eulachon (Federal Threatened-Southern DPS, No State Listing)

Eulachon (commonly called smelt, candlefish, or hooligan) is a small, anadromous fish from the eastern Pacific Ocean. In North America they range from northern California into the southeastern Bering Sea. On March 18, 2010, NMFS listed the southern DPS of eulachon as threatened under the ESA, followed by designating Critical Habitat for the southern DPS on October 20, 2011 (76 FR 65323). The southern DPS ranges from Nass River, British Columbia, to Mad River, California, and includes Coos Bay and its upper reaches. NMFS has not designated EFH for the Coos Bay system. Prior to being listed as threatened under the ESA in 2010, the commercial catch of eulachon from the Columbia River from 1938 to 1992 averaged approximately 2 million pounds per year. Since the mid-1990s, however, eulachon populations have decreased dramatically. Between the years of 1993 to 1996 the average annual catch dropped to approximately 43,000 pounds, a nearly 98 percent decline.

Eulachon are plankton-feeders, chiefly eating crustaceans such as copepods and euphausiids (Barraclough 1964). They typically spend three to five years in saltwater before returning to freshwater to spawn. Many sources note that runs tend to be erratic, appearing in some years but not others (NMFS 2006). They do not feed in fresh water and remain there only a few weeks to spawn (Rogers et al. 1990).

There is currently little information available about eulachon presence in Coos Bay. Monaco et al. (1990) described eulachon as rare in Coos Bay. While eulachon were mentioned as occurring in other studies conducted in the bay in 1971, Wagoner et al. (1990) stated that “eulachon may have occurred in large numbers in past years [in Coos Bay], but they have apparently not been abundant enough in recent years to attract an active dipnet fishery”. More recently, Miller and Shanks (2005) surveyed the distribution of 28 identified larval and juvenile fish species in Coos Bay for more than three years between 1998 and 2001, but did not encounter eulachon.

Adults begin moving through the bay as early as December and spawning typically occurs from January to mid-May, with the peak in February to mid-March. When present, eulachon may utilize both shallow and deep water habitats within the estuary as they migrate to spawning grounds. They will only spawn in lower reaches of rivers and major tributaries (i.e., the Coos River), as they need moving water and large substrate to spawn. Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents. When the larvae reach juvenile size, they disperse to the ocean as soon as able. Juveniles may migrate out as early as February to as late as almost mid-summer (Chuck Wheeler pers comm.). Adult eulachon do not always die after spawning so they could return to the ocean.

Very little is known about the offshore distribution of adult or immature eulachon outside the spawning season, although abundances in particular locations show responses to oceanic conditions (Emmett and Brodeur 2000). Eulachon appear to live near the ocean bottom on the continental shelf at moderate depths that commonly range from 20 to 200 meters, but they may occur as deep as 500 meters (Hay and McCarter 2000).

#### 3.4.3.3 Green Sturgeon (Federal Threatened-Southern DPS, No State Listing)

Green sturgeon are long-lived, slow-growing fish, and are the most marine-oriented of the sturgeon species. Although they are members of the class of bony fishes, the skeleton of sturgeons is composed mostly of cartilage. Instead of scales sturgeon have five rows of characteristic bony plates on their body called scutes. The backbone of the sturgeon curves upward into the caudal fin, forming their shark-like tail. On the ventral, or underside, of their flattened snouts are sensory barbels and a siphon-shaped, toothless mouth.

Green sturgeon is a widely distributed and marine-oriented species. They are believed to spend the majority of their lives foraging in nearshore oceanic waters, bays, and estuaries, ranging from nearshore waters in Baja California to those in Canada. They utilize both freshwater and saltwater habitat and spawn in deep pools or holes in large, turbulent, freshwater river mainstems (Moyle et al. 1992).

There are two distinct population segments defined for green sturgeon—a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NMFS 2008). The southern DPS includes all spawning populations of green sturgeon south of the Eel River in California.

The southern DPS of the North American green sturgeon was federally-listed as threatened on April 7, 2006, under the ESA. The species has not warranted protective listing status by the State of Oregon. Studies have confirmed the migratory nature of green sturgeon between northern and southern DPS units. As such, NMFS took an inclusive approach when determining the geographical area occupied by the southern DPS and designated Critical Habitat from the Bering Sea, Alaska, to the U.S. California and Mexico border.

Younger green sturgeon reside in freshwater, with adults returning to freshwater to spawn when they are about 15 years of age and more than 4 feet in size. The species only spawns every 2 to 5 years (Moyle 2002). Adults typically migrate into freshwater beginning in late February and spawning occurs from March to July, with peak activity from April to June (Moyle et al. 1995). Specific spawning habitat preferences are unclear, but eggs likely are broadcast over large cobble substrates. They range from clean sand to bedrock substrates as well (Moyle et al. 1995). It is likely that cold, clean water is important for proper embryonic development.

The principal factor in the decline of the southern DPS is the reduction of their spawning area in California. Other threats to the southern DPS include insufficient freshwater flow rates in spawning areas, contaminants (e.g., pesticides), bycatch of green sturgeon in fisheries, potential poaching (e.g., for caviar), entrainment by water projects, influence of exotic species, small population size, impassable barriers, and elevated water temperatures. If a green sturgeon spawns in Oregon, it is not part of the southern DPS and not considered threatened under the ESA. Both southern and northern DPS green sturgeon may occur in Coos Bay, in addition to white sturgeon (Mike Gray pers comm.).

Green sturgeon spend more time in the ocean, as they have less tolerance for freshwater than white sturgeon, but they do come in and out of the bay.

The distribution of green sturgeon is not well known, although southern DPS green sturgeon are reported to congregate in coastal waters and estuaries and are present in Coos Bay. Southern DPS individuals were documented to occur by sampling in a 2006 study (Israel and May 2006). Because Coos Bay is not their natal stream, southern DPS green sturgeon are likely to be present from June through October. While in Coos Bay estuary, they are likely feeding in shallow areas and seeking out the deep water for resting.

#### 3.4.3.4 Marine Mammals

Three federally-listed marine mammals with a potential to occur near the Project site are discussed below.

**Steller Sea Lion (Federal Endangered, No State Listing)**

The Steller sea lion (*Eumetopias jubatus*), also called northern sea lion, ranges along the North Pacific coast from Japan to southern California (USFWS 2007a). It breeds on rocky beaches, often on islands, and at other times is frequently seen hauled out on select coastal rocks, jetties, marinas, and navigation buoys. It forages at sea for fish and invertebrates, sometimes to several hundred miles from land. The Oregon population was estimated at over 5,000 in 2002 and productivity appears to be increasing (NOAA website). There are no rookeries in Coos County. The nearest (one of Oregon's two primary rookeries) is at Orford Reef in Curry County (Brown 1988, NMFS 1992b). There is a haul-out site at Cape Arago in Coos County, roughly ten miles from the Project site area (ORBIC, NMFS website). While an occasional Steller sea lion might enter Coos Bay and the species is included on the North Spit wildlife list (USDI 2005), there are no suitable haul-out sites within the Project site and the species is not expected to occur there.

Steller sea lion Critical Habitat includes all major Steller sea lion rookeries and associated air and aquatic zones. Critical Habitat includes an air zone that extends 3,000 feet above areas historically occupied by sea lions at each major rookery in California and Oregon, which is measured vertically from sea level. Critical habitat includes an aquatic zone that extends 3,000 feet seaward in state and federally managed waters from the baseline or basepoint of each major rookery in California and Oregon. The following are designated as Critical Habitat in Oregon:

- Rogue Reed: Pyramid Rock; and
- Orford Reef: Long Brown Rock and Seal Rock.

Based on the above information, Critical Habitat for the Steller sea lions is not designated within the LNG carrier transit route zones. However, haulout areas at Cape Arago located in the vicinity of the LNG carrier transit route are part of the Oregon Islands National Wildlife Refuge. Steller sea lions are likely to occur within the LNG carrier transit route zones.

**Gray Whale (Federal Endangered, State Endangered)**

The gray whale *(Eschrichtius robustus)* is a large baleen whale that is distributed in the northern Pacific Ocean in western and eastern stocks. The eastern Pacific stock feeds in the summer in Chukchi Sea, western Beaufort, and the northern Bering Sea. They migrate from November through early February south to lagoons on the Pacific coast of central and southern Baja California. Northward migration occurs after the calving and breeding season, from early February to May. These whales have the longest known migration of any mammal. Adult females reach 15 meters in length and males reach up to 14.3 meters and weigh up to 33,850 kilograms. Gray whales feed on benthic species that are buried in sediments.

According to OPDR (2007), gray whales are the most predominant whales seen along the Oregon coast. They migrate twice a year during winter and spring as stated above. About 200 of them feed along the coast during the summer months. Gray whales have on occasion penetrated Coos Bay beyond the Project site areas and have been seen in Coos Bay at about the same frequency as killer whales. Gray whales may be encountered in the LNG carrier transit route zones during their southern migration from November through early February or from early February to May during the northern migration.

**Southern-Resident Killer Whale (Federal Endangered, No State Listing)**

The killer whale (*Orcinus orca*) is a wide-ranging predator of the open ocean that has a worldwide distribution but is most common in the subarctic, temperate, and subantarctic waters (Maser et al. 1981). The southern resident killer whale was proposed for delisting in 2012 and is currently under review (77 FR 70733). Along the North Pacific coast, resident killer whales occur from Oregon and Washington to the Bering Sea (NMFS 2006) and their distribution is correlated to food supplies (Maser et al. 1981). This federally-listed species feeds primarily on fish and marine mammals. According to Maser et al. (1981), killer whales are most abundant in the Puget Sound in November and late summer. Most southern California killer whale sightings occur in fall, winter, and early spring. Based on this information, killer whales could be encountered in Oregon during the fall, winter, and spring, with occasional sightings throughout the year. Killer whales occasionally enter bays in pursuit of salmon and pinnipeds and have on occasion penetrated Coos Bay beyond the Project site. They could also occur within the LNG carrier transit route zones.

#### 3.4.3.5 Waterway for LNG Marine Traffic

Additional federal threatened or endangered species that could occur within the zones of the LNG carrier transit route are described below. The locations of federal threatened or endangered species are shown in Figure 3.5-2.

**Blue Whale (Federal Endangered, State Endangered)**

Blue whales (*Balaenoptera musculus*) are distributed from the equator to polar icepacks in both the northern and southern hemispheres. The eastern North Pacific population winters off Mexico and Central America and feeds off the coast from California to British Columbia during the summer and fall from June through November. Blue whales are most likely seen off the Oregon coast from late May through June and from August through October. This species is a baleen whale that feeds on euphausiids, commonly referred to as krill. Adult male blue whales reach up to 32.6 meters in length and weigh up to 133 metric tons. Females reach 33.3 meters in length and may weigh in excess of 151 metric tons. According to the OPRD (2007), occasional blue whales are sighted off the Oregon coast. Blue whales may be encountered along the LNG carrier transit route between the summer months specified above.

**Fin Whale (Federal Endangered, State Endangered)**

Fin whales (*Balaenoptera physalus*) are widely distributed throughout the world's oceans. The wintering grounds in the Pacific Ocean are from central California to Cabo San Lucas at the southern tip of the Baja California peninsula in Mexico. Their summer range extends from California to the Chukchi Sea in the southern Arctic Ocean between Alaska and Siberia. This species likely occurs along the Pacific coast from California to Washington from May to September. Adult female fin whales reach a length of 27.3 meters and a weight up to 100 metric tons. Adult males reach a length of 24.4 meters and weigh up to 89 metric tons. Fin whales are reported to return to the same feeding grounds year after year. It is not known if feeding grounds are located within the LNG carrier transit route. This species primarily feeds on euphausiids and secondly on fishes and cephalopods (i.e., squid). According to the OPRD (2007), occasional fin whales are sighted off the Oregon coast. This species may be encountered in the LNG carrier transit route from May to September.

**Humpback Whale (Federal Endangered, State Endangered)**

The humpback whale (*Megaptera novaeangliae*) is probably best known for its breaching and underwater vocalizations. This species is distributed in both the northern and southern hemispheres, from tropical waters to the edge of the polar ice. In the eastern Pacific, humpback whales have been observed from the Chukchi Sea to southern Mexico. Adult male humpbacks reach 15 meters in length and females reach up to 18 meters in length. This species feeds on benthic and pelagic euphausiids and small schooling fishes. OPRD (2007) states that humpbacks are sometimes seen off the Oregon coast at the same time as gray whales, but are not observed as frequently because their herd size is smaller. Humpbacks may be encountered in any of the three zones of the LNG carrier transit route from spring through early fall.

**North Pacific (Right) Whale (Federal Endangered, No State Listing)**

The northern right whale *(Eubalaena glacialis)* is a large baleen whale that reaches up to 18 meters and 100 tons. The winter distribution includes the Oregon coast south to central Baja California, Mexico (Maser et al. 1981). Summer distribution is in cool temperate waters in the north Pacific from the Bering Sea to latitude 50 degrees north. Northern right whales feed solely on zooplankton consisting of copepods and euphausiids and occasionally on pteropods (Maser et al. 1981). OPRD (2007) does not list the northern right whale as one of the species that may occasionally be observed along the Oregon coast. However, based on the distribution information, the northern right whale may be encountered in the LNG carrier transit route during winter months.

**Sei Whale (Federal Endangered, State Endangered)**

Sei whales (*Balaenoptera borealis*) are distributed worldwide, including an eastern Pacific stock that is found from Alaska to Mexico This species is found off the central California coast in the late summer or early fall and appears to move farther south and offshore in the winter. No information was found for this species distribution along the Oregon coast. Sei whales feed on copepods, euphausiids, sauries, anchovies, herring, sardines, squid, and jack mackerel. Adult males reach a maximum length of 17.7 meters and females reach a maximum length of 18.6 meters in the northern hemisphere. The OPRD (2007) does not list the Sei whale as one of the species that can be observed off the Oregon Coast. However, based on the information from Maser et al. (1981), this species may be encountered in the LNG carrier transit route during summer months.

**Sperm Whale (Federal Endangered, State Endangered)**

The sperm whale (*Physeter macrocephalus*) is the largest of the toothed (Odontoceti) whales and is distributed worldwide except for the pack ice of polar regions. Their diet consists of fishes and cephalopods. Adult male sperm whales may reach up to 16.8 meters in length (the average is 14.6 meters) and females grow up to 11.7 meters and weigh 37 metric tons. Sperm whales migrate toward polar regions in the summer and to temperate regions in the winter. OPRD (2007) states that sperm whales are occasionally sighted off the Oregon coast from March to September. Sperm whales may be encountered in the LNG carrier transit route from spring to fall.

### 3.4.3.6 Sea Turtles

**Green Sea Turtle (Federal Threatened, State Endangered)**

Green sea turtles (*Chelonia mydas*) have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego south (NMFS 2007a). Green sea turtles primarily use three types of habitat: oceanic beaches (for nesting), convergence zones in the open ocean, and benthic feeding grounds in coastal areas (NMFS 2007a). Green sea turtles could potentially be encountered within the LNG carrier transit route.

**Leatherback Sea Turtle (Federal Endangered, State Endangered)**

Leatherback sea turtle (*Dermochelys coriacea*) nesting grounds are located around the world, with the largest remaining nesting assemblages found on the coasts of northern South America and West Africa (NMFS 2007). Adult leatherback sea turtles are capable of tolerating a wide range of water temperatures and have been sighted along the entire coast of the United States and as far north as the Gulf of Maine and south to Puerto Rico, the U.S. Virgin Islands (USVI), and into the Gulf of Mexico (NMFS 2007). The Pacific subspecies has declined so drastically that a Pacific Leatherback Conservation Area, wherein gillnet fishing is restricted, has been established stretching from central California to central Oregon (LBJ 2006). Leatherback sea turtles could potentially be encountered within the LNG carrier transit route.

**Loggerhead Sea Turtle (Federal Endangered, State Threatened)**

Loggerhead sea turtles (*Caretta caretta*) occupy three different ecosystems during their lives—the terrestrial zone, the oceanic zone, and the neritic (coastal) zone. Loggerhead sea turtles are circumglobal in distribution, occurring throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian oceans. Loggerhead sea turtles are the most abundant species of sea turtle found in U.S. coastal waters (NMFS 2007b). Occasional sightings are reported along the coasts of Washington and Oregon, but most records are of juveniles off the coast of California (NMFS 2007b). Loggerhead sea turtles could potentially be encountered within the LNG carrier transit route.

**Olive Ridley Sea Turtle (Federal Threatened, No State Listing)**

The olive ridley sea turtle (*Lepidochelys olivacea*) occurs within the tropical regions of the Pacific, Atlantic, and Indian oceans. Important nesting areas for the olive ridley include the west coast of Mexico and Central America (NMFS 1998). Olive ridley sea turtle populations had declined from former times but olive ridleys are still the most abundantly nesting turtle on the Pacific coast (Cornelius 1982). This species does not nest in the United States, but during feeding migrations olive ridley turtles nesting in the East Pacific may disperse into waters off the U.S. Pacific coast as far north as Oregon. Though remote, Olive ridley sea turtles could potentially be encountered within the LNG carrier transit route.

### 3.4.4 Environmental Consequences (Construction and Operation)

Environmental consequences for the construction and operation of the Project that have not been previously addressed in the individual sections for vegetation, wildlife, and fisheries are discussed below as they specifically relate to ESA-listed species. The most notable consequences of the Project will be the permanent loss of vegetation and wildlife habitat at the Project site. Overall potential LNG-related environmental consequences from the construction and operation of the proposed LNG export facility are discussed in Section 3.5. Of note, if an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the endangered or threatened species are located, the LNG will float briefly on the water until it vaporizes and will not have an adverse effect on the species unless they come in direct contact with the LNG.

#### 3.4.4.1 Botanical Resources

**Western Lily (Federal Endangered, State Endangered)**

The western lily is one of the rarest plants on the west coast. No effects to the species are anticipated by the Project. During surveys conducted to detect its presence it has been absent from the Project site and the areas to be impacted by the Project are not expected to include western lily habitat.

**Point Reyes Bird's Beak (Federal Species of Concern, State Endangered)**

The primary threat to Point Reyes bird's-beak is habitat loss due to development. The species is also threatened by off-road vehicle use, water pollution, and habitat alteration due to invasion by non-native dense-flowered cordgrass (*Spartina densiflora*), which has not been observed at the Project site. Suitable habitat for the Point Reyes bird's-beak will be impacted by fill required for the gas processing facility and South Dunes laydown area. Though individual Point Reyes bird's-beak has not been identified in the areas of impact by the Project, large communities of the species exist in neighboring areas.

### 3.4.4.2 Terrestrial Wildlife

No direct impacts to threatened or endangered terrestrial wildlife species are anticipated as a result of the construction of the Project.

**Bald Eagles (Federal Delisted, State Threatened)**

Potential effects to bald eagle populations will be minimal. Foraging habitat occurs in and along the bay, but no suitable nesting habitat exists in the area where construction will occur. The Bald and Golden Eagle Protection Act requires protection of this species from disturbance within 660 feet from nest sites. While no nests were observed at the Project site and the nearest reported nest site in the ORBIC database, active at least as recently as 2003, is on Mettman Ridge above Glasgow, roughly three miles from the Project site, a pre-construction survey will be conducted to ensure that there is no inadvertent disturbance to this species.

**California Brown Pelican**

In the past, brown pelicans have been impacted by human disturbances at nesting colonies and roosting habitats. Nesting and roosting habitats within the Coos Bay estuary have not been documented and the species is not believed to breed in or near the Project site. Potential effects to brown pelican populations by the Project are anticipated be minimal. Foraging habitat for this species exists in Coos Bay adjacent to Jordan Cove and the brown pelican has been observed in the Project area near the proposed slip location. Noise and human activities associated with construction and operation of the proposed Project are likely to be the only direct effect to brown pelicans to the extent that brown pelicans occur near one or more of the Project's action areas. However, the possibility of adverse effects to the species is expected to be minimal as they would avoid these areas and the Coos Bay estuary provides ample foraging for the species outside of the impact area.

Onshore fish cleaning stations at various locations throughout the bay, often associated with boat ramps, have been mentioned as possibly attracting brown pelicans to possibly feed on offal (Marshall et al. 2006). The closest designated fish cleaning station is located inland at the Empire boat ramp more than two miles to the southwest on the other side of the bay. The Project is not anticipated to have a measurable effect on the foraging route of pelicans related to the Project.

**Marbled Murrelet**

The effects of the Project to be considered for MAMUs include disturbance and habitat impacts. While the Project does not occur within ¼ mile of designated Critical Habitat, its proximity to the coast requires evaluation of the Project vicinity to determine if there is habitat (i.e., nesting platforms) that may be affected by noise disturbance and human activities. Human activities attract corvids (i.e., crows, ravens, jays, magpies, etc.) to the area, largely from food and garbage related to construction activities. This gives the corvids an opportunity to have predation to MAMUs if there is nesting habitat in the vicinity. The single largest cause of murrelet nest failure found in Nelson and Hamer (1995b) was predation in 56 percent of failed nests, due mostly to corvids.

In surveys conducted for the Project (LBJ 2006, SHN 2012) no potential MAMU habitat was detected within the Project vicinity. Potential adverse effects to marbled murrelet populations will be minimal since this species does not nest on the Project site. MAMUs could occur along the bay or fly over the Project site while in transit between nesting and feeding sites. Conservation measures proposed in Section 3.4.5 would ensure that the Project site will be kept clear of construction debris and food wastes that could attract predators. No impact to MAMUs is anticipated from the construction or operation of the Project.

**Northern Spotted Owl**

No potential effects to northern spotted owl populations will occur because this species is absent from coastal Coos County and therefore not expected to occur in or near the Project site.

**Short-tailed Albatross**

Short-tailed albatross may occur within the EEZ coastal zone used by LNG carrier traffic. The species have infrequently collided with airplanes in flight but collisions with ships are unknown and are expected to be unlikely. Although the annual ship traffic will increase due to the proposed Project, LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tugboats from 50 miles offshore to the Port. Short-tailed albatross are expected to avoid LNG marine traffic.

The effects of a cargo spill from an LNG carrier would be quite different from results of spills from crude or refined petroleum ships. Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting the potential food species (squid, fish, eggs of flying fish, shrimp, and other crustaceans) in the water. Ignited LNG would affect species on the water surface but not species submerged in the water.

Based on the double-hulled construction of LNG carriers and the outstanding operating and safety record of LNG carriers, the probability of any incidents that could result in the loss of LNG cargo is extremely low. Any potential spills that could affect short-tailed albatrosses offshore would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

No mitigation, enhancement, or protection measures are proposed to specifically conserve short-tailed albatross.

**Streaked Horned Lark**

Industrial development has reduced habitat available to breeding and wintering larks. Construction and operation activities occurring on or near habitat used by streaked horned larks migrating through Coos Bay or wintering over could negatively affect foraging, causing the birds to flee or to spend more time alert and less time foraging.

Potential adverse effects to streaked horned lark populations are anticipated to be negligible. It has been determined that suitable habitat does not exist in or near the Project site due to the lack of proximity to open water at the few locations where sparsely vegetated lark habitat potentially exists. In addition, encroachment by European beachgrass and other noxious weed species increasingly makes potential habitat unlikely to be used by the larks, especially given the vast amounts of potential habitat on the North Spit and along that coast that remain relatively undisturbed by human influence. While an occasional individual may show up on a mudflat in the vicinity to forage, streaked horned larks are not expected in the Project site.

**Western Snowy Plover**

Stockpiling of material dredged from the slip area was proposed as part of the import terminal project. Due to the snowy plover population on the North Spit, there was a concern that a stockpile area could attract snowy plover individuals from this population. To address this concern, stockpiling is no longer part of the Project. Potential adverse effects to snowy plover populations will be minimal because there does not appear to be any nesting habitat within the Project site. While an occasional individual may show up on a mudflat, snowy plovers are not expected in the Project area.

Some concern exists that the construction of the Project might increase the local predator population, but it is not expected since snowy plover predators already occur on the site and the Project does not include the addition of any elements (with the exception of increased human activity) likely to attract them. Snowy plover predators identified along the Oregon coast include the American crow, common raven, red fox, raccoon, striped skunk, black rat, and feral cat. An increase in the numbers of these predators could be detrimental to the recovery of snowy plover populations.

Threats to western snowy plover habitat include introduction of European beachgrass that encroaches on the available nesting and foraging habitat; disturbance from humans, dogs, and off-highway-vehicles in important foraging and nesting areas; and predators such as the American crow and common raven (FWS 2005f). Increased nest predation of western snowy plovers by corvids within the Project area and in affected occupied stands is possible, particularly if corvids are attracted to construction sites by trash or discarded food. However, the distance to the closest documented nest negates this probability.

Increased predator density related to increased human presence and habitat removal was identified as a potential concern related to terminal construction. Jordan Cove has identified measures to minimize impacts. During construction and operation, the Project site would be kept clear of construction debris and food wastes that could attract predators such as birds (e.g., American crows) and mammals (e.g., rats, raccoons). Covered, animal-proof receptacles would be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. During construction the site would be policed on a daily basis to remove any food or other debris left by construction workers. During operations the facility and grounds would be regularly inspected to assure that no garbage is allowed to accumulate. This should minimize predation on snowy plover eggs and chicks; however, corvids and other predators could still be attracted to the area due to the increased activity.

### 3.4.4.3 Fisheries and Marine Species

For the purposes of this report, fisheries and marine species include federally-listed fish, marine mammals and sea turtles that have the potential to be affected by construction and operation of the Project or by the marine traffic generated along the LNG export facility transit route.

Impacts on the aquatic environment by the Project which could in turn affect fish and marine species include turbidity, chemical contamination, loss of benthic and shoreline habitat, acoustic effects from pile driving, and stranding of sea life from ship wakes. In addition, effects on aquatic resources if an unignited LNG spill were to occur along the LNG carrier transit route or if the vapor from an LNG spill were to come in contact with an ignition source resulting in a fire are remote possibilities. Analysis of these effects, along with the beneficial effects from restoration of estuary functions, are discussed in Section 3.3.6 and are incorporated by reference for this section. Additional environmental consequences related to these potential effects on federally-listed species from construction and operation of the Project are discussed below.

**OC Coho Salmon**

Direct and indirect effects from Project actions would likely affect OC coho salmon due to turbidity, potential chemical contamination, and interim habitat loss. The proposal to complete in-water work between July 1 and August 31 results in fewer OC coho salmon exposed to the activities and serves to minimize, but not eliminate, exposure to direct adverse conditions. OC coho salmon will have minimal habitat loss, but that loss will result in adverse effects to the species due to permanent loss of forage at the slip site. Beneficial estuarine compensatory mitigation is proposed to compensate for the loss of forage and ecological functions by re-introducing intertidal habitat subject to tidal flushing; however, a delay of several years is expected before the area reaches full ecological potential.

Essential physical and biological features (PCEs) for estuaries include whether an area is free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between freshwater and saltwater, natural cover, and forage. The action area for the proposed eelgrass mitigation site for the Project contains one or more PCEs within the acceptable range of values required to support the biological processes for which the species use the habitat. Coho salmon adults and smolts would migrate through this area and use the area to make the physiological transition between marine and freshwater environments. There would not be any loss of estuarine wetlands (i.e., diking and filling) for the proposed mitigation and the net result would be increased habitat value in the Coos Bay estuary. The site, located south of the airport's runway extension project, is considered to provide relatively low ecological function, which mitigation could improve.

Coho salmon outmigrating in Coos Bay are typically larger than sub-yearling juvenile Chinook salmon and are much less susceptible to stranding from potential ship wakes than the smaller Chinook salmon in Coos Bay. As noted for the model of the waves in Section 3.3.6, ship wakes would be generally small and similar to naturally occurring waves. Considering the conditions, including vessels entering and leaving at high slack tide, low vessel speed, and wave height within normal range, along with infrequent occurrence of susceptible fish, it appears unlikely that LNG carrier traffic would contribute to juvenile coho salmon stranding.

Some loss of juvenile salmon could occur from entrainment and impingement in the cooling water required for the LNG carriers while loading LNG at the berth. This potential would be the same as any deep draft vessel while loading or unloading cargo. However, few coho salmon would be as small as 60 mm since most would be outmigrating at age 1+ and would likely be greater than 120 mm. Many of the juvenile coho salmon would actively be able to avoid being entrained or impinged. Also, the location of the intakes on most LNG carriers would be near the inner portion of the slip away from the main channel. This may, depending on coho salmon distribution, reduce the overall chance of coho salmon being in the vicinity of the intakes.

NMFS (2008) in their assessment of effects of loss of juvenile coastal coho salmon from local airport expansion assumed 4 percent of Coos Bay coho salmon smolts survived to return as adults. Even so, due to the extremely small portion of total water intake relative to the volume of Coos bay, the relative portion of juvenile salmonids that would suffer direct mortality would be small, unless fish were highly concentrated at the point of intake. The population appears to have a 96 percent mortality rate before returning as adults. Even if a salmon individual was adversely affected, the mortability rate relative to the natural mortality rate of the overall population is not anticipated to be significant.

Depending on their reaction to localized changes in the light regime in the Project action area, coho salmon may have migration delays, be moved into less protected deepwater habitat, or they may become more susceptible to predation as light increases predators' ability to see fish.

Actual distribution of juvenile coho salmon within the Project action area is unknown. However, juvenile salmonid studies in the lower Columbia River observed that juvenile coho salmon were in greater abundance away from the shoreline areas, often in deep water during their outmigration (Johnsen and Sims 1973, Dawley et al. 1986, Ledgerwood et al. 1991). Carson et al. (2001) found that in the lower Columbia River less than 20 percent of all fish were found along the shore and were about evenly split between the channel and channel margins. Based on studies in the Columbia River, there is no reason to suggest that the water intake area on vessels moored at the LNG Terminal would have any higher abundance of juvenile salmonids than the rest of the bay area, and in fact it may be lower as the fish would have to enter the off-channel slip that is out of the main flow region. Coho salmon migrating to the ocean would likely be more closely associated with the main channels than the nearshore area and the inset slip, reducing their chance of encountering the intakes.

**Euchalon (Southern DPS)**

The potential for eulachon to be affected by the Project would occur during seasonal migrations by adults to inland rivers to spawn and the outmigration of larvae and juveniles after hatching. Eulachon do not feed in fresh water and their presence in Coos Bay would be limited. Given the deep and shallow water habitats available along the bay transit route, there is a low likelihood that there would be a significant impact on the spawning runs of eulachon in Coos Bay. Adults could avoid the LNG carriers in the channel by using the shallow areas of the channel that the LNG carriers will not be using. In addition, the effects of LNG carrier traffic on spawning runs is not one of the threats listed by NMFS for the eulachon.

Eulachon are not anticipated to be present in shoreline wave areas where they could potentially be stranded. From the analysis of potential fish strandings from ship wakes discussed in Section 3.3.6, Pearson et al. (2006) conducted an extensive stranding study in the Columbia River and sampled shoreline areas in all seasons. Even though eulachon were present in the river system, the study did not report the capture of any eulachon, indicating they may not be present in shoreline waves to be stranded. As with coho salmon, eulachon would likely utilize the intertidal and eelgrass mitigation sites (once developed) for the transition between marine and freshwater environments.

The likelihood of effects to larval and juvenile stages of eulachon as they outmigrate through the Coos Bay estuary is anticipated to be minimal. During this downstream dispersal period, if the larvae somehow ended up in the slip waters they could potentially be entrained in the LNG carriers during the intake of cooling water. However, as the larvae are carried by currents and tides, it would seem highly likely that they would be carried past the slip and would not be drawn into slip waters. Once the larvae have grown to juvenile size, they naturally disperse to the ocean as soon as they are able. Any juveniles occurring in the Project action area would be migratory in nature. The low number of all stages of eulachon that are likely to be in Coos Bay further reduces the potential for the species to be affected by the Project.

**Green Sturgeon**

Southern DPS green sturgeon occurring in the Project area are expected to reside primarily in the deeper waters of the bay, depending on the time of day, tidal cycle, and activity. Project-induced turbidity or chemical contamination is discountable due to green sturgeon spatial distribution. Indirect effects may occur from the construction fill of approximately 10.6 acres of shallow water habitat for prey species consisting of ghost shrimp and clams. However, in addition to the compensatory estuarine habitat mitigation that will be implemented for the Project, there is extensive shallow water habitat available for foraging throughout the bay. The construction fill will have no impact on population spatial structure or diversity of green sturgeon.

**Marine Mammals**

Potential effects to the Steller sea lions and whales that may be encountered along the LNG carrier transit route include environmental contaminants, impacts to foraging areas, debris, and vessel collisions. Direct effects could include injury and/or mortality due to ship strikes and potential adverse effects from a ship spill and/or release of LNG at sea. Spills and/or released LNG could indirectly affect whales by impacting forage species.

Potential adverse effects to Steller sea lion populations will be minimal because sea lions do not normally occur as far into Coos Bay as the Project site. Sea lions tend to stay closer to the harbor entrance and are known to frequent the Charleston boat harbor and also to haul out on the northeast spit of clam island (created by dredge spoils). While an occasional individual might enter Coos Bay, there are no suitable haul-out sites within the Project site and the species is not expected to occur there.

Of the federally-listed whales, gray whales and killer whales are the only species that have been known to occasionally enter Coos Bay beyond the Project site, although this is an infrequent occurrence. Potential adverse effects to these populations in Coos Bay is anticipated to be minimal.

Eight species of federally listed whales have been identified that could potentially occur off the coast of Oregon. These species tend to feed during the summer in the northern latitudes and migrate to the tropical southern latitudes in the winter for breeding. However, whales could be encountered off the coast of Oregon throughout the year. The Project area applicable to whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head. Within the EEZ area, effects to whales would be associated with LNG carriers inbound and outbound from the LNG Terminal. All of these whale species are federally protected under the Marine Mammal Protection Act (MMPA).

The Project may affect whales because they may occur within the EEZ analysis area during operation of the Project. The proposed action would increase shipping traffic (LNG carriers, tugs and barge units) within the EEZ analysis area. However, the Project is not likely to adversely affect whales because:

- Existing information indicates ship strikes to whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to whales over known frequencies of incidents.
- JCEP would provide a ship strike avoidance measures package to shippers calling on the LNG Terminal. The package will consist of multiple measures to avoid striking marine mammals.

- LNG carriers approaching and departing from the Port of Coos Bay would be traveling slowly and escorted by tractor tugs.
- Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting the mammals in the water. Ignited LNG would affect species on the water surface but not mammals submerged in the water.

Conservation measures include the development of a plan to minimize potential ship strikes to cetaceans, and possibly other listed (Steller sea lion, sea turtles) and non-listed marine species by LNG carriers. LNG carriers would transit to and from the slip at slow speeds (between 4 to 6 knots once inside the Coos Bay navigation channel) and would result in minimal wakes, such that marine mammals would not be affected by the wakes of passing LNG carriers.

There is an ongoing threat of ship strikes to whales; however, from available accounts (Laist et al. 2001; Jensen and Silber 2003) ship-whale collisions occur fairly infrequently. Ship strikes of blue whales averaged 0.6 deaths or injury per year (1 death or injury per 1.67 year) in Pacific waters between 2002 and 2006 (Carreta et al. 2008). During six years, from 2002 to 2007, one blue whale was struck and killed by a ship off the coast of Oregon (Barre 2008). That computes to 0.17 blue whale death per year due to ship strikes in Oregon and Washington coastal waters. The likelihood of a ship-whale collision varies by species of whale. Researchers have found that fin and humpback whales are struck by ships relatively often (Laist et al. 2007), while killer whales have only rarely been documented as being injured or killed by a collision (Jensen and Silber 2003; NMFS 2008). However, it is assumed that many ship strikes with whales are unknown and unreported.

The incremental LNG carrier traffic of 90 ships per year plus the three attending tugs over the current annual Port traffic of approximately 50 ships will, logically, result in a higher probability of potential incidents of ships hitting species in the water. However, most mobile species will be able to avoid interaction with moving objects in the waterway.

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the endangered or threatened species are located (Figures 3.5-2 and 3.5-3), the LNG will float on the water until it vaporizes and will not have an adverse effect on the species, unless they come in direct contact with the LNG. Some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting the species in the water, given the ambient water temperatures in the transit route. If the vapor from an LNG spill were to come in contact with an ignition source the resulting fire would burn back to the spill source and would affect species on the water or in the area that come in direct contact with the fire. Species in the water would not be affected as the fire would be above the water in the area of the spill where the vaporized LNG is flammable. In either case of lower or higher water temperatures based on the spill scenario, mobile species will move out of the area until the water temperatures return to normal.

**Sea Turtles**

Potential effects to sea turtles that may be encountered along the LNG carrier transit route include environmental contaminants, impacts to foraging areas, debris, and vessel collisions. Direct effects of the Project include injury and/or mortality due to ship strikes and potential adverse effects from a ship spill and/or release of LNG at sea, as discussed for marine mammals. Spills and/or released LNG could indirectly affect sea turtles by impacting forage species.

Increased LNG carrier traffic may increase potential vessel strikes to sea turtles within the EEZ analysis area. They can be injured or killed when struck by a vessel, especially by an engaged propeller. Based on their warm water requirements, sea turtles are likely to only be occasional visitors to waters as far north as Oregon. Given the low population and occurrence of sea turtles in Oregon coastal waters, the increase of LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to sea turtles. LNG carriers approaching or departing from the Port of Coos Bay would be traveling slowly and escorted by tractor tugs within 50 nautical miles offshore of the LNG Terminal. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because reports of strandings in California are more frequent. LNG carriers are expected to transit at least 50 miles off the coast and so would be expected to avoid nearshore feeding areas.

Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting sea turtles in the water. Ignited LNG would affect species on the water but not sea turtles submerged in the water.

### 3.4.5 Mitigation, Enhancement, and Protection Measures

General mitigation, enhancement, and protection measures to reduce potential adverse effects to botanical and wildlife resources are included in Section 3.1.7 and 3.2.7, respectively. General measures to address potential adverse effects to fish and marine species from the construction of the slip and access channel for the LNG Terminal, land disturbing activities from the construction of the Project, dredging for the slip and access channel, maintenance dredging for the facility and LNG carrier route, ballast water discharge, the intake of cooling water for carriers while at the LNG berth are discussed in Section 3.3.7. These measures are incorporated by reference in this section. Additional conservation measures specific to individually listed species are discussed below.

A BA for all federal species that have the potential to be affected by the Project is required, as previously discussed, to comply with Section 7 of the ESA. JCEP will not begin construction and/or use of any of the proposed facilities, including related ancillary areas for staging, storage, temporary work areas, and new or to-be-improved access roads, until 1) the BiOp has been issued for federally-listed species; 2) associated state and federal authorizations and permits are in place; and 3) JCEP has received written notification from the FERC that construction and/or implementation of conservation measures may begin.

#### 3.4.5.1 Botanical Resources

**Western Lily**

Although the western lily has not been observed in the surveys conducted to date, to ensure that this species will not be affected by the Project, pre-construction surveys will be conducted. If surveys find an occurrence, the results would be reported immediately to the USFWS and ODA to initiate coordination and consultation to ensure potential effects to the western lily are mitigated with appropriate conservation measures, as required by Section 7 of the ESA.

**State-Listed Species**

To ensure that state-listed species will not be affected by the Project, pre-construction surveys of the affected areas of the Project site will be conducted for Point Reyes bird's-beak, pink sand verbena, silvery phacelia, and Wolf's evening primrose. Although the surveys are not required by any state or federal regulations, voluntary actions will help prevent further declines of species populations and avoid the potential need for future listing.

If a survey finds an occurrence of any state threatened or endangered species, the results will be reported and additional coordination and consultation will be initiated with the ODA and other appropriate resource agencies. This may include following existing relocation and monitoring guidance. The Point Reyes bird's beak, in particular, is a hemi-parasite that attaches to a host plant and any relocation efforts will propose removing the area around existing plants.

#### 3.4.5.2 Wildlife

**Birds**

Bald Eagle

Pre-construction surveys of the Project site for the bald eagles will be conducted by a qualified biologist. Surveys will include a search for active nests in appropriate habitat in areas in and adjacent to the Project that may provide nesting habitat. If a bald eagle nest is located less than 660 feet (line-of-site) from the planned Project construction activities, the planned Project construction activities will be adjusted accordingly or resumed as planned until one of the following has occurred:

1. The nesting season is over and the individuals have either successfully raised young and they have fledged and left the nest site;
2. Nest abandonment has been determined by the appropriate state or federal regulatory agency, and authorization for work has been given within the nesting season; or
3. Project activities are relocated more than 660 feet (line-of-sight) from the active nest.

Streaked Horned Lark

Bird surveys conducted to date did not identify the presence of the streaked horned lark within the Project vicinity. No mitigation measures are anticipated.

Western Snowy Plover

JCEP reviewed a list of conservation measures provided by the USFWS, BLM, and ODFW through the JCEP Interagency Task Force Working Group for the LNG import facility previously proposed. JCEP agreed to provide funding as enumerated below. The funding would be provided to the entity as defined by the agencies and it would be the responsibility of the particular entity to administer the funding. It should be noted that these measures were developed partially in response to the concern that a previous Port stockpile site proposed would provide potential habitat. The Port stockpile site is no longer part of the Project. JCEP is willing to provide the funding on the condition that no additional requirements would be placed on the Project relative to the snowy plover issue (other than those discussed in this section). JCEP is also requesting that the funding of these conservation measures be used in part to contribute to other habitat mitigation requirements imposed by the ODFW.

Funding by JCEP at present includes:

- Year 1 (when construction begins) JCEP would provide $60,000 for fencing, signage, application of shell hash, tree removal, and one year of maintenance.

- Years 2 and 3 JCEP would provide $30,000 each year for annual maintenance, a beachgrass elimination grant, and shell hash.
- Years 4 to 2018 JCEP would provide $10,000 for annual maintenance.

In addition to these conservation measures, JCEP has agreed to mitigate Project impacts to western snowy plovers through implementation of BMPs, along with education and outreach programs. Increased predator density related to increased human presence and habitat removal was identified as potential concerns related to Project construction. JCEP will address these concerns through the following BMPs discussed below.

Eliminating human sources of food in proximity to breeding locations (e.g., parking areas) adjacent to coastal breeding areas such as uncovered garbage and littered food scraps may indirectly help reduce predator numbers or help prevent their numbers from increasing. During construction and operation, the Project site will be kept clear of construction debris and food wastes that could attract predators. Covered, animal proof receptacles will be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. During construction the site would be policed on a daily basis to remove any food or other debris left by construction workers. During operations the Project site would be regularly inspected to assure that no garbage is allowed to accumulate.

Structures associated with the Project will be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately, in coordination and consultation with the USFWS. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the MBTA.

The placement of dredged material on land will be regularly policed to ensure that no denning is occurring in the hillocks. This should not be as significant a concern, as proposed placement areas will be part of the construction activities and the continuous activities will discourage use by individual birds. If necessary, nylon mesh or other exclusion fencing would be installed around the perimeter of the placement areas to prevent the establishment of coyote or skunk dens until the slopes are stabilized or constructed upon.

Surveys previously conducted indicate that 76 percent of beach visitors were unaware of restrictions associated with snowy plovers. This indicates that increased education could have a significant impact on public awareness of issues surrounding snowy plovers. Furthermore, the USFS at the Oregon Dunes National Recreation Area and BLM staff have reported that the majority of contacted individuals are more willing to comply with beach use restrictions after better understanding the reasons for them.

The JCEP would train all construction and operations staff on the need for snowy plover conservation, current snowy plover regulations and recreational use restrictions, and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on a leash, and remaining on established roads and trails. The training program would be developed based on guidance provided in Appendix K of the 2007 Plover Recovery Plan, or would be contracted for through State/local agencies or organizations who may have pre-existing plover education and outreach programs experience. Prior to implementation, the training program would be submitted for comment to members of the Western Snowy Plover Working Team.

Environmental training would also be provided to operational personnel to ensure that all personnel are aware of and comply with the management tools in place to affect the recovery and maintenance of the snowy plover population on the North Spit. Printed educational materials would be posted at the Project site for the life of the Project. Materials would also be distributed to existing North Spit employers for their use in training their personnel. The types of educational materials may vary, but could include posters, table tents, maps, brochures, or factsheets. Numerous sources for existing educational materials are provided in Appendix K of the Plover Recovery Plan.

Intensive biological monitoring of snowy plover on the North Spit is presently being conducted by ORBIC and the population is one of the most closely monitored snowy plover populations on the West Coast. JCEP will fund one additional entry level Wildlife Services position dedicated to snowy plover predator monitoring and control during the 42-month construction period. This staff member would be employed by Oregon Wildlife Services, which is administered by the U.S. Department of Agriculture and Animal and Plant Health Inspection Services. The specific duties of this additional staff member would be determined by Wildlife Services based on North Spit management needs, but would concentrate on predator management. This additional position would allow Wildlife Services to better evaluate predator densities and more quickly and effectively respond in the unlikely event that predator pressure on the North Spit increases during Project construction.

In the event that a clearly demonstrable and sustained decrease in snowy plover productivity is detected by the ongoing ORBIC monitoring, JCEP would coordinate with the USFWS, ORBIC, Wildlife Services, BLM, OPRD, ODFW, and other interested parties to identify adaptive management strategies, as appropriate, to help reverse any such trend.

#### 3.4.5.3 Fisheries (included Marine Species)

Conservation measures developed for the Project within the Project action area to conserve other fish and marine species in Section 3.3.7 would also benefit coho salmon, eulachon, and green sturgeon if they are present during the construction and operation of the Project. Additional species-specific mitigation, enhancement, and protection measures are discussed below.

**Whales**

Routine activities of the LNG Terminal after construction include primarily traffic of LNG carriers and associated maritime activities. Listed marine species may be affected by the associated increase in ship traffic and could be harmed or killed from chance collisions with vessels, from eating floating plastic debris from slip site related activities, or through exposure to hydrocarbons from accidental oil spills. LNG carriers will transit to and from the slip at slow speeds that will result in minimal wakes, such that marine mammals will not be affected by the wakes of passing LNG carriers. JCEP will provide the LNG fleet servicing the LNG Terminal with measures proposed by NMFS for avoidance of marine mammals and sea turtles to further reduce the likelihood of adverse effects on these species. Mitigation, protection, and enhancement measures to address all of these potential effects are described in further detail below.

JCEP would request all LNG carriers calling on the LNG Terminal to reduce speeds to 10 knots or less within 30 nautical miles of the entrance to Coos Bay during the whale migratory period. During the 96-hour pre-notification process to be followed by all LNG carriers calling on the LNG Terminal, JCEP would check with the NMFS for information on the migratory patterns of whales within the route of the LNG carrier and would inform the ship's master of the patterns reported by NMFS. JCEP would request that all LNG carrier operators consult current whale sighting information prior to calling on the LNG Terminal and be aware of the reported locations of whales and plan their operations accordingly. LNG carriers would be requested to reduce their speed to 10 knots or less when mother and calf pairs, groups, or large assemblages are observed near an underway LNG carrier. LNG carriers would be requested to route around and maintain a 100-yard distance from the whales observed and to avoid crossing in front of the whales and maintain a parallel route, if possible.

JCEP would provide a ship strike avoidance measures package to shippers calling on the LNG LNG Terminal. This package would include the measures proposed by NMFS for avoidance of marine mammals to further reduce the likelihood of adverse effects on these species. Some of the suggested measures include the following:

- Provide training to LNG carrier crews, including the use of a reference guide such as the *Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska* by Pieter Folkens. This is a pamphlet that would be provided to LNG carriers calling on the LNG Terminal and would be included as part of the terminal use agreement to the shippers.
- Provide a copy of the NMFS CD-rom-based training program entitled *A Prudent Mariner's Guide to Right Whale Protection* as part of a ship strike avoidance measures package to all LNG carriers calling on the LNG Terminal. While this CD-rom-based training program is specific to right whales, NMFS has stated that the guidance and avoidance measures are also applicable to fin, humpback, and sperm whales.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the ship to 10 knots or less to avoid striking protected species.
- When whales are sighted maintain a distance of 90 meters (or 100 yards) or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce ship speed to ten knots or less when pods or large assemblages of cetaceans are observed near an underway ship.
- When whales are sighted in a ship's path or in proximity to a moving ship, reduce speed to 10 knots or less or shift the engine to neutral until whales are clear of the area or path of the ship. LNG carrier masters would be requested to provide reports of sightings of marine mammal while in the EEZ action area and to provide the report upon docking at the LNG Terminal. This reporting request would be included in the Ship Strike Avoidance Measures Package provided to each LNG carrier calling on the LNG Terminal and compliance with the measures and the reporting would be included in all terminal service agreements with shippers.

LNG carrier crews would be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the ship. If the injury or death is caused by collision with the ship, appropriate regulatory agencies (FERC or NMFS) would be notified within 24 hours of the incident. Information to be provided would include the date and location (latitude/longitude) of the strike, the ship name, the species, or a description of the animal, if possible.

JCEP has been working with the Coast Guard and ODE in the development of an LNG Management Plan. The LNG Management Plan is the primary process used in reducing risk through proper mitigation measures. The interagency group has been given a step by step process in how risk is mitigated in both safety and security issues.

As part of the LNG Management Plan, JCEP is proposing that LNG carriers would not be allowed to move past the 50-mile voluntary traffic lanes offshore unless it is acceptable for them to continue into the LNG Terminal. In addition, JCEP is also proposing that LNG carriers would not be allowed to anchor offshore the Oregon coast. The New Carrissa incident occurred when a ship inappropriately anchored in heavy seas just off the coast. LNG carriers would only be allowed to enter closer than 50 miles when all conditions are suitable to enter the Port.

Further, JCEP has committed to providing tractor tugs to escort each LNG carrier into the port and to the berth. This type of tug has not been previously available in the Port. These tugs have the capability to fully maneuver the LNG carriers even without ship power.

**Sea Turtles**

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of whales and possibly Steller sea lions are observed near an underway ship would provide some protection to green turtles. However, it is highly unlikely that sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines, and LNG Management Plan to minimize risk of spills and releases at sea that were described for whales apply to sea turtles.

## 3.5 REFERENCES

Aagard, K., H.R. Sanborn and R.W. Sternberg. 1971. A fluvial and hydrographic survey of Coos Bay, Oregon. Submitted to Weyerhaeuser Company, North Bend, OR. 16 pp.

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindely and M.L. Moser. 2002. Status review for North American Green Sturgeon, *Acipenser medirostric*. National Marine Fisheries Service Southwest and Northwest Fisheries Science Centers and North Carolina Cooperative Fish and Wildlife Research Unit.

Adamus, P. R., K. Larsen, G. Gillson, and C. R. Miller. 2001. Oregon Breeding Bird Atlas. CD-ROM.OFO Special Publication No. 16.Oregon Field Ornithologists, Eugene.

Akins, G. and C. Jefferson. 1973. Coastal wetlands of Oregon; a natural resource inventory report. Oregon Coastal Conservation Dev. Comm.Florence. 159 pp.

Altman, B. 2003. Horned Lark. Pp. 425-248 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. OregonStateUniversity Press, Corvallis.

Anchor Environmental CA, L.P. 2003. Literature review of effects of resuspended sediments due to dredging operations. Prepared for Los Angeles Contaminated Sediments Task Force, Los Angeles, CA. Anchor Environmental CA, L.P. One Park Plaza Suite 600 Irvine, CA. June.

Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Anthony, R. G., M. C. Hansen, M. Sandler, N. V. Marr, C. A. Schuler, and R. S. Lutz. 1990. Short-term effects of triploid grass carp on waterfowl and Bald Eagles at Devil’s Lake, Oregon. Unpubl.rep., Oreg. Coop. Wildl. Res. Unit, Oreg. State Univ., Corvallis.

Armstrong, R.h., Hermans, M.C., Koski, K., and Willson, M.F. 2006. Eulachon: A Review fo Biology and an Annotated Bibliography, Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, Juneau, Alaska.

Arneson, R.J. 1975. Seasonal variation in tidal dynamics, water quality, and sediments in the Coos Bay estuary. M.S. thesis.Oregon State University, Corvallis.250 pp.

Baker, C.A. 1978. A study of estuarine sedimentation in South Slough, Coos Bay, Oregon. M.S. thesis.Portland State University, Portland.104 pp.

Baker, P. 1995. Review of ecology and fishery of the Olympia oyster, *Ostrea lurida* with annotated bibliography. *J. Shellfish Res.* 14(2):501-518

Baker, P., N.B. Terwilliger. 1999. Reestablishment of a native oyster: Implications for population distribution and structure. *J. Shellfish Res.* 19(1):687

Behnke, R.J. 1979. Monograph of the native trouts of the genus Salmo of western North America. 163 p. (Available Regional Forester, 11177 West 8th Avenue, PO Box 25127, Lakewood, CO 80225.).

Behnke, R.J. 1992. Native trout of western North America. Am. Fish. Soc, Bethesda, 275p. Biological Review Team (BRT). 2003. Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead. Draft Report. Northwest Fisheries Science Center, Seattle, Washington; Southwest Fisheries Science Center, Santa Cruz Laboratory, Santa Cruz, California. February 2003.

Bisson, P.A., and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 2:371-374.

Bourke, R.H., B. Glenne and B.W. Adams. 1971. The nearshore physical oceanographic environment of the Pacific Northwest coast. Oregon State University Reference 71-45.Department of Oceanography, OSU, Corvallis.

Bourne, N. and D.W. Smith. 1972. The effect of temperature on the larval development of the horse clam, *Tresus capax* (Gould). *Proc. Natl. Shellfish. Assoc.* 62:35-37

Bray, R.N., A.D. Bates and J.M.Land. 1997. Dredging-A handbook for engineers. Second Edition. Arnold, London.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. *Lichens of North America*. New Haven:YaleUniversity Press. 795 pp.

Brown, R.F. 1988. Assessment of pinniped populations in Oregon, April 1984 to April 1985.NMFS-NWAFC Proc. Rept. 88-05.44 pp.

Brumbaugh, R. and R. Reppert. 1994. *National Wetland Mitigation Banking Study: First phase report.* Institute for Water Resources Water Resources Support Center, U.S. Army Corps of Engineers, Alexandria, Virginia 22315 From: http://www.iwr.usace.army.mil/iwr/pdf/94wmb4.pdf Accessed April 4, 2006.

Burger, C.V., R.L. Wilmot and D.B. Wangaard. 1985. Comparison of spawning areas and times for two runs of Chinook salmon (*Oncorhynchus kisutch*) in the Kenai River, Alaska. Can. J. Fish.Aquat. Sci. 42:693-700.

Burt, W.V. and W.B. McAllister. 1959. Recent studies in the hydrography of Oregon estuaries. Fish. Comm. Oreg. Res. Briefs 7(1): 14-27.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples and F.W. Waknitz. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Technical Memorandum NMFS-NWFSC-27. August 1996.

California Department of Fish & Game, Wildlife & Habitat Data Analysis Branch. (August 6, 2005). California Natural Diversity Database.Sacramento: CDFG.

California Department of Fish and Game. 2006. *California Natural Diversity Database*. Online: http://www.dfg.ca.gov/whdab/html/cnddb.html.

Carlton, James T & Geller, Jonathan, B. 1993. Ecological Roulette: The Global Transport of Nonindigenous Marine Organism. Science, Vol. 261..

Carroll, J.C. and R.N. Winn. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Brown Rock Crab, Red Rock Crab, and Yellow Crab

Chew, K.K. and A.P. Ma. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)–common littleneck clam. U.S. Fish Wildl.Serv. Biol. Rep. 82(11).U.S. Army Corps of Engineers, TR EL-82-4.22 pp.

Christy J. A., J. S. Kagan, and A. M. Wiedemann.(1998). *Plant Associations of the Oregon Dunes National Recreation Area, Siuslaw National Forest, Oregon*. NR: U.S. Department of the Agriculture, Forest Service Pacific Northwest Region. Technical Paper R6-NR-ECOL-TP-09-98.123 pp.

Christy, J. A. 2002. *Limbella fryei (*Williams*)* Ochyra. Red Data Sheet, Oregon Natural Heritage Program, 821 SE 14th Ave., Portland, OR, USA. Viewed on 3-27-06 at www.artdata.slu.se/guest/ SSCBryo/fact_doc/Limbella_fryei.PDF

Cleaver, F.C. 1951. Fisheries Statistics of Oregon. Contribution Number 16.Fish Commission of Oregon, Department of Research.Portland, Oregon.

Collins, M.A. 1995. Dredging induced near-filed resuspended sediment concentrations and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Comyns, B.H. 1997. Growth and mortality of fish larvae in the north central Gulf of Mexico and implications to recruitment. Ph.D. diss., Lousiana State Univ., Baton Rouge, LA.199 p.

Connor, P.M. 1972. Acute toxicity of heavy metals to some marine larvae. Marine Pollution Bulletin, 3, pp.190-192.

Contreras, A. 1998. Birds of Coos County, Oregon: Status and distribution. Cape Arago Audubon Soc. and Oreg.Field Ornithol.(Spec. Publ. 12), Eugene.

Copeland, B.J. 1998. Salt Marsh Restoration: Coastal Habitat Enhancement. North Carolina Sea Grant College Program, Raleigh, NC.32 pp.

Cornelius, S.E. 1982. Status of Sea turtles along the Pacific coast of Middle America. Pages 211-219 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D.C. 583 pp.

Couch, D. and T.J. Hassler. 1989. Species Profiles: Life histories and environmental

Crowder, L.C., S.J. Lyman, W.F. Figuiera and J. Priddy. 2000. Source-sink dynamics and the problem of siting marine reserves. Bull. Mar. Sci. 66: 799-820.

Currin, Rebecca. (November 2012). Email correspondence between Rosalind Litzky and Rebecca Currin, Botanist about ODA regulations about state endangered and threatened species.

Csuti, B., T. A. O'Neil, M. M. Shaughnessy, E. P. Gaines, and J. C. Hak. 2001. Atlas of Oregon Wildlife, 2nd ed. Oregon State University Press, Corvallis. 525 pp.

Cummings, T.E. and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Coastal Rivers Investigation Report 70-11. Fish Comm. Oregon.22 pp.

DeWitt, J.W. 1954. A survey of the coastal cutthroat trough, *Salmo clarki clarki Richardson*, in California, Calif. Fish Game 40:329-335.

Dicken, S.N., C.L. Johannessen and B. Hanneson. 1961. Some recent physical changes of the Oregon coast. Department of Geography, University of Oregon, Eugene.151 pp.

Eltzroth, M. S. 1987. Checklist of the Birds of Oregon, 4th ed. Audubon Society of Corvallis.17 pp.

Environmental Protection Information Center (EPIC). 2001. Petition to list the North American Green Sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the Endangered Species Act. Petition To National Marine Fisheries Service by Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California, petitioners.

Erickson, D.L., J.A. North, J.E. Hightower, J. Weber, and L. Lauck. 2002. Movement and habitat use of green sturgeon Acipenser medirostris in the Rogue River, Oregon, USA. Journal of Applied Ichthyology 18 (2002) 565-569.

Essential Fish Habitat (EFH) Core Team for West Coast Groundfish. 1998. Appendix: Life History Descriptions for the West Coast Groundfish. National Marine Fisheries Service. Seattle, WA. June, 1998. Available: http://www.nwr.noaa.gov/1sustfsh/efhappendix/page1.html

Farr, R.A. and J.C. Kern. 2004. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Farr, R.A. and T.A. Rien. 2002. Green Sturgeon Population Characteristics In Oregon.

Farr, R.A., M.L. Hughes, and T.A. Rien. 2001. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Farr, R.A., M.L. Hughes, and T.A. Rien. 2003. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R

Federal Register Vol. 71 No. 129. July 6, 2006. Northern Right Whale (*Eubalaena glacialis*)

Federal Register. 2001. Endangered and threatened wildlife and plants: 90-day finding for a petition to list green sturgeon as threatened under the Endangered Species Act. 14 December 2001, pages 64793-64794.

Fleming, K. 1999. Northern Anchovy. *In*: Orsi, James J., editor. Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California. http://www.estuaryarchive.org/archive/orsi_1999

Florida Institute of Oceanography. 1996. Impacts and Direct Effects of Sand Dredging for Beach Renourishment on the Benthic Organisms and Geology of the West Florida Shelf.

Report to Dept. of Interior MMS. September. Available at http://www.mms.gov/sandandgravel/PDF/flben.pdf

Forsman, E. D. 2003. Spotted Owl. Pp. 319-320 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: a community profile. U.S. Fish and Wildlife Service Biological Rep. 85 (7.2).152 pp.

Garrett, M. G., J. W. Watson, and R. G. Anthony. 1993. Bald Eagle home ranges and habitat use in the Columbia River estuary. J. Wildl. Manage. 57:19-27.

Gaumer, T.F., G.P. Robart and A. Geiger. 1978. Oregon bay clam distribution, abundance, planting sites and effects of harvest. Annual Report October 1, 1977 to September 30, 1978. Oregon Department of Fish and Wildlife. 65 pp.

Gaumer, T.F.,D. Demory and L. Osis. 1973. 1971 CoosBay resource use study. Fish Comm. Oregon. 30 pp.

Gerstein, Edmund, R. Undated. Parametric Projectors Protecting Marine Mammals From Vessel Collisions, 157th Meeting Lay Language Papers.

Glavich, D. A. 2003. "The Distribution, Ecology, and Taxonomy of *Bryoria spiralifera* and *B. pseudocapillaris*on the Samoa Peninsula, Humboldt Company, Coastal Northern California," The Bryologist: Vol. 106, No. 4, pp. 588–595. Omaha: American Bryological and Lichenological Society, Inc.

Grant, J. and B. Thorpe. 1991. Effects of suspended sediment on growth, respiration, and excretion of the soft-shell clam (*Mya arenaria* ). *Can. J. Fish.Aquat. Sci.* 48(7):1285-1292

Groot, C. and L. Margolis (eds). 1991. Pacific Salmon Life Histories. UBC Press, Vancouver. 543 pp.

Gross, M.R. 1987. Evolution of Diadromy in Fishes. Am. Fish. Soc. Symp. 1:14-25Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*).Pp. 311-294 in C. Groot and L. Morgolis (eds.), Pacific Salmon Life Histories.UBC Press.Vancouver, B.C., Canada.

Guerra-Garcia, J.M.; J. Corzo; and Carlos Garcia-Gomez. 2003. Short-term benthic recolonization after dredging in the Harbour of Ceuta, North Africa. Marine Ecology, Vol. 24, Number 3, Sept. pp. 217-229(13).

Haagen, J. T. (1989). *Soil Survey of CoosCountyOregon*. NR:U.S. Department of Agriculture, Soil Conservation Service in cooperation with Oregon Agricultural Experiment Station.

Healey, M.C. 1982. The ecology of juvenile salmon in Georgia Strait, British Columbia, p. 203-229. In: W.J. McNeil and D.C. Himsworth (eds), Salmon Ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pp. 311-294 in C. Groot and L. Morgolis (eds.), Pacific Salmon Life Histories.UBC Press.Vancouver, B.C., Canada.

Henny, C. J., and J. E. Pagel. 2003. Peregrine Falcon. Pp. 166-170 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds.Oregon State University Press, Corvallis.

Hickman, J. C. ed. 1993. *The Jepson Manual*. Berkeley: University of California Press Berkeley.

Hitchcock, C.L., and A. Cronquist.(1973). Flora of the Pacific Northwest. NR: University of Washington Press.

Hjort, R.C., P.L. Hulett, L.D. LaBolle and H.W. Li. 1984. Fish and invertebrates of revetments and other habitats, the Willamette River, Oregon. Technical Report E-84-9 prepared for US Army Corps of Engineers under Intra-Army Order No. WESRF-82-106.83 pp. + Appendices.

Hoffnagle, J. and R. Olson. 1974. The salt marshes of the Coos Bay Estuary. Port Coos Bay Comm. and University of Oregon Institute of Marine Biology, Charleston. 86 pp.

Hornig, S., A. Sterling and S.D. Smith. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Ghost Shrimp and Blue Mud Shrimp.

Hostick, G. 1974. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Fish Commission Oregon Coastal Rivers Investigation Information Report 74-11. 22 pp.

Houde, E.D. and J.A. Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Estuar. Coast. Shelf Sci. 18:403-419.

Hunter, J. E., D. Fix, G. A. Schmidt, and J. C. Power. 2005. *Atlas of the Breeding Birds of Humboldt County, California*. Seattle: Reischling Press, Inc. pp. 440.

Imper, D. K. 2003. Letter from D. Imper at Arcata Field Office (U.S. Fish and Wildlife Service) to Roseburg Office (U.S. Fish and Wildlife Service).

Imper, D. K. and John O. Sawyer, PhD. October 1992. *Botanical Survey of the Crescent City Marsh wildlife Area*. Arcata: CSU& CDFG.

Imper, David K. (February 18, 2003). "Port Orford Sewage Offshore Discharge—Proposed Drilling Location." unpublished letter/email to Rob Burns, USFWS Roseburg Office. Arcata: FWO.

Isaacs, F. B., and R. G. Anthony. 2003. Bald Eagle. Pp. 140-144 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

Jameson, R. J. 2007. U.S. Geologic Survey: Translocated Sea Otter populations off the Oregon and Washington Coasts. Viewed on 3-27-2007 at http://biology.usgs.gov/s+t/SNT/noframe/pn175.htm

Jarvis, R. L. 2003. Canada Goose. Pp. 82-86 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds.Oregon State University Press, Corvallis.

Jefferts, C.A. 1977. The vertical distribution of infauna: a comparison of dredged and undredged areas in Coos Bay, Oregon. M.S. thesis.Oregon State University, Corvallis.45 pp.

Johnson, O.W., M.H. Ruckelshaus, W.S. Grant, F.W. Waknitz, A.M. Garrett, G.J. Bryant, K. Neely, and J.J. Hard. 1999. Status Review of Coastal Cutthroat Trout from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-37. January

Johnson, O.W., R.S. Waples, T.C. Wainwright, K.G. Neely, F.W. Waknitz, and L.T. Parker. 1994. Status review of Oregon's Umpqua River sea-run cutthroat trout. NOAA Technical Memorandum NMFS-NWFSC-15. Available: http://www.nwfsc.noaa.gov/pubs/tm/TM15/techmemo15.html

Johnson, O.W., T.A. Flagg, D.J. Maynard, G.B. Milner and F.W. Waknitz. 1991. Status review for Lower Columbia River Coho Salmon. NOAA F/NWC-202. June.

Johnson, O.W., W.S. Grant, R.G. Kope, K. Neely, F.W. Waknitz, and R.S. Naples. 1997. Status Review of Chum Salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-32. December

Johnston, J.M. 1982. Life histories of anadromous cutthroat with emphasis on migratory behavior. In E.L. Brannon and E.O. Salo (eds.), Proceedings of the salmon and trout migratory behavior symposium, p. 123-127. Univ. Washington, Seattle.

Kalt, Jen. (Winter 2006). "Crescent City Marsh and Western Lily Threatened by Two Proposed Developments," Darlingtonia. Arcata: CNPS, North Coast Chapter.

Kennedy, V.S. and J.A. Mihursky. 1971. Upper temperature tolerances of some estuarine bivalves. *Chesapeake Sci.* 12(4):193-204

Kjelson, M.A., P.F. Raguel, and F.W. Fisher. 1982. Life history of fall run-Chinook salmon, Oncorhynchus tshawytscha, in the Sacramento-San Joaquin Estuary, California. In Estuarine Comparison, edited by V.S. Kennedy, pp.393-411.Academic Press, New York, New York.

Koski, K.V. 2009. *The Fate of Coho Salmon Nomads: The Story of an Estuarine-Rearing Strategy Promoting Resilience*, The Nature Conservancy Alaska Field Office, Juneau, Alaska.

Kraeg, B. 1979. Natural resources of Coquille estuary. Estuary inventory report Vol. 2, No. 7. ODFW, Corvallis. 48 pp.

Lagerquist, B. A. and and Mate, B.R. Humpback Whale Sightings off the Oregon and Northern California Coast, During Summer 2002. Hatfield Marine Sciences Center, Oregon State University. No date

LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. *A Framework for Assessing the Need for Seasonal Restrictions on Dredging and Disposal Operations. Technical Report D-91-1,*U.S. Army Engineer Waterways Experiment Station, Dredged Material Research Program, Vicksburg, MS. 74 pp.

Lauten, D. J., K. A. Castelein, E. Seckinger, and E. P. Gaines. 2006. The distribution and reproductive success of the western snowy plover along the Oregon coast – 2005. Unpubl. Rep. ORNHIC, Portland. 60 pp.

Lawson, P.W., E. Bjorkstedt, M. Chilcote, C. Huntington, J. Mills, K. Moore, T. Nickelson, G. Reeves, H. Stout and T.C. Wainwright. 2004. Identification of historical populations of coho salmon (Onchorhynchus kisutch) in the Oregon Coast Evolutionarily Significant Unit. Northwest Fisheries Science Center 2032 SE OSU Drive, NewportOR97365.

LBJ Enterprises (LBJ). 2006. *2006-2006 Pre-construction wildlife surveys for proposed Jordan Cove Liquified Natural Gas Plant, Coos Bay, Oregon*. May 10, 2006 Revised December 26, 2006.

Levy, D.A. and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish.Aquat. Sci. 39:270-276.

Li, H.W., C.B. Schreck and R.A. Tubb. 1984. Comparison of habitats near spur dikes, continuous revetments, and natural banks for larval, juvenile and adult fishes of the Willamette River. Water Resources Research Institute, WRRI-95. Oregon State University, Corvallis, Oregon.15 pp.

Lister, D.B., C.E. Walker and M.A. Giles. 1971. Cowichan River Chinook salmon escapements and juvenile production 1965-1967. Can. Fish.Serv. 1971-3, 8 p.

Litle, K. and J.K. Parrish (eds). 2003. Where the River Meets the Sea: Case Studies of Pacific Northwest Estuaries. Pacific Northwest Coastal Ecosystems Regional Study, Seattle.

Lopez-Jamar, E.; J. Mejuto. 1988. Infaunal benthic recolonization after dredging operations in La Coruna Bay, NW Spain. Cahiers de Biologie Marine CBIMA5, Vol. 29, Number 1, pg. 37-49.

Macleod, J. 1970. Shad census study report-Coos-Millicoma rives. Oregon Game Commission, Portland.

Marshall, D. B., M. G. Hunter, and A. L. Contreras, Eds. 2003. Birds of Oregon: A General Reference. State University Press, Corvallis.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness.*Natural History of Oregon Coast Mammals*. U.S. Department of Agriculture, Forest Service, General Technical Report PNW-133, 1981.

Matthiessen, C.G. 1960. Observations on the ecology of the soft clam, *Mya arenaria*, in a salt pond. *Limn. Oceanogr.* 5(3): 291-300

McCauley, J.E.; R.A. Parr and D.R. Hancock. 1977. Benthic infauna and maintenance dredging: a case study. Water Research, Vol. 11, Number 2, pg. 233-242.

Methot, R.D. 1981. Spatial covariation of daily growth rates of larval northern anchovy, *Engraulis mordax*, and northern lampfish, *Stenobrachius leucopsarus*. Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 178: 424-431.

Miller, J. A., and A. L. Shanks. 2004. Ocean-estuary coupling in the Oregon upwelling region: the abundance and transport of juvenile fish and larval invertebrates. Marine Ecology Progress Series 271:267-279.

Miller, R.J. and E.L. Brannon. 1982. The origin and development of life history patterns in Pacific salmonids. In Brannon, E.L., and E.O. Salo (eds.), Proceedings of the Salmon and Trout Migratory Behavior Symposium, p. 296-309. School of Fisheries, Univ. Wash., Seattle.

Minerals Management Service (MMS). 1996. East Florida Shelf Benthic Repopulation Study. Feb. Available at www.gomr.mms.gov.

Misitano, D.A. 1977. Species composition and relative abundance of larval and post larval fishes in the Columbia River Estuary, 1973. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 75(1): 218-222.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. New York, Van Nostrand Reinhold.

Moffat & Nichol.2006. Jordon Cove LNG Terminal Coos Bay, Oregon, report on turbidity due to dredging. MNI Project No. 5797 Document No. 5797RP0009. Prepared for Black & Veatch and Jordon Cove Energy Project, L.P.

Moore, J.W., K.D. Martin and M.E. Gray.2000. Coos Bay salinity intrusion study-the effects of deepening the shipping channel on striped bass and other fish populations. ODFW Contract Number W66QKZ01017672.

Morgan, B. and K. Melcher. 2003. Sturgeon tagging project in select coastal estuaries 2003. Oregon Department of Fish and Wildlife, Columbia River Management, Clackamas, OR.

Morris, R.H., D.P. Abbott and E.C. Haderlie. 1980. Intertidal invertebrates of California. Stanford University Press, Stanford.

Moyle, P.B., P.J. Foley and R.M. Yoshiyama. 1992. Status of green sturgeon, *Acipencer medirostris*, in California. Final Report submitted to National Marine Fisheries Service, Terminal Island, CA.

Musick, J.A. and M.M. Harbin. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25(11): 6-30.

Myers, J.M., R.G. Kope, G.J. Bryant, D.Teel, L.J. Lierheimer, T.C. Wainwright, W. S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35. February 1998

Nakamura, G. and J.K. Nelson. (2001). *Selected Rare Plants of Northern California*. NR: University of California Agricultural and Natural Resources. Publication Number 3395.

Narver, W.W. 1970. Diel vertical movements and feeding of underyearling sockeye salmon and the limnetic zooplankton in Babine Lake, British Columbia. J. Fish. Res. Board Can. 27:281-316.

National Audubon Society. Website: http://www.audubon.org/bird/cbc/index.html.

National Marine Fisheries Service, 2009. Designation of Critical Habitat for the Southern Distinct Population Segment of Green Sturgeon, Final ESA Section 4(b) (2) Report, October 2009.

National Marine Fisheries Service. 2008. Coho ESU Critical Habitat Designations. Federal Register (73 FR 7816)

National Marine Fisheries Service. 2008. Formal Consultation for the Coos Bay airport Expansion in North Bend, Coos County, Oregon, NMFS No. 2008/03298.

National Marine Fisheries Service. 2008. Speed Restrictions to Reduce Ship Collisions with Right Whales, Federal Register (73 FR 60173).

National Marine Fisheries Service. 2011. Biological Opinion for the Ocean Terminals Dock Construction, sheet Pile, and Placement of Fill, Coos Bay, Coos County, Oregon, NMFS Consultation No. 2011/03866.

National Marine Fisheries Service. 2012. ESA/EFH Concurrence Letter for Southwest Oregon Airport Mitigation Site Dike Repair, Coos Bay, Coos County, Oregon, NMFS No. 2012/00604.

National Marine Fisheries Service and the U.S. Fish and Wildlife Service. 1998. Recovery Plan for U.S. Pacific Populations of the Olive Ridley Turtle (*Lepidochelys olivacea*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and the U.S. Fish and Wildlife Service. 2006. Killer whale fact sheet. Viewed on 3-26-2007 at http://www.nwr.noaa.gov/Marine-Mammals/Whales-Dolphins-Porpoise/Killer-Whales/ESA-Status/upload/kwfactsheet.pdf

National Marine Fisheries Service, 50 CFR § 226.202. Stellar Sea Lion

National Marine Fisheries Service.1992b. Recovery plan for the Steller sea lion (*Eumetopia jubatus*).Prepared by the Steller Sea Lion Recovery Team for the National Marine Fisheries Service, Silver Springs, MD.92 pp.

National Marine Fisheries Service. 2009. Designation of Critical Habitat for the Southern Distinct Population of Green Sturgeon, Final ESA Section 4 (b)(2) Report. National Marine Fisheries Service, Silver Spring, MD.

National Marine Protected AreasCenter. 2007. South Slough National Estuarine Reserve. Viewed on 3/22/07 at http://mpa.gov/helpful_resources/south_slough.htm.

National Marine Protected Areas of the United States. Viewed on 3-27-07 at http://mpa.gov/helpful_resources/south_slough.htm)

National Oceanic and Atmospheric Administration (NOAA) and South Slough National Estuarine Research Reserve. 2005. Enhanced Coastal Observational System and Predictive Hydrodynamic Model for Improvement Management of the Coos Bay Estuary, Oregon.

National Oceanic and Atmospheric Administration (NOAA). 2007. Office of Protected Resources: Leatherback Turtle (*Dermochelys coriacea*). Viewed on 3-23-2007 at http://www.nmfs.noaa.gov.pr/species/turtles/leatherback.htm

National Oceanic and Atmospheric Administration (NOAA). 2007a. Office of Protected Resources: Green Turtle (*Chelonia mydas*). Viewed on 3-26-2007 at http://www.nmfs.noaa.gov/pr/species/turtles/green.htm

National Oceanic and Atmospheric Administration (NOAA). 2007b. Office of Protected Resources: Loggerhead Turtle (*Caretta caretta*). Viewed on 3-26-2007 at http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm

National Oceanic and Atmospheric Administration. Website: http://66.102.7.104/search?q=cache:49aLQdRyYDAJ:www.nwr.noaa.gov/1srd/Recovery/domains/willow/WMU_Plan/pdfs/TechApps/AppendixB/AppB-8_StellerSeaLions.pdf+oregon+status+%22northern+sea+lion%22&hl=enNehls, H. B. 2003a. Brown Pelican. Pp. 53-54 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

National Oceanic and Atmospheric Administration (NOAA). 2008. Impacts to Marine Fisheries Habitat from NonFishing Activities in the Northeastern United State, NOAA Technical Memorandum NMFS-NE-209.

National Oceanic and Atmospheric Administration (NOAA). March 2010. Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California; NMFS Technical Memorandum NMFS-NWFSC-105.

National Oceanic and Atmospheric Administration (NOAA). 2013. *Bringing the Olympia Oyster Home* (Coos Bay, Oregon), National Estuarine Research Reserve system Science Collaborative, www.nerrs.noaa.gov.

National Oceanic and Atmospheric Administration (NOAA). 2013. U.S. Pacific Marine Mammal Stock Assessments: 2012, NOAA Technical Memorandum: NOAA-TM-NMFS-SWFSC-504. NMFS, Southwest Fisheries Science Center.

Neave, F. 1961. Pacific salmon: ocean stocks and fishery developments. Pac. Sci. Congr. Proc. 1957(10):59-62.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727.

Newell, R.C., L.J. Seiderer and D.R. Hitchcock. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: an Annual Review 36: 127-178.

Northern Pacific Coast.University of Washington Press, United States.

Northwest Area Committee. (December 2004). Coos Bay, Oregon Geographic Response Plan (GRP).

Oberrecht, Kenn. No date. Salmon and Trout in Estuaries.South Slough National Estuarine Research Reserve. Viewed on 3-29-07 at http://www.oregon.gov/DSL/SSNERR/docs/EMIpubs/salmon.pdf

Oregon Biodiversity Information Center.(2010). *Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources*. Portland:Portland State University.

**---.** (October 19, 2012). data request results. NR:Portland State University.

Oregon Department of Agriculture. 2006. Noxious Weed Policy and Classification System. Oregon Department of Agriculture, Noxious Weed Control Program, Salem, OR.

Oregon Department of Environmental Quality (DEQ). 1978. STORET retrieval data. Unpub.water quality data.

Oregon Department of Fish and Wildife. 2006. Website: http://ftp.dfw.state.or.us/fish/commercial/landing_stats/2004/.

Oregon Department of Fish and Wildlife (ODFW). 1979. Habitat classification and inventory methods for the management of Oregon estuaries. Prepared by Research and Development Section ODFW for Oregon Land Conservation and development Commission.

Oregon Department of Fish and Wildlife (ODFW). 1979. Natural resources of Coos Bay estuary. Prepared by ODFW Research and Development Section for Oregon Land Conservation and Development Commission.Vol. 2, No. 6.

Oregon Department of Fish and Wildlife (ODFW).1998. Coos Basin creel survey-1998.ODFW Charleston, Oregon. Unpublished reports on file ODFW Charleston, OR.

Oregon Department of Fish and Wildlife (ODFW).1999. Coos Bay, Coos and Millicoma Rivers and Coquille River creel surveys-1999.ODFW Charleston, Oregon. Unpublished reports on file at ODFW Charleston, OR.

Oregon Department of Fish and Wildlife (ODFW). 2001. Oregon marine fisheries 2000 status report. Compiled by ODFW Marine Resources Program, Newport, Oregon. March.

Oregon Department of Fish and Wildlife (ODFW). 2002. Relationships Between Bank Treatment / Nearshore Development and Anadromous/ Resident Fish in the Lower Willamette River, Annual Progress Report, May 2000-June 2001.

Oregon Department of Fish and Wildlife (ODFW). 2003. Relationships Between Bank Treatment / Nearshore Development and Anadromous/ Resident Fish in the Lower Willamette River, Annual Progress Report, July 2001-June 2002.

Oregon Department of Fish and Wildlife (ODFW). 2005a. Oregon native fish status report 2005 public draft Volume I-species management unit summaries. ODFW, 3406 Cherry Avenue N.E., Salem Oregon 97303-4924.

Oregon Department of Fish and Wildlife (ODFW). 2005b. DRAFT Oregon's Nearshore Marine Resources Management Strategy. ODFW, Marine Resources Program, 2040 SE Marine Science Drive, Newport, Oregon 97365.

Oregon Department of Fish and Wildlife (ODFW). 2006. Comments submitted to Oregon Department of Energy on Resource Reports for the Jordon Cove Energy Project and for the Pacific Connector Gas Pipeline Project. September 8. Oregon Department of Energy, 625 Marion Street NE, Salem OR 97301-3737.

Oregon Department of Fish and Wildlife (ODFW). January 2006. Oregon's Nearshore Strategy. ODFW, Marine Resources Program, 2040 SE Marine Science Drive, Newport, Oregon 97365.

Oregon Department of Fish and Wildlife (ODFW). 2008. Background documents, Oregon Fish and Wildlife Commission, Marine Reserves Briefing, Newport, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2008/2009. Shellfish and Estuarine Assessment of Coastal Oregon (SEACOR) Study, Coos Bay, Oregon.

Oregon Department of Fish and Wildlife. 2012. Oregon Recreational Dungeness Crab Fishery, 2007-2011, Newport, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2013. Oregon Wolf Conservation and Management, 2012 Annual Report, Salem, Oregon.

Oregon Department of Parks and Recreation.2007. Whale Watching Center website.Viewed on 3/22/07 at http://www.whalespoken.org/OPRD/PARKS/WhaleWatchingCenter/watch_weeks.shtml Oregon Division of State Lands.Viewed on 3-27-07 at http://www.oregon.gov/DSL/SSNERR/interpcenter.shtml.

Oregon Division of State Lands (DSL). 2007. South Slough National Estuarine Research Reserve. Viewed on 3/22/07 at: http//www.oregon.gov/DSL/SSNERR/interpcenter.shtml.

Oregon Invasive Species Council.(Accessed 2012)."100 Most Dangerous Invaders to Keep Out." Accessed at: http://www.oregon.gov/oisc/Pages/most_dangerous.aspx

*Oregon Estuary Plan Book*. 1987. URL: www.inforain.org/mapsatwork/oregon estuary/.

Oregon Natural Heritage Program Information Center (June 2005). Data request results. NR: ORNHIC.

Oregon Ocean Resources Management Task Force. 1991. *The Oregon Ocean Plan*. 117 pp.

Oregon Secretary of State. (2011). "Oregon Revised Statutes (ORS 564)." Salem: OSS.

---. (October 15, 2012). "Administrative Rules, Department of Agriculture, Division 73**,** Plants: Wildflowers and Endangered, Threatened, and Candidate Species." Salem: OSS.

Oregon Plan for Salmon and Watershed. 2008. *Recovery of Wild Coho Salmon in Salmon Basin*, Report No. OPSW-ODFW-2009-10.

Oregon Wetlands Joint Venture. 1994. *Joint Venture Implementation Plans: Southern Oregon Coast*. From: http://www.ohjv.org/pdfs/southern_oregon_coast.pdf. Site accessed: April 3, 2006.

Pacific Fishery Management Council (PFMC). 1998a. Final environmental assessment/regulatory review for Amendment 11 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon, (October 1998). http://www.pcouncil.org/groundfish/gffmp/gfall.html

Pacific Fishery Management Council (PFMC). 1998b. Appendix D - description and identification of EFH for the coastal pelagic species FMP. Amendment 8 to the Coastal Pelagic Species FMP. December 1998. Pp. 26-38.

Pacific Fishery Management Council (PFMC). 1998c. Essential Fish Habitat - West Coast Groundfish. Modified from: Final EA/Regulatory Impact Review for Amendment 11 to the Pacific Coast Groundfish FMP. October 1998. Available: http://swr.ucsd.edu/hcd/grndfsh.pdf

Pacific Fishery Management Council (PFMC). 1999. Appendix A - identification and description of Essential Fish Habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. August 1999. Available: http://www.pcouncil.org/Salmon/a14efh/efhindex.html

Pacific Fishery Management Council (PFMC). 2001. Second draft - fishery management plan and environmental impact statement for U.S. West Coast-based fisheries for highly migratory species. May 2001. Available: http://www.pcouncil.org/HMS/2draftfmp/2fmpindex.html

Pacific States Marine Fisheries Commission (PSMFC). 1996. White sturgeon. Available: http://www.psmfc.org/habitat/edu_wsturg_fact.html

Parr, R.A. 1974. Harbor dredging and benthic fauna: a case study. M.S. thesis, Oregon State University, Corvallis, Oregon.114 pp.

Partnership for Coastal Watershed. 2013. Bird trends, Cape Arago Audubon Society Coos Bay Christmas Bird County.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco, 1997.Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries. Vol. II: Species life history summaries. ELMR Rep. No. 11.NOAA/NOS Strategic Environmental Assessment Div., Silver Spring, MD.377 p.

Pauly, G.B. Van Der Raay and D. Troutt. 1988. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Pacific oyster.

Pauly, G.B., D.A. Armstrong, R. Van Citter and G.L. Thomas. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Dungeness Crab.

Pearcy, W. G. 1962. Ecology of an estuarine population of winter flounder *Pseudopleuronectes americanus* (Walbaum). Bulletin of the Bingham Oceanographic Collection **18**:1-78.

Pearcy, W., and S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? Fishery Bulletin **72**:201-213.

Peddicord, R.K. and V.A. McFarland. 1978. *Effects of Suspended Dredged Material on Aquatic Animals.* U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, Technical Report D-78-29, 102 pp. + app.

Pennekamp, J.S. and M.P. Quaak. 1990. Impact on the environment of turbidity caused by dredging. Terra et Aqua, 42, pp.10-20.

Pennekamp, J.S., R.C. Eskamp, W.F. Rosenbrand, A. Mullie, G.L. Wessel, T. Arts and I.K. Decibel. 1996. Turbidity caused by dredging; viewed in perspective. Terra et Aqua, 64, pp.10-17.

Percy, K.L., D.A. Bella, C. Sutterlin and P.C. Klingeman. 1974. Description and information sources for Oregon estuaries. Sea Grant Coll. Prog., Oreg. State Univ., Corvallis.294 pp.

Perdue, J.A., J.H. Beattie and L.K. Chew. 1981. Some relationships between gametogenic cycle and summer mortality phenomenon in the Pacific Oyster (*Crassostrea gigas*) in WashingtonState. *J. Shellfish Res.* 1(1):9-16.

Pitcher, T.J. 1986. Functions of shoaling in teleosts. In Fisher, T.J. (ed.), The behavior of teleost fishes, p. 294-337. Johns Hopkins Univ. Press, Baltimore, MD.

Pojar, J. and A. MacKinnon, eds. (1994). Plants of the Pacific NorthwestCoast: Washington, Oregon, British Columbia & Alaska. Vancouver: Lone Pine Publishing.

Pyle, P. 1997. Identification Guide to North American Birds, Part 1. Slate Creek Press, Bolinas, CA. 732 pp.

Recht, F. 1999. Yaquina and AlseaBays are important salmon habitat. Pacific States Marine Commission, 205 SE Spokane Street, Suite 100, Portland, Oregon97202

Reimers, P.E. 1971. The movement of yearling coho salmon through Sixes River Estuary. Fish Comm. Oregon, Coastal Rivers Investigation Info. Rep. 71-2, 15 p.Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Reimers, P.E. and R.E. Loeffel. 1967. The length of residence of juvenile fall Chinook salmon in selected Columbia River tributaries. Fish Comm. Oreg. 13, 5-19 p.requirements of coastal fishes and invertebrates (Pacific Northwest): Olympia Oyster.

Rheault, R.B. 2002. Eelgrass is great, but shellfish aquaculture is better. Available at http://www.ecsga.org/libraryitems/eelgrass.htm

Rich, A.A. 1997. Testimony of Alice A. Rich, Ph.D., regarding water rights applications for the Delta Wetlands Project, proposed by Delta Wetlands Properties for Water Storage on Webb Tract, BaconIsland, BouldinIsland, and Holland Tract in Contra Costa and San JoaquinCounties. July.Calif. Dept. of Fish and Game Exhibit DFG-7. Submitted to State Water Resources Control Board.

Rich, W.H. 1920. Early history and seaward migration of Chinook salmon in the Columbia and SacramentoRivers. U.S. Bureau of Fisheries Bulletin 37:2-73.

Richardson, S. 1973. Abundance and distribution of larval fishes in waters off Oregon, May-October 1969, with special emphasis on the northern anchovy, *Engraulis mordax*. Fishery Bulletin **71**:697-711.

Richardson, S., and W. Pearcy. 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fishery Bulletin **75**:125-145.

Rien, T.A. and R.P. Beamesderfer. 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society 123:255-265, 1994.

Rien, T.A., L.C. Burner, R.A. Farr, M.D. Howell and J.A. North. 2001. Green sturgeon population characteristics in Oregon. Oregon Department of Fish and Wildlife 17330 Southeast Evelyn Street Clackamas, OR 97015. Project Number: F-178-R.

Rien, T.A., R.P. Beamesderfer and C.A. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks for white sturgeon. California Fish and Game 80:161-170.

Robinson, A.M. and W.P. Breese. 1982. The spawning season of four species of clams in Oregon. *J. Shellfish Res*. 2(1):55-57

Rodenkirk, T. In prep.Status and distribution of Bird Species of Coos County, Oregon.

Rosenkeeter, J., K. Dugi and C. Ide.1970. Coos Bay estuary report, Area A-1.Unpublished data, Oregon Institute of Marine Biology, University of Oregon, Charleston, Oregon.

Salo, E.O. 1991. Life history of chum salmon (*Oncorhynchus keta*) Pages 231-309 in Groot. C. and L. Margolis (eds.). 1991 Pacific salmon life histories.Vancouver, British Columbia.

Sandercock, F.K. 1991. Life history of coho salmon (Oncorhynchus kisutch). Pages 395-446 in Groot and Margolis (ed). Pacific Salmon Life Histories. UBC Press, Vancouver, Canada

Sanders, G. 1985. Summary of age, sex, run timing, and length-weight characteristics of Alaska steelhead, p. 29-49. In Alaska Dep. Fish Game, Alaska Steelhead Workshop 1985, unpubl. manuscr., 134 p. (Available from Environmental and Technical Services Division, National Marine Fisheries Service, 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)

Sayce, C.D. and D.F. Tufts. 1972. The effects of high water temperature on the razor clam, *Siliqua patula* (Dixon). *Proc. Natl. Shellfish. Assoc.* 62:31-34

Schlosser, S. and J. Bloeser. 2006. The collaborative study of juvenile rockfish, cabezon, and kelp greenling habitat associations between Morro Bay, California and Newport, Oregon. February. Final Report to: Pacific States Marine Fisheries Commission Summarizing data for 2003, 2004, and 2005.

Schreck, C.B., H.W. Li, R.C. Hjort and C.S. Sharpe. 1986. Stock identification of Columbia River Chinook salmon and steelhead trout. Final Report to Bonneville Power Administration, Contract DE-A179-83BP13499, Project 83-451, 184 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208).

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish.Res. Board Can. 966p.

Sedell, J.R. and J.L. Frogatt. 1984. Importance of streamside forests to large rivers – the isolation of the Willamette River, Oregon, USA, from its floodplain by snagging and streamside forest removal: International Vereinigung fuer Theoretische und Angewandte Limnologie Verhandlugen, v. 22, P. 1828-1834.

Sedell, J.R. and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.

Seymour, A.H. 1956. Effects of temperature upon young Chinook salmon. PhD dissertation, University of Washington, Seattle, Washington.

Seymour, A.H. 1956. Effects of temperature upon young Chinook salmon. PhD dissertation, University of Washington, Seattle, Washington.

Shapovalov L. and A.C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo Gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddel Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game, Fish Bull.98, 375 p.

SHN Consulting Engineers & Geologists, Inc. 2006a. Sediment sampling and analysis plan, Jordon Cove, Coos Bay, Oregon. SHN 365 N. 4th Street, Coos Bay, OR.

SHN Consulting Engineers & Geologists, Inc. 2006b. Botanical Resources Assessment Report, Jordan Cove Energy Project Coos County, Oregon. SHN 365 N. 4th Street, Coos bay, OR. March.

SHN Consulting Engineers & Geologists, Inc. (November 2012). Botanical Resources Assessment Report." Coos Bay:SHN.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. Pp. 343-364 in V.S. Kennedy (ed.) Estuarine Comparisons. Academic Press, New York. 709 pp.

Slotta, L.S., C.K. Sollitt, D.A. Bella, D.H. Hancock, J.E. McCauley and R. Parr. 1973. Effects of hopper dredging and in-channel spoiling in Coos Bay, Oregon. Oregon State University, Corvallis.147 pp.

Smith, P.E. 1985. Year class strength and survival of O-group clupeoids. *In* proceedings of the symposium on the biological characteristics of herring and their implications for management, pp 69-82. Ed. By J.R. Brett, Canadian Journal of Fisheries and Aquatic Sciences: 42(Suppl. I): 1-278.

Sorenson, D.L., M.M. McCarthy, E.J. Middlebrooks and D.B. Porcella. 1977. Suspended and dissolved solids effects on freshwater biota. EPA-600/3-77-042.U.S. Environmental Protection Agency, Corvallis, OR.

South Slough National Estuarine Research Reserve (NERR). South Slough NERR Management Plan (2006)

Steneck R.S., M.H. Graham, B.J. Bourque, D. Corbett, J.M. Erlandson, J.A. Estes and M.J. Tegner. 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation.

Stern, E.M. and W.B. Stickle. 1978. *Effects of Turbidity and Suspended Material in Aquatic Environments: Literature Review.* U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, Technical Report D-78-21, 117 pp.

Stevens, Thompson and Runyan, Inc. (STR). 1974. Coos-Curry environmental protection program: Vol 1-water resources management plan; Vol 2-Technical appendix. Coos-Curry Council of Governments.Coos Bay.

Strathmann, M.F. 1987. Reproduction and development of marine invertebrates of the

Strong, C. S., B. S. Keitt, W. R. McIver, C. J. Palmer, and I. Gafney. 1995. Distribution and population estimates of Marbled Murrelets at sea in Oregon during the summers of 1992 and 1993. Pp. 339-352 *in* Ecology and conservation of the Marbled Murrelet (C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, eds.). U.S. Dept. Agric., For.Serv. Gen. Tech. Rep. PSW-GTR-152.Albany, CA.

Sulkin, S.D. and G. McKeen. 1994. Influence of temperature on larval development of four co-occurring species of the Brachyuran genus *Cancer*. *Mar. Bio.* 118(4):593-600

Sumner, F.H. 1972. A contribution to the life history of the cutthroat trout in Oregon with emphasis on the coastal subspecies, *Salmo clarki clarki Richardson*. OregonState Game Comm., Corvallis, OR 142 p.

Taylor, E.B. 1990a. Environmental correlates of life-history variation in juvenile Chinook salmon, Oncorhynchus tshawytscha (Walbaum). J. Fish Biol. 37:1-17.

Taylor, E.B. 1990b. Phenotypic correlates of life-history variation in juvenile Chinook salmon Oncorhynchus tshawytscha. J. Anim. Ecol. 59:455-468.

Thayer, G.W., W.J. Kenworthy and M.S. Fonseca. 1984. The ecology of seagrass meadows of the AtlanticCoast: A community profile. U. S. Fish and Wildlife Service, FWS/OBS-84/02.147 pp.

Tibor, David, P., ed. (2001). *Inventory of Rare and Endangered Plants of California, 6th Edition; Special Publication No. 1*.Sacramento: California Native Plant Society.

Trotter, P.C. 1989. Coastal cutthroat trout: a life history compendium. Transactions of the American Fisheries Society 118: 463-473.

U. S. Coast Guard. 2012. Standards for Living Organisms in Ships Ballast Water Discharged in U.S. Waters – Federal Register (77 FR 17254)

U.S.Coast Guard. 2004. Coos Bay, Oregon Geographic Response Plan (GRP). Marine Safety Office Portland Planning Department 6767 N. Basin Ave.Portland, OR97217-3992.

U.S. Army Corps of Engineers (USACE). 1975. Coos Bay, Oregon, deep draft navigation project: environmental impact statement, draft supplement. Portland District.Vol.I and II.

U.S. Army Corps of Engineers (USACE).1998. Coos Bay sediment evaluation report. NR: NR.

U.S. Army Corps of Engineers (USACE).1999. Coos Bay sediment evaluation report. NR: NR.

U.S. Army Corps of Engineers (USACE).2005. Coos Bay sediment quality evaluation report. NR: NR. https//www.nwp.usace.army.mil/ec/h/hr/Reports/Coos_Bay/CoosBat-2004.pdf.

U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC). 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. USACE ERDC TN-DOER-E9.May.

U.S. Department of Agriculture (1995).“General Technical Report PSW-GTR-157. American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection.” Forest Service:Pacific Southwest Research Station.

U.S. Fish and Wildlife Service.(1973). *Federal Endangered Species Act of 1973*, as amended. NR: USFWS.

U.S. Fish and Wildlife Service (USFWS). 2004. Establishment of Two Experimental Populations of Wolf’s Evening Primrose, Final Report, USFWS Section 6 Grant No. OR-EP-2, Seg. 15.

U.S. Fish and Wildlife Service (USFWS). 2006. Letter to FERC regarding review of draft Resource Reports for the construction, operation, and maintenance of the Jordon Cove Energy Project (JCEP) liquefied natural gas (LNG) import terminal on the North Spit of Coos Bay, Oregon; (FERC Docket Nos. PF06-25-000 and PF06-26-000).FERC 888 First Street, N.E., Room 1A, Washington D.C. 20426.

U.S. Fish and Wildlife Service. 2005. Brown Pelican (*Pelecanus occidentalis*) Information viewed 11-2-2005 at http://ecos.fws.gov/docs/life_histories/B02L.html

U.S. Fish and Wildlife Service. 2007. Marbled Murrelet (Brachyramphus marmoratus marmoratus): Endangered Species Fact Sheet. Viewed on 3-23-2007 at http://www.fws.gov/oregonfwo/EndSpp/FactsBirds/MarMurlet.htm

U.S. Fish and Wildlife Service. 2007a. Oregon islands National Wildlife Refuge website. Viewed on 3-28-07 at http://www.fws.gov/refuges/profiles/index.cfm?id=13599)

U.S. Fish and Wildlife Service. 2007b. OregonCoast Wildlife Refuge Complex. Viewed on 3-29-07 at http://www.fws.gov/oregoncoast/wildlife.htm.

U.S. Fish andWildlife Service.(2007c) National Wetland Inventory website. Viewed on March 28, 2007 at http://www.fws.gov/nwi/ (1987)

U.S. Fish and wildlife Service. (2007d) National Bald Eagle Management Guidelines. 23pp. NR:USFWS.

United States Department of the Interior, Bureau of Land Management. 1994. *Coos Bay District Proposed Resource Management Plan Environmental Impact Statement Map Package.*

US Department of the Interior, Bureau of Land Management, Coos Bay District, Umpqua Field Office. 2005. *Coos Bay District Final North Spit Plan, An Update to the CoosBay Shorelands Plan of 1995.*

US Department of the Interior, Bureau of Land Management.(NR). “Table 3: Bureau Sensitive and Assessment Plant Species Documented (D) and Suspected (S) on the North Spit by Scientific Name, Common Name or Group, Presence, Status, and Habitat.” North Bend: BLM, Coos Bay District.

US Department of the Interior, Bureau of Land Management. 2005. Draft North Spit Plan. Coos Bay District, Umpqua Field Office.98 pp.

US Department of the Interior, Bureau of Land Management. 2007. National Landscape Conservation System. Viewed on March 27, 2007 at http://www.blm.gov/or/resources/nlcs/index.php

US Department of the Interior, Bureau of Land Management.March 2005a. Status Report: *Cordylanthus maritimus Bentham ssp. palustris (Behr) Chuang and Heckard (Point Reyes bird's-beak).*North Bend: BLM, Coos Bay District.

Vronskiy, B.B. 1972. Reproductive biology of the Kamchatka River Chinook salmon (*Oncorhychus tshawytscha* (Walbaum)). J. Ichthyol. 12:259-273.

Wagoner, L.J., K.K. Jones, R.E. Bender, J.A. Butler, D.E. Demory, T.F. Gaumer, J.A. Hurtado, W.G. Mullarky, P.E. Reimers, N.T. Richmond and T.J. Rumreich. 1990. Coos River fish management plan.Oregon Department of Fish and Wildlife.

Ward, D.L. (ed.). 1992. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Final Research Report.Oregon Department of Fish and Wildlife.Funded by Port of Portland.92 pp.

Ward, D.L. and A.A. Nigro. 1992. Differences in fish assemblages among habitats found in the lower Willamette River, Oregon: application of and problems with multivariate analysis. Fisheries Research. 13:119-132.

Ward, D.L. and R.A. Farr. 1989. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.16 pp.

Ward, D.L. and R.A. Farr. 1990. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.13 pp.

Ward, D.L. and R.A. Farr. 1991. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.12 pp.

Ward, D.L., A.A. Nigro, R.A. Farr and C.J. Knutsen. 1994. Influence of waterway development on migrational characteristics of juvenile salmonids in the lower Willamette River, Oregon. North American Journal of Fisheries Management 14: 362-371.

Ward, D.L., P.J. Connolly, R.A. Farr and A.A. Nigro. 1988. Feasibility of evaluating the impacts of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.58 pp.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D. J. Teel, R.G. Kope, and R.S. Waples. 1995. Status Review of Coho Salmon from Washington, Oregon, and California NOAA Technical Memorandum NMFS-NWFSC-24 September 1995. NOAA.

Wilsey and Ham. 1974. Estuarine resources of the OregonCoast. A natural resource inventory report to the Oregon Coastal Conservation and Development Commission.233 pp.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific coast of North America. J. Fish. Res. Board Can. 23(3):365-393.

Wood , E.F., W.E. Odum, and J.C. Zieman. 1969. Influence of sea grasses on the productivity of coastal lagoons. pp. 495-502. *In*, A. Ayala Castanares and F. B. Phleger, Eds.

*Coastal Lagoons*.Universidad Nacional Autonoma de Mexico, Ciudad Universitaria, Mexico, D. F.

TABLES

# FIGURES

# APPENDIX A.3
## Correspondence

# APPENDIX B.3

## Botanical Resources Assessment Report
## Jordan Cove Energy Project
## Coos County, Oregon

# APPENDIX C.3

## 2005-2006 Pre-Construction Wildlife Surveys for Proposed Jordan Cove Liquefied Natural Gas Plant, Coos Bay, Oregon

# APPENDIX D.3

## Wildlife Assessment and Survey Report, Jordan Cove Energy Project, Coos Bay, Oregon

# APPENDIX E.3

## Jordan Cove Fisheries Report
## October 2006

# APPENDIX F.3

## Report on Zooplankton Sampling Adjacent to the Proposed Jordan Cover LNG Terminal

## Oregon Institute of Marine Biology Survey Report
January 2011

APPENDIX G.3

Noxious Weed Policy and Classification System (ODA)
2013

APPENDIX H.3

Oregon Invasive Species Council Action Plan
2012-2016

# APPENDIX I.3

## USFWS Final Snowy Plover Recovery Plan
## 2007

# Status review update of Southern Resident killer whales

Michael J. Ford

Conservation Biology Division
Northwest Fisheries Science Center
National Marine Fisheries Service

July 31, 2013

*We are much more interested in conserving actual morphological, ecological and genetic diversity than in structuring conservation around a nebulous taxonomic level about which, in the past, there has been so much disagreement – Mallet 1995*

## Acknowledgements

Phil Morin, Barb Taylor, Robin Waples, Marilyn Dalhleim, Lynne Barre, Candice Emmons Robyn Angliss and Brad Hanson provided valuable comments on an earlier draft of this report. Kristy Long provided the summary of public comments.

## Introduction

On August 2, 2012, the National Marine Fisheries Service received a petition submitted by the Pacific Legal Foundation on behalf of the Center for Environmental Science Accuracy and Reliability, Empresas DelBosque, and Coburn Ranch to delist the endangered Southern Resident killer whale (SRKW) distinct population segment (DPS) under the Endangered Species Act (ESA). On November 28, 2012, NMFS published a 90-day finding (77 FR 70773) that the petition presented substantial scientific information indicating that the petitioned action may be warranted and that NMFS would initiate a status review. The petition focused specifically on issues of taxonomy and whether the SRKW constituted a DPS, and NMFS therefore determined that the status review would also focus on these issues rather than on the extinction risk status of the SRKW more broadly.

On March 21, 2013, after a public comment period on the 90-day finding, the NMFS Northwest Region requested that the Northwest Fisheries Science Center conduct a scientific review and evaluation of the petition, the key scientific papers cited in the petition, the biological information received from the public, and any other best available relevant information. Specifically, the Northwest Region requested the Center to consider if there is new best available information that would lead to different conclusions from those of the 2004 BRT (Krahn *et al.* 2004) regarding the existence of a North Pacific resident killer whale taxon (species or subspecies) or the discreteness or significance of the SRKW with reference to this taxon. This report is intended to address the Northwest Region's request.

## Summary of taxonomic issues addressed by the 2004 BRT

In evaluating the status of the southern resident killer whales (SRKW), the previous NMFS biological review teams (BRTs) had to explicitly address the issue of the uncertain taxonomy of the killer whale. These issues are discussed extensively in the BRT reports (Krahn *et al.* 2004; Krahn *et al.* 2002) and in the report of the NMFS Workshop on Cetacean Taxonomy (Reeves *et al.* 2004). Briefly, at the time of the first SRKW status review (Krahn *et al.* 2002), the most recently published taxonomy of killer whales placed them in a single polytypic species, *Orcinus orca*, as described by Linnaeus in 1758 (Heyning *et al.* 1988; Rice 1998). However, the 2002 BRT report stated that killer whale taxonomy was uncertain and that several authors had recently proposed new *Orcinus* species on the basis of morphological variation and potential reproductive isolation among ecologically distinct populations of killer whales in Antarctica (Berzin *et al.* 1983; Mikhalev *et al.* 1981) and the North Pacific (Baird 2000). Even general reviews of *O. orca* taxonomy, while ultimately concluding that *O. orca* should probably be considered a single species, also emphasized the uncertain taxonomy. For example, Heyning and Dahlheim (1988, p.

5, emphasis added) noted that "The genus *Orcinus currently* is considered monotypic by most authorities with geographic variation noted in size and color pattern, but *a worldwide systematic review is needed*" and "Until more substantial data are presented, a *conservative* view of recognizing only one highly variable species *probably* is warranted."

Faced with this taxonomic uncertainty, the 2002 BRT evaluated a wide variety of potential taxonomic scenarios and considered the DPS status of SRKW within hypothesized taxa (see Table 8 in Krahn *et al.* 2002). Ultimately, the BRT remained uncertain about both the global taxonomy of killer whales and whether or not the SRKW met the criteria to be considered a DPS, and faced with this uncertainty NMFS concluded that listing the SRKW under the ESA was not warranted. The agency noted the taxonomic uncertainty described by the BRT, and as a result indicated it would reassess its decision after a reconsideration of killer whale taxonomy (NMFS 2002).

Subsequent to the 2002 "not warranted" finding, in 2004 NMFS initiated another status review in response to a finding by a U.S. District Court that in using a possibly outdated taxonomy, NMFS failed to make use of the best data available. In addition to initiating a new status review, NMFS also held a cetacean taxonomy workshop that, in part, reviewed and summarized information relating to the uncertainties surrounding killer whale taxonomy (Reeves *et al.* 2004). Based on the findings of the workshop and new genetic data analyzed after the 2002 status review, the 2004 BRT concluded that the North Pacific resident killer whales satisfied Reeve's *et al.* (2004) criteria for being a subspecies (Krahn *et al.* 2004, p. 41). Specifically, the BRT cited studies noting differences between the resident and transient ecotypes in external morphology, reproductive isolation in sympatry, foraging behavior and diet; acoustic dialects and vocal behavior, and mtDNA and nuclear genetic characteristics (see Krahn *et al.* 2002; 2004). The 2004 BRT further concluded that the SRKW population met the USFWS & NMFS (1996) criteria for being a DPS of the North Pacific resident subspecies, citing differences between the SRKW and other resident populations in ecological setting, range, genetic variation, and behavioral and cultural traits (Krahn *et al.* 2004). The BRT emphasized, however, that there was some scientific uncertainty related to both the taxonomic and DPS conclusions.

## Summary of the substantive points made in the petition

After a brief summary of killer whale natural history, the petition notes that there are varying scientific opinions regarding the definition of species, and that the definitions of sub-species and other intraspecific terms such as Distinct Population Segments (DPS) are subject to even greater uncertainty and scientific debate. The petition notes that splitting taxa ever more finely does not necessarily result in conservation benefits and may result in a false perception of risk.

The petition then briefly summarizes the current *Orcinus* taxonomy, followed by a more extensive summary of the Workshop on Cetacean Taxonomy convened by

NMFS in 2004 (Reeves *et al.* 2004). After summarizing some of the conclusions in the workshop report, the petition concludes that the workshop participants were unable to identify additional species within the currently recognized species *O. orca*. The petition further indicates that in the petitioners' opinion NMFS contradicted the workshop's recommendations when it concluded that the North Pacific fish-eating ('resident') killer whales are a subspecies of *O. orca*, and that the southern resident population is a DPS of this subspecies.

The petition follows with considerable discussion questioning whether the ESA allows for identification of DPS within subspecies, a legal question beyond the scope of this biological review.

Finally, the petition reviews some published studies related to the question of whether the North Pacific resident killer whales meet the criteria for subspecies designation, focusing on the lack of a Latin trinomial name for the proposed subspecies, and the genetic, morphological or ecological evidence as it relates to the question of subspecies status. The review focuses considerable attention (nearly six pages) on a recent genetic study by Pilot *et al.* (2010), arguing that the study provides clear evidence that the putative North Pacific resident killer whale subspecies is not genetically isolated from other killer whale populations. The petition concludes by reviewing some of the morphological, behavioral, and ecological differences among the North Pacific killer whale ecotypes, arguing that these are likely to be largely learned behaviors and therefore not important to consider when identifying subspecies or conservation units. See the Appendix for a detailed review of the biological arguments made in the petition.

## Summary of public comments

The public comment period on the 90-day finding closed on January 28, 2013. The Northwest Region received over 2,750 comments. Despite the request for specific scientific and commercial information, the vast majority of commenters simply noted their opposition to the petition to delist SRKWs, while a handful of comments supported the petition. The Northwest Region did, however, receive several substantive comments regarding both the biological and legal aspects of the DPS determination as raised in the petition. The substantive points raised in the comments are briefly summarized in Table 1.

**Table 1 -- Summary of Substantive Public Comments Received on Pacific Legal Foundation (PLF) 2012 Petition to Delist Southern Resident Killer Whale (SRKW) Distinct Population Segment (DPS).**

| Organization/ Commenter | Summary of comments |
|---|---|
| Marine Mammal Commission (MMC) | • Disagrees that the petition may be warranted; recommends reversing 90-day finding and devoting resources to higher priorities<br>• Listing SRKW as a DPS of a subspecies is appropriate, using 2nd prong of Chevron analysis (*Chevron USA v. Natural Resources Defense Council*) as applied to the definition of a DPS<br>• Recommends that consistent with NMFS precedent and applicable case law, NMFS interpret ESA definition of "species" to include DPSs of both species and subspecies<br>• Research has identified multiple, geographically distinct populations of killer whales that have unique behavioral and ecological traits<br>• MMC believes PLF's arguments related to Pilot *et al.* 2010 are incorrect and inconsistent; references several new papers on genetics and speciation<br>• Pilot *et al.* 2010 findings are not sufficient to refute treatment of North Pacific residents as a putative subspecies or the designation of SRKWs as a DPS<br>• Pilot *et al.* 2010 does not provide conclusive evidence of recent mating between SRKWs and other resident populations or between resident killer whales and any other regional ecotype; used unusually liberal criteria to assign parentage based on genetic data<br>• Parsons *et al.* in review found that "estimates of genetic distance between two predominant North Pacific ecotypes [resident and transient] indicate negligible levels of gene flow." |
| Humane Society of the United States | • Opposes further consideration of the petition as it does not present substantial scientific information that the listing is no longer warranted; population is appropriately listed as endangered<br>• Disagrees with the petitioners that SRKWs are an unlistable entity under the ESA<br>• Basing conclusion that the population is not a subspecies on limited male-mediated gene flow between populations from Pilot *et al.* 2010 ignores more recent work by Ford *et al.* 2011 that detected no gene flow among populations |
| Center for Biological Diversity | • Petition fails to present substantial information that SRKWs are not a DPS; does not comport with ESA's plain language, ignores NMFS policy, and disregards scientific record that indicates significant speciation of the global taxon<br>• ESA allows NMFS to designate a DPS of a subspecies; if ESA were ambiguous, NMFS' DPS policy allows designation of a subspecies and deserves deference; case law cited by petitioners does not support their claim<br>• Data and information support speciation for North Pacific and SRKW populations such as genetic data; morphological data, including body size; behavioral variation including vocalization, food preference, and social organization |
| Animal Legal Defense Fund (ALDF) | • Opposes delisting petition on legal as well as scientific bases<br>• Petition mischaracterizes Pilot *et al.* 2010 and Morin *et al.* 2010 and took conclusions out of context<br>• Petitioners legal argument is inconsistent with case law and statutory interpretation |

| | |
|---|---|
| | • ALDF counters the three primary assumptions in the petition – (1) ESA does not require formal taxonomic recognition, (2) Pilot *et al.* 2010 does not contradict a subspecies designation, (3) Morin *et al.* 2010 unequivocally urges a subspecies designation<br>• ALDF also organized a comment campaign, we received hundreds of individual comments opposing the delisting |
| Rus Hoelzel | • Clarifies Pilot *et al.* 2010 conclusions<br>• Does not believe a subspecies must be defined before designating a DPS; see examples in Fallon *et al.* 2007 using genetic markers to designate DPSs where a subspecies has not been designated<br>• Notes that gene flow is allowed when determining discreteness<br>• Notes the petition does not address significance<br>• Supports current DPS listing |
| The Whale Museum | • Opposes delisting petition; supports 2004 status review and listing<br>• Pilot *et al.* 2010 do not reference cross ecotype mating involving SRKWs; Barrett-Lennard *et al.* 2000 supports reproductive isolation too<br>• SRKW DPS is both discrete and significant |
| Orca Conservancy | • Opposes delisting petition<br>• MMPA does not provide adequate protection for SRKWs; ESA allows protection from indirect threats, requires section 7 consultations and permits, allows more citizen oversight and recourse<br>• Morin *et al.* 2010 is more reliable than Pilot *et al.* 2010 because it relies on more base pairs and more microsatellites, which contradict conclusion of interbreeding in modern times |
| Northwest Environmental Defense Center | • Petition is inconsistent with science, court decisions on the prior listing, and the ESA.<br>• Economic concerns listed in the petition cannot be considered and would not be resolved even with delisting<br>• NMFS is within its statutory authority to list SRKW DPS<br>• Current science supports and requires the continued protection of SRKW DPS – pinnipeds can tell residents apart from transients based on acoustics; SRKWs are a demographically closed population; best available science has not changed much since 2005<br>• MMPA protections alone are insufficient to protect and recover – procedural issues (jeopardy and adverse mod), takings, and legal tools in ESA |
| Miami Seaquarium | • Agrees with petitioner that SRKW DPS is not a listable entity; ESA does not authorize listing a DPS of a subspecies; North Pacific subspecies itself is a "nonexistent and scientifically unjustifiable" listing unit<br>• "Taxonomic inflation" is occurring – unjustified elevation of subspecies to species and populations to subspecies or DPSs<br>• 2005 listing of SRKW DPS as endangered resulted in collateral issues including impacts on CA farmers and whether to include Lolita in the listing. Notes that PLF filed its petition to delist SRKW DPS "long before" PETA/ALDF filed their petition to add Lolita to the SRKW DPS. NMFS should carefully and promptly consider the PLF petition, which if granted would negate the need to consider these collateral issues. |
| Animal Welfare Institute, CBD, Center for Whale Research, EarthJustice, | • Petition is based on a narrow and incorrect construction of ESA and the best scientific and commercial data available; incorrect legal arguments and one-sided interpretation of science; do not, and cannot, address or demonstrate that status has improved or threats have been reduced<br>• ESA defines "species" broadly; authorizes listing a DPS of a subspecies - |

| | |
|---|---|
| Friends of the Earth, Friends of the San Juans, International Marine Mammal Project of Earth Island Institute, Marine Mammal Connection Society, NRDC, Oceana, Orca Network, Dr. David Bain, Will Anderson, Dr. Samuel Wasser | Congress did not intend DPSs to be constrained by taxonomy; designating DPSs of subspecies is consistent with longstanding agency interpretations<br>• PLF arguments lack merit; the justification included does not support those arguments<br>• Focus on genetics and interbreeding is misplaced as genetic data is not the sole evidence for determining "markedly separate" populations<br>• Significant scientific evidence supports designation of SRKW population as a DPS – physical separation from other KW populations; morphological data, including body size, supports speciation of NP and SRKW populations; and behavioral variation, including vocalization, food preference, and social organization meet DPS criteria<br>• SRKWs meet the ESA listing criteria – EarthJustice provides a five factor analysis |
| Whale and Dolphin Conservation | • Opposes petition; threats continue and delisting is not appropriate<br>• Notes the ESA definition of "species" and NMFS' interpretation unambiguously refute PLF's legal argument as has been the case with their recent attempts to challenge other ESA listings<br>• Notes that the DPS policy does not prohibit listing if occasional gene flow occurs beyond the listed population; Pilot *et al.*'s main conclusion from their data emphasized social cohesion of killer whales to produce genetic differences between populations despite capacity for dispersal outside their groups. |
| Change.org – Bruce Gorcyzcki | • J, K, and L pods don't associate or interbreed with other ecotypes in the North Pacific<br>• SRKWs have been determined as a discrete population with their own social groupings, dialect and behaviors<br>• SRKWs' absence from the ecosystem would upset the balance |
| Individual – Ruth Muzzin | • Petition should be denied as it does not present new information, such as population numbers, and does not demonstrate that the DPS has recovered or become extinct; none of the delisting criteria are met<br>• NMFS has listed a DPS of a subspecies previously – e.g., ringed seals, bearded seals, and Atlantic sturgeon |
| Individual – David Bain | • Describes characteristics of "newer" and "older" species in an evolutionary sense with respect to reproductive isolation, morphology (dorsal fin and jaw sizes), and geographic isolation<br>• Transients are older species and distinct in all ways species are expected to differ<br>• Residents and offshore have reached a plateau, but additional differentiation would be expected over evolutionary time, though reproductive isolation is occurring; overlap in color patters and range; SRKWs appear the only group of residents to use the CA current system thereby giving them a slightly different ecological niche.<br>• Morin *et al.* 2010 found the evidence of interbreeding in Pilot *et al.* 2010 was an artifact attributable to incomplete DNA sequencing<br>• SRKWs should be considered a subspecies and are eligible for ESA listing regardless of whether a DPS of a subspecies is eligible. Endangered status should be retained. |
| Individual – Sharon Grace | • Petition is without merit<br>• Commenter references many threats and effects on population abundance and social structure<br>• Notes Pilot *et al.* 2010 examples are not SRKWs; some inbreeding is okay for DPS designation |

| | |
|---|---|
| Individual – Jodi Smith | • Morin *et al.* 2010 confirms that genes are slow to change over time, making differentiation difficult even though it happens<br>• In addition to genetic isolation, SRKWs are distinct based on social organization, dietary preference, and behavior. Recent evidence from a review of Southern Hemisphere killer whale populations is likely to conclude distinction as well (de Bruyn *et al.* 2013)<br>• Delisting SRKWs will not alleviate water restrictions for CA farmers as many other threats exist for CA spawning salmon |

## Taxonomic issues, general principles

The petition states that it is motivated in part by a general concern about "taxonomic inflation", or the tendency to increasingly split taxa into smaller subunits based on minor differences between putative taxa (petition p. 11). The petition notes that this can be a problem even at the species level, but seems particularly concerned with the incorrect identification of subspecies, due in part to a lack of consistent and rigorous subspecies definitions in the scientific literature (petition, p. 11).

The petition is correct in its conclusion that taxonomic uncertainty is a practical and conceptual problem for implementing conservation policy, particularly under laws such as the Endangered Species Act that rely on designation of particular species or intraspecific groups of organisms for special protections. Even the definition of a species is subject to ongoing scientific debate, with dozens of species concepts circulating in the scientific literature and debate about whether species are 'real' entities or simply categories invented for human convenience (Hey *et al.* 2003; Mallet 1995). As the petition notes, subspecies concepts have been subject to less intensive theoretical treatment than have species, but even so there are numerous definitions of subspecies in the scientific literature (reviewed by Haig *et al.* 2006). Other definitions of intraspecific groupings, such as Evolutionarily Significant Units (e.g., Crandall *et al.* 2000; Moritz 1994; Waples 1991), Distinct Population Segments (DPS; USFWS *et al.* 1996), and stocks (Dizon *et al.* 1992; McElhany *et al.* 2000) have also been the subject of considerable scientific debate and controversy ( reviewed by Ford 2003; Fraser *et al.* 2001).

The petition focuses considerable attention on the societal costs associated with designating insufficiently discrete taxa, but does not discuss the converse conservation problem of failing to identify discrete taxa when they exist. Failure to identify species, subspecies or other intraspecific varieties when they do in fact exist has clear conservation costs, mostly notably the potential loss of such unique groups through failure to protect them. This problem has been extensively discussed in the scientific literature, and has provided the motivation for several explicit definitions of both subspecies and ESUs (Avise *et al.* 1990; Crandall *et al.* 2000). The potential for outdated or incorrect taxonomy, particularly at the subspecies level, has been a motivation for more explicit subspecies definitions and suggestions to review outdated taxonomic designations (Haig *et al.* 2006). For example, with regard to designation of cetacean species and subspecies, Reeves *et al.* (2004) noted that

> *There has been a tendency to err in the direction of avoiding designating too many taxa rather than making sure that all potentially recognized taxa have been designated. In other words, the direction of precaution toward stability in traditional taxonomy has not been appropriate for conservation.*

and

> *Cetacean taxonomy in the latter half of the 20th century was conservative in part as an over-reaction to the excessive splitting that occurred during the 19th century.* (p. 30)

In other words, at least in Reeves *et al.*'s view, the currently accepted cetacean taxonomy tends to err on the side of lumping discrete taxa together rather than splitting them apart. To facilitate accurate designation of new cetacean taxa, particularly at the subspecies level, Reeve's *et al.* recommended the following definition of subspecies:

> *In addition to the use of morphology to define subspecies, the subspecies concept should be understood to embrace groups of organisms that appear to have been on independent evolutionary trajectories (with minor continuing gene flow), as demonstrated by morphological evidence or at least one line of appropriate genetic evidence. Geographical or behavioral differences can complement morphological and genetic evidence for establishing subspecies. As such, subspecies could be geographical forms or incipient species.* (p. 7).

Based on the discussion above, the problem of how to deal with taxonomic uncertainty in applying laws such as the ESA is not a new issue. Neither are concerns about wasting resources or causing economic harm through listing of inappropriately designated taxa. For example, the issue of balancing the competing tensions of conserving genetic resources but doing so when only biologically warranted was a motivating factor in the development of both the NMFS ESU concept (Waples 1991) and the joint USFWS & NMFS DPS policy (USFWS *et al.* 1996). It is beyond the scope of this review to attempt to resolve all of the bigger picture issues surrounding the intersection of taxonomy and conservation status. In developing and applying its policy on DPS, however, NMFS did explicitly consider the need to identify conservation units under the ESA at an appropriate scale.

## New information since 2004

In this section we briefly summarize information relevant to both the taxonomic and DPS questions that has been published in the scientific literature since the 2004 status review.

### Morphology and color variation

The only published quantitative analysis of variation in pigmentation patterns in North Pacific killer whales remains that of Baird and Stacey (1988), which found significant differences between residents and transients and among resident populations in the frequencies of alternative saddle patch patterns. Several authors (Baird 2000; Dahlheim *et al.* 2008; Ford *et al.* 2000 ) have also described qualitative differences in morphology among the three Pacific ecotypes. All of these studies except for Dahlheim *et al.* (2008) were considered by the 2004 BRT in their status review report.

While not describing morphological variation *per se*, a study by Zerbini *et al.* (2007) demonstrated that the ecotypes can be unambiguously distinguished based on visual appearance of dorsal fin shape and saddle patch pigmentation. In that study, ecotype determination of unknown groups of whales was made independently by both visual examination of photographs and genetic analysis of the mtDNA control region. In all 32 cases where both photographs and genetic data were available, the ecotype designation based on the photographs matched that based on the mtDNA control region.

Since 2004, there have been multiple studies published on morphological and ecological variation among Antarctic killer whales, confirming and extending the more preliminary information that was available to the 2004 BRT. Pitman and Ensor (2003) describe field observations and descriptions of three distinct types of Antarctic killer whale (designated A, B, and C) differentiated by size, pigmentation, habitat and apparent prey preferences. The C type appeared to correspond to *O. glacialis*, a dwarf form of killer whale previous described by Berzin and Vladimirov (1983) but not generally accepted as a distinct species due to small sample size and lack of a type specimen (Heyning *et al.* 1988). Pitman *et al.* (2007) used aerial photographs to quantify the length distribution of a sample of 221 Type C whales, and confirmed this type as smaller than the Type A whales. Based on historical and contemporary photographs, Pitman *et al.* (2011) described a new “Type D” killer whale characterized by a very small eye patch and somewhat bulbous head and inhabiting the Southern Ocean between 40 and 60 degree south. More recently, Olsen *et al.* (2012) observed groups of east Antarctic killer whales that were intermediate in some morphological characters between types B and C.

### Feeding ecology and diet

Since the 2004 BRT report, several additional studies have been published on the diet and feeding ecology of North Pacific killer whales. Herman *et al.* (2005 ) and Krahn *et al.* (2007) examined variation in organic contaminants and fatty acid composition of blubber biopsy samples and carbon and nitrogen stable isotope ratios in dermal samples from 169 samples (between the two studies), obtained primarily from the Gulf of Alaska and the Aleutian Islands but including some samples from Puget Sound and the U.S. west coast. All three ecotypes were represented, although the number of offshore samples was small (4 in the 2005 study and 9 in the 2007 study). The studies found significant variation among the three ecotypes in fatty acid profiles and contaminant burdens and ratios, likely reflective of different diets and foraging locations (Figure 1). Nitrogen stable isotope ratios also differed significantly between transients and residents, with transients having more enriched $^{15}$N levels consistent with a marine mammal diet. Offshores had nitrogen ratios that were between residents and transients, and not significantly different from either. Alaskan residents sampled from different areas also varied considerably in both nitrogen and carbon stable isotope profiles, presumably reflecting differences in foraging location and/or prey types.

Ford and Ellis (2006) and Hanson *et al.* (2010) conducted field observations of resident killer whale predation combined with genetic analysis of prey remains and field collected fecal samples to evaluate resident killer whale diets in the Salish Sea. Both studies observed predation of only fish, and analysis of prey remains and fecal DNA indicated a summer diet dominated by Chinook salmon (*Oncorhynchus tshawytscha*). Dahlheim and White (2010) describe foraging behavior and prey preferences for Alaskan transient killer whales. Killer whale diet information, including considerable unpublished data, was further reviewed by an independent science panel in 2012 (Hilborn *et al.* 2012; NMFS 2013).

In the Antarctic, Pitman and Durban (2012) described a field study of foraging behavior of Type B killer whales, documenting predation of primarily Weddell seals (*Leptonychotes weddellii*) using a cooperative hunting behavior that involved washing the seals off of ice flows. Olsen *et al.* (2012) described Type A and B killer whales in a common feeding aggregation. Foote *et al.* (2009) describe variation in stable isotope ratios and tooth wear potentially indicative of two killer whale foraging types in the North Atlantic.

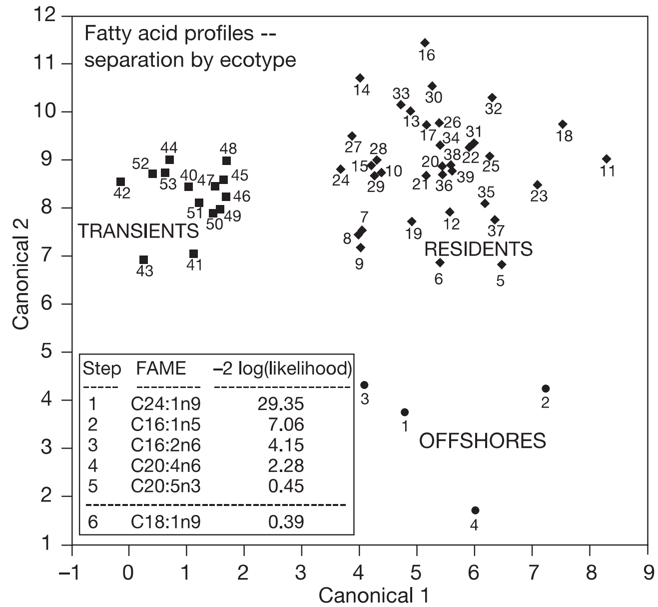



**Figure 1 -- Orcinus orca. First 2 discriminant functions showing separation of killer whale ecotypes based on fatty acid profiles of the blubber biopsies. Reproduced from Herman *et al.* (2005).**

Deecke *et al.* (2005) found significant differences in the acoustic behavior of transients and residents during foraging events, with transients calling significantly less frequently than residents. The difference appears to be related to hearing abilities of their preferred prey; marine mammals have excellent hearing in the frequency range of the killer whale calls while fish do not. These results are consistent with earlier work (Deecke *et al.* 2002) demonstrating that harbor seals displayed predator avoidance behavior during playback experiments using transient calls but not during experiments using resident calls. Deecke *et al.* (2011) and Beck *et al.* (2011) found differences in group size and acoustic behavior between seal-eating and fish-eating killer whales in the North Atlantic. Based on the phylogenetic relationships between the Atlantic and Pacific populations (Foote *et al.* 2011b; Morin *et al.* 2010), Beck *et al.* (2011) concluded that such foraging specialization and associated behaviors must have arisen independently in both oceans and be fairly plastic traits. Dahlheim *et al.* (2008) describe foraging behavior of offshore killer whales including highly worn teeth suggesting feeding on abrasive prey such as sharks. Ford *et al.* (2011a) collected prey samples from offshore killer whales and identified the prey as Pacific sleeper sharks (*Somniosus pacificus*). On a research cruise off the Oregon and Washington coasts in spring of 2013, an offshore whale was observed foraging on Chinook salmon (NWFWC unpublished data).

## Genetics

The genetic information available at the time of the 2004 status review consisted of several studies focusing on variation in the mtDNA control region and at multiple nuclear microsatellite loci (see tables 1 and 2 of Krahn *et al*. 2004). Two studies, both in the form of preliminary reports, were cited as being particularly influential due to their large sample sizes: a global study of 211 killer whales analyzed at 17 microsatellite loci (Hoelzel 2004), and a similar study of 219 whales sequenced at the mtDNA control region (LeDuc *et al.* 2004). Both studies produced a somewhat inconclusive picture of population structure, as summarized by Krahn *et al.* (2004, p. 15-16):

> *The understanding of killer whale population genetic structure has expanded considerably since the 2002 status review. In particular, the mtDNA differentiation among eastern North Pacific resident, transient, and offshore populations can now be seen in the context of variation worldwide. The most notable result from the new mtDNA data is the lack of strong mtDNA structure worldwide, suggesting that the current distribution of killer whales populations may be relatively young on an evolutionary scale (e.g., several hundred thousand years compared to the ≈5 million year old age of the Orcinus genus [Waples and Clapham 2004]) and possibly associated with a population bottleneck followed by a worldwide expansion. With respect to identifying conservation units, one of the implications of the new data is that the relative degree of mtDNA divergence among populations is not necessarily a good predictor of the length of time that the populations have evolved independently. For example, killer whales with the same haplotype as in Southern Residents have also been found in Alaska, Russia, Newfoundland, and the United Kingdom (Figure 2). Evolutionarily, these whales with the southern resident haplotype are almost certainly more closely related to other geographically proximate populations than to each other (a hypothesis supported by the microsatellite data, Table 3) and therefore, share a mtDNA haplotype purely by chance. Because of this finding, it would be inappropriate to rely heavily on simple mtDNA divergence as a criterion for identifying conservation units, especially on a global scale. On a local scale, however, mtDNA clearly remains useful for helping to identify populations, especially when combined with other types of information.*
>
> *In addition to more mtDNA data, the amount of nuclear microsatellite data has expanded greatly in the last 2 years, both in terms of whales and loci analyzed. Within the eastern North Pacific, both the mtDNA and microsatellite data remain consistent with a hypothesis of four to five resident populations, at least two to three transient populations and at least one offshore population (Figure 1). The issue of whether any contemporary gene flow occurs among eastern North Pacific populations remains unresolved, but the microsatellite data are consistent with either low levels of gene flow (at most a few mating events among populations per generation) or divergence times of at least several hundred to several thousand years (M. Ford 2004, Hoelzel 2004). Despite some uncertainty about the evolutionary history that produced the current patterns of variation, both the mtDNA and the microsatellite data indicate a high degree*

*of contemporary reproductive isolation among eastern North Pacific killer whale populations.*

As we discuss below, our understanding of global killer whale population structure has improved considerably since 2004, although some uncertainties remain.

We identified 10 studies of the genetic population structure of killer whales that have been published since the 2004 status review (Table 2). Three of these – Hoelzel *et al.* (2007), LeDuc *et al.* (2008), and Pilot *et al.* (2010) – are expanded and published versions of the preliminary reports considered by the 2004 BRT (Hoelzel 2004, LeDuc and Taylor 2004).

Hoelzel *et al.* (2007) analyzed 203 killer whales sampled from the North Pacific (including samples of the resident, transient and offshore ecotypes) and Iceland at 16 microsatellite loci and the mtDNA control region (~1000 bp). Similar to preliminary results reported to the 2004 BRT (Hoelzel 2004), they found significant differentiation among all groups of samples but estimated that rates of gene flow among most groups, including between ecotypes, was significantly greater than zero. Among North Pacific resident groups, they found that genetic differentiation at microsatellite loci was proportional to geographic distance between the groups. The most geographically distant resident groups had similar levels of genetic divergence to that between the residents and the transients. Using genetic assignment tests, they identified 5 putative migrant individuals, but none between residents and transients. In fitting a model of divergence with migration, they estimated low but non-zero (< 1 migrant/generation) rates of gene flow between residents and transients, and between the Alaskan resident and Icelandic groups. From the same type of analysis, they estimated that the divergence time between residents and transients was 4000 – 36,000 years ago, depending on mutation rate assumptions, and hypothesized that most if not all of the population structure observed evolved after the most recent glacial maximum.

Using the same data, Pilot *et al.* (2010) expanded upon Hoelzel *et al.*'s (2007) results by conducting a parentage analysis within and among populations in order to directly estimate contemporary gene flow. The study also extended the assignment test analyses of Hoelzel *et al.* (2010) using two additional methods. Out of 213 samples, they found a total of 3 putative first generation migrants (individuals sampled from a population but with a genetic profile more similar to a different population), and 8 putative second generation migrants (individuals inferred to be the offspring of a first generation migrant). Of these 11 putative migrants, 8 were within the same ecotype (exchanges between California and Alaska transients, or between Alaskan and Russian residents), 2 were between transients and the Icelandic group (both second generation), and 1 was between transients and offshores (second generation). Using a model fitting approach, rates of gene flow between residents and transients and from the offshores into residents and transients were estimated to be <1% per generation. Rates of gene flow from both residents and transients into the offshore group were estimated to 2.2 – 3.6%. Gene flow rates between resident populations were estimated to be 0.5% - 2.4%, except for the rates between Russian and Bering Sea groups and between Bering Sea and Alaskan groups which were much higher (14% - 28%).

Pilot et al's parentage analysis identified at least one parent for 95 individuals, but more than half these (57) were rejected by the authors as spurious. The remaining parentage assignments suggested low dispersal (42/43 maternal assignments were to a mother within the offspring's population) and very high male-mediated gene flow (10/22 paternal assignments were to a male not in the offspring's population). No parentage assignments were made between members of different ecotypes. The authors suggested that the discrepancy between the low rates of intra-ecotype gene flow estimated by using assignment tests and model-fitting and the high rates estimated from parentage analysis could be explained by a recent range expansion leading to increasing contact among formally isolated populations. Another possible explanation, suggested by the large number of assignments rejected as spurious, is that the parentage analysis may not have had sufficient power to exclude all false paternity assignments.

Ford *et al.* (2011b) conducted a similar parentage and assignment test analysis, but focused the parentage analysis exclusively on the southern resident population and did not attempt to identify potential parents outside of this population. The authors did test for the presence of first generation immigrants into the SRKW population, however, and found no evidence of recent gene flow into the SRKW population.

Another significant development in our understanding of global killer whale population structure has resulted from sequencing full ~16,390 bp mitochondrial genomes from a large number of individuals (Morin *et al.* 2010). Sequencing the full mitogenome has increased the number mtDNA base pairs examined by over 16 fold compared to the earlier studies that focused exclusively on the ~1000 bp control region. This increase in sequence evaluated has greatly improved the resolution of the estimated mtDNA gene trees, and significantly altered our understanding of killer whale population structure, particularly as it relates to the degree of divergence among some of the known ecotypes.

Morin *et al.* (2010) sequenced and analyzed full mitochondrial genomes from 139 killer whales sampled primarily from the North Pacific, North Atlantic, and Antarctic areas, with a smaller number of additional samples from the tropical Pacific. In contrast to earlier results based on only the control region, the phylogenetic tree constructed from the full length mitogenome sequences showed strong genetic structure associated with many of the previously identified ecotypes (Figure 2). In particular, the North Pacific residents, North Pacific transients, North Pacific offshores, and Antarctic type B and type C groups each formed distinct monophyletic clades. The North Pacific transients were particularly divergent from most other killer whale groups, including the sympatric residents and offshores. For example, there were 57 fixed sequence differences between the transients and the residents and offshores. The estimated time to the most recent common ancestor of all of the mtDNA haplotypes was ~700,000 years, and the divergence time between the haplotypes characterizing the residents and those characterizing the offshores was 177,000 years ago. Haplotypes characterizing the Antarctic B and C types were estimated to share a common ancestor 155,000 years ago. The Antarctic B and C types were also each found to have a sequence substitution inferred to be due to natural selection (Foote *et al.* 2011a). Based on the clear genetic divergence among ecotypes, combined with divergence at microsatellite loci and previously reported morphological and ecological differences, Morin *et al*. (2010) concluded that the North Pacific transients and Antarctic B and C types each met criteria for being considered full species, and the other known ecotypes (North Pacific residents, offshores, North Atlantic populations, and the Antarctic A type) each met criteria for being considered distinct subspecies, but could be elevated to species with if additional data supported evolutionary distinctiveness.

Utilizing the same dataset of mitogenome sequences, Foote *et al.* (2011b) conducted additional analyses on the relationship between North Pacific and North Atlantic populations. Based on the structure of the mitogenome tree, they suggested that over the past ~300,000 years there have been several episodes of migration of whales between the Pacific and Atlantic oceans. The timing and pattern of these inferred episodes further suggested that the Pacific resident and transient ecotypes may have initially diverged in allopatry (transients in Pacific, residents in Atlantic), and then subsequently came into contact following a migration event of residents back into the Pacific. Using the same isolation-divergence model used by Hoelzel *et al.* (2007), Foote *et al.* (2011b) also found non-zero but extremely low rates of bi-directional female gene flow between the Atlantic and Pacific (< 1 migrant / 150,000 years).

Foote *et al.* (Foote *et al.* 2009; Foote *et al.* 2011c)conducted analyses focused on understanding killer whale population structure within the North Atlantic, and found evidence for two ecological types (fish eating/mammal eating) similar to what has been observed in the Pacific and Antarctic. Genetically, the fish eating whales from Norway and Iceland formed a genetically distinct grouping based on both mtDNA control region (1000bp) sequences and microsatellite variation. Other groups of populations, particularly from Gibraltar and the Canary Islands, also clearly formed discrete populations based on the microsatellite variation, but clustered with other groups (Pacific offshores, Antarctic type A) in the mtDNA tree.

Parsons *et al.* (2013) conducted a study of population structure of a large (462) sample of resident and transient killer whales from the Gulf of Alaska, the Aleutian Islands and the Sea of Okhotsk. The focus of the study was primarily on elucidating population structure within each ecotype, but the study is also the largest study to date (in terms of whales and loci) of nuclear genetic variation between the resident and transient ecotypes. Using two different assignment methods, all samples with sufficient data (n> 20 loci) assigned unambiguously to their known ecotype. When individuals with greater levels of missing data were included, a single individual (missing data at 15/27 loci) assigned to the 'incorrect' ecotype at a low level of confidence (0.54). These results, combined with the lack of any shared mtDNA haplotypes, led the authors to conclude that there is at most negligible gene flow between the two ecotypes.

**Table 2 – Summary of published genetic analyses of killer whale population structure since the 2004 status review**

| Study[1] | Geographic focus | Number of samples | Type of data |
|---|---|---|---|
| Hoelzel *et al.* (2007), Pilot *et al.* (2010) | North Pacific plus Iceland | 203 | Microsatellites (16), mtDNA control region (~1000 bp) |
| LeDuc *et al.* (2008) | Antarctic (with comparison to published data in Pacific and Atlantic) | 80 | mtDNA control region (~1000 bp) |
| Foote *et al.* (2009) | North Atlantic | 125 | mtDNA control region (partial) |
| Morin *et al.* (2010), Foote *et al.* (2011b), Foote *et al.* (2011a) | North Pacific, North Atlantic, Antarctic, some tropical | 143 | mtDNA full genome (~16,390 bp) |
| Foote *et al.* (2011c) | North Atlantic (with comparison to published data in Pacific and Antarctic) | 85 | mtDNA control region and full genomes; microsatellites (17) |
| Ford *et al.* (2011b) | Southern Residents, North Pacific | 78 | Microsatellites (26) |
| Parsons *et al.* (2013) | North Pacific | 462 | mtDNA control region (~1000 bp); microsatellites (27) |

[1]Separate papers based on largely the same data are grouped.

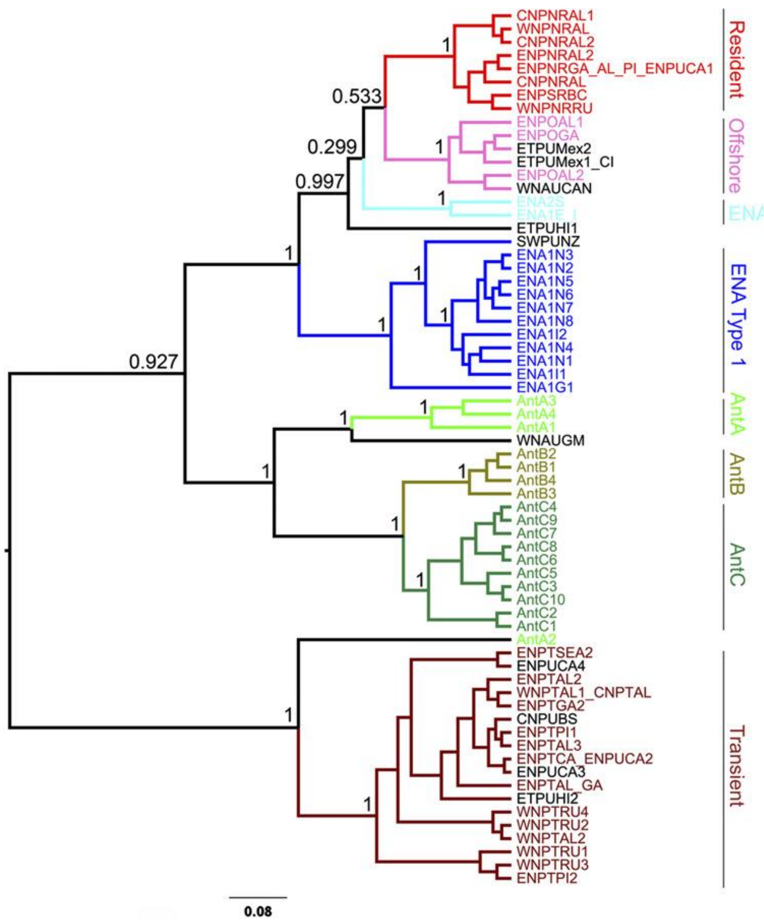



**Figure 2 -- Whole mitochondrial genome phylogeny of 66 unique killer whale haplotypes. Posterior probabilities are indicated for nodes of interest. Whales of known type are indicated in color, and those of unknown type are in black type. Reproduced from Morin *et al.* (2010).**

### *Summary, genetics*

Our understanding of killer whale population structure has improved considerably since 2004, due both to analysis of new samples, larger numbers of nuclear loci, and the collection of full mitogenome data. At least at the high latitude areas examined, the full mitogenome trees are much more geographically and ecotypically structured than was true of the control region trees available in 2004. The genetic studies published since 2004 also clearly support earlier suggestions of differentiation between some of the Antarctic ecotypes.

Despite the greater resolution provided by the mitogenome data compared to that of only the control region sequences, the total depth of the mitochondrial phylogeny within *O. orcus* remains relatively shallow compared to the levels of divergence typically observed between mammalian sister species. For example, Johns and Avise (1998), Avise *et al.* (1998) and Baker and Bradley (2006) have reviewed divergence at the mitochondrial cytochrome-b gene for a large number of mammal sister species, and levels of divergence are typically >5%, although some are much lower. The divergence between resident and transient killer whales is ~0.4% (based on sequences from Morin *et al.* (2010)), suggesting that if the ecotypes are species they are relatively young species. The relatively shallow divergence could also be consistent with incipient speciation (Riesch *et al.* 2012), or with subspecies (Reeves *et al.* 2004).

Evaluating variation at multiple nuclear genes is also important for gaining a full understanding of population structure, both to reduce the stochastic noise associated with inference at a single locus such as mtDNA and to ensure that population processes mediated by male gene flow are evaluated.

Studies of nuclear variation published since 2004 have provided results consistent with what was available to the 2004 BRT, albeit with considerable improvements in terms of numbers of samples and loci analyzed. In 2013, as in 2004, all published studies of killer whale population structure that use nuclear loci have utilized microsatellites, although the number of loci has increased from 17 (Hoelzel 2004) to 27 in the most recent study (Parsons *et al.* 2013). The studies that have most directly attempted to estimate rates of gene flow among populations using nuclear loci (Hoelzel *et al.* 2007, Pilot *et al.* 2010), estimate no contemporary gene flow between the North Pacific residents and either transients or offshores, and at most very little contemporary gene flow between transients and offshores. The most sophisticated estimates of historical gene flow (the Ima2-based estimates from Hoelzel *et al.* 2007) are all <1 migrant/generation among the Pacific ecotypes. The largest available study of microsatellite variation among North Pacific killer whales (Parsons *et al.* 2013) also found no evidence for contemporary gene flow between residents and transients. Estimates of rates of gene flow within the North Pacific resident populations vary somewhat, but most analyses indicate little gene flow, particularly into or out of the more southern populations. All of these results continue to strongly support the 2004 BRT's conclusion that there is a "… high degree of contemporary reproductive isolation among eastern North Pacific killer whale populations" (Krahn *et al.* 2004, p. 16).

Our understanding of killer whale population structure outside of the North Pacific has also progressed considerably since 2004. Studies of variation among killer whale groups in the Antarctic (Leduc *et al.* 2008; Morin *et al.* 2010) in particular have confirmed the presence of distinct groups that correspond to the ecological/morphological groups previously identified (Pitman *et al.* 2003; Pitman *et al.* 2007). Population structure in the Atlantic is also starting to be elucidated (Foote *et al.* 2009), as is the relationship between the North Atlantic and North Pacific (Foote *et al.* 2011b).

Despite this considerable progress, it is also clear that a full understanding of killer whale structure at a global scale remains incomplete. There have been no published genetic studies focusing on samples from tropical areas (although Morin *et al.* 2010 included some tropical samples), and large portions of the killer whale's range, including the coasts of South America, Africa, Australia, and eastern North America, remain essentially unanalyzed.

In addition to the lack of sampling in some areas, the issue of the evolutionary age of the Pacific ecotypes and of killer whale populations worldwide remains somewhat uncertain and subject to varying estimates. Based on the low levels of mtDNA control region divergence, Hoelzel *et al.* (2002) hypothesized that killer whales globally experienced a population bottleneck 145,000 to 210,000 years ago. By fitting population genetic models to microsatellite and mtDNA control region data, Hoelzel *et al.* (2007) estimated the divergence time between the Pacific ecotypes at 20,000-30,000 years ago. In contrast, Morin *et al.* (2010) estimated the time to the most recent common ancestor of the killer whale mitogenomes that characterize the ecotypes to be 170,000 to 700,000 years ago, implying a much deeper divergence time than had been estimated previously. However, Hoelzel *et al.* (2007) estimated divergence times between populations, whereas Morin *et al.* (2010) estimated divergence time among gene sequences and these estimates are not expected to be the same (topic reviewed by Edwards *et al.* 2000). Hoelzel *et al.*'s estimate was based on a much smaller mtDNA segment than the Morin *et al.* estimate, but Hoelzel's estimate also included information from nuclear loci. In addition, all of these estimates are sensitive to the estimated or assumed mutation rate, which differed between the studies. It is therefore not immediately obvious which of these estimates is more reflective of the true evolutionary age of the ecotypes, or even that these estimates are necessarily inconsistent with each other. Additional nuclear sequence data is likely to improve the precision of the estimated divergence times.

### Review papers

Riesch *et al.* (2012) and Foote (2012) recently reviewed evidence for ongoing ecological speciation among killer whale ecotypes. Riesch *et al.* focus particularly on the role that cultural factors might play in promoting ecological divergence and reproductive isolation. Both reviews conclude that most if not all of the behavioral, ecological and perhaps even some of the morphological (e.g., size) differences between the North Pacific ecotypes are likely to be non-heritable, culturally transmitted traits. Riesch *et al.* concluded that the reproductive and social isolation observed among ecotypes is largely culturally based, and there is no evidence for either pre or post-zygotic reproductive incompatibility. Ultimately, Riesch *et al.* concluded that there is not sufficient evidence to conclude that the ecotypes are currently separate species or subspecies, but rather that "We could be witnessing the early stages of an adaptive radiation of killer whales, whereby a variety of incipient species are beginning to exploit diverse ecological niches, or conversely, we could be looking at an old and continuing process by which new ecotypes periodically form and become extinct again." Foote (2012) evaluates much of the same information, and concludes that it is very hard to prove conclusively from field data alone that the specific process of ecological speciation (Schluter 2001; Schluter 2009) is occurring in killer whales or any "non-model" organism. Foote suggests that genome scans, by identifying specific functional genes subject to natural selection, might be a fruitful way to evaluate the causes of divergence in such systems. de Bruyn *et al.* (2013) recently reviewed information on Southern hemisphere killer whales both in Antarctica and in temperate latitudes and concluded that there is relatively little information on the social structure and ecology of killer whales in this region and that firm designation of ecotypes outside of the North Pacific may be premature.

## Summary and Conclusions

### Determination of the Taxon

Based on several lines of evidence, including differences in morphology, behavior, diet and feeding ecology, acoustical dialects and practices, and both mtDNA and nuclear DNA variation, the 2004 BRT concluded (with some uncertainty) that the North Pacific resident killer whales were a subspecies of *O. orca* distinct from the sympatric transient whales (Krahn *et al.* 2004, p. 40-41). With somewhat less confidence, the BRT also concluded that the North Pacific resident subspecies consisted of only the North Pacific residents, and did not include killer whales of the offshore ecotype or fish-eating killer whales from elsewhere in the world.

After reviewing information in the petition, the public comments, and the scientific literature published in the nine years since the 2004 status review, we found no new information that would likely lead to a different conclusion from that of the 2004 BRT. In particular, all of the new genetic data and analyses published since 2004 (Table 2), including the Pilot *et al.* (2010) paper discussed extensively by the petition, are either consistent with or strengthen the 2004 BRT's conclusion that there is a high degree of contemporary reproductive isolation among the North Pacific killer whale ecotypes. No genetic analysis published since the 2004 status review has indicated a higher level of interbreeding among the ecotypes than was indicated by the analyses considered by the 2004 BRT.

In addition to new genetic analyses, the studies on feeding ecology and diet published since 2004 are also generally consistent with or strengthen the 2004 BRT's conclusions that the ecotypes differ in diet and feeding ecology. The one new study that touches indirectly on morphological differences between the ecotypes (Zerbini *et al.* 2007) supports the 2004 BRT's conclusion (based on earlier literature) that the ecotypes can be morphologically differentiated. No new information on acoustics or behavior contradicts the conclusions of the 2004 BRT. Recent observations (NWFSC unpublished data) indicate that offshores consume at least some Chinook salmon, but stable isotope and tooth wear data also indicate substantial dietary differences. The petition discusses numerous questions regarding the morphological, behavioral and ecological data cited by the 2004 BRT, but does not raise issues not already discussed by the BRT or the 2004 Taxonomic workshop.

A broader scientific consensus regarding whether the North Pacific ecotypes are a subspecies of *O. orca* remains mixed, as was the case at the time of the 2004 BRT (Krahn *et al.* 2004; Reeves *et al.* 2004). Some experts have suggested that the ecotypes clearly meet criteria for subspecies or species designation (Morin *et al.* 2010), and at least one scientific society (the Society for Marine Mammalogy) now formally recognizes North Pacific residents and transients as subspecies (Committee on Taxonomy 2012). Other experts are less certain that either species or subspecies status is currently appropriate, based on some estimates of non-zero male mediated gene flow among ecotypes (Hoelzel public comments; de Bruyn *et al.* 2013; Riesch *et al.* 2012). Some of this lack of consensus appears to be related to differing conceptions of subspecies definitions rather than substantial disagreement about the biological differences characterizing the ecotypes.

Although the 2004 BRT concluded that the North Pacific resident killer whales meet the criteria for being a subspecies, the BRT expressed some uncertainty about whether to also include Pacific offshores, tropical Pacific killer whales, and by extension perhaps also Atlantic fish-eating killer whales in this subspecies as well (Krahn *et al.* 2004, pp. 40-41). The data available since 2004 tend to strengthen the BRT's conclusion that the North Pacific resident killer whales are taxonomically distinct from the sympatric offshores and allopatric populations of killer whales in the tropics and Atlantic. In particular, Morin *et al.* (2010) found that the North Pacific residents form a monophyletic mtDNA clade distinct from offshores, Atlantic whales and the limited number of Pacific tropical whales included in the study (Figure 1). Estimated rates of gene flow between residents and Atlantic populations differ greatly between studies, but generally suggest that such gene flow is occurring on evolutionary rather than ecological time scales. The fact that the three Pacific ecotypes retain their genetic and ecological distinctiveness when in sympatry also strongly suggests they are currently on divergent evolutionary trajectories. Nonetheless, as was the case in 2004 clearly demarcating the phylogenetic boundaries of the resident taxon remains somewhat uncertain and the rationale for taxonomically distinguishing the residents from the offshores and from fish eating whales in the Atlantic appears somewhat less compelling than taxonomically distinguishing transients from other North Pacific killer whales.

Taken together, however, the best available information clearly strengthens the lines of evidence cited by the 2004 BRT (Krahn *et al.* 2004) to support the designation of the North Pacific resident and transient killer whales as an unnamed subspecies of *O. orca.*

### Determination of the DPS

As of December 31, 2012, the SRKW population consisted of 84 individuals divided into three pods (26 in J, 19 in K, and 39 in L) (Center for Whale Research and NWFSC unpublished data). An additional captive animal originating from the SRKW population and with a genotype consistent with a southern resident origin (Hoelzel *et al.* 2007; Hoelzel pers. com.), "Lolita", has resided at the Miami Seaquarium since her capture in August of 1970 (Hoyt 1981). Lolita's original pod is not known with certainty, but her acoustic calls are typical of L pod (Ford 1987; Candice Emmons, personal communication).

The 2004 BRT concluded that there was strong evidence that the SRKW are discrete as defined by the 1996 DPS policy, citing significant genetic differentiation, separate demographic trajectories, differences in core and summer range, and behavioral differences with other resident populations (Krahn *et al.* 2004, p 44). The BRT was less certain that the SRKW met the DPS policy's criteria for significance, but concluded (by a 2-to-1 margin) that they did, citing differences in ecological setting, range, marked differences in genetic variation, and potential cultural differences.

The new information subsequent to 2004 is consistent with and generally strengthens the conclusion that the SRKW are a discrete population within the North Pacific resident taxon. In particular, recent genetic studies all indicate that SRKW are significantly differentiated from other resident populations. New information on the winter range of SRKW provides for a considerably more complete picture than was available in 2004, and continues to indicate that the SRKW (particularly L and K pods) have a winter and summer range distinct from other resident populations, although it does overlap substantially with the northern resident population. A recent analytical comparison of demographic rates found significant differences in both survival and fecundity rates between the southern resident population and the northern resident population, providing further evidence of demographic discreteness (Ward *et al.* 2013). In short, as in 2004 all the available information clearly indicates that the southern residents are a distinct population.

Compared to 2004, new information related to the significance of the SRKW to the North Pacific resident taxon provides a somewhat more nuanced picture. Each of the factors listed by the 2004 BRT in support of the significance criteria is discussed below with reference to new information.

Ecological setting and range – The 2004 BRT noted that the southern residents appeared to occupy a distinct ecological setting, being the only North Pacific resident population to spend substantial time in the California Current ecosystem and having a diet somewhat different from other resident populations, particularly those in Alaska. The BRT also cited the possibility that the southern residents historically utilized the large runs of salmon to the Sacramento and Columbia River as a major source of prey. With regard to range, the BRT noted that the southern residents were the only resident population to be observed to spend time in Puget

Sound and off the coasts of Washington, Oregon and California and that if they were to go extinct this would result in a significant gap/reduction in the resident's range.

New information since 2004 generally continues to support most of these conclusions, but also challenges some of them. In particular, new information on the coastal distribution of the southern and northern resident populations confirms that the southern residents spend substantial time in coastal areas of Washington, Oregon and California and utilize salmon returns to these areas (NWFSC unpublished data). However, there is also new information indicating that the Northern Resident population may also spend more time off the Washington coast than was previously believed (Riera *et al.* 2011; NWFSC unpublished data), and the known northern range of the southern residents is now Chatham Strait in SE Alaska based on photographs taken in 2007 (John Ford, DFO, pers. com). In addition, diet information on the Alaskan resident populations indicates that some of these populations also consume salmon, although not the Chinook salmon that dominate the southern and northern resident diets (Saulitis *et al.* 2000). Updated diet data from the southern and northern resident populations confirms that these two populations have very similar diets and consume many of the same salmon stocks (Ford *et al.* 2010; Hanson *et al.* 2010). Overall, the southern residents remain unique in occupying the most southern part of the resident's range, and are clearly occupying a somewhat different ecological setting from populations in Alaska and further west around the Pacific Rim. The southern portion of the southern resident's range is also quite distinct from that of the northern resident population, but the southern and northern residents clearly share a similar ecological setting throughout much of their range.

Genetic differentiation – Genetic data available since 2004 confirms or strengthens the conclusions that the southern resident population is genetically differentiated from other resident populations. In particular, there are no new data to change the 2004 BRT's conclusions that the southern resident population differs markedly from other North Pacific resident populations at both nuclear and mitochondrial genes.

Behavioral and cultural diversity – The 2004 BRT noted several instances of known and apparent cultural differentiation among resident killer whale populations, and hypothesized, based on studies in other long-lived mammals, that such diversity could be important for the survival of the North Pacific resident taxon as a whole. Since 2004, several studies have contributed further information to this topic. For example, Ward *et al.* (Ward *et al.* 2013; 2011) found significant differences in survival among the three southern resident pods and between the southern and northern resident populations. These differences are likely related to differences in diet and habitat use, both of which appear to be culturally determined. Riesch *et al.* (2012) and Foote (2012) reviewed cultural differences, particularly acoustic behavior and prey preferences, among killer whale populations and ecotypes, and concluded that such cultural differences may be leading to reproductive isolation and subsequent ecological speciation. On the whole, therefore, the available data appear consistent with the BRT's conclusion that such cultural differences may be important factors in the overall viability of the resident killer whale taxon.

Overall, new information on genetics and behavioral and culture diversity available since 2004 is consistent with or strengthens the 2004 BRT's conclusion that the southern resident killer whale population meets the significance criteria of the DPS policy. New information on ecological setting and range tends to weaken the 2004 BRT's conclusion somewhat, as it indicates greater overlap in range or diet with other resident and offshore populations than was previously believed. Overall, the new information available since 2004 appears consistent with the 2004 BRT's conclusion that southern resident killer whales are likely to be a DPS of the unnamed North Pacific resident subspecies.

## Appendix – Review of specific points made in the petition

### Workshop on Cetacean Taxonomy

p. 14 – "No experts in the field of cetacean taxonomy were included to inform the workshop participants." The list of participants is in Appendix 1 of workshop report (Reeves *et al.* 2004). It contains multiple experts on cetacean taxonomy, such John Heyning, Marilyn Dahlheim, William Perrin, and James Mead. In the paragraph preceding the sentence quoted above, the petition references papers by Perrin, Heyning and Dahlheim as authoritative on killer whale taxonomy.

p. 14 – 17 – In summarizing the Cetacean Taxonomy workshop, the petition fails to mention that among the workshop's conclusions was that "Overall, a majority of participants felt that Resident- and Transient-type killer whales in the ENP [Eastern North Pacific] probably merited species or sub-species status." (Reeves *et al.* 2004 pp. 5 and 72).

p. 17 – "Most importantly of all, the workshop contained the following: [C]onsideration of whether to add the 'southern resident' killer whales of the eastern North Pacific to the U.S. Endangered Species List hinged on poorly understood evolutionary relationships between this population and killer whales globally (LJ/04/KW10). In the absence of a fundamental understanding and agreement on the number of species and subspecies of killer whales, consensus could not be reached on whether this whale population was significant to the taxon to which it belongs."

The petitioners present this statement as a conclusion of the workshop. However, the text quoted appears in the first page of the workshop report and is referring to the inability of the 2002 BRT (Krahn *et al.* 2002) to reach a consensus on killer whale taxonomy. In other words, this statement is describing the motivation for the workshop, not the workshop's conclusion.

p. 17-18 – The discussion of the 2006 listing fails to cite the BRT reports (Krahn *et al.* 2002, 2004) and the discussions therein regarding killer whale taxonomy and population structure.

### Scientific basis for identification of subspecies

p. 26 – "Contradicting the scientific consensus in the cetacean's [sic] workshop, and without any support from the broader taxonomic community, the Service unilaterally created a killer whale subspecies – the North Pacific residents – based apparently on geographic distribution."

This statement is misleading. With regard to killer whale taxonomy, the taxonomy workshop report stated: "Overall, a majority of participants felt that the Resident- and Transient-type killer whales in the ENP probably merit at least species or subspecies status." (Reeves *et al.* 2004, p. 72). In addition, the BRT report discusses multiple lines of evidence both for and against sub-species, and clearly does not rely solely on geography (Krahn *et al.* 2004).

p. 26, 27 – The petition notes that NMFS has not provided a Latin trinomial for the hypothesized North Pacific Resident sub-species, and suggests that "... the Service has chosen to ignore 275 years of biological classification and taxonomic nomenclatural convention...". The issue of nomenclature was in fact explicitly discussed in the BRT report, which noted that all the biological issues surrounding the subspecies will need to be resolved before the nomenclature can be settled (Krahn *et al.* 2004, p. 18). In addition, the Cetacean Taxonomy Workshop report contains a section that specifically discusses unnamed subspecies, noting several examples and concluding that "Designation of unnamed subspecies can provide a mechanism for allowing recognition of highly differentiated forms without having to wait until its nomenclature is settled." (Reeves *et al.* 2004, p. 8). The Society for Marine Mammalogy also recognizes the residents and transients as unnamed subspecies of *O. orca* (Committee on Taxonomy 2012).

### Genetic data

The petition relies heavily on a recent paper, Pilot *et al.* (2010), that uses a variety of analyses to estimate rates of interbreeding among groups of killer whales (see section above for a summary of this paper). Much of the petition's discussion of this paper is misleading, misrepresenting both the results of the Pilot *et al.* study and how these results combine with the results of other studies to provide a more complete description of killer whale population structure.

p. 29 – "Pilot *et al.* (2010) reported that comparative assessments of kinship, parentage, and dispersal reveal high levels of kinship and male-mediated gene flow within local populations, including among ecotypes that are highly divergent within the mtDNA phylogeny."

Using the parentage and assignment methods the petition appears to prefer, Pilot *et al.* found a single putative instance of interbreeding (gene flow) between whales from different the Pacific ecotypes – an offshore whale that genetically assigned to the transient ecotype (Pilot *et al.* 2010 Appendix S3). They found no instances of putative interbreeding between the residents and transients or residents and offshores. We therefore disagree with petition's conclusion that Pilot *et al.* (2010) found "high levels" of male mediated gene flow among ecotypes. Another, larger study (in terms of whales sampled and loci genotyped) found no instances of interbreeding among ecotypes (Parsons *et al.* 2013).

p. 29 – "In contrast to the Service's insistence that its speculative unnamed North Pacific resident subspecies (and Southern Resident DPS) are genetically isolated, Pilot *et al.* (2010) show that they are not."

The 2004 BRT did not claim that the ecotypes were completely isolated, merely that there was a "… high degree of contemporary reproductive isolation…" (Krahn *et al.* 2004 p. 16). The petition's claims to the contrary, the Pilot *et al.* (2010) results show that there is at most rare and episodic contemporary gene flow between the transient and offshore ecotypes and no evidence of contemporary gene flow between the resident and offshore ecotypes or the resident and transient ecotypes. Using model fitting methods to estimate historical gene flow, Pilot *et al.* (2010) estimate that there has been low (generally < 1%) rates of gene flow among the ecotypes historically (see Table 5 of Pilot *et al.* 2010). These rates are consistent with the BRT's interpretation of a high degree of reproductive isolation, and are also consistent with the information available to the 2004 BRT when it made its evaluation (see Tables 4 and 5 of Hoelzel 2004).

p. 30 – "The significance of the findings of Pilot *et al.* (2010) is threefold.
First, they demonstrate with data that social interactions among killer whale pods do occur in the wild and they occur more frequently than has been reported (i. e., many interactions are simply "missed" by human observers who cannot watch a vast area of ocean to take note of killer whale pod interactions, 24 hours a day, 7 days a week, year round)."

Actually, Pilot *et al.* (2010) only studied patterns of genetic data, and contained no data or analysis of social interactions.

p. 30 – "The genetic data provide evidence that these inter-pod social interactions occur, and that they can and do result in mating among individuals in different pods, including mating among individuals of different ecotypes (i.e., between resident and transient killer whales)."

As we explain above, Pilot *et al.* (2010) found no direct evidence at all of mating between resident and transient killer whales (see Appendix S3 of Pilot *et al.*), and their indirect (model fitting) methods indicated that rates of gene flow between residents and transients were less than one half a percent (Table 5 of Pilot *et al.*). Pilot *et al.* did find somewhat higher rates of gene flow among resident populations (ie, within the resident ecotype), but even these were very low for all pairs of populations except between Russia and the Bering Sea and Bering Sea and Alaska: "In residents, very high gene flow rates were revealed from RU to BS (0.28) and from BS to AR (0.14), and much lower rates (ranging from 0.005 to 0.024) between other pairs of resident populations." (p. 26).

p. 33 – "Therefore, if only mtDNA is considered in an analysis, the loss of mtDNA variation in populations (also referred to as lineage sorting) can give an erroneous appearance of populations (and putative species) being genetically isolated because they are trying to maintain taxonomic differences (i.e., Morin *et al.* 2010) while at the same time ecotypes and populations are not isolated for nuclear genetic variation. This is precisely the case with killer whales, a fact the Service did not acknowledge in its 2005 listing of the killer whale DPS, or in its 2011 status review of the population."

There are multiple inaccuracies with this statement and the discussion of mtDNA patterns that surrounds it in the Petition. First, the BRT explicitly discussed the strengths and limitations of mitochondrial (maternal) and nuclear genetic markers (see pp. 22-23 of Krahn *et al.* 2002 and p. 16 of Krahn *et al.* 2004). Second, the statement seems to imply that North Pacific killer whales ecotypes and populations are not strongly differentiated at nuclear loci. This is simply not correct: Hoelzel *et al.* (2007), Pilot *et al.* (2010), Morin *et al.* (2010), and Parson *et al.* (2013) all describe patterns of microsatellite (nuclear) variation among populations, and all find significant levels of divergence consistent with generally low rates of gene flow (typically < 1 migrant/generation among ecotypes and very much less for some analyses). A preliminary version of one of these analyses (Hoelzel 2004) was discussed extensively by the 2004 BRT (Krahn *et al.* 2004 pp. 11-13).

With regard to 'lineage sorting' of mtDNA, this phenomena was explicitly considered by the BRT (see Krahn *et al.* 2002 p. 23 paragraph 3), who ultimately concluded that much of mtDNA variation among populations was in fact random and due to stochastic events. That conclusion, although reasonable at the time, must now be updated based on the new whole mitogenome data of Morin *et al.* (2010), which shows that when whole mitogenomes are considered patterns of mtDNA variation among killer whales are not at all random but instead are very highly correlated with ecotype. This new result, combined with the new nuclear data reported in the same paper and by Hoelzel *et al.* (2007), Pilot *et al.* (2010) and Parsons *et al.* (2013), in fact strengthens the original conclusion of the BRT that North Pacific killer whale ecotypes are highly reproductively isolated from each other.

p. 34 – "Thus, outbreeding occurs (particularly those in different ecotypes) but is limited by the frequency of interactions in the ocean, rather than by killer whales trying to maintain taxonomic or population isolation."

The implication that the only factor limiting interbreeding between resident killer whales and transient killer whales is infrequent opportunity for interactions in the ocean is not consistent with the available data. For example, both residents and transients are frequently observed in the Salish Sea, often on the same day and in the same general location but have never been observed to interact or socialize (Baird 2000). The ocean is indeed vast, but the resident and transient ecotypes have a primarily coastal distribution, have a long distance means of potentially locating each other through their acoustic calls, and are frequently sighted in the same general vicinity by human observers (see e.g. Table 2 of Zerbini *et al.* 2007). It therefore seems highly implausible that only lack of random encounters is limiting gene flow between ecotypes.

p. 35 – "Thus, the Service has erroneously attributed the patterns of genetic variation and behavior between ecotypes to genetic differences, when learned behaviors are responsible for these ecotypes."

It seems reasonable to conclude that "patterns of genetic variation" have a genetic basis. With regard to the behavioral and ecological differences among the ecotypes, the BRT never concluded that these traits were genetically based. For example, the 2004 BRT report summarized arguments for and against multiple species of North Pacific killer whales, and in the "Arguments for a single species" section noted: "Foraging specializations and other behavioral characteristics such as distinct vocalizations may be learned and therefore are not good indicators of species status (Barrett-Lennard and Heise 2004)." The BRT did consider the ecological, social and foraging differences among the ecotypes as one of several lines of evidence for subspecies status (Krahn *et al.* 2004, p. 39-40), but never claimed that these were genetically based characteristics. In discussing the factors leading to the conclusion that the southern resident killer whales are a DPS, the BRT discussed ecological setting, range, genetic differentiation, and behavioral and cultural diversity (Krahn *et al.* 2004 p. 44-45). In other words, in its DPS determination the BRT stated explicitly that it was considering behavioral and cultural factors in addition to genetic variation in assessing DPS status, consistent with USFWS and NMFS policy on DPS determination.

p. 36 – "In sum, there is no competent genetic evidence to support the designation of the North Pacific resident whale population as a subspecies."

At a minimum, this is a debatable point. Rates of contemporary gene flow have been estimated as zero between the residents and either the transient and offshore ecotypes (Pilot *et al.* 2010, Ford *et al.* 2011, Parsons *et al.* 2013). The three ecotypes can be unambiguously identified using either mtDNA or nuclear genetic data (Morin *et al.* 2010, Parsons *et al.* 2013) or photographs (Zerbini *et al.* 2007). These genetic differences are maintained in sympatry, a factor even biologists concerned about taxonomic inflation view as important evidence of taxonomic distinctiveness (Zachos *et al.* 2013). There is no question that there is some uncertainty regarding the taxonomic status of the North Pacific ecotypes and that it is possible for reasonable experts to come to somewhat different conclusions (see pp. 41 and 45 of Krahn *et al.* 2004, for example). But to conclude that there is "no competent genetic evidence" is inconsistent with the available information.

### Morphological data

p. 36 - 38 – "The Service fails to distinguish the difference between variation that is primarily due to environmental influences on development, such as body size, and variation that has a genetic basis." "In the listing decision, references to morphological differences that distinguish ecotypes are based upon studies that are anecdotal, qualitative, or pseudo-quantitative in nature (Baird & Stacey 1988; Baird 2000). There are no data to substantiate objectively actual distribution of these traits in the wild. There are no data to support the genetic basis for variation in these traits (e.g., body size, which is primarily influenced by environment rather than genetics in most mammals). Further, there are no data to support the presumption that the morphological differences in question have any functional significance (i.e., they confer a survival advantage to an ecotype). The Service's key morphological "evidence" to describe three ecotypes of killer whales in the 2005 listing rule is subjective, or involves incomplete qualitative comparisons, or both (Table 1)."

In fact, the 2004 BRT noted similar points in evaluating the morphological data (see Krahn *et al.* p. 38), and with the exception of the saddle patch pigmentation trait never claimed that the morphological differences among the ecotypes were necessarily genetically based or proven to be adaptive. Indeed, the criteria for subspecies designation suggested by Reeves *et al.* (2004) and used by the BRT do not require that morphological variation be proven to either genetically based or adaptive in order for it be used as one of several factors to delineate subspecies. It is also important to note that at the time of the status reviews in 2002-2004 (and even now) relatively little data were available for offshore killer whales.

Nonetheless, we agree with the petitioners that much of the information on morphological variation within and among the North Pacific ecotypes is qualitative in nature and would benefit from additional quantitative analysis. It is important to note, however, that the qualitative differences among the ecotypes that have been described are based on decades of field observations by biologists who have spent their entire careers studying killer whales. The BRT therefore felt comfortable including these descriptions as one of several lines of information related to potential taxonomic status. Subsequent to the 2004 BRT report, the analyses of Zerbini *et al.* (2007) indicates that at least when comparing multiple individuals of each ecotype the groups can be reliably distinguished on the basis of morphology.

p. 39 – "Saddle patches are another morphological trait used to treat the North Pacific resident whale population as a separate subspecies. Yet again there is substantial overlap among ecotypes, and the categories of patterns have been described differently by different authors. Evans *et al.* (1984) described three patterns, while Baird and Stacey (1988) described five. As shown in the line drawings from each paper on the following page (Evans *et al.* 1984; Baird and Stacey 1988), there is no overlap in the patterns, yet the Service relied on this subjective classification in its listing decision even in the absence of supporting data such as field notes, photographs, or measurements. Finally, the Service did not acknowledge another source of error in classifying saddle patch patterns: saddle patches are not always symmetrical. Therefore, different classifications can be obtained depending upon which side of the killer whale is photographed, leading to erroneous assignments."

The BRT did not use or cite the Evans *et al.* (1984) study, which was focused on patterns of killer whale pigmentation at a global scale and did not include ecotype information. The Baird and Stacey (1988) paper clearly cites the sources of the photographs they analyzed, which are from readily available publications. The publication also clearly stated that only photographs of the left side of the whales were used. The Petition speculates that right-hand-side photographs may produce different results, but provides no analysis to back up this statement.

p. 42 – "The Service fails to recognize the evolutionarily more parsimonious explanation that the behavioral traits it uses to distinguish among supposed subspecies or ecotypes are learned rather than the result of genetic differences."

As was noted above, the BRT reports never concluded that variation in vocalization or behavioral traits is genetically based.

p. 42-42 – "In a recent paper, Rehn *et al.* (2010) reported that a killer whale vocalization associated with high arousal behaviors is common to all killer whales and does not vary regardless of pod, ecotype, or location in the Pacific. Thus, this innate behavior is consistent with the killer whale's current classification as a single species"

The experimental design of the Rehn *et al.* (2010) paper was to examine isolated, non-interacting, groups of killer whales in order to find common and thus presumably innate call types. While the finding of such a call type certainly is consistent with the known evolutionarily recent common ancestry of the ecotypes, it is not strong evidence that they belong to a single species. Indeed, the Pacific ecotypes and killer whales worldwide share a great many traits due to common ancestry. For that matter, they share a great many traits in common with other delphinids. However, simply sharing traits is obviously not strong evidence that two putative taxa are conspecific or are not reproductively isolated. Humans and chimpanzees, for example, share ~99% of their genomes (Mikkelsen *et al.* 2005), but few would argue that they are not distinct species.

p. 48 – "An unbiased method would have used DNA amplification primers and reaction conditions capable of detecting types of potential prey other than just fish (i.e., marine mammals, birds, and squid). Such a method would use a pair of conserved DNA amplification primers for animals (i.e., 16sRNA), or combinations of primers that would amplify fish, marine mammals, birds, and squid, followed by application of culture independent methods (e.g., PCR, cloning of PCR products, and sequencing of the clone library). That would provide DNA sequences from virtually all animal DNAs in a sample, even if they are at low frequency. This method is widely used in microbial genomics and forensics, and is needed to detect total diversity of the prey items in the sample (Hugenholtz *et al.* 1998)."

The petition is correct that primers used in the Hanson *et al.* (2010) study were designed specifically to detect fish prey. This was in part to avoid amplifying DNA from the killer whales being sampled. However, another study (Ford *et al.* 2011b) did use 16s ribosomal DNA primers to obtain PCR amplicons from ~200 killer whale fecal samples collected from the southern resident population, including many of the same samples used in the Hanson (2010) study. These primers have been demonstrated to amplify both harbor seal and harbor porpoise, two common marine mammals preyed upon by transient killer whales. In controlled experiments in which harbor seal or harbor porpoise DNA was mixed with killer whale DNA and amplified and sequenced using these primers, the harbor porpoise and harbor seal sequences were readily detectable, along with that of killer whale. Using the same primers and methods, marine mammal sequences (other than killer whale) were not detected in any of the >200 fecal samples collected from the field (Hempelmann 2012).

## References


Avise, J., and R. Ball, 1990 Principles of genealogical concordance in species concepts and biological taxonomy. Oxford surveys in evolutionary biology **7:** 45-67.

Avise, J. C., D. Walker and G. C. Johns, 1998 Speciation durations and Pleistocene effects on vertebrate phylogeography. Proceedings of the Royal Society B-Biological Sciences **265:** 1707-1712.

Baird, R. W., 2000 The killer whale -- foraging specializations and group hunting, pp. 127-153 in *Cetacean societies: field studies of dolphins and whales*, edited by J. Mann, R. C. Connor, P. L. Tyack and H. Whitehead. University of Chicago Press, Chicago.

Baird, R. W., and P. J. Stacey, 1988 VARIATION IN SADDLE PATCH PIGMENTATION IN POPULATIONS OF KILLER WHALES (ORCINUS-ORCA) FROM BRITISH-COLUMBIA, ALASKA, AND WASHINGTON STATE. Canadian Journal of Zoology-Revue Canadienne De Zoologie **66:** 2582-2585.

Baker, R. J., and R. D. Bradley, 2006 Speciation in mammals and the genetic species concept. Journal of Mammalogy **87:** 643-662.

Beck, S., S. Kuningas, R. Esteban and A. D. Foote, 2011 The influence of ecology on sociality in the killer whale (Orcinus orca). Behavioral Ecology.

Berzin, A. A., and V. L. Vladimirov, 1983 A NEW SPECIES OF KILLER WHALE (CETACEA, DELPHINIDAE) FROM THE ANTARCTIC WATERS. Zoologichesky Zhurnal **62:** 287-295.

Committee on Taxonomy, 2012 List of marine mammal species and subspecies. Society for Marine Mammology, http://www.marinemammalscience.org, consulted on April 25, 2013.

Crandall, K. A., O. R. P. Bininda-Emonds, G. M. Mace and R. K. Wayne, 2000 Considering evolutionary processes in conservation biology. Trends in Ecology and Evolution **15:** 290-295.

Dahlheim, M. E., A. Schulman-Janiger, N. Black, R. Ternullo, D. Ellifrit *et al.*, 2008 Eastern temperate North Pacific offshore killer whales (Orcinus orca): Occurrence, movements, and insights into feeding ecology. Marine Mammal Science **24:** 719-729.

Dahlheim, M. E., and P. A. White, 2010 Ecological aspects of transient killer whales Orcinus orca as predators in southeastern Alaska. Wildlife Biology **16:** 308-322.

de Bruyn, P. J. N., C. A. Tosh and A. Terauds, 2013 Killer whale ecotypes: is there a global model? Biological Reviews **88:** 62-80.

Deecke, V. B., J. K. B. Ford and P. J. B. Slater, 2005 The vocal behaviour of mammal-eating killer whales: communicating with costly calls. Animal Behaviour **69:** 395-405.

Deecke, V. B., M. Nykanen, A. D. Foote and V. M. Janik, 2011 Vocal behaviour and feeding ecology of killer whales Orcinus orca around Shetland, UK. Aquatic Biology **13:** 79-U186.

Deecke, V. B., P. J. B. Slater and J. K. B. Ford, 2002 Selective habituation shapes acoustic predator recognition in harbour seals. Nature **420:** 171-173.

Dizon, A. E., C. Lockyer, W. F. Perrin, D. P. Demaster and J. Sisson, 1992 Rethinking the stock concept: a phylogeographic approach. Conservation Biology **6:** 24-36.

Edwards, S. V., and P. Beerli, 2000 Perspective: Gene divergence, population divergence, and the variance in coalescence time in phylogeographic studies. Evolution **54:** 1839-1854.

Foote, A. D., 2012 Investigating ecological speciation in non-model organisms: a case study of killer whale ecotypes. Evolutionary Ecology Research **14:** 447-465.

Foote, A. D., P. A. Morin, J. W. Durban, R. L. Pitman, P. Wade *et al.*, 2011a Positive selection on the killer whale mitogenome. Biology Letters **7:** 116-118.

Foote, A. D., P. A. Morin, J. W. Durban, E. Willerslev, L. Orlando *et al.*, 2011b Out of the Pacific and Back Again: Insights into the Matrilineal History of Pacific Killer Whale Ecotypes. PLoS ONE **6.**

Foote, A. D., J. Newton, S. B. Piertney, E. Willerslev and M. T. P. Gilbert, 2009 Ecological, morphological and genetic divergence of sympatric North Atlantic killer whale populations. Molecular Ecology **18:** 5207-5217.

Foote, A. D., J. T. Vilstrup, R. de Stephanis, P. Verborgh, S. C. A. Nielsen *et al.*, 2011c Genetic differentiation among North Atlantic killer whale populations. Molecular Ecology **20:** 629-641.

Ford, J., and G. Ellis, 2006 Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series **316:** 185–199.

Ford, J. K. B., G. M. Ellis and K. C. Balcomb, 2000 *Killer whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington State. Second edition.* . UBC Press, Vancouver, BC, Canada.

Ford, J. K. B., G. M. Ellis, C. O. Matkin, M. H. Wetklo, L. G. Barrett-Lennard *et al.*, 2011a Shark predation and tooth wear in a population of northeastern Pacific killer whales. Aquatic Biology **11:** 213-224.

Ford, J. K. B., B. M. Wright, G. M. Ellis and J. R. Candy, 2010 Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p.

Ford, M. J., 2003 Conservation Units and Preserving Diversity in *Salmonid perspectives on evolution*, edited by A. Hendry. Oxford University Press, Oxford.

Ford, M. J., M. B. Hanson, J. A. Hempelmann, K. L. Ayres, C. K. Emmons *et al.*, 2011b Inferred Paternity and Male Reproductive Success in a Killer Whale (Orcinus orca) Population. Journal of Heredity **102:** 537-553.

Fraser, D. J., and L. Bernatchez, 2001 Adaptive evolutionary conservation: towards a unified concept for defining conservation units. Molecular Ecology **10:** 2741-2752.

Haig, S. M., E. A. Beever, S. M. Chambers, H. M. Draheim, B. D. Dugger *et al.*, 2006 Taxonomic considerations in listing subspecies under the US Endangered Species Act. Conservation Biology **20:** 1584-1594.

Hanson, M., R. Baird, J. Ford, J. Hempelmann-Halos, D. Van Doornik *et al.*, 2010 Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research **11:** 69-82.

Hempelmann, J., 2012 Memorandum from Jennifer Hemplemann to Michael Ford. November 20, 2012 (via email).

Herman, D. P., D. G. Burrows, P. R. Wade, J. W. Durban, C. O. Matkin *et al.*, 2005 Feeding ecology of eastern North Pacific killer whales, Orcinus orca, from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. Marine Ecology Progress Series **302:** 275-291.

Hey, J., R. S. Waples, M. L. Arnold, R. K. Butlin and R. G. Harrison, 2003 Understanding and confronting species uncertainty in biology and conservation. Trends in Ecology & Evolution **18:** 597-603.

Heyning, J., and M. Dahlheim, 1988 Orcinus orca. Mammalian Species **304:** 1-9.

Hilborn, R., S. Cox, F. Gulland, D. Hankin, N. Hobbs *et al.*, 2012 The Effects of Salmon Fisheries on Southern Resident Killer Whales: Final Report of the Independent Science Panel. Prepared with the assistance of D.R. Marmorek and A.W. Hall, ESSA Technologies Ltd., Vancouver, B.C. for National Marine Fisheries Service (Seattle. WA) and Fisheries and Oceans Canada (Vancouver. BC). xv + 61 pp. + Appendices. .

Hoelzel, A. R., 2004 Report on killer whale population genetics for the BRT review on the status of the Southern Resident population. Unpubl. report to BRT. (Available from L. Barre, NOAA Fisheries, NWR, 7600 Sand Point Way NE, Seattle, WA 98115.), pp.

Hoelzel, A. R., J. Hey, M. E. Dahlheim, C. Nicholson, V. Burkanov *et al.*, 2007 Evolution of population structure in a highly social top predator, the killer whale. Molecular Biology and Evolution **24:** 1407-1415.

Hoelzel, A. R., A. Natoli, M. E. Dahlheim, C. Olavarria, R. W. Baird *et al.*, 2002 Low worldwide genetic diversity in the killer whale (*Orcinus orca*): implications for demographic history. Proceedings of the Royal Society of London, Series B **269:** 1467-1473.

Hoyt, E., 1981 *The whale called killer*. E.P. Dutton, New York.

Johns, G. C., and J. C. Avise, 1998 A comparative summary of genetic distances in the vertebrates from the mitochondrial cytochrome b gene. Molecular Biology and Evolution **15:** 1481-1490.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss *et al.*, 2004 2004 Status review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act, pp. 73 in *NOAA Technical Memorandum*. Northwest Fisheries Science Center, Seattle.

Krahn, M. M., D. P. Herman, C. O. Matkin, J. W. Durban, L. Barrett-Lennard *et al.*, 2007 Use of chemical tracers in assessing the diet and foraging regions of eastern North Pacific killer whales. Marine Environmental Research **63:** 91-114.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor *et al.*, 2002 Status Review of Southern Resident killer whales (Orcinus orca) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-54. 133pp.

LeDuc, R., and B. Taylor, 2004 Revision of meeting document LJ/04/KW7, Mitochondrial sequence variation in North Pacific killer whales, Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management, April 30–May 2, 2004, La Jolla, California. Unpubl. report to BRT. (Available from L. Barre, NOAA Fisheries, NWR, 7600 Sand Point Way NE, Seattle, WA 98115.).

Leduc, R. G., K. M. Robertson and R. L. Pitman, 2008 Mitochondrial sequence divergence among Antarctic killer whale ecotypes is consistent with multiple species. Biology Letters **4:** 426-429.

Mallet, J., 1995 A SPECIES DEFINITION FOR THE MODERN SYNTHESIS. Trends in Ecology & Evolution **10:** 294-299.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright and E. P. Bjorkstedt, 2000 Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC **42:** 156p.

Mikhalev, Y., M. ivashin, V. Savusin and F. Zelenaya, 1981 The distribution and biology of killer whales in the Southern Hemisphere. Report of the International Whaling Commission **1:** 551-566.

Mikkelsen, T. S., L. W. Hillier, E. E. Eichler, M. C. Zody, D. B. Jaffe *et al.*, 2005 Initial sequence of the chimpanzee genome and comparison with the human genome. Nature **437:** 69-87.

Morin, P. A., F. I. Archer, A. D. Foote, J. Vilstrup, E. E. Allen *et al.*, 2010 Complete mitochondrial genome phylogeographic analysis of killer whales (Orcinus orca) indicates multiple species. Genome Research **20:** 908-916.

Moritz, C., 1994 Defining 'evolutionarily significant units' for conservation. Trends in Ecology and Evolution **9:** 373-375.

NMFS, 2002 Endangered and Threatened Wildlife and Plants: 12-Month Finding for a Petition To List Southern Resident Killer Whales as Threatened or Endangered Under the Endangered Species Act (ESA). Federal Register **67:** 44133-44138.

NMFS, 2013 Effects of Salmon Fisheries on Southern Resident Killer Whales. http://www.nwr.noaa.gov/protected_species/marine_mammals/cetaceans_whales_dolphins_porpoise/toothed_whales/killer_whales/southern_resident_killer_whale/effects_of_salmon_fisheries_on_southern_resident_killer_whales.html, pp.

Olson, P. A., P. Ensor and S. Kuningas, 2012 Observations of killer whales off East Antarctica, 82-95E, in 2009. Journal of Ceacean Research and Management **12:** 61-64.

Parsons, K., J. Durban, A. Burdin, V. Burkanov, R. Pitman *et al.*, 2013 Geographic patterns of genetic differentiation among killer whales in the northern Pacific. Journal of Heredity **doi: 10.1093/jhered/est037**.

Pilot, M., M. E. Dahlheim and A. R. Hoelzel, 2010 Social cohesion among kin, gene flow without dispersal and the evolution of population genetic structure in the killer whale (Orcinus orca). Journal of Evolutionary Biology **23:** 20-31.

Pitman, R., and P. Ensor, 2003 Three forms of killer whales (*Orcinus orca*) in Antarctic waters. Journal of Ceacean Research and Management **5:** 131-139.

Pitman, R. L., and J. W. Durban, 2012 Cooperative hunting behavior, prey selectivity and prey handling by pack ice killer whales (Orcinus orca), type B, in Antarctic Peninsula waters. Marine Mammal Science **28:** 16-36.

Pitman, R. L., J. W. Durban, M. Greenfelder, C. Guinet, M. Jorgensen *et al.*, 2011 Observations of a distinctive morphotype of killer whale (Orcinus orca), type D, from subantarctic waters. Polar Biology **34:** 303-306.

Pitman, R. L., W. L. Perryman, D. Leroi and E. Eilers, 2007 A dwarf form of killer whale in Antarctica. Journal of Mammalogy **88:** 43-48.

Reeves, R., W. Perrin, B. Taylor, C. Baker and S. Mnesnick, 2004 Report of the workshop on shortcomings of cetacean taxonomy in relation to needs of conservation and management, April 30-May2, 2004 La Jolla, California. . NOAA-TM-NMFS-SWFSC-363**:** 94pp.

Rice, D. W., 1998 *Marine Mammals of the World. Systematics and Distribution.* Allen Press, Lawrence, KS.

Riera, A., J. K. B. Ford, J. Hildebrand and N. Chapman, 2011 Acoustic monitoring of killer whale populations off the west coast of Vancouver Island. Journal of the Acoustic Society of America **129:** 2607.

Riesch, R., L. G. Barrett-Lennard, G. M. Ellis, J. K. B. Ford and V. B. Deecke, 2012 Cultural traditions and the evolution of reproductive isolation: ecological speciation in killer whales? Biological Journal of the Linnean Society **106:** 1-17.

Saulitis, E., C. Matkin, L. Barrett-Lennard, K. Heise and G. Ellis, 2000 FORAGING STRATEGIES OF SYMPATRIC KILLER WHALE (ORCINUS ORCA) POPULATIONS IN PRINCE WILLIAM SOUND, ALASKA. Marine Mammal Science **16:** 94-109.

Schluter, D., 2001 Ecology and the origin of species. Trends in Ecology & Evolution **16:** 372-380.

Schluter, D., 2009 Evidence for Ecological Speciation and Its Alternative. Science **323:** 737-741.

USFWS, and NMFS, 1996 Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register **61:** 4722.

Waples, R. S., 1991 Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. Marine Fisheries Review **53:** 11-22.

Ward, E., M. Ford, R. Kope, J. Ford, A. Velez-Espino *et al.*, 2013 Estimating the impacts of Chinook salmon abundance and prey removal by ocean fishing on Southern Resident killer whale population dynamics. NOAA Technical Memorandum NMFS-NWFSC **in prep**.

Ward, E. J., B. X. Semmens, E. E. Holmes and K. C. Balcomb, 2011 Effects of Multiple Levels of Social Organization on Survival and Abundance. Conservation Biology **25:** 350-355.

Zachos, F. E., M. Apollonio, E. V. Barmann, M. Festa-Bianchet, U. Gohlich *et al.*, 2013 Species inflation and taxonomic artefacts-A critical comment on recent trends in mammalian classification. Mammalian Biology **78:** 1-6.

Zerbini, A. N., J. M. Waite, J. W. Durban, R. LeDuc, M. E. Dahlheim *et al.*, 2007 Estimating abundance of killer whales in the nearshore waters of the Gulf of

Alaska and Aleutian Islands using line-transect sampling. Marine Biology **150:** 1033-1045.

NOAA Technical Memorandum NMFS-NE-209

# Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Regional Office
Gloucester, Massachusetts
February 2008

## Recent Issues in This Series:

191. **Essential Fish Habitat Source Document: Northern Shortfin Squid, *Illex illecebrosus*, Life History and Habitat Characteristics. 2nd ed.** By Lisa C. Hendrickson and Elizabeth M. Holmes. November 2004. v + 36 p., 13 figs., 1 table. NTIS Access. No. PB2005- 101437. [*Online publication only.*]

192. **Essential Fish Habitat Source Document: Atlantic Herring, *Clupea harengus*, Life History and Habitat Characteristics. 2nd ed.** By David K. Stevenson and Marcy L. Scott. July 2005. vi + 84 p., 40 figs., 7 tables. NTIS Access. No. PB2005-107567. [*Online publication only.*]

193. **Essential Fish Habitat Source Document: Longfin Inshore Squid, *Loligo pealeii*, Life History and Habitat Characteristics. 2nd ed.** By Larry D. Jacobson. August 2005. v + 42 p., 20 figs., 1 table. NTIS Access. No. PB2005-110684. [*Online publication only.*]

194. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2005**. By Gordon T. Waring, Elizabeth Josephson, Carol P. Fairfield, and Katherine Maze-Foley, eds. Dana Belden, Timothy V.N. Cole, Lance P. Garrison, Keith D. Mullin, Christopher Orphanides, Richard M. Pace III, Debra L. Palka, Marjorie C. Rossman, and Fredrick W. Wenzel, contribs. March 2006. v + 392 p., 45 figs, 79 tables, 5 app., index. NTIS Access No. PB 2007-104395.

195. **A Large Marine Ecosystem Voluntary Environmental Management System Approach to Fisheries Practices**. By Frank J. Gable. December 2005. v + 84 p., 38 figs., 10 tables. NTIS Access. No. PB____-______.

196. **Essential Fish Habitat Source Document: Haddock, *Melanogrammus aeglefinus*, Life History and Habitat Characteristics. 2nd ed**. By Jon K.T. Brodziak. December 2005. vi + 64 p., 27 figs., 2 tables. NTIS Access. No. PB2006-103439. *[Online publication only.]*

197.Withdrawn from series.

198. **Essential Fish Habitat Source Document: Bluefish, *Pomatomus saltatrix*, Life History and Habitat Characteristics. 2nd ed**. By Jon K.T. Brodziak. December 2005. vi + 89 p., 48 figs., 5 tables, 1 app. NTIS Access. No. PB2006-103439. *[Online publication only.]*

199. **Distribution and Abundance of Fish Eggs Collected during the GLOBEC Broad-Scale Georges Bank Surveys, 1995-1999**. By John D. Sibunka, Donna L. Johnson, and Peter L. Berrien. August 2006. iv + 72 p., 28 figs., 1 table. NTIS Access. No. PB2008-107379. *[Online publication only.]*

200. **Essential Fish Habitat Source Document: Black Sea Bass, *Centropristis striata*, Life History and Habitat Characteristics (2nd ed.** By Amy F. Drohan, John P. Manderson, and David B. Packer. February 2007. vi + 68 p., 33 figs., 2 tables. NTIS Access No. PB2008-107378. *[Online publication only.]*

201. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2006**. By Gordon T. Waring, Elizabeth Josephson, Carol P. Fairfield, and Katherine Maze-Foley, eds. Dana Belden, Timothy V.N. Cole, Lance P. Garrison, Keith D. Mullin, Christopher Orphanides, Richard M. Pace III, Debra L. Palka, Marjorie C. Rossman, and Fredrick W. Wenzel, contribs. March 2007. vi + 378 p., 92 figs, 84 tables, 5 app., index. NTIS Access No. PB2007-112570.

202. **Evaluation of Northern Right Whale Ship Strike Reduction Measures in the Great South Channel of Massachusetts**. By RL Merrick and TVN Cole. March 2007. NTIS Access No. PB 2008-107377.

203. **Essential fish habitat source document: Spiny dogfish, *Squalus acanthias*, life history and habitat characteristics, 2nd edition**. By LL Stehlik. December 2007. NTIS Access No. PB2008-107376.

204. **An Evaluation of the Northeast Region's Study Fleet pilot program and Electronic Logbook System: Phases I and II**. By Michael C. Palmer, Susan E. Wigley, John J. Hoey, and Joan E. Palmer. December 2007. NTIS Access No PB2008-107374.

205. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2007**. By GT Waring, E Josephson, CP Fairfield, and K Maze-Foley, Editors. November 2007. NTIS Access No _______.

206. **Growth of Black Sea Bass (Centropristis striata) in Recirculating Aquaculture Systems.** By Dean M. Perry, David A. Nelson, Dylan H. Redman, Stephan Metzler, and Robin Katersky. October 2007. NTIS Access No. PB2008-107374.

207. **Analysis of Atlantic Sea Scallop (Placopecten magellanicus) Fishery Impacts on the North Atlantic Population of Loggerhead Sea Turtles (Caretta caretta).** By Richard Merrick and Heather Haas. February 2008. NTIS Access No PB2008-107373.

208. **Global Applications of the Large Marine Ecosystem Concept 2007-2010.** By Kenneth Sherman, Marie-Chirstine Aquarone, and Sally Adams. June 2007. NTIS Access No. PB______-_______.

**NOAA Technical Memorandum NMFS-NE-209**

This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

# Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States

Michael R Johnson[1], Christopher Boelke[1], Louis A Chiarella[1], Peter D Colosi[1], Karen Greene[2], Kimberly Lellis-Dibble[3], Heather Ludemann[4], Michael Ludwig[5], Sean McDermott[1], Jill Ortiz[1], Diane Rusanowsky[6], Marcy Scott[1], and Jeff Smith[7]

*[1]NOAA Fisheries Service (NOAA), Northeast Regional Office, 55 Great Republic Dr., Gloucester, MA 01930*
*[2]NOAA, James J. Howard Marine Science Lab, 74 Magruder Rd., Highlands, NJ 07732*
*[3]Current Address: Univ. of Rhode Island, Dept. of Natural Resources Science, Coastal Institute in Kingston, 1 Greenhouse Rd., Kingston, RI 02881*
*[4]Current Address: 646 Shotwell St., San Francisco, CA 94110*
*[5]Current Address: Ocean and Coastal Consultants, 35 Corporate Dr., Suite 1200 Trumbull, CT 06611*
*[6]NOAA, Milford Lab, 212 Rogers Ave., Milford, CT 06460*
*[7]NOAA, Office of Habitat Conservation, 1315 East-West Highway, Silver Spring, MD 20910*

**US DEPARTMENT OF COMMERCE**
**Carlos M Gutierrez, Secretary**
**National Oceanic and Atmospheric Administration**
**Vice Admiral Conrad C Lautenbacher, Jr, USN (ret), Administrator**
**National Marine Fisheries Service**
**James W Balsiger, Acting Assistant Administrator for Fisheries**
**Northeast Regional Office**
**Gloucester, Massachusetts**

**February 2008**

## Editorial Notes

**Species Names:** The NEFSC Editorial Office's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes, mollusks, and decapod crustaceans and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals. Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species.

**Statistical Terms:** The NEFSC Editorial Office's policy on the use of statistical terms in all technical communications is generally to follow the International Standards Organization's handbook of statistical methods.

**Internet Availability:** This issue of the NOAA Technical Memorandum NMFS-NE series is being published both in hard copy and as a Web document in PDF format and can be accessed at: http://www.nefsc.noaa.gov/nefsc/publications/.

# TABLE OF CONTENTS

# LIST OF TABLES

## PREFACE

The genesis of this report was a technical workshop held in Mystic, CT, on January 10-12, 2005 entitled "Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities." The workshop and report were conceived by the Northeast Region Essential Fish Habitat Steering Committee which is composed of representatives from NOAA National Marine Fisheries Service Northeast Regional Office (NERO), NOAA National Marine Fisheries Service Northeast Fisheries Science Center (NEFSC), New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), and the Atlantic States Marine Fisheries Commission (ASMFC). The workshop was sponsored jointly by NOAA National Marine Fisheries Service, NEFMC and ASMFC.

The original intent of the workshop was to provide the necessary information to the NEFMC and MAFMC to assist them in updating the nonfishing impact analyses within their Fishery Management Plans as required by the Essential Fish Habitat (EFH) regulations. As work progressed, we realized that this information would be extremely useful to a much larger audience of agencies, consultants, and components of the public involved in marine and aquatic habitat assessment activities, and so this comprehensive report was developed. For this reason, the scope of impact assessment for this report was expanded to include a more general approach to coastal fishery habitat and is not limited to EFH. Our goal is to ensure that the best scientific information is available for use in making sound decisions with respect to the various environmental reviews and permitting processes conducted within the marine environment.

The comprehensive nature of this report required extensive collaboration among the authors, which includes NOAA National Marine Fisheries Service staff within the NERO Habitat Conservation Division and Headquarters Office of Habitat Conservation (OHC). We would like to thank the participants of the technical workshop who graciously provided their time and expertise towards identifying and assessing the range of impacts that threaten coastal resources in the northeast region of the United States (see appendix for list of participants). We would particularly like to thank the following individuals for their advice, time, and valuable assistance in the preparation and review of this report: Claire Steimle, Northeast Fishery Science Center (NEFSC) – Library Assistance; numerous staff of the NOAA Library; numerous reviewers, including Jen Costanza, Kathi Rodrigues, Dr. David Stevenson, and David Tomey– NOAA National Marine Fisheries Service, NERO; Jeanne Hanson – NOAA National Marine Fisheries Service, Alaska Regional Office; Joanne Delaney – NOAA National Marine Sanctuaries Program; and Ruth M. Ladd –US Army Corps of Engineers, New England District. In addition, we appreciate the advice provided by the technical and editorial reviewers at the NEFSC: Donna A. Busch, Dr. Jarita Davis, Dr. Ashok Deshpande, Dr. David Dow, Laura Garner, Dr. Jon Hare, Clyde L. MacKenzie, Jr., Donald G. McMillan, Dr. Thomas Noji, Dave Packer, and Dr. Robert Reid.

Louis A. Chiarella
Chair, Northeast Region
Essential Fish Habitat Steering Committee

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACZA | ammoniacal copper zinc arsenate |
| ANS | aquatic nuisance species |
| ATOC | Acoustic Thermometry of Ocean Climate |
| AVS | acid volatile sulfides |
| BMP | best management practice |
| BOD | biological oxygen demand |
| C | Celsius |
| CCA | chromated copper arsenate |
| cm | centimeters |
| CSOs | combined sewer overflows |
| CWA | Clean Water Act |
| dB | decibel |
| DC | direct current |
| DDE | dichlorodiphenyl dichloroethylene |
| DDT | dichlorodiphenyl trichloroethane |
| DNA | deoxyribonucleic acid |
| DO | dissolved oxygen |
| ELMR | Estuarine Living Marine Resources |
| EMF | electromagnetic field |
| EEZ | Exclusive Economic Zone |
| EFH | essential fish habitat |
| ESP | electric service platform |
| F | Fahrenheit |
| FMP | fishery management plan |
| ft | feet or foot |
| GIS | geographic information system |
| HAB | harmful algal bloom |
| HARS | Historic Area Remediation Site |
| HEA | Habitat Equivalency Analysis |
| Hz | Hertz |
| IPCC | Intergovernmental Panel on Climate Change |
| km | kilometer |
| L | liter |
| LC50 | chemical concentration which causes the death of 50% of the experimental test animals |
| LFAS | low frequency active sonar |
| LNG | liquefied natural gas |
| LWD | large woody debris |
| m | meter |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| ml | milliliter |
| mm | millimeter |
| MMS | Minerals Management Service |
| MOA | Memorandum of Agreement |
| MPRSA | Marine Protection, Research, and Sanctuaries Act |

| | |
|---|---|
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MSD | marine sanitation device |
| NATO | North Atlantic Treaty Organization |
| NEFMC | New England Fishery Management Council |
| NEPA | National Environmental Policy Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | nonpoint source |
| NS&T | National Status and Trends |
| NRC | National Research Council |
| OCS | Outer Continental Shelf |
| PAH | polycyclic aromatic hydrocarbons |
| PCB | polychlorinated biphenyl |
| pH | the measure of acidity or alkalinity of a solution |
| POP | persistent organic pollutant |
| PPCP | pharmaceuticals and personal care products |
| ppt | parts per thousand |
| s | second |
| SAV | submerged aquatic vegetation |
| SCUBA | self-contained underwater breathing apparatus |
| SURTASS | Surveillance Towed Array Sensor System |
| TBT | tributyltin |
| THC | thermohaline circulation |
| TOC | total organic carbon |
| TOY | time-of-year |
| US ACE | United States Army Corps of Engineers |
| US EPA | United States Environmental Protection Agency |
| μA | microamp |
| μg | micrograms |
| μV | microvolt |

# GLOSSARY OF TERMS

| | |
|---|---|
| alevins | young salmonid fish distinguished by an attached yolk sac |
| alkalinity | the quantitative capacity of water to neutralize an acid |
| amnesic shellfish poisoning | caused by domoic acid, an amino acid, as the contaminant of shellfish |
| anadromous | migrating from the sea to fresh water to spawn |
| anoxia | complete absence of oxygen in aquatic habitats |
| anthropogenic | effects, processes, or materials that are derived from human activities |
| aquatic nuisance species | introduced (nonnative) organisms that produce harmful impacts on aquatic natural resources |
| autotrophic | a class of organism that produces organic compounds from carbon dioxide as a carbon source, by using either light or reactions of inorganic chemical compounds, as a source of energy; also known as a producer in a food chain |
| beach nourishment | the replacement of sand on an eroded beach from an outside source such as an offshore sand deposit, an inlet tidal delta, or an upland sand quarry |
| benthic | in or associated with the seafloor |
| benthos | organisms living on, in, or near the bottom of water bodies |
| bioaccumulation | the accumulation of substances, such as pesticides, methylmercury, or other organic chemicals in an organism or part of an organism |
| biocide | a chemical substance capable of killing different forms of living organisms (e.g., pesticide) |
| borrow pit | an excavation dug to provide material for fill elsewhere; used in aggregate or mineral mining and in beach nourishment |
| carcinogenic substance | cancer causing agent |
| catadromous | migrating from fresh water to the sea to spawn |
| climax community | a community of organisms the composition of which is more or less stable and in equilibrium with existing natural environmental conditions |

| | |
|---|---|
| creosote | a brownish oily liquid consisting chiefly of aromatic hydrocarbons obtained by distillation of coal tar and used especially as a wood preservative |
| cytolysis | the dissolution or destruction of a cell |
| demersal | dwelling at or near the bottom of a body of water |
| denitrification | the process of reducing nitrate and nitrite (highly oxidized forms of nitrogen available for consumption by many groups of organisms) into gaseous nitrogen |
| desalination | any of several processes that remove the excess salt and other minerals from water in order to obtain fresh water suitable for consumption or irrigation |
| diadromous | migratory between fresh and salt waters |
| diel | occurring on a daily basis, such as vertical migrations in some copepods and fish |
| dissolved oxygen | a measure of the amount of gaseous oxygen dissolved in an aqueous solution |
| echolocation | the biological sonar used by dolphins and whales for navigation and foraging |
| ecosystem | a natural unit consisting of all plants, animals, and microorganisms in an area functioning together with all the nonliving physical factors of the environment |
| endocrine disruptor | an exogenous (outside the body) agent that interferes with the production, release, transport, metabolism, binding, action, or elimination of natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes |
| entrainment | the voluntary or involuntary movement of aquatic organisms from the parent water body into a surface diversion or through, under, or around screens, resulting in the loss of the organisms from the population |
| epibiota | attached plants and animals that settle and grow on natural or artificial surfaces |
| epipelagic | part of the open ocean comprising the water column from the surface down to approximately 200 meters |
| estrogenic substances | compounds that mimic female steroid hormones or inhibit male steroid hormones |

| | |
|---|---|
| eutrophication | enrichment of nutrients causing excessive plant growth that can reduce oxygen concentration and kill aquatic organisms |
| extirpate | to eliminate completely certain populations within the range of a given species |
| gas supersaturation | the overabundance of gases in turbulent water, such as at the base of a dam spillway, which can cause a fatal condition in fish |
| genotype | the genetic constituents in each cell of an organism |
| glacial till | an unsorted, unstratified mixture of fine and coarse rock debris deposited by a glacier |
| hardpan | a layer of hard subsoil or clay |
| headwater | the source of water for a river or stream |
| heterotrophic | a class of organism that requires organic substrates to get its carbon for growth and development; also known as a consumer in the food chain |
| hydrophobicity | the property of being water-repellent or tending to repel and not absorb water |
| hyperplasia | an increase in the number of the cells causing an organ or tissue to increase in size |
| hypersaline | salinity well in excess of that of sea water |
| hypertrophy | an increase in the size of an organ or in a select area of the tissue caused by an increase in the size of cells, while the number stays the same |
| hyporheic zone | saturated zone under a river or stream, composed of substrates with interstices filled with water |
| hypoxia | a low oxygen condition in aquatic habitats |
| ichthyoplankton | eggs and larvae of fish that drift in the water column |
| immunotoxicity | adverse effects on the functioning of the immune system that result from exposure to chemical substances |
| impingement | involuntary contact and entrapment of aquatic organisms on the surface of intake screens caused by the approach velocity exceeding the swimming capability of the organism |
| littoral zone | also called the intertidal zone, it lies between the high tide mark and the low tide mark |

| | |
|---|---|
| lotic | pertaining to running water, as opposed to lentic or still waters |
| macroinvertebrate | an animal lacking a backbone and visible without the aid of magnification |
| meroplankton | organisms that are planktonic for only a part of their life cycles, usually the larval stage |
| methylmercury | formed from inorganic mercury by the action of anaerobic organisms that live in aquatic systems and sediments; a bioaccumulative environmental toxin |
| mutagenic | agent causing genetic mutations |
| neurotoxic shellfish poisoning | shellfish poisoning caused by exposure to a group of polyethers called brevetoxins |
| oligohaline | brackish water with a salinity of 0.5 to 5.0 parts per thousand |
| organochlorides | a large, diverse group of organic compounds containing at least one covalently bonded chlorine atom, some of which are considered to be persistent organic pollutants and are harmful to the environment (e.g., PCB, DDT, chlordane, dioxins) |
| organometal | A member of a broad class of compounds whose structures contain both carbon and a metal (e.g., methylmercury and tetra-ethyl lead) - persistent and bioaccumulative environmental toxins |
| osmoregulation | the physiological mechanism for the maintenance of an optimal and constant fluid concentration and pressure in and around the cells |
| paralytic shellfish poisoning | caused by a group of toxins elaborated by planktonic algae (dinoflagellates, in most cases) upon which the shellfish feed |
| parr | developmental stage of young salmonid fish that follows the fry and lasts for one to three years in their native stream before becoming smolts |
| pelagic | associated with the water column |
| phytoplankton | microscopic plants that drift in the water column |
| planktivorous | feeding on plankton (e.g., most fish larvae and many pelagic fishes) |
| pycnocline | a layer of rapid change in water density with depth mainly caused by changes in water temperature and salinity |
| radionuclide | an atom with an unstable nucleus that can occur naturally but can also be artificially produced; also known as radioisotope |

| | |
|---|---|
| redd | an area in gravel where salmonids bury their eggs; also known as nests or gravel nests |
| reflective turbulence | changes in water velocity caused by wave energy reflection from solid structures in the nearshore coastal area, resulting in increased turbidity |
| riparian | land directly adjacent to a stream, lake, or estuary |
| salmonid | belonging to, or characteristic of the family salmonidae, which includes salmon, trout, and whitefish |
| sedimentation | the deposition by settling of suspended solids |
| siltation | sedimentary material consisting of very fine particles intermediate in size between sand and clay |
| smoltification | a suite of physiological, morphological, biochemical, and behavioral changes, including development of the silvery color of adults and a tolerance for seawater, that take place in young salmonid fish they prepare to migrate downstream and enter the sea |
| soil infiltration | the passage of water through the surface of the soil into the soil profile via pores or small openings |
| spermatogenesis | the process by which male gametes are formed in many sexually reproducing organisms |
| synergistic | combined effects being greater than the sum of individual effects |
| tailwater | an area immediately below a dam where the river water is cooler than normal and rich in nutrients |
| tannins | astringent, plant polyphenol compounds that bind and precipitate proteins; used in manufacturing inks and dyes |
| thermocline | a vertical temperature gradient in some layer of a body of water that is appreciably greater than the gradients above and below it |
| time-of-year restrictions | seasonal constraints for dredging to avoid or minimize impacts of sensitive periods in the life-history of an organism, such as spawning, egg development, and migration |
| tonne | sometimes referred to as a metric tonne, the measurement of mass equal to 1,000 kilograms |
| trophic level | the position that an organism occupies in a food chain |

| | |
|---|---|
| turbidity | the cloudiness or haziness of water caused by individual particles or suspended solids |
| volitional fish passage | any type of structure that provides fish passage over, through, or around an obstruction in a river or stream (e.g., dam) that can be successfully achieved under the fish's own power (as opposed to trap and truck methods) |
| xenobiotic | a chemical which is found in an organism but which is not normally produced or expected to be present in it (e.g., pollutants, such as dioxins or PCB congeners) |

# INTRODUCTION

## Report Purpose

This report stems from a workshop entitled "Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities," which was held January 10 – 12, 2005 in Mystic, CT. The workshop convened a group of experts in the field of environmental, marine habitat, and fisheries impact assessment from federal and state government agencies. The goals of the workshop were to: (1) describe known and potential adverse effects of human induced, nonfishing activities on fisheries habitats; (2) create a matrix of the degree of impacts associated with various activities in riverine, estuarine, and marine habitats; and (3) develop a suite of best management practices (BMPs) and conservation recommendations that could be used to avoid or minimize adverse impacts to fisheries habitats. Refer to Chapter One-Technical Workshop on Impacts to Coastal Fisheries Habitat from Nonfishing Activities, for a detailed summary of the technical workshop.

The general purpose and goals of this report are to:

1. Identify human activities that may adversely impact Essential Fish Habitat (EFH) and other coastal fishery habitat. As Stevenson et al. (2004) characterized the impacts to EFH from fishing activities in the northeast region, the focus of this report is on nonfishing activities.
2. Review and characterize existing scientific information regarding human-induced impacts to EFH and other coastal fishery habitat.
3. Provide BMPs and conservation measures that can be implemented for specific types of activities that avoid or minimize adverse impacts to EFH and other coastal fishery habitat.
4. Provide a comprehensive reference document for use by federal and state marine resource managers, permitting agencies, professionals engaged in marine habitat assessment activities, the regulated community, and the public.
5. Ensure that the best scientific information is available for use in making sound decisions with respect to project planning, environmental assessment, and permitting.

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service is mandated to protect and conserve fishery resources, an activity which includes engaging in consultation with federal agencies on actions that may adversely affect NOAA's trust resources. It is anticipated that the information in this report will be used to assist federal agencies and their consultants in the preparation of impact assessments for EFH and other NOAA's trust resources. In addition, this report will assist National Marine Fisheries Service habitat specialists in: (1) reviewing proposed projects; (2) considering potential impacts that may adversely affect NOAA's trust resources; and (3) providing consistent and scientifically supported conservation recommendations. This report will also provide insight for the public and the regulated community on the issues of concern to National Marine Fisheries Service along with approaches to design and implementation of projects that avoid and minimize adverse effects to fish habitat.

## Organization of the Report

The document is organized by activities that may potentially impact EFH and other fishery habitat occurring in riverine, estuarine/coastal, and marine/offshore areas. Chapter One describes the technical workshop that was conducted and presents the results of those discussions and habitat impact evaluations. The major activities that were identified as impacting these three habitat areas include:

- coastal development
- energy-related activities
- alteration of freshwater systems
- marine transportation
- offshore dredging and disposal
- physical and chemical effects of water intake and discharge facilities
- agriculture and silviculture
- introduced/nuisance species and aquaculture
- global effects and other impacts

Each subsequent chapter characterizes impacts associated with the major activities listed above. Each chapter describes the adverse effects of various activities on fishery habitat and the species associated with those habitats, provides the scientific references to support those findings, and concludes with best management practices or conservation recommendations that could be implemented to avoid or minimize those particular adverse effects. Although the activities and effects identified in the technical workshop are reflected in the appropriate chapter, the reader may notice some minor variation in the order and content if the chapter author(s) failed to locate information in the literature on a specific topic or believed additional discussion of effects were warranted. The preparers of this report have attempted to summarize the current knowledge of impacts and effects from existing and potential activities in the coastal areas of the northeast region of the United States. However, the reader should not consider the information in the report as comprehensive for all activities and impacts on fishery habitats. For more detailed analyses and understanding, the reader should refer to the cited references and the most current literature regarding specific activities and impacts.

The BMPs and conservation measures provided in this report are designed to minimize or avoid the adverse effects of human activities on fishery habitat and to promote the conservation and enhancement of fishery habitat. The BMPs and conservation measures provided in this report reflect many of the conservation principals recommended in Hanson et al. (2003). These general principles include: (1) nonwater-dependent actions should not be located in fishery habitat if such actions may have adverse impacts on those resources; (2) activities that may result in significant adverse affects on fishery habitat should be avoided where less environmentally harmful alternatives are available; (3) if alternatives do not exist, the impacts of these actions should be minimized; and (4) environmentally sound engineering and management practices should be employed for all actions that may adversely affect fishery habitat.

The conservation measures and BMPs included with each activity present a series of practices or steps that can be undertaken to avoid or minimize impacts to fishery habitats. Not all of these suggested measures are applicable necessarily to any one project or activity that may adversely affect habitat. More specific or different measures based on the best and most current scientific information may be developed as part of the project planning or regulatory processes. The conservation recommendations and BMPs provided represent a generalized menu of the types of measures that can contribute to the conservation and protection of fishery habitat and other coastal aquatic habitats.

The final chapter contains a brief discussion of the purpose and application of compensatory mitigation used to offset adverse effects on fishery habitat. We have chosen to include a discussion on compensatory mitigation in its own chapter because its application is not generally considered a best management practice or a recommendation to conserve fishery habitat. Instead, compensatory mitigation is a method of offsetting adverse effects after they have occurred. For that reason, compensatory mitigation should be considered only after all measures to avoid and then minimize impacts have been exhausted. Compensatory mitigation should never be used as a first-line conservation measure.

Some of the impact types described in one chapter may also be found in other chapters containing similar impacts or activities. Therefore, the reader may find some redundancy in the various chapters. Because the report's focus was to describe the impacts to living marine resources and habitats associated with specific anthropogenic activities and often have similar adverse affects on living marine resources, some redundancy in the descriptions of impacts between various chapters was unavoidable.

## Characterization of Habitat in the Northwest Atlantic Ocean

The general focus of this report pertains to effects on marine, estuarine, and diadromous fishes and their habitats. However, the preparers of the report have attempted to provide a broad perspective of coastal aquatic habitat and the organisms that depend upon those habitats in an ecosystem context. Although the report often refers to "fishery habitat" or "fish," the definitions of these resources should not necessarily be limited to any particular regulatory or management mandate, such as EFH. The authors have attempted to include information on known or potential impacts that may affect the ecological functions and values for habitats for all species of fish and invertebrates. Because the focus of this report is on impacts to fish and fishery habitats, we have included only limited discussions on impacts specific to marine mammals and sea turtles.

Habitats provide living things with the basic life requirements of nourishment and shelter (Stevenson et al. 2004). According to Deegan and Buchsbaum (2005), a habitat includes the physical environment, the chemical environment, and the many organisms that compose a food web. This report employs a similarly broad definition to discuss the multitude of adverse effects on habitats in the coastal northeastern United States. For example, the quality of the water in which aquatic organisms live, feed, and reproduce is a facet of their habitat, and the presence of contaminants or alterations to the water has important implications on the health of those organisms. Habitats may also provide a broader range of benefits to the ecosystem, such as the way seagrasses physically stabilize the substrate and help recirculate oxygen and nutrients (Stevenson et al. 2004). These habitats do not exist in isolation but are linked through ecological and oceanographic processes that are a part of the larger ecosystem. For example, the movement of the water plays a major role in the interconnection of habitats by transporting nutrients, food, larvae, sediments, and pollutants among them (Tyrrell 2005).

The northwest Atlantic Ocean includes a broad range of habitats with varying physical and biological properties extending from the cold waters of the Gulf of Maine south to the more temperate climate of the Mid-Atlantic Bight. In this region, the oceanographic and physical processes interact to form a network of expansively to narrowly distributed habitat types (Stevenson et al. 2004). The offshore component of this region, also known as the Northeast US Continental Shelf Ecosystem (Sherman et al. 1996), is composed of four distinct subregions: the Gulf of Maine, Georges Bank, the Mid-Atlantic Bight, and the continental slope (Stevenson et al. 2004). In addition, the region contains freshwater rivers and streams that flow towards the sea into numerous bays and estuaries that serve as important refuge and nursery areas for marine species. This report focuses on the three major systems composing this ecosystem: riverine, estuarine/nearshore, and marine/offshore environments.

The habitat classifications described by Jury et al. (1994) and adopted by NOAA as a national standard for organizing its Estuarine Living Marine Resources (ELMR) program's database are useful because they facilitate consideration of physico-chemical interactions in water quality and habitat impacts and implications for aquatic organisms. Conveniently, this approach also aligns with ambient suspended sediment and particulate loads because maximum turbidity zones of temperate, well-mixed estuaries typically coincide with low salinity regions (Herman and Heip 1999). Accordingly, this report has used the three ELMR salinity ranges developed for coastal aquatic habitats to describe "riverine" (<0.5 ppt), "estuarine/nearshore" (0.5-25.0 ppt), and "marine/offshore" (>25.0 ppt) conditions.

## *Riverine*

Riverine habitats, located along the coast of New England and the Mid-Atlantic, provide essential habitat to anadromous and catadromous ("diadromous") fishes. These habitats include freshwater streams, rivers, streamside wetlands, and the banks and associated vegetation that may be bordered by other freshwater habitats (NEFMC 1998). Depending upon the local water velocity and other physical characteristics, riverine systems may include a variety of benthic substrates ranging from exposed bedrock, cobble, and other hard bottom types to extremely unconsolidated, soft bottom material. These features have a great bearing on the fish and invertebrate species that may be present.

Riverine habitats serve multiple purposes including migration, feeding, spawning, nursery, and rearing functions. An important component of a river system also includes the riparian corridor. The term "riparian" refers to the land directly adjacent to a stream, lake, or estuary. A healthy riparian area has vegetation supporting prey items (e.g., insects); contributes necessary nutrients; provides large woody debris that creates channel structure and cover for fish; and provides shade, which controls stream temperatures (NEFMC 1998).

## *Estuarine/nearshore*

Estuaries are the bays and inlets influenced by both the ocean and rivers that serve as the transition zone between fresh and salt water. In the northeastern United States, they also may include the substantial inland reaches of large river systems where salinities exceed 0.5 ppt. For instance, ocean tides influence the lower 153 miles of the Hudson River, and oligohaline salinities (0.5 pp – 5 ppt) can extend well inland under low flow conditions. Typically, the northernmost intrusion of brackish water does not extend past the city of Poughkeepsie, nearly 75 miles north of The Battery at the southern tip of Manhattan, NY.

Estuaries support a community of plants and animals that are adapted to the zone where fresh and salt waters mix. Estuarine habitats fulfill fish and wildlife needs for reproduction, feeding, refuge, and other physiological necessities (NEFMC 1998). Coastal and estuarine features such as salt marshes, mud flats, rocky intertidal zones, sand beaches, and submerged aquatic vegetation are critical to inshore and offshore habitats and fishery resources of the northeastern United States (Stevenson et al. 2004). For example, healthy estuaries include eelgrass beds that protect young fish from predators, provide habitat for fish and wildlife, improve water quality, and can help stabilize sediments. In addition, mud flats, high salt marshes, and saltmarsh creeks also provide productive shallow water habitat for epibenthic fishes and decapods. Inshore habitats are dynamic and heterogeneous environments that support the majority of marine and anadromous fishes at some stage of development (NEFMC 1998).

### *Marine/offshore*

The Gulf of Maine is an enclosed coastal sea, characterized by relatively cold waters and deep basins with a patchwork of various sediment types. Georges Bank is a relatively shallow coastal plateau that slopes gently from north to south and has steep submarine canyons on its eastern and southeastern edge. It is characterized by highly productive, well-mixed waters and strong currents. The Mid-Atlantic Bight is composed of the sandy, relatively flat, gently sloping continental shelf from southern New England to Cape Hatteras, NC. The continental slope begins at the continental shelf break and continues eastward with increasing depth until it becomes the continental rise. It is fairly homogenous, with exceptions at the shelf break, some of the canyons, the Hudson Shelf Valley (offshore New York), and areas of glacially rafted hard bottom (Stevenson et al. 2004).

The offshore benthic habitat features include sand waves, shell aggregates, gravel beds, boulder reefs, and submerged canyons which provide nursery areas for many fish species (NEFMC 1998). Many marine organisms inhabit the stable offshore environment for multiple stages of their life history.

## Essential Fish Habitat

In 1996, the US Congress declared that "one of the greatest long-term threats to the viability of the commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States" (Magnuson-Stevens 1996, sec. 2.a.9.). Along with this declaration, Congress added new habitat conservation provisions to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the federal law that governs US marine fisheries management. The MSA requires that fishery management plans describe and identify essential fish habitat, minimize adverse effects on habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat. Essential fish habitat has been defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (Magnuson-Stevens 1996, sec. 3.10.).

The MSA also requires federal agencies to consult with the Secretary of Commerce, acting through the NOAA's National Marine Fisheries Service, on all actions authorized, funded or undertaken, or proposed to be authorized or undertaken by the agency, that may adversely affect EFH. The process developed for conducting these EFH consultations is described in the EFH regulations (50 CFR §600.905 – 920). In summary, federal agencies initiate consultation by preparing and submitting an EFH assessment to the National Marine Fisheries Service that describes the action, analyzes the potential adverse effects of the action on EFH, and provides the agency's conclusions regarding the effects of the action on EFH. In response, the National Marine Fisheries Service provides the agencies with conservation recommendations to conserve EFH by avoiding, minimizing, mitigating, or otherwise offsetting the adverse effects to EFH. Adverse effect is defined as any impact which reduces the quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of or injury to benthic organisms, prey species, and their habitat and other ecosystem components. Adverse effects may be site-specific or habitat-wide, including individual, cumulative, or synergistic consequences of actions [50 CFR §600.910(a)]. This broad definition of adverse effects has been employed in this report to describe the various activities and sources of nonfishing impacts that can degrade fisheries habitat.

Once the National Marine Fisheries Service provides conservation recommendations, the federal action agencies must provide a detailed response in writing to the Nationial Marine Fisheries Service. The response must include measures proposed for avoiding, mitigating, or offsetting the impact of a proposed activity on EFH. If the federal action agency chooses not to adopt National Marine Fisheries Service's conservation recommendations, it must explain its reasons for not following the recommendations.

## Impacts to Habitat

Habitat alteration and disturbance occur from natural processes and human activities. Deegan and Buchsbaum (2005) placed human impacts to marine habitats into three categories: (1) permanent loss; (2) degradation; and (3) periodic disturbance. Permanent loss of habitat can result from activities such as wetland filling, coastal development, harbor dredging, and offshore mining operations (Robinson and Pederson 2005). Habitat degradation may be caused by physical changes, such as increased suspended sediment loading, overshadowing from new piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Periodic disturbances are created by activities such as trawling and dredging for fish and shellfish and maintenance dredging of navigation channels.

The primary differences between these three categories are that permanent loss is irreversible, habitat degradation may or may not be reversible, and periodic disturbance is generally reversible once the source of disturbance is removed (Deegan and Buchsbaum 2005). These authors indicate that recovery times for degraded habitat depend on the nature of the agent causing the degradation and the physical characteristics of the habitat. Recovery times for periodic disturbances will vary depending on the intensity and periodicity of the disturbance and the nature of the habitat itself. Natural fluctuations in habitats, such as storms and long-term climatic changes, occur independently of anthropogenic impacts.

Deegan and Buchsbaum (2005) state that "habitat quantity is a measure of the total area available, while habitat quality is a measure of the carrying capacity of an existing habitat." Generally, activities that lead to a permanent loss of habitat reduce the quantity of habitat, whereas habitat degradation and periodic disturbances result in a loss of habitat quality. The reduced quality of habitat (e.g., siltation, eutrophication, and alteration of salinity and food webs) may be equally damaging to the biological community as a loss in habitat quantity. As Deegan and Buchsbaum (2005) have noted, "the physical structure of the habitat does not need to be directly altered for negative consequences to occur." For example, reductions in water quality can impair and limit the ability of aquatic organisms to grow, feed, and reproduce.

The end point of gradual declines in the quality of habitat can be the complete loss of habitat structure and function (Deegan and Buchsbaum 2005). Losses of habitat quantity and quality may reduce the ability of a region to support healthy and productive fish populations. From the population perspective, the loss of habitat quantity and quality creates stresses on a population. Populations that are stressed by one or more factors can be more susceptible to stresses caused by other factors (Robinson and Pederson 2005), resulting in cumulative effects. These authors call for a holistic approach to fishery management: one that considers the interactions among exploitation, contaminants, and habitat degradation on various fish stocks.

Lotze et al. (2006) show that severe depletion of marine resources (i.e., 50% reduction in abundance level) first began with the onset of European colonization. This study found that 45% of species depletions and 42% of extinctions involved multiple human impacts, mostly exploitation and habitat loss. Seventy eight percent of resource recoveries are attributed to both habitat protection and restricted exploitation, while only 22% of recoveries are attributed to reduced exploitation alone (Lotze et al. 2006). These authors also conclude that reduced exploitation, increased habitat protection, and improved water quality need to be considered together and that the cumulative effects of multiple human interventions must be included in both management and conservation strategies.

## References for Introduction

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Herman P, Heip C. 1999. Biogeochemistry of the MAximum TURbidity zone of Estuaries (MATURE): some conclusions. Journal of Marine Systems 22:89-104.

Jury S, Field J, Stone S, Nelson D, Monaco M. 1994. Distribution and abundance of fishes and invertebrates in North Atlantic estuaries. Silver Spring (MD): NOAA/NOS Strategic Environmental Assessments Division. ELMR Report 13. 221 p.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-9.

Magnuson-Stevens Fishery Conservation and Management Act. 1996. P.L. 94-265, 16 U.S.C. 1801 et seq. [Internet]. [cited 2008 Jul 31]. Available from: http://www.nmfs.noaa.gov/sfa/magact/.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Robinson WE, Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.

Sherman, K, Jaworski NA, Smayda TJ, editors. 1996. The Northeast Shelf Ecosystem: assessment, sustainability, and management. Cambridge (MA): Blackwell Science. 564 p.

Stevenson D, Chiarella L, Stephan D, Reid R, Wilhelm K, McCarthy J, Pentony M. 2004. Characterization of the fishing practices and marine benthic ecosystems of the Northeast U.S. Shelf, and an evaluation of the potential effects of fishing on essential fish habitat. Woods Hole (MA): National Marine Fisheries Service, Northeast Fisheries Science Center, NOAA Technical Memorandum NMFS-NE-181. 179 p.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

# CHAPTER ONE: TECHNICAL WORKSHOP ON IMPACTS TO COASTAL FISHERIES HABITAT FROM NONFISHING ACTIVITIES

## Introduction

A technical workshop was hosted by the Northeast Region Essential Fish Habitat Steering Committee on January 10-12, 2005 in Mystic, CT, to seek the views and recommendations of approximately 40 scientists, resource managers, and other marine resource professionals on threats to fishery habitat from nonfishing activities in the northeast coastal region. The participants of the workshop, entitled *Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities*, were federal and state environmental managers and regulators, as well as individuals from academic institutions and other organizations that have expertise and knowledge of various human-induced impacts on coastal environmental resources. A list of workshop participants and their affiliations is provided in the appendix of this report. The workshop's primary purpose was to convene marine resource professionals to review and evaluate existing information on nonfishing impacts for the purpose of updating, as necessary, fishery management plans under the New England and Mid-Atlantic Fishery Management Councils. In addition, the National Marine Fisheries Service sought to develop a nonfishing impacts reference document for use by professionals engaged in marine habitat assessment, permitting agencies, and state and federal marine resource managers. The information gathered during the workshop was used by the Northeast Region's Habitat Conservation Division staff to prepare selected chapters in the report. In general, the activities and effects contained within the various chapters of this report reflect the categories of activities and effects evaluated and discussed during the workshop.

The specific goals/tasks of the workshop included:

1. Identify all known and potential adverse effects for each category of nonfishing activity by life history strategies or stages (i.e., benthic/demersal and pelagic) and ecosystem strata (i.e., riverine, estuarine, and marine). This list of activities may also include adverse impacts to identified prey species or other specific life history requirements for species.
2. Create a matrix of nonfishing impacts for life history strategies/stages and ecosystem strata and ask the participants of the workshop to score the severity of each impact by using a relative scoring method.
3. Develop a suite of conservation measures and best management practices (BMPs) intended to avoid and minimize the adverse effects on fishery habitat and resources.
4. Identify possible information and data limitations and research needs in assessing impacts on fishery habitat or measures necessary to avoid and minimize those impacts.

Conservation measures were, to the extent possible, based on methods and technologies that have been evaluated through a scientific, peer-reviewed process. The intent was to develop recommendations that provide resource managers and regulators with specific methods and technologies yet have flexibility in their applications for various locations or project types. Ideally, providing a suite of conservation measures appropriate for various activities would give the end user several options of recommendations to consider.

Based upon the results of the workshop and effects scoring, some recommended research needs were developed. Identified research needs included basic life history requirements for some species and habitat types, physiological and biochemical responses of organisms to various physical and chemical perturbations and stressors, and technological advances in understanding or solutions to impact assessment and mitigation. Refer to the Conclusions and Recommendations chapter at the end of this report for a discussion on recommended research.

The format of the two-day workshop consisted of a series of breakout sessions, attended by the workshop participants, which represented the primary categories of nonfishing activities believed to threaten fishery resources and habitats in the northeast coast. There were ten separate breakout sessions conducted during the workshop, which are reflected in the chapters of this report. For each of the breakout sessions, a matrix of activities and known or potential adverse effects to fishery habitat, prepared by the workshop organizers, was reviewed by the workshop participants. The participants were encouraged to openly discuss and evaluate the relevance and significance for each of the activities and effects and to provide any additional activities and effects not included in the matrix. A large number of nonfishing activities occur within the coastal region and have a wide range of effects and intensities on fishery habitat. Each activity type and effect identified was evaluated in the context of life history strategies or stages (i.e., benthic and demersal) and ecosystem type or strata (i.e., riverine, estuarine/nearshore, and marine/offshore), in order to identify the importance of those factors. Following an open discussion, the participants were asked to score, by life history strategies/stages and ecosystem strata, the various activities and adverse effects on the impact matrix. In addition, participants were asked to include specific and relevant "conservation recommendations" and BMPs to avoid and minimize adverse effects to fishery habitat and resources.

On the last day of the workshop, the participants engaged in an informal discussion on the significance of cumulative effects and how multiple and additive effects can influence impacts to fishery habitat and resources. While the discussions were general in nature and few specifics of cumulative effects were discussed, there was a general agreement that cumulative effects are important and should play a larger role in assessment of habitat impacts. We found that the scores provided by the participants in the impact matrices for most breakout sessions to be relatively consistent throughout. While the variability in scores for some impact categories was high, we believe that the mean and median values for most effects' scores provide an accurate reflection of professional judgment by the participants. The relatively high variability in the scores of some activity types and effects may be due to varying interpretations of ecosystem strata and life history strategies or stages by the participants.

## Effects Scoring System

Because one workshop goal was to assess the severity or degree of threat for known and potential impacts to fishery habitats, the workshop organizers strived to develop a semiquantitative scoring system that could measure the relative impacts for each activity and effect based upon the professional judgment of the participants. Developing defined values for measuring the significance of adverse effects for an activity is difficult and can depend upon the type of habitat being affected; the characteristic, intensity, and duration of the activity and disturbance; and a number of natural physical, chemical, and biological processes that may be occurring in the area and at the time of the activity. For this reason, the workshop organizers chose a semiquantitative scoring system with a range from 0 to 5, with a 1 being the lowest impact and a 5 being the highest impact. A "0" was used if an impact is not expected to occur or is not applicable, and a "UN" (unknown) was used if the participant does not know the degree of impact for a particular activity.

We believe that a relative scoring method that allows for flexibility and professional judgment in assigning a value for an effect is better than an absolute scoring system that has discreet and predefined values. Using a relative scoring range of 0 through 5 provided the participants a choice from a continuum of impact values for each effect and avoids the difficulty in finding consensus for the definition of predefined values. We then calculated the mean and median values of each effect and assigned a qualitative value of the threat for each effect by using the following criteria:

If either the mean or median value was greater than or equal to 4.0, a “high” index score was assigned; if the mean value was between 2.1 and 3.9, a “medium” index score was assigned; and if the mean value was less than or equal to 2.0, a “low” index score was assigned.

Note: We defined the “high” index score to include either mean or median values in order to be risk averse in identifying activities that are known to be or may be a potentially high threat. Only mean values were used in assessing “medium” and “low” index scores.

## Workshop Summary

The results of the workshop scoring in each session are listed in Table 1 through 10. “High,” “medium,” and “low” index scores are notated as H, M, and L, respectively. As might be expected, there were positive correlations between the highest scoring effects and the ecosystem types in which those activities generally occur. For example, the high scoring effects in the alteration of freshwater systems and agriculture and silviculture sessions were generally all in the riverine ecosystem. Except for the offshore dredging and disposal session, there were fewer effects that were scored high in the marine/offshore ecosystem compared to the riverine and estuarine/nearshore ecosystems. This suggests the participants viewed the intensity of effects from nonfishing impacts to decrease as the distance from the activity increases. As one might expect, many of the far field effects that scored high were those activities that affect the water column (e.g., ocean noise, impacts to water quality) or effects that are capable of being transported by currents (oil spills or drilling mud releases). In addition, the global effects and other impacts session had high scores more evenly distributed across all ecosystems because of the nature of the impacts discussed in this session (e.g., climate change, atmospheric deposition, ocean noise). The number of activities and threats identified in the coastal development session were greater than other sessions because of the cross cutting nature of activities associated with human coastal development. Because of this, some activity types and effects assessed in the coastal development session were discussed to some degree in other sessions.

Some sessions had index scores with relatively high variability. For example, the scores for all activity types of the offshore dredging and disposal session had relatively low mean values and high standard deviations for effects in the estuarine/nearshore ecosystem. About half of the participants in this session either did not provide a score for impacts in the riverine or estuarine/nearshore ecosystems, or they marked them as “not-applicable.” Participants who provided a score for these two ecosystems generally scored them relatively high. This suggests a difference in participants’ interpretation of where “offshore” activities are located. Specifically, some individuals may consider the “offshore” area to be within close enough proximity of the nearshore and estuarine environments to adversely affect these areas, while others may perceive the “offshore” area to be too far removed to have a noticeable effect. There were activities in other sessions, such as beach nourishment in coastal development, with scores with high standard deviations. The high variability in perceived threats may be a reflection of regional perspectives. While the majority of the participants involved in this workshop were from the New England region, about one-quarter of the participants were from the mid-Atlantic or southeast regions where beach nourishment projects are much more common. The associated impacts to benthic habitats from beach nourishment are also generally thought to be greater in the New England (where cobble or hard bottom habitats may be present) and south Atlantic (where live bottom habitats may be present) regions than in the mid-Atlantic. However, because the responses of the workshop participants were anonymous, it was not possible to test this hypothesis.

Many of the effects that were scored as high in the workshop sessions were those that are well documented in the literature as having adverse effects on coastal resources. For example, nutrient enrichment and siltation/sedimentation effects were scored as high in nearly all workshop sessions, demonstrating the widely accepted views that these impacts translate to general reductions in the quality and quantity of fishery resources and habitats. Some of the more unexpected results of the workshop session scores are those effects that had high mean and/or median values but may be a topic that does not have a wealth of research documenting those impacts. Some of these results may be based upon a collective judgment by the participants that these activities or effects require additional scientific investigations to resolve the perceived risks and concerns. In several of these effects or activities, the authors of the associated report chapters were unable to locate information in the scientific literature regarding those threats. For example, release of pharmaceuticals and endocrine disruptors were two effects that were scored high in the workshop session, and yet the potential scope and intensity of adverse effects that these chemicals have on fishery resources has not been thoroughly investigated.

Those activities and effects considered by the workshop participants to have “high” threats to fishery habitat warrant further investigations, including research in characterizing and quantifying these impacts on fishery resources, as well as investigating methods for avoiding and/or minimizing the impacts. Refer to the Conclusions and Recommendations chapter for further discussions regarding the workshop results.

**Table 1. Habitat impact categories in coastal development workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Nonpoint Source Pollution and Urban Runoff | Nutrient loading/eutrophication | H | H | M | H | H | M |
| | Loss/alteration of aquatic vegetation | H | H | L | H | H | L |
| | Release of petroleum products | M | M | M | M | M | M |
| | Alteration of water alkalinity | M | M | L | M | M | L |
| | Release of metals | H | H | M | M | H | M |
| | Release of radioactive wastes | M | M | L | M | M | L |
| | Release of pesticides | H | H | M | H | H | M |
| | Release of pharmaceuticals | H | M | L | H | H | L |
| | Alteration of temperature regimes | H | M | L | H | M | L |
| | Sedimentation/turbidity | H | H | L | H | H | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Introduction of pathogens | M | M | L | M | M | L |
| Road Construction and Operation | Release of sediments in aquatic habitat | H | M | L | M | M | L |
| | Increased sedimentation/turbidity | H | H | L | H | H | L |
| | Impaired fish passage | H | M | L | H | H | L |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | H | L | H | H | L |
| | Introduction of exotic invasive species | M | M | L | M | M | L |
| | Loss/alteration of aquatic vegetation | H | H | L | H | H | L |
| | Altered tidal regimes | H | H | L | H | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Fragmentation of habitat | H | M | L | H | H | L |
| | Altered salinity regimes | M | M | L | M | M | L |
| Flood Control/ Shoreline Protection | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered sediment transport | H | H | L | H | H | L |
| | Alteration/loss of benthic habitat | H | H | L | M | M | L |
| | Reduction of dissolved oxygen | M | M | L | M | M | L |
| | Impaired fish passage | H | M | L | H | M | L |
| | Alteration of natural communities | H | M | L | M | M | L |
| | Impacts to riparian habitat | H | M | L | H | M | L |
| | Loss of intertidal habitat | H | H | L | M | H | L |
| | Reduced ability to counter sea level rise | H | H | L | M | H | L |
| | Increased erosion/accretion | H | H | L | H | H | L |
| Beach Nourishment | Altered hydrological regimes | M | M | L | M | M | L |
| | Altered temperature regimes | L | L | L | L | L | L |
| | Altered sediment transport | M | M | L | M | M | L |
| | Alteration/loss of benthic habitat | M | M | L | L | M | L |
| | Alteration of natural communities | M | M | M | L | M | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |

**Table 1 (continued). Habitat impact categories in coastal development workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshor | Riverine | Estuarine/ Nearshore | Marine/ Offshor |
| Wetland Dredging and Filling | Alteration/loss of habitat | H | H | L | H | H | L |
| | Loss of submerged aquatic vegetation | H | H | L | M | H | L |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Reduction of dissolved oxygen | M | M | L | M | M | L |
| | Release of nutrients/eutrophication | M | M | L | M | M | L |
| | Release of contaminants | M | M | L | M | M | L |
| | Altered tidal prism | M | M | L | M | M | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Loss of fishery productivity | H | H | L | H | H | L |
| | Introduction of invasive species | M | M | L | M | M | L |
| | Loss of flood storage capacity | H | H | L | H | H | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |
| Overwater Structures | Shading impacts to vegetation | M | M | L | M | M | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Benthic habitat impacts | M | M | L | M | M | L |
| | Increased erosion/accretion | M | M | L | M | M | L |
| | Eutrophication from bird roosting | M | M | L | M | M | L |
| | Shellfish closures because of bird roosting | H | M | L | M | M | L |
| | Changes in predator/prey interactions | H | H | L | H | H | L |
| Pile Driving and Removal | Energy impacts | M | M | L | M | M | L |
| | Benthic habitat impacts | M | M | L | M | M | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Shading impacts to vegetation | M | M | L | M | M | L |
| | Changes in hydrological regimes | M | M | L | M | M | L |
| | Changes in species composition | M | M | L | M | M | L |
| Marine Debris | Entanglement | M | M | L | M | M | L |
| | Ingestion | L | M | L | M | M | M |
| | Contaminant releases | L | M | L | L | M | M |
| | Introduction of invasive species | M | M | L | M | M | M |
| | Introduction of pathogens | L | M | L | L | M | M |
| | Conversion of habitat | L | M | L | L | M | L |

**Table 2. Habitat impact categories in energy-related activities workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Petroleum Exploration, Production, and Transportation | Underwater noise | M | M | M | M | M | M |
| | Habitat conversion | H | H | H | H | H | M |
| | Loss of benthic habitat | M | H | M | M | M | M |
| | Contaminant discharge | M | H | M | M | H | M |
| | Discharge of debris | M | M | M | M | M | L |
| | Oil spills | H | H | H | H | H | H |
| | Siltation/sedimentation/turbidity | M | M | M | M | M | M |
| | Resuspension of contaminants | M | H | M | M | M | L |
| | Impacts from clean-up activities | H | H | M | M | H | M |
| Liquified Natural Gas | Habitat conversion | H | H | M | M | M | M |
| | Loss of benthic habitat | H | H | M | M | M | L |
| | Discharge of contaminants | H | H | H | H | H | H |
| | Discharge of debris | M | M | M | M | M | L |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | M |
| | Resuspension of contaminants | M | H | M | M | H | L |
| | Entrainment/impingement | M | M | M | M | H | M |
| | Alteration of temperature regimes | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | L | M | M | L |
| | Underwater noise | M | M | M | H | H | M |
| | Release of contaminants | H | H | M | H | H | M |
| | Exclusion zone impacts | M | M | L | M | M | L |
| | Physical barriers to habitat | M | M | M | M | M | L |
| | Introduction of invasive species | H | H | M | H | M | M |
| | Vessel impacts | H | H | L | M | M | L |
| | Benthic impacts from pipelines | H | H | M | M | M | M |
| Offshore Wind Energy Facilities | Loss of benthic habitat | M | H | H | L | M | M |
| | Habitat conversion | M | H | H | L | M | M |
| | Siltation/sedimentation/turbidity | L | M | M | L | M | M |
| | Resuspension of contaminants | L | M | L | L | M | L |
| | Alteration of hydrological regimes | L | M | M | L | M | M |
| | Altered current patterns | L | M | M | L | M | M |
| | Alteration of electromagnetic fields | L | L | L | L | L | L |
| | Underwater noise | L | L | M | L | M | H |
| | Alteration of community structure | M | H | M | L | H | M |
| | Erosion around structure | L | M | M | L | L | L |
| | Spills associated w/ service structure | M | H | M | L | M | M |

**Table 2 (continued). Habitat impact categories in energy-related activities workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Wave/Tidal Energy Facilities | Habitat conversion | H | H | M | M | M | M |
| | Loss of benthic habitat | H | H | M | M | M | L |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | L |
| | Resuspension of contaminants | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | M | M | H | L |
| | Altered current patterns | M | M | M | M | H | M |
| | Entrainment/impingement | M | M | L | H | H | M |
| | Impacts to migration | M | M | L | H | M | L |
| | Electromagnetic fields | L | L | L | L | L | L |
| Cables and Pipelines | Loss of benthic habitat | H | H | M | L | M | L |
| | Habitat conversion | H | H | M | M | M | M |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | M |
| | Resuspension of contaminants | H | H | M | M | M | M |
| | Altered current patterns | M | M | M | L | M | L |
| | Alteration of electromagnetic fields | L | L | L | L | L | L |
| | Underwater noise | L | L | L | L | M | M |
| | Alteration of community structure | M | M | M | M | M | M |
| | Erosion around structure | L | M | M | L | M | M |
| | Biocides from hydrostatic testing | M | M | M | M | M | M |
| | Spills associated w/ service structure | H | H | M | M | M | M |
| | Physical barriers to habitat | H | H | H | L | L | L |
| | Impacts to submerged aquatic vegetation | M | H | M | M | M | L |
| | Water withdrawal | M | M | L | H | H | L |
| | Impacts from construction activities | M | H | H | M | M | M |
| | Impact from maintenance activities | M | M | M | L | M | M |
| | Thermal impacts associated with cables | L | L | L | L | L | L |
| | Impacts associated with armoring of pipe | M | M | M | L | L | L |
| | Impacts to migration | H | H | H | L | L | L |

**Table 3. Habitat impact categories in alteration of freshwater systems workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Dam Construction /Operation | Impaired fish passage | H | H | L | H | H | L |
| | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered temperature regimes | H | H | L | H | M | L |
| | Altered sediment/ large woody debris transport | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Alteration of extent of tide | H | H | L | H | H | L |
| | Alteration of wetlands | H | H | L | H | H | L |
| | Change in species communities | H | M | L | H | M | L |
| | Bank erosion because of drawdown | M | L | L | M | L | L |
| | Riparian zone development | H | M | L | H | M | L |
| | Acute temperature shock | H | M | L | H | M | L |
| Dam Removal | Release of contaminated sediments | H | H | L | H | M | L |
| | Alteration of wetlands | H | M | L | H | M | L |
| Stream Crossings | Impacts to fish passage | H | M | L | H | M | L |
| | Alteration of hydrological regimes | H | M | L | H | M | L |
| | Bank erosion | H | L | L | M | L | L |
| | Habitat conversion | H | M | L | H | M | L |
| Water Withdrawal/ Diversion | Entrainment and impingement | M | M | L | H | M | L |
| | Impaired fish passage | H | H | L | H | H | L |
| | Altered hydrological regimes | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Altered temperature regimes | H | H | L | H | M | L |
| | Release of nutrients/eutrophication | H | M | L | H | M | L |
| | Release of contaminants | H | M | L | H | M | L |
| | Altered stream morphology | H | L | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Change in species communities | H | M | L | H | H | L |
| | Alteration in groundwater levels | H | L | L | H | L | L |
| | Loss of forested/palustrine wetlands | H | L | L | H | L | L |
| | Impacts to water quality | H | M | L | H | M | L |
| | Loss of flood storage | M | L | L | M | L | L |

**Table 3 (continued). Habitat impact categories in alteration of freshwater systems workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Dredging and Filling, Mining | Reduced flood water retention | H | M | L | H | M | L |
| | Reduced nutrient uptake and release | M | M | L | M | M | L |
| | Reduced detrital food source | H | M | L | M | M | L |
| | Altered hydrological regimes | H | M | L | H | M | L |
| | Increased storm water runoff | H | M | L | H | M | L |
| | Loss of riparian and riverine habitat | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | L | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Release of nutrients/eutrophication | H | M | L | H | H | L |
| | Release of contaminants | H | M | L | H | M | L |
| | Loss of submerged aquatic vegetation | H | H | L | H | H | L |
| | Change in species communities | H | H | L | H | M | L |

**Table 4. Habitat impact categories in marine transportation workshop session (N=18)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Construction and Expansion of Ports and Marinas | Loss of benthic habitat | H | H | H | M | M | M |
| | Siltation/sedimentation/turbidity | H | H | M | M | M | M |
| | Contaminant releases | H | H | M | M | H | M |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Altered tidal prism | M | H | L | M | H | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Underwater blasting/noise | M | M | L | M | M | M |
| | Loss of submerged aquatic vegetation | H | H | M | H | H | M |
| | Conversion of substrate/habitat | H | H | M | M | M | M |
| | Loss of intertidal flats | H | H | L | L | M | L |
| | Loss of water column | M | M | L | H | H | L |
| | Altered light regime | M | M | L | M | M | L |
| | Derelict structures | M | M | L | M | M | L |
| Operations and Maintenance of Ports and Marinas | Contaminant releases | H | H | M | M | M | M |
| | Storm water runoff | H | H | M | M | M | L |
| | Underwater noise | M | M | L | M | M | L |
| | Alteration of light regimes | M | M | L | M | M | L |
| | Derelict structures | M | M | L | L | L | L |
| | Mooring impacts | M | M | L | L | L | L |
| | Release of debris | M | M | L | M | L | L |
| Operation and Maintenance of Vessels | Impacts to benthic habitat | H | H | L | M | M | L |
| | Resuspension of bottom sediments | M | M | L | M | M | L |
| | Erosion of shorelines | M | M | L | M | M | L |
| | Contaminant spills and discharges | M | H | M | M | H | M |
| | Underwater noise | M | M | M | M | M | M |
| | Derelict structures | M | M | L | L | L | L |
| | Increased air emissions | L | L | L | L | L | L |
| | Release of debris | M | M | L | L | L | L |
| Navigation Dredging | Conversion of substrate/habitat | H | H | M | M | M | L |
| | Loss of submerged aquatic vegetation | H | H | M | H | H | L |
| | Siltation/sedimentation/turbidity | H | H | M | H | M | L |
| | Contaminant releases | H | H | M | M | M | M |
| | Release of nutrients/eutrophication | M | M | M | M | M | L |
| | Entrainment and impingement | M | M | M | M | M | L |
| | Underwater blasting/noise | M | M | L | M | M | L |
| | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered tidal prism | M | M | L | M | M | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | H | H | L | M | M | L |
| | Loss of intertidal flats | H | H | L | H | H | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Contaminant source exposure | M | M | M | M | M | L |

**Table 5. Habitat impact categories in offshore dredging and disposal workshop session (N=22)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Offshore Mineral Mining | Loss of benthic habitat types | L | L | H | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | L |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Changes in bottom topography | L | L | M | L | L | L |
| | Changes in sediment composition | L | L | H | L | L | L |
| | Sediment transport from site (erosion) | L | L | M | L | L | L |
| | Impacts to water quality | L | L | M | L | L | M |
| | Release of contaminants | L | L | M | L | L | M |
| | Change in community structure | L | L | H | L | L | M |
| | Changes in water flow | L | L | M | L | L | M |
| | Noise impacts | L | L | L | L | L | M |
| Petroleum Extraction | Contaminant releases | L | L | H | L | L | H |
| | Drilling mud impacts | L | L | H | L | L | H |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Release of debris | L | L | M | L | L | L |
| | Noise impacts | L | L | M | L | L | M |
| | Changes in light regimes | L | L | M | L | L | M |
| | Habitat conversion | L | L | M | L | L | M |
| | Pipeline installation | L | L | M | L | L | L |
| Offshore Dredge Material Disposal | Burial/disturbance of benthic habitat | L | M | H | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | M |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Release of contaminants | L | L | M | L | L | M |
| | Release of nutrients/eutrophication | L | L | M | L | L | M |
| | Altered hydrological regimes | L | L | M | L | L | M |
| | Altered current patterns | L | L | M | L | L | M |
| | Changes in bottom topography | L | L | M | L | L | L |
| | Changes in sediment composition | L | L | H | L | L | L |
| | Changes in water bathymetry | L | L | M | L | L | L |
| Fish Waste Disposal | Introduction of pathogens | L | L | H | L | L | H |
| | Release of nutrients/eutrophication | L | L | H | L | L | H |
| | Release of biosolids | L | L | H | L | L | M |
| | Loss of benthic habitat types | L | L | H | L | L | L |
| | Behavioral affects | L | L | M | L | L | M |
| Vessel Disposal | Release of contaminants | L | L | M | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | M |
| | Changes in bathymetry | L | L | M | L | L | L |
| | Changes in hydrodynamics | L | L | M | L | L | M |
| | Changes in community structure | L | L | H | L | L | M |
| | Impacts during deployment | L | L | M | L | L | M |
| | Release of debris | L | L | M | L | L | L |

**Table 6. Habitat impact categories in chemical effects: water discharge facilities workshop session (N=19)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Sewage Discharge Facilities | Release of nutrients/eutrophication | H | H | H | H | H | H |
| | Release of contaminants | H | H | H | H | H | H |
| | Impacts to submerged aquatic vegetation | H | H | M | H | H | M |
| | Reduced dissolved oxygen | H | H | M | H | H | M |
| | Siltation/sedimentation/turbidity | H | H | M | H | H | M |
| | Impacts to benthic habitat | H | H | M | M | M | M |
| | Changes in species composition | H | H | M | H | H | M |
| | Trophic level alterations | H | H | M | H | H | M |
| | Introduction of pathogens | H | H | M | M | H | M |
| | Introduction of harmful algal blooms | H | H | H | H | H | M |
| | Bioaccumulation/biomagnification | H | H | H | H | H | M |
| | Behavioral avoidance | M | H | M | M | H | M |
| | Release of pharmaceuticals | M | M | M | M | M | M |
| Industrial Discharge Facilities | Alteration of water alkalinity | H | M | M | M | M | L |
| | Release of metals | H | H | M | M | M | M |
| | Release of chlorine compounds | H | H | M | H | H | M |
| | Release of pesticides | H | H | M | H | H | M |
| | Release of organic compounds | H | H | H | M | H | M |
| | Release of petroleum products | H | H | M | M | H | M |
| | Release of inorganic compounds | H | H | M | H | H | M |
| | Release of organic wastes | M | M | M | M | M | M |
| | Introduction of pathogens | M | M | M | M | M | M |
| Combined Sewer Overflows | Potential for all of the above effects | H | H | H | H | H | H |

**Table 7. Habitat impact categories in physical effects: water intake and discharge facilities workshop session**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Discharge Facilities | Scouring of substrate | M | M | L | L | L | L |
| | Turbidity/sedimentation | H | H | M | M | M | L |
| | Alteration of sediment composition | H | H | M | L | L | L |
| | Reduced dissolved oxygen | H | H | M | H | H | L |
| | Alteration of salinity regimes | H | H | L | H | H | M |
| | Alteration of temperature regimes | H | H | M | H | H | M |
| | Conversion/loss of habitat | M | M | M | M | M | M |
| | Habitat exclusion/avoidance | H | H | L | H | H | L |
| | Restrictions to migration | H | H | L | H | H | L |
| | Acute toxicity | M | H | M | H | H | M |
| | Behavioral changes | M | M | L | M | M | L |
| | Cold shock | M | M | M | H | M | L |
| | Stunting of growth in fishes | M | M | L | M | M | L |
| | Attraction to flow | H | H | M | H | H | M |
| | Alteration of community structure | H | H | M | H | H | M |
| | Changes in local current patterns | M | M | L | M | M | L |
| | Physical/chemical synergies | M | H | M | M | M | M |
| | Increased need for dredging | H | H | L | H | H | L |
| | Ballast water discharge | H | H | M | M | M | M |
| | Gas-bubble disease/mortality | M | M | L | M | H | L |
| | Release of radioactive wastes | H | H | M | H | H | M |
| Intake Facilities | Entrainment/impingement | H | H | H | H | H | H |
| | Alteration of hydrological regimes | H | H | M | H | H | L |
| | Flow restrictions | H | H | L | H | H | L |
| | Construction related impacts | H | M | M | M | M | M |
| | Conversion/loss of habitat | H | H | M | H | H | M |
| | Seasonal loss of habitat | M | M | L | M | M | M |
| | Backwash (cleaning of system) | M | M | L | M | M | L |
| | Alteration of community structure | H | H | L | H | H | L |
| | Increased need for dredging | H | H | M | H | H | L |
| | Ballast water intake | H | H | M | H | H | M |

**Table 8. Habitat impact categories in agriculture and silviculture workshop session (N=11)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Cropland, Rangelands, Livestock, and Nursery Operations | Release of nutrients/eutrophication | H | H | L | H | H | L |
| | Bank/soil erosion | H | H | L | M | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Siltation/sedimentation/turbidity | H | H | L | H | H | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Entrainment and impingement | M | L | L | H | L | L |
| | Impaired fish passage | M | L | L | H | M | L |
| | Reduced soil infiltration | M | L | L | M | L | L |
| | Release of pesticides | H | H | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Soil compaction | M | M | L | M | L | L |
| | Loss/alteration of wetlands | H | H | L | M | M | L |
| | Land-use change (post agriculture) | H | M | L | H | M | L |
| | Introduction of invasive species | M | M | L | M | L | L |
| | Introduction of pathogens | H | M | L | M | M | L |
| | Endocrine disruptors | H | H | L | H | H | L |
| | Change of community structure | M | M | L | M | M | L |
| | Change in species composition | H | M | L | M | M | L |
| Silviculture and Timber Harvest Activities | Reduced soil infiltration | M | M | L | M | L | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Impaired fish passage | M | L | L | H | M | L |
| | Bank/soil erosion | H | M | L | H | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Release of pesticides | H | H | L | H | H | L |
| | Release of nutrients/eutrophication | H | H | L | H | H | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Loss/alteration of wetlands | H | M | L | H | M | L |
| | Soil compaction | M | L | L | M | L | L |
| Timber and Paper Mill Processing Activities | Chemical contaminant releases | H | H | L | H | H | L |
| | Entrainment and impingement | M | L | L | H | M | L |
| | Thermal discharge | H | L | L | M | L | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Conversion of benthic substrate | H | M | L | M | L | L |
| | Loss/alteration of wetlands | M | M | L | M | M | L |
| | Alteration of light regimes | M | L | L | M | L | L |

**Table 9. Habitat impact categories in introduced/nuisance species and aquaculture workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Introduced/ Nuisance Species | Habitat alterations | H | H | M | M | M | M |
| | Trophic alterations | M | H | M | M | M | M |
| | Gene pool alterations | H | H | M | H | H | M |
| | Alterations of communities | H | H | M | M | H | M |
| | Introduced diseases | M | H | M | M | H | M |
| | Changes in species diversity | H | H | H | H | H | M |
| | Alteration in health of native species | M | M | M | M | M | M |
| | Impacts to water quality | M | M | M | M | M | M |
| Aquaculture | Discharge of organic waste | M | H | M | M | M | M |
| | Seafloor impacts | M | H | M | M | M | M |
| | Introduction of exotic invasive species | H | H | M | M | H | M |
| | Food web impacts | H | H | M | H | H | M |
| | Gene pool alterations | H | H | M | H | M | M |
| | Impacts to water column | M | M | M | M | H | M |
| | Impacts to water quality | M | H | L | M | H | M |
| | Changes in species diversity | M | H | M | M | H | M |
| | Sediment deposition | H | H | M | L | L | L |
| | Introduction of diseases | M | H | M | M | M | M |
| | Habitat replacement/exclusion | H | H | M | M | M | L |
| | Habitat conversion | H | H | M | M | H | M |

**Table 10. Habitat impact categories in global effects and other impacts workshop session (N=17)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Climate Change | Alteration of hydrological regimes | H | H | M | H | H | H |
| | Alteration of temperature regimes | H | H | H | H | H | H |
| | Changes in dissolved oxygen | H | H | M | H | H | M |
| | Nutrient loading/eutrophication | M | H | M | M | M | M |
| | Release of contaminants | H | H | M | M | M | M |
| | Bank/soil erosion | H | M | L | M | M | L |
| | Alteration in salinity | M | H | M | M | H | M |
| | Alteration of weather patterns | H | H | M | H | H | H |
| | Alteration of alkalinity | M | M | M | M | M | M |
| | Changes in community structure | H | H | H | H | H | H |
| | Changes in ocean/coastal use | M | M | M | M | M | M |
| | Changes in ecosystem structure | M | H | L | M | H | L |
| | Loss of wetlands | H | H | L | H | H | L |
| Ocean Noise | Mechanical injury to organisms | M | M | H | M | M | H |
| | Impacts to feeding behavior | M | M | M | M | M | M |
| | Impacts to spawning behavior | M | M | M | M | M | M |
| | Impacts to migration | M | M | M | M | M | M |
| | Exclusion of organisms to habitat | M | M | M | M | M | M |
| | Changes in community structure | M | M | M | M | M | M |
| Atmospheric Deposition | Nutrient loading/eutrophication | H | H | M | H | H | M |
| | Mercury loading/bioaccumulation | H | H | M | H | H | H |
| | Polychlorinated biphenyls and other contaminants | H | H | M | H | H | M |
| | Alteration of ocean alkalinity | M | M | M | M | M | M |
| | Alteration of climatic cycle | M | M | M | M | M | M |
| Military/ Security Activities | Exclusion of organisms to habitat | L | L | M | L | M | M |
| | Noise impacts | M | M | M | M | M | H |
| | Chemical releases | M | H | M | M | M | M |
| | Impacts to tidal/intertidal habitats | M | M | L | L | M | L |
| | Blasting injuries from ordinances | M | M | M | M | M | M |
| Natural Disasters and Events | Loss/alteration of habitat | H | H | M | H | H | M |
| | Impacts to habitat from debris | M | M | M | M | M | L |
| | Impacts to water quality | M | H | M | H | H | M |
| | Impacts from emergency response | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | M | M | M | L |
| | Changes in community composition | M | H | M | M | M | M |
| | Underwater landslides | L | L | M | L | L | M |
| Electromag-netic Fields | Changes to migration of organisms | M | M | M | M | M | M |
| | Behavioral changes | M | M | M | M | M | M |
| | Changes in predator/prey relationships | L | M | M | M | M | M |

# CHAPTER TWO: COASTAL DEVELOPMENT

## Introduction

Urban growth and development in the United States continues to expand in coastal areas at a rate approximately four times greater than that in other areas of the country (Hanson et al. 2003). Although loss of coastal wetlands to development has decreased in the last several decades, the percentual rate of loss has remained similar to that of the 1920-1950 periods (Valiela et al. 2004). Rate of loss of coastal wetlands was estimated to be 0.2% per year from 1922-1954, while loss rates from 1982-1987 were approximately 0.18% per year (Valiela et al. 2004). The construction of urban, suburban, commercial, and industrial centers and corresponding infrastructure results in land use conversions that typically remove vegetation and create additional impervious surface. At least one study has correlated ecosystem-level changes with the addition of impervious surfaces in coastal, urbanized areas. Holland et al. (2004) found reduced abundance of stress-sensitive macroinvertebrates and altered food webs in headwater tidal creeks when impervious cover exceeded 20-30% land cover. In fact, measurable adverse changes in the physical and chemical environment were observed when the impervious cover exceeded 10-20% land cover (Holland et al. 2004). Runoff from impervious surfaces and storm sewers is the most widespread source of pollution into the nation's waterways (USEPA 1995).

This chapter discusses the various sources of anthropogenic pollution, as well as other impacts to fishery habitat associated with coastal development. This report has employed the broad definition of adverse effect provided in the essential fish habitat (EFH) regulations to include "direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components." (50 CFR § 600.810). For this reason, impacts to the health and physiology of the fishery resources from physical, chemical, and biological factors are included. There are a number of impacts discussed in this chapter that overlap to some degree with those in other chapters of this report. We have attempted to minimize redundant information, and references to other chapters are provided when the topic has been treated in more detail elsewhere in the report.

## Discharge of Nonpoint Source Pollution and Urban Runoff

The major threats to marine and aquatic habitats are a result of increasing human population and coastal development, which contribute to an increase in anthropogenic pollutant loads. These pollutants are released into estuarine and coastal habitats by way of point and nonpoint source discharges.

The US Environmental Protection Agency (US EPA) defines "nonpoint source" as anything that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act, which refers to "discernable, confined and discrete conveyance" from which pollutants are or may be discharged (for discussions of point source pollution and discharges, see the chapters on Chemical Effects: Water Discharge Facilities and Physical Effect: Water Intake and Discharge Facilities). Nonpoint source (NPS) pollution comes from many diffuse sources. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification are the major contributors to NPS pollution. The general categories of NPS pollution are: sediments, nutrients, acids and salts, metals, toxic chemicals, and pathogens. While all pollutants can become toxic at high enough levels, a number of compounds can be toxic at relatively low levels. The US EPA has identified and designated these compounds as "priority pollutants." Some of these "priority pollutants" include: (1) metals, such as cadmium, copper, chromium, lead, mercury, nickel, and zinc that arise from industrial operations, mining, transportation, and agriculture use; (2) organic compounds, such as pesticides, polychlorinated biphenyl (PCB) congeners, solvents, petroleum hydrocarbons, organometallic compounds, phenols, formaldehyde, and biochemical methylation of metals in aquatic sediments; (3) dissolved gases, such as chlorine and ammonium; (4) anions, such as cyanides, fluorides, sulfides, and sulphates; and (5) acids and alkalis (USEPA 2003a).

While our understanding of the individual, cumulative, and synergistic effects of all contaminants on the coastal ecosystem are incomplete, pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). Although the effects of NPS pollution are usually lower in severity than are those of point source pollution, they may be more widespread and damaging to fish and their habitats in the long term. NPS pollution may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are finally detected, they may not be tied to any one event or source, and they may be difficult to correct, clean up, or mitigate. Increasing human populations and development within coastal regions generally leads to an increase in impervious surfaces, including but not limited to roads, residential and commercial development, and parking lots. Impervious surfaces cause greater volumes of run-off and associated contaminants in aquatic and marine waters.

Urban runoff is generally difficult to control because of the intermittent nature of rainfall and runoff, the large variety of pollutant source types, and the variable nature of source loadings (Safavi 1996). The 2000 National Water Quality Inventory (USEPA 2002) reported that runoff from urban areas is the leading source of impairment in surveyed estuaries and the third largest source of impairment in surveyed lakes. Urban areas can have a chronic and insidious pollution potential that one-time events such as oil spills do not.

It is important to note that the affects of pollution on coastal fishery resources may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat that individual pollutants may represent for aquatic organisms depends upon the type and concentration of the chemical compound and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong bottom currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

### *Nutrient loading and eutrophication*

In the northeastern United States, highly eutrophic conditions have been reported in a number of estuarine and coastal systems, including Boston Harbor, MA, Long Island Sound, NY/CT, and Chesapeake Bay, MD/VA (Bricker et al. 1999). While much of the excess nutrients within coastal waters originates from sewage treatment plants, nonpoint sources of nutrients from municipal and agricultural run-off, contaminated groundwater and sediments, septic systems, wildlife feces, and atmospheric deposition from industry and automobile emissions contribute significantly (Hanson et al. 2003; USEPA 2005). Failing septic systems contribute to NPS pollution and are a negative consequence of urban development. The US EPA estimates that 10-25% of all individual septic systems are failing at any one time, introducing feces, detergents, endocrine disruptors, and chlorine into the environment (Hanson et al. 2003). Sewage waste contains significant amounts of organic matter that cause a biochemical oxygen demand, leading to eutrophication of coastal waters (Kennish 1998) (see also the chapter on Chemical Effects: Water Discharge Facilities). O'Reilly (1994) found that extensive hypoxia in the northeastern United States has been more chronic in river-estuarine systems from Chesapeake Bay to Narragansett Bay, RI, than in systems to the north, except for episodic low dissolved oxygen in Boston Harbor/Charles River, MA, and the freshwater portion of the Merrimack River, MA/NH. The US EPA's National Coastal Condition Report II (USEPA 2004) reported similar trends in northeast coast estuaries and also noted signs of degraded water quality in estuaries north of Cape Cod, MA. Although the US EPA report found much of the Acadian Province (i.e., Maine and New Hampshire) to have good water quality conditions, it identified Great Bay, NH, as only having fair to poor conditions (USEPA 2004).

Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including: reductions in submerged aquatic vegetation (SAV) through reduced light transmittance, epiphytic growth, and increased disease susceptibility (Goldsborough 1997); mass mortality of fish and invertebrates through poor water quality; and alterations in long-term natural community dynamics. The effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (*Pseudopleuronectes americanus*) (Bejda et al. 1992). Short and Burdick (1996) correlated eelgrass losses in Waquoit Bay, MA, with anthropogenic nutrient loading primarily as a result of an increased number of septic systems from housing developments in the watershed. The environmental effects of excess nutrients and elevated suspended sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

There is evidence that nutrient overenrichment has led to increased incidence, extent, and persistence of blooms of nuisance and noxious or toxic species of phytoplankton; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from planktonic algae (O'Reilly 1994). Heavily developed watersheds tend to have reduced stormwater storage capacity, and the various sources of nutrient input can increase the incidence, extent, and persistence of harmful algal blooms (O'Reilly 1994). See also the chapters on Introduced/Nuisance Species and Aquaculture and Chemical Effects: Water Discharge Facilities for more information on harmful algal blooms.

### *Introduction of pathogens*

Introduction of pathogens to aquatic habitats has become more common and widespread over the last 30 years, and various factors may be responsible, including NPS pollution from highly urbanized areas (O'Reilly 1994). Urban runoff typically contains elevated levels of pathogens, including bacteria, viruses, and protozoa, often a result of introductions of bacteria from leaking septic systems, agricultural manure, domestic animals, wildlife, and other sources of NPS pollution and can lead to beach and shellfish harvesting area closures (USEPA 2005). Pathogens are generally harmful to human health through the consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). While many pathogens affecting marine organisms are associated with upland runoff, there are also naturally occurring marine pathogens that affect fish and shellfish (Shumway and Kraeuter 2000). Some naturally occurring pathogens, such as bacteria from the genus *Vibrio*, or the dinoflagellate *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species requires additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997).

## *Sedimentation and turbidity*

Land runoff from coastal development can result in an unnatural influx of suspended particles from soil erosion having negative effects on riverine, nearshore, and estuarine ecosystems. Impacts from this include high turbidity levels, reduced light transmittance, and sedimentation which may lead to the loss of SAV and other benthic structure (USEPA 2005; Orth et al. 2006). Other effects include disruption in the respiration of fishes and other aquatic organisms, reduction in filtering efficiencies and respiration of invertebrates, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991; Wilber and Clarke 2001; USEPA 2005). For example, Breitburg (1988) found the predation rates of striped bass (*Morone saxatilis*) larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory. De Robertis et al. (2003) found reductions in the rate of pursuit and probability of successful prey capture in piscivorous fish at turbidity levels as low as 10 nephelometric turbidity units, while the prey consumption of two species of planktivorous fish were unaffected at this turbidity level. In another laboratory study, rainbow smelt (*Osmerus mordax*) showed signs of increased swimming activity at suspended sediment concentrations as low as 20 mg/L, suggesting fish responded to increased suspended sediment concentrations with an “alarm reaction” (Chiasson 1993).

## *Release of petroleum products*

Petroleum products consist of thousands of chemical compounds that can be toxic to marine life including polycyclic aromatic hydrocarbons (PAH), which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). PAH have been found to be significantly higher in urbanized watersheds when compared to nonurbanized watersheds (Fulton et al. 1993). By far, the largest amount of petroleum released through human activity comes from the use of petroleum products (e.g., cars, boats, paved urban areas, and two-stroke engines) (ASMFC 2004). Most of the petroleum consumption activities are land-based; however, rivers and storm and wastewater streams carry the petroleum to marine environments such as estuaries and bays. Although individual petroleum product releases are small, they are widespread and common and when combined, they contribute nearly 85% of the total petroleum pollution from human activities (ASMFC 2004).

Petroleum products can be a major stressor on inshore fish habitats. Short-term impacts include interference with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fishes, especially early life-history stages (Gould et al. 1994). PAH can degrade aquatic habitat, consequently interfering with biotic communities and may be discharged into rivers from nonpoint sources, including municipal run-off and contaminated sediments. Oil has been shown to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others and, in general, the early life stages (i.e., eggs and larvae) of organisms are most sensitive (Gould et al. 1994; Rice et al. 2000).

Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. The water column may be polluted with oil as a result of wave action and currents dispersing the oil. Benthic habitat and the shoreline can be covered and saturated with oil, leading to the protracted damage of aquatic communities, including the disruption of population dynamics. Oil can persist in sediments for decades after the initial contamination, causing disruption of physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996). These changes may lead to disruption of community organization and dynamics in affected regions and permanently diminish fishery habitat. Carcinogenic and mutagenic properties of oil compounds have been identified (Larsen 1992; Gould et al. 1994). For more detail on oil spills, see the chapter on Energy-related Activities.

### *Alteration of water alkalinity*

Fishery resources are known to be sensitive to changes in water alkalinity. Rivers and the brackish waters of estuaries are especially sensitive to acidic effluents because of the lower buffering capacity of freshwater as compared to that of salt water. The influx of pH altering flows to aquatic habitats can hinder the sustainability of fisheries. Municipal run-off, contaminated groundwater, and atmospheric deposition are potential nonpoint sources of acid influx to aquatic habitats. Acidification may disrupt or prevent reproduction, development, and growth of fish (USFWS and NMFS 1999). Osmoregulatory problems in Atlantic salmon (*Salmo salar*) smolts have been demonstrated to be related to habitats with low pH (Staurnes et al. 1996). Low pH in estuarine waters has been shown to cause cellular changes in the muscle tissues of Atlantic herring (*Clupea harengus*), which may lead to a reduction in swimming ability (Bahgat et al. 1989).

### *Alteration of temperature regimes*

Alteration of natural temperature regimes can occur in riverine and estuarine ecosystems because of land runoff from urbanized areas. Radiant heating from impervious surfaces, such as concrete and asphalt can increase the water temperature of streams, rivers, and bays. The removal of shoreline and riparian vegetation can reduce shading effects and raise the water temperature of creeks and ponds that drain into larger water bodies. Temperature influences biochemical processes, behavior (e.g., migration), and physiology of aquatic organisms (Blaxter 1969), and long-term thermal pollution may change natural community dynamics.

Because warmer water holds less oxygen than colder water does, increased water temperatures reduce the dissolved oxygen concentration in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. In addition, increased water temperatures in the upper strata of the water column can increase water column stratification, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries with excess nutrients (Kennedy et al. 2002). Stratification could also affect primary and secondary productivity by suppressing nutrient upwelling and mixing in the upper regions of the water column, potentially altering the composition of phytoplankton and zooplankton. Impacts to the base of the food chain would not only affect fisheries but could impact entire ecosystems.

### *Release of metals*

Metal contaminants are found in the water column and can persist in the sediments of coastal habitat, including urbanized areas, as well as fairly uninhabited regions, and are a potential environmental threat (Larsen 1992; Readman et al. 1993; Buchholtz ten Brink et al. 1996). High levels of metals, such as mercury, copper, lead, and arsenic, are found in the sediments of New England estuaries because of past industrial activity (Larsen 1992) and may be released into the water column during navigation channel dredging or made available to organisms as a result of storm events. Some activities associated with shipyards and marinas have been identified as sources of metals in the sediments and surface waters of coastal areas (Milliken and Lee 1990; USEPA 2001; Amaral et al. 2005). These include copper, tin, and arsenic from boat hull painting and scraping, hull washing, and wood preservatives. Treated wood used for pilings and docks releases copper compounds that are applied to preserve the wood (Poston 2001; Weis and Weis 2002). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). Refer to the Overwater Structures section of this chapter for more information on treated wood products and their effects on aquatic organisms. Urban stormwater runoff often contains metals from automobile and industrial facilities, such as mercury, lead (used in batteries), and nickel and cadmium (used in brake linings). Refer to the chapter on Marine Transportation for more information on channel dredging and storm water impacts from marinas and shipyards.

At low concentrations, metals may initially inhibit reproduction and development of marine organisms, but at high concentrations, they can directly contaminate or kill fish and invertebrates. Shifts in phytoplankton species composition may occur because of metal accumulation and may lead to an alteration of community structure by replacing indigenous producers with species of lesser value as a food source for consumers (NEFMC 1998). Metals are known to produce a number of toxic effects on marine fish species, including skeletal deformities in Atlantic cod (*Gadus morhua*) from cadmium exposure (Lang and Dethlefsen 1987), larval developmental deformities in haddock (*Melanogrammus aeglefinus*) from copper exposure (Bodammer 1981), and reduced viable hatch rates in winter flounder embryos and increased larval mortality from silver exposure (Klein-MacPhee et al. 1984). Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977). Copper may also bioaccumulate in bacteria and phytoplankton (Milliken and Lee 1990). Metals have been implicated in disrupting endocrine secretions of aquatic organisms, potentially disrupting natural physiological processes (Brodeur et al. 1997; Thurberg and Gould 2005). Refer to the Chemical Effects: Water Discharge Facilities chapter for a broader discussion on endocrine-disrupting chemicals. While long-term impacts do not appear significant in most marine organisms, metals can move upward through trophic levels and accumulate in fish (bioaccumulation) at levels that can eventually cause health problems in human consumers (NEFMC 1998). See also Global Effects and Other Impacts chapter for mercury loading/bioaccumulation via the atmosphere.

### *Release of radioactive wastes*

Radioactive wastes may be a potential threat to aquatic habitats used by fish and shellfish species. Fishery resources may accumulate radioactive isotopes in tissues that could lead to negative effects on the resource and consumers (ICES 1991). Potential sources of radioactive wastes are urban stormwater runoff, municipal landfills, atmospheric deposition, contaminated groundwater, and sediments (e.g., past offshore dumping locations [NEFMC 1998]).

### *Release of toxic compounds*

Many different toxic compounds, including “priority pollutants” described previously, have been found in urban runoff (USEPA 2005). The US EPA reported that at least 10% of urban runoff samples contained toxic pollutants (USEPA 2005). Organic contamination contained within urban runoff, particularly chlorinated and aromatic compounds, has been implicated in causing immuno-suppression in juvenile chinook salmon (*Oncorhynchus tshawytscha*) (Arkoosh et al. 2001). The organophosphate insecticide, malathion, has been implicated in the mass mortality of American lobsters (*Homarus americanus*) in Long Island Sound during 1999 (Balcom and Howell 2006). In addition, impairment of immune response and stress hormone production were identified as examples of the sublethal effects from exposure of this compound on American lobsters (Balcom and Howell 2006). Refer to the subsections release of metals, pesticides, and herbicides in this chapter for additional information on toxic compounds.

### *Release of pesticides and herbicides*

Although agricultural run-off is a major source of pesticide pollution in aquatic systems, residential areas are also a notable source (see Agriculture and Silviculture chapter for a discussion on agricultural runoff of pesticides). Other sources of pesticide discharge into coastal waters include atmospheric deposition and contaminated groundwater (Meyers and Hendricks 1982). Pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus then ingested by macroinvertebrates, which in turn are eaten by larger invertebrates and fish (ASMFC 1992). For example, winter flounder liver tissues taken in 1984 and 1985 in Boston and Salem Harbors in Massachusetts were found to have the two highest mean concentrations of total dichlorodiphenyl trichloroethane (DDT) found in all New England sites sampled (NOAA 1991). Samples taken of soft parts from softshelled clams (*Mya arenaria*) during the same time period indicated that Boston Harbor mussels were moderately to highly contaminated with DDT when compared to nationwide sites (NOAA 1991).

There are three basic ways that pesticides can adversely affect the health and productivity of fisheries: (1) direct toxicological impact on the health or performance of exposed fish; (2) indirect impairment of the productivity of aquatic ecosystems; and (3) loss or degradation of habitat (e.g., aquatic vegetation) that provides physical shelter for fish and invertebrates (Hanson et al. 2003).

For many marine organisms, the majority of effects from pesticide exposures are sublethal, meaning that the exposure does not directly lead to the mortality of individuals. Sublethal effects can be of concern, as they impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003). Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish (Moore and Waring 2001; Gould et al. 1994). For example, evidence has shown that DDT and its chief metabolic by-product, dichlorodiphenyl dichloroethylene (DDE), can act as estrogenic compounds, either by mimicking estrogen or by inhibiting androgen effectiveness (Gilbert 2000). DDT has been shown to cause deformities in winter flounder eggs and Atlantic cod embryos and larvae (Gould et al. 1994). Generally, however, the sublethal impacts of pesticides on fish health are poorly understood.

The direct and indirect effects that pesticides have on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems (Preston 2002). This factor includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as macroinvertebrates that are prey species for fish. Because pesticides are specifically designed to kill insects, it is not surprising that these chemicals are relatively toxic to insects and crustaceans that inhabit river systems and estuaries. The use of pesticides to control mosquitoes has been suggested as a potential factor in the mass mortality of American lobsters in Long Island Sound during 1999 (Balcom and Howell 2006). Recent lab studies have shown that lobsters are considerably more sensitive to the effects of the mosquito adulticide, malathion, than are any other species previously tested. Sublethal effects (i.e., impairment of immune response and stress hormone production) occur at concentrations in parts per billion and at concentrations much lower than those observed to cause lethal effects (Balcom and Howell 2006). Lab studies have shown that American lobsters have a 96-hour LC50 (i.e., Lethal

Concentration 50- the duration and chemical concentration which causes the death of 50% of the test animals) of 33.5 ppb with immunotoxicity resulting at 5 ppb, suggesting a high sensivity in this species to both lethal and sublethal toxicity effects from malathion in seawater (De Guise et al. 2004).

Herbicides may alter long-term natural community structure by hindering aquatic plant growth or destroying aquatic plants. Hindering plant growth can have notable effects on fish and invertebrate populations by limiting nursery and forage habitat. Chemicals used in herbicides may also be endocrine disrupters, exogenous chemicals that interfere with the normal function of hormones (NEFMC 1998). Coastal development and water diversion projects contribute substantial levels of herbicides entering fish and shellfish habitat. A variety of human activities such as noxious weed control in residential development and agricultural lands, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, and aquatic habitat restoration results in contamination from these substances.

### *Conservation measures and best management practices (BMPs) for discharge of nonpoint source pollution and urban runoff (adapted from Hanson et al. 2003)*

1. Remove unnecessary impervious surfaces such as abandoned parking lots and buildings from riparian and shoreline areas and reestablish wetlands and native vegetation, whenever possible. Construction of new impervious surfaces should be avoided or minimized.
2. Implement BMPs for sediment control during construction and maintenance operations, including: avoiding ground disturbing activities during the wet season; minimizing the temporal and spatial extent of the disturbance; using erosion prevention and sediment control methods; maintaining natural buffers of vegetation around wetlands, streams, and drainage ways; and avoiding building activities in areas of steep slopes and areas with highly erodable soils. Whenever appropriate, recommend the use of methods such as sediment ponds, sediment traps, bioswales, or other facilities designed to slow runoff and trap sediment and nutrients (USEPA 1993).
3. Protect, enhance, and restore vegetated buffer zones along streams and wetlands that include or influence fishery habitat.
4. Manage stormwater to duplicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
5. Encourage proposed residential and commercial developments to utilize municipal wastewater facilities capable of treating sewage to the maximum extent practicable. Any proposed residential developments utilizing septic systems should include modern, state of the art systems. Ensure that they are properly sited and maintained.
6. Encourage communities to implement "smart-growth" development and land-use planning that reduces urban sprawl and minimizes impervious surfaces.
7. Encourage the use of nontreated wood materials in construction near aquatic environments.
8. Incorporate integrated pest management and BMPs as part of the authorization or permitting process to ensure the reduction of pesticide contamination in fishery habitat (Scott et al. 1999).
9. Avoid the use of pesticides and herbicides in and near aquatic habitats.
10. Refrain from aerial spraying of pesticides on windy days.
11. Address nonpoint source pollution by assessing cumulative impacts of past, present, and foreseeable future development activies on aquatic habitats in the review process.

# Commercial and Domestic Water Use

Freshwater withdrawn for human use from riverine environments can alter natural current and sedimentation patterns, water quality, water temperature, and associated biotic communities (NEFMC 1998). Natural freshwater flows are subject to human alteration through water diversion for agriculture and industrial uses and modifications to the watershed. An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide, as well as in New England (Deegan and Buchsbaum 2005). For example, the flow of the Ipswich River in Massachusetts has been reduced to about one-half historical levels because of water withdrawals for human uses and about one-half of the native fish species on the river have been eliminated or greatly reduced (Bowling and Mackin 2003). Water withdrawal for freshwater drinking supply, power plant coolant systems, and irrigation occurs along urban and suburban areas, causing potential detrimental effects on aquatic habitats. The water withdrawal limits the amount of freshwater flowing into estuaries, which can affect the health and productivity of the ecosystem. For example, diversion of freshwater leading to increased salinities can result in oysters relocating upstream where less suitable habitat may be available and in areas subjected to higher levels of pollution (MacKenzie 2007). Urbanization leads to increases in the amount of impervious surface (e.g., roads and parking lots), which causes water to flow off the land more quickly than if the land was undeveloped and forested, reducing the natural recharge of groundwater. Alteration of the natural hydroperiod can affect circulation patterns in estuarine systems, leading to both short-term and long-term changes (Deegan and Buchsbaum 2005). In addition, the use of desalinization plants to meet industrial and municipal water needs may further alter chemical and physical environments by discharging hypersaline water into the aquatic ecosystem. Refer to the chapters on Physical Effects: Water Intake and Discharge Facilities and Alteration of Freshwater Systems for additional information on domestic and commercial freshwater usage.

### *Conservation measures and best management practices for commercial and domestic water use (adapted from Hanson et al. 2003)*

1. Ensure that the design of water diversion projects provide adequate passage, water quality, and proper timing of water flows for all life history stages of anadromous fish and that they maintain and restore adequate channel, floodplain, riparian, and estuarine conditions.
2. Incorporate juvenile and adult fish passage facilities on water diversion projects.
3. Seasonal restrictions should be used to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

# Road Construction and Operation

The building and maintenance of roads can affect aquatic habitats by increasing rates of erosion, debris slides, landslides, sedimentation, introduction of exotic species, and degradation of water quality (Furniss et al. 1991; Hanson et al. 2003). Paved and dirt roads introduce an impervious or semipervious surface into the landscape, which intercepts rain and increases runoff, carrying soil, sand, and other sediments (Ziegler et al. 2001) and oil-based materials more quickly into aquatic habitats. Roads constructed near streams, wetlands, and other sensitive areas may cause sedimentation in these habitats and further diminish flood plain storage capacity, subsequently increasing the need for dredging in those systems. Sedimentation and the release of contaminants into aquatic habitats can be acute following heavy rain and snow and as a result of improper road maintenance activities. Even carefully designed and constructed roads can be a source of sediment and pollutants if they are not properly maintained (Hanson et al. 2003).

The effects of roads on aquatic habitat include: (1) contaminant releases; (2) increased release of sediments; (3) reduced dissolved oxygen; (4) changes in water temperature; (5) elimination or introduction of migration barriers; (6) changes in stream flow; (7) introduction of nonnative plant species; (8) altered salinity regimes; and (9) changes in channel configuration.

### *Contaminant releases*

Roads constructed near or adjacent to aquatic habitats can be a source of chemical contaminants, such as deicing chemicals, road salt, fertilizers, and herbicides to control roadside vegetation and petroleum products from vehicles or from the road asphalt itself (Furniss et al. 1991).

Nationally, an estimated 18 million tons of deicing salt, primarily sodium and calcium chlorides, are used each year and state and local governments spend approximately $10 million annually to remediate road salt contamination (USEPA 2005). Road salts dissolve and enter adjacent soils, groundwater, and surface waters through runoff, which can cause toxicity in plants, fish, and other aquatic organisms. These effects are particularly pronounced in smaller water bodies adjacent to salted areas. Stormwater runoff from roads can contain oil, grease, and other hydrocarbons from asphalt, wearing of tires, deposition from automobile exhaust, and oiling of roadsides and unpaved roads with crankcase oil (USEPA 2005). Refer to the Discharge of Nonpoint Source Pollution and Urban Runoff section of this chapter for information on impacts from stormwater runoff.

### *Sedimentation, siltation, and turbidity*

The rate of soil erosion around roads is primarily a function of storm intensity, surfacing material, road slope, and traffic levels (Hanson et al. 2003). In addition, road maintenance activities such as road sanding to prevent icing and road repair can also cause sedimentation in adjacent aquatic habitats. For roads located in steep terrain, mass soil movement triggered by roads can last for decades after roads are built (Furniss et al. 1991). Surface erosion results in increased deposition of fine sediments (Bilby et al. 1989; MacDonald et al. 2001; Ziegler et al. 2001), which has been linked to a decrease in salmon fry emergence, decreased juvenile densities, and increased predation in some species of salmon (Koski 1981).

### *Reduced dissolved oxygen*

The introduction of stormwater runoff from roads can increase the organic loads in adjacent streams and rivers, increasing the biological oxygen demand and reducing dissolved oxygen concentrations. Reduced dissolved oxygen concentrations can cause direct mortality of aquatic organisms or result in sub-acute effects such as reduced growth and reproductive success. Bejda et al. (1992) found that the growth of juvenile winter flounder was significantly reduced when dissolved oxygen (DO) levels were maintained at 2.2 mg/L or when DO varied diurnally between 2.5 and 6.4 mg/L for a period of 11 weeks.

### *Loss and alteration of vegetation and altered temperature regimes*

Roads located near streams often involve the removal of riparian vegetation for construction and safety and maintenance. Roads built adjacent to streams result in changes in water temperature and increased sunlight reaching the stream as riparian vegetation is removed and/or altered in composition (Hanson et al. 2003). Roads can also alter natural temperature regimes in riverine and estuarine ecosystems because of radiant heating effect from the road surfaces. Riparian vegetation is an important component of rearing habitat for coldwater species, such as salmonids, providing shade for maintaining cool water temperatures, food supply, and channel stability and structure (Furniss et al. 1991).

Temperature effects biochemical processes, behavior (e.g., migration), and physiology of aquatic organisms (Blaxter 1969), and long-term thermal pollution may change natural community dynamics. In addition, increased water temperatures can reduce the dissolved oxygen concentration in bodies of water that are not well mixed. This may exacerbate eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States.

### Impaired fish passage

Roads can also reduce or eliminate upstream and downstream fish passage through improperly placed culverts at road-stream crossings (Belford and Gould 1989; Clancy and Reichmuth 1990; Evans and Johnston 1980; Furniss et al. 1991). Improperly designed stream crossings adversely effect fish and aquatic organisms by blocking access to spawning, rearing, and nursery habitat because of: (1) perched culverts constructed with the bottom of the structure above the level of the stream, effectively acting as dams and physically blocking passage; and (2) hydraulic barriers to passage are created by undersized culverts which constrict the flow and create excessive water velocities (Evans and Johnston 1980; Belford and Gould 1989; Furniss et al. 1991; Jackson 2003). Smooth-bore liners made from high density plastic help meet the goal of passing water and protecting roadways from flooding, but they greatly increase flow velocities through the passage. Culverts can be plugged by debris or overtopped by high flows. Road damage, channel realignment, and extreme sedimentation from roads can cause stream flow to become too shallow for upstream fish movement (Furniss et al. 1991). Additional information on impaired fish passage is discussed in the Alteration of Freshwater Systems chapter of this report.

### Introduction of exotic invasive species

Roads can be the first point of entry for nonnative, opportunistic grass species that are seeded along road cuts or introduced from seeds transported by tires and shoes (Greenberg et al. 1997; Lonsdale and Lane 1994). Nonnative plants may be able to move away from the roadside and into aquatic sites, where they may out-compete native species and alter the structure and function of the aquatic ecosystem (see also the chapter on Introduced/Nuisance Species and Aquaculture).

### Altered hydrological regimes

Roads can result in adverse effects to hydrologic processes. They intercept rainfall directly on the road surface, in road cut banks, and as subsurface water moving down the hillslope; they also concentrate flow, either on the road surfaces or in adjacent ditches or channels (Hanson et al. 2003). Roads can divert or reroute water from flow paths that would otherwise be taken if the road were not present (Furniss et al. 1991). The hydrology of riverine and estuarine systems can be affected by fragmentation of the habitat caused by the construction of roads and culverts (Niering 1988; Mitsch and Gosselink 1993). These structures also reduce natural tidal flushing and interfere with natural sediment-transport processes, all of which are important functions that maintain the integrity of coastal wetlands (Tyrrell 2005). As discussed previously, roads can alter flood plain storage patterns. These hydrological changes may lead to increased erosion and sedimentation in adjacent streams.

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002).

### *Altered tidal and salinity regimes*

As discussed above, roads can alter hydrologic processes by rerouting flow paths and concentrating stormwater flow towards salt marsh and tidal creeks. Together with the removal of vegetation adjacent to roads, a large and rapid influx of freshwater can alter the salinity regime and species composition of estuarine habitats. Roads and culverts can also restrict the flow in tidal creeks, lowering the head-of-tide, altering the estuarine community, and restricting the access of anadromous fish.

### *Altered stream morphology*

The geometry of a stream is affected by the amount of water and sediment that the stream carries. These factors may be altered by roads and stream crossings. Adjustments to stream morphology are usually detrimental to fish habitat (Furniss et al. 1991). Alteration of stream morphology can change stream velocity and increase sedimentation of the streambed, which can have adverse effects on spawning and migration of anadromous fish.

### *Conservation measures and best management practices for road construction and operation (adapted from Hanson et al. 2003)*

1. Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes.
2. Build bridges for crossing aquatic environments, rather than utilizing culverts, whenever possible. If culverts must be used, they should be sized, constructed, and maintained to match the gradient, flow characteristics, and width of the stream so as to accommodate a 100-year flood event, but equally to provide for seasonal migratory passage of adult and juvenile fish.
3. Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
4. Specify erosion control measures in road construction plans.
5. Avoid side casting of road materials into streams.
6. Use only native vegetation in stabilization plantings.
7. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Maintain roadway and associated stormwater collection systems properly.
9. Control the practice of roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Sweep and remove sand after winter to reduce sediment loading in streams and wetlands.
10. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for road construction projects.

## Flood Control/Shoreline Protection

As human populations in coastal areas grow, development pressure increases and structures are often constructed along the coastline to prevent erosion and stabilize shorelines. The protection of coastal development and human communities from flooding can result in varying degrees of change in the physical, chemical, and biological characteristics of existing shoreline and riparian habitat. Attempts to protect “soft” shorelines such as beaches to reduce shoreline erosion are inevitable consequences of coastal development. Structures placed for coastal shoreline protection include breakwaters, jetties and groins, concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), and sandbags (Hanson et al. 2003). These structures are designed to slow or stop the shoreline from eroding, but in many cases the opposite occurs as erosion rates increase along the adjacent areas. Many shoreline “hardening” structures, such as seawalls and jetties, tend to reduce the complexity of habitats and the amount of intertidal habitats (Williams and Thom 2001). Generally, “soft” shoreline stabilization approaches (e.g., beach nourishment, vegetative plantings) have fewer adverse effects on hydrology and habitats.

Flood control measures in low-lying coastal areas include dikes, ditches, tide gates, and stream channelization. These measures are generally designed to direct water away from flood prone areas and, in the case of tide gates, prevent tidal water and storm surge from entering these areas. Adjacent aquatic habitat can become altered, and short- and long-term impacts to local fish and shellfish populations may be associated with the presence of the erosion control structures. Coastal marshes typically have a gradient of fresh to salt tolerant vegetation. These coastal wetland systems drain freshwater through tidal creeks that eventually empty into the bay or estuary. The use of water control structures can have long-term adverse effects on tidal marsh and estuarine habitats by interfering with the exchange of fresh and brackish water within the marsh habitat.

### *Altered hydrological regimes*

Water control structures within marsh habitats intercept and carry away freshwater drainage, block freshwater from flowing across seaward portions of the marsh, increase the speed of runoff of freshwater to the bay or estuary, lower the water table, permit saltwater intrusion into the marsh proper, and create migration barriers for aquatic species (Hanson et al. 2003). In deep channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life. Long-term effects of flood control on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, reduced invertebrate populations, and general loss of productive wetland characteristics (Hanson et al. 2003). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods.

### *Altered temperature regimes*

Shoreline modifications, including the construction of seawalls and bulkheads, invariably involve the removal of shoreline vegetation which eliminates shading and can cause increased water temperatures in rivers and the nearshore intertidal zone (Williams and Thom 2001). Conversely, increased shading from seawalls and bulkheads constructed along shorelines may unnaturally reduce local light levels and primary production rates and reduce water temperatures of the water column adjacent to the structures (Williams and Thom 2001). Tide gates prevent or reduce tidal flushing to an area, causing stagnant water behind the structure and increased water temperature regimes (Williams and Thom 2001). Breakwaters and jetties can also alter hydrological processes which may result in altered fluctuations of nearshore temperature (Williams and Thom 2001).

### *Reduced dissolved oxygen*

Breakwaters and jetties affect nearshore hydrological processes, as well as river flow and tidal currents when these structures are placed at the mouth of rivers and estuaries (Williams and Thom 2001). This can alter the timing and volume of water exchange to rivers, bays, and estuaries and result in reductions in water circulation and dissolved oxygen concentrations for some areas, particularly when combined with eutrophic conditions. Flood control structures, such as tide gates, dikes, and ditches, can restrict the exchange of water within wetlands, which can create stagnant conditions and reduce dissolved oxygen concentrations (Spence et al. 1996; Williams and Thom 2001).

### *Altered sediment transport and increased erosion/accretion*

As discussed above, shoreline stabilization structures such as breakwaters, jetties, and groins affect nearshore hydrological processes which can alter wave energy and current patterns that, in turn, can affect littoral drift and longshore sediment transport (Williams and Thom 2001). In comparisons between natural and seawalled shorelines, Bozek and Burdick (2005) found no statistically significant effects on several salt marsh processes in Great Bay, NH. However, at high-energy sites, the authors found trends indicating greater sediment movement and winnowing of fine grain sediments adjacent to seawalls (Bozek and Burdick 2005).

These structures can also impact sediment budgets in estuaries and rivers. Alterations to sediment transport can affect bottom habitats, beach formation, and sand dune size (Williams and Thom 2001). Hardened shorelines, from the construction of seawalls, groins, and revetments, directly affect nearshore sediment transport by impounding natural sediment sources. Shoreline structures can cause beach erosion and accretion in adjacent areas. Long-term, chronic impacts may result in a reduction of intertidal habitat, bottom complexity, and associated soft-bottom plant and animal communities (Williams and Thom 2001). In tidal marshes, floodgates and dikes restrict sediment transport which is a natural part of the marsh accretion process. The use of these structures can result in subsidence of the marsh and loss of salt marsh vegetation.

### *Alteration and loss of benthic and intertidal habitat*

As discussed above, breakwaters, jetties, and groins can affect nearshore hydrological processes, such as wave energy and current patterns and, in turn, can have detrimental impacts on benthic habitats. Increased sedimentation as a result of reflective turbulence (changes in water velocity caused by wave energy reflection from solid structures in the nearshore coastal area) and turbidity can reduce or eliminate vegetated shallows (Williams and Thom 2001). In addition, these structures can alter the geomorphology of existing habitats, resulting in a large-scale replacement of soft-bottom, deepwater habitat with shallow and intertidal, hard structure habitats (Williams and Thom 2001). Alterations to the shoreline as a result of bulkhead and other hard shoreline structures can increase wave energy seaward of the armoring, causing scouring of bottom sediments and loss of salt marsh vegetation.

### *Altered stream morphology*

Flood and erosion control structures such as bulkheads, levees, and dikes built along streams and rivers, as well as the canalization of streams and rivers, result in simplified riverine habitat and a reduction in pools and riffles that provide habitat for fish (Spence et al. 1996). In addition, altered stream hydrology and morphology can change sediment grain size and reduce the organic matter available to small organisms that serve as prey for larger species in the food web (Williams and Thom 2001).

### *Impacts to riparian habitat*

As discussed above, shoreline modifications such as the construction of seawalls and bulkheads, involve the removal of shoreline vegetation which eliminates shading and can cause increased water temperatures in rivers and the nearshore, intertidal zone (Williams and Thom 2001). The loss of riparian vegetation reduces the forage and cover for aquatic organisms and the input of large woody debris and smaller organic detritus, including leaves (Spence et al. 1996).

### *Impaired fish passage*

Tide gates and other flood control structures can eliminate or restrict access of fish to salt marshes. Tide gates can create physical barriers for estuarine fish species that utilize salt marsh wetlands for feeding and early development. High flow rates at tide gates or culvert openings can prevent small fish from accessing critical marsh and freshwater habitat. In some cases, fish can become trapped behind tide gates, preventing them from accessing deeper water and potentially stranding them during periods of low water (Williams and Thom 2001).

### *Alteration of natural communities*

Armoring of shorelines to prevent erosion and maintain or create shoreline real estate simplifies habitats, reduces the amount of intertidal habitat, and negatively affects nearshore processes and the ecology of coastal species (Williams and Thom 2001). For example, Chapman (2003) found a paucity of mobile species associated with seawalls in a tropical estuary, compared with surrounding areas. In that study, approximately 50% of taxa found on natural rocky shorelines were absent on constructed seawall, and seawalls were found to have a diminished proportion of rare taxa. Alterations to the shoreline from hydraulic action include increased energy seaward of the armoring from reflected wave energy, narrowing of the dry beach, coarsening of the substrate, steepening of the beach slope, reduction of sediment storage capacity, a loss of organic debris, and a reduction of downdrift sediment (Williams and Thom 2001). Bozek and Burdick (2005) found no statistically significant effects of seawalls on salt marsh processes in Great Bay, NH; however, their data indicated seawalls tended to eliminate the high-diversity vegetative zones at the upper border of the salt marsh. Installation of breakwaters and jetties can result in community changes, including burial or removal of resident biota, changes in the habitat structure, alteration in prey and predator interaction, and physical obstructions that can alter the recruitment patterns of larvae (Williams and Thom 2001).

### *Reduced ability to counter sea-level rise*

The effect of shoreline erosion and land subsidence will likely be exacerbated by sea-level rise because of global climate change. Sea level rose 10-20 cm (4-8 inches) in the 20$^{th}$ century and may rise another 18-59 cm (7-23 inches) by 2100 (IPCC 2007). As sea levels continue to rise, salt marshes, mudflats, and coastal shallows must be able to shift horizontally without interruption from natural or manmade barriers (Bigford 1991). Hard structures, such as seawalls, bulkheads, and jetties may inhibit the shoreward migration of marsh wetlands (Kelley 1992) and SAV beds (Orth et al. 2006). In addition, global climate change is expected to cause greater precipitation and more intense storms in the mid-high latitudes in the northern hemisphere (Nedeau 2004). Along with rising sea levels, these factors may exacerbate coastal erosion and increase the apparent need for shoreline protection. See Global Effects and Other Impacts chapter for more information on global climate change.

### *Conservation measures and best management practices for flood control/shoreline protection (adapted from Hanson et al. 2003)*

1. Avoid or minimize the loss of coastal wetlands as much as possible, including encouraging coastal wetland habitat preservation. Preservation of coastal upland buffers between buildings and wetlands may allow for the inland migration of wetlands as sea levels rise.
2. Avoid the diking and draining of tidal marshlands and estuaries, whenever possible.
3. Use "soft" approaches (such as beach nourishment, vegetative plantings, and placement of large woody debris), in lieu of "hard" shoreline stabilization and modifications (such as concrete bulkheads and seawalls, concrete or rock revetments), whenever possible.
4. Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when "hard" shoreline stabilization is deemed necessary.
5. Include efforts to preserve and enhance fishery habitat (e.g., provide new gravel for spawning or nursery habitats; remove barriers to natural fish passage; and use of weirs, grade control structures, and low flow channels to provide the proper depth and velocity for fish) to offset impacts from proposed riparian habitat and stream modifications.
6. Construct a low-flow channel to facilitate fish passage and help maintain water temperature in reaches where water velocities require armoring of the riverbed.
7. Replace in-stream fish habitat by installing boulders, rock weirs, and woody debris and by planting riverine aquatic cover vegetation to provide shade and habitat.
8. Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.
9. Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
10. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
11. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for flood control and shoreline protection projects.

## Beach Nourishment

Beach nourishment, the process of mechanically or hydraulically placing sediments (i.e., sand and gravel) directly on an eroding shore to restore or form a protective or desired recreational beach, has been steadily increasing along the eastern US coastline since the 1960s (Greene 2002). Beaches and shorelines are dynamic, constantly eroding and accreting because of exposure to waves, currents, and wind. Beach nourishment serves as a "soft," sacrificial barrier to protect the beach and property along the coast from storm and flood damage. Between 1923 and 2004, it is estimated that approximately 515 million cubic yards of beach sediment have been deposited on the

US east coast barrier island shoreline from Maine to Florida, including 966 instances of beach nourishment at 343 locations (Valverde et al. 1999; PSDS 2005).

Beach nourishment as a protective measure against coastal flooding and storm damage may be considered less of an impact to marine organisms and fishery habitat than are most "hard" structure solutions discussed in the previous section. However, beach nourishment can have a number of short- and long-term impacts on fishery resources, including displacing benthic organisms during and after nourishment, interference with respiration and feeding in finfish and filter feeding invertebrates, temporary removal of benthic prey, burial of habitat that serves as foraging and shelter sites, potential burial of demersal and benthic species, and mortality of species at vulnerable life stages, such as eggs, larvae, and juveniles (Greene 2002). Sand or cobble material needed for beach nourishment is generally dredged from offshore areas, referred to as borrow or mining sites, and either hydraulically pumped through pipes or loaded onto barges for transfer and placement on the beach. Fish and invertebrates in and around the borrow site can be subjected to entrainment, sedimentation, and increased turbidity during the dredging and transport of the beach material. In addition, the creation of borrow pits may alter the bottom topography and sediment transport processes in offshore habitats and form depressions with low-dissolved oxygen. Nourished beaches seldom last as long as natural beaches, and natural coastal processes erode the replenished sand, requiring additional nourishment of those beaches (Pilkey and Dixon 1996). The life span of a nourished beach can be highly variable and primarily dependent upon storm intensity and frequency following the completion of a project. According to Pilkey and Dixon (1996), the life span of most nourished beaches is 2-5 years. Beach nourishment projects are often conducted at a high economic cost, and they can represent a long-term and cumulative impact on the marine biological community.

Increased global precipitation, more intense storms, and sea level rise predicted for the mid-high latitudes in the northern hemisphere because of global climate change will likely exacerbate erosional forces on beaches (Nedeau 2004) and increase the frequency of beach renourishment to protect eroding shoreline. See Global Effects and Other Impacts chapter for more on global climate change.

### *Altered hydrological regimes*

Sand removed from borrow sites can potentially affect the geomorphology of offshore sand bars and shoals that absorb incoming waves, causing greater wave energy and/or change refraction patterns (Greene 2002). This may increase the erosion rate at the nourished beach and adjacent, nonnourished beaches. In addition, nourished beaches tend to have altered sediment grain size, shape, and distribution across the beach, which can lead to changes in the hydrodynamic patterns in the intertidal beach zone (Pilkey and Dixon 1996; Greene 2002).

In addition, the conditions in deeply excavated borrow pits can become anaerobic during certain times of the year. The dissolved oxygen concentration within these deep pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984). For example, construction grade aggregate removal in Raritan Bay, NJ, Long Island Sound, and the intercoastal waterway in New Jersey have left deep pits and large depressions that are more than twice the depth of the surrounding area. The pits have remained chemically, physically, and biologically unstable with limited biological diversity for more than five decades. These borrow pits in Raritan Bay were found to possess depressed benthic communities and elevated levels of highly hydrated and organically enriched sediments (Pacheco 1984).

### *Altered sediment transport*

Longshore transport of sediments may be affected by the creation of borrow pits, which can be deep depressions taking several years to refill and can alter the nearshore sediment budget (Greene 2002). Longshore sediment transport may also be affected in the nearshore environment if material placed on the beach is not compatible with natural or historic material. In addition, nearshore rock groins are sometimes constructed in order to reduce erosion of the nourished beach, which alters the downdrift of sediment and may starve adjacent beaches of sand.

### *Alteration/loss of benthic habitat*

Sand infauna and sessile benthic organisms in the path of dredging equipment at the borrow site are generally removed and killed during mining. In addition, some mobile organisms, such as crustaceans and larval and juvenile fish, can be entrained by the dredge equipment. Following mining, species diversity of benthic infaunal organisms within borrow pits drops precipitously, but recolonization in sandy sediments typically occurs through larval transport and migration of postsettlement life-stages (i.e., juveniles and adults) (Greene 2002).

Benthic fauna at the beach site will be killed by burial following nourishment unless an organism is capable of burrowing through the overburden of sand (Greene 2002). Several factors determine survival of beach invertebrate fauna, including the ability for vertical migration through the sand overburden and the recruitment potential of larvae, juveniles, and adult organisms from adjacent areas (Greene 2002). Peterson et al. (2000) found an 86-99% reduction in the abundance of dominant species of beach macro-invertebrates ten weeks after nourishment on a North Carolina beach. These observations were made between the months of June and July, when the abundances of beach macro-invertebrates are typically at their maximum and providing the important ecosystem service of feeding abundant surf fishes and ghost crabs (Peterson et al. 2000).

### *Alteration of natural communities*

The recovery of the benthic infauna at a borrow site is dependent upon a number of factors, including the amount of material removed, the fauna present at the site and surrounding area prior to dredging, and the degree of sedimentation that occurs following dredging (Greene 2002). For sand habitats, the recovery time of benthic infauna within borrow sites has been reported to be as rapid as less than one year, while other studies have indicated recovery may take greater than five years (Greene 2002). Some differences in recovery time may be attributed to the fact that most benthic infauna recolonization studies look at abundance of individuals but fail to measure trophic level changes and the life history of individuals in the samples (Greene 2002). The postdredging benthic community may function very differently than does the predredging community. The borrow pits may require several years to refill with sediment and may contain a greater silt content than do the surrounding areas (Greene 2002). Generally, the degree of alteration of the sediment composition appears to be the largest factor in determining long-term impact at a borrow site (Greene 2002). The dissolved oxygen concentration within borrow pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984).

Similar to the findings on the recovery of benthic infauna at borrow sites, results of studies assessing the recovery of organisms at nourished beaches are highly variable (Greene 2002). While some studies conclude that beach infauna populations may recover to predredging levels between two to seven months, other studies suggest recovery times are much longer (Greene 2002). Peterson et al. (2000) found a large reduction in prey abundance and body size of benthic macroinvertebrates at a nourished intertidal beach that likely translated to trophic level impacts on surf zone fishes and shorebirds.

### *Increased sedimentation/turbidity*

High turbidity in the water column and sedimentation on adjacent benthic habitats can result from resuspension of sediment at the discharge pipe and from sediment winnowing from the nourished beach into the surf zone. In addition, turbidity can also increase between the borrow site and the target beach when sand is lost during hopper loading, from leaks in the pipelines carrying sand to the beach, and from the dredging activity at the borrow site itself. High turbidity and suspended sediments can be persistent in the nearshore waters long after a beach is nourished if mud balls, silt, and clays are present in the mined sediment (Greene 2002).

Generally, the severity of the effects of suspended sediments on aquatic organisms increases as a function of sediment concentration and the duration of exposure (Newcombe and Jensen 1996). Some of the effects of suspended sediments on marine organisms can include altered foraging patterns and success (Breitburg 1988), gill abrasion and reduced respiratory functions, and death (Wilber and Clark 2001). The sensitivity of species to suspended sediments is highly variable and dependent upon the nature of the sediment and the life history stage of the species. The eggs and larval stages of marine and estuarine fish are generally highly sensitive to suspended sediment exposures compared to some freshwater taxa studied (Wilber and Clark 2001). Sedimentation from beach nourishment may also have adverse effects on invertebrates that serve as prey for fish (Greene 2002). Refer to the Marine Transportation and Offshore Dredging and Disposal chapters for more information regarding turbidity and sedimentation impacts on aquatic organisms.

### *Conservation measures and best management practices for beach nourishment (adapted from Hanson et al. 2003)*

1. Avoid sand mining in areas containing sensitive marine benthic habitats (e.g., spawning and feeding sites, hard bottom, cobble/gravel substrate, shellfish beds).
2. Avoid beach nourishment in areas containing sensitive marine benthic habitats adjacent to the beach (e.g., spawning and feeding sites, hard bottom, cobble/gravel substrate).
3. Conduct beach nourishment during the winter and early spring, when productivity for benthic infauna is at a minimum; this may minimize the impacts for some beach sites.
3. Assess source material for compatibility with that of material to be placed on beach (e.g., grain size and shape, color). Slope of nourished beach should mimic the natural beach profile.
4. Use upland beach material sources, if compatible, to avoid impacts associated with offshore sand mining.
5. Preserve, enhance, or create beach dune and native dune vegetation in order to provide natural beach habitat and reduce the need for nourishment.
6. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels at the beach and borrow sites.
7. Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Address the cumulative impacts of past, present, and foreseeable future development activies on aquatic habitats by considering them in the review process for beach nourishment projects.

## Wetland Dredging and Filling

The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Even development projects that appear to have minimal individual wetland impacts can have significant cumulative effects on the aquatic ecosystem. This section discusses the impacts on fishery habitat from dredging and filling freshwater and tidal wetlands for development purposes. Additional information on dredging and filling in freshwater wetlands and rivers and streams is provided in the chapter on Alteration of Freshwater Systems, and dredging and disposal of dredge material in subtidal habitats (e.g., navigation channel dredging and marine mining) have been addressed in the chapters on Marine Transportation and Offshore Dredging and Disposal. The primary impacts to fishery habitat from the introduction of fill material in or adjacent to wetlands include: (1) physical loss of habitat; (2) loss or impairment of wetland functions; and (3) changes in hydrologic patterns.

The discharge of dredge and fill materials are regulated under Section 404 of the Clean Water Act (CWA) of 1972 for all "waters of the United States," which include both freshwater and tidal wetlands. Some of the types of discharge of fill material covered under Section 404 of the CWA include: (1) placement of fill that is necessary to the construction of a structure or impoundment; (2) site development fills for recreational, industrial, commercial, or residential uses; (3) causeway or road fills, dams, or dikes; (4) artificial islands; (5) property protection and/or reclamation devices such as riprap, groins, seawalls, breakwaters, and revetments; (6) beach nourishment; (7) levees; (8) fill for structures such as sewage treatment facilities, intake and outfall pipes associated with power plants and subaqueous utility lines; and (9) artificial reefs.

### *Loss and alteration of wetland vegetation*

Salt marsh wetlands serve as habitat for early life history stages of many fish species, as well as shellfish, crabs, and shrimp, which use the physical structure of the marsh grasses as refuge from predators (Tyrrell 2005). Smaller fish, such as mummichog (*Fundulus heteroclitus*), Atlantic silverside (*Menidia menidia*), sticklebacks (*Gasterosteids*, spp.), and sheepshead minnow (*Cyprinidon variegates*), rely on salt marshes for parts of their life cycles. These species form the prey base of many larger, commercially important species such as a number of flounder species, black sea bass (*Centropristis striata*), and bluefish (*Pomatomus saltatrix*) (Collette and Klein-MacPhee 2002).

Filling wetlands removes productive habitat and eliminates the important functions that both aquatic and many terrestrial organisms depend upon. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) caused by degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Niering 1988; Mitsch and Gosselink 1993).

### *Altered hydrological regimes*

The discharge of dredged or fill material into aquatic habitats can modify current patterns and water circulation by obstructing the flow or by changing the direction or velocity of water flow and circulation. As a result, adverse changes can occur in the location, structure, and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; the deposition of suspended particulates; the rate and extent of mixing of dissolved and suspended components of the water body; and water stratification (Hanson et al. 2003). Altering the hydrology of wetlands can affect the water table, groundwater discharge, and soil salinity, causing a shift in vegetation patterns and quality of the habitat. Hydrology can be affected by fragmenting the habitat caused by the construction of roads and residential development or by building bulkheads, dikes, levees, and other structures designed to prevent or remove floodwater from the land around the wetlands (Niering 1988; Mitsch and Gosselink 1993). These structures also reduce natural tidal flushing and interfere with natural sediment-transport processes, all of which are important functions that maintain the integrity of the marsh habitat (Tyrrell 2005). Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005). Alteration of the hydrology and soils of salt marsh wetlands has led to the invasion of an exotic haplotype of the common reed (*Phragmites australis*), which has spread dramatically and degraded salt marsh habitats along the Atlantic coast (Posey et al. 2003; Tyrrell 2005).

### *Loss of flood storage capacity*

Coastal wetlands absorb and store rain and urban runoff, buffering upland development from floods. In addition, coastal marshes provide a physical barrier that protects upland development from storm surge. As a result, the loss and alteration of coastal wetlands can cause upland development to be more prone to flooding from storms and heavy rains. Furthermore, altering the hydrological regimes of wetlands through construction of dikes, levees, and tide gates can redirect floodwater towards rivers and estuaries and bypass the natural flood storage functions of coastal wetlands.

### *Altered current patterns*

Replacing wetlands with roads, buildings, and other impervious surfaces increases the volume and intensity of storm water runoff, which can accelerate the rate of coastal erosion. Placing dredge material onto intertidal mud habitats can dramatically alter tidal flow. These effects can change the geomorphology and current patterns of rivers and estuaries and adversely affect habitat suitability for certain species. For example, counter current flows set up by freshwater discharges into estuaries are important for larvae and juvenile fish entering those estuaries. Behavioral adaptations of marine and estuarine species allow larvae and early juveniles to concentrate in estuaries (Deegan and Buchsbaum 2005).

### *Altered temperature regimes*

The loss of riparian and salt marsh vegetation can increase the amount of solar radiation reaching streams and rivers and results in an increase in the water temperatures of those water bodies (Moring 2005). Replacing coastal wetlands with impervious surfaces such as asphalt, which absorb more solar radiation than does vegetation, tends to raise the water temperature in adjacent aquatic environments. Altered temperature regimes have the ability to affect the distribution; growth rates; survival; migration patterns; egg maturation and incubation success; competitive ability; and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003b). In freshwater habitats of the northeastern United States, the temperature regimes of cold-water fish such as salmon, smelt, and trout may be exceeded, leading to local extirpation of these species (Moring 2005). The removal of riparian vegetation can also have the effect of lowering water temperatures during winter, which can increase the formation of ice and delay the development of incubating fish eggs and alevins in salmonids (Hanson et al. 2003).

### *Release of rutrients/eutrophication*

When functioning properly, riparian and tidal wetlands support denitrification of nitrate-contaminated groundwater. While sediment particles can bind to some nutrients, resuspension of sediments following a disturbance tends to cause a rapid release of nutrients to the water column (Lohrer and Wetz 2003). Coastal wetlands reduce the risk of eutrophication in estuaries and nearby coastal waters (Tyrrell 2005) by absorbing nutrients in groundwater and storm water. Eliminating or degrading coastal wetlands through dredge and fill activities can eliminate these important wetland functions and adversely affect estuarine and marine ecosystems.

### *Release of contaminants*

The removal of wetlands eliminates an important wetland function: pollution filtration (Niering 1988; Mitsch and Gosselink 1993). Wetlands are capable of absorbing metals, pesticides, excess nutrients, oxygen-consuming substances, and other pollutants that would otherwise be transported directly to aquatic environments. In addition, dredging and filling of wetlands can release contaminants that have accumulated in the sediments into adjacent aquatic habitats.

### *Increased sedimentation/turbidity*

When functioning properly, riparian and tidal wetlands filter sediment and runoff from floodplain development. Siltation, sedimentation, and turbidity impacts on riverine and estuarine habitats can be worsened by the loss and replacement of wetlands with impervious surfaces. Suspended sediments in aquatic environments reduce the availability of sunlight to aquatic plants, cover fish spawning areas and food supply, interfere with filtering capacity of filter feeders, and can clog and harm the gills of fish (USEPA 2003b).

### *Loss of fishery productivity*

Hydrological modifications from dredge and fill activities and general coastal development are known to increase the amount of run-off entering the aquatic environment and may contribute to the reduced productivity of fishery resources. Many wetland dependent species, such as mummichog, Atlantic silverside, sticklebacks, and sheepshead minnow, are important prey for larger, commercially important species such as a number of flounder species, black sea bass, and bluefish (Collette and Klein-MacPhee 2002). Although there have been sharp declines or collapses of many estuarine-dependent fisheries in the United States, attributing reductions in fishery productivity directly to losses of wetland habitat can be complicated (Deegan and Buchsbaum 2005). Recent wetland losses can be quantified for discrete regions and the nation as a whole; however, a number of other factors, such as overfishing, cultural eutrophication, and altered input of freshwater caused by flood control structures, probably all contribute to a reduction in the productivity of fisheries. Since the implementation of the Clean Water Act in 1972, the major problems for coastal habitats have changed from outright destruction to more subtle types of degradation, such as cultural eutrophication (Deegan and Buchsbaum 2005).

### *Introduction of invasive species*

A nonnative haplotype of the common reed, *Phragmites australis,* has expanded its range along the entire east coast of the United States, primarily in wetland habitats disturbed by nutrient loading and hydrological alterations of salt marsh wetlands (Posey et al. 2003). *Phragmites* is tolerant of low-salinity conditions in salt marshes, which can occur with tidal restrictions from the construction of tide gates, bulkheads, and dikes. Under these conditions, *Phragmites* can out-compete native salt marsh vegetation such as *Spartina* sp. (Burdick et al. 2001; Deegan and Buchsbaum 2005). Salt marshes that are dominated by *Phragmites* may have reduced function and productivity compared to that of salt marshes consisting of native marsh vegetation (Tyrrell 2005).

### *Conservation measures and best management practices for wetland dredging and filling (adapted from Hanson et al. 2003)*

1. Apply a sequence of measures to avoid, minimize, and mitigate adverse impacts in wetlands to all proposed dredging projects. Dredging and filling within wetlands should be avoided to the maximum extent practicable.
2. Consider only "water-dependent" dredge and fill projects in wetlands and only after upland alternatives have been investigated.
3. Do not dispose dredge material in wetlands, and ensure that these materials meet or exceed applicable state and/or federal water quality standards.
4. Identify and characterize fishery habitat functions/services in the project areas prior to any dredge and fill activities.
5. Identify the direct and indirect affects of wetland fills on fishery habitat during proposed project reviews, including alterations of hydrology and water quality as a result of the proposed project.
6. Assess the cumulative impact from past, current, and all reasonably foreseeable future dredge and fill operations that impact aquatic habitats via federal, state, and local resource management and permitting processes.
7. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Undertake activities in wetlands, if required, using only low ground pressure vehicles.
9. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for wetland dredge and fill projects.

## Overwater Structures

With increasing coastal development comes a concomitant interest in the construction and operation of waterfront facilities, the use of coastal waterways, and the environmental implications of these activities (Barr 1993). Overwater structures include commercial and residential piers and docks, floating breakwaters, moored barges, rafts, booms, and mooring buoys. These structures are typically located from intertidal areas to areas of water depths approximately 15 m below mean low water (i.e., the shallow subtidal zone). Light, wave energy, substrate type, depth, and water quality are the primary factors controlling the plant and animal assemblages found at a particular site. Overwater structures and associated use activities can alter these factors and interfere with key ecological functions such as spawning, rearing, and the use of refugia. Site-specific factors (e.g., water clarity, current, depth) and the type and use of a given overwater structure determine the occurrence and magnitude of these impacts (Hanson et al. 2003).

### *Shading impacts to vegetation*

Overwater structures create shade which reduces the light levels below the structure. Shading from overwater structures can reduce prey organism abundance and the complexity of the habitat by reducing aquatic vegetation and phytoplankton abundance (Haas et al. 2002). The size, shape, and intensity of the shadow cast by a particular structure are dependent upon its height, width, construction materials, and orientation. In field studies conducted in Massachusetts, the most significant factors affecting shading impacts on eelgrass were the height of the structure above vegetation, orientation of the dock, and dock width (Burdick and Short 1999). High and narrow piers and docks produce narrower and more diffuse shadows than do low and wide structures. Increasing the numbers of pilings used to support a pier increases the shade cast by pilings on the under-pier environment. In addition, less light is reflected underneath structures built with light-absorbing materials (e.g., wood) than from structures built with light-reflecting materials (e.g., concrete or steel). Under-pier light levels have been found to fall below threshold amounts for the photosynthesis of diatoms, benthic algae, eelgrass, and associated epiphytes and other autotrophs. Eelgrass and other macrophytes can be reduced or eliminated, even through partial shading of the substrate, and have little chance to recover (Kenworthy and Hauners 1991). Structures that are oriented north-south produce a shadow that moves across the bottom throughout the day, resulting in a smaller area of permanent shade than those that are oriented east-west (Burdick and Short 1999; Shafer 1999). In a report investigating effects of residential docks in south Florida, Smith and Mezich (1999) found approximately 40% of the docks surveyed had additions fixed to them (e.g., boat lifts and cradles, floating docks, finger piers). These structural additions increased the dock area (and seagrass impacts) and ranged from 16-77%, and contributed to mean seagrass impacts of 47% beyond the footprint of the dock.

Similar shading impacts to salt marsh vegetation from docks and piers have been reported. A study in Connecticut measuring the density and average plant height of salt marsh vegetation below docks and adjacent areas found a reduction in vegetative reproductive capacity caused by the presence of docks (Kearney et al. 1983). This study concluded that the height of the dock was a strong determining factor in the effects to salt marsh vegetation.

### *Altered hydrological regimes*

Alterations to wave energy and water transport from overwater structures can impact the nearshore detrital foodweb by altering the size, distribution, and abundance of substrate and detrital materials (Hanson et al. 2003). The disruption of longshore transport can alter substrate composition and can present potential barriers to the natural processes that build spits and beaches and provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning (Hanson et al. 2003).

### *Contaminant releases*

Kennish (2002) identified a number of contaminants associated with overwater structures that can be released into the aquatic environment, including detergents, petroleum products, and copper. Treated wood used for pilings and docks releases contaminants into the aquatic environment. Creosote-treated wood pilings and docks commonly release PAH and other chemicals, such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA), which are applied to preserve the wood (Poston 2001; Weis and Weis 2002). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). The presence of CCA in the food chain can also cause a localized reduction in species richness and diversity (Weis and Weis 2002). These preservatives are known to leach into marine waters after installation, but the rate of leaching is highly variable and dependent on many factors, including the age of the treated wood. Concrete or steel, on the other hand, are relatively inert and do not leach contaminants into the water.

### *Benthic habitat impacts*

Additional impacts associated with overwater structures may include damage to seagrasses and substrate scour from float chains and anchors (Kennish 2002). Docks located in intertidal areas that are exposed during low tides result in vessels resting on the substrate, which may impact shellfish beds, SAV, and intertidal mudflats. Vessels operating in shallow water to access docks may cause a resuspension of bottom sediments and may physically disrupt aquatic habitats, such as bank and shoreline (Barr 1993) and SAV through "prop dredging" (Burdick and Short 1999). Barr (1993) identified a number of potential impacts to aquatic ecosystems from resuspension of sediments caused by vessel activity, including reductions in primary productivity (e.g., phytoplankton and SAV), alteration of temperature, dissolved oxygen and pH of the water, abrasion and clogging of fishes gill filaments, and reductions in egg development and the growth of some fishes and invertebrates. Glasby (1999) found that epibiota on pier pilings at marinas subject to shading were markedly different than those in surrounding rock reef habitats. Shading by overwater structures may be responsible for the observed reductions in juvenile fish populations found under piers and the reduced growth and survival of fishes held in cages under piers, when compared to open habitats (Able et al. 1998; Duffy-Anderson and Able 1999).

### *Increased erosion/accretion*

Pilings can alter adjacent substrates with increased deposition of sediment from changes in current fields or shell material deposition from piling communities. Changes in substrate type can alter the nature of the flora and fauna native to a given site. Kearney et al. (1983) found that docks and pier walkways cause shading impacts to salt marsh vegetation, reduce plant root mat, and may lead to soil erosion in the area of the structures. In the case of pilings, native dominant communities typically associated with sand, gravel, mud, and eelgrass substrates may be replaced by communities associated with shell hash substrates (Penttila and Doty 1990; Nightingale and Simenstad 2001; Haas et al. 2002). In addition to impacts to eelgrass habitat from overwater structures, Penttila and Doty (1990) found that changes to current fields around structures caused altered sediment distribution and topography that created depressions along piling lines.

### *Changes in predator/prey interaction*

Fish use visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The reduced-light conditions found under an overwater structure limit the ability of fish, especially juveniles and larvae, to perform these essential activities (Hanson et al. 2003). In addition, the use of artificial lighting on docks and piers creates unnatural nighttime conditions that can increase the susceptibility of some fish to predation and interfere with predator/prey interactions (Nightingale and Simenstad 2001).

### *Cumulative effects*

While the effect of some individual overwater structures on fishery habitat may be minimal, the overall impact may be substantial when considered cumulatively. For example, although shading impacts on seagrasses may affect a relatively small area around overwater structures, fragmentation of seagrass beds along a highly developed shoreline or within a bay can be considerable. Fragmentation of seagrass habitat can lower the integrity of the remaining seagrass beds, leaving it more susceptible to other impacts (Burdick and Short 1999). The additive effect of these structures increases the overall magnitude of impact, reduces the ability of the habitat to support native plant and animal communities, and makes the habitat more susceptible to damage from storms and disease.

### *Conservation measures and best management practices for overwater structures (adapted from Hanson et al. 2003)*

1. Use upland boat storage whenever possible to minimize need for overwater structures.
2. Locate overwater structures in sufficiently deep waters to avoid intertidal and shade impacts, to minimize or preclude dredging, to minimize groundings, and to avoid displacement of SAV, as determined by a preconstruction survey.
3. Design piers, docks, and floats to be multi-use facilities serving multiple homeowners in order to reduce the overall number of such structures and the nearshore habitat that is impacted.
4. Incorporate measures that increase the ambient light transmission under piers and docks. Some of these measures include: maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint; grated decking material; using the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate; and aligning piers, docks, and floats in a north-south orientation to allow the path of the sun to cross perpendicular to the length of the structure and reduce the duration of shading.
5. Encourage seasonal use of docks and off-season haul-out.
6. Avoid placing floating docks in areas supporting SAV. Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal zone, and ensure that adequate water depth is available between the substrate and the bottom of the float throughout all tide cycles.
7. Incorporate float stops in dock proposals when it is impracticable or impossible to avoid placing floating docks in water deep enough to avoid contact with the bottom to avoid mechanical and/or hydraulic damage to the substrate from the float during low tides. Float stops should be designed to provide a minimum of 2 ft of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
8. Conduct in-water work during the time of year when managed species and prey species are least likely to be impacted.
9. Avoid the use of treated wood timbers or pilings to the extent practicable. The use of alternative materials such as untreated wood, concrete, or steel is recommended. Concrete and steel pilings are generally considered to be less damaging, since they help reflect light under docks and generally do not release contaminants into the aquatic environment.
10. Orient artificial lighting on docks and piers such that illumination of the surrounding waters at night is avoided.
11. Address the cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the review process for overwater structure projects.

## Pile Driving and Removal

Pilings provide support for the decking of piers and docks; they function as fenders and dolphins to protect structures, support navigation markers, and are used to construct breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic or a combination thereof, and they are usually driven into the substrate with impact hammers or vibratory hammers (Hanson et al. 2003). Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers utilize a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. While impact hammers are able to drive piles into most substrates (e.g., hardpan, glacial till), vibratory hammers are limited to softer, unconsolidated substrates (e.g., sand, mud, gravel). Piles can be removed by using a variety of methods, including vibratory hammer, direct pull, clamshell grab, or cutting/breaking the pile below the mudline. Vibratory hammers can be used to remove all types of pile, including wood, concrete, and steel. Broken stubs are often removed with a clamshell and crane. In other instances, piles may be cut or broken below the mudline, leaving the buried section in place (Hanson et al. 2003).

### *Sound energy impacts*

Pile driving with impact hammers can generate intense underwater sound pressure waves that may adversely affect fish species and their habitats. These pressure waves have been shown to injure and kill fish (CalTrans 2001; Longmuir and Lively 2001). Injuries directly associated with pile driving include rupture of the swimbladder and internal hemorrhaging, but these have been poorly studied (CalTrans 2001).

### *Benthic habitat impacts*

The extraction of piles can result in altered sediment composition and depressions in the bottom, which may cause erosion and loss of sediment. Bottom depressions may fill in with fine sediments and silt, changing the characteristics of the benthic habitat. Removal of piles may cause sediments to slough off and elevate the suspended sediment concentrations at the work area (Hanson et al. 2003). The subsequent sedimentation and turbidity can impact adjacent sensitive habitats, such as SAV.

### *Increased sedimentation/turbidity and contaminant releases*

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments. Contaminants contained within the sediments in the area of pilings can become available to aquatic plants and animals when pilings are extracted from the substrate. Sediment plumes may also be created around the pilings when they are installed, although it is usually much less than the turbidity created during removal. Some turbidity may be generated when piles are installed or removed with hydraulic jets, although this technique may not be widely used in the northeast coastal region. Vibratory pile removal tends to cause the sediments to slough off, resulting in relatively low levels of suspended sediments and contaminants (Hanson et al. 2003). Vibratory removal of piles may be preferable in some circumstances because it can be used on all types of piles, providing that they are structurally sound. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing the stub is left in place and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles, however, may suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate with these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling (Hanson et al. 2003). For more information on turbidity and sedimentation, consult the chapters on Physical Effects: Water Intake and Discharge Facilities and Marine Transportation. Additional information on contaminant releases can be reviewed in the Chemical Effects: Water Discharge Facilities chapter.

### *Conservation measures and best management practices for pile driving and removal (adapted from Hanson et al. 2003)*

1. Drive piles during low tide periods when substrates are exposed in intertidal areas.
2. Use a vibratory hammer to install piles, when possible. Under those conditions where impact hammers are required for reasons of seismic stability or substrate type, it is recommended that the pile be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer.
3. Implement measures to attenuate the sound or minimize impacts to aquatic resources during piling installation. Methods to mitigate sound impacts include, but are not limited to, the following:
    a. Surround the pile with an air bubble curtain system or dewatered cofferdam.
    b. Drive piles during low water conditions for intertidal areas.
    c. Utilize appropriate work windows that avoid impacts during sensitive times of year (e.g., anadromous fish runs and spawning, larval, and juvenile development periods).
4. Remove creosote-coated piles completely rather than cutting or breaking off if the pile is structurally sound.
5. Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
    a. Remove piles with a vibratory hammer when practicable, rather than with the direct pull or clamshell method.
    b. Remove the pile slowly to allow sediment to slough off at or near the mudline.
    c. Hit or vibrate the pile first to break the bond between the sediment and pile to minimize the potential for the pile to break, as well as reduce the amount of sediment sloughing off the pile during removal.
    d. Encircle the pile or piles with a silt curtain that extends from the surface of the water to the substrate.
6. Fill all holes left by the piles with clean, native sediments, if possible.
7. Place piles on a barge equipped with a basin to contain all attached sediment and runoff water after removal. Creosote-treated timber piles should be cut into short lengths to prevent reuse, and all debris, including attached, contaminated sediments, should be disposed of in an approved upland facility.
8. Drive broken/cut stubs with a pile driver sufficiently below the mudline to prevent release of contaminants into the water column as an alternative to their removal.
9. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for pile driving projects.

## Marine Debris

Marine debris is a chronic problem along much of the US coast, resulting in littered shorelines and estuaries and creating hazards for marine organisms. Marine debris consists of a large variety of anthropogenic materials such as generic litter, hazardous wastes, and discarded or lost fishing gear and can have varying degrees of negative effects on the coastal ecosystem (Hanson et al. 2003). It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Several laws and regulatory programs exist to prevent or control the disposal of industrial wastes and the release of marine debris from ocean sources, including commercial merchant vessels (e.g., galley waste and other trash), recreational boaters and fishermen, offshore oil and gas exploration and facilities, military and research vessels, and commercial fishing vessels (Cottingham 1988). Despite these laws and regulations, marine debris continues to adversely impact our waters (Hanson et al. 2003). See the Marine Transportation chapter for more information on marine debris.

Land-based sources of marine debris account for approximately 80% of the marine debris on the beaches and in the waters of the Gulf of Maine (Hoagland and Kite-Powell 1997), as well as other coastal areas of the United States (Hanson et al. 2003). Land-based debris can originate from a wide variety of sources, including combined sewer overflows and storm drains; storm-water runoff; landfills; solid waste disposal; manufacturing facilities; poorly maintained garbage bins; floating structures (i.e., docks and piers); and general littering of beaches, rivers, and open waters (Cottingham 1988; Hanson et al. 2003). Plastics account for 50-60% of marine debris collected from the Gulf of Maine (Hoagland and Kite-Powell 1997).

### *Entanglement and ingestion*

Entanglement and ingestion of marine debris by marine species is known to affect individuals of at least 267 species worldwide, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (Laist 1997). Plastic debris may be ingested by seabirds, fish and invertebrates, sea turtles, and marine mammals, which can obstruct the animal's intestinal tract and cause infections and death (Cottingham 1988). A study of marine debris ingestion by seabirds in the southern Atlantic Ocean found that 73% of all birds sampled had ingested some type of marine debris, and plastics composed 66% of all debris occurrences (Copello and Quintana 2003).

### *Introduction of invasive species*

Marine debris discarded from commercial cargo and recreational vessels are one of the primary methods of transporting nonindigenous marine life around the world, some of which have become invasive species that can alter the structure and function of aquatic ecosystems (Valiela 1995; Carlton 2001; Niimi 2004). Refer to the chapters on Marine Transportation, and Introduced/Nuisance Species and Aquaculture for more information on invasive species.

### *Contaminant releases and introduction of pathogens*

The type of debris from land-based sources can include raw or partially treated sewage, litter, hazardous materials (e.g., PAH, paint, solvents), and discarded trash. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. It may contain condoms, tampons, and contaminated hypodermic syringes, all of which can pose physical and biological threats to fishery habitat (Hanson et al. 2003). Toxic substances in plastics, for example, can persist in the environment and bioaccumulate through the food web and can kill or impair fish and invertebrates that use habitat polluted by these materials.

### *Conversion of habitat*

Because of the wide range and diversity of sources and materials contributing to marine debris, the effects on aquatic habitats are likewise wide-ranging and diverse. Floating or suspended trash can directly affect fish and invertebrates that may consume or are entangled by the debris. Debris that settles to the bottom of rivers, estuaries, and open ocean areas may continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate sessile animals and plants. Debris can be transported by currents to other areas where it can become snagged and attached to benthic reefs, damaging these sensitive habitats.

### *Conservation measures and best management practices for marine debris (adapted from Hanson et al. 2003)*

1. Require all existing and new commercial construction projects near the coast (e.g., marinas and ferry terminals, recreational facilities, boat building and repair facilities) to develop and implement refuse disposal plans.
2. Encourage proper trash disposal in coastal and ocean settings.
3. Provide resources to the public on the impact of marine debris and guidance on how to reduce or eliminate the problem.

## References for Coastal Development

Able KW, Manderson JP, Studholme AL. 1998. The distribution of shallow water juvenile fishes in an urban estuary: The effects of manmade structures in the lower Hudson River. Estuaries 21(4B):731-44.

Amaral M, Lee V, Rhodes J. 2005. Environmental guide for marinas: controlling nonpoint source and storm water pollution in Rhode Island: best management practices for marinas. [Internet]. Narragansett (RI): University of Rhode Island, Coastal Resources Center, Rhode Island Sea Grant. [cited 2007 Dec 28]. Available from: http://seagrant.gso.uri.edu/BMP/BMP.html.

Arkoosh MR, Clemons E, Huffman P, Kagley AN, Casillas E, Adams N, Sanborn HR, Collier TK, Stein JE. 2001. Increased susceptibility of juvenile chinook salmon to vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries. Journal of Aquatic Animal Health 13(3):257-68.

[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

[ASMFC] Atlantic States Marine Fisheries Commission. 2004. NRC report outlines the impacts of oil on marine fish habitat. Habitat Hotline Atlantic 11(3):1-5.

Bahgat FJ, King PE, Shackley SE. 1989. Ultrastructural changes in the muscle tissue of *Clupea harengus* L. larvae induced by acid pH. Journal of Fish Biology 34:25-30.

Balcom B, Howell P. 2006. Responding to a resource disaster: American lobsters in Long Island Sound 1999-2004. Groton (CT): University of Connecticut, Connecticut Sea Grant. CTSG-06-02. 22 p.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth symposium on coastal and ocean management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Belford DA, Gould WR. 1989. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management 9(4):437-45.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Bilby RE, Sullivan K, Duncan SH. 1989. The generation and fate of road-surface sediment in forested watersheds in southwestern Washington. Forest Science 35(2):453-68.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology: Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New

York (NY): Academic Press. p 177-252.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Bodammer JE. 1981. The cytopathological effects of copper on the olfactory organs of larval fish (*Pseudopleuronectes americanus* and *Melanogrammus aeglefinus*). Copenhagen (Denmark): ICES CM-1981/E: 46.

Bowling A, Mackin K. 2003. The state of the Ipswich River. Ipswich (MA): Ipswich River Watershed Association. 9 p.

Bozek CM, Burdick DM. 2005. Impacts of seawalls on saltmarsh plant communities in the Great Bay Estuary, New Hampshire USA. Wetlands Ecology and Management 13:553-68.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Bricker SB, Clement CG, Pirhalla DE, Orlando SP, Farrow DRG. 1999. National estuarine eutrophication assessment: effects of nutrient enrichment in the Nation's estuaries. Silver Spring (MD): NOAA, NOS, Special Projects Office and the National Centers for Coastal Ocean Science. 71 p.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Burdick DM, Buchsbaum R, Holt E. 2001. Variation in soil salinity associated with expansion of *Phragmites australis* in salt marshes. Environmental and Experimental Botany 46(3):247-61.

Burdick DM, Short FT. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23(2):231-40.

Caltrans. 2001. San Francisco-Oakland Bay Bridge East Span seismic safety project, pile installation demonstration project, fisheries impact assessment. Sacramento (CA): California Department of Transportation. 59 p.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chapman MG. 2003. Paucity of mobile species on constructed seawalls: effects of urbanization on biodiversity. Marine Ecology Progress Series 264:21-9.

Chiasson AG. 1993. The effects of suspended sediment on rainbow smelt (*Osmerus mordax*): a laboratory investigation. Canadian Journal of Zoology 71:2419-24.

Clancy CG, Reichmuth DR. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management 10(2):244-6.

Collette BB, Klein-MacPhee G, editors. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine. 3rd ed. Washington (DC): Smithsonian Institution Press. 748 p.

Copello S, Quintana F. 2003. Marine debris ingestion by southern giant petrels and its potential relationship with fisheries in the Southern Atlantic Ocean. Marine Pollution Bulletin 46(11):1504-15.

Cottingham D. 1988. Persistent marine debris: challenge and response: the federal perspective. Fairbanks (AK): Alaska Sea Grant. Report No. 88-1.

Deegan LA, RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

De Guise S, Maratea J, Perkins C. 2004. Malathion immunotoxicity in the American lobster (*Homarus americanus*) upon experimental exposure. Aquatic Toxicology 66(4):419-25.

DeLorenzo ME, Scott GI, Ross PE. 2001. Toxicity of pesticides to aquatic microorganisms: a review. Environmental Toxicology and Chemistry 20(1):84-98.

De Robertis A, Ryer CH, Veloza A, Brodeur RD. 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60:1517-1526.

Duffy-Anderson JT, Able KW. 1999. Effects of municipal piers on the growth of juvenile fishes in the Hudson River estuary: a study across a pier edge. Marine Biology 133(3):409-18.

Evans WA, Johnston B. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington (DC): US Department of Agriculture, Forest Service. 163 p.

Fulton MH, Scott GI, Fortner A, Bidleman TF, Ngabe B. 1993. The effects of urbanization on small high salinity estuaries of the southeastern United States. Archives of Environmental Contamination and Toxicology 25(4):476-84.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19th ed. Bethesda (MD): American Fisheries Society. p 297-323.

Gilbert SF. 2000. Developmental biology. [Internet]. Sunderland (MA): Sinauer Associates. 6th ed. [updated 2007 Oct 17; cited 2006 May 17]. Available from: http://www.ncbi.nlm.nih.gov/

Glasby TM. 1999. Effects of shading on subtidal epibiotic assemblages. Journal of Experimental Marine Biology and Ecology 234:275-90.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. 68 p + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Greenberg CH, Crownover SH, Gordon DR. 1997. Roadside soils: a corridor for invasion of xeric scrub by nonindigenous plants. Natural Areas Journal 17(2):99-109.

Greene K. 2002. Beach nourishment: a review of the biological and physical impacts. Washington (DC): ASMFC. Habitat Management Series #7. 179 p.

Haas MA, Simenstad CA Jr, Cordell JR, Beauchamp DA, Miller BS. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA. [Internet]. Seattle (WA): Washington State Transportation Center (TRAC), University of Washington, and Washington State Department of Transportation. Final Research Report WA-RD 550.1. [cited 2008 Jul 9]. 114 p. Available from: http://depts.washington.edu/trac/bulkdisk/pdf/550.1.pdf

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hoagland KD, Carder JP, Spawn RL. 1996. Chapter 15: Effects of organic toxic substances. In: Stevenson RJ, Bothwell ML, Love RL, editors. Algal ecology: freshwater benthic ecosystems. San Diego (CA): Academic Press. p 469-96.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Holland AF, Sanger DM, Gawle CP, Lerberg SB, Santiago MS, Riekerk GHM, Zimmerman LE, Scott GI. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298(2):151-78.

[IPCC] Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 996 p. Available from: http://www.ipcc.ch.

[ICES] International Council for the Exploration of the Sea. 1991. Report of the study group on ecosystem effects of fishing activities. 11-15 March 1991; Lowestoft, England. Copenhagen (Denmark): ICES C.M. 1991/G:7 Session Y.

Jackson SD. 2003. Design and construction of aquatic organism passage at road-stream crossings: ecological considerations in the design of river and stream crossings. In: Irwin CL, Garrett P, McDermott KP, editors. 2003 Proceedings of the International Conference on Ecology and Transportation; 2003 Aug 24-29; Lake Placid, NY. Raleigh (NC): Center for Transportation and the Environment, North Carolina State University. p 20-9.

Kearney VF, Segal Y, Lefor MW. 1983. The effects of docks on salt marsh vegetation. Hartford (CT): Connecticut Department of Environmental Protection, Water Resources Unit. 22 p.

Kelley JT. 1992. Sea-level change and coastal erosion in the western Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Regional Synthesis Series No. 1. p 27-44.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Kennish MJ. 1998. Pollution impacts on marine biotic communities. Boca Raton (FL): CRC Press.

Kennish MJ. 2002. Impacts of motorized watercraft on shallow estuarine and coastal marine environments. Journal of Coastal Research Special Issue 37:1-202.

Kenworthy JW, Hauners DE. editors. 1991. The light requirements of seagrasses: proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses. Beaufort (NC): NMFS Beaufort Laboratory. NOAA Technical Memorandum NMFS-SEFC-287. 179 p.

Klein-MacPhee G, Cardin JA, Berry WJ. 1984. Effects of silver on eggs and larvae of the winter flounder. Transactions of the American Fisheries Society 113(2):247-51.

Koski KV. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapport Et Proces-Verbaux Des Reunions Du Conseil International Pour L'Exploration De La Mer (ICES) 178:330-3.

Laist DW. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe JM, Rogers

DB, editors. Marine debris: sources, impacts, and solutions. New York (NY): Springer. p 99-139.

Lang T, Dethlefsen V. 1987. Cadmium in skeletally deformed and normally developed Baltic cod (*Gadus morhua* L.). Copenhagen (Denmark): ICES CM-1987/ E:30. 18 p.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Lohrer AM, Wetz JJ. 2003. Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek. Marine Pollution Bulletin 46(9):1156-63.

Longmuir C, Lively T. 2001. Bubble curtain systems for use during marine pile driving. New Westminister (BC), Canada: Fraser River Pile and Dredge LTD. 9 p.

Lonsdale WN, Lane AM. 1994. Tourist vehicles as vectors of weed seeds in Dadoed National Park, northern Australia. Biological Conservation 69(3):277-83.

MacDonald LH, Sampson RW, Anderson DM. 2001. Runoff and road erosion at the plot and road segment scales, St John, US Virgin Islands. Earth Surface Processes and Landforms 26:251-72.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Meyers TR, Hendricks JD. 1982. A summary of tissue lesions in aquatic animals induced by controlled exposures to environmental contaminants, chemotherapeutic agents, and potential carcinogens. Marine Fisheries Review 44(12):1-17.

Milliken AS, Lee V. 1990. Pollution impacts from recreational boating: a bibliography and summary review. Narragansett (RI): Rhode Island Sea Grant. National Sea Grant Depository Publication # RIU-G-002.

Mitsch WJ, Gosselink JG. 1993. Wetlands. 2$^{nd}$ ed. New York (NY): Van Nostrand Reinhold. 722 p.

Moore A, Waring CP. 2001. The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar* L.). Aquatic Toxicology 52:1-12.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant

College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1991. Status and trends in concentrations of selected contaminants in Boston Harbor sediments and biota. Seattle (WA): National Ocean Service, Office of Oceanography and Marine Assessment. NOAA Technical Memorandum NOS OMA 56.

Nedeau E. 2004. Effects of climate change on the Gulf of Maine region. [Internet]. Gulf of Maine Council on the Marine Environment. [cited 2008 Jul 9]. 12 p. Available from: http://www.gulfofmaine.org/summit/ClimateChangeKbase.pdf.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Niering WA. 1988. The Audubon Society nature guides. Wetlands. New York (NY): Alfred A. Knopf. 638 p.

Nightingale BJ, Simenstad CA Jr. 2001. Overwater structures: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 9]. 133 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finalmar.pdf.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, William SL. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Pacheco A. 1984. Final report, Seasonal occurrence of finfish and larger invertebrates at three sites in Lower New York Harbor, 1981-1982. Sandy Hook (NJ): NOAA/NMFS. Special report for USACE, New York District. 53 p.

Penttila D, Doty D. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Olympia (WA): Washington Department of Fisheries. Draft Progress Report. 41 p.

Peterson CH, Hickerson DHM, Johnson GG. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16(2):368-78.

Pilkey OH, Dixon KL. 1996. The Corps and the shore. Washington (DC): Island Press. 272 p.

Posey MH, Alphin TD, Meyer DL, Johnson JM. 2003. Benthic communities of common reed *Phragmites australis* and marsh cordgrass *Spartina alterniflora* marshes in Chesapeake Bay. Marine Ecology Progress Series 261:51-61.

Poston T. 2001. Treated wood issues associated with overwater structures in freshwater and marine environments. [Internet]. Olympia (WA): Washington State Departments of Transportation, Fish and Wildlife, and Ecology. White Paper. [cited 2008 Jul 9]. 85 p. Available from: http://wdfw.wa.gov/hab/ahg/finaltw.pdf.

Preston BL. 2002. Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment. Environmental Management 29(3):311-23.

[PSDS] Program for the Study of Developed Shorelines. 2005. The U.S. beach nourishment experience: including New England, east coast barrier islands, Pacific coast and Gulf of Mexico shorelines. [Internet]. Cullowhee (NC): Western Carolina University, c2006. [Cited 2008 Jul 9]. Available from: http://psds.wcu.edu/1038.asp.

Readman JW, Kwong LLW, Grondin D, Bartocci J, Villeneuve JP, Mee LD. 1993. Coastal water contamination from triazine herbicide used in antifouling paints. Environmental Science and Technology 27(9):1940-2.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Safavi HR. 1996. Quality control of urban runoff and sound management. Hydrobiologia: Diapause in the Crustacea:131-41.

Scott GI, Fulton MH, Moore DW, Wirth EF, Chandler GT, Key PB, Daugomah JW, Strozier ED, Devane J, Clark JR, and others. 1999. Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems. Toxicology and Industrial Health 15:200-13.

Shafer DJ. 1999. The effects of dock shading on the seagrass *Halodule wrightii* in Perdido Bay, Alabama. Estuaries 22(4):936-43.

Short FT, Burdick DM. 1996. Quantifying, eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19(3):730-9.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Smith KN, Mezich RR. 1999. Blending management and research for protection of manatee habitat in Florida: the seagrass dock effect. In: Poster presentation at the 15th Biennial International Estuarine Research Federation Conference; 1999 Sep 25-30; New Orleans, LA. Port Republic (MD): Coastal and Estuarine Research Federation.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

[USEPA] US Environmental Protection Agency. 1993. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. [Internet]. Washington (DC): US EPA Office of Water. EPA-840-B-92-002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/OWOW/NPS/MMGI.

[USEPA] US Environmental Protection Agency. 1995. National water quality inventory: 1994 Report to Congress. Washington (DC): US EPA Office of Water. EPA-841-R-95-005.

[USEPA] US Environmental Protection Agency. 2001. National management measures guidance to control nonpoint source pollution from marinas and recreational boating. Washington (DC): EPA Office of Water. EPA-841-B-01-005.

[USEPA] US Environmental Protection Agency. 2002. National water quality inventory: 2000 Report to Congress. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-R-02-001. [cited 2008 Jul 9]. Available from: http://www.epa.gov/305b/2000report/.

[USEPA] US Environmental Protection Agency. 2003a. Guide for industrial waste management. Washington (DC): US EPA Office of Solid Waste. EPA-530-R-03-001.

[USEPA] US Environmental Protection Agency. 2003b. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2004. National coastal condition report II.

[Internet]. Washington (DC): US EPA Office of Research and Development/ Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

Valiela I. 1995. Marine ecological processes, 2nd ed. New York (NY): Springer-Verlag.

Valiela I, Rutecki D, Fox S. 2004. Salt marshes: biological controls of food webs in a diminishing environment. Journal of Experimental Marine Biology and Ecology 300(1-2):131-59.

Valverde HR, Trembanis AC, Pilkey OH. 1999. Summary of beach nourishment episodes on the U.S. East Coast Barrier Islands. Journal of Coastal Research 15(4):1100-18.

Vandermeulen JH, Mossman D. 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences 53:1741-53.

Weis JS, Weis P. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-10.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White Paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. 99 p. [cited 2008 Jul 9]. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

Ziegler AD, Sutherland RA, Gaimbelluca TW. 2001. Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads. Earth Surface Processes and Landforms 26(3):235-50.

# CHAPTER THREE: ENERGY-RELATED ACTIVITIES

## Petroleum Exploration, Production, and Transportation

### *Introduction*

The exploration, production, and transportation of petroleum have the potential to impact riverine, estuarine, and marine environments on the northeastern US coast. Petroleum exploration, production, and transportation are a particular concern in areas such as the Gulf of Maine and Georges Bank, which support important fishery resources and represent significant value to the US economy. Although petroleum exploration and production do not currently occur within the northeast coastal and offshore region, the transportation of oil and gas (i.e., pipelines and tankers) and the associated infrastructure are widespread. It is expected that issues relating to petroleum development will continue to gain importance as world energy costs and demands rise. The Energy Policy Act of 2005 (Pub. L. 109-58, § 357, 42 U.S.C. §15912) authorizes the Minerals Management Service (MMS) to perform surveys (exploration) for petroleum reserves on the Outer Continental Shelf (OCS) of the United States. The OCS is the submerged lands, subsoil, and seabed lying between the United States' seaward jurisdiction and the seaward extent of federal jurisdiction.

Petroleum exploration involves seismic testing, drilling sediment cores, and test wells in order to locate potential oil and gas deposits. Petroleum production includes the drilling and extraction of oil and gas from known reserves. Oil and gas rigs are placed on the seabed and as oil is extracted from the reservoirs, it is transported directly into pipelines. While rare, in cases where the distance to shore is too great for transport via pipelines, oil is transferred to underwater storage tanks. From these storage tanks, oil is transported to shore via tanker (CEQ 1977). According to the MMS, there are 21,000 miles of pipeline on the United States OCS. According to the National Research Council (NRC), pipeline spills account for approximately 1,900 tonnes per year of petroleum into US OCS waters, primarily in the central and western Gulf of Mexico (NRC 2003).

The major sources of oil releases as a result of petroleum extraction include accidental spills and daily operational discharges. The NRC estimates the largest anthropogenic source of petroleum hydrocarbon releases into the marine environment is from petroleum extraction-related activities. Approximately 2,700 tonnes per year in North America and 36,000 tonnes per year worldwide are introduced to the marine environment as a result of "produced waters" (NRC 2003). "Produced waters" are waters that are pumped to the surface from oil reservoirs which cannot be separated from the oil. Produced waters are either injected back into reservoirs or discharged into the marine environment (NRC 2003). Over 90% of the oil released from extraction activities is from produced water discharges which contain dissolved compounds (i.e., polycyclic aromatic hydrocarbons, PAH) and dispersed crude oil (NRC 2003). These compounds stay suspended in the water column and undergo microbial degradation or are sorbed onto suspended sediments and are deposited on the seabed. Elevated levels of PAH in sediments are typically found up to 300 m from the discharge point (NRC 2003).

While petroleum extraction and transportation can result in impacts to the marine environment, it is important to note that natural seeps contribute to approximately 60% of all petroleum hydrocarbons that are released into the marine environment (NRC 2003). In addition, land-based runoff and discharges by two–stroke recreational boating engines account for nearly 22% of the total petroleum released into the marine environment in North America (NRC 2003).

## *Underwater noise*

Oil and gas activities generate noise from drilling activities, construction, production facility operations, seismic exploration, and supply vessel and barge operations that can disrupt or damage living marine resources. The effects of oil exploration-related seismic energy may cause fish to disperse from the acoustic pulse with possible disruption to their feeding patterns (Marten et al. 2001). Larvae and young fish are particularly sensitive to noise generated from underwater seismic equipment. Noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement and feeding), interfering with echolocation and communication, or injuring hearing organs (Richardson et al. 1995). Noise issues related to petroleum tanker traffic can adversely affect fishery resources within the marine environment, particularly within estuarine areas which host much of the nation's petroleum land-based port activities. Refer to the chapters on Marine Transportation and Global Effects and Other Impacts for information regarding impacts to fishery resources from underwater noise.

## *Habitat conversion and loss*

Petroleum extraction and transportation can lead to a conversion and loss of habitat in a number of ways. Activities such as vessel anchoring, platform or artificial island construction, pipeline laying, dredging, and pipeline burial can alter bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or shelter habitat, can also result. The installation of pipelines associated with petroleum transportation can have direct and indirect impacts on offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. The destruction of benthic organisms and habitat can occur through the installation of pipelines on the sea floor (Gowen 1978). Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if facilities are left in place after production ends.

The discharge of drilling cuttings (i.e., crushed sedimentary rock) during petroleum extraction operations can result in varying degrees of change to the sea floor and affect feeding, nursery, and shelter habitat for various life stages of marine organisms. Cuttings may adversely affect bottom-dwelling organisms at the site by burial of immobile forms or forcing mobile forms to migrate. The accumulation of drill cuttings on the ocean floor can alter the benthic sedimentary environment (NRC 2003).

Physical damage to coastal wetlands and other fragile areas can be caused by onshore infrastructure and pipelines associated with petroleum production and transportation. Physical alterations to habitat can occur from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries. For additional information regarding impacts of pipelines associated with petroleum production, refer to the section on Cables and Pipelines in this chapter of the report.

## *Contaminant discharge*

A variety of contaminants can be discharged into the marine environment as a result of petroleum extraction operations. Waste discharges associated with a petroleum facility include drilling well fluids, produced waters, surface runoff and deck drainage, and solid-waste from wells (i.e., drilling mud and cuttings) (NPFMC 1999). In addition to crude oil spills, chemical, diesel, and other contaminant spills can occur with petroleum-related activities (NPFMC 1999).

Produced waters contain finely dispersed oil droplets that can stay suspended in the water column or can settle out into sediments. Produced waters are generally more saline than seawater and contain elevated concentrations of radionuclides, metals, and other contaminants. Elevated levels of contaminated sediments typically extend up to 300 m from the discharge point (NRC 2003). In estuarine waters, higher saline produced waters can affect the salt wedge and form dense saltwater plumes.

The discharge of oil drilling mud can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. The addition of contaminants can reduce or eliminate the suitability of the water column and substrate as habitat for fish species and their prey. The discharge of oil-based drill cuttings are currently not permitted in US waters; however, where oil-based drill cuttings have been discharged, there is evidence that sediment contamination and benthic impacts can occur up to 2 km from the production platform (NRC 2003).

The petroleum refining process converts crude oil into gasoline, home heating oil, and other refined products. The process of refining crude oil into various petroleum products produces effluents, which can degrade coastal water quality. Oil refinery effluents contain many different chemicals at different concentrations including ammonia, sulphides, phenol, and hydrocarbons. Toxicity tests have shown that most refinery effluents are toxic, but to varying extents. Some species are more sensitive and the toxicity may vary throughout the life cycle. Experiments have shown that not only can the effluents be lethal, but they can often have sublethal effects on growth and reproduction (Wake 2005). Field studies have shown that oil refinery effluents often have an adverse impact on aquatic organisms (i.e., an absence of all or most species), which is more pronounced in the area closest to the outfall (Wake 2005).

The operation of oil tankers can discharge contaminants into the water column and result in impacts to pelagic and benthic organisms. Older tankers that do not have segregated ballast tanks (i.e., completely separated from the oil cargo and fuel systems) can discharge ballast water containing contaminants (NRC 2003).

### *Discharge of debris*

Petroleum extraction and transportation can result in the discharge of various types of debris, including domestic wastewater generated from offshore facilities, solid-waste from wells (i.e., drilling mud and cuttings), and other trash and debris from human activities associated with the facility (NPFMC 1999). Debris, either floating on the surface, suspended in the water column, covering the benthos, or along the shoreline can have deleterious impacts on fish and shellfish within riverine habitat, as well as in benthic and pelagic habitats in the marine environment (NEFMC 1998). Debris from petroleum extraction and transportation activities can be ingested by fish (Hoagland and Kite-Powell 1997). Reduction and degradation of habitat by debris can alter community structure and affect the sustainability of fisheries.

### *Oil spills*

In even moderate quantities, oil discharged into the environment can affect habitats and living marine resources. Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS and in nearshore coastal areas and can occur from a number of sources, including equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms (Hanson et al. 2003). Oil spills can also be attributed to support activities associated with product recovery and transportation and can also involve various contaminants including hazardous chemicals and diesel fuel (NPFMC 1999).

Oil, characterized as petroleum and any derivatives, can be a major stressor to inshore fish habitats. Oil can kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of the marine ecosystem (NRC 2003). Short-term impacts include interference with the reproduction, development, growth and behavior (e.g., spawning and feeding) of fishes, especially at early life-history stages (Gould et al. 1994). Petroleum compounds are known to have carcinogenic and mutagenic properties (Larsen 1992). Various levels of toxicity have been observed in Atlantic herring (*Clupea harengus*) eggs and larvae exposed to crude oil in concentrations of 1-20 ml/L (Blaxter and Hunter 1982). Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. These impacts may eventually lead to disruption of community organization and dynamics in affected regions. Oil can persist in sediments for years after the initial contamination (NRC 2003), interfering with physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996).

Oil spills can have adverse effects to both subtidal and intertidal vegetation. Direct exposure to petroleum can lead to die off of submerged aquatic vegetation (SAV) in the first year of exposure. Certain species which propagate by lateral root growth rather than seed germination may be less susceptible to oil in the sediment (NRC 2003). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Kelp located in low energy environments can retain oil in their holdfasts for extended periods of time. Oil spills are known to cause severe and long-term damage to salt marshes through the covering of plants and contamination of sediments. Lighter and more refined oils such as No. 2 fuel oil are extremely toxic to smooth cordgrass (*Spartina alterniflora*) (NRC 2003). Impacts to salt marsh habitats from oil spills depend on type, coverage, and amount of oil. Oil spills within salt marshes will likely have a greater impact in the spring growing season, compared to the dormant periods in the fall and winter.

Habitats that are susceptible to damage from oil spills include the low-energy coastal bays and estuaries where heavy deposits of oil may accumulate and essentially smother intertidal and salt marsh wetland communities. High-energy cobble environments are also susceptible to oil spills, as oil is driven into sediments through wave action. For example, many of the beaches in Prince William Sound, AK, with the highest persistence of oil following the *Exxon Valdez* oil spill were high-energy environments containing large cobbles overlain with boulders. These beaches were pounded by storm waves following the spill, which drove the oil into and well below the surface (Michel and Hayes 1999). Oil contamination in sediments may persist for years. For example, subsurface oil was detected in beach sediments of Prince William Sound twelve years after the *Exxon Valdez* oil spill, much of it unweathered and more prevalent in the lower intertidal biotic zone than at higher tidal elevations (Short et al. 2002).

Oil can have severe detrimental impacts on offshore habitats, although the effects may not be as acute as in inshore, sheltered areas. Offshore spills or wellhead blowouts can produce an oil slick on surface waters which can disrupt entire pelagic communities (i.e., phytoplankton and zooplankton). The disruption of plankton communities can interfere with the reproduction, development, growth, and behavior of fishes by altering an important prey base.

Physical and biological forces act to reduce oil concentrations (Hanson et al. 2003). Generally, the lighter fraction aromatic hydrocarbons evaporate rapidly, particularly during periods of high wind and wave activity. Heavier oil fractions typically pass through the water column and settle to the bottom. Suspended sediments can adsorb and carry oil to the seabed. Hydrocarbons may be solubilized by wave action which may enhance adsorption to sediments, which then sink to the seabed and contaminate benthic sediments (Hanson et al. 2003). Tides and hydraulic gradients allow movement of soluble and slightly soluble contaminants (e.g., oil) from beaches to surrounding streams in the hyporheic zone (i.e., the saturated zone under a river or stream, comprising substrate with the interstices filled with water) where pink salmon (*Oncorynchus* *gorbuscha*) eggs incubate (Carls et al. 2003). Oil can reach nearshore areas and affect productive nursery grounds, such as estuaries that support high densities of fish eggs and larvae. An oil spill near a particularly important hydrological zone, such as a gyre where fish or invertebrate larvae are concentrated, could also result in a disproportionately high loss of a population of marine organisms (Hanson et al. 2003). Epipelagic biota, such as eggs, larvae and other planktonic organisms, would be at risk from an oil spill. Planktonic organisms cannot actively avoid exposure, and their small size means contaminants may be absorbed quickly. In addition, their proximity to the sea surface can increase the toxicity of hydrocarbons several-fold and make them more vulnerable to photo-enhanced toxicity effects (Hanson et al. 2003).

Many factors determine the degree of damage from a spill, including the composition of the petroleum compound, the size and duration of the spill, the geographic location of the spill, and the weathering process present (NRC 2003). Although oil is toxic to all marine organisms at high concentrations, certain species and life history stages of organisms appear to be more sensitive than others. In general, the early life stages (i.e., eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Some marine species may be particularly susceptible to hydrocarbon spills if they require specific habitat types in localized areas and utilize enclosed water bodies, like estuaries or bays (Stewart and Arnold 1994).

Small but chronic oil spills may be a particular problem to the coastal ecosystem because residual oil can build up in sediments. Low-levels of petroleum components from such chronic pollution have been shown to accumulate in fish tissues and cause lethal and sublethal effects, particularly at embryonic stages. Effects on Atlantic salmon (*Salmo salar*) from low-level chronic exposure to petroleum components and byproducts (i.e., polycyclic aromatic hydrocarbons [PAH]) have been shown to increase embryo mortality, reduce growth (Heintz et al. 2000), and lower the return rates of adults returning to natal streams (Wertheimer et al. 2000).

As spilled petroleum products become weathered, the aromatic fraction of oil is dominated by PAH as the lighter aromatic components evaporate into the atmosphere or are degraded. Because of its low solubility in water, PAH concentrations probably contribute little to acute toxicity (Hanson et al. 2003). However, lipophilic PAH (those likely to be bonded to fat compounds) may cause physiological injury if they accumulate in tissues after exposure (Carls et al. 2003; Heintz et al. 2000). Even concentrations of oil that are diluted sufficiently to not cause acute impacts in marine organisms may alter certain behavior or physiological patterns. For example, “fatty change,” a degenerative disease of the liver, can occur from chronic exposure to organic contaminants such as oil (Freeman et al. 1981).

Sublethal effects that may occur with exposure to PAH include impairment of feeding mechanisms for benthic fish and shellfish, growth and development rates, energetics, reproductive output, juvenile recruitment rates, increased susceptibility to disease and other histopathic disorders (Capuzzo 1987), and physical abnormalities in fish larvae (Urho and Hudd 1989). Effects of exposure to PAH in benthic species of fish include liver lesions, inhibited gonadal growth, inhibited spawning, reduced egg viability and reduced growth (Johnson et al. 2002). Gould et al. (1994) summarized various toxicity responses to winter flounder (*Pseudopleuronectes americanus*) exposed to PAH and other petroleum-derived contaminants, including liver and spleen diseases, immunosuppression responses, tissue necrosis, altered blood chemistry, gill tissue clubbing, mucus hypersecretion, altered sex hormone levels, and altered reproductive impairments. For Atlantic cod (*Gadus morhua*) exposed to various petroleum products, responses included reduced growth rates, gill hyperplasia, increased skin pigmentation, hypertrophy of gall bladder, liver disease, delayed spermatogenesis, retarded gonadal development and other reproductive impairments, skin lesions, and higher parasitic infections (Gould et al. 1994).

## *Oil spill clean-up activities*

There are a number of oil spill response and cleanup methods available. Chemical dispersants are used primarily in open water environments. Dispersants contain surfactant chemical that under proper mixing conditions and concentrations attach to oil molecules and reduce the interfacial tension between oil molecules (NOAA 1992). This allows oil molecules to break apart and thus break down the oil slick. Depending on the environmental conditions and biological resource present, dispersants can result in acute toxicity. Exposure to high concentrations of oil dispersants has been shown to block the fertilization of eggs and induce rapid cytolysis of developing eggs and larvae in Atlantic cod (Lonning and Falk-Petersen 1978). Other methods of cleanup for open water spills include in-situ burning and nutrient and microbial remediation. In each case, impacts are dependent on the resources present in the particular location. Other forms of shoreline cleanup include the use of sorbents, trenching, sediment removal, and water flooding/pressure washing. Sediment removal and pressure washing will result in direct impact to the benthos. Trampling and cutting of salt marsh vegetation during cleanup activities can be severe, causing damage to plants and forcing oil into the sediments. However, impacts associated with the cleanup activities need to be weighed against the impacts created by the the spill itself.

## *Siltation, sedimentation, and turbidity*

Exploratory and construction activities may result in resuspension of fine-grained mineral particles, usually smaller than silt, in the water column. Fish and invertebrate habitat may be adversely affected by elevated levels of suspended particles (Arruda et al. 1983), which can result in both lethal and sublethal impacts to marine organisms (Newcombe and MacDonald 1991; Newcombe and Jensen 1996). Short-term impacts from increases in suspended particles may include high turbidity, reduced light, and sedimentation which may lead to the loss or complexity of benthic habitat (USFWS and NMFS 1999). Suspended particles can reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area, especially if the turbidity is persistent (Gowen 1978). Groundfish and other fish species can suffer reduced feeding ability and limited growth if high levels of suspended particles persist in the water column. Other problems associated with suspended solids include disrupted respiration and water transport rates in marine organisms, reduced filtering efficiencies in invertebrates, reduced egg buoyancy, disrupted ichthyoplankton development, reduced growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Gowen 1978; Messieh et al. 1991; Barr 1993). Demersal eggs of fish and invertebrates can be adversely impacted by sediment deposition and suffocation. For example, hatching is delayed for striped bass (*Morone saxatilis*) and white perch (*Morone americana*) exposed to sediment concentrations as low as 100 mg/L for 1 day (Wilber and Clarke 2001). Berry et al. (2004) reported a decreased hatching success for winter flounder eggs with increasing depth of burial by sediment. No hatching occurred at burial depths of approximately 2 mm. Breitburg (1988) found the predation rates of striped bass larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory. Anadromous fish passage in estuarine and riverine environments can also be adversely impacted by increased turbidity. For example in laboratory experiments, rainbow smelt (*Osmerus mordax*) showed signs of increased swimming activity at suspended sediment concentrations as low as 20 mg/L, suggesting fish responded to increased sediment concentrations with an “alarm reaction” (Chiasson 1993).

Shallow water environments, rocky reefs, nearshore and offshore rises, salt and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than are open-water habitats. This is due, in part, to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978).

### *Conservation recommendations and best management practices for petroleum exploration, production, and transportation (adapted from Hanson et al. 2003)*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area. Construction should be sited to minimize impacts to fishery resources.
2. Avoid the discharge of produced waters into marine and estuarine environments. Reinject produced waters into the oil formation whenever possible.
3. Avoid discharge of drilling mud and cuttings into the marine, estuarine, and riverine environment.
4. Avoid placing roads and bridges and structures associated with petroleum exploration and production in the nearshore marine environment. Particular care should be made to avoid SAV, intertidal flats, and salt marsh habitat.
5. Use methods to transport oil and gas that limit the need for handling in sensitive fishery habitats.
6. Use horizontal directional drilling for installation of pipelines in areas containing sensitive habitats, whenever possible.
7. Provide for monitoring and leak detection systems at oil extraction, production, and transportation facilities that preclude oil from entering the environment.
8. Evaluate impacts to habitat during the decommissioning phase, including impacts during the demolition phase.
9. Schedule dredging and excavation activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Ensure that oil extraction, production, and transportation facilities have developed and implemented adequate oil spill response plans. Assist government agencies responsible for oil spills (e.g., US Coast Guard, state and local resource agencies) in developing response plans and protocols, including identification of sensitive marine habitats and development and implementation of appropriate oil spill-response measures.
11. Potential adverse impacts to marine resources from oil spill clean-up operations should be weighed against the anticipated adverse affects of the oil spill itself. The use of chemical dispersants in nearshore areas where sensitive habitats are present should be avoided.
12. Address the cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the review process for petroleum exploration, production, and transportation projects.

## Liquefied Natural Gas (LNG)

### *Introduction*

Liquefied Natural Gas (LNG) is expected to provide a large proportion of the future energy needs in the northeastern United States. In recent years there has been an increase in proposals for new LNG facilities, including both onshore and offshore facilities from Maine to Delaware. In the northeastern United States, there are currently onshore LNG facilities operating in Everett, MA, and Cove Point, MD, and two offshore LNG facilities have been approved to operate in Massachusetts Bay.

The LNG process cools natural gas to its liquid form at approximately -260 degrees Fahrenheit (F). This reduces the volume of natural gas to approximately 1/600$^{th}$ of its gaseous state volume, making it possible for economical transportation with tankers. Upon arrival at the destination, the LNG is either regasified onshore or offshore and sent out into an existing pipeline infrastructure, or transported onshore for storage and future regasification. The process of regasification occurs when LNG is heated and converted back to its gaseous state. LNG facilities can utilize either "open loop," "closed loop," or "combined loop" systems for regasification. Open loop systems utilize warm seawater for regasification, and closed loop systems generally utilize a recirculating mixture of ethylene glycol for regasification. Combined loop systems utilize a combination of the two systems.

Onshore LNG facilities generally include a deepwater access channel, land-based facilities for regasification and distribution, and storage facilities. Offshore facilities generally include some type of a deepwater port with a regasification facility and pipelines to transport natural gas into existing gas distribution pipelines or onshore storage facilities. Deepwater ports require specific water depths and generally include some form of exclusion zone for LNG vessel and/or port facility security.

### *Habitat conversion and loss*

The conversion of habitat and/or the loss of benthic habitats can occur from the construction and operation of LNG facilities. The placement of pipelines and associated structures on the seafloor can impact benthic habitats from physical occupation and conversion of the seafloor. The installation of pipelines can impact shellfish beds, hard-bottomed habitats, and SAV (Gowen 1978). Plowing or trenching for pipeline installation and side-casting of material can lead to a conversion of substrate and habitat. Placement of anchors for the construction of the deepwater port facilities can have direct impact to the substrate and benthos.

Because of the large size of LNG tankers, dredging may need to occur in order to access onshore terminals. The deepening of channel areas and turning basins can result in permanent and temporary dredging impacts to fishery habitat, including the loss of spawning and juvenile development habitat caused by changes in bathymetry, suitable substrate type, and sedimentation. Disruption of the areas from dredging and sedimentation may cause spawning fish to leave the area for more suitable spawning conditions. Dredging, as well as the equipment used in the process such as pipelines, may damage or destroy other sensitive habitats such as emergent marshes and SAV, including eelgrass beds (Mills and Fonseca 2003) and macroalgae beds. The stabilization and hardening of shorelines for the development of upland facilities can lead to a direct loss of SAV, intertidal mudflats, and salt marshes that serve as important habitat for a variety of living marine resources. See the Marine Transportation, Offshore Dredging and Disposal, and Coastal Development chapters for more detailed information on impacts from dredging.

### *Discharge of contaminants*

Discharge of contaminants can occur as a result of spills during offloading procedures associated with either onshore or offshore facilities. There is limited information and experience regarding the aquatic impacts resulting from an LNG spill; however, because of the toxic nature of natural gas, acute impacts to nearby resources and habitats can be expected.

Biocides (e.g., copper and aluminum compounds) are often utilized in the hydrostatic testing of pipelines. LNG tankers utilize large amounts of seawater for regasification purposes (i.e., open-loop system), for engine cooling, and for ship ballast water. Biocides are commonly utilized to prevent pipeline and engine fouling from marine organisms and are subsequently discharged into surrounding waters. Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977). The release of contaminants can reduce or eliminate the suitability of water bodies as habitat for fish species and their prey. In addition, contaminants, such as copper and aluminum, can accumulate in sediments and become toxic to organisms contacting or feeding on the bottom.

### *Discharge of debris*

LNG facilities can result in the discharge of debris, including domestic waste waters generated from the offshore facility, and other trash and debris from human activities associated with the facility (NPFMC 1999). Impacts from the discharge of debris from LNG are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Siltation, sedimentation, and turbidity*

LNG construction activities may result in increased suspended sediment in the water column caused by dredging, the installation of pipelines, anchors and chains, and the movement of vessels through confined areas, and upland site development. Impacts from siltation and sedimentation from LNG are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Entrainment and impingement*

Intake structures for traditional power plants can result in impingement and entrainment of marine organisms through the use of seawater for cooling purposes (Enright 1977; Helvey 1985; Callaghan 2004). Likewise, intake structures utilized for the LNG regasification process can result in impingement and entrainment of living marine resources. "Open-loop" LNG regasification systems utilize seawater for warming into a gaseous state and are typically utilized when ambient water temperatures are greater than about 45°F. In addition, "combined loop" systems can utilize seawater for partial regasification. Depending on the geographic location and the water depth of the intake pipe, phytoplankton, zooplankton, and fish eggs and larvae can be entrained into the system. Juvenile fish can also be impinged on screens of water intake structures (Hanson et al. 1977; Hanson et al. 2003). Normal ship operations utilize intake structures for ballast water and engine cooling and can result in additional impingement and entrainment of resources, as well.

The entrainment and impingement impacts on aquatic organisms from LNG facilities have the potential to be substantial. For example, an assessment of impacts of a proposed LNG facility in the Gulf of Mexico determined that an open-loop regasification system could utilize 176 million gallons of water per day, which may entrain 1.6 billion fish and 60 million shrimp larvae per year, 3.3 billion fish eggs per year, and 500 billion zooplankton per year (R. Ruebsamen, pers. comm.). Additional entrainment and impingement impacts were expected for vessel ballast and cooling water uses. In the northeastern United States, an offshore LNG regasification facility approved in Massachusetts Bay with a closed-loop system has estimated annual mortality rates caused by vessel ballast and cooling water for the eggs and larvae for Atlantic mackerel (*Scomber scombrus*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), and Atlantic cod of 8.5 million, 7.8 million, 411,000, and 569,000, respectively (USCG 2006).

### *Alteration of temperature regimes*

The operation of LNG facilities can result in the alteration of temperature regimes. Discharge of water from engine cooling operations can be at temperatures up to 10°F higher than surrounding waters. Water utilized for the purposes of regasification could be discharged at temperatures colder than the surrounding water by about 10-15°F. Changes in water temperatures can alter physiological functions of marine organisms, including respiration, metabolism, reproduction, and growth. In riverine and estuarine environments, changes to water temperatures can impact the egg and juvenile life stages of Atlantic salmon (USFWS and NMFS 1999). Thermal effluent in inshore habitat can cause severe problems by directly altering the benthic community or adversely affecting marine organisms, especially egg and larval life stages (Pilati 1976; Rogers 1976). For example, the seaward migration of juvenile American shad (*Alosa sapidissima*) are cued to water temperatures (Richkus 1974; MacKenzie et al. 1985), and temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969; Stanley and Colby 1971).

### *Alteration of hydrological regimes*

The operation of LNG facilities can affect the hydrology of confined waterbodies, waterbodies with limited flows such as streams and rivers, and estuaries fed by streams and rivers. Depending upon the characteristics of the waterbody and the nature of the water intake and discharge, altered stream flow can result in reductions in stream flow and subsequent degradation of ecosystem functions (Reiser et al. 2004).

### *Alteration of salinity regimes*

The operation of LNG tankers can result in the alteration of hydrological regimes caused by the discharge of brine from onboard desalination operations. For example, the operation of LNG tankers within riverine and estuarine environments can impact anadromous fish by altering salinity regimes (Dodson et al. 1972; Leggett and O'Boyle 1976) and affecting the ability of fish to access migration corridors.

### *Underwater noise*

Underwater noise sources generate sound pressure that can disrupt or damage marine life. LNG activities generate noise from construction, production facility operations, and tanker traffic. Larvae and young fish are particularly sensitive to noise generated from underwater seismic equipment. It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement, feeding), interfering with echolocation and communication or injuring hearing organs (Richardson et al. 1995). Noise issues related to LNG tanker traffic may adversely affect fishery resources in the marine environment, particularly in estuarine areas where some LNG port activities are located or proposed. A more thorough review of underwater noise can be found in the chapter on Global Effects and Other Impacts.

### *Exclusion zones*

Because of security concerns, LNG tankers and terminals include safety and exclusion areas. Different types of restrictions are put in place based on the distance from the facility. However, restrictions on commercial and recreational fishing activities around the LNG facilities can lead to a displacement of fishing effort to other/adjacent areas. This in turn, may increase fishing effort and habitat impacts to more ecologically sensitive areas.

## *Introduction of invasive species*

Introductions of nonnative invasive species into marine and estuarine waters are a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species can be released unintentionally when ships release ballast water (Hanson et al. 2003; Niimi 2004). Hundreds of species have been introduced into United States waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). LNG tankers entering US waters are generally loaded with cargo and do not need to release large amounts of ballast water. However, even small amounts of released ballast water have the potential to contain invasive exotic species. In addition, as vessels are unloaded and ballast is taken on in US waters, the water may contain species that are potentially invasive to other locations. The transportation of nonindigenous organisms to new environments can have severe impacts on habitat (Omori et al. 1994), change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce exotic lethal disease. Refer to the chapters on Marine Transportation and Introduced/Nuisance Species and Aquaculture for more information on invasive species and shipping.

## *Conservation recommendations and best management practices for LNG facilities*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
2. Recommend the use of "closed loop" systems, which minimize the volume of water utilized for regasification, over "open loop" systems. This will serve to minimize the level of impingement and entrainment of living marine resources.
3. Locate facilities that use surface waters for regassification and engine cooling purposes away from areas of high biological productivity, such as estuaries.
4. Design intake structures to minimize entrainment or impingement.
5. Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter the temperature regimes of the receiving waters, which could cause a change in species assemblages and ecosystem function. Strategies should be implemented to diffuse the heated effluent.
6. Avoid the use of biocides (e.g., aluminum, copper, chlorine compounds) to prevent fouling where possible. The least damaging antifouling alternatives should be implemented.
7. Implement operational monitoring plans to analyze impacts resulting from intake and discharge structures and link them to a plan for adaptive management.
8. Provide for monitoring and leak detection systems at natural gas production and transportation facilities that preclude gas from entering the environment.
9. Schedule dredging and excavation activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Address cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the project review process of LNG facilities construction and operations. Based on evaluation of the foreseeable impacts to fishery habitats, a determination can be made regarding the most suitable location and operational procedures for LNG facilities. Ideally, such an analysis would be done at the regional or national level based on natural gas usage and need.

11. Ensure that gas production and transportation facilities have developed and implemented adequate gas spill response plans. Assist government agencies responsible for gas spills (e.g., US Coast Guard, state and local resource agencies) in developing response plans and protocols, including identification of sensitive marine habitats and development and implementation of appropriate gas spill-response measures.

## Offshore Wind Energy Facilities

### *Introduction*

Offshore wind energy facilities (windmills) convert wind energy into electricity through the use of turbines. An offshore facility generally consists of a series of wind turbine generators, an inner-array of submarine electric cables that connect each of the turbines, and a single electric service platform (ESP). Electricity is transmitted from the ESP to an onshore facility through one or a series of submarine cables.

While there are no operating offshore wind facilities in the United States at the writing of this report, there is an increasing number of proposals to develop offshore wind facilities within the northeast region. The construction and operation of offshore wind facilities has the potential to adversely affect fishery habitats.

### *Habitat conversion and loss*

The construction of offshore wind turbines and support structures can result in benthic habitat conversion and loss because of the physical occupation of the natural substrate. Scour protection around the structures, consisting of rock or concrete mattresses, can also lead to a conversion and loss of habitat. For example, the total seafloor area occupied by 130 wind turbines, ESP and associated scour mats for an offshore wind farm proposed in Nantucket Sound, MA, is expected to be approximately 3.21 acres (USACE 2004). Should scour around cables and the base of structures occur, subsequent substrate stabilization activity would lead to additional impact on benthic habitat. Likewise, the burial and installation of submarine cable arrays can impact the benthic habitat through temporary disturbance from plowing and from barge anchor damage. In some cases, plowing or trenching for cable installation can permanently convert benthic habitats when top layers of sediments are replaced with new material. The installation of cables and associated barge anchor damage can adversely affect SAV, if those resources are present in the project area. Cable maintenance, repairs, and decommissioning can also result in impacts to benthic resources and substrate.

### *Siltation, sedimentation, and turbidity*

The construction of wind turbine and support structures can cause increased turbidity in the water column and sedimentation impacts on adjacent benthic habitats. Likewise, the subsurface installation of underwater cables can result in similar impacts. Most of these impacts are relatively short-term and should subside after construction is completed. Maintenance and repairs of wind turbines and submarine electric cables can be expected to persist during the operation of the wind generator facilities. Increased sedimentation and turbidity during the decommissioning of wind energy facilities could be greater than the construction impacts if all submarine structures were to be removed. Siltation, sedimentation, and turbidity impacts related to the construction and maintenance activities from offshore wind energy projects are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

## *Alteration of hydrological regimes*

The placement of wind energy facilities, especially large arrays or "farms," in marine and estuarine habitats may affect hydrological regimes by altering tidal and current patterns. Altered current patterns could affect the distribution of eggs and larvae and the distribution of species within estuaries and bays, as well as the migration patterns of anadromous fishes.

## *Alteration of electromagnetic fields*

Background direct current electric fields originate from the metallic core of the Earth and the electric currents flowing in the upper layer of the Earth's crust. The strength of this geomagnetic field is highest at the magnetic poles and the lowest at the equator. Marine fishes, such as elasmobranches and anadromous fishes, utilize natural electromagnetic fields (EMFs) for navigation and migratory behavior (Gill et al. 2005). Studies have shown sharks and rays are capable of detecting artificial EMFs (Meyer et al. 2005), and some species have a remarkable sensitivity to electric fields in seawater (Kalmijn 1982). Some species of fish have shown sensitivity to underwater EMFs, including several species of sharks (i.e., *Scyliorhinus canicula, Mustelus canis,* and *Prionace glauca)* and thornback skate (*Raja clavata*) (Kalmijn 1982); and sea lamprey (*Petromyzon marinus*), eels (*Anguilla sp.*), Atlantic cod, plaice (*Pleuronectes platessa*), yellowfin tuna (*Thunnus albacares*) and Atlantic salmon (Gill et al. 2005). Electrical cables associated with offshore wind energy facilities produce EMFs (and induced electric fields) which could interfere with fish behavior. However, at the present time there is no conclusive evidence that EMFs have an adverse effect on marine species (Gill et al. 2005).

## *Underwater noise*

Underwater noise during construction of turbines may have impacts to hearing in fish and may cause fish to disperse with possible disruption to their feeding and spawning patterns. Underwater noise from the operation of wind turbines may decrease the effective range for sound communication in fish and mask orientation signals (Wahlberg and Westerberg 2005). Atlantic salmon and cod have been shown to detect offshore windmills at a maximum distance of about .04 km to 25 km at high wind speeds (i.e., >13 m/s), and noise from turbines can lead to permanent avoidance by fish within ranges of about 4 m (Wahlberg and Westerberg 2005). Noise from construction of wind farms (e.g., pile driving) could have significant effects on fish (Hoffmann et al. 2000). It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement, feeding), interfering with echolocation and communication or injuring hearing organs (Richardson et al. 1995). A more thorough review of underwater noise can be found in the chapter on Global Effects and Other Impacts.

## *Alteration of community structure*

Offshore wind energy facilities have the potential to alter the local community structure of the marine ecosystem. There is significant debate as to whether the presence of underwater vertical structures (e.g., oil platforms) contribute to new fish production by providing additional spawning and settlement habitat or simply attract and concentrate existing fishes (Bohnsack et al. 1994; Pickering and Whitmarsh 1997; Bortone 1998). The aggregation of fish in the vicinity of the wind turbine structures may subject certain species to increased fishing. Additive and synergistic effects of multiple stressors, such as the presence of electric cables on the seafloor and underwater sound generated by the turbines, could have cumulative effects on marine ecosystem and community dynamics (e.g., predator-prey population densities, migration corridors).

### *Discharge of contaminants*

An ESP serves as a connection point for the inner-array of cables as well as a staging area for maintenance activities. Hazardous materials that may be stored at the ESP include fluids from transformers, diesel fuel, oils, greases and coolants for pumps, fans and air compressors. Discharge of these contaminants into the water column can affect the water quality in the vicinity of the offshore wind facility. Further information regarding the impacts of oil spills and contaminants can be found in the Petroleum Exploration, Production, and Transportation section of this chapter, and the chapters on Coastal Development and Chemical Affects: Water Discharge Facilities of the report.

### *Conservation recommendations and best management practices for offshore wind energy facilities*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
2. Avoid placing cables associated with offshore wind facilities near sensitive benthic habitats, such as SAV.
3. Use horizontal directional drilling to avoid impacts to sensitive habitats, such as salt marshes and intertidal mudflats.
4. Make contingency plans and response equipment available to respond to spills associated with service platforms.
5. Use scour protection for turbines and associated structures and cables to the minimum practicable in order to avoid alteration and conversion of benthic habitat.
6. Bury cables to an adequate depth in order to minimize the need for maintenance activities and to reduce conflicts with other ocean uses.
7. Time construction of facilities to avoid impacts to sensitive life stages and species. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for offshore wind energy facilities construction and operations.

## Wave and Tidal Energy Facilities

### *Introduction*

Wave power facilities involve the construction of stationary or floating devices that are attached to the ocean floor, the shoreline, or a marine structure like a breakwater with exposure to adequate "wave climate." Ocean wave power systems can be utilized in the offshore or nearshore environments. Offshore systems can be situated in deep water, typically in depths greater than 40 m (131 ft). Some examples of offshore systems include the Salter Duck, which uses the bobbing motion of the waves to power a pump that creates electricity. Other offshore devices use hoses connected to floats that move with the waves. The rise and fall of the float stretches and relaxes the hoses, which pressurizes the water, which in turn rotates a turbine. In addition, some seagoing vessels can be built to capture the energy of offshore waves. These floating platforms create electricity by funneling waves through internal turbines.

Wave energy can be utilized to generate power from the nearshore area in three ways:

1. Floats or pitching devices generate electricity from the bobbing or pitching action of a floating object. The object can be mounted to a floating raft or to a device fixed on the ocean floor. A

similar device, the pendulor, is a wave-powered device consisting of a rectangular box, which is open to the sea at one end. A flap is hinged over the opening and the action of the waves causes the flap to swing back and forth. The motion powers a hydraulic pump and a generator.

2. Oscillating water columns generate electricity from the wave-driven rise and fall of water in a cylindrical shaft. The rising and falling water column drives air into and out of the top of the shaft, powering an air-driven turbine.
3. Wave surge or focusing devices, also called "tapered channel" or "tapchan" systems, rely on a shore-mounted structure to channel and concentrate the waves, driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity by using standard hydropower technologies (USDOE 2003).

Tidal energy facilities are designed to generate power in tidal estuaries through the use of turbines. A barrage, or dam, can be placed across a tidal river or estuary. This design utilizes a build-up of water within a headpond to create a differential on either side (depending on the tide), and then the water is released to turn the turbines. While less efficient, tidal power facilities can also utilize water currents to turn turbines. Turbines can be designed in a number of ways and include the "helical-type" turbines, as well as the "propeller-type" turbines. Turbines are generally placed within areas of fast moving water with strong currents to take advantage of both ebb and flow tides. For impacts associated with conventional hydropower facilities, refer to the chapter on Alteration of Freshwater Systems.

### *Habitat conversion and loss*

The construction of tidal and wave energy facilities includes the placement of structures within the water column, thus converting open water habitat to anthropogenic structure. The placement of support structures, transmission lines, and anchors on the substrate will result in a direct impact to benthic habitats which serve as feeding or spawning habitats for various species. Large-scale tidal power projects which utilize a barrage can cause major changes in the tidal elevations of the headpond which can affect intertidal habitat. Alterations in the range and duration of tide flow can adversely affect intertidal communities that rely on specific hydrological regimes. Mud and sand flats may be converted to subtidal habitat, while high saltmarsh areas that may be normally flooded only on the highest spring tides can become colonized by terrestrial vegetation and invasive species (Gordon 1994).

### *Siltation, sedimentation, and turbidity*

Construction of tidal facilities in riverine and estuarine areas can result in increased sedimentation. Structures placed within riverine and estuarine habitats can reduce the natural transport of sediments and cause an accretion of silt and sediments within impoundments. Deposition of sediments can adversely impact benthic spawning habitats of various anadromous fish species, including riffle and pool complexes. Clean gravel substrates, which are preferred by rainbow smelt and Atlantic salmon, can be subjected to increased siltation from alterations in the sediment transport. Shallow water environments, rocky reefs, nearshore and offshore rises, salt, and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than open-water habitats. This is due, in part, to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978). Impacts from siltation and sedimentation from wave and tidal power facilities are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

## Alteration of hydrological regimes

Water circulation patterns and the tidal regimes can be altered during the operation of a barrage-type tidal facility. This can result in poor tidal flushing of the headwaters of estuaries and rivers and can lead to decreased water quality and increases in water temperature (Rulifson and Dadswell 1987). Altered current patterns could affect the distribution of eggs and larvae and the distribution of species within estuaries and bays as well as the migration patterns of anadromous fishes. Hydrological regimes may also be impacted by flows passing through and around tidal turbines and support structures.

## Entrainment, impingement, and other impacts to migration

Water control structures, such as dams, alter the flow, volume, and depth of water within impoundments and below the structures. Water impoundments tend to stratify the water column, increasing water temperatures and decreasing dissolved oxygen levels. Projects operating as "store and release" facilities can drastically affect downstream water flow and depth, resulting in dramatic fluctuations in habitat accessibility, acute temperature changes and an overall decline in water quality (NEFMC 1998). The construction of dams, with either inefficient or nonexistent fish bypass structures, has been a major cause of the population decline of US Atlantic salmon (USFWS and NMFS 1999). Tidal energy facilities located within estuaries or riverine environments have the potential to directly impact migrating fish (Dadswell et al. 1986). Dadswell and Rulifson (1994) reported various physical impacts to fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, including mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found between 21-46% mortality rates for tagged American shad passing through the turbine. The physical presence of tidal power facilities can impact the return of diadromous fishes to natal rivers (Semple 1984). Refer to the chapter on Alteration of Freshwater Systems for further information on impacts from water control structures.

## Alteration of electromagnetic fields

Electrical distribution cables associated with ocean wave-power facilities produce EMFs similar to offshore wind energy facilities and may interfere with fish behavior (Gill et al. 2005). Refer to the discussion under the Offshore Wind Energy Facilities in this chapter for information on the affects of EMFs.

## Conservation recommendations and best management practices for wave and tidal energy facilities

1. Do not permit the construction of barrage-type tidal energy facilities because of the potential for large impacts to the ecosystem and migratory fishery resources.
2. Require preconstruction assessments for analysis of potential impacts to fishery resources for all projects. Assessments should include comprehensive monitoring of the timing, duration, and utilization of the area by diadromous and resident species, potential impacts from the project, and contingency planning using adaptive management.
3. Do not site projects in areas that may result in adverse effects to sensitive marine and estuarine resources and habitats.
4. Avoid project siting of any wave or tidal energy facility within riverine, estuarine, and marine ecosystems utilized by diadromous species.
5. Time construction of facilities to avoid impacts to sensitive life stages and species. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

6. Include impacts associated with the decommissioning and/or dismanteling of wave or tidal energy facility as part of the environmental analyses. Contingency for removal of structures should be required as part of any permits or licenses.
7. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for wave and tidal facilities construction and operations.

# Cables and Pipelines

## *Introduction*

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for oil and gas. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats.

## *Habitat conversion and loss*

The installation of cables and pipelines can result in the loss of benthic habitat from dredging and plowing through the seafloor. This can result in a direct loss of benthic organisms, including shellfish. Construction impacts can result in long-term or permanent damage, depending on the degree and type of habitat disturbance and best management practices employed for a project. The installation of pipelines can impact shellfish beds, hard-bottomed habitats, and SAV (Gowen 1978). Cables can damage complex habitats containing epifaunal growth during installation, if allowed to "sweep" along the bottom while being positioned into the correct location. Shallow water environments, rocky reefs, nearshore and offshore rises, salt and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than are open-water habitats. This is due to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978). Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if pipelines are left in place after production ends.

Pipelines installed on the seafloor or over coastal wetlands can alter the environment by causing erosion and scour around the pipes, resulting in escarpments on coastal dune and salt marshes, and on the seafloor. Alterations to the geomorphology of coastal habitats from pipelines can exacerbate shoreline erosion and fragment wetlands. Because vegetated coastal wetlands provide forage and protection to commercially important invertebrates and fish, marsh degradation caused by plant mortality, soil erosion, or submergence will eventually decrease productivity.

Pipelines are generally buried below ground by digging trenches or canals. Digging trenches may change the coastal hydrology by: (1) facilitating rapid drainage of interior marshes during low tides or low precipitation; (2) reducing or interrupting freshwater inflow and associated littoral sediments; and (3) allowing saltwater to move farther inland during periods of high tides (Chabreck 1972). Saltwater intrusion into freshwater marsh often causes a loss of salt-intolerant emergent plants and SAV (Chabreck 1972; Pezeshki et al. 1987). Soil erosion and a net loss of organic matter may also occur (Craig et al. 1979).

Conversion of benthic habitat can occur if cables and pipelines are not buried sufficiently within the substrate. Conversion of habitats can also occur in areas where a layer of fine sediment is underlain with coarser materials. Once these materials are plowed for pipeline/cable installation, they can be mixed with underlying coarse sediment, and thus, alter the substrate composition. This can adversely affect the habitat of benthic organisms which rely on soft sand or mud habitats. The armoring of pipeline with either rock or concrete can result in permanent habitat alterations if placed within soft substrate. The placement of cables and pipelines often necessitates removal of hard bottom or rocky habitats in the pipeline corridor. These habitats are removed by using explosives or mechanical fracturing and can result in a reduction of available hard bottom substrate and habitat complexity.

Subsea pipelines that are placed on the substrate have the potential to create physical barriers to benthic invertebrates during migration and movement. In particular, the migration of American lobster (*Homarus americanus*) between inshore and offshore habitats can be adversely affected if pipelines are not buried to sufficient depths (Fuller 2003). Furthermore, erosion around buried pipelines and cables can lead to uncovering of the structure and the formation of escarpements. This, in turn, can interfere with the migratory patterns of benthic species.

### *Siltation, sedimentation, and turbidity*

The installation of cables and pipelines can lead to increased turbidity and subsequent sedimentation, caused by either the plowing or jetting method of installation. Elevated siltation and turbidity during cable and pipeline installation is typically short-term and restricted to the area surrounding the cable and pipeline corridor. However, pipelines that are left unburied and exposed can cause erosion of the substrate and cause persistent siltation and turbidity in the surrounding area. Maintenance activities related to cables and pipelines, as well as removal for decommissioned cables and pipelines, can release suspended sediments into the water column. Long-term effects of suspended sediment include reduced light penetration and lowered photosynthesis rates and the primary productivity of the area (Gowen 1978). Impacts from siltation, sedimentation, and turbidity from cables and pipelines are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Release of contaminants*

Petroleum products can be released into the environment if pipelines are broken or ruptured by unintentional activities, such as shipping accidents or deterioration of pipelines. A review of impacts from petroleum spills can be found in the Petroleum Exploration, Production, and Transportation section of this chapter. In addition, resuspension of contaminants in sediments, such as metals and pesticides, during pipeline installation can have lethal and sublethal effects to fishery resources (Gowen 1978). Contaminants may have accumulated in coastal sediments from past industrial activities, particularly in heavily urbanized areas. Metals may initially inhibit reproduction and development of marine organisms, but at high concentrations they can directly or indirectly contaminate or kill fish and invertebrates. The early life-history stages of fish are the most susceptible to the toxic impacts associated with metals (Gould et al. 1994). The release of contaminants can reduce or eliminate the suitability of water bodies as habitat for fish species and their prey. In addition, contaminants, such as copper and aluminum, can accumulate in sediments and become toxic to organisms contacting or feeding on the bottom.

Impacts to sensitive wetland and subtidal habitats can be avoided during pipeline and cable installation using horizontal directional drilling techniques, which allow the pipe or cable to be installed in a horizontal drill hole below the substrate. "Frac-outs" (i.e., releases of drilling mud or other lubricants, such as bentonite mud) can occur during the drilling process, and material can escape through fractures in the underlying rock. This typically happens when the drill hole encounters a natural fracture in the rock or when insufficient precautions are taken to prevent new fractures from occurring. Fishery habitats can be adversely affected if a "frac-out" occurs during the installation process and discharges drilling mud or other contaminants into the surrounding area.

Cranford et al. (1999) found that chronic intermittent exposure to sea scallops (*Placopecten magellanicus*) of dilute concentrations of operational drilling wastes, characterized by acute lethal tests as practically nontoxic, can affect growth, reproductive success, and survival.

Maintenance of cables and pipelines can also result in subsequent impacts to the aquatic environment. The maintenance of pipelines includes the "pigging" of pipelines to clean out residual materials from time-to-time. The release of these materials into the surrounding environment can lead to water quality impacts and contamination of adjacent benthic habitats. For example, biocides (e.g., copper and aluminum compounds) are often utilized in the hydrostatic testing of pipelines and are subsequently discharged into surrounding waters. Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977).

### *Alteration of electromagnetic fields*

Underwater electrical distribution cables produce EMFs that may interfere with fish behavior (Gill et al. 2005). However, at the present time there is no conclusive evidence that EMFs have an adverse effect on marine species (Gill et al. 2005). See also the discussion of underwater EMFs in the Offshore Wind Energy Facilities section of this chapter and the Global Effects and Other Impacts chapter of the report.

### *Underwater noise*

The installation of cables and pipelines can produce underwater noise that may disrupt or damage fishery resources. Noise from construction activities (e.g., pile driving) can have significant effects on fish (Hoffmann et al. 2000). Larvae and young fish are particularly sensitive to noise generated from underwater explosives during blasting. It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (movement, feeding), interfering with echolocation and communication, or injuring hearing organs (Richardson et al. 1995).

### *Alteration of community structure*

The construction of pipelines and other underwater structures has the potential to alter the local community structure of the marine ecosystem. There is significant debate as to whether the presence of underwater vertical structures (e.g., oil platforms) contribute to new fish production by providing additional spawning and settlement habitat or simply attract and concentrate existing fish within an area (Bohnsack et al. 1994; Pickering and Whitmarsh 1997; Bortone 1998). Underwater pipelines are anthropogenic structures that could have similar attraction and production issues relating to fishery management. As with wind turbines and offshore LNG facilities, aggregation of fishes in the vicinity of pipeline structures may subject certain species to increased fishing pressure. By altering the age and species composition in the area around pipelines, predator/prey interactions and reproduction can be altered, and these changes may have community-level affects on fisheries.

### *Conservation recommendations and best management practices for cables and pipelines (adapted from Hanson et al. 2003)*

1. Align crossings along the least environmentally damaging route. Sensitive habitats such as hard-bottom (e.g., rocky reefs), SAV, oyster reefs, emergent marsh, and mud flats should be avoided.

2. Use horizontal directional drilling where cables or pipelines would cross sensitive habitats, such as intertidal mudflats and vegetated intertidal zones, to avoid surface disturbances. Measures should be employed to avoid/minimize impacts to sensitive fishery habitats from potential frac-outs, including:
    a. The use of nonpolluting, water-based lubricants should be required.
    b. Drill stem pressures should be monitored closely so that potential frac-outs can be identified.
    c. Drilling should be halted, if frac-outs are suspected.
    d. Above ground monitoring should be employed to identify potential frac-outs.
    e. Spill clean-up plan and protocols should be developed, and clean-up equipment should be on-site to quickly respond to frac-outs.
3. Avoid construction of permanent access channels since they disrupt natural drainage patterns and destroy wetlands through excavation, filling, and bank erosion.
4. Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation. Original marsh elevations should be restored.
5. Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
6. Bury pipelines and submerged cables where possible. Unburied pipelines or pipelines buried in areas where scouring or wave activity eventually exposes them can result in impacts to invertebrate migratory patterns.
7. Use silt curtains or other types of sediment control in order to protect sensitive habitats and resources.
8. Limit access for equipment to the immediate project area avoid access through sensitive resources.
9. Avoid the use of open trenching for installation. Methods in which the trench is immediately backfilled reduce the impact duration and should therefore be employed when possible.
10. Conduct construction during the time of year that will have the least impact on sensitive habitats and species. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
11. Evaluate impacts to habitat during the decommissioning phase, including impacts during the demolition phase and impacts resulting from permanent habitat losses.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for cable and pipeline construction and operations.
13. Ensure that oil and gas pipeline systems include leak detection capabilities to minimize potential impacts from spills.

## References for Energy-related Activities


Arruda JA, Marzolf GR, Faulk RT. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. Ecology 64(5):1225-35.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth flatfish biology conference- poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology: Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New York (NY): Academic Press. p 177-252.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Blaxter JHS, Hunter JR. 1982. The biology of the clupeoid fishes. In: Blaxter JHS, Russel FS, Yonge M, editors. Advances in marine biology – Vol. 20. New York (NY): Academic Press. p 187-91.

Bohnsack JA, Harper DE, McClellan DB, Hulsbeck M. 1994. Effects of reef size on colonization and assemblage structure of fishes at artificial reefs off southeastern Florida, U.S.A. Bulletin of Marine Science 55(2-3):796-823.

Bortone SA. 1998. Resolving the attraction-production dilemma in artificial reef research: Some yeas and nays. Fisheries 23(3):6-10.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Callaghan TP. 2004. Entrainment and impingement of organisms in power plant cooling. In: Cleveland CJ, editor. Encyclopedia of Energy, Vol. 2. Amsterdam (The Netherlands): Elsevier. p 447-57.

Capuzzo JM. 1987. Biological effects of petroleum hydrocarbons: assessment of experimental results. In: Boesch DF, Rabalais NN, editors. Long-term environmental effects of offshore oil and gas development. London (England): Elsevier Applied Science. p 343-410.

Carls MG, Thomas RE, Lilly MR, Rice SD. 2003. Mechanism for transport of oil-contaminated groundwater into pink salmon redds. Marine Ecology Progress Series 248:245-55.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chabreck RH. 1972. Vegetation, water, and soil characteristics of the Louisiana coastal region. Baton Rouge (LA): LSU Agricultural Experimental Station.

Chiasson AG. 1993. The effects of suspended sediment on rainbow smelt (*Osmerus mordax*): a laboratory investigation. Canadian Journal of Zoology 71:2419-24.

[CEQ] Council on Environmental Quality. 1977. Oil and gas in coastal lands and waters. Washington (DC): US Government Printing Office. 153 p.

Craig NJ, Turner RE, Day JW Jr. 1979. Land Loss in coastal Louisiana (U.S.A.). Environmental Management 3(2):133-44.

Cranford PJ, Gordon DC Jr, Lee K, Armsworthy SL, Tremblay GH. 1999. Chronic toxicity and physical disturbance effects of water- and oil-based drilling fluids and some major constituents on adult sea scallops (*Placopecten magellanicus*). Marine Environmental Research 48(3):225-56.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: A region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Dadswell MJ, Rulifson RA, Daborn GR. 1986. Potential impact of large-scale tidal power developments in the upper Bay of Fundy on fisheries resources of the northwest Atlantic. Fisheries 11(4):26-35.

Dodson JJ, Leggett WC, Jones RA. 1972. The behavior of adult American shad (*Alosa sapidissima*) during migration from salt to fresh water as observed by ultrasonic tracking techniques. Journal of the Fisheries Research Board of Canada 29(10):1445-9.

Drake LA, Jenkins PT, Dobbs FC. 2005. Domestic and international arrivals of NOBOB (no ballast on board) vessels to lower Chesapeake Bay. Marine Pollution Bulletin 50(5):560-5.

Enright JT. 1977. Power plants and plankton. Marine Pollution Bulletin 8(7):158-61.

Freeman HC, Uthe JF, Sangalang GB, Garside ET. 1981. Contaminant/liver histopathology in Canadian Atlantic cod (*Gadus morhua*). Copenhagen (Denmark): ICES CM-1981/ E: 50.

Fuller C. editor. 2003. A workshop on the potential effects of the construction and operation of subsea pipelines on lobster movement and behavior. Blue Atlantic Lobster Workshop Proceedings; 2003 Jun 24; Providence, RI. Willington (CT): ENSR International. 152 p.

Gill AB, Gloyne-Phillips I, Neal KJ, Kimber JA. 2005. The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms-a review. Final Report: Collaborative Offshore Wind Energy Research into the Environment. London (England): COWRIE 1.5 Electromagnetic Fields Review. 128 p.

Gordon DC Jr. 1994. Intertidal ecology and potential power impacts, Bay of Fundy, Canada. Biological Journal of the Linnean Society 51(1-2):17-23.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Gowen AW. 1978. The environmental effects of outer continental shelf (OCS) pipelines. Initial findings. Boston (MA): New England River Basins Commission 4:24-43.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Heintz RA, Rice SD, Wertheimer AC, Bradshaw RF, Thrower FP, Joyce JE, Short JW. 2000. Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha* after exposure to crude oil during embryonic development. Marine Ecology Progress Series 208:205-16.

Helvey M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47:18-26.

Helvey M. 2002. Are southern California oil and gas platforms essential fish habitat? ICES Journal of Marine Science 59(Suppl.):S266-S271.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Hoffman E, Astrup J, Larsen F, Munch-Petersen S. 2000. Effects of marine windfarms on the distribution of fish, shellfish, and marine mammals in the Horns Rev Area. Lyngby (Denmark): Danish Institute for Fisheries Research. Report to ELSAMPROJEKT A/S. Report No. Baggrundsrapp 24. 42 p.

Johnson LL, Collier TK, Stein JE. 2002. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAH) to protect estuarine fish. Aquatic Conservation: Marine and Freshwater Ecosystems 12(5):517-38.

Kalmijn AJ. 1982. The electric and magnetic field detection in Elasmobranch fishes. Science 218(4575):916-18.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Leggett WC, O'Boyle RN. 1976. Osmotic stress and mortality in adult American shad during transfer from saltwater to freshwater. Journal of Fish Biology 8(6):459-69.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Lonning S, Falk-Petersen IB. 1978. The effects of oil dispersants on marine eggs and larvae. Astarte 11:135-8.

MacKenzie C, Weiss-Glanz LS, Moring JR. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. Washington (DC): US Fish and Wildlife Service. Biological Report 82(11.37). 18 p.

Marten K, Herzing D, Poole M, Newman-Allman K. 2001. The acoustic predation hypothesis: Linking underwater observations and recordings during Odontocete predation and observing the effects of loud impulsive sounds on fish. Aquatic Mammals 27(1):56-66.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Meyer CG, Holland KN, Papastamatiou YP. 2005. Sharks can detect changes in the geomagnetic field. Journal of the Royal Society Interface 2(2):129-30.

Michel J, Hayes MO. 1999. Weathering patterns of oil residues eight years after the *Exxon Valdez* oil spill. Marine Pollution Bulletin 38(10):855-63.

Mills KE, Fonseca MS. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-34.

[NOAA] National Oceanic and Atmospheric Administration. 1992. An introduction to coastal habitats and biological resources for oil spill response. Seattle (WA): Hazardous Materials Response and Assessment Division. Report No. HMRAD 92-4.

[NRC] National Research Council. 2003. Oil in the sea III: inputs, fates and effects. Washington (DC): National Academy Press.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe CP, MacDonald DD. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11(1):72-82.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

[NPFMC] North Pacific Fisheries Management Council. 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. Anchorage (AK): NPFMC. 367 p.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

Pezeshki SR, Delaune RD, Patrick WH Jr. 1987. Response of the freshwater marsh species, *Panicum hemitomon* Schult., to increased salinity. Freshwater Biology 17(2):195-200.

Pickering H, Whitmarsh D. 1997. Artificial reefs and fisheries exploitation: a review of the ‘attraction versus production’ debate, the influence of design and its significance for policy. Fisheries Research 31(1-2):39-59.

Pilati DA. 1976. Cold shock: biological implications and a method for approximating transient environmental temperatures in the near-field region of a thermal discharge. Science of the Total Environment 6(3):227-37.

Reiser DW, Chapin D, DeVries P, Ramey MP. 2004. Flow regime and ecosystem interactions in spring dominated streams: Implications for selecting instream flow methods. Hydroecologie Appliquee 14(1):93-104.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

Richkus WA. 1974. Factors influencing the seasonal and daily patterns of alewife (*Alosa pseudoharengus*) migration in a Rhode Island river. Journal of the Fisheries Research Board of Canada 31:1485-97.

Rogers CA. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. Fisheries Bulletin 74(1):52-8.

Rulifson RA, Dadswell MJ. 1987. Mortality of fish passing through tidal, low-head hydropower turbines and possible mitigation strategies. In: Proceedings of Ocean 87: the ocean-an international workplace; 1987 Sep 28-Oct 1; Halifax, Nova Scotia. Columbia (MD): Marine Technology Society and IEEE Ocean Engineering Society. p 944-9.

Semple JR. 1984. Possible effects of tidal power development in the upper Bay of Fundy on anadromous fish passage. In: Update on the environmental consequences of tidal power in the upper reaches of the Bay of Fundy. Dartmouth (Nova Scotia): Canadian Technical Report of the Fisheries and Aquatic Sciences No. 1256:565-75.

Short JW, Lindeberg MR, Harris PM, Maselko J, Rice SD. 2002. Vertical oil distribution within the intertidal zone 12 years after the *Exxon Valdez* oil spill in Prince William Sound, Alaska. Proceedings of the 25th Arctic and Marine Oilspill Program Technical Seminar. Ottawa (Ontario): Minister of Supply and Services Canada. p 57-72.

Stanley JG, Colby PJ. 1971. Effects of temperature on electrolyte balance and osmoregulation in the alewife (*Alosa pseudoharengus*) in fresh and sea water. Transactions of the American Fisheries Society 100(4):624-38.

Stewart PL, Arnold SH. 1994. Environmental requirements Atlantic herring (*Clupea harengus harengus*) in eastern Canada and its response to human impacts. Dartmouth (Nova Scotia): Canadian Technical Report of Fisheries and Aquatic Sciences 2003: ix + 37p.

Urho L, Hudd R. 1989. Sublethal effects of an oil spill on fish (herring) larvae in the northern Quark, in the Baltic. In: Blaxter JHS, Gamble JC, Westernhagen HV, editors. The early life history of fish; 1988 Oct 3-5; Bergen, Norway. Third ICES Symposium: Rapports et Proces-Verbaux Des Reunions 191. Copenhagen (Denmark): International Council for the Exploration of the Sea. p 494.

[USACE] US Army Corps of Engineers. 2004. Cape Wind Energy Project Draft Environmental Impact Statement (Cape Wind DEIS). Vol. 1. Concord (MA): US Army Corp of Engineers, New England District.

[USCG] US Coast Guard. 2006. Environmental impact statement/environmental impact report for the Neptune LNG deepwater port license application. Washington (DC): USCG-2005-22611.

[USDOE] US Department of Energy. 2003. A consumer's guide to energy efficiency and renewable energy: Ocean wave power. [Internet]. [updated 2003 Feb 7; cited 2007 Dec 19]. Available from: http://www.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50009.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

Vandermeulen JH, Mossman D. 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences 53:1741-53.

Wahlberg M, Westerberg H. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Progress Series 288:295-309.

Wake H. 2005. Oil refineries: a review of their ecological impacts on the aquatic environment. Estuarine, Coastal and Shelf Science 62:131-40.

Wertheimer AC, Heintz RA, Thedinga JF, Maselko JM, Rice SD. 2000. Straying of adult pink salmon from their natal stream following embryonic exposure to weathered *Exxon Valdez* crude oil. Transactions of the American Fisheries Society 129(4):989-1004.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

# CHAPTER FOUR: ALTERATON OF FRESHWATER SYSTEMS

## Introduction

Freshwater riverine and riparian habitats located in the northeastern coastal United States provide important habitat for the growth, survival, and reproduction of diadromous fishes and are critical to maintaining healthy estuarine ecosystems. Some of the diadromous fish (species that migrate between freshwater and saltwater for specific life history functions) inhabiting the Northeast include Atlantic salmon (*Salmo salar*), striped bass (*Morone saxatilis*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), rainbow smelt (*Osmerus mordax*), Atlantic sturgeon (*Acipenser oxyrinchus*), shortnose sturgeon (*Acipenser brevirostrum*), and American eel (*Anguilla rostrata*). Not only are diadromous fishes subject to environmental impacts in the marine environment, but they also encounter dams, pollution, effects of urbanization, and habitat changes in freshwater (Moring 2005). In addition, some forage species that are important prey for marine fisheries depend upon freshwater habitats for portions of their life cycle. The health and availability of freshwater systems and the preservation and maintenance of associated functions and values are vital to the diversity, health, and survival of marine fisheries.

Free flowing rivers, ponds, and lakes act as migratory corridors, spawning, nursery, and rearing areas and provide forage and refuge for life stages of these species. Riverine and riparian corridors, and palustrine and lacustrine wetlands provide important functions and values for resident and migratory fish, freshwater mussels, reptiles, amphibians, and insects (Chabreck 1988). Riparian corridors provide shade, nutrients, and habitat enhancing debris in riverine systems (Bilby and Ward 1991), which are essential elements necessary for these aquatic resources to thrive. In addition to supporting aquatic resources, freshwater wetlands perform important and broad ecological functions by reducing erosion, attenuating floodwater velocity and volume, improving water quality by the uptake of nutrients, and reducing sediment loads (Howard-Williams 1985; De Laney 1995; Fletcher 2003). Freshwater habitats are intricately connected to terrestrial and coastal ecosystems, making them vulnerable to a wide array of anthropogenic disturbances that can alter the functions, values, quantity, and accessibility of freshwater wetlands used by migratory fish (Beschta et al. 1987; Naiman 1992).

Biological, chemical, and physical threats to freshwater environments from terrestrial and aquatic sources have led to habitat fragmentation and degradation (Bodi and Erdheim 1986; Wilbur and Pentony 1999; USEPA 2000; Kerry et al. 2004). In particular, nonfishing activities, such as mining, dredging, fill placement, dam construction and alterations of hydrologic regimes, thermal discharges, and nonpoint source pollution have degraded and eliminated freshwater habitats (Zwick 1992; Wilbur and Pentony 1999; Hanson et al. 2003). Examples of nonpoint source pollution include urban stormwater and agricultural runoff (e.g., petroleum products, metals, pesticides, fertilizers, and animal wastes). Refer to the Coastal Development and Agriculture and Silviculture chapters for more detailed discussion on nonpoint source pollution. The federal Clean Water Act (CWA) has eliminated certain types of disposal activities, limited fill activities, and otherwise resulted in improved protection of the nation's wetlands and waterways. Despite these and other regulations to protect aquatic habitat, anthropogenic impacts continue, dramatically affecting fish habitat, including prey species and fisheries (Wilson and Gallaway 1997; Bodi and Erdheim 1986; Hanson et al. 2003; Ormerod 2003; Kerry et al. 2004).

## Dam Construction and Operation

The history and effects of dam construction on passage and habitat is well documented (Larinier 2001; Heinz Center 2002). Among the major identified causative factors of the population demise of Atlantic salmon, dam construction and operation may be the most dramatic (NEFMC 1998; Parrish et al. 1998; USFWS and NMFS 1999). In the United States, 76,000 dams have been identified in the National Inventory of Dams by the US Army Corps of Engineers and the Federal Emergency Management Agency (Heinz Center 2002). This number may be as high as 2 million when small-scale dams are included (Graf 1993). Dam construction and operation in the northeastern United States have occurred for centuries to provide power generation, navigation, fire and farm ponds, reservoir formation, recreation, irrigation, and flood control. Important for the local economy when originally constructed, today many of these structures are obsolete, unused, abandoned, or decaying. Fish passages in any given river system may not be consistent or effective throughout, limiting the ability for Atlantic salmon and many other migratory and resident species to reach necessary habitat. Sections 18 and 10j of the Federal Power Act require fish passage and protection and mitigation for damages to fish and wildlife, respectively, at hydroelectric facilities.

The effects of dam construction and operation on fisheries and aquatic habitat include: (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow patterns alteration; (3) thermal impacts; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; (5) habitat fragmentation; (6) alteration to sediment and nutrient budgets; and (7) limitations on gene flow within populations.

### *Impaired fish passage*

The construction of dams with either no fish passage or ineffective passage was the primary agent of the population decline of US Atlantic salmon (USFWS and NMFS 1999; NEFMC 1998). By 1950, less than 2% of the original habitat for Atlantic salmon in New England was accessible because of dams (Buchsbaum 2005). Dams physically obstruct passage and alter a broad range of habitat characteristics essential for passage and survival. Without any mechanism to get around a dam, there is no upstream passage to spawning and nursery habitat. Fish that gather at the base of the dam will either spawn in inadequate habitat, die, or return downstream without spawning. The presence of a fish passage structure does not necessarily ensure access to upstream habitat. Even with a structure in place, passage is contingent on many factors, including water-level fluctuations, altered seasonal and daily flow regimes, elevated temperatures, reduced water velocities, and discharge volumes (Haro et al. 2004).

Safe, timely, and effective downstream passage by fish is also hindered by dams. The time required for downstream migration is greatly increased because of reduced water flows within impoundments (Raymond 1979; Spence et al. 1996; PFMC 1999). This delay results in greater mortality associated with predation and the physiological stress associated with migration. Downstream passage for fish is hindered or prevented while passing over spillways and through turbines (Ruggles 1980; NEFMC 1998) and by entrainment or impingement on structures associated with a hydroelectric facility. Dadswell and Rulifson (1994) reported on the physical impacts observed in fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, which included mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found 21-46% mortality rates for experimentally tagged American shad passing through the turbine.

Fragmentation of aquatic habitat caused by dams can result in a loss of genetic diversity and spawning potential that may make populations of fish more vulnerable to local extirpation and extinctions, particularly for species functioning as a metapopulation (Morita and Yamamoto 2002).

### Altered hydrologic, salinity, and temperature regimes

Dams and dam operations alter flow patterns, volume, and depth of water within impoundments and below the dam. These hydrological alterations tend to increase water temperatures, stratify the water column, and decrease dissolved oxygen concentrations in the water impoundments. Projects operating as "store and release" facilities can drastically affect downstream water flow and depth, resulting in dramatic fluctuations in habitat accessibility, acute temperature changes, and overall water quality. Although large, impounding dams have the ability to alter the hydrology of large segments or entire rivers, smaller, run-of-the river dams that do not contain impoundments generally have little or no ability to alter downstream hydrology (Heinz Center 2002).

Reductions in river water temperatures are common below dams if the intake of the water is from lower levels of the reservoir. Stratification of reservoir water not only affects temperature but can create oxygen-poor conditions in deeper areas and, if these waters are released, can degrade the water quality of the downstream areas (Heinz Center 2002).

By design, dams often reduce peak flows as flood control measures. However, reductions of peak flows can decrease the physical integrity of the downstream river because the floodplains (including side channels, islands, bars, and beaches) are not as extensively connected to the river (Heinz Center 2002). In addition, dams can also reduce low flows during periods of drought and when dam operators reduce water releases in order to maintain water levels in the impoundments (Heinz Center 2002).

Dams with deep reservoirs have high hydrostatic pressures at the bottom and can force atmospheric gases into solution. If these waters are released below the dam, either by water spilling over dams or through turbines, it can cause dissolved gas supersaturation, resulting in injury or death to fish traversing the dam (NEFMC 1998; Heinz Center 2002).

Tidal fresh habitat is limited to a narrow zone in river systems where the water is tidally influenced, yet characteristically fresh (i.e., < 0.5 ppt salinity). This narrow habitat type may be altered or lost because of dam construction and operations.

### Alteration of stream bed and stream morphology

The construction of a dam fragments habitat, altering both upstream and downstream biogeochemical processes and resulting in a wide array of direct and indirect cumulative impacts (Poff et al. 1997; Heinz Center 2002). Multiple habitat variables are affected by dams, principally streambed properties (Spence et al. 1996), the transport of sediments and large woody debris (Spence et al. 1996; PFMC 1999), and overall stream morphology.

Dams typically reduce peak flows as a flood control measure and can reduce low flows when water releases are reduced to save water during drought. As the range of flows in the river are decreased, the width of the active portion of the watershed is reduced and the river channel shrinks (Heinz Center 2002).

### Altered sediment/large woody debris transport

Dams affect the physical integrity of watersheds by fragmenting the lengths of rivers, changing their hydrologic characteristics, and altering their sediment regimes by trapping most of the sediment entering the reservoirs and disrupting the sediment budget of the downstream landscape (Heinz Center 2002). Because water released from dams is relatively free of sediment, downstream reaches of rivers may be altered by increased particle size, erosion, channel shrinkage, and deactivation of floodplains (Heinz Center 2000).

Large woody debris (LWD) and other organic matter are often removed from rivers containing dams, as well as for other reasons, such as aesthetics, road and bridge maintenance, and commercial and recreational uses. Organic debris provides habitat for a variety of aquatic organisms, such as Atlantic salmon, by promoting habitat complexity, including the formation of pool and riffle complexes and undercut banks (Montgomery et al. 1995; Abbe and Montgomery 1996; Spence et al. 1996). Removing organic debris may change the structure, function, and value of the river system. From a broader perspective, removal of LWD from a river system disrupts a link between the forest and the sea (Maser and Sedell 1994; NRC 1996; Collins et al. 2002; Collins et al. 2003).

### *Riparian zone development and alteration of wetlands*

Riparian wetlands may be lost to water level increases upstream and flow alterations downstream of the dam. Generally, the greater the storage capacity of a dam, the more extensive are the downstream geomorphological and biological impacts (Heinz Center 2002). Lost wetlands result in a loss of floodplain and flood storage capacity, and thus a reduced ability to provide flood control during storm events. A healthy riparian corridor is well vegetated, harbors prey items, contributes necessary nutrients, provides LWD that creates channel structure and cover for fish, and provides shade, which controls stream temperatures (Bilby and Ward 1991; Hanson et al. 2003). When vegetation is removed from riparian areas, water temperatures tend to increase and LWD is less common. The result is less refuge for fish, fundamental changes in channel structure (e.g., loss of pool habitats), instability of stream banks, and alteration of nutrient and prey sources within the river system (Hanson et al. 2003). Riparian zone development can be considered a secondary effect of dam construction. Residential, recreational, and commercial development may result from the associated impoundment.

### *Changes to native aquatic communities*

Impoundments can concentrate predators and disease carrying organisms and disrupt fish development, thereby altering the community structure at various trophic levels and potentially changing the natural habitat and fishery dynamics of the aquatic habitat. In addition, the loss of wetlands by the increased impoundment level and reduction of freshwater input and sediments below the dam can have potentially serious impacts on both fish and invertebrate populations (NEFMC 1998).

Impoundments also create an opportunity for nonnative species to become established. Common carp (*Cyprinus carpio*), northern pike (*Esox lucius*), and walleye (*Sander vitreus*) are a few examples. These species have the ability to dramatically alter local habitats and aquatic communities. In some instances, introduced species such as smallmouth bass (*Micropterus dolomieu*) become managed as a sport fish to the exclusion of native species. Over time, these introduced species become accepted as part of the "natural" condition. Like the changes associated with creating an impoundment, these introduced species can change the community dynamics of the riverine system.

### *Conservation measures and best management practices for dam construction and operation (adapted from Hanson et al. 2003 and PFMC 1999)*

1. Avoid the construction of new dam facilities, where possible.
2. Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
3. Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
4. Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
5. Consider all upstream passage types, including natural-like bypass channels, denil-type and vertical slot fishways, Alaskan steeppass, fishlifts, etc. Volitional passage is preferable to trap and truck methods.
6. Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
7. Operate facilities to create flow conditions that provide for passage, water quality, proper timing of life history stages, and properly functioning channel conditions, and to avoid strandings and redd (i.e., spawning nest) dewatering. Run-of-river, such that the volume of water entering an impoundment exits the impoundment with minimal fluctuation of the headpond, is the preferred mode of operation for fishery and aquatic resource interests. Water flow monitoring equipment should be installed upstream and downstream of the facility. Generally, fluctuations in headpond water levels should be kept between 6 and 12 inches.
8. Coordinate maintenance and operations which require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
9. Use seasonal restrictions for construction, maintenance, and operations of dams to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
11. Encourage the preservation of LWD, whenever possible. If possible, relocate debris as opposed to removing it completely. Remove LWD only to prevent damage to property or threats to human health and safety.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for dam construction and operation.
13. Consider the removal of a dam when it is feasible (see the following section on dam removal).

## Dam Removal

A number of factors may be considered in determining the efficacy of removing a dam, including habitat restoration, safety, and economics (Babbitt 2002; Heinz Center 2002). Dam removal provides overall environmental benefits to freshwater habitats and aquatic resources. The recovery of some anadromous species, such as Atlantic salmon and rainbow smelt, may be dependent on targeted dam removals, principally those dams blocking passage to high quality spawning and rearing habitat. Dam removal reconnects previously fragmented habitat, allowing the natural flow of water, sediment, nutrients, and the genetic diversity of fish populations and reestablishes floodplains and riparian corridors (Morita and Yokota 2002; Nislow et al. 2002).

The Heinz Center (2002) provides a thorough overview of environmental, economic, and social issues to consider when evaluating dam removal. Because there are a number of concerns and interests surrounding dams and their use, the overall benefits of dam removal must be weighed against all potential adverse impacts. It is important to bear in mind that although the removal of a dam may reverse most of the undesirable changes, it is unlikely to restore completely the natural conditions because of other dams on the river and the other anthropogenic effects on streams, such as channel control and land use management (Heinz Center 2002).

For many local residents, the impoundments created by these dams define a way of life for the community. Changing the existing conditions may not necessarily be perceived as good for all parties. For example, an impoundment may contain stocked game fish which provide recreational opportunities for the community. Dam removal may eliminate these species or bring about interactions with formerly excluded diadromous species. However, because dams alter sediment and nutrient transport processes and raise water levels upstream of the structure, dam removal can result in short and long-term impacts upstream and downstream.

The effects of dam removal on fisheries and aquatic habitat include: (1) release of contaminants; (2) short-term water quality degradation; (3) flow pattern alteration; (4) loss of benthic and sessile invertebrates; and (5) alterations of the riparian landscape and associated functions and values.

### *Release of contaminated sediments and short-term water quality degradation*

Dam removal typically results in an increased transfer of sediments downstream of the dam, while the spatial and temporal extent of sediment transfer depends on the size of the dam and total sediment load. Sediments accumulated behind dams can bind and adsorb contaminants that when remobilized after the removal of a dam have the potential to adversely affect aquatic organisms including the eggs, larvae, and juvenile stages of finfish, filter feeders, and other sedentary aquatic organisms (Heinz Center 2002). For example, a reduction in macroinvertebrate abundance, diatom richness, and algal biomass has been attributed to the downstream transport of fine sediments previously stored within a dam impoundment (Thomson et al. 2005). However, as fine sediment loads are reduced and replaced by coarser materials in the streambed, macroinvertebrate and finfish assemblages should recover from the disturbance (Thomson et al. 2005). Dam removal can impact overall water quality during and after the demolition phase, although these are typically temporary effects that generally do not result in chronic water quality degradation (Nechvatal and Granata 2004; Thomson et al. 2005).

### *Flow pattern alteration*

Dam removal generally changes downstream conditions by increasing the water and sediment discharges which tend to decrease channel gradients and increase stream depths and widths (Heinz Center 2002). In addition, flood events may increase; reactivate the floodplain; and reconnect side channels, islands, bars, and beaches. Reconnecting and increasing the active floodplain may help reduce low flow conditions in a river. Removal of a dam restores the natural timing of peak and low flows, which have important consequences for the biological components of the ecosystem. For example, seed production among native trees and spawning migrations of anadromous fish species often coincides with peak flows in the spring (Heinz Center 2002).

### *Loss of benthic and sessile invertebrates*

As discussed above, remobilized sediments after the removal of a dam have the potential to adversely affect aquatic organisms including benthic and sessile invertebrates. However, although water quality often is degraded immediately following removal, the abundance and diversity of aquatic invertebrates should increase as the sediment budget and hydrology of the river approaches a natural equilibrium (Heinz Center 2002).

## *Alteration of wetlands*

Lowering the water level will alter the wetland structure upstream of the old dam site and the associated wildlife assemblage. Lowering of impoundments can result in the alteration of existing wetlands (Nislow et al. 2002). As water levels recede, fringing wetlands may be lost while new wetlands are formed along the new riparian border. Newly exposed stream banks may need armoring or other erosion control methods to protect them. The history of the project, geomorphology of the watershed, and location in the river system, among other factors, will dictate the types of environmental issues dam removal will present. Geomorphic effects of downstream sediment transport may have long-term implications (Pizzuto 2002). However, many of these impacts are short-term, dissipating with time as the river system comes to a natural equilibrium (Bushaw-Newton et al. 2002; Thomson et al. 2005).

## *Conservation measures and best management practices for dam removal (adapted from Hanson et al. 2003)*

1. Conduct a comprehensive evaluation of the historic and existing hydrology, hydraulics, and sediment transport prior to the decision to remove a dam to assess possible adverse and cumulative effects of the removal of the structure on the watershed. Dam removal assessments should adopt a watershed scale of analysis.
2. Conduct an assessment of the biotic component of the effected area, particularly if anadromous fish restoration is one of the objectives of the dam removal. For example, the assessment may include characterization of the historic distribution and abundance of fish species, their various life history habitat requirements, and their limiting environmental factors. The assessment should also evaluate the predicted physical and chemical conditions following dam removal to determine if additional restoration may be necessary.
3. Conduct sufficient testing to evaluate the type, extent, and level of contamination upstream of the dam prior to the decision to remove a dam. Contaminated sediments, if extensively present, may require mechanical or hydraulic removal prior to the removal of the dam.
4. Conduct sufficient evaluation of the streambed within the impoundment to plan for any necessary streambed modifications.
5. Consider the possible necessity for removal of the dam in stages to control the release of sediments, if sediments are expected to be released downstream.
6. Schedule dam removal during the less sensitive time of year for aquatic resources, particularly outside the expected migratory period. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
7. Plan for revegetating the newly exposed stream bank with native vegetation.
8. Establish a contingency plan in the event that the stream channel needs modification (addition of riffle and pool complex, added features to create habitat complexity, meanders, etc.) to facilitate fish passage and habitat functions.
9. Establish a monitoring protocol to evaluate success of the restoration for fish passage and utilization.
10. Conduct outreach to the public to provide an understanding of the benefits of dam removal.

## Stream Crossings

Stream crossings are characterized as any structure providing access over a stream, river, or other water body for transportation purposes (e.g., roads, utilities). The feasibility of effective fish passage at stream crossings may be complex. Land ownership, utility crossing, flood protection for low-lying properties, and safety along the transportation corridor must be considered. Unfortunately, many transportation corridors interact and interfere with fisheries corridors (i.e., streams and rivers). These transportation corridors require structures for crossing rivers, streams, and other water bodies. If improperly designed, stream crossings can alter, degrade, fragment or eliminate aquatic habitat and potentially impede, or eliminate, passage for resident and migratory species (Evans and Johnston 1980; Belford and Gould 1989; Clancy and Reichmuth 1990; Furniss et al. 1991; USGAO 2001; Jackson 2003). Until recently, the primary concerns related to designing these structures were cost, designed load capacity, and hydraulics. Furthermore, common practice for repairing deficient structures often resulted in maintaining inadequate stream crossing conditions (e.g., "slip-lining" with smaller diameter pipe, lining of culvert with concrete, or replacing the structure in-kind).

Some American states and Canadian provinces have recognized the concerns relating to fish passage and stream crossings. For example, the Maine Department of Transportation and Commonwealth of Massachusetts Riverways Program, among others, have independently published guidelines for addressing fish passage at stream crossings (MEDOT 2004; MRP 2005). These and similar documents provide extensive information regarding fish and aquatic organism passage, habitat continuity, and wildlife passage requirements for environmentally-sound and safe transportation across streams, rivers, and other waterbodies.

The construction, maintainance, and operation of roadways at stream crossings can also affect aquatic habitats by increasing rates of erosion, debris slides or landslides and sedimentation, introduction of exotic species, and degradation of water quality (Furniss et al. 1991; Hanson et al. 2003). However, the focus of this chapter is the design and operation of the fish passage structure. Refer to the Coastal Development chapter in this report for information pertaining to impacts associated with roadways and vehicular traffic at stream crossings.

### *Impacts to fish passage*

Improperly designed stream crossings can block fish and aquatic organism passage in a variety of ways, including: (1) perched culverts constructed with the bottom of the structure above the level of the stream effectively act as a dam and physically block passage; and (2) hydraulic barriers to passage are created by undersized culverts which constrict the flow and create excessive water velocities (Evans and Johnston 1980; Belford and Gould 1989; Furniss et al. 1991; Jackson 2003). Smooth-bore liners made from high density plastic help meet the goal of passing water and protecting roadways from flooding, but they greatly increase flow velocities through the passage. Conversely, oversized culverts with large, flat bottom surfaces reduce water depth. Insufficient water depths may also be another hydraulic impediment to passage (Haro et al. 2004). In situations where water velocities are not physically limiting and water depths are sufficient, the impediments to passage may be a lack of resting pools. Many stream crossings, particularly longer culverts, are placed over wide stretches of river. Fish may not be capable of burst speeds and sustained swimming throughout the length of the crossing. Under such conditions, migrating fish are unable to reach spawning habitat.

### *Alteration of hydrologic regimes*

Undersized and/or improperly placed stream crossings can also affect water quality. Undersized structures can act as dams, impounding water and increasing water temperature. In extreme cases, if flows are sufficiently reduced and the impounded area deep enough, increased surface temperatures can create thermal stratification and reduce dissolved oxygen. In addition, as water flows through the structure the temperature of the water can rise, affecting aquatic organisms downstream. Undersized culverts can also cause flooding upstream of the crossing, affecting upland and riparian habitat.

### *Conservation measures and best management practices for stream crossings*

1. Design stream crossings for the target finfish species and various age classes. Other aquatic species, such as amphibians, reptiles, and mammals, should also be considered in the designs, as they play a role in healthy ecosystems.
2. Design structures to provide safe and timely passage to minimize injury and limit excessive predation.
3. Design and install new structures in a manner not to interfere with fish and aquatic organism passage and that complies with all applicable regulations.
4. Design structures to provide sufficient water depth and maintain suitable water velocities for target species during the migration season. Consider seasonal headwater and tailwater levels and how variations in them could affect passage of all aquatic life stages. Design considerations may include constructing a low flow channel, weir structure, energy dissipation pools, and designing structures for bank full width.
5. Consider the presence of nonnative, invasive aquatic species in fish passage design for stream crossings, particularly where the crossing may present an existing barrier to passage.
6. Design the structure to maintain or replicate natural stream channel and flow conditions to the greatest extent practicable. An open bottom arch or bridge is preferred. The structure should be able to pass peak flows in accordance with state and federal regulations. Ensure sufficient hydrologic data have been collected.
7. Bury culverts and pipes sufficiently to replicate a natural streambed. Doing so will also provide habitat functions, such as resting pools and reduced water velocities for longer structures.
8. Match the gradient of the stream crossing with the natural stream channel grade. Perched culverts should be removed, wherever practicable.
9. Maintain or stabilize upstream and downstream channel and bank conditions if the stream crossing structure causes erosion or accretion problems. Use of native vegetation should be required for erosion control and sediment stabilization.
10. Ensure the location and overall design of the fish passage structure and the stream crossing are compatible with local stream conditions and stream geomorphology.
11. Ensure that materials for the fish passage structure are nontoxic to fish and other aquatic organisms. Pressure treated lumber should be avoided.
12. Develop construction design and methods for repairing and replacing stream crossings that take into account fish passage requirements.
13. Conduct in-water construction activities during a time of year that would have the least environmental impacts to aquatic species (e.g., low flow seasons). Temporary diversions and coffer dams may be suitable alternatives with proper planning. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

14. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for stream crossing projects.

## Water Withdrawal and Diversion

Freshwater is becoming limited because of natural events (e.g., droughts), increasing commercial and residential demand of potable water, and inefficient use. Freshwater is diverted for human use from groundwater, lakes, and riverine environments or is stored in impoundments. The withdrawal or impoundment of water can alter natural current and sedimentation patterns, water quality, water temperature, and associated biotic communities (NEFMC 1998). Natural freshwater flows are subject to alteration through water diversion and use and modifications to the watershed such as deforestation, dams, tidal restrictions, and stream channelization (Boesch et al. 1997). Water withdrawal for freshwater drinking supply, power plant cooling systems, and irrigation occurs along urban and agricultural areas and may have potentially detrimental effects on aquatic habitats. Increased water diversion is associated with human population growth and development (Gregory and Bisson 1997). Water diversion is not only associated with water withdrawal and impoundment, but it also represents water discharges, which alter the flow and velocity and have associated water quality issues (Hanson et al. 2003). Water withdrawal in freshwater systems can also affect the health of estuarine systems. Refer to the Physical Effects: Water Intake and Discharge Facilities and Coastal Development chapters for additional information on the affects of water withdrawal on estuarine systems.

The effects of water withdrawal and diversion on freshwater fishery habitat can include: (1) entrainment and impingement; (2) impaired fish passage; (3) alteration of flow and flow rates, and processes associated with proper flows; (4) degradation of water quality (e.g., water temperature, dissolved oxygen) associated with proper water depth, drainage, and sedimentation patterns; (5) loss and/or degradation of riparian habitat; and (6) loss of prey and forage.

### *Entrainment and impingement*

The diversion of water for power plant cooling and other reservoirs results in entrainment and impingement of invertebrates and fishes (especially early life-history stages of fish) (NEFMC 1998). Fish and invertebrate populations may be adversely affected by adding this source of mortality to the early life stage which often determines recruitment and strength of the year-class. Important habitat for aquatic organisms around water intakes may become unavailable for recruitment and settlement (Travnichek et al. 1993).

### *Impaired fish passage and altered hydrologic regimes*

Water diversion and the withdrawal or discharge of water can result in a physical barrier to fish passage (Spence et al. 1996). Excessive water withdrawal can greatly reduce the usable river channel. Rapid reductions or increases in water flow, associated with dam operations for example, can greatly affect fish migratory patterns. Depending on the timing of reduced flows, fish can become stranded within the stream channel, in pools, or just below the river in an estuary system.

### *Water quality degradation*

The release of water with poor quality (e.g., altered temperatures, low dissolved oxygen, and the presence of toxins) affects migration and migrating behavior. The discharge of irrigation water into a freshwater system can degrade aquatic habitat (NRC 1996) by altering currents, water quality, water temperature, depth, and drainage and sedimentation patterns. Both water quantity and quality can greatly affect the usable zone of passage within a channel (Haro et al. 2004). Altered temperature regimes have the ability to affect the distribution; growth rates; survival; migration patterns; egg maturation and incubation success; competitive ability; and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003). In freshwater habitats of the northeastern United States, the temperature regimes of cold-water fish such as salmon, smelt, and trout may be exceeded leading to extirpation of the species in an area. Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005).

### *Release of contaminants*

Irrigation discharges are often associated with contaminants and toxic materials (e.g., metals, pesticides, fertilizers, salts, and nutrients) and possibly introduced pathogens, all of which stress the habitat and aquatic organisms (USEPA 2003). Studies evaluating pesticides in runoff and streams generally find that concentrations can be relatively high near the application site and soon after application but are significantly reduced further downstream and with time (USEPA 2003). However, some pesticides used in the past (e.g., dichlorodiphenyl trichloroethane [DDT]) are known to persist in the environment for years after application.

Soil transported from irrigated croplands and rangelands usually contains a higher percentage of fine and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides and herbicides (Duda 1985; USEPA 2003). In addition, irrigation water has a natural base load of dissolved mineral salts, and return flows convey the salt to the receiving streams or groundwater reservoirs. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that aquatic functions are impaired. However, if the process of water diversion and the return flow of saline drainage water is repeated many times along a stream or river, downstream habitat quality can become progressively degraded (USEPA 2003).

### *Siltation and sedimentation*

Water diversions can alter sediment and nutrient transport processes (Christie et al. 1993; Fajen and Layzer 1993), which can hinder benthic processes and communities. Suspended sediments in aquatic environments can reduce the availability of sunlight to aquatic plants, interfere with filtering capacity of filter feeders, and clog and harm the gills of fish (USEPA 2003). Increased suspended sediments may degrade or eliminate spawning and rearing habitats, impede feeding, negatively affect the food sources of fishes, severely alter the aquatic food web, and thus negatively affect the growth and survival of diadromous fish. Fine sediments are potentially detrimental to Atlantic salmon development and survival during all life stages. For example, sediments can fill interstitial spaces, embedding the substrate and preventing oxygenated water from reaching the incubating eggs within redds and inhibiting the removal of waste metabolites; eliminate refuge utilized by fry and parr to avoid predators; create a homogeneous environment which can lead to lower fish densities; reduce macroinvertebrate abundance; and decrease the depth and area of pools utilized by juveniles and adults (Danie et al. 1984; Fay et al. 2006). In addition, Breitburg (1988) found the predation rates of striped bass larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory.

## *Loss of wetlands and flood storage*

Healthy riparian corridors are well vegetated, support abundant prey items, maintain nutrient fluxes, provide LWD that creates channel structure and cover for fish, and provide shade, which controls stream temperatures (Bilby and Ward 1991; Hanson et al. 2003). Riparian wetland vegetation can be affected by long-term or frequent changes in water levels caused by water withdrawals and diversions. Removal of riparian vegetation can impact fish habitat by reducing cover and shade, by reducing water temperature fluctuations, and by affecting the overall stability of water quality characteristics (Christie et al. 1993). As river and stream water levels recede because of withdrawals, fringing wetlands may be lost and armoring or other erosion control methods may be needed to protect newly exposed stream banks. The results are less refuge for fish, fundamental changes in channel structure (e.g., loss of pool habitats), instability of stream banks, and alteration of nutrient and prey sources within the river system (Hanson et al. 2003). The changes to the natural habitat caused by irrigation water discharges can potentially lead to large-scale aquatic community changes. Changes in flow patterns may affect the availability of prey and forage species. In conjunction with anthropogenic watershed changes, water diversions and associated riparian impacts have been associated with the increase in some harmful algal blooms (Boesch et al. 1997), which further impact an array of aquatic habitat characteristics. Lost wetlands correlate to a loss of floodplain and flood storage capacity, and thus a reduced ability to act as flood control during storm events.

For additional information on water diversion impacts, refer to the Physical Affects: Water Intake and Discharge Facilities, Chemical Affects: Water Discharge Facilities, and Agriculture and Silviculture chapters in this report.

## *Conservation measures and best management practices for water withdrawal/ diversion (adapted from Hanson et al. 2003)*

1. Design projects to create flow conditions adequate to provide for passage, water quality, proper timing for all life history stages, and avoidance of juvenile stranding and redd (i.e., spawning nest) dewatering, as well as to maintain and restore properly functioning channel, floodplain, riparian, and estuarine conditions.
2. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
3. Establish adequate instream flow conditions for anadromous fish.
4. Design intakes with minimal flows to prevent impingement/entrainment (e.g., ≤0.5 feet per second).
5. Screen water diversions on fish-bearing streams, as needed.
6. Design thermal discharges such that ambient stream temperatures are maintained or a zone of passage is provided to maintain suitable temperatures for fish passage.
7. Incorporate juvenile and adult fish passage facilities on all water diversion projects.
8. Whenever possible, contaminants and sediments should be removed from water discharge prior to entering rivers and other aquatic habitats.
9. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in water withdrawal project review processes.

## Dredging and Filling

The dredging and filling of riparian and freshwater wetlands directly remove potentially important habitat and alter the habitat surrounding the developed area. Expansion of navigable waterways is associated with economic growth and development and generally adversely affects benthic and water-column habitats. Routine dredging is required to maintain the desirable depth as the created channel fills with sediment. Direct removal of riverine habitat from dredge and fill activities may be one of the biggest threats to riverine habitats and anadromous species (NEFMC 1998).

Dredge and fill activities in riverine and riparian habitats can affect fisheries habitat in a number of ways, including: (1) reducing the ability of the wetland to retain floodwater; (2) reducing the uptake and release of nutrients; (3) decreasing the amount of detrital food source, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) converting habitats by altering water depth or the substrate type (i.e., substrate conversion); (5) removing aquatic vegetation and preventing natural revegetation; (6) hindering physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983; Cloern 1987; Dennison 1987; Barr 1993; Benfield and Minello 1996; Nightingale and Simenstad 2001); (7) directly eliminating sessile or semimobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990; McGraw and Armstrong 1990; Barr 1993; Newall et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000); (10) reducing dissolved oxygen through reduced photosynthesis and through chemical processes associated with the release of reactive compounds in the sediment (Nightingale and Simenstad 2001).

Filling wetlands removes productive habitat and eliminates the important functions that both aquatic and many terrestrial organisms depend upon. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) because of degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Mitsch and Gosselink 1993).

### *Flood storage capacity*

Impervious surfaces decrease the capacity of a watershed to absorb pulses of freshwater input (e.g., heavy rain, snowmelt). Similarly, stormwater drain systems decrease the storage by directing water directly into a nearby wetland or river system. The rate and volume of stormwater runoff from land into rivers and streams is greater in watersheds with high percentages of impervious surface cover and extensive drainage systems, which reduce the stormwater storage capacity (American Rivers 2002). Measurable adverse changes in the physical and chemical environment were observed when the impervious cover exceeded 10-20% of the land cover (Holland et al. 2004). Flashy, high-velocity pattern of flows and associated pulse of contaminants from upland sources can have long-term, cumulative impacts on freshwater wetlands and riverine, estuarine, and marine ecosystems. As development continues throughout the region, the ability to minimize loss of flood storage capacity and mitigate consequences of increasing coverage of impervious surfaces will be significant planning issues (American Rivers 2002). Refer to the Coastal Development chapter for additional information on stormwater runoff and nonpoint source pollution.

Impacts associated with dredging and filling of aquatic habitats and wetlands are discussed in greater detail in the Offshore Dredging and Disposal Activities, Marine Transportation, and Coastal Development chapters of this report.

### *Conservation measures and best management practices for dredging and filling (adapted from Hanson et al. 2003)*

1. Avoid the filling of wetlands and riparian habitat whenever possible. Ensure proposed dredge and fill projects in wetlands are water-dependent.
2. Utilize best management practices (BMPs) to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include constructing silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge).
3. Require the use of multiple-season biological sampling data (both pre- and post-construction) when appropriate to assess the potential and resultant impacts on habitat and aquatic organisms.
4. Test sediment compatibility for open-water disposal per the US Environmental Protection Agency (US EPA) and US Army Corps of Engineers requirements for inshore and offshore, unconfined disposal.
5. Plan dredging and filling activities to avoid submerged aquatic vegetation and special aquatic sites. This may include the placement of pipes for hydraulic dredging and anchoring of barges and other vessels associated with the dredging project.
6. Design the dredge footprint to avoid littoral zone habitat, and appropriate buffers should be in place to protect these areas from wind driven waves and boat wakes.
7. Schedule dredging activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Reference all dredging projects in a geographical information system (GIS) compatible format for long-term evaluation.
9. Identify sources of sedimentation within the watershed that may exacerbate repetitious maintenance activities. Implement appropriate management techniques to control these sources.
10. Address cumulative impacts of past, present, and foreseeable future dredging operations on aquatic habitats by considering them in the review process.

## Mining

Most modern mining operations in the northeast US region involve bulk mineral commodities (aggregates such as sand, gravel, and crushed stone), but the region has a long history of mineral mining for mica, feldspar, copper, iron, gold, silver, and coal, as well as peat (Lepage et al. 1991; Boudette 2005; VADMME 2007). While some mineral mining continues in this region, many operations have ceased entirely (Lepage 1991). Some of these abandoned mines have become a source of groundwater or surface water contamination and have been identified by the US EPA's Superfund Program (USEPA 2007) and other nonfederal programs for cleanup. Currently, the US EPA Superfund Program lists cleanup sites on the Susquehanna River in Pennsylvania from coal mining and tributaries leading to East Penobscot Bay in Maine and the Connecticut River in Vermont from copper and other metal mining.

Few active mining sites in the northeast US region currently affect fishery resources as they generally are not located adjacent to or in rivers that support didromous fish. In addition, because access for diadromous fish to historic spawning grounds has been adversely affected by dams and poor water quality throughout the region (Moring 2005), the potential adverse effects of mining operations on these species have been reduced in recent times. Nonetheless, some sand and gravel extraction projects occur within rivers and their tributaries of the northeast US region. Although limited information is available on this subject, it appears the number of active sand and gravel operations that may adversely affect diadromous fish in the northeast US region is relatively small compared to other regions of the United States. However, considering the potential direct and indirect effects from historic and current mining activities on long-term water quality and health of diadromous species, a brief discussion on this topic is warranted in this section.

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations (NEFMC 1998). On-site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning and reclamation, and abandonment. Mining operations often occur in urban settings or around existing or historic mining sites; however, mining in remote settings where human activity has caused little disruption and aquatic resources are most productive may cause significant impacts (NRC 1999). Existing state and federal regulations have been established to restrict various environmental impacts associated with mining operations. However, the nature of mining will always result in some alteration of habitat and natural resources (NRC 1999).

Some of the impacts associated with the extraction of material from within or near a stream or river bed include: (1) disruption of preexisting balance between sediment supply and transporting capacity, leading to channel incision and bed degradation; (2) increased suspended sediment, sediment transport, turbidity, and gravel siltation; (3) alteration in the morphology of the channel and decreased channel stability; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) alteration of the channel hydraulics during high flows caused by material stockpiled or left abandoned; (6) removal of instream roughness, including LWD; (7) reduced groundwater elevations and stream flows caused by dry pit or wet pit mining; and (8) destruction of the riparian zone during extraction operations (Pearce 1994; Packer et al. 2005). In addition, structures used in mining extraction and transportation often cause additional impacts to wetland and riverine habitats (Starnes and Gasper 1996). Other impacts include fragmentation and conversion of habitat, alteration of temperature regimes, reduction in oxygen concentration, and the release of toxic materials.

### *Mineral mining*

Although there is a long history of mining in the northeast region of the United States, few active mineral mining operations remain that are located in or adjacent to streams or rivers in this region, and even fewer mineral mining operations occur in streams and rivers utilized by diadromous fish. Nonetheless, mineral mining has occurred in the northeast US region in the past, as evidenced by a number of completed and ongoing remediation sites in areas that have supported or historically supported diadromous fish (USEPA 2007). A brief discussion on the potential impacts to aquatic habitats is provided below.

The effects of mineral mining on riverine habitat depend on the type, extent, duration, and location of the mining activity. Surface mining typically involves suction dredging, hydraulic mining, panning, sluicing, strip mining, and open-pit mining. Surface mining has a greater potential impact on riverine habitat than does underground or shaft mining, depending on other aspects of the mining activities, including processing and degree of disturbance (Spence et al. 1996; Hanson et al. 2003). Elimination of vegetation, topographic alterations, alteration of soil and subsurface geological structure and alteration of surface and groundwater hydrologic regimes are potential effects of surface mining (Starnes and Gasper 1996). Soil erosion and sediment runoff may be the greatest impact of surface mining, contributing a greater sediment load per area of disturbance compared with other activities because of the degree of soil, topographic, and vegetation disturbance (Nelson et al. 1991).

### *Sand and gravel mining*

Sand and gravel are the most valuable and extensively exploited nonfuel mineral resources in the eastern US region and are mined in all states from Virginia to Maine (Bolen 2007). According to Starnes and Gasper (1996), sand and gravel extraction is the least regulated of all mining industries, and approximately 80% of this resource is extracted under jurisdiction of state and local laws only. These authors state that sand and gravel mining is "widely used in large US rivers and can increase the sediment bed load through resuspension, physically eliminate benthic organisms, and destroy fish spawning and nursery areas, all of which ultimately change aquatic community composition" (Starnes and Gasper 1996); however, they do not identify specific rivers that are affected or state whether the rivers support diadromous fish species. The Virginia Department of Mines, Minerals and Energy states, "Sand and gravel are extracted from coastal sand pits, river terraces or dredged from the rivers themselves" (VADMME 2007). In 2005, over 15,000 tons of sand were mined from two operations along the Roanoke River in Virginia (VADMME 2007). In addition, a dredge and fill permit was granted by the US Army Corps of Engineers to allow sand extraction in the St. John River, ME, for use in road sanding operations (USACE 2005). Although sand and gravel mining may not be a significant threat to diadromous fish in the northeast US region at this time, at least some activity is currently taking place, and any increase in activity represents potential future threat.

Gravel and sand mining operations can involve wet-pit mining (i.e., removal of material below the water table); dry pit mining on beaches, exposed bars, and ephemeral streambeds; or subtidal mining. Impacts associated with sand and gravel mining in riverine environments are similar to mineral mining impacts and include: turbidity plumes and resuspension of sediment and nutrients, removal of spawning habitat, and alteration of stream channel morphology. These physical perturbations often lead to alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, and loss of suitable habitat (Packer et al. 2005). For information pertaining to impacts associated with mining and dredging in marine habitats refer to the chapter on Offshore Dredging and Disposal Activities.

### *Peat mining*

Peat is mined in the United States primarily for horticultural and industrial purposes, including a filtration medium to remove toxic materials and a fuel/oil absorbent (Jasinski 2007). Peat mining occurs in a number of states in the northeast US region, although at relatively small scales. In Maine, at least one peat mining operation exists in the Narraguagus River watershed, which burns mixtures of peat and wood chips to generate electricity (Lepage et al. 1991; USFWS and NMFS 1999).

The impacts associated with peat mining include the release of contaminants (i.e., peat fiber, arsenic residues, and other toxic chemicals), siltation, increased stormwater runoff from roads and other unvegetated areas, and altered hydraulic flow regimes (NEFMC 1998; USFWS and NMFS 1999). Peat mining has been associated with acidic conditions in eastern Maine watersheds, such as Narraguagus River, and has been identified as a potential contributor to Atlantic salmon declines (USFWS and NMFS 1999).

### *Alteration of stream bed and stream morphology*

Surface mining can alter channel morphology by making the stream channel wider and shallower and removing the natural sediment load. Consequently, the suitability of stream reaches as rearing habitat may decrease, especially during summer low-flow periods when deeper waters are important for survival. Gravel bar skimming or "scalping," which involves the removal of the surface from gravel bars without excavating below the low water flow level, can significantly impact aquatic habitat (Packer et al. 2005). Bar skimming creates a wide, flat cross section in the stream channel, which eliminates confinement of the low flow channel. A reduction in pool frequency may adversely affect migrating adults that require holding pools (Spence et al. 1996). Changes in the frequency and extent of bedload movement and increased erosion and turbidity can also remove spawning substrates, scour redds, result in a direct loss of eggs and young, or reduce their quality by deposition of increased amounts of fine sediments. These changes can affect the early life stages of Atlantic salmon, which exhibit an affinity for specific habitat types (Fitzsimons et al. 1999; Hedger et al. 2005). Extraction of sand and gravel in riverine ecosystems can directly eliminate the amount of gravel available for spawning if the extraction rate exceeds the deposition rate of new gravel in the system. Gravel excavation also reduces the supply of gravel to downstream habitats. The extent of suitable spawning habitat may be reduced where degradation reduces gravel depth or exposes bedrock (Spence et al. 1996). Associated with stream morphology alterations are resultant increased temperatures from a reduction in summer base flows; altered width to depth ratios; decreased riparian vegetation; decreased dissolved oxygen concentration as water temperatures increase; decreased nutrients from loss of floodplain connection and riparian vegetation; and decreased food production (e.g., loss of invertebrate prey populations) (Spence et al. 1996).

### *Sedimentation and siltation*

Sedimentation effects of mining may be immediate or delayed. During gravel extraction, for example, fine material can travel long distances downstream in the form of turbidity plumes. Silt can also be released during peat mining operations (USFWS and NMFS 1999). Sedimentation may be a delayed effect because gravel removal typically occurs at low flow when the stream has the least capacity to transport fine sediments out of the system. Increased sedimentation results when the spring freshet inundates an extraction area that is less stable than before mining operations. The extent and duration of sedimentation and siltation is likely to be higher than normal as unstable sediment washes freely into the system during higher rates of flow, acting as a migratory barrier to anadromous fish, such as Atlantic salmon, and increasing entrainment of sediment in downstream habitat. The result can be a degradation or loss of spawning and rearing habitat within the system (Spence et al. 1996).

### *Release of contaminants*

Peat mining can negatively impact diadromous fish, including Atlantic salmon, from the discharge of low pH water containing peat silt and dissolved metals and pesticides (USFWS and NMFS 1999). However, only one peat mining operation has been identified on the Narraguagus

River in Maine, and monitoring efforts at the site suggests that impacts are being controlled (USFWS and NMFS 1999).

Although current mineral mining operations in the northeast region of the United States are not a significant threat to rivers supporting diadromous fish, the effects of historic mining operations continue to be remediated (USEPA 2007). Harmful or toxic materials can be released directly from mining operations, including processing and machinery. Mining can introduce high levels of metals, sulfuric acid, mercury, cyanide, arsenic, and processing reagents into waterways. Water pollution by metals and acids is associated with mineral mining because ores, rich in sulfides, are commonly mined to extract gold, silver, copper, zinc, and lead (NRC 1999). In combination with anoxic conditions, sulfur-containing sediments can create additional levels of toxicity in addition to acid conditions (Brouwer and Murphy 1995). The improper handling or discharge of tailings and settling ponds can result in a direct loss of living aquatic resources as a result of decreased water quality and increased concentration levels of toxic substances. Locating settling ponds in unstable or landslide prone upland sites makes them prone to dangerous, instantaneous releases of large quantities of toxins. Groundwater and surface water may be incidentally contaminated by leaching of toxic substances from upland settling ponds.

### *Conservation measures and best management practices for mining (adapted from Hanson et al. 2003 and Packer et al. 2005)*

1. Use upland aggregate sources before beginning any mining activities in active channels or floodplains.
2. Avoid mining operations in rivers and streams identified as important migratory pathways, spawning, and nursery habitat for anadromous fish.
3. Conduct a thorough assessment and characterization of aquatic resources, sediments, and potential sources of point and nonpoint contaminants prior to gravel removal.
4. Design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to riverine habitat if operations cannot be avoided. This includes, but is not limited to, migratory corridors, foraging and spawning areas, and stream/river banks.
5. Minimize the spatial extent and the depth of mine extraction operation to the maximum extent practicable.
6. Schedule necessary in-water activities when the fewest species and least vulnerable life stages are present. Seasonal restrictions should be used to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
7. Identify upland or off-channel (where channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to rivers and streams identified as important pathways for anadromous fish, if possible.
8. Utilize best management practices to avoid spills of dirt, fuel, oil, toxic materials, and other contaminants. Prepare a spill prevention plan and maintain appropriate spill containment and water repellent/oil absorbent cleanup materials on the project location.
9. Treat wastewater (e.g., acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle onsite to minimize discharge to streams. Treat wastewater before discharge for compliance with state and federal clean water standards.
10. Reclaim mining wastes that contain contaminants such as metal, acids, arsenic, or other substances if leachate could enter aquatic habitats through surface or groundwater.

11. Use best management practices to minimize opportunities for sediment to enter streams and waterways. Methods such as contouring, mulching, silt curtains, and settling ponds should be part of the operations plan. Monitor turbidity during operations and alter operations if turbidity levels reach or exceed a predetermined level.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in mining project review processes.

## Emerging Issues for Freshwater Systems

### *Endocrine disruptors, pharmaceuticals, and nanoparticles*

Growing concerns have mounted in response to the effects of endocrine-disrupting chemicals on humans, fish, and wildlife (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). One of the sources of endocrine disrupting compound is the effluent of residential and commercial wastewater treatment facilities, as well as agricultural runoff (USGS 2002). Some of the chemicals shown to be estrogenic include polychlorinated biphenyl (PCB), dieldrin, DDT, phthalates, and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture and may be present in irrigation water. Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Refer to the Chemical Effects: Water Discharge Facilities chapter for more information on endocrine disruptors. In addition to endocrine disrupting compounds, recent studies have found municipal wastewater effluent entering streams and rivers containing human and veterinary pharmaceuticals, including antibiotics and natural and synethetic hormones (USGS 2002).

Other recent concerns are the release of substances referred to as nanoparticles into the aquatic environment. Nanoparticles, such as fullerenes (e.g., 60-carbon molecules often referred to as "buckyballs") may have great potential for use in the pharmaceutical, lubricant, and semiconductor industries, as well as applications in energy conversion. However, the micro-fine particulate waste generated from the production and use of nanoparticles may adversely affect the distribution, feeding, ecology, respiration, and nutrient regeneration of microorganisms, such as bacterivorous and herbivorous protozoa, protists, and phagotrophic or mixotrophic microalgae (Colvin 2003).

### *Harmful algal blooms*

Impervious surfaces and stormwater drain systems can increase the rate and volume of stormwater runoff into rivers and streams. This direct flushing of water generates large pulses of runoff into rivers and streams, carrying with it nutrients and a wide-range of pollutants that flow into estuaries and coastal areas. Nutrient-rich waters have been associated with harmful algal blooms (HABs), which can deplete the oxygen in the water during bacterial degradation of algal tissue and can result in hypoxic or anoxic "dead zones" and large-scale fish kills in rivers, estuaries, and coastal areas (Deegan and Buchsbaum 2005; MDDNR 2007). For example, HABs have been responsible for fish kills in the freshwater portions of the Potomac River in Virginia and the Corsica River in Maryland, as well as in the Potomac and Chesapeake Bay estuaries (MDDNR 2007). HABs affecting Gulf of Maine waters have resulted in shellfish bed closures and mortalities to endangered marine mammals (NOAA 2008; WHOI 2008). While the causes of HABs in coastal waters of New England are unclear, large pulses of freshwater rivers and streams in the region as a result of elevated rainfall and snowmelt in the spring are being examined as contributing factors in creating conditions favorable for algal growth (NOAA 2008). Refer to the Coastal Development and Introduced/Nuisance Species and Aquaculture chapters for more information on HABs.

### *Introduced and nusiance species*

Introductions of nonnative nuisance species are a significant threat to freshwater and coastal ecosystems in the United States (Carlton 2001). Nonnative species may be released intentionally (i.e., fish stocking and pest control programs) or unintentionally during industrial shipping activities (e.g., ballast water releases), aquaculture operations, recreational boating, biotechnology, or from aquarium discharge (Hanson et al. 2003; Niimi 2004). For example, increased competition for food sources between the invasive exotic zebra mussel (*Dreissena polymorpha*) and open-water commercial and recreational species have altered the trophic structure in the Hudson River estuary, NY, by withdrawing large quantities of phytoplankton and zooplankton from the water column, thus increasing competition with planktivorous fish (Strayer et al. 2004). Refer to the Introduced/Nuisance Species and Aquaculture chapter for information on introduced and nuisance species.

## References for Alteration of Freshwater Systems


Abbe TB, Montgomery DR. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers-Research and Management 12(2-3):201-21.

American Rivers, Natural Resources Defense Council, Smart Growth America. 2002. Paving our way to water shortages: how sprawl aggravates the effects of drought. [Internet]. Washington (DC): Smart Growth America. [cited 2007 Dec 21]. 31 p. Available from: http://www.smartgrowthamerica.org/waterandsprawl.html.

Arruda JA, Marzolf GR, Faulk RT. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. Ecology 64(5):1225-35.

Babbitt B. 2002. What goes up, may come down: learning from our experiences with dam construction in the past can guide and improve dam removal in the future. BioScience 52(8):656-8.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Belford DA, Gould WR. 1989. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management 9(4):437-45.

Benfield MC, Minello TJ. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fishes 46:211-6.

Beschta RL, Bilby RE, Brown GW, Holtby LB, Hofstra TD. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo EO, Cundy TW, editors. Streamside management: forestry and fishery interactions. Seattle (WA): University of Washington, College of Forest Resources. p 191-232.

Bilby RE, Ward JW. 1991. Characteristics and function of large woody debris in streams draining old-growth, clearcut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-508.

Bodi FL, Erdheim E. 1986. Swimming upstream: FERC's failure to protect anadromous fish. Ecology Law Quarterly 13(1):7-50.

Boesch DF, Anderson DM, Horner RA, Shumway SE, Tester PA, Whitledge TE. 1997. Harmful algal blooms in coastal waters: options for prevention, control and mitigation. Silver Spring (MD): NOAA Coastal Ocean Office. NOAA Coastal Ocean Program Decision Analysis Series No. 10. 46 p. + appendix.

Bolen W. 2007. Sand and Gravel, Construction. US Geological Survey Minerals Yearbook-2005. [Internet]. US Department of the Interior, US Geological Survey. [updated 2008 May 19; cited 2008 Jul 15]. 21 p. Available from:

http://minerals.usgs.gov/minerals/pubs/commodity/sand_&_gravel_construction/sandgmyb05.pdf.

Boudette EL. 2005. Gold in New Hampshire. [Internet]. Concord (NH): New Hampshire Department of Environmental Services. Environmental Fact Sheet CO-GEO-1. [cited 2008 Jul 15]. 4 p. Available from: http://www.des.state.nh.us/factsheets/geo/geo-1.htm.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Brouwer H, Murphy T. 1995. Volatile sulfides and their toxicity in freshwater sediments. Environmental Toxicology and Chemistry 14 (2):203-8.

Buchsbaum R. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Bushaw-Newton KL, Hart DD, Pizzuto JE, Thomson JR, Egan J, Ashley JT, Johnson TE, Horwitz RJ, Keeley M, Lawrence J, and others. 2002. An integrative approach towards understanding ecological responses to dam removal: the Manatawny Creek study. Journal of the American Water Resources Association 38 (6):1581-99.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chabreck RA. 1988. Coastal marshes: ecology and wildlife management. Minneapolis (MN): University of Minnesota Press. 138 p.

Christie RW, Allen DE, Jobsis GJ. 1993. Diversions. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 181-186.

Clancy CG, Reichmuth DR. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management 10(2):244-6.

Cloern JE. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7(11-12):1367-81.

Collins BD, Montgomery DR, Haas AD. 2002. Historical changes in the distribution and functions of large wood in Puget lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59:66-76.

Collins BD, Montgomery DR, Sheikh AJ. 2003. Reconstructing the historic riverine landscape of the Puget lowland. In: Bolton S, Montgomery DR, Booth D, Wall L, editors. Restoration of Puget Sound rivers. Seattle (WA): University of Washington Press. p 79-128.

Colvin VL. 2003. The potential environmental impact of engineered nanomaterials. Nature Biotechnology 21:1166-70.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: a region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Danie DS, Trial JG, Stanley JG. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic)-Atlantic salmon. Washington (DC): US Fish and Wildlife Service, FWS/OBS-82/11.22 and the US Army Corps of Engineers, TR EL-82-4. 19 p.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dennison WC. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany 27(1):15-26.

De Laney TA. 1995. Benefits to downstream flood attenuation and water quality as a result of constructed wetlands in agricultural landscapes. Journal of Soil and Water Conservation 50:620-6.

Duda AM. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Water Resources Bulletin 21(2):225-34.

Evans WA, Johnston B. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington (DC): US Department of Agriculture, Forest Service. 163 p.

Fajen OF, Layzer JB. 1993. Agricultural practices. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 257-67.

Fay C, Bartron M, Craig S, Hecht A, Pruden J, Saunders R, Sheehan T, Trial J. 2006. Status review for anadromous Atlantic salmon (*Salmo salar*) in the United States. [Internet]. Report to the National Marine Fisheries Service and US Fish and Wildlife Service. [cited 2008 Jul 15]. 294 p. Available from: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsalmon.pdf.

Fitzsimons JD, Fodor G, Williston B, Carl L, Gentile T. 1999. Spawning habitat selection and suitability for Atlantic salmon. In: IAGLR '99. The 42nd Conference of the International Association for Great Lakes Research: Great Lakes, Great Science, Great Cities; 1999 May 24-28; Cleveland (OH): Case Western Reserve University. p A32-3.

Fletcher R. 2003. Loss of wetlands: how are bird communities affected? [Internet]. American Institute of Biological Sciences, c2000-2007. [cited 2007 Dec 21]. Available from: http://www.actionbioscience.org/environment/fletcher.html.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 297-323.

Graf WL. 1993. Landscapes, commodities, and ecosystems: the relationship between policy and science for American rivers. In: Sustaining our water resources (1993) Commission on geosciences, environment and resources (CGER). Washington (DC): National Academy Press. p 11-42.

Gregory SV, Bisson PA. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In: Stouder DJ, Bisson PA, Naiman RJ, editors. Pacific Salmon and their ecosystems: status and future options. New York (NY): Chapman and Hall. p 277-314.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Haro A, Castro-Santos T, Noreika J, Odeh M. 2004. Swimming performance of upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fisheries and Aquatic Sciences 61(9):1590-601.

Hedger RD, Dodson JJ, Bergeron NE, Caron F. 2005. Habitat selection by juvenile Atlantic salmon: the interaction between physical habitat and abundance. Journal of Fish Biology 67:1054-71.

Heinz Center. 2002. Dam removal: science and decision making. Washington (DC): The H. John Heinz III Center for Science, Economics, and the Environment. 236 p.

Holland AF, Sanger DM, Gawle CP, Lerberg SB, Santiago MS, Riekerk GHM, Zimmerman LE, Scott GI. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298(2):151-78.

Howard-Williams C. 1985. Cycling and retention of nitrogen and phosphorus in wetlands: theoretical and applied perspective. Freshwater Biology 15(4):391-431.

Jackson SD. 2003. Design and construction of aquatic organism passage at road-stream crossings: ecological considerations in the design of river and stream crossings. In: Irwin CL, Garrett P, McDermott KP, editors. 2003 Proceedings of the International Conference on Ecology and Transportation; 2003 Aug 24-29; Lake Placid, NY. Raleigh (NC): Center for Transportation and the Environment: North Carolina State University. p 20-9.

Jasinski SM. 2007. USGS Minerals Yearbook: peat. [Internet]. US Department of the Interior, US Geological Survey. [cited 2008 Jul 15]. 6 p. Available from: http://minerals.usgs.gov/minerals/pubs/commodity/peat/myb1-2006-peat.pdf.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Kerry J, Boorse D, Buchsbaum R. 2004. Effect of nutrient enrichment and salinity on salt marsh invertebrates in the Plum Island Estuary. Biological Bulletin 207:174.

Larinier M. 2001. Environmental issues, dams and fish migration. In: Dams, fish and fisheries: opportunities, challenges and conflict resolution. Rome (Italy): FAO Fisheries Technical Paper No. 419. p 45-89.

Larson K, Moehl CE. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): Washington Sea Grant, University of Washington. p 102-12.

Lepage CA, Foley ME, Thompson WB. 1991. Mining in Maine: past, present, and future. [Internet]. Augusta (ME): Maine Geological Survey. Open-File 91-7. [updated 2005 Oct 6; cited 2007 Dec 21]. 11 p. Available from: http://www.maine.gov/doc/nrimc/mgs/explore/mining/minemaine.htm.

[MEDOT] Maine Department of Transportation. 2004. Fish passage policy and design guide. 2nd ed. [Internet]. Augusta (ME): Maine Department of Transportation. 80 p. [updated 2005 Jan 3; cited 2007 Dec 21]. Available from: http://www.maine.gov/mdot-stage/environmental-office-homepage/documents.

[MDDNR] Maryland Department of Natural Resources. 2007. Harmful algae blooms in Maryland. [Internet]. [cited 2007 Dec 21]. Five articles available from: http://www.dnr.state.md.us/bay/hab/index.html.

Maser C, Sedell JR. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. Delray Beach (FL): St. Lucie Press. 200 p.

[MRP] Massachusetts Riverways Program. 2005. Massachusetts stream crossings handbook. [Internet]. Boston (MA): Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Department of Fish and Game. [cited 2007 Dec 21]. Available from: http://www.mass.gov/dfwele/river/programs/rivercontinuity/guidancedoc.htm.

McGraw K, Armstrong D. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): University of Washington Sea Grant. p 113-31.

Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 p.

Montgomery DR, Smith RD, Schmidt KM, Pess GR. 1995. Pool spacing in forest channels. Water

Resources Research 31(4):1097-105.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

Morita K, Yamomoto S. 2002. Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations. Conservation Biology 16(5):1318-23.

Morita K, Yokota A. 2002. Population viability of stream-resident salmonids after habitat fragmentation: a case study with white-spotted charr (*Salvelinus leucomaenis*) by an individual based model. Ecological Modelling 155:85-94.

Naiman RJ, editor. 1992. Watershed management: balancing sustainability and environmental change. New York (NY): Springer-Verlag New York. 542 p.

[NOAA] National Oceanic and Atmopheric Administration. 2008. Worst New England Harmful Algal Bloom in 30 Years. [Internet]. Silver Spring (MD): NOAA; Center for Sponsored Coastal Ocean Research (CSCOR). [updated 2008 May 14; cited 2008 Sep 22]. Available from: http://www.cop.noaa.gov/news/fs/ne_hab_200505.html.

[NRC] National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. Washington (DC): National Academy Press. 452 p.

[NRC] National Research Council. 1999. Hardrock mining on federal lands. Appendix B. Potential environmental impacts of hardrock mining. Washington (DC): National Academy Press. p 149-168.

Nechvatal M, Granata T. 2004. Dam removal as a solution to increase river water quality. In: Self sustaining solutions for streams, wetlands, and watersheds; 2004 Sep 12-15; St. Paul, MN. St. Joseph (MI): American Society of Agricultural and Biological Engineers.

Nelson RL, McHenry M, Platts WS. 1991. Mining. In: Meehan WR, editor. Influences of forest and rangeland management in salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 425-58.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Nightingale B, Simenstad CA Jr. 2001. Dredging activities: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 15]. 119 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finaldrg.pdf.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Nislow KH, Magilligan FJ, Fassnacht H, Bechtel D. 2002. Effects of dam impoundment on the flood regime of natural floodplain communities in the upper Connecticut River. Journal of the American Water Resources Association 38(6):1533-48.

Ormerod SJ. 2003. Current issues with fish and fisheries: editor's overview and introduction. Journal of Applied Ecology 40(2):204-13.

[PFMC] Pacific Fisheries Management Council. 1999. Appendix A: identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. [Internet]. Portland (OR). [updated 2007 May 8; cited 2007 Dec 21]. Available from: http://www.pcouncil.org/salmon/salfmp/a14.html.

Packer DB, Griffin K, McGlynn KE. 2005. National Marine Fisheries Service national gravel extraction guidance. [Internet]. Washington (DC): US Department of Commerce. [Internet]. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm.

Parrish DL, Behnke RJ, Gephard SR, McCormick SD, Reeves GH. 1998. Why aren't there more Atlantic salmon (*Salmo salar*)? Canadian Journal of Fisheries and Aquatic Sciences 55(Suppl. 1):281-7.

Pearce JB. 1994. Mining of seabed aggregates. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 48-50.

Pizzuto J. 2002. Effects of dam removal on river form and process. BioScience 52(8):683-91.

Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE, Stromberg JC. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47:769-84.

Raymond HL. 1979. Effects of dams and impoundments on migrations of juvenile Chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-29.

Ruggles CP. 1980. A review of the downstream migration of Atlantic salmon. Halifax (Nova Scotia): Freshwater and Anadromous Division, Resource Branch, Department of Fisheries and Oceans. Canadian Technical Report of the Fisheries and Aquatic Sciences No. 952. ix + 39 p.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Starnes LB, Gasper DC. 1996. Effects of surface mining on aquatic resources in North America. Fisheries 21(5):24-6.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Thomson JR, Hart DD, Charles DF, Nightengale TL, Winter DM. 2005. Effects of removal of a small dam on downstream macro invertebrate and algal assemblages in a Pennsylvania stream. Journal of the North American Benthological Society 24(1):192-207.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

[USACE] US Army Corps of Engineers. 2005. Maine programmatic general permit no. NAE-2005-584 (2005 Jul 5). Concord (MA): Army Corps of Engineers, New England District.

[USEPA] US Environmental Protection Agency. 2000. Environmental screening checklist and workbook for the water transportation industry. Washington (DC): US EPA Office of Water. EPA-305-B-00-004.

[USEPA] US Environmental Protection Agency. 2003. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 15]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2007. US EPA Superfund Program. [Internet]. [updated 2007 Dec 18; cited 2007 Dec 21]. Available from: http://www.epa.gov/superfund/index.htm.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

[USGAO] US General Accounting Office. 2001. Restoring fish passage through culverts on Forest Service and BLM lands in Oregon and Washington could take decades. Washington (DC): US GAO. GAO-02-136. 29 p.

[USGS] US Geological Survey. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams. [Internet]. Reston (VA): US Geological Survey. USGS Fact Sheet FS-027-02. [cited 2008 Jul 15]. 2 p. Available from: http://toxics.usgs.gov/pubs/FS-027-02/pdf/FS-027-02.pdf.

[VADMME] Virginia Department of Mines, Minerals, and Energy. 2007. Mineral Resources. [Internet]. Richmond (VA): VADMME. [cited 2007 Dec 28]. Fourteen articles available from: http://geology.state.va.us/DMR3/Mineralresources.shtml.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Wilson WJ, Gallaway BJ. 1997. Synthesis in applied fish ecology: twenty years of studies on effects of causeway development on fish populations in the Prudhoe Bay Region, Alaska. American Fisheries Society Symposium 19:326-39.

[WHOI] Woods Hole Oceanographic Institute. 2008. Northeast PSP, New England harmful algal bloom/red tide information. [Internet]. Woods Hole (MA): WHOI. [updated 2008 May 30; cited 2008 Sep 22]. Available from: http://www.whoi.edu/northeastpsp/.

Zwick P. 1992. Stream habitat fragmentation-a threat to biodiversity. Biodiversity and Conservation 1:80-97.

# CHAPTER FIVE: MARINE TRANSPORTATION

## Introduction

The demand for increased capacity of marine transportation vessels, facilities, and infrastructure is a global trend that is expected to continue in the future. This demand is fueled by a need to accommodate growing vessel operations for cargo handling activities and human population growth in coastal areas. As coastal areas continue to grow, there is a concomitant increase in the demand for water transportation services and recreational opportunities.

It is also important to note that coastal areas under high developmental pressure are often located adjacent to productive and sensitive aquatic environments. Historically, human settlements in the northeastern United States were probably established on the basis of availability to food resources and marine transportation. Coastal features such as estuaries and embayments satisfied these needs as they are highly productive ecosystems ideal for fishing, farming, or hunting and are sheltered waters that provide access to rivers and the ocean for transportation purposes. Today, urban growth and development in coastal areas are growing at a rate approximately five times that of other areas of the country and over one-half of all Americans live within 50 miles of the coast (Markham 2006). The continued demand on the coast today is likely attributed to the highly desirable aesthetic quality and recreational opportunities, including access to fishing, beaches, and boating.

The expansion of port facilities, vessel operations, and commercial and recreational marinas can have adverse impacts on fishery habitat. The growth of the marine transportation industry is accompanied by land-use changes, including over-water or in-water construction, filling of aquatic habitat and wetlands, and increased maintenance activities. Although some categories of habitat impacts resulting from activities related to port and marina construction and maintenance and vessel operations may be minimal and site specific, the cumulative effects of these activities over time can have substantial impacts on habitat.

The construction of new ports and marinas typically involves the removal of sediments by dredging from intertidal and subtidal habitats in order to create navigational channels, turning basins, anchorages, and berthing docks for the size and types of vessels expected to use the facilities. For existing ports and marinas, dredging is generally conducted on a routine basis in order to maintain the required depths as sediment is transported and deposited into the channels, basins, anchorages, and docks. The construction of new ports and marinas, or the expansion of existing facilities, is often referred to as “improvement” dredging; whereas, dredging existing ports and marinas in order to maintain an assigned or authorized depth is generally referred to as “maintenance” dredging. Because the chemical, physical, and biological impacts associated with both “improvement” and “maintenance” dredging are similar in nature, both types of dredging are discussed in the Navigation Dredging section of this chapter. Other impacts associated with newly constructed and expanded ports and marinas are covered under the Construction and Expansion of Ports and Marinas section of this chapter.

## Construction and Expansion of Ports and Marinas

Construction of ports and marinas can change physical and chemical habitat parameters such as tidal prism, depth, water temperature, salinity, wave energy, sediment transport, and current velocity. Alterations to physical characteristics of the coastal ecosystems can cause adverse effects to biological parameters, such as the composition, distribution, and abundance of shellfish and submerged aquatic vegetation (SAV). These changes can impact the distribution of nearshore habitats and affect aquatic food webs.

### Loss and conversion of habitat

Port and marina facilities are typically located in areas containing highly productive intertidal and subtidal habitats, including saltmarsh wetlands and SAV. Coastal wetlands provide a number of important ecological functions, including foraging, spawning/breeding, protection from predators, as well as nutrient uptake and release and retention of storm and floodwaters. Vegetated wetlands and intertidal habitats are some of the most highly productive ecosystems in the world, and support one or more life stages of important commercial and recreational fishery resources in the United States (Dahl 2006). One of the most obvious habitat impacts related to the construction of a port or marina facility is alteration or loss of physical space taken up by the structures required for such a facility. The construction of ports and marinas can alter or replace salt marsh, SAV, and intertidal mud flat habitat with "hardened" structures such as concrete bulkheads and jetties that provide relatively few ecological functions. Boston Harbor, MA, exemplifies a northeastern coastal port transformed by expansive dredging and filling of former shallow estuarine waters and salt marsh wetlands. Between 1775 and 1980, wetland filling within the harbor extensively altered the shoreline, with the airport alone amounting to 2,000 acres of filled intertidal salt marsh wetlands (Deegan and Bushbaum 2005).

Over-water structures, such as commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys are associated with port and marina facilities and are constructed over both subtidal and intertidal habitats. Although they generally have less direct physical contact with benthic habitats than in-water structures, float, raft, and barge groundings at low tides and the scouring of the substrate by the structures and anchor chains can be substantial. Piles and other in-water structures can alter the substrate below and adjacent to the structures by providing a surface for encrusting communities of mussels and other sessile organisms, which can create shell deposits and shift the biota normally associated with sand, gravel, mud, and eelgrass substrates to those communities associated with shell hash substrates (Penttila and Doty 1990; Nightingale and Simenstad 2001a).

Shoreline armoring is an in-water activity associated with the construction and operation of marinas and ports, intended to protect inland structures from storm and flood events and to prevent erosion that is often a result of increased boat traffic. Armoring of shorelines to prevent erosion and maintain or create shoreline development simplifies habitats, reduces the amount of intertidal habitat, and affects nearshore processes and the distribution of aquatic communities (Williams and Thom 2001). Hydraulic effect alterations to the shoreline include increased energy seaward of the armoring from reflected wave energy, which can exacerbate erosion by coarsening the substrate and altering sediment transport (Williams and Thom 2001). Installation of breakwaters and jetties can also result in community changes, including burial or removal of resident biota, changes in cover, preferred prey species, predator interaction, and the movement of larvae (Williams and Thom 2001). Chapman (2003) found a paucity of mobile species associated with seawalls in a tropical estuary, compared with surrounding areas.

### Altered light regimes and loss of submerged aquatic vegetation

Alteration of the light regimes in coastal waters can affect primary production, including the distribution and density of SAV, as well as the feeding and migratory behavior of fish. Over-water structures shade the surface of the water and attenuate the sunlight available to the benthic habitat under and adjacent to the structures. The height, width, construction materials used, and the orientation of the structure in relation to the sun can influence how large a shade footprint an over-water structure may produce and how much of an adverse impact that shading effect may have on the localized habitat (Fresh et al. 1995; Burdick and Short 1999; Shafer 1999; Fresh et al. 2001). High, narrow piers and docks produce more diffuse shadows which have been shown to reduce shading impacts to SAV (Burdick and Short 1999; Shafer 1999).

The density of pilings can also determine the amount of light attenuation created by dock structures. Piling density is often higher in larger, commercial shipping ports than in smaller recreational marinas, as larger vessels and structures often require a greater number of support structures such as fenders and dolphin piles. Light limitations caused by pilings can be reduced through adequate spacing of the pilings and the use of light reflecting materials (Thom and Shreffler 1996; Nightingale and Simenstad 2001a). In addition, piers constructed over solid structures, such as breakwaters or wooden cribs, would further limit light transmittance and increase shading impacts on SAV.

Although shading impacts are greatest directly under a structure, the impacts on SAV may extend to areas adjacent to the structure as shadows from changing light conditions and adjacent boats or docks create light limitations (Burdick and Short 1999; Smith and Mezich 1999). A decrease in SAV and primary productivity can impact the nearshore food web, alter the distribution of invertebrates and fish, and reduce the abundance of prey organisms and phytoplankton in the vicinity of the over-water structure (Kahler et al. 2000; Nightingale and Simenstad 2001a; Haas et al. 2002).

The sharp light contrasts created by over-water structures because of shading during the day and artificial lighting at night can alter the feeding, schooling, predator avoidance, and migratory behaviors of fish (Nightingale and Simenstad 2001a; Hanson et al. 2003). Fish, especially juveniles and larvae, rely on visual cues for these behaviors. Shadows create a light-dark interface which may increase predation by ambush predators and increase starvation through limited feeding ability (Able et al. 1999; Hanson et al. 2003). In addition, the migratory behavior of some species may favor deeper waters away from shaded areas during the day and lighted areas may affect migratory movements at night, contributing to increased risk of predation (Nightingale and Simenstad 2001a).

### *Altered temperature regimes*

Shoreline modifications, including the construction of seawalls and bulkheads, can alter nearshore temperature regimes and natural communities. Modified shorelines invariably contain less shoreline vegetation than do natural shorelines, which can reduce shading in the nearshore intertidal zone and cause increases in water temperatures (Williams and Thom 2001). Conversely, seawalls and bulkheads constructed along north facing shorelines may unnaturally reduce light levels and reduce water temperatures in the water column adjacent to the structures (Williams and Thom 2001).

### *Siltation, sedimentation, and turbidity*

The construction of a new port or marina facility is usually associated with profound changes in land use and in-water activities. Because a large proportion of the shoreline associated with a port is typically replaced with impervious surfaces such as concrete and asphalt, stormwater runoff is exacerbated and can increase the siltation and sedimentation loads in estuarine and marine habitats. The upland activities related to building roads and buildings may cause erosion of topsoil which can be transported through stormwater runoff to the nearshore aquatic environment, increasing sedimentation and burying benthic organisms. Construction and expansion of ports and marinas generally include dredging channels, anchorages, and berthing areas for larger and greater numbers of vessels, which contribute to localized sedimentation and turbidity. In addition, the use of underwater explosives to construct bulkheads, seawalls, and concrete docks may temporarily resuspend sediments and cause excessive turbidity in the water column and impact benthic organisms. Refer to the section on Navigation Dredging later in this chapter for information on channel dredging.

Impacts associated with increased suspended particles in the water column include high turbidity levels, reduced light transmittance, and sedimentation which may lead to reductions or loss of SAV and other benthic habitats. Elevated suspended particles have also been shown to adversely affect the respiration of fish, reduce filtering efficiencies and respiration of invertebrates, reduce egg buoyancy, disrupt ichthyoplankton development, reduce the growth and survival of filter feeders, and decrease the foraging efficiency of sight-feeders (Messieh et al. 1991; Barr 1993).

Structures such as jetties and groins may be constructed to reduce the accretion of sediment in navigable channels, so by design they alter littoral sediment transport and change sedimentation rates. These structures may reduce sand transport, cause beach and shoreline erosion to down drift areas, and may also interfere with the dispersal of larvae and eggs along the coastline (Williams and Thom 2001). Substrate disturbance from pile driving and removal can increase turbidity, interfere with fish respiration, and smother benthic organisms in adjacent areas (Mulvihill et al. 1980). In addition, contaminants in the disturbed sediments may be resuspended into the water column, exposing aquatic organisms to potentially harmful compounds (Wilbur and Pentony 1999; USEPA 2000; Nightingale and Simenstad 2001b). Refer to the Coastal Development chapter for a more detailed discussion on impacts related to pile driving and removal.

### *Contaminant releases*

The construction of ports and marinas can alter natural currents and tidal flushing and may exacerbate poor water quality conditions by decreasing water circulation. Bulkheads, jetties, docks, and pilings can create water traps that accumulate contaminants or nutrients washed in from land based sources, vessels, and facility structures. These conditions may create areas of low dissolved oxygen, dinoflagellate blooms, and elevated toxins.

Contaminants can be released directly into the water during construction activities associated with new ports and marinas or indirectly through storm water runoff from land-based operations. Accidental and incidental spills of petroleum products and other contaminants, such as paint, degreaser, detergents, and solvents, can occur during construction operations of a facility. Large amounts of impervious surfaces at ports and marinas can increase, and in some cases direct, stormwater runoff and contaminants into aquatic habitats. The use of certain types of underwater explosives to construct bulkheads, seawalls, and concrete docks may release toxic chemicals (e.g., ammonia) in the water column that can impact aquatic organisms.

Wood pilings and docks used in marina and port construction are often treated with chemicals such as chromated copper arsenate, ammoniacal copper zinc, and creosote to help extend the service of the structures in the marine environment. These preservatives can leach harmful chemicals into the water that have been shown to produce toxic affects on fish and other organisms (Weis et al. 1991). Creosote-treated wood for pilings and docks has also been used in marine environments and has been shown to release polycyclic aromatic hydrocarbons (PAH) continuously and for long periods of time after installation or treatment; whereas other chemicals that are applied to the wood, such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA), tend to leach into the environment for shorter durations (Poston 2001). Affects from exposure of aquatic organisms to PAH include carcinogenesis, phototoxicity, immunotoxicity, and disturbance of hormone regulation (Poston 2001). The rate and duration that these preservatives can be leached into marine waters after installation are highly variable and dependent on many factors, including the length of time since the treatment of the wood and the type of compounds used in the preservatives. The toxic effects of metals such as copper on fish are well known and include body lesions, damage to gill tissue, and interrupted cellular functions (Gould et al. 1994). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). The presence of CCA in the food chain may cause localized reductions in species richness and diversity (Weis and Weis 2002). Concrete, steel, or nontreated wood are relatively inert and generally do not leach contaminants into the water.

Dredging and filling of intertidal and subtidal habitats can resuspend sediments into the water column that may have been contaminated by nearby industrial activities. Information on contaminant releases from dredging can be found in the Navigation Dredging section of this chapter and the Chemical Effects: Water Discharge Facilities chapter of the report.

### *Altered tidal, current, and hydrologic regimes*

One of the primary functions of a marina or port is to shelter and protect boats from wave energy. In-water structures of ports and marinas such as bulkheads, breakwaters, jetties, and piles result in localized changes to tidal and current patterns. These alterations may exacerbate poor water quality conditions in these facilities by reducing water circulation. In addition, in-water structures interfere with longshore sediment transport processes resulting in altered substrate amalgamation, bathymetry, and geomorphology. Changing the type and distribution of sediment may alter key plant and animal assemblages, starve nearshore detrital-based foodwebs, and disrupt the natural processes that build spits and beaches (Nightingale and Simenstad 2001a; Hanson et al. 2003).

The protected, low energy nature of marinas and ports may alter fish behavior as juvenile fish show an affinity to structure and may congregate around breakwaters or bulkheads (Nightingale and Simenstad 2001a). These alterations in behavior may make them more susceptible to predation and may interfere with normal migratory movements.

### *Underwater blasting and noise*

Noise from underwater blasting and in-water construction generates intense underwater sound pressure waves that may adversely affect marine organisms. These pressure waves have been shown to injure and kill fish (Caltrans 2001; Longmuir and Lively 2001; Stotz and Colby 2001). Fish are known to use sound for prey and predator detection as well as social interaction (Richard 1968; Myrberg 1972; Myrberg and Riggio 1985; Hawkins 1986; Kalmijn 1988), and underwater blasting and noise may alter the their distribution and behavior (Feist et al.1996).

Generally, aquatic organisms that possess air cavities (i.e., lungs and swim bladders) are more susceptible to underwater blasts than those without (Keevin et al. 1999). In addition, smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and the eggs and embryos tend to be particularly sensitive; however, fish larvae tend to be less sensitive to blasts than eggs or post-larvae fish, probably because the larvae stages do not yet possess air bladders (Wright 1982; Keevin et al. 1999).

Blasting may be used for dredging new navigation channels and boat basins or expanding existing channels in areas containing rock substrates, boulders, and ledges. The construction of new in-water structures, such as bulkheads, seawalls, and concrete docks also may involve blasting. Blasting represents a single point of disturbance with a restricted, and often predictable, mortality zone. In addition, blasting engineers purposefully focus the blast energy towards fracturing rock substrate and prevent excess energy from being released into the water column (Keevin et al. 1999). Techniques used to prevent blasting damage to structures in the vicinity of a project, such as bubble curtains, may be effective mitigation measures for reducing blasting impacts on aquatic biota (Keevin et al. 1999). Although the use of bubble curtains have been shown to be effective at minimizing pressure wave impacts on fish (Keevin et al. 1997; Longmuir and Lively 2001), the difficulty of deploying bubble curtains in field conditions may reduce the efficacy of this technology in mitigating these effects (Keevin et al. 1997).

Unlike blasting, pile driving is a repeating sound disturbance that can last for extended periods of time during construction. There are several factors which affect the type and intensity of sound pressure waves during pile driving, including the size and material of the piling, the firmness of the substrate, and the type of pile-driving hammer that is used (Hanson et al. 2003). Wood and concrete piles produce lower sound pressures than do steel piles. Pile driving in firmer substrate, which requires more energy, will produce more intense sound pressures (Hanson et al. 2003). Both impact hammers and vibratory hammers are commonly used when driving pilings into the substrate. Vibratory hammers produce sounds with more energy in the lower frequencies (15-26 Hz), compared to higher frequency noise generated by impact hammers (100-800 Hz) (Carlson et al. 2001). The behavioral response elicited by fish differs in these two ranges of sound frequencies. Fish respond to sounds similar to vibratory hammers by consistently displaying an avoidance response and not habituating to the sound despite repeated exposure (Dolat 1997; Knudsen et al. 1997; Sand et al. 2000). In contrast to vibratory hammers, fish may be initially startled by an impact hammer but eventually become habituated and no longer respond to the stimuli. Acclimation to the sound may place fish in more danger as they remain in range of potentially harmful sound pressure waves (Dolat 1997). Refer to the chapter on Global Effects and Other Impacts for additional information on underwater noise impacts to aquatic organisms.

### *Conservation recommendations and best management practices for construction and expansion of ports and marinas*

1. Encourage federal, state, and local authorities to assist port authorities and marinas in developing management plans that avoid and minimize impacts to the coastal environment and that are consistent with coastal zone management plans.
2. Encourage implementation of environmental management systems for ports and marinas that incorporate strong operational controls and best management practices (BMPs) into existing job descriptions and work instruction.
3. Encourage marinas to participate in NOAA/US EPA's Coastal Nonpoint Program and the Clean Marina Initiative.
4. Explore alternative port developments such as satellite ports and offshore terminals, which may decrease some impacts associated with traditional inshore port facility developments.
5. Conduct site suitability analyses for new or proposed expansion of port and marina facilities to reduce and avoid habitat degradation or loss. Some of the analyses that should be conducted include identifying alterations to current and circulation patterns, water quality, bathymetric and topographic features, fisheries utilization and species distributions, and substrate features.
6. Conduct pre- and post-project biological surveys over multiple growing seasons to assess impacts on submerged and emergent aquatic vegetation communities.
7. Site new or expansions of port and marina facilities in deep-water areas to the maximum extent practicable to avoid the need for dredging. Areas that are subject to rapid shoaling or erosion will likely require more frequent maintenance dredging and should be avoided.

8. Avoid areas identified as supporting high abundance and diversity of species (e.g., SAV beds, intertidal mudflats, emergent wetlands, fish spawning areas) when locating new or expanded port and marina facilities.
9. Encourage the use of preproject surveys by qualified biologists/botanists to identify and map invasive plants within the proposed project area, and develop and implement an eradication plan for nonnative species.
10. Consider excavating uplands as a less-damaging alternative for new or expanded port and marina facilities instead of dredging intertidal or shallow subtidal habitat. However, water quality modeling should be conducted to evaluate potential impacts associated with enclosed and poorly flushed marinas.
11. Retain and preserve marine riparian buffers to maintain intertidal microclimate, flood and stormwater storage capacity, and nutrient cycle.
12. Consider low-wake vessel technology and appropriate vessel routes in the facility design and permitting process to minimize impacts to shorelines and shallow water habitats. Vessel speeds should be adapted to minimize wake damage to shorelines, and no-wake zones should be considered in highly sensitive areas, such as fish spawning habitat and SAV beds.
13. Do not locate new port and marina facilities in areas that have reduced tidal exchange and/or shallow water habitats, such as enclosed bays, salt ponds, and tidal creeks.
14. Implement construction designs for new ports and marinas to facilitate good tidal exchange and surface water movement and provide an adequate migratory corridor for fish. When possible, structures that impede tidal exchange and that may interfere with the movement of marine organisms, such as solid breakwaters, should be avoided.
15. Ensure that new ports and marinas incorporate BMPs in the construction operation plans that prevent and minimize the release of contaminants and debris caused by construction equipment and activities. The plan should include a spill response plan and training, and spill response equipment should be installed and maintained properly on-site.
16. Implement seasonal restrictions when necessary to avoid construction-related impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods).
17. For structures located over SAV, the amount of light reaching vegetation below the dock should be maximized by providing adequate height over the water, minimizing the width of the dock, and orienting the length of the dock in a north-south direction.
18. The use of wood preservatives, such as creosote, ACZA and CCA should be avoided, where possible. If CCA treated wood must be used, the wood can be presoaked for several weeks or the wood can be coated with plastic sheath to reduce/eliminate leaching. Concrete and steel pilings are generally considered to be less damaging, since they reflect light more than wood docks and generally do not release contaminants into the aquatic environment. However, concrete pilings and docks generally increase the overall size of the overwater structure and may not be preferable in areas containing SAV.
19. Site floating docks, which limit light transmittance more than elevated structures, only in nonvegetated areas. When used, floating docks should either be located in areas of adequate depth so that adequate clearance between the float and the bottom is maintained, or fitted with structures (i.e., float stops) that prevent the float from contacting the bottom. Float stops should be designed to provide a minimum of 2 feet of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
20. Orient night lighting such that illumination of the surrounding waters is avoided.

21. Reduce sound pressure impacts during pile installation by using wood or concrete piles, rather than hollow steel piles which produce intense, sharp spikes of sound that are more damaging to fish.
22. Use technologies that have been designed to reduce the adverse effects of underwater sound pressure waves such as air bubble curtains and metal or fabric sleeves to surround the pile. Air bubble systems must have adequate airflow, and the pile should be fully contained to ensure that sound attenuation is successful.
23. Conduct pile driving during low tides in intertidal and shallow subtidal areas.
24. Employ vibratory hammers when removing old piles to help minimize the release of suspended sediments, silt, and contaminants into the water column; these may be preferable over direct pull or the use of a clamshell dredge.
25. Reduce or eliminate the amount of sediment released into the water column by cutting the pile off below the mudline and leaving the stub in place when removing old piles.
26. Mitigate impacts to marine organisms, particularly those with air cavities (i.e., swim bladders and lungs), from underwater blasting by employing BMPs such as focusing the blast energy towards a solid rock substrate rather than towards the water column; installing noise attenuating devices such as air curtains; conducting the blasting during periods of low-water or low-tide; using delayed blasts that produce sequenced, lesser-charged explosions that reduce the shockwave; stemming (capping) the charge bore hole with material that contains the blast; and repelling charges that frighten fish from the blast area prior to blasting (Keevin 1998).
27. Consult federal and state resource agencies prior to work that involves blasting to assess the marine resource utilization of the area. Biological surveys may be required to assess the presence of fishery resources. Time-of-year restrictions should be employed to avoid impacting sensitive species and life history stages that use the area. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
28. Integrate measures to reduce nonpoint source (NPS) pollution, such as a stormwater management plan into the design, maintenance, and operation of a port or marina. Some examples of BMPs for stormwater management include (adapted from Amaral et al. 2005):
    a. Minimize the amount of impervious surfaces surrounding the port or marina facility and maintain a buffer zone between the coastal zone and upland facilities.
    b. Implement runoff control strategies to decrease the amount of contaminants entering marine waters from upland sources. This can be accomplished by using alternative surface materials such as crushed gravel, decreasing the slope of surfaces towards the waters' edge, and installing filtering systems or settling ponds.
    c. Designate specific enclosed areas for maintenance activities such as sanding, painting, engine repairs. Use tarp enclosures or spray booths for abrasive blasting to prevent residue from reaching surface waters.
    d. Provide and maintain appropriate storage, transfer, containment, and disposal facilities for liquid hazardous material, such as solvents, antifreeze, and paints.
29. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in port and marina review processes.

## Operation and Maintenance of Ports and Marinas

Existing ports and marinas can be a source of impacts to fishery resources and habitat that may differ from those relating to construction and expansion of new facilities. These impacts may be associated with the operation of the facilities, equipment impacts, and stormwater runoff. Examples of port or marina impacts include chronic pollution releases, underwater noise, altered light regimes, and repeated physical disturbances to benthic habitats.

### *Contaminant release and storm water runoff*

Ports and marinas can be a source of contaminants directly associated with facility activities and by stormwater runoff from the facility and the surrounding urbanized areas. The long-term operation of a marina or port can provide a chronic presence of contaminants to the localized area that can have an adverse effect on the quality of fishery habitat and population dynamics (Wilbur and Pentony 1999).

The oil and fuel that accumulates on dock surfaces, facilities properties, adjacent parking lots, and roadways may enter coastal waters through stormwater runoff and snowmelt. Oil and fuel contains PAH and other contaminants that are known to bioaccumulate in marine organisms and impact the marine food web (Nightingale and Simenstad 2001a; Amaral et al. 2005). In addition, these contaminants can persist in bottom sediments where they can be resuspended through a variety of activities such as propeller scouring and dredging. Marina activities such as vessel refueling, engine repair, and accidental vessel sinking may increase the risk of fuel and oil contamination of the surrounding environment (Amaral et al. 2005).

Marina facilities such as storage areas for paint, solvents, detergents, and other chemicals may pose a risk of introducing additional contaminants to the marine environment resulting in both acute and chronic toxicity to marine biota (Amaral et al. 2005). These products are often a routine and essential part of marina or port operations, and if handled and stored improperly they can increase the risk of accidental spillage. Various port and vessel maintenance activities may contribute to metal contamination to the surrounding waters. For example, elevated levels of copper are often associated with ports and marinas, especially those with a high density of recreational boats because of the type of antifouling paints used on those boats. A number of other metals have been detected in the sediments and surface waters of marinas, including arsenic (used in paints and wood preservatives), zinc (leached from anodes used to reduce corrosion of boat hulls and motors), mercury (used in float switches for bilge and other storage tank pumps), lead (used in batteries), nickel, and cadmium (used in brake linings) (USEPA 2001). However, stormwater runoff may be the primary source of copper in most marinas in urban areas (Warnken et al. 2004).

Wooden pilings and docks in marinas and ports are typically treated with some type of preservative, such as chromated copper arsenate, ammoniacal copper zinc, and creosote. These preservatives can leach harmful chemicals into the water that have been shown to have toxic effects on fish and other organisms (Weis et al. 1991). Concrete, steel, or nontreated wood are relatively inert and do not leach contaminants into the water. Refer to this chapter's section on Construction and Expansion of Ports and Marinas and the Coastal Development chapter for more information on the affects of copper and other wood preservatives on aquatic resources.

Because marinas and ports typically contain large areas of impervious surfaces and are located at the interface between land and water, stormwater runoff can be greater at these facilities compared with other types of land uses. The organic particulates that are washed into marine waters from the surrounding surfaces can add nutrients to the water and cause eutrophication in bays and estuaries. A number of sources of organic matter from ports and marinas can degrade water quality and reduce dissolved oxygen concentrations, including sewage discharges from recreational and commercial boats, trash tossed overboard, fish wastes disposed of into surface waters, pet wastes, fertilizers, and food wastes (USEPA 2001). Eutrophication often leads to abnormally high phytoplankton populations, which in turn can reduce the available light to SAV beds. Changes in water quality caused by eutrophication can sometimes have a more severe impact on seagrass populations than shading from over-water structures or physical uprooting by vessel and float groundings (Costa et al. 1992; Burdick and Short 1999).

### *Release of debris*

Solid waste is another problematic issue associated with port and marina operations. A great deal of solid waste is generated through daily operations of a commercial port as well as the recreational activities of a marina. This waste may include plastics such as fishing line, bottles, tarps, food containers, and shopping bags, or paper products and other materials, which can be released as debris into the surface waters through accidental loss from vessels or through stormwater runoff from upland facilities. Activities such as sanding, pressure washing, sand blasting, and discarding rags and oil/fuel filters can contribute to marine debris if improper handling and disposal is allowed (USEPA 2001). If this waste is collected and disposed of properly the impacts to the environment can be minimized (Amaral et al. 2005). Plastics are a large component of the trash released into marine waters, accounting for 50-60% of marine debris collected from the Gulf of Maine (Hoagland and Kite-Powell 1997). Plastics contain toxic substances that can persist in the environment and bioaccumulate through the food web, impairing metabolic functions in fish and invertebrates that use habitats polluted by plastic debris. Some chemicals found in plastics, known as “endocrine disruptors,” may interfere with the endocrine system of aquatic organisms (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as “environmental hormones” that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts.

Marine debris can directly affect fish and invertebrates that may consume or become entangled by the debris. Plastic debris may be ingested by seabirds, fish and invertebrates, sea turtles, and marine mammals, which can cause infections and death of the animal (Cottingham 1988). Debris can be transported by currents to other areas where it can become snagged and attached to benthic habitat, damaging sensitive reef habitat. Additional information on impacts associated with marine debris can be found under Operation and Maintenance of Vessels section of this chapter and in the Coastal Development chapter of this report.

### *Underwater noise*

The ambient noises emanating from ports and marinas are from a combination of boat propellers, engines, pumps, generators, and other equipment within vessels and shore-side equipment. In coastal areas the sounds of cargo and tanker traffic are multiplied by complex reflected paths from scattered and reverberated noises caused by littoral geography. Commercial and private fishing boats, pleasure craft, personal watercraft (i.e., jet skis), industrial vessels, public transport ferries, and shipping safety and security services such as tugs boats, pilot boats, enforcement vessels, and coastal agency support craft generate sounds that can impact marine organisms, particularly fish and marine mammals. Exposure to continuous noise may also create a shift in hearing thresholds for marine organisms resulting in hearing losses at certain frequency ranges (Jasny et al. 1999). Refer to the Global Effects and Other Impacts chapter and the Operation and Maintenance of Vessels and the Construction and Expansion of Ports and Marinas sections in this chapter for more information on underwater noise.

## *Derelict structures*

Increased vessel activity in and around port and marina operations increase the probability of the grounding of vessels, which may not always be removed immediately from the aquatic environment. In addition to being public health and navigational hazards, derelict or abandoned vessels can cause various impacts to coastal habitats. Grounded vessels can physically damage and smother benthic habitats, create changes in wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht et al. 2001; Zelo and Helton 2005). However, the most common environmental threat of a derelict or abandoned vessel is the release of oil or other pollutants. These hazardous materials may be part of a vessel's cargo, fuel and oil related to vessel operations, or chemicals contained within the vessel's structure which may be released over time through decay and corrosion. Refer to the Operation and Maintenance of Vessels section of this chapter for more information on impacts associated with derelict structures and grounded vessels.

## *Mooring and floating dock impacts*

Vessel mooring impacts, although localized, can reduce habitat quality and complexity. Accidental vessel groundings can smother or crush shellfish, scour vegetation, and disturb substrates (Nightingale and Simenstad 2001a). Disturbance of substrates can lead to increased turbidity, reduced light penetration, decreased dissolved oxygen levels, and the possible resuspension of contaminants. In addition, moored vessels contacting the bottom during low tides can cause the bottom habitat in the area of the mooring to be unavailable for fish and other marine biota during the time the vessel is resting on the bottom. Vessels that contact the bottom can create scouring of the substrate and result in permanent alteration or loss of benthic habitats, such as eelgrass. Demersal eggs (e.g., Atlantic herring [*Clupea harengus*]) and larvae that utilize an area can also be destroyed from the impact of the vessel or shading. Floating piers and docks may also alter wave energy, current patterns, and longshore sediment transport, especially in areas that experience strong current velocities (Nightingale and Simenstad 2001a).

Depending upon the type and configuration, the mooring tackle itself may cause impacts to substrate and benthos, including SAV. Typical vessel moorings consist of an anchor connected to a surface buoy by a long length of heavy chain. In most moorings, some portion of the anchor chain drags and often scours the bottom and forms a depression in the sediment surface (Walker et al. 1989). In areas influenced strongly by tides and currents or wind, the bottom scouring takes on a circular or "V" configuration when the anchor chain is allowed to drag along the bottom as the vessel or buoy swings with the tide or wind (Nightingale and Simenstad 2001a). The resulting scour holes allow further erosion and loss of the physical integrity of the habitat, which can lead to fragmentation of seagrass meadows (Walker et al. 1989; Hastings et al. 1995). Hastings et al. (1995) attributed an approximate 18% direct loss of seagrass habitat from boat moorings in one bay in Western Australia. Refer to the Coastal Development chapter of this report for a more detailed discussion on impacts from overwater structures.

## *Alteration of light regimes*

As discussed in other sections of this chapter, overwater structures shade the surface of the water and attenuate the light available to benthic habitat under and adjacent to the structures. The height, width, construction materials used, and orientation of the structure in relation to the sun can influence how large a shade footprint an over-water structure may produce and how much of an adverse impact that shading effect may have on the benthic habitat (Burdick and Short 1999; Shafer 1999; Fresh et al. 2001; Nightingale and Simenstad 2001a). Refer to the chapter on Coastal

Development and the Construction and Expansion of Ports and Marinas section of this chapter for more information on docks structures and light attenuation.

### *Conservation recommendations and best management practices for the operation and maintenance of ports and marinas (adapted from Amaral et al. 2005; Hanson et al. 2003)*

1. Consider environmental impacts through port development and operations plans, including:
   a. assess all activities at facility and identify potential environmental impacts
   b. determine compatibility with port environmental practices and assess available control technologies
   c. evaluate and monitor effectiveness of control technologies
   d. develop and implement environmental management
2. Encourage marinas to participate in NOAA/US EPA's Coastal Nonpoint Program and the Clean Marina Initiative.
3. Ensure that marina and port facility operations have an oil spill response plan in place, which has been shown to improve the response and recovery times of oil spills.
4. Ensure that marina or port facilities have adequate oil spill response equipment accessible and clearly marked. Oil spill response equipment may include oil booms, absorbent pads, and oil dispersant chemicals.
5. Use dispersants that remove oils from the environment, rather than those that simply move them from the surface to the ocean bottom.
6. Install automatic shut-off nozzles at fuel dispensing sites and require the use of fuel/air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel oil spilled into surface waters by vessels using fuel stations.
7. Promote the use of oil-absorbing materials in the bilge areas of all boats with inboard engines.
8. Place containment berms around fixed pieces of machinery that use oil and gas within the facility.
9. Encourage public education and signage to promote proper disposal of solid debris and polluting materials.
10. Encourage the proper disposal of materials produced and used by the operation, cleaning, maintenance, and repair of boats to limit the entry of solid and contaminated waste into surface waters.
11. Recommend the placement of garbage containers to supervised areas and use containers that have lids in order to reduce the potential for litter to enter the marine environment.
12. Promote the use of pumpout facilities and restrooms at marinas and ports to reduce the release of sewage into surface waters. Ensure that these facilities are maintained and operational, and provide these services at convenient times, locations, and reasonable cost. In addition, promote the use of these facilities through public education and signage.
13. Develop a harbor management plan which addresses the maintenance and operation of pumpout facilities.
14. Prevent the disposal of fish waste or other nutrient laden material in marina or port basins through the use of public education, signage, and by providing alternate fish waste management practices.
15. Ensure that measures to reduce NPS pollution, such as a stormwater management plan, are integrated into the maintenance and operation of a port or marina.

16. Recommend site-specific solutions to NPS pollution by considering the frequency of marina operations and potential pollution sources. Management practices should be tailored to the specific issues of each marina.
17. Encourage the removal of unnecessary impervious surfaces surrounding the port or marina facility and maintain a buffer zone between the aquatic zone and upland facilities.
18. Ensure that stormwater runoff from parking lots and other impervious surfaces is collected and treated to remove contaminants prior to delivery to any receiving waters. This can be accomplished by using alternative surface materials such as crushed gravel, decreasing the slope of surfaces towards the water's edge, and installing filtering systems or settling ponds.
19. Recommend that specific, enclosed areas are designated for maintenance activities such as sanding, painting, engine repairs. Using tarp enclosures or spray booths for abrasive blasting will also prevent residue from reaching surface waters.
20. Ensure that facilities provide for appropriate storage, transfer, containment, and disposal facilities for harmful liquid material, such as solvents, antifreeze, and paints.
21. Recommend that facilities provide a containment system and a filtering and treatment system for vessel wash down wastewater.
22. Ensure that floating structures, including barges, mooring buoys, and docks are located in adequate water depths to avoid propeller scour and grounding of vessel and floating structures. When floating docks cannot be located in adequate depth to avoid contact on the bottom at low tides, recommend that float stops (structural supports to prevent the float from resting on the bottom) are installed. Float stops should be designed to provide a minimum of 2 feet of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
23. Recommend anchoring techniques and mooring designs that avoid scouring from anchor chains. For example, anchors that do not require chains (e.g., helical anchors) or moorings that use subsurface floats to prevent anchor chains from dragging the bottom are some designs that should be considered.
24. When moorings with anchor chains cannot be avoided, recommend that areas prone to high current and wind velocity be avoided, where the sweep of the anchor chain on the bottom can cause the greatest damage.
25. Recommend the use of concrete, nontreated wood or steel dock materials to avoid the leaching of contaminants associated with wood preservatives.

## Operation and Maintenance of Vessels

Vessel activity in coastal waters is generally proportional to the degree of urbanization and port and harbor development within a particular area. Benthic, shoreline, and pelagic habitats may be disturbed or altered by vessel use, resulting in a cascade of cumulative impacts in heavy traffic areas (Barr 1993). The severity of boating-induced impacts on coastal habitats may depend on the geomorphology of the impacted area (e.g., water depth, width of channel or tidal creek), the current velocity, the sediment composition, the vegetation type and extent of vegetative cover, as well as the type, intensity, and timing of boat traffic (Yousef 1974; Karaki and vanHoften 1975; Barr 1993). Recreational boating activity mainly occurs during the warmer months which coincide with increased biological activity in east coast estuaries (Stolpe and Moore 1997; Wilbur and Pentony 1999). Similarly, frequently traveled routes such as those traveled by ferries and other transportation vessels can impact fish spawning, migration, and recruitment behaviors through noise and direct disturbance of the water column (Barr 1993).

Other common impacts of vessel activities include vessel wake generation, anchor chain and propeller scour, vessel groundings, the introduction of invasive or nonnative species, and the discharge of contaminants and debris (Hanson et al. 2003).

### *Impacts to benthic habitat*

Vessel operation and maintenance activities can have a wide range of impacts to benthic habitat, ranging from minor (e.g., shading of SAV) to potentially large-scale impacts (e.g., ship groundings and fuel or toxic cargo spills). Direct disturbances to bottom habitat can include propeller scouring and vessel wake impacts on SAV and other sensitive benthic habitats and direct contact by groundings or by resting on the bottom at low tides while moored. Propeller scarring can result in a loss of benthic habitat, decrease productivity, potentially fragment SAV beds, and lead to further erosion and degradation of the habitat (Uhrin and Holmquist 2003). Eriksson et al. (2004) found that boating activities can have direct and indirect impacts on SAV, including drag and tear on plant tissues resulting from increased wave-action, reduction in light availability caused by elevated turbidity and resuspension of bottom sediments, and altered habitat and substrate that causes plants to be uprooted and can inhibit recruitment. The disturbance of sediments and rooted vegetation decreases habitat suitability for fish and shellfish resources and can effect the spatial distribution and abundance of fauna (Nightingale and Simenstad 2001a; Uhrin and Holmquist 2003; Eriksson et al. 2004).

### *Resuspension of bottom sediments/turbidity*

The degree of sediment resuspension and turbidity that is produced in the water column from vessel activity is complex but is generally dependent upon the wave energy and surge produced by the vessel, as well as the size of the sediment particles, the water depth, and the number of vessels passing through an area (Karaki and vanHoften 1975; Barr 1993). These activities typically increase turbidity and sedimentation on SAV and other sensitive benthic habitats (Klein 1997; Barr 1993; Nightingale and Simenstad 2001a; Eriksson et al. 2004). Studies investigating sedimentation impacts on eelgrass have found that experimental burial of 25% of the plant height can result in greater than 50% mortality (Mills and Fonseca 2003). Klein (1997) reported that turbidity generated by boats operating in shallow waters can exceed safe levels by up to 34-fold.

The resuspension of sediments can affect habitat suitability for fish and shellfish resources and effect the spatial distribution and abundance of fauna (Nightingale and Simenstad 2001a; Uhrin and Holmquist 2003; Eriksson et al. 2004). The egg and larval stages of marine and estuarine fish are generally highly sensitive to suspended sediment exposures (Wilber and Clark 2001), and juvenile fish may be susceptible to gill injury when suspended sediment levels are high (Klein 1997). Sedimentation and turbidity impacts associated with boating may be more pronounced in areas that contain shallow water habitat where the bottom is composed of fine sediments (Klein 1997).

### *Shoreline erosion*

Wave energy caused by industrial and recreational shipping and transportation can have substantial impacts on aquatic shoreline and backwater areas which can eventually cause the loss and disturbance of shoreline habitats (Karaki and vanHoften 1975; Barr 1993; Klein 1997). Vessel wakes along frequently traveled routes can cause shoreline erosion, damage aquatic vegetation, disturb substrate, and increase turbidity. Wave energy and surge produced by vessels are dependent upon a number of factors, including the size and configuration of the vessel hull, the size of the vessel, and the speed of the vessel (Karaki and vanHoften 1975; Barr 1993). The degree of erosion on shorelines caused by vessels is complex, but it is generally dependent upon the wave energy and surge produced by the vessel and the slope of the shoreline, the type of sediment (e.g., clay, sand), and the type and amount of shoreline vegetation, as well as the characteristics of the water body (e.g., water depth and bottom topography) and distance between the vessel and shoreline (Karaki and vanHoften 1975; Barr 1993).

### *Contaminant spills and discharges*

A variety of substances can be discharged or accidentally spilled into the aquatic environment, such as gray water (i.e., sink, laundry effluent), raw sewage, engine cooling water, fuel and oil, vessel exhaust, sloughed bottom paint, boat washdown water, and other vessel maintenance and repair materials that may degrade water quality and contaminate bottom sediments (Cardwell et al. 1980; Cardwell and Koons 1981; Krone et al. 1989; Waite et al. 1991; Hall and Anderson 1999; Hanson et al. 2003).

Industrial shipping and recreational boating can be sources of metals such as arsenic, cadmium, copper, lead, and mercury (Wilbur and Pentony 1999). Metals are known to have toxic effects on marine organisms. For example, laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and impairment of vertical migration for larvae at copper concentrations greater than 300 µg/L (Blaxter 1977). Copper may also bioaccumulate in bacteria and phytoplankton (Milliken and Lee 1990). Metals may enter the water through various vessel maintenance activities such as bottom washing, paint scraping, and application of antifouling paints (Amaral et al. 2005). For example, elevated copper concentrations in the vicinity of shipyards have been associated with vessel maintenance operations such as painting and scraping of boat hulls (Milliken and Lee 1990). Studies have shown a positive relationship between the number of recreational boats in a marina and the copper concentrations in the sediments of that marina (Warnken et al. 2004). Copper and an organotin, called tributyltin (TBT), are common active ingredients in antifouling paints (Milliken and Lee 1990). The use of TBT is primarily used for large industrial vessels to improve the hydrodynamic properties of ship's hulls and fuel consumption, while recreational vessels typically use copper-based antifouling paints because of restrictions introduced in the Organotin Antifouling Paint Control Act of 1988 (33 U.S.C. 2401), which bans its use on vessels less than 25 m in length (Milliken and Lee 1990; Hofer 1998).

Herbicides are also used in some antifouling paints to inhibit the colonization of algae and the growth of seaweeds on boat hulls and intake pipes (Readman et al. 1993). Similar to copper, the highest concentrations of herbicides in nearshore waters are associated with recreational marinas, which may be because of a higher frequency of use of these types of antifouling paints for pleasure boats compared to commercial vessels (Readman et al. 1993). The leaching of these chemicals into the marine environment could affect community structure and phytoplankton abundance (Readman et al. 1993).

Fuel and oil spills can affect animals directly or indirectly through the food chain. Fuel, oil, and some hydraulic fluids contain PAH which can cause acute and chronic toxicity in marine organisms (Neff 1985). Toxic effects of exposure to PAH have been identified in adult finfish at concentrations of 5-50 ppm and the larvae of aquatic species at concentrations of 0.1-1.0 ppm (Milliken and Lee 1990). Small, but chronic oil spills are a potential problem because residual oil can build up in sediments and affect living marine resources. Even though individual releases are small, they are also frequent and when combined they contribute nearly 85% of the total input of oil into aquatic habitats from human activities (ASMFC 2004). Incidental fuel spills involving small vessels are probably common events, but these spills typically involve small amounts of material and may not necessarily adversely affect fishery resources. Larger spills may have significant acute adverse affects, but these events are relatively rare and usually involve small geographic areas.

Outboard engines, as opposed to inboard engines that are generally used for larger, commercial vessels, are unique in that their exhaust gases cool rapidly and leave some hydrocarbon components condensed and in the water column rather than being released into the atmosphere (Moore and Stolpe 1995). Outboard engine pollution, particularly from two-cycle engines, can contribute to the concentrations of hydrocarbons in the water column and sediment (Milliken and Lee 1990). Two-cycle outboard engines accomplish fuel intake and exhaust in the same cycle and tend to release unburned fuel along with the exhaust gases. In addition, two-cycle engines mix lubricant oil with the fuel, so this oil is released into the water along with the unburned fuel. There are over 100 hydrocarbon compounds in gasoline, including additives to improve the efficiency of the fuel combustion (Milliken and Lee 1990). Once discharged into the water, petroleum hydrocarbons may remain suspended in the water column, concentrate on the surface, or settle to the bottom (Milliken and Lee 1990).

Any type of fuel or oil spill has the potential to cause impacts to organisms and habitats in the water column, on the bottom, and on the shoreline, but it is unknown to what extent these effects are individually or cumulatively significant. Effects on fish from low-level chronic exposure may increase embryo mortality, reduce growth, or alter migratory patterns (Heintz et al. 2000; Wertheimer et al. 2000). For more details on the impacts of oil or fuel spills, see the chapter on Energy-related Activities.

Gray water and sewage discharge from boats may impact water quality by increasing nutrient loading and biological oxygen demand of the local area and through the release of disease causing organisms and toxic substances (Thom and Shreffler 1996; Klein 1997). Positive correlations between boating activity levels and elevated levels of fecal coliform bacteria in nearshore coastal waters have been reported (Milliken and Lee 1990). Although the Clean Water Act (CWA) of 1972 makes it illegal to discharge untreated wastes into coastal waters and the Federal Water Pollution Control Act requires recreational boats be equipped with marine sanitation devices (MSDs), it is legal to discharge treated wastes, and illegal discharges of untreated waste may be common (Milliken and Lee 1990; Amaral et al. 2005). Despite these laws, many vessels may not be equipped with MSDs and on-shore pumpout stations are not common (Amaral et al. 2005). Impacts from vessel waste discharges may be more pronounced in small, poorly flushed waterways where pollutant concentrations can reach unusually high levels (Klein 1997).

### *Underwater noise*

The noise generated by vessel operations is usually concentrated in ports, marinas, and heavily used shipping lanes or routes and may impact fish spawning, migration, and recruitment behaviors (Hildebrand 2004). Exposure to continuous noise may also create a shift in hearing thresholds for marine organisms resulting in hearing losses at certain frequency ranges (Jasny et al. 1999). Reducing vessel noise is a difficult task because of the economic incentives that encourage the expansion of commercial shipping and the lack of alternatives for efficient global transport of large and high tonnage material (Hildebrand 2004).

Small craft with high-speed engines and propellers (e.g., recreational boats with outboard engines) typically produce higher frequency noise than do larger vessels that generate substantial low-frequency noise because of their size and large, slow-speed engines and propellers (Kipple and

Gabriele 2004). A noise study of three size-classes of vessels (i.e., small, 17-30 feet; medium, 50-100 feet; and large, >100 feet) in Glacier Bay, AK, found that, on average, overall sound levels were higher for the larger vessel categories (Kipple and Gabriele 2004). However, vessel sound levels in this study were generally measured at vessel speeds less than 10 knots, and the investigators found increasing sound levels with greater vessel speed (Kipple and Gabriele 2004). Scholik and Yan (2002) reported significant elevation of the auditory threshold of the fathead minnow (*Pimephales promelas*), after exposure to noise from an idling 55 horsepower outboard motor. Furthermore, the frequencies of the noise from the outboard engine corresponded to the frequencies of the fish's auditory threshold shifts, specifically in this species' most sensitive hearing range (1.0-2.0 kHz).

Commercial shipping vessels are a major source of low frequency (5-500 Hz) noise in the marine environment and may be one of the most pervasive sources of anthropogenic ocean noise (Jasny et al. 1999; Stocker 2002; Hildebrand 2004). Low frequencies travel long distances in the marine environment, which is probably why these frequencies are also used by marine mammals for communication (Jasny et al. 1999). Ship noise is generated from the use of engines and other on-board mechanical devices such as pumps, cooling systems, and generators, as well as movement of water across the hull and propellers (Stocker 2002; Hildebrand 2004). These sounds are amplified and transferred to the water through the ship's hull (Stocker 2002). The size and frequency of use for commercial vessels traversing the ocean and nearshore waters may explain why they are considered a major source of noise impacts compared to the more numerous fishing and pleasure craft found in coastal waters (Hildebrand 2004).

There are several factors which influence sound attenuation in shallow coastal waters including temperature variations or thermoclines, bottom geography, and sediment composition. Vessel noise may reverberate or scatter off geological features and anthropogenic structures in the water (Stocker 2002).

Sonar is another source of anthropogenic noise attributed to vessel operation. It is used for various purposes such as depth sounding and fish finding and can vary in range depending on the use (15-200 kHz for commercial navigation, 1-20 kHz for other positioning and navigation, and 100-3,000 Hz for long range sonar) (Stocker 2002). Refer to the Global Effects and Other Impacts chapter of this report for more information on ocean noise.

### *Release of debris*

As discussed in the Operation and Maintenance of Ports and Marinas section of this chapter, the release of solid waste in coastal waters is a considerable concern. Billions of pounds of debris are dumped into the oceans each year (Milliken and Lee 1990), and vessel traffic is a significant source of this waste because of accidental loss, routine practices of dumping waste, and illegal dumping activities (Cottingham 1988). Entanglement in or ingestion of this debris can cause fish, marine mammals, and sea birds to become impaired or incapacitated, leading to starvation, drowning, increased vulnerability to predators, and physical wounds (Milliken and Lee 1990). Marine debris can also cause direct physical damage to habitat features through smothering or physical disturbance.

Plastics are an especially persistent form of solid waste. Plastics tend to concentrate along coastal areas because they float on the surface and can be transported by ocean currents (Milliken and Lee 1990). Commercial fishing, merchant vessel, cruise ship, and recreational boats are major contributors to marine plastic debris (Cottingham 1988; Milliken and Lee 1990). Cottingham (1988) estimated that merchant vessels are the primary source of plastic refuse in New England. Refer to the Operation and Maintenance of Ports and Marinas section in this chapter for information on plastic debris and the Coastal Development chapter of this report for more information on general marine debris.

### *Abandoned and derelict vessels*

Derelict or abandoned vessels can cause a variety of impacts to habitats and are public health and navigational hazards. Grounded vessels may physically damage and smother benthic habitats, create changes in wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht et al. 2001; Zelo and Helton 2005). The potential impact footprint of a grounded vessel can be much larger than the vessel itself as vessels move or break up during storm events, which can scour bottom habitat, amplify impacts, and complicate removal (Zelo and Helton 2005). The physical impacts of a grounded vessel can be greater in shallow water since the wreck is more likely to be unstable and move, may break up more rapidly because of wave and current forces, and is more likely to need urgent removal because of navigation concerns which may lead to additional resource impacts (Michel and Helton 2003). Refer to the Offshore Dredging and Disposal Activities chapter of this report for information regarding intentional sinking of vessels for disposal and creation of artificial reefs.

The most common environmental threat of a derelict or abandoned vessel is the release of oil or other pollutants. These hazardous materials may be part of a vessel's cargo, fuel and oil related to vessel operations, or chemicals contained within the vessel's structure which may be released through decay and corrosion over time. Rusting vessel debris can also cause iron enrichment in enclosed areas, which has been associated with harmful algal blooms (Helton and Zelo 2003; Michel and Helton 2003).

The historical focus of laws regarding derelict or abandoned vessels was the protection of the property rights of shipowners and the recovery of cargo (Michel and Helton 2003). Existing federal laws and regulations do not provide clear authority or funding to any single agency for the removal of grounded or abandoned vessels that harm natural resources but which are not otherwise obstructing or threatening to obstruct navigation or threatening a pollution discharge (Helton and Zelo 2003). In many cases vessels are abandoned and are left to continually damage the marine environment because a responsible party cannot be identified or a funding source for removal cannot be secured (Zelo and Helton 2005). Physical impacts, in particular, can persist for decades when vessels are left in the marine environment, and in some cases simply removing a vessel is enough to allow natural recolonization of benthic organisms (Zelo and Helton 2005).

Removal of a derelict vessel will ensure that the vessel does not become a navigation hazard to other ships and that hazardous materials are not released during storms which can damage the wreckage further. It also ensures that abandoned vessels do not become illegal dumpsites for oil, industrial waste, and other hazardous materials, including munitions (Helton and Zelo 2003). Salvage and wreck removal activities can result in unintended habitat impacts. For example, fuel spillage may occur during salvage operations of a wrecked vessel. The potential for collateral impacts should be considered when planning a salvage operation (Michel and Helton 2003). Wrecks in shallow water are often removed and scuttled in deep water to prevent further damage to more vulnerable, nearshore benthic habitats and to avoid the risks involved in bringing an unstable vessel into port (Michel and Helton 2003).

Although many of the habitat impacts described above can be averted if derelict vessels are removed while still afloat, abandoned and neglected floating vessels can also create habitat impacts (Zelo and Helton 2005). These vessels may shade seagrass beds, scour subtrates with anchor chains, or release pollutants from decaying hull materials and paints (Sunda 1994; Negri et al. 2002; Smith et al. 2003; Zelo and Helton 2005).

## *Nonnative and invasive species*

Nonnative species, some of which are invasive, have been introduced to coastal areas through industrial shipping and recreational boating (Omori et al. 1994; Wilbur and Pentony 1999; Hanson et al. 2003; Pertola et al. 2006). These introductions can be in the form of fouling organisms on the bottom of vessels as they are transported between water bodies or through the release of ballast water from large commercial vessels. Modern ships can carry 10 to 200 thousand tons of ballast water at a time and transport marine organisms across long distances and in relatively short time periods (Hofer 1998). This expeditious travel increases the risk that the organisms taken up in ballast water will be viable when introduced into a distant port or marina during deballasting (Wilbur and Pentony 1999). Pertola et al. (2006), in an investigation of dinoflagellates and other phytoplankton from the ballast tank sediments of ships at ports in the northeastern Baltic Sea, found a large assemblage of germinated dinoflagellate cysts in 90% of all ships and at all ports sampled. Ship traffic can transport, in large numbers, nonnative and invasive species of phytoplankton that can be harmful to native aquatic species (Pertola et al. 2006). The nonnative green algae (*Codium fragile*), is an example of a species that has invaded the northeastern US coast, the eastern Atlantic Ocean, Mediterranean Sea, and New Zealand and has displaced native species of *Codium* (Walker and Kendrick 1998; Tyrrell 2005). Shipping has been implicated as the major agent of spread of this species (Walker and Kendrick 1998), as well as of the zebra mussel (*Dreissena polymorpha*) (Strayer et al. 2004). This invasive species has been shown to have had an adverse effect on the populations of some native species of fish (e.g., *Alosa* spp.), as well as phytoplankton, zooplankton, aquatic vegetation, water chemistry, and zoobenthos (Strayer et al. 2004).

Introduced species can adversely impact habitat qualities and functions by altering the community structure, competing with native species, and introducing exotic diseases (Omori et al. 1994; Wilbur and Pentony 1999; Carlton 2001). Additional discussion of the effects of introduced species can be found in the chapters on Introduced/Nuisance Species and Aquaculture and Physical Effect: Water Intake and Discharge Facilities.

## *Conservation recommendations and best management practices for vessel operation and maintenance*

1. Encourage marinas to participate in NOAA/US EPA's Coastal Nonpoint Program and the Clean Marina Initiative.
2. Ensure that commercial ships and port facilities have oil-spill response plans in place which improve response and recovery in the case of accidental spillage.
3. Ensure that commercial ships and or port facilities have adequate oil-spill response equipment accessible and clearly marked.
4. Use dispersants that remove oils from the environment rather than dispersants that simply move them from the surface to the ocean bottom.
5. Promote the use of oil-absorbing materials in the bilge areas of all boats with inboard engines.
6. Promote the use of fuel/air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel and oil spilled into surface waters during fueling of boats.
7. Encourage recreational boats to be equipped with marine sanitation devices (MSDs) to prevent untreated sewage to be pumped overboard.
8. Encourage ship designs that include technologies capable of reducing noise generated and transmitted to the water column, such as the use of muffling devices already required for land-based machinery that may help reduce the impacts of vessel noise.

9. The effects of proposed and existing vessel traffic and associated underwater noise should be assessed for potential impacts to sensitive areas such as migration routes and spawning areas for marine animals.
10. Exclude vessels or limit specific vessel activities such as high intensity, low-frequency sonar, to known sensitive marine areas if evidence indicates that these activities have a substantial adverse effect to marine organisms.
11. Promote education and signage on all vessels to encourage proper disposal of solid debris at sea.
12. Encourage the use of innovative cargo securing and stowing designs that may reduce solid debris in the marine environment from the transportation of commercial cargo.
13. Use appropriate equipment and techniques to salvage and remove grounded vessels and follow all necessary state and federal laws and regulations. If possible, avoid using the propulsion systems of salvage tugs that can cause propeller wash and scour the bottom. Instead, moor the tugs and use a ground tackle system to provide maneuvering and pull.
14. Minimize additional seafloor damage when a derelict vessel has to be dragged across the seafloor to deep water by following the same ingress path. Alternatively, identify the least sensitive, operationally feasible towpath. Dismantling derelict vessels in place when stranded close to shore may cause less environmental impact than dredging or dragging a vessel across an extensive shallow habitat.
15. Reduce the risk of a sudden release of the entire cargo when a submerged derelict vessel contains hazardous aqueous solutions that pose limited environmental risks, such as mild acids and bases, by allowing the release of the cargo under controlled conditions. The controlled release plan can include water-quality monitoring to validate the calculated dilution rates and plume distance assumptions. All applicable state and federal laws and regulations regarding the release of chemicals into the water should be followed.
16. Develop a contingency plan for uncontrolled releases during vessel salvage operations. The salvage plan should include a risk assessment to determine the most likely release scenarios and use the best practices of the industry.
17. Schedule nonemergency salvage operations while including environmental considerations to minimize potential impacts on natural resources. Environmental considerations include periods when few sensitive species are present, avoidance of critical reproductive periods, and weather patterns that influence the trajectory of potential releases during operations
18. Choose a scuttling site for a derelict vessel in a deep-water location in federal or Exclusive Economic Zone (EEZ) waters that does not contain any sensitive resources or geological hazards. Ensure that all proposed disposal of vessels in the open ocean adheres to state and federal guidance and regulations, including section 102(a) of the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act), and under 40 CFR § 229.3 of the US EPA regulations. Refer to the Offshore Dredging and Disposal Activities chapter for additional recommendations and BMPs for the disposal of vessels.

# Navigation Dredging

## *Introduction*

Channel dredging is a ubiquitous and chronic maintenance activity associated with port and harbor operation and vessel activity (Barr 1987; NEFMC 1998). Navigational dredging occurs in rivers, estuaries, bays, and other areas where ports, harbors, and marinas are located (Messieh and El-Sabh 1988). The locations of these facilities often coincide with sensitive aquatic habitats that are vital for supporting fishery production (Newell et al. 1998).

For the purposes of navigation, dredging can be generally classified as either creating new or expanded waterways with greater profiles, depths, and scope or as maintenance of existing waterways for the purpose of maintaining established profiles, depths, and scope. Although the latter category represents the most common dredging scenario, new construction, or "improvement" dredging as it is sometimes called, has become increasingly common at larger ports and harbors throughout the United States. Several corresponding factors have likely led to greater need for navigational "improvements" and increases in the operating depths and the sizes of existing ports and harbors, including: (1) increased demand for marine cargo and transportation; (2) expansion of commercial fleets; (3) increased demand for larger capacity commercial and recreational vessels; and (4) increased urbanization and infrastructure development along the coast (Messieh et al. 1991; Wilbur and Pentony 1999; Nightingale and Simenstad 2001b). In particular, this demand for larger capacity commercial cargo vessels has led to an increased competition among the major coastal ports to provide facilities to accommodate these vessels. Improvement dredging may occur in areas that have not previously been subjected to heavy vessel traffic and dredging activities, such as new commercial marinas or the creation of a new channel or turning basin in an existing port or marina facility. Because improvement dredging is often conducted in areas that have been less affected by previous dredging and vessel activities, the impacts are generally more severe than the impacts associated with regular maintenance dredging activities unless the sediments involved in the maintenance dredging contain high levels of contaminants (Allen and Hardy 1980).

Maintenance dredging is generally required in most navigation channels and port and marina facilities because of the continuous deposition of sediments from freshwater runoff or littoral drift. Navigation channels require maintenance dredging to remove accumulated sediments, typically conducted on a temporal scale of one to ten years (Nightingale and Simenstad 2001b). Alterations in sedimentation patterns of estuaries resulting from increased coastal development and urbanization often increases the sediment influx and the frequency for maintaining existing channels and ports. Dredging for other purposes, such as aggregate mining for sand and gravel, conveyance of flood flows, material for beach nourishment, and removal of contaminated sediments or construction of subtidal confined disposal of contaminated sediments, may be done separately or in conjunction with navigation dredging (Nightingale and Simenstad 2001b). Refer to the Offshore Dredging and Disposal Activities chapter of this report for more information on offshore aggregate mining and to the Coastal Development chapter of this report contains information on the affects of beach nourishment and other coastal development activities.

There is a variety of methods and equipment used in navigation dredging, and a detailed explanation and assessment is beyond the scope of this report. However, one can categorize dredging activities as either using hydraulic or mechanical equipment. The type of equipment used for navigation dredging primarily depends on the nature of the sediments to be removed and the type of disposal required. Some of the factors that determine the equipment type used are the characteristics of the material to be dredged, the quantities of material to be dredged, the dredging depth, the distance to the disposal area, the physical environmental factors of the dredging and disposal area, the contamination level of sediments, the methods of disposal, the production (i.e., rate of material removed) required, and the availability of the dredge equipment (Nightingale and Simenstad 2001b).

Hydraulic dredging involves the use of water mixed with sediments that forms a slurry, which is pumped through a pipeline onto a barge or a hopper bin for off-site disposal. To increase the productivity of the dredging operation (i.e., maximizing the amount of solid material transported to the disposal site), some of the water in the sediment slurry may be allowed to overflow out of the hopper which can increase the turbidity in the surrounding water column. If the disposal site is relatively close to the dredge site, the slurry may be pumped through a pipeline directly to the disposal site (e.g., beach disposal).

Mechanical dredging typically involves the use of a clamshell dredge, which consists of a bucket of hinged steel that is suspended from a crane. The bucket, with its jaws open, is lowered to the bottom and as it is hoisted up, the jaws close and carry the sediments to the surface. The sediments are then placed in a separate barge for transport to a disposal site. Bucket dredges tend to increase the suspended sediment concentrations compared to hydraulic dredges because of the resuspension created as sediment spills through the tops and sides of the bucket when the bucket contacts the bottom, during withdrawal of the bucket through the water column, and when it breaks the water's surface (Nightingale and Simenstad 2001b). Closed or "environmental" buckets are designed to reduce the sediment spill from the bucket by incorporating modifications such as rubber seals or overlapping plates and are often used in projects involving contaminated sediments.

The location and method of disposal for dredged material depends on the suitability of the material determined through chemical, and often, biological analyses conducted prior to the dredging project. Generally, sediments determined to be unacceptable for open water disposal are placed in confined disposal facilities or contained aquatic disposal sites and capped with uncontaminated sediments. Sediments that are determined to be uncontaminated may be placed in open-water disposal sites or used for beneficial uses. Beneficial uses are intended to provide environmental or other benefits to the human environment, such as shoreline stabilization and erosion control, habitat restoration/enhancement, beach nourishment, capping contaminated sediments, parks and recreation, agriculture, strip mining reclamation and landfill cover, and construction and industrial uses (Nightingale and Simenstad 2001b). Open water disposal sites can be either predominantly nondispersive (i.e., material is intended to remain at the disposal site) or dispersive (i.e., material is intended to be transported from the disposal site by currents and/or wave action (Nightingale and Simenstad 2001b). The potential for environmental impacts is dependent upon the type of disposal operation used, the physical characteristics of the material, and the hydrodynamics of the disposal site. Refer to the chapter on Offshore Dredging and Disposal Activities for more detailed information on dredge material disposal.

Dredging to deepen or maintain ports, marinas, and navigational channels involves a number of environmental effects to fishery habitats, including the direct removal or burial of demersal and benthic organisms and aquatic vegetation, alteration of physical habitat features, the disturbance of bottom sediments (resulting in increased turbidity), contaminant releases in the water column, light attenuation, releases of oxygen consuming substances and nutrients, entrainment of living organisms in dredge equipment, noise disturbances, and the alteration of hydrologic and temperature regimes. Dredging is often accompanied by a significant decrease in the abundance, diversity, and biomass of benthic organisms in the affected area and an overall reduction in the aquatic productivity of the area (Allen and Hardy 1980; Newell et al. 1998). The rate of recovery of the benthic community is dependent upon an array of environmental variables which reflect interactions between sediment particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long time periods (Newell et al. 1998).

### *Loss or conversion of benthic habitat and substrate*

Alterations in bathymetry, benthic habitat features, and substrate types caused by navigational dredging activities may have long-term effects on the functions of estuarine and other aquatic environments. The effects of an individual project are proportional to the scale and time required for a project to be completed, with small-scale and short-term dredging activities having less impact on benthic communities than long-term and large-scale dredging projects (Nightingale and Simenstad 2001b). Dredging can have cumulative effects on benthic communities, depending upon the dredging interval, the scale of the dredging activities, and the ability of the environment to recover from the impacts. The new exposed substrate in a dredged area may be composed of material containing more fine sediments than before the dredging, which can reduce the recolonization and productivity of the benthos and the species that prey upon them.

The impacts to benthic communities vary greatly with the type of sediment, the degree of disturbance to the substrate, the intrinsic rate of reproduction of the species, and the potential for recruitment of adults, juveniles, eggs, and larvae (Newell et al. 1998). Following a dredging event, sediments may be nearly devoid of benthic infauna, and those that are the first to recolonize are typically opportunistic species which may have less nutritional value for consumers (Allen and Hardy 1980; Newell et al. 1998).

In general, dredging can be expected to result in a 30-70% decrease in the benthic species diversity and 40-95% reduction in number of individuals and biomass (Newell et al. 1998). Recovery of the benthic community is generally defined as the establishment of a successional community which progresses towards a community that is similar in species composition, population density, and biomass to that previously present or at nonimpacted reference sites (Newell et al. 1998). The factors which influence the recolonization of disturbed substrates by benthic infauna are complex, but the suitability of the postdredging sediments for benthic organisms and the availability of adjacent, undisturbed communities which can provide a recruitment source are important (Barr 1987; ICES 1992). Rates of benthic infauna recovery for disturbed habitats may also depend upon the type of habitat being affected and the frequency of natural and anthropogenic disturbances. Benthic infauna recovery rates may be less than one year for some fine-grained mud and clay deposits, where a frequent disturbance regime is common, while gravel and sand substrates, which typically experience more stability, may take many years to recover (Newell et al. 1998). Post-dredging recovery in cold waters at high latitudes may require additional time because these benthic communities can be comprised of large, slow-growing species (Newell et al. 1998).

### *Loss of submerged aquatic vegetation*

Submerged aquatic vegetation provides food and shelter for many commercially and recreationally important species, attenuates wave and current energy, and plays an important role in the chemical and physical cycles of coastal habitats (Thayer et al. 1997). The loss of vegetated shallows results in a reduction in important rearing and refugia functions utilized by migrating and resident species. Seagrass beds are more difficult to delineate and map than some other subtidal habitats because of their spatial and temporal dynamic nature, making these habitats more vulnerable to being inadvertently dredged (Thayer et al. 1997; Deegan and Buchsbaum 2005). Dredging causes both direct and indirect impacts to SAV. The physical removal of plants through dredging is a direct impact, while the reduction in light penetration and burial or smothering that is a result of the turbidity plumes and sedimentation created by the dredge are indirect impacts (Deegan and Buchsbaum 2005). While SAV may regrow in a dredged area if the exposure to excessive suspended sediments is not protracted and most of the accumulated sediments are removed by currents and tides after dredging ceases (Wilber et al. 2005), the recolonization by SAV may be limited if the bottom sediments are destabilized or the composition of the bottom sediments is altered (Thayer et al. 1997). Even when bottom sediments are stabilized and are conducive to SAV growth, channel deepening may result in the area having inadequate light regimes necessary for the recolonization of SAV (Barr 1987).

Dredge and fill operations require a permit review process which is regulated by state and federal agencies. Advancement in understanding the physical impacts of dredging on SAV and recognition of the ecological significance of these habitats has allowed special consideration for SAV beds during the permit review process. Most reviewing agencies discourage dredging activities in or near SAV beds as well as in areas that have been historically known to have SAV and areas that are potential habitats for SAV recruitment (Orth et al. 2002).

While the physical disturbance to SAV beds from dredge activities may have significant localized effects, water quality problems such as eutrophication, pollution and sedimentation have resulted in large-scale declines to SAV in some areas of the northeastern US coast (Goldsborough 1997; Deegan and Buchsbaum 2005; Wilber et al. 2005). The small, localized disturbance of SAV associated with dredging may be viewed as a significant impact in the context of diminished regional health and distribution resulting from stressors such as poor water quality and cumulative effects such as dredging, boating (propeller scour), and shoreline alteration (Goldsborough 1997; Thayer et al. 1997; Deegan and Buchsbaum 2005). The environmental effects of excess nutrients and sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

### *Loss of intertidal habitat and wetlands*

Intertidal habitats (e.g., mud and sand flats) and wetlands (e.g., salt marsh) are valuable coastal habitats which support high densities and diversities of biota by supporting biological functions such as breeding, juvenile growth, feeding, predator avoidance, and migration (Nightingale and Simenstad 2001b). These valuable habitats are also some of the most vulnerable to alterations through coastal development, urbanization, and the expansion of ports and marinas.

The loss of intertidal habitat and the deepening of subtidal habitat during dredging for marina development and for navigation can alter or eliminate the plant and animal assemblages associated with these habitats, including SAV and shellfish beds (Nightingale and Simenstad 2001b; MacKenzie 2007). Dredging in intertidal habitats can alter the tidal flow, currents, and tidal mixing regimes of the dredged area as well as other aquatic habitats in the vicinity, leading to changes in the environmental parameters necessary for successful nursery habitats (Barr 1987). Dredging in tidal wetlands can also encourage the spread of nonnative invasive organisms by removing or disturbing the native biota and altering the physical and chemical properties of the habitat (Hanson et al. 2003; Tyrrell 2005).

Navigational dredging converts shallow subtidal or intertidal habitats into deeper water environments through the removal of sediments (Nightingale and Simenstad 2001b, Deegan and Buchsbaum 2005). The historical use of dredged materials was to infill wetland, salt marshes, and tidal flats in order to create more usable land. The Boston Harbor, MA, area is a prime example of this historical trend, where thousands of acres of salt marsh and intertidal wetlands have been filled over time (Deegan and Buchsbaum 2005). Filling wetlands eliminates the biological, chemical, and physical functions of intertidal habitat such as flood control, nutrient filter or sink, and nursery habitat. Although direct dredging and filling within intertidal wetlands are relatively rare in recent times, the lost functions and values of intertidal wetlands and the connectivity between upland and subtidal habitat is difficult and costly to create and restore (Nightingale and Simenstad 2001b).

### *Underwater noise*

Fish can detect and respond to sounds for many life history requirements, including locating prey and avoiding predation, spawning, and various social interactions (Myrberg 1972; Myrberg and Riggio 1985; Kalmijn 1988). The noise generated by pumps, cranes, and by the mechanical action of the dredge itself has the ability to alter the natural behavior of fish and other aquatic organisms. Feist et al. (1996) reported that pile-driving operations had an affect on the distribution and behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*). Fish may leave an area for more suitable spawning grounds or may avoid a natural migration path because of noise disturbances.

The noise levels and frequencies produced from dredging depend on the type of dredging equipment being used, the depth and thermal variations in the surrounding water, and the topography and composition of the surrounding sea floor (Nightingale and Simenstad 2001b; Stocker 2002). However, dredging activities from both mechanical and hydraulic dredges produce underwater sounds that are strongest at low frequencies and because of rapid attenuation of low frequencies in shallow water, dredge noise normally is undetectable underwater at ranges beyond 20-25 km (Richardson et al. 1995). Although the noise levels from large ships may exceed those from dredging, single ships usually do not produce strong noise in one area for a prolonged period of time (Richardson et al. 1995). The noise created during dredging can produce continuous noise impacts for extended periods of time (Nightingale and Simenstad 2001b).

### *Siltation, sedimentation, and turbidity*

Dredging degrades habitat quality through the resuspension of sediments which creates turbid conditions and can release contaminants into the water column, in addition to impacting benthic organisms and habitat through sedimentation. Turbidity plumes ranging in the hundreds to thousands mg/L are created and can be transported with tidal currents to sensitive resource areas. Alterations in bottom sediments, bottom topography, and altered circulation and sedimentation patterns related to dredge activities can lead to shoaling and sediment deposition on benthic resources such as spawning grounds, SAV, and shellfish beds (Wilber et al. 2005; MacKenzie 2007). Early life history stages (eggs, larvae, and juveniles) and sessile organisms are the most sensitive to sedimentation impacts (Barr 1987; Wilber et al. 2005). Some estuarine and coastal habitats are prone to natural sediment loads and sediment resuspension because of the relatively dynamic nature of the ecosystems; therefore, most organisms adapted to these environments have tolerance to some level of suspended sediments and sedimentation (Nightingale and Simenstad 2001b).

The reconfiguration of sediment type and the removal of biogenic structure during dredging may decrease the stability of the bottom and increase the ambient turbidity levels (Messieh et al. 1991). This increased turbidity and sedimentation can reduce the light penetration of the water column which then can adversely affect SAV and reduce primary productivity (Cloern 1987; Dennison 1987; Wilbur and Pentony 1999; Mills and Fonseca 2003; Wilbur et al. 2005). The combination of decreased photosynthesis and the interaction of the suspended material with dissolved oxygen in the water may result in short-term oxygen depletion (Nightingale and Simenstad 2001b).

If suspended sediment loads remain high, fish may experience respiratory distress and reduced feeding ability because of sight limitations, while filter feeders may suffer a reduction in growth and survival (Messieh et al.1991; Barr 1993; Benfield and Minello 1996; Nightingale and Simenstad 2001b). Prolonged exposure to suspended sediments can cause gill irritation, increased mucus production, and decreased oxygen transfer in fish (Nightingale and Simenstad 2001b; Wilber et al. 2005). Reduced dissolved oxygen concentrations and increased water temperatures may be cumulative stressors that exacerbate the effects of respiratory distress on fish from extended exposure to suspended sediments (Nightingale and Simenstad 2001b). In addition, mobile species may leave an area for more suitable feeding or spawning grounds, or avoid migration paths because of turbidity plumes created during navigational dredging.

Increased turbidity and sedimentation may also bury benthic organisms and demersal fish eggs. The depth of burial and the density of the substrate may limit the natural escape response of some organisms that are capable of migrating vertically through the substrate (Barr 1987; Wilber et al. 2005). In addition, anoxic conditions in the disturbed sediments may decrease the ability of benthic organisms to escape burial (Barr 1987). Short-term burial, where sediment deposits are promptly removed by tides or storm events, may have minimal effects on some species (Wilber et al. 2005). However, even thin layers of fine sediment have been documented to decrease gas exchange in fish eggs and adversely affect the settlement and recruitment of bivalve larvae (Wilber et al. 2005). An in-situ experiment with winter flounder (*Pseudopleuronectes americanus*) eggs exposed to sediment deposition from a navigational dredging project found a slightly lower larval survival rate compared to control sites, but the differences were not statistically significant (Klein-MacPhee et al. 2004). However, the viability of the larvae in this experiment was not monitored beyond burial escapement. Similarly, laboratory experiments with winter flounder eggs buried to various depths (i.e., control, <0.5 mm, and up to 2 mm) indicated a decreased hatch success and delayed hatch with increasing depth; but differences were not statistically significant (Berry et al. 2004). The same study also exposed winter flounder eggs to both clean, fine-grained sediment and highly contaminated, fine-grained sediment at various depths from 0.5-6.0 mm. The investigators found that eggs buried to depths of 4 mm with clean sediments did not hatch, while eggs buried to depths of 3 mm with contaminated sediments had little or no hatching success (Berry et al. 2004). Although there are clearly adverse effects to sessile benthic organisms and life stages from sedimentation from dredging activities, additional investigations are needed to assess lethal and sublethal thresholds for more species and under different sediment types and quality. In addition, better understanding about the relationship between natural and anthropogenic sources of suspended sediments and population-level effects is needed.

The use of certain types of dredging equipment can result in greatly elevated levels of fine-grained particles in the water column. Mechanical dredging techniques such as clam shell or bucket dredges usually increase suspended sediments at the dredge site more than hydraulic dredge techniques such as hopper or cutterheads, unless the sediment and water mixture (slurry) removed during hydraulic dredging is allowed to overflow from the barge or hopper and into the water column, a technique often used to reduce the number of barge trips required (Wilber and Clarke 2001). Mechanical dredges are most commonly used for smaller projects or in locations requiring maneuverability such as close proximity to docks and piers or in rocky sediments (Wilber et al. 2005), although small hydraulic dredges can be used to reduce suspended sediment concentrations in the dredging area and minimize impacts on adjacent benthic habitats, such as SAV or shellfish beds.

Seasonal or time-of-year (TOY) restrictions to dredging activities are used to constrain the detrimental affects of dredging to a timeframe that minimizes impacts during sensitive periods in the life history of organisms, such as spawning, egg development, and migration (Nightingale and Simenstad 2001b; Wilber et al. 2005). Segregating dredging impacts by life history stages provides a means for evaluating how different impacts relate to specific organisms and life history strategies (Nightingale and Simenstad 2001b). The application of TOY restrictions should be based upon the geographic location, species and life history stages present, and the nature and scope of the dredging project. Because the employment of TOY restrictions may have some negative effects, such as extending the overall length of time required for dredging and disposal, increasing the impacts on less economically valuable or poorly studied species, and increasing the economic costs of a project, the benefits of TOY restrictions should be evaluated for each individual dredging project (Wilber et al. 2005; Nightingale and Simenstad 2001b).

### Contaminant release and source exposure

Contaminated sediments are a concern because of the risk of transport of the contaminants and the exposure to aquatic organism and humans through bioaccumulation and biomagnification (Nightingale and Simenstad 2001b). Navigation dredging can create deep channels where currents are reduced and fine sediments may be trapped. Nutrients and contaminants can bind to fine particles such as those that may settle in these deep channels (Newell et al. 1998; Messiah et al. 1991). Dredging and disposal causes resuspension of the sediments into the water column and the contaminants that may be associated with the sediment particles. The disturbance of bottom sediments during dredging can release metals (e.g., lead, zinc, mercury, cadmium, copper), hydrocarbons (e.g., PAH), hydrophobic organics (e.g., dioxins), pesticides, pathogens, and nutrients into the water column and allow these substances to become biologically available either in the water column or through trophic transfer (Wilbur and Pentony 1999; USEPA 2000; Nightingale and Simenstad 2001b). Generally, the resuspension of contaminated sediments can be reduced by avoiding dredging in areas containing fine sediments. In addition, the biological and/or chemical testing requirements under the Marine Protection, Research, and Sanctuaries Act and the Clean Water Act are designed to minimize adverse effects of dredge material disposal on the environment. For additional information regarding the affects of contaminants associated with resuspended sediments, refer to the chapters on Offshore Dredging and Disposal Activities and Chemical Affects: Water Discharge Facilities in this report.

### Release of nutrients/eutrophication

Dredging can degrade water quality through resuspension of sediments and the release of nutrients and other contaminants into the water column. Nutrients and contaminants may adhere to these fine particles (Newell et al. 1998; Messieh et al. 1991). The resuspension of this material creates turbid conditions and decreases photosynthesis. The combination of decreased photosynthesis and the release of organic material with high biological oxygen demand can result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001b). Long-term anoxia can occur if highly organic sediments are dredged or discharged into estuaries, particularly in enclosed or confined bodies of water. The loss of SAV is linked to poor water quality from increased turbidity and nutrient loading (Deegan and Buchsbaum 2005; Wilber et al. 2005).

### Entrainment and impingement

Entrainment is the direct uptake of aquatic organisms by the suction field created by hydraulic dredges. Benthic infauna are particularly vulnerable to entrainment by dredging, although some mobile epibenthic and demersal species such as shrimp, crabs, and fish can be susceptible to entrainment as well (Nightingale and Simenstad 2001b). Elicit avoidance responses to suction dredge entrainment has been reported for some demersal and pelagic mobile species (Larson and Moehl 1990; McGraw and Armstrong 1990). The susceptibility to entrainment for some pelagic species may be related to the degree of waterway constriction in the area of the dredging, which makes it more difficult for fish to avoid the dredge operation (Larson and Moehl 1990; McGraw and Armstrong 1990).

## Altered tidal, current, and hydrologic regimes

Large channel deepening projects can potentially alter ecological relationships through a change in freshwater inflow, tidal circulation, estuarine flushing, and freshwater and saltwater mixing (Nightingale and Simenstad 2001b). Dredging may also modify longshore current patterns by altering the direction or velocity of water flow from adjacent estuaries. These changes in water circulation are often accompanied by changes in the transport of sediments and siltation rates resulting in alteration of local habitats used for spawning and feeding (Messieh et al. 1991).

Altered circulation patterns around dredged areas can also lead to changes in sediment composition and deposition and in the stability of the seabed. The deep channels created during navigational dredging may experience reduced current flow that allows the area to become a sink for fine particles as they settle out of the water column or slump from the channel walls (Newell et al. 1998). In some cases this may change the sediment composition from sand or shell substrate to a substrate consisting of fine particles which flocculate easily and are subject to resuspension by waves and currents (Messieh et al. 1991). This destabilization of the seabed can lead to changes in sedimentation rates and a reduction in benthic resources, such as shellfish beds and SAV (Wilber et al. 2005). In addition, changes in substrate type can smother demersal eggs, affect larval settlement, and increase predation on juveniles adapted to coarser bottom substrates (Messieh et al. 1991; Wilber et al. 2005).

Navigational dredging can remove natural benthic habitat features, such as shoals, sand bars, and other natural sediment deposits. The removal of such features can alter the water depth, change current direction or velocity, modify sedimentation patterns, alter wave action, and create bottom scour or shoreline erosion (Barr 1987). Channel dredging can alter the estuarine hydrology and the mixing zone between fresh and salt water, leading to accelerated upland run-off, lowered freshwater aquifers, and greater saltwater intrusion into aquifers, as well as reduce the buffering capabilities of wetlands and shallow water habitats (Barr 1987; Nightingale and Simenstad 2001b).

Navigational channels that are substantially deeper than surrounding areas can become anoxic or hypoxic as natural mixing is decreased and detrital material settles out of the water column and accumulates in the channels. This concentration of anoxic or hypoxic water can stress nearshore biota when mixing occurs from a storm event (Allen and Hardy 1980). The potential for anoxic conditions can be reduced in areas that experience strong currents or wave energy, and sediments are more mobile (Barr 1987; Newell et al. 1998).

## Altered temperature regimes

Channel and port dredging can alter bottom topography, increase water depths, and change circulation patterns in the dredged area, which may increase stratification of the water column and reduce vertical mixing. This thermal layering of water may create anoxic or hypoxic conditions for benthic habitats. Deepened or new navigation channels may create deep and poorly flushed areas that experience reduced light penetration and water temperatures. Temperature influences biochemical processes and deep channels may create zones of poor productivity that can serve as barriers to migration for benthic and demersal species and effectively fragment estuarine habitats.

## Conservation recommendations and best management practices for navigational dredging

1. Avoid new dredging to the maximum extent practicable. Activities that would likely require dredging (such as placement of piers, docks, marinas, etc.) should instead be located in deep water or designed to alleviate the need for maintenance dredging.
2. Reduce the area and volume of material to be dredged to the maximum extent practicable.

3. Ensure that the volumes of dredge material are appropriately considered and that the identified disposal sites are adequate in containing the material. For example, the volume of material removed for the allowable over-depth dredging (usually 2 feet below the authorized or target depth) should be included in the disposal volume calculations.
4. Ensure that areas proposed for dredging are necessary in order to maintain the necessary and authorized target depths of the channel. Recent bathymetric surveys should be reviewed to evaluate the existing depths of the area proposed for dredging. Areas within the proposed dredge area that are at or deeper than the target depths should be avoided, whenever practicable.
5. Identify sources of erosion in the watershed that may be contributing to excessive sedimentation and the need for regular maintenance dredging activities. Implement appropriate management techniques to ensure that actions are taken to curtail those causes.
6. Use settling basins to act as sediment traps to prevent accretion of sediments in the navigational channel, when appropriate. This reduces the need for frequent maintenance dredging of the entire channel.
7. Consider the effects of increased boat traffic to an area when assessing a new dredging project or expanding existing channels. Increases in the speed, size, and density of boat traffic in an area may require increased frequency of maintenance dredging and produce a number of secondary impacts, such as shoreline erosion, sedimentation, and turbidity.
8. Identify the user group during the planning process to ensure that the dredging project meets the basic needs of the target user without exceeding an appropriate size and scope, or encouraging inappropriate use.
9. Consider time-of-year dredging restrictions, which may reduce or avoid impacts to sensitive life history stages, such as migration, spawning, or egg and young-of-year development. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Avoid projects that involve dredging intertidal and wetland habitat.
11. Avoid dredging in areas with SAV, areas which historically supported SAV, and areas which are potential habitat for recolonization by SAV.
12. Conduct both historic surveys of the area and predredge surveys because of the spatial and temporal dynamic nature of SAV beds.
13. Avoid dredging in areas supporting shellfish beds.
14. Consider beneficial uses for uncontaminated sediments when practicable and feasible. Priority should be given to beneficial uses of material that contributes to habitat restoration and enhancement, landscape ecology approach, and includes pre- and post-disposal surveys.
15. Avoid beneficial use projects that impose unnatural habitats and features and involve habitat trade-offs (substituting one habitat type for another).
16. Ensure that sediments are tested for contaminants and meet or exceed US EPA requirements and standards prior to dredging and disposal.
17. Assess cumulative impacts for current activities in the vicinity of a proposed dredging project, as well as for activities in the past and foreseeable future.
18. Ensure that bankward slopes of the dredged area are slanted to acceptable side slopes (e.g., 3:1 ratio) to ensure that sloughing of the channel side slopes does not occur.
19. Avoid placing pipelines and accessory equipment used in conjunction with dredging operations close to algae beds, eelgrass beds, estuarine/salt marshes, and other high value habitat areas.
20. Use silt curtains in some locations to reduce impacts of suspended sediments on adjacent benthic resources.
21. Avoid dredging in fine sediments when possible to reduce turbidity plumes and the release of nutrients and contaminants which tend to bind to fine particles.

22. Include information on control sites and predredging sampling for comparison and monitoring of impacts in environmental assessments for dredging projects.
23. Ensure that disposal sites are properly sited (i.e., avoid sensitive resources and habitats) and are appropriate for the type of dredge material proposed for disposal.
24. Ensure that disposal sites are being properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material.

## References for Marine Transportation


Able KW, Manderson JP, Studholme AL. 1999. Habitat quality for shallow water fishes in an urban estuary: the effects of man-made structures on growth. Marine Ecology Progress Series 187:227-35.

Allen KO, Hardy JW. 1980. Impacts of navigational dredging on fish and wildlife a literature review. Washington (DC): Biological Services Program, USFWS.

Amaral M, Lee V, Rhodes J. 2005. Environmental guide for marinas: controlling nonpoint source and storm water pollution in Rhode Island: best management practices for marinas. [Internet]. Narragansett (RI): University of Rhode Island, Coastal Resources Center, Rhode Island Sea Grant. [cited 2007 Dec 28]. Available from: http://seagrant.gso.uri.edu/BMP/BMP.html.

[ASMFC] Atlantic States Marine Fisheries Commission. 2004. NRC report outlines the impacts of oil on marine fish habitat. Habitat Hotline Atlantic 11(3):1-5.

Barr BW. 1987. The dredging handbook: a primer for dredging in the coastal zone of Massachusetts. Boston (MA): Massachusetts Coastal Zone Management. Publication No. 14, 870-181-500-6-87-CR.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Benfield MC, Minello TJ. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fishes 46:211-6.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. Ninth flatfish biology conference- poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Burdick DM, Short FT. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23(2):231-40.

Caltrans. 2001. San Francisco-Oakland Bay Bridge East Span seismic safety project, pile installation demonstration project, fisheries impact assessment. Sacramento (CA): California Department of Transportation. 59 p.

Cardwell RD, Koons RR. 1981. Biological considerations for the siting and design of marinas and affiliated structures in Puget Sound. Olympia (WA): Washington Department of Fisheries. Technical Report No. 60. 31 p.

Cardwell RD, Olsen SJ, Carr MI, Sanborn EW. 1980. Biotic, water quality and hydrologic characteristics of skyline marina in 1978. Olympia (WA): Washington Department of Fisheries. Technical Report No. 54. 103 p.

Carlson TJ, Ploskey G, Johnson RL, Mueller RP, Weiland MA, Johnson PN. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Richland (WA): US Army Corps of Engineers, Portland District. 35 p + appendices.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chapman MG. 2003. Paucity of mobile species on constructed seawalls: effects of urbanization on biodiversity. Marine Ecology Progress Series 264:21-9.

Cloern JE. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7(11-12):1367-81.

Costa JE, Howes BL, Giblin AE, Valiela I. 1992. Monitoring nitrogen and indicators of nitrogen loading to support management action in Buzzards Bay. In: McKenzie DH, Hyatt DE, McDonald VJ, editors. Ecological indicators. New York (NY): Elsevier Applied Science. p 499-531.

Cottingham D. 1988. Persistent marine debris: challenge and response: the federal perspective. Fairbanks (AK): Alaska Sea Grant. Report No. 88-1.

Dahl TE. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. [Internet]. Washington (DC): US Department of the Interior; Fish and Wildlife Service. [cited 2008 Jul 21]. 112 p. Available from: http://wetlandsfws.er.usgs.gov/status_trends/National_Reports/trends_2005_report.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dennison WC. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany 27(1):15-26.

Dolat SW. 1997. Acoustic measurements during the Baldwin Bridge demolition. Waterford (CT): Prepared for White Oak Construction by Sonalysts. 34 p + appendices.

Eriksson BK, Sandstrom A, Iscus M, Schreiber H, Karas P. 2004. Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuarine, Coastal and Shelf Science 61(2):339-49.

Feist BE, Anderson JJ, Miyamoto R. 1996. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Seattle (WA): Fisheries Research Institute-University of Washington. FRI-UW-9603. 58 p.

Fresh KL, Williams B, Penttila D. 1995. Overwater structures and impacts on eelgrass (*Zostera marina*) in Puget Sound, Washington. In: Puget Sound Research '95 Proceedings; 1995 Jan 12-14; Bellevue, WA. Olympia (WA): Puget Sound Water Quality Authority. p 537-43.

Fresh KL, Williams BW, Wyllie-Echeverria S, Wyllie-Echeverria T. 2001. Mitigating impacts of overwater floats on eelgrass *Zostera marina* L. in Puget Sound, Washington. In: Proceedings of Puget Sound Research 2001-The fifth Puget Sound Research Conference; 2001 Feb 12-14; Bellevue, WA. Olympia (WA): Puget Sound Action Team.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. p 68 + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Haas MA, Simenstad CA Jr, Cordell JR, Beauchamp DA, Miller BS. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA. [Internet]. Seattle (WA): Washington State Transportation Center (TRAC), University of Washington, and Washington State Department of Transportation. Final Research Report WA-RD 550.1. [cited 2008 Jul 9]. 114 p. Available from: http://depts.washington.edu/trac/bulkdisk/pdf/550.1.pdf.

Hall LW Jr, Anderson RD. 1999. A deterministic ecological risk assessment for copper in European saltwater environments. Marine Pollution Bulletin 38(3):207-18.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hastings K, Hesp P, Kendrick G. 1995. Seagrass loss associated with boat moorings at Rottnest Island, Western Australia. Ocean & Coastal Management 26:225-46.

Hawkins AD. 1986. Underwater sound and fish behaviour. In: Pitcher TJ, editor. The behavior of teleost fishes. Baltimore (MD): The Johns Hopkins University Press. p 114-51.

Heintz RA, Rice SD, Wertheimer AC, Bradshaw RF, Thrower FP, Joyce JE, Short JW. 2000. Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha* after exposure to crude oil during embryonic development. Marine Ecology Progress Series 208:205-16.

Helton D, Zelo I. 2003. Developing information and support necessary to prioritize and support removal of abandoned vessels impacting coral resources. In: Proceedings of the 13th

Biennial Coastal Zone Conference; 2003 Jul 13-17; Baltimore, MD. Charleston (SC): NOAA Coastal Services Center.

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Hofer T. 1998. Part II: Environmental and health effects resulting from marine bulk liquid transport. Environmental Science and Pollution Research 5(4):231-7.

[ICES] International Council for the Exploration of the Sea. 1992. Report of the ICES working group on the effects of extraction of marine sediments on fisheries. Copenhagen (Denmark): ICES Cooperative Research Report # 182.

Jasny M, Reynolds J, Horowitz C, Wetzler A. 1999. Sounding the depths: supertankers, sonar, and rise of undersea noise. Los Angeles (CA): Natural Resources Defense Council. Marine Mammal Protection Project. 38 p.

Kahler T, Grassley M, Beauchamp DA. 2000. A summary of the effects of bulkheads, piers, and other artificial structures and shorezone development on ESA listed salmonids in lakes. [Internet]. Bellevue (WA): Final Report to the City of Bellevue. [cited 2007 Dec 28]. 74 p. Available from: http://www.cityofbellevue.org/pdf/Utilities/dock_bulkhead.pdf.

Kalmijn AJ. 1988. Hydrodynamic and acoustic field detection. In: Atema J, Fay RR, Popper AN, Tavolga WN, editors. Sensory biology of aquatic animals. New York (NY): Springer-Verlag. p 83-130.

Karaki S, vanHoften J. 1975. Resuspension of bed material and wave effects on the Illinois and upper Mississippi Rivers caused by boat traffic. St. Louis (MO): US Army Engineer District. Cont. No. LMSSD 75-881.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C, and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Keevin TM. 1998. A review of natural resource agency recommendations for mitigating the impacts of underwater blasting. Reviews in Fisheries Science 6(4):281-313.

Keevin TM, Gaspin JB, Gitschlag GR, Hempen GL, Linton TL, Smith M, Wright DG. 1999. Underwater explosions: natural resource concerns, uncertainty of effects, and data needs. In: Proceedings of the twenty-fifth annual conference on explosives and blasting technique; 1999 Feb 7-10; Nashville, TN. Cleveland (OH): International Society of Explosive Engineers. p 105-16.

Keevin TM, Hempen GL, Schaeffer DJ. 1997. Use of a bubble curtain to reduce fish mortality during explosive demolition of Locks and Dam 26, Mississippi River. In: Proceedings of the twenty-third annual conference on explosives and blasting technique; 1997 Feb 2-5; Las Vegas, NV. Cleveland (OH): International Society of Explosive Engineers. p 197-206.

Kipple B, Gabriele C. 2004. Glacier Bay watercraft noise-noise characterization for tour, charter, private, and government vessels. Bermerton (WA): Naval Surface Warfare Center-Detachment Bermerton. Technical Report NSWCCD-71-TR-2004/545. 47 p.

Klein R. 1997. The effects of marinas and boating activities upon tidal waters. Owing Mills (MD): Community and Environmental Defense Services. 23 p.

Klein-MacPhee G, Macy WK, Berry W. 2004. *In situ* effects of suspended particulate loads produced by dredging on eggs of winter flounder (*Pseudopleuronectes americanus*). In: Ninth flatfish biology conference- oral presentation; 2004 Dec 1-2; Water's Edge Resort, Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Knudsen FR, Schreck CB, Knapp SM, Enger PS, Sand O. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology 51:824-9.

Krone CA, Brown DW, Burrows DG, Chan S-L, Varanasi U. 1989. Butyltins in sediment from marinas and waterways in Puget Sound, Washington State, USA. Marine Pollution Bulletin 20(10):528-31.

Larson K, Moehl CE. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): Washington Sea Grant, University of Washington. p 102-12.

Longmuir C, Lively T. 2001. Bubble curtain systems for use during marine pile driving. New Westminister (British Columbia): Fraser River Pile and Dredge LTD. 9 p.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

McGraw K, Armstrong D. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): University of Washington Sea Grant. p 113-31.

Messieh SN, El-Sabh MI. 1988. Man-made environmental changes in the southern Gulf of St. Lawrence, and their possible impact on inshore fisheries. In: El-Sabh MI, Murty TS, editors. Natural and man-made hazards. Boston (MA): D. Reidel Publishing Co. p 499-523.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Michel J, Helton D. 2003. Environmental considerations during wreck removal and scuttling. In: Abandoned Vessel Program (AVP) Conference Proceedings-National Maritime Salvage Conference; 2003 Sep 9-11; Crystal City, VA. Arlington (VA): American Salvage Association.

Milliken AS, Lee V. 1990. Pollution impacts from recreational boating: a bibliography and summary review. Narragansett (RI): Rhode Island Sea Grant. National Sea Grant Depository Publication # RIU-G-002.

Mills KE, Fonseca MS. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-34.

Moore M, Stolpe NE. 1995. Boating workshop raises tough questions. Commercial Fisheries News 22(7):6B-7B and 15B.

Mulvihill EL, Francisco CA, Glad JB, Kaster KB, Wilson RE. 1980. Biological impacts of minor shoreline structures in the coastal environment: state of the art review. Sidell (LA): US Fish and Wildlife. FWS/OBS-77/51. Vol. 1. 156 p.

Myrberg AA Jr. 1972. Using sound to influence the behavior of free-ranging marine mammals. In: Winn HE, Olla BL, editors. Behavior of marine animals. Vol. 2: Vertebrates. New York (NY): Plenum Press. p 435-68.

Myrberg AA Jr, Riggio RJ. 1985. Acoustically mediated individual recognition by a coral reef fish (*Pomacentrus partitus*). Animal Behaviour 33:411-6.

Neff JM. 1985. Polycyclic aromatic hydrocarbons. In: Rand GM, Petrocelli SR, editors. Fundamentals of aquatic toxicology. Washington (DC): Hemisphere Publishing. p 416-54.

Negri AP, Smith LD, Webster NS, Heyward AJ. 2002. Understanding ship-grounding impacts on a coral reef: potential effects of anti-foulant paint contamination on coral recruitment. Marine Pollution Bulletin 44:111-7.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Nightingale BJ, Simenstad CA Jr. 2001a. Overwater structures: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 9]. 133 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finalmar.pdf.

Nightingale B, Simenstad CA Jr. 2001b. Dredging activities: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 17]. 119 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finaldrg.pdf.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

Orth RJ, Batiuk RA, Moore KA. 2002. A perspective on two decades of policies and regulations influencing the protection and restoration of submerged aquatic vegetation in Chesapeake Bay, USA. Bulletin of Marine Science 71(3):1391-403.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, William SL. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Penttila D, Doty D. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Olympia (WA): Washington Department of Fisheries. Draft Progress Report. 41 p.

Pertola S, Faust MA, Kuosa H. 2006. Survey on germination and species composition of dinoflagellates from ballast tanks and recent sediments in ports on the South Coast of Finland, North-Eastern Baltic Sea. Marine Pollution Bulletin 52(8):900-11.

Poston T. 2001. Treated wood issues associated with overwater structures in freshwater and marine environments. [Internet]. Olympia (WA): Washington State Departments of Transportation, Fish and Wildlife, and Ecology. White Paper. [cited 2008 Jul 9]. 85 p. Available from: http://wdfw.wa.gov/hab/ahg/finaltw.pdf.

Precht WF, Aronson RB, Swanson DW. 2001. Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. Bulletin of Marine Science 69(2):1001-12.

Readman JW, Kwong LLW, Grondin D, Bartocci J, Villeneuve JP, Mee LD. 1993. Coastal water contamination from triazine herbicide used in antifouling paints. Environmental Science and Technology 27(9):1940-2.

Richard JD. 1968. Fish attraction with pulsed low-frequency sound. Journal of the Fisheries Research Board of Canada 25(7):1441-52.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

Sand O, Enger PS, Karlsen HE, Knudsen F, Kvernstuen T. 2000. Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. Environmental Biology of Fishes 57(3):327-36.

Scholik AR, Yan HY. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63:203-9.

Shafer DJ. 1999. The effects of dock shading on the seagrass *Halodule wrightii* in Perdido Bay, Alabama. Estuaries 22(4):936-43.

Smith KN, Mezich RR. 1999. Blending management and research for protection of manatee habitat in Florida: the seagrass dock effect. In: Poster presentation at the 15th Biennial International Estuarine Research Federation Conference; 1999 Sep 25-30; New Orleans, LA. Port Republic (MD): Coastal and Estuarine Research Federation.

Smith LD, Negri AP, Philipp E, Webster NS, Heyward AJ. 2003. The effects of antifoulant-paint-contaminated sediments on coral recruits and branchlets. Marine Biology 143:651-7.

Stocker M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America 112(5):2431.

Stolpe NE, Moore M. 1997. Boating workshop raises tough questions. [Internet]. New Jersey Fishing. Commercial Fisheries News 22(7); c2007 [cited 2007 Dec 28]. Available from: http://www.fishingnj.org/artobm2.htm.

Stotz T, Colby J. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 p + appendices.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Sunda WG. 1994. Trace metal/phytoplankton interactions in the sea. In: Bidoglio G, Stumm W, editors. Chemistry of aquatic systems: local and global perspectives. Norwell (MA): Kluwer Academic Publishers Group. p 213-47.

Thayer WG, Fonseca MS, Kenworthy JW. 1997. Ecological value of seagrasses: a brief summary for the ASMFC habitat committee's SAV subcommittee. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. p 68 + appendices.

Thom RM, Shreffler DK. 1996. Eelgrass meadows near ferry terminals in Puget Sound: characterization of assemblages and mitigation impacts. Sequim (WA): Battelle Pacific Northwest Laboratories.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

Uhrin AV, Holmquist JG. 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Marine Ecology Progress Series 250:61-70.

[USEPA] US Environmental Protection Agency. 2000. Environmental screening checklist and workbook for the water transportation industry. Washington (DC): US EPA Office of Water. EPA-305-B-00-004.

[USEPA] US Environmental Protection Agency. 2001. National management measures guidance to control nonpoint source pollution from marinas and recreational boating. Washington (DC): US EPA Office of Water. EPA-841-B-01-005.

Waite ME, Waldock MJ, Thain JE, Smith DJ, Milton SM. 1991. Reductions in TBT concentrations in UK estuaries following legislation in 1986 and 1987. Marine Environmental Research 32:89-111.

Walker DI, Kendrick GA. 1998. Threats to macroalgal diversity: marine habitat destruction and fragmentation, pollution, and introduces species. Botanica Marina 41(1):105-12.

Walker DI, Lukatelich RJ, Bastyan G, McComb AJ. 1989. Effect of boat moorings on seagrass beds near Perth, Western Australia. Aquatic Botany 36(1):69-77.

Warnken J, Dunn RJK, Teasdale PR. 2004. Investigation of recreational boats as a source of copper at anchorage sites using time-integrated diffusive gradients in thin film and sediment measurements. Marine Pollution Bulletin 49(9-10):833-43.

Weis JS, Weis P. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-10.

Weis P, Wies JS, Coohill LM. 1991. Toxicity to estuarine organisms of leachates from chromated copper arsenate treated wood. Archives of Environmental Contamination and Toxicology 20:118-24.

Wertheimer AC, Heintz RA, Thedinga JF, Maselko JM, Rice SD. 2000. Straying of adult pink salmon from their natal stream following embryonic exposure to weathered *Exxon Valdez* crude oil. Transactions of the American Fisheries Society 129(4):989-1004.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White Paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. [cited 2008 Jul 9]. 99 p. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

Wright DG. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Winnipeg (Manitoba): Western Region, Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1052.

Yousef YA. 1974. Assessing effects on water quality by boating activity. Washington (DC): US Environmental Protection Agency. EPA-670/2-74-072. 60 p.

Zelo I, Helton D. 2005. Removal of grounded, derelict or abandoned vessels as site restoration. In: Abandoned Vessel Program (AVP) Conference Proceedings-International Oil Spill Conference; 2005 May 15-19; Miami Beach, FL. Seattle (WA): NOAA Ocean Service Office of Response and Restoration. 15 p.

# CHAPTER SIX: OFFSHORE DREDGING AND DISPOSAL ACTIVITIES

## Introduction

This chapter describes activities associated with offshore dredging and disposal and their potential effects on living marine resources and habitats in the northeast region of the United States. For purposes of this discussion, the "offshore" environment is defined as those waters and seabed areas considered to be "estuarine" environments and extending offshore to and occasionally beyond the edge of the continental shelf. For example, while the open waters of Chesapeake Bay, MD/VA, and Long Island Sound, NY/CT, are considered offshore for this discussion, the coves and embayments within those waters bodies are not. In addition, Raritan Bay, NY/NJ, (lower New York Harbor) and similar areas are considered offshore environments. Dredging and disposal activities within riverine habitats have been discussed in the Alteration of Freshwater Systems chapter of this report, and information on dredging within navigation channels can be reviewed in the Marine Transportation chapter of this report.

## Offshore Mineral Mining

### *Introduction*

There is an increasing demand for beach nourishment sand and a smaller, but growing, demand for construction and "stable fill" grade aggregates. As the historic landside sources of these materials have been reduced, there has been a corresponding move towards mining the continental shelf to meet this demand. It is expected that the shift to offshore mineral extraction will continue and escalate, particularly in areas where glacial movements have relocated the desired material to the continental shelf. Typically, these deposits are not contaminated because of their offshore location and isolation from anthropogenic pollution sources. Beginning in the mid-1970s, the US Geological Survey began mapping the nature and extent of the aggregate resources in coastal and nearshore continental shelf waters throughout the northeast beyond the 10-m isobath. Between 1995 and 2005, the Minerals Management Service (MMS), which oversees offshore mineral extractions, regulated the relocation of over 23 million cubic yards of sand from the Outer Continental Shelf (OCS) for beach nourishment projects (MMS 2005a). The OCS is defined as an area between the seaward extent of states' jurisdiction and the seaward extent of federal jurisdiction. Currently, the MMS, in partnership with 14 coastal states, is focusing on collecting and analyzing geologic and environmental information in the OCS in order to study sand deposits suitable for beach nourishment and wetlands protection projects and to assess the environmental impacts of OCS mining in general (Drucker et al. 2004). With the advances in marine mining and "at sea" processing, aggregate extraction can occur in waters in excess of 40 m **(**MMS 2005a**)**.

Mineral extraction is usually conducted with hydraulic dredges by vacuuming or, in some cases, by mechanical dredging with clamshell buckets in shallow water mining sites. Mechanical dredges can have a more severe but localized impact on the seabed and benthic biota, whereas hydraulic dredges may result in less intense but more widespread impact (Pearce 1994). The impacts of offshore mineral mining on living marine resources and their habitats include: (1) the removal of substrates that serve as habitat for fish and invertebrates; (2) creation of (or conversion to) less productive or uninhabitable sites such as anoxic depressions or highly hydrated clay/silt substrates; (3) release of harmful or toxic materials either in association with actual mining, or from incidental or accidental releases from machinery and materials used for mining; (4) burial of productive habitats during beach nourishment or other shoreline stabilization activities; (5) creation of harmful suspended sediment levels; and (6) modification of hydrologic conditions causing adverse impacts to desirable habitats (Pearce 1994; Wilber et al. 2003).

In addition, mineral extraction can potentially have secondary and indirect adverse effects on fishery habitat at the mining site and surrounding areas. These impacts may include accidental or intentional discharges of mining equipment and processing wastes and degradation or elimination of marine habitats from structures constructed to process or transport mined materials. These secondary effects can sometimes exceed the initial, direct consequences of the offshore mining.

### *Loss of benthic habitat types*

Offshore benthic habitats occurring on or over target aggregates may be adversely affected by mining. The mineral extraction process can disrupt or eliminate existing biological communities within the mining or borrow areas for several years following the excavation. Filling in of the borrow areas and reestablishment of a stable sediment structure is dependent upon the ability of bottom currents to transport similar sediments from surrounding areas to the mining site (ICES 1992). The principal concern noted by the International Council for the Exploration of the Sea (ICES) Working Group on the Effects of Extraction of Marine Sediments on Fisheries was dredging in spawning areas of commercial fish species (ICES 1992). Of particular concern to the ICES Working Group are fishery resources with demersal eggs (e.g., Atlantic herring [*Clupea harengus*] and sand lance [*Ammodytes marinus*]). They report that when aggregates are removed, Atlantic herring eggs are taken with them, resulting in lost production to the stock. Stewart and Arnold (1994) list the impacts on Atlantic herring from offshore mining to include the entrainment of eggs, larvae, and adults; burial of eggs; and effects of the turbidity plume on demersal egg masses. Gravel and coarse sand have been identified as preferred substrate for Atlantic herring eggs on Georges Bank and in coastal waters of the Gulf of Maine (Stevenson and Scott 2005).

### *Conversion of substrate/habitat and changes in community structure*

Disposal of residues (“tailings”) of the mining process can alter the type, as well as the functions and values, of habitats which can then alter the survival and growth of marine organisms. The tailings are often fine-grained and highly hydrated, making them very dissimilar to the natural seafloor, particularly in depths where wave energy and currents are capable of winnowing or sorting sediments and relocating them to depositional areas. It has been found that wave forces are affecting habitats in the New York Bight at depths in excess of 22 m (USACE 2005a). In laboratory experiments, benthic dwelling flatfishes (Johnson et al. 1998a) and crabs (Johnson et al. 1998b) persistently avoided sediments comprised of mine tailings.

Additionally, there can be adverse impacts from aggregate and/or mineral mining on nearby habitats associated with the removal and disturbance of substrate (Scarrat 1987). Seabed alteration can fragment habitat, reduce habitat availability, and disrupt predator/prey interactions, resulting in negative impacts to fish and shellfish populations. Not all offshore aggregate mining results in adverse impacts on seabed resources. Hitchcock and Bell (2004) conducted a detailed study of the effects from a small-scale, aggregate mining operation off the south coast of the United Kingdom and found physical impacts on the seabed to be limited to a downtide zone approximately 300 m from the dredge area. Related studies at this mining operation reported no detectable impact on the surrounding benthic communities, despite a small change in seabed particle size distribution (Hitchcock and Bell 2004).

Long-term mining can alter the habitat to such a degree that recovery may be extremely protracted and create habitat of limited value to benthic communities during the entire recovery period (van Dalfsen et al. 2000). For example, construction grade aggregate removal in Long Island Sound, Raritan Bay (lower New York Harbor) and the New Jersey portion of the intercoastal waterway have left borrow pits that are more than twice the depth of the surrounding area. The pits have remained chemically, physically, and biologically unstable with limited diversity communities for more than five decades. These pits were used to provide fill material for interstate transportation projects and have been investigated to assess their environmental impact (Pacheco 1984). Borrow pits in Raritan Bay were found to possess depressed benthic communities and elevated levels of highly hydrated and organically enriched sediments (Pacheco 1984). In one example, aggregate mining operations from the 1950s through the 1970s created a 20 m deep borrow pit in an area of Raritan Bay that, although the mining company was required to refill the pit, remains today as a rapid deposition area filling with fine-grained sediment and organic material emanating from the Hudson River and adjacent continental shelf (Pacheco 1984**)**. The highly hydrated sediments filling the depressions are of limited utility to colonizing benthic organisms.

In offshore mining operation sites, the character of the sediment which is exposed or subsequently accumulates at the extraction site is important in predicting the composition of the colonizing benthic community (ICES 1992). If the composition and topography of the extraction site resembles that which originally existed, then colonization of it by the same benthic fauna is likely (ICES 1992).

### *Changes in sediment composition*

A review of studies conducted in Europe and Great Britain found that infilling and subsequent benthic recovery of borrow areas may take from 1-15 years, depending upon the tide and current strength, sediment characteristics, the stock of colonizing species and their immigration distance (ICES 1992). Typically the reestablishment of the community appears to follow a successional process similar to those on abandoned farmlands. Germano et al. (1994) described this process, reporting that pioneering species (i.e., Stage I colonizers) usually do not select any particular habitat but attempt to survive regardless of where they settle. These species are typically filter feeders relying on the availability of food in the overlying water rather than the seafloor on which they reside. Thus, their relationship to the substrate is somewhat tenuous, and their presence is often ephemeral. However, their presence tends to provide some stability to the seafloor, facilitating subsequent immigrations by other species that bioturbate the sediment seeking food and shelter. Their arrival induces further substrate consolidation and compaction. These colonizers are usually deemed to be Stage II community species. The habitat modification activities of Stage I and II species advance substrate stability and consolidation enough for it to support, both physically and nutritionally, the largest community members (i.e., Stage III). The benthic community instability caused by dredging gives rise to one of the principal justifications for retaining benthic disturbances: the disrupted site may become heavily populated by opportunistic (i.e., Stage I) colonizer species that flourish briefly and provide motile species with an abundance of food during late summer and fall periods (Kenny and Rees 1996). However, if environmental stresses are chronic, the expected climax community may never be attained (Germano et al. 1994).

If the borrow area fails to refill with sediment similar to that which was present prior to mining, the disturbed area may not possess the original physical and chemical conditions and recovery of the community structure may be restricted or fail to become reestablished. Dredge pits that have been excavated to depths much greater than the surrounding bottom often have very slow infill rates and can be a sink for sediments finer than those of the surrounding substrate (ICES 1992).

### *Changes in bottom topography and hydrology*

The combination of rapid deposition, anomalous sediment character, and an uneven topography, as compared to the surrounding seafloor, limit recolonization opportunities for harvesting purposes (Wilk and Barr 1994). By altering bottom topography, aggregate mining can reduce localized current strength, resulting in lowered dissolved oxygen concentrations and increased accumulation of fine sediments inside borrow pits (ICES 1992). One potential benefit of some borrow pits is that they appear to provide refugia for pelagic species such as alewife (*Alosa pseudoharengus*) and scup (*Stenotomus chrysops*), as well as demersal species such as tautog (*Tautoga onitis*) and black sea bass (*Centropristis striata*) during seasonally fluctuating water temperatures (Pacheco 1984). However, it is doubtful these benefits outweigh the persistent adverse affects associated with borrow pits (Palermo et al. 1998; Burlas et al. 2001). Other consequences of aggregate mining may include alteration of wave and tidal current patterns which could affect coastal erosion (ICES 1992).

### *Siltation, sedimentation, and turbidity*

Offshore mining can increase the suspended sediment load in the water column, increasing turbidity that can then adversely affect marine organisms, particularly less motile organisms such as shellfish, tunicates, and sponges. The duration of the turbidity plume in the water column depends upon the water temperature, salinity, current speed, and the size range of the suspended particles (ICES 1992). The distance the dredged material is transported from the excavation site will be dependent upon the current strength, storm resuspension, water salinity and temperature, and the grain size of the suspended material (ICES 1992).

The life stages of the affected taxa are an important factor affecting the type and extent of the adverse impacts (Wilber and Clarke 2001). As a general rule, the severity of sedimentation and turbidity effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996; Wilber and Clarke 2001). In particular, the eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Stewart and Arnold (1994) list the impacts on Atlantic herring from offshore mining to include the effects of the turbidity plume on demersal egg masses.

### *Impacts to water quality*

The release of material into the water column during offshore mining operations can degrade water quality if the excavated material is high in organic content or clay. The effects of mixing on the water column are likely to include increased consumption of oxygen by decomposing organic matter and the release of nutrients (ICES 1992). However, mined aggregate material is typically low in organic content and clay, and any increase in the biological oxygen demand is thought to be minor and of limited spatial extent (ICES 1992).

Deep borrow pits can become anaerobic during certain times of the year. The dissolved oxygen concentration within these pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984).

## *Release of contaminants*

A number of factors (i.e., environmental, geochemical, and biological) influence the potential release and bioavailability of sediment contaminants. The toxicity of such releases, in general, is primarily dependent upon the contaminant involved, its concentration in the sediments and its chemical/geochemical state. Persistent organic pollutants (POPs), such as polyaromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyl (PCBs), are sequestered in the total organic carbon (TOC) fraction of sediments (USEPA 2003a; USEPA 2003b; USEPA 2003c). Similarly, heavy metals are sequestered by acid volatile sulfides (AVS) and the TOC fraction of marine sediments (USEPA 2005a). For POPs like PAHs, the ratio of the concentrations of these contaminants relative to those of the fractions govern bioavailability and hence toxicity (USEPA 2003a). In the case of metals, bioavailability is governed by an excess of AVS concentrations relative to the metal concentrations as normalized by TOC (USEPA 2005a). Sand and gravel sediments typically contain low TOC and AVS concentrations, and where there is a prominent source of POPs and metals, such as in highly industrialized riverways, these coarser sediments could in fact release such contaminants when disturbed or oxidized. However, the coarse-grained sediments typically targeted for aggregate mining tend to be found in high-energy environments which are not depositional areas that can be sinks for fine-grained material containing POPs and metals. Since most offshore sand and gravel deposits do not have prominent nearby sources of POPs and metals, these deposits are generally low in contaminants (ICES 1992; Pearce 1994). Thus, the mining of offshore sand and gravel material typically do not release high levels of contaminants. In addition, because of their relatively large particle size, low surface area relative to total bulk, and low surface activity (i.e., few clay or organic materials to interact chemically), there is usually little chemical interaction in the water column (Pearce 1994). However, extraction of material in estuaries or deep channels, where fine material accumulates and is subject to anthropogenic pollution deposition, may be more likely to release harmful chemicals during dredging and excavation (Pearce 1994). Refer to the chapters on Coastal Development, Marine Transportation, and Chemical Effects: Water Discharge Facilities for additional information on the release of contaminants during dredging and excavation.

## *Sediment transport from site*

Excavation at an offshore mining site that contains fine material can release suspended sediments into the water column during the excavation, as well as in the sorting or screening process. The distance the dredged material is transported from the excavation site will be dependent upon the current strength, storm resuspension, water salinity and temperature, and the grain size of the suspended material (ICES 1992). Some of the potential effects of redeposition of fines include smothering of demersal fish eggs on spawning grounds and the suffocation of filter-feeding benthos, such as shellfish and anemones (ICES 1992; Pearce 1994). Small-scale aggregate mining operations that are conducted in relatively shallow water and involving sandy, coarse-grained sediments often have relatively minimal physical and biological impacts on the surrounding seabed (Hitchcock and Bell 2004).

## *Noise impacts*

Anthropogenic sources of ocean noise appear to have increased over the past decades, and have been primarily attributed to commercial shipping, offshore gas and oil exploration and drilling, and naval and other uses of sonar (Hildebrand 2004). Offshore mineral mining likely contributes to the overall range of anthropogenic ocean noise, but little information exists regarding specific effects on marine organisms and their habitats or the importance of offshore mining relative to other sources of anthropogenic noise. The dredging equipment noise generated in offshore mining may be similar to navigation channel dredging in nearshore habitats; however, because of the greater water depths involved in offshore mining, the noise may be propagated for greater distances than in confined nearshore areas (Hildebrand 2004). Reductions in Atlantic herring catches on the Finnish coast were hypothesized to be due to disturbance to the herring movement patterns by noise and activity associated with sand and gravel mining activities (Stewart and Arnold 1994). Refer to the chapters on Global Affects and Other Impacts and Marine Transportation for additional information on noise impacts.

### *Conservation measures and best management practices for offshore mineral mining*

1. Avoid mining in areas containing sensitive or unique marine benthic habitats (e.g., spawning and feeding sites, surface deposits of cobble/gravel substrate).
2. Complete a comprehensive characterization of the borrow site and its resources prior to permit completion. Some of the components of a thorough assessment include:
    a. Determine the optimum dimensions of the borrow pit (i.e., small and deep areas or wide and shallow areas) in terms of minimizing the effects on resources.
    b. Prioritize the optimal locations of sand mining in terms of effects on resources.
    c. Assess the sand infill rates of borrow pits after completion.
    d. Assess the sediment migration patterns and rates as well as the side slope and adjacent natural seabed stability of the borrow pits after completion.
    e. Model and estimate the effect of massive and/or long-term sand mining on the surrounding seabed, shoreface (i.e., inner continental shelf), sand budgets, and resources.
    f. Assess the effect of removal (by dredging) of offshore sand banks/shoals on the surrounding natural seabed, adjacent shoreline, and the resources that use those habitats.
    g. Assess the effect of massive and/or long-term sand mining on the ecological structure of the seabed.
    h. Assess the effect of noise from mining operations on the feeding, reproduction, and migratory behavior of marine mammals and finfish.
3. Use site characterization and appropriate modeling to determine the areal extent and depth of extraction that affords expedited and/or complete recovery and recolonization times.
4. Employ sediment dispersion models to characterize sediment resuspension and dispersion during mining operations. Use model outputs to design mining operations, including "at sea" processing, to limit impacts of suspended sediment and turbidity on fishery resources and minimize the area affected.
5. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in offshore mining review processes.
6. Use seasonal restrictions when appropriate to avoid temporary impacts to habitat during species critical life history stages (e.g., spawning, and egg, embryo, and juvenile development). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. Resource managers should incorporate adequate time for habitat recovery of affected functions and values to levels required by managed species.

# Petroleum Extraction

## Introduction

After some intense but unsuccessful petroleum exploration on the northeastern US continental shelf, the attention for commercial quantities of oil and gas have been directed elsewhere. Georges Bank and the continental shelf off New Jersey were thought to contain significant reserves of natural gas and several exploratory wells were drilled to locate and characterize those reserves in the late 1980s and early 1990s. At that time, few commercially viable reserves were found and the focus of petroleum exploration shifted to other regions. However, this could change in the future considering the escalating market prices and dwindling supplies of petroleum. Should renewed interest in offshore petroleum exploration and extraction in the northeast region occur, existing regulatory guidance on petroleum exploration and extraction, as well any recent research and development efforts, should be employed to ensure that marine resource impacts can be avoided, minimized, and compensated for these types of activity.

Petroleum extraction has impacts similar to mineral mining but usually with significantly less of an impact footprint (excluding spills). However, there is more risk and occurrence of adverse impacts associated with equipment operation, process related wastes and handling of byproducts (e.g., drill cuttings and spent drilling mud) which can disrupt and destroy pelagic and benthic habitats (Malins 1977; Wilk and Barr 1994). Potential releases of oil and petroleum byproducts into the marine environment may also occur as a result of production well blow-outs and spills.

Drilling muds are used to provide pressure and lubrication for the drill bit and to carry drill cuttings (crushed rock produced by the drill bit) back to the surface. Drilling muds and their additives are complex and variable mixtures of fluids, fine-grained solids, and chemicals (MMS 2005b). Some of the possible impacts associated with petroleum extraction include the dispersion of soluble and colloidal pollutants, as well as the alteration of turbidity levels and benthic substrates. Many of these impacts can be mitigated by on-site reprocessing and by transferring substances deemed inappropriate for unrestricted openwater disposal to landside disposal.

For more information on petroleum-related impacts and conservation recommendations for petroleum exploration, production, and transportation refer to the Energy-related Activities chapter of this report.

# Offshore Dredged Material Disposal

## Introduction

The disposal of dredged material in offshore waters involves environmental effects beyond those associated with the actual dredging operations. The US Army Corps of Engineers (USACE) disposes approximately 65% of its dredged material in open water, as opposed to “upland,” or land disposal (Kurland et al. 1994). Although some adverse environmental effects can be avoided with land disposal, there are a number of drawbacks including securing large tracts of land, material handling problems, overflow and runoff of polluted water, saltwater intrusion into groundwater, and costs of transporting material to land disposal sites (Kurland et al. 1994).

Disposal of dredged material is regulated under the Clean Water Act (CWA) and the Marine Protection, Research, and Sanctuaries Act (MPRSA), also known as the Ocean Dumping Ban Act (33 U.S.C. § 1251 and 1401 et seq.). The differences in the two Acts are found in the necessity and type(s) of sediment testing required by each. Generally, ocean dumping only requires biological testing if it is determined that the sediments do not meet the testing exclusion criteria as specified under the MPRSA (i.e., are contaminated). While the CWA provides for biological testing, it does not require such tests to determine whether the sediment meets the 404b testing guidelines unless specified by the USACE or the US Environmental Protection Agency (US EPA). The US EPA and the USACE are currently involved in discussions intended to combine the testing and evaluation protocols described in regulations, and in the "Greenbook" (Ocean Dumping Ban Act) and "Inland" (CWA) testing manuals. Currently, the US EPA and USACE use a tiered approach under both Acts, based upon empirical data gathered from each evaluated dredging project for determining the appropriate management options for dredge spoils (i.e., unconfined open water disposal, open water disposal with capping [CWA only], no open water disposal, or confined area disposal in harbors). Under the CWA, sediment quality guidelines or benchmarks can be used in the lower tiers to determine compliance with 404b guidelines or the need for futher testing. Although not required under the MPRSA, regulators in practice often use sediment chemistry to help determine the contaminant and sampling requirements for biological tests.

Offshore disposal sites are identified and designated by the US EPA using a combination of the MPRSA and National Environmental Policy Act (NEPA) criteria. However, the permitted use of designated disposal sites under these laws is not usually associated with the designation of the sites. To be eligible to use an offshore (i.e., federal waters) disposal site for dredged materials, project proponents must demonstrate: (1) that there are no reasonable and practical alternative disposal options available and; (2) that the sediments are compatible with natural sediments at the disposal site and are not likely to disrupt or degrade natural habitats and/or biotic communities (USEPA 2005b). Dredge material disposed at sites managed under the MPRSA must meet Ocean Dumping Ban Act criteria, which do not permit disposal of contaminated dredged material (USEPA 2005b).

### *Burial/disturbance of benthic habitat*

Studies using sidescan sonar and bottom video have been used to distinguish natural sediment character and evidence of past dumping of mud and boulders on sand bottom (Buchholtz ten Brink et al. 1996). These studies have indicated that not only have dumped materials disturbed and altered benthic habitats, but that in some cases (such as on Stellwagen Basin) the material dumped in the past was scattered far from the intended target areas (Buchholtz ten Brink et al. 1996). The discharge of dredged material disturbs benthic and pelagic communities during and after disposal. The duration and persistence of those impacts to the water column and seafloor are related to the grain size and specific gravity of the dredge spoil. Impacts to benthic communities are identified and assessed in the site designation documents (Battelle 2004; URI 2003), which may include benthic communities being buried and smothered and the physicochemical environment in which they reside being altered.

However, Rhoads and Germano (1982, 1986) and Germano et al. (1994) note that recolonization of benthic infauna at a disposal site following dumping often leads to increased occurrences of opportunistic species (Stage I), which are then heavily preyed upon by Stage II and III (e.g., target fisheries) species. According to these studies, this plethora of prey, resulting from the disturbance of the community structure, can at least temporarily increase the productivity at the disposal site. However, chronic disturbance from repeated disposal may prevent Stage III communities from establishing (Germano et al. 1994).

### *Conversion of substrate/habitat and changes in sediment composition*

Dumping dredged materials results in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. The discharges can adversely affect infauna, including benthic and epibenthic organisms at and adjacent to the disposal site by burying immobile organisms or forcing motile organisms to migrate from the area. Benthic infauna species that have greater burrowing capabilities may be better able to extricate themselves from the overburden of sediment. Seasonal constraints on dredging and disposal not withstanding, it is assumed that there is a cyclical and localized reduction in the populations of benthic organisms at a disposal site. Plants and benthic infauna present prior to a discharge are unlikely to recolonize if the composition of the deposited material is significantly different (NEFMC 1998). Altered sediment composition at the disposal site may reduce the availability of infaunal prey species, leading to reduced habitat quality (Wilber et al. 2005).

### *Siltation, sedimentation, and turbidity*

Increased suspended sediment released during the discharge process and the associated increase in turbidity may hinder or disrupt activities in the pelagic zone (i.e., predator–prey relationships and photosynthesis rates). It has been estimated that less than 5% of the material in each disposal vessel is unaccounted for during and after the disposal activity (Bohlen et al. 1996), but the specific volume is influenced by both mechanical and sediment characteristics.

The discharge of dredged material usually results in elevated levels of fine-grained mineral particles, usually smaller than sand (i.e., silt/clay), and organic particles being introduced into the water column (i.e., suspended sediment plumes). The suspended particulates reduce light penetration, which affects the rate of photosynthesis and the primary productivity of an aquatic area. Typically, the suspended materials are dispersed and diluted to levels approaching ambient within 1-4 hours of the release (Bohlen et al. 1996). However, the turbidity plume resulting from a discharge can last much longer, particularly near the bottom, if the dredge material is composed of fine-grain material. In the plume field, living marine resources may experience either reduced or enhanced feeding ability as a result of the disruption of water clarity, depending upon the predator-prey relationships and the type(s) of avoidance/feeding methodologies used by the species. For instance, summer flounder (*Paralichthys dentatus*) and bluefish (*Pomatomus saltatrix*) are sight feeders and avoid areas with reduced water clarity resulting from suspended sediment such as might be found at a dredging or disposal site (Packer et al. 1999). Conversely, recent deposits of sediment at dumpsites have been reported to act as an attractant for other species of fish and crustaceans such as winter flounder (*Pseudopleuronectes americanus*) and American lobster (*Homarus americanus*) even though winnowing of fine-grained material from the excavation site or deposit mound was ongoing at the site (USACE 2001).

Generally, the severity of the effects of suspended sediments on aquatic organisms increases as a function of the sediment concentration and the duration of exposure (Newcombe and Jensen 1996). Some of the effects of suspended sediments on marine organisms can include altered foraging patterns and success (Breitburg 1988), gill abrasion and reduced respiratory functions, and death (Wilber and Clark 2001). The sensitivity of species to suspended sediments is highly variable and dependent upon the nature of the sediment and the life history stage of the species. Mortality caused by suspended sediments for estuarine species have been reported from less than 1000 mg/L for 24 hours in highly sensitive species (e.g., Atlantic silversides [*Menidia menidia*], juvenile bluefish [*Pomatomus saltatrix*]) to greater than 10,000 mg/L for 24 hours in tolerant species (e.g., mummichog [*Fundulus heteroclitus*], striped killifish [*Fundulus majalis*], spot [*Leiostomus xanthurus*], oyster toadfish [*Opsanus tau*], hogchoker [*Trinectes maculates*]) (Wilber and Clark 2001). The egg and larval stages of marine and estuarine fish exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages studied (Wilber and Clark 2001). Impacts that have been identified for demersal eggs of fish from sedimentation and suspended sediments include delayed hatching and decreased hatching success (Wilber and Clark 2001; Berry et al. 2004). The development of larvae may be delayed or altered after exposure of elevated suspended sediments, and increased mortality rates in the larvae of some species, such as striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*), have been reported with exposure of suspended sediment concentrations less than or equal to 500 mg/L for 3 to 4 days (Wilber and Clark 2001).

The effects of sedimentation on benthic organisms can include smothering and decreased gas exchange, toxicity from exposure to anaerobic sediments, reduced light intensity, and physical abrasion (Wilber et al. 2005). Mobile benthic species that require coarse substrates, such as gravel or cobble (e.g., American lobster) may be forced to seek alternate habitat that is less optimal or compete with other species or individuals for suitable habitat (Wilber et al. 2005). Messieh et al. (1981) investigated sedimentation impacts on Atlantic herring in laboratory experiments and found increased mortality in herring eggs, early hatching and shorter hatching lengths, and reduced feeding success in herring larvae leading to stunted growth and increased mortality.

Although there is generally a consensus among scientists and resource managers that elevated suspended sediments and sedimentation on benthic habitat caused by dredging and disposal of dredge spoils result in adverse impacts to marine organisms, the specific effects on biological communities need to be better quantified. Additional research is needed to investigate dose-response models at scales appropriate for dredging and disposal and for appropriate species and life history stages (Wilber et al. 2005).

### *Release of contaminants*

Dredged material suspended in the water column can react with the dissolved oxygen in the water and result in localized depression of the oxygen level. However, research has indicated that reductions in dissolved oxygen levels during offshore sediment disposal is not appreciable or persistent in the general sediment classes found in the northeast region (USACE 1982; Fredette and French 2004; USEPA 2004).

In certain situations, trace levels of toxic metals and organics, pathogens, and viruses adsorbed or adhered to fine-grained particulates in the dredged material may become biologically available to organisms either in the water column or through food chain processes. Some of these pollutants and their concentrations are evaluated during project-specific sediment testing required under the MPRSA and CWA. Adverse chemical effects at the disposal site can be minimized through the sediment testing requirements under the MPRSA and CWA, since the discharge of potentially toxic materials are generally prohibited. Risk assessment approaches are used to further evaluate potential impacts using results from the MPRSA and CWA bioaccumulation and toxicity testing. In addition, monitoring is conducted to ensure that the biological and ecological functions and values are maintained within the site, notwithstanding the physical impacts associated with continued use of the site. However, some discharges of contaminated material may be permitted under CWA disposal regulations, if the sediments meet minimum testing criteria or the toxic affects can be managed by capping with clean material.

Fredette and French (2004) concluded that, after thirty-five years of monitoring and research, dredged material evaluated through preproject testing and deposited in properly located ocean disposal sites will remain where it is placed and have no unacceptable adverse effects on nearby marine resources. Furthermore, they concluded that the only discernible adverse impacts were near-field and short-term. These determinations were based on the magnitude of disposal activity relative to natural (e.g., storms) and other anthropogenic (e.g., outfalls) impacts (Rhoads

1994; Rhoads et al. 1995) and the low level of disposal-related impacts that have been documented (Fredette et al. 1993).

### *Changes in bottom topography, altered hydrological regimes, and altered current patterns*

A concern often raised is the stability of dredge spoil sediments placed on the seafloor. Because ocean disposal sites are typically located in low current areas with water depths in excess of the active erosion zone, the material is generally contained within the disposal site. However, before 1985, dredged material sites were occasionally located in water depths insufficient to retain materials placed there (USEPA 1986). For example, the Mud Dump Site, located in the New York Bight Apex slope area off New York Harbor, contains water depths as shallow as 15 m and the site experienced extensive erosion by a nor'easter storm in October 1992 (USEPA 1997). Reclassified as a remediation site in 1997, the site is now known as the Historic Area Remediation Site (HARS). Erosion was reported at depths of 26 m, and the winnowed sediment included grain sizes up to small cobble. Fortunately, much of the sediment was relocated into deeper portions of the site westward of the erosion field (USEPA 1997). More comprehensive evaluation protocols have been put into place since 1985 to prevent dredged or fill material discharged at authorized sites from modifying current patterns and water circulation by obstructing the flow, changing the direction or velocity of water flow and circulation, or otherwise significantly altering the dimensions of a water body.

The USACE utilizes more than twenty selected or designated offshore dredged material disposal sites in the northeast region of the United States. Several of these sites have been used because they are dispersive in nature. These sites are used, normally, to put littoral material back into the nearshore drift pattern. The containment sites have an average size of 1.15 square nautical miles in size (USACE 2005b). By law and regulation, the significant adverse effects of dredged material disposal activities must be contained within the designated or selected disposal site and even those impacts must not degrade the area's overall ecological health. There is some dispersion of fine-grained sediments and contaminants outside the sites. Each site is required to have and be managed under a dredged material monitoring and management plan that assesses the health and well-being of the site and surrounding environment. Monitoring of disposal sites is a part of these plans, which is designed to ensure that any degradation of resources or alteration in seafloor characteristics are identified and would illicit actions by permitting agencies (USEPA 2004).

### *Release of nutrients/eutrophication*

Nutrient overenrichment, or eutrophication, is one of the major causes of aquatic habitat decline associated with human activities (Deegan and Buchsbaum 2005). There are point sources of nutrients, such as sewage treatment outfalls, and nonpoint sources, such as urban storm water runoff, agricultural runoff, and atmospheric deposition, which have been discussed in other chapters of this report. Elevated levels of nutrients have undesirable effects, including: (1) increased incidence, extent, and persistence of blooms of noxious or toxic species of phytoplankton; (2) increased frequency, severity, spatial extent, and persistence of hypoxia; (3) alterations in the dominant phytoplankton species, which can reduce the nutritional and biochemical nature of primary productivity; and (4) increased turbidity levels of surface waters, leading to reductions in submerged aquatic vegetation (O'Reilly 1994).

Sediment particles can bind to some nutrients, and resuspension of sediments following dredge material disposal can cause a rapid release of nutrients to the water column (Lohrer and Wetz 2003). Ocean disposal of dredge material with high organic content can result in oxygen reduction (hypoxia) or even anaerobic conditions (anoxic) on the bottom and overlaying waters, particularly during periods when strong thermoclines are present (Kurland et al. 1994). Hypoxic and anoxic conditions can kill benthic organisms or even entire communities and lead to a proliferation of stress-tolerant species of reduced value to the ecosystem (Kurland et al. 1994). Generally, offshore waters are less sensitive to disposal of dredge material containing nutrients than inshore, enclosed water bodies.

Both the MPRSA and CWA regulations prohibit the discharge of dredge material containing high organic content and nutrient levels if the discharge results in adverse effects to the marine environment. However, prior to the stricter regulations instituted in the 1980s, the discharge of sewage sludge was permitted for decades in nearshore and offshore waters of many urbanized centers of the northeastern US coast (Barr and Wilk 1994).

### *Conservation measures and best management practices for dredge material disposal*

1. Ensure that all options for disposal of dredged materials at sea are comprehensively assessed. The consideration of upland alternatives for dredged material disposal sites must be evaluated before offshore sites are considered.
2. Ensure that adequate sediment characterizations are completed and available for making informed decisions.
3. Ensure that adequate resource assessments are completed and available during project evaluation.
4. Employ sediment dispersion models to characterize sediment resuspension and dispersion during operations. Use model outputs to design disposal operations, including measures to avoid and minimize impacts from suspended sediment and turbidity on living marine resources. Sediment dispersion models should be field-verified to various sediment and hydraulic conditions to ensure they have been calibrated appropriately to predict sediment transport and dispersion.
5. Consider "beneficial uses" of dredged material, as appropriate.
6. Ensure that the site evaluation criteria developed for selection or designation of dredged material disposal sites have been invoked and evaluated, as appropriate.
7. Avoid dredged material disposal activities in areas containing sensitive or unique marine benthic habitats (e.g., spawning and feeding sites, surface deposits of cobble/gravel substrate).
8. Employ all practicable methods for limiting the loss of sediment from the activity. Consider closed or "environmental" buckets, when appropriate.
9. Ensure that disposal sites are being properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material.
10. Use sequential dredging to avoid dredging activity during specific time periods in particularly environmentally sensitive areas of large navigation channel dredging projects. This can avoid turbidity and sedimentation, bottom disruption, and noise in sensitive areas used by fishery resources during spawning, migration, and egg development.
11. Require appropriate monitoring to avoid and minimize individual and cumulative impacts of the disposal operations.
12. Use seasonal restrictions when appropriate to avoid temporary impacts to habitat during critical life history stages (e.g., spawning, egg and embryo development, and juvenile growth). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. Resource managers should incorporate

adequate time for habitat recovery of affected functions and values to levels required by managed species.

# Fish Waste Disposal

## *Introduction*

Fish waste or material resulting from industrial fish processing operations from either wild stocks or aquaculture consists of particles of flesh, skin, bones, entrails, shells, or process water (i.e., liquid “stickwater” or “gurry”). The organic components of fish waste have a high biological oxygen demand and, if not managed properly, can pose environmental and health problems. Generally, the solid wastes make up 30-40% of total production, depending on the species processed (IMO 2005a). Most fish wastes degrade rapidly in warm weather and can cause aesthetic problems and strong odors as a result of bacterial decomposition if not stored properly or disposed of quickly. Because these waste streams are generally required to be pretreated and fully processed on-site, disposed at a suitable upland site, or sent through municipal sewage treatment, at sea disposal is no longer widely employed in the northeastern United States. However, these materials are sometimes discharged at sea, when appropriate.

Permitting of at sea disposal should be coordinated with appropriate federal and state agencies. Processors should contact the US EPA to determine whether federal permits are necessary for the activity. In order to determine if a federal permit applies, the US EPA must determine if the material constitutes an environmental risk or is a traditional and acceptable "fish waste" disposal defined under Section 102(d) of the Ocean Dumping Ban Act, 33 U.S.C. Part 1412(d) and the regulations promulgated at 40 C.F.R. Part 220. Generally, permits are not required for the transportation or the ocean disposal of fish waste unless: 1) disposal is proposed in harbors or other protected and enclosed waters, and the location is deemed by the EPA as potentially endangering human health, the marine environment or ecological systems; or 2) the waste contains additives or disinfectants from the processing or treatment. In these cases, National Pollutant Discharge Elimination System (NPDES) permits may be required if chlorine or other similar chemicals are used. If an environmental or human health risk is determined, the applicant may be required to submit an assessment of the disposal area and potential impacts to marine resources and follow disposal guidelines consistent with the provisions of the London Convention 1972 (IMO 2005a). Permits required for ocean disposal of fish wastes define the discharge rate of the fluids, residual tissue, and hard part pieces by using a dispersion model. Inputs to the model include discharge flow rate, tissue dimensions, mixing rates, local current patterns, and the specific gravity of the solids (USEPA 2005c). The US EPA may also consult with applicable federal and state regulatory and resource agencies and regional fisheries councils, to identify any areas of concern with respect to the disposal area and activity. Persons wishing to dispose of fish wastes in the ocean may be required to submit specific dilution modeling in support of the proposed disposal and participate in monitoring to verify the results of the modeling (USEPA 2005c).

Bivalve shells, when brought ashore and processed, are not allowed to be returned to the ocean for the purpose of waste disposal. Reuse of the shells as “cultch” in oyster farming operations is a standard, traditional fishing practice in the northeastern United States and does not require permitting, but prior to disposal the shells may be required to meet water quality criteria, principally regarding residual tissue volume.

The guidelines established by the London Convention 1972 place emphasis on progressively reducing the need to use the sea for dumping of wastes. Implementation of these guidelines and the regulations promulgated by US EPA for the disposal of fish wastes includes consideration of potential waste management options that reduce or avoid fish waste to the disposal stream. For example, applications for disposal should consider reprocessing to fishmeal, composting, production of silage (i.e., food for domestic animals/aquaculture), use in biochemical industry products, use as fertilizer in land farming, and reduction of liquid wastes by evaporation (IMO 2005a).

### *Introduction of pathogens*

Ocean disposal of fish wastes has the potential to introduce pathogens to the marine ecosystem that could infect fish and shellfish. In particular, aquaculture operations that raise nonnative species or those that provide food to animals derived from nonindigenous sources could introduce disease vectors to native species (IMO 2005a). However, the disposal guideline provisions implemented as part of the Ocean Dumping Ban Act is designed to ensure wide dispersion of the gurry and limited accumulation of soft parts waste on the sea floor. Models developed to predict the effects of authorized discharges of fish wastes were designed to avoid the accumulation of biodegradable materials on the seafloor and introduction of pathogens.

### *Release of nutrients/eutrophication*

The organic components of fish wastes have a high biological oxygen demand (BOD) and if not managed properly could result in nutrient over-enrichment and reductions in the dissolved oxygen. In ocean disposal, these affects may be seen with mounding of wastes, subsequent increases in BOD and contamination with bacteria associated with partly degraded organic wastes (IMO 2005a). However, disposal guidelines require that dumpsite selection criteria maximizes waste dispersion and consumption of the wastes by marine organisms.

### *Release of biosolids*

Generally, the solid wastes generated by fish waste disposal comprises approximately 30-40% of total production, depending upon the species processed (IMO 2005a). Biosolid waste at fish disposal sites could result in nutrient over-enrichment and reduced dissolved oxygen concentration. However, the disposal guideline provisions implemented as part of the Ocean Dumping Ban Act require wide dispersion of the gurry and limited accumulation of soft parts waste on the sea floor.

### *Alteration of benthic habitat*

Ocean disposal of fish wastes that fail to meet permit conditions and guidelines have the potential to degrade fishery habitat by adversely affecting the productivity and ecological functions of the benthic community. Concentration and mounding of wastes can increase the BOD and reduce dissolved oxygen concentration of an area resulting in reductions in the ability to support small consumer organisms such zooplankton and amphipods. This can then affect species at higher trophic levels that depend upon these consumers for food. However, disposal guidelines require dump-site selection criteria that maximize waste dispersion and consumption of the wastes by marine organisms and disposal monitoring that ensures permit conditions are met (USEPA 2005c). In addition, guidelines and permit review must consider chemical contamination of the marine environment from the waste disposal. For example, the potential presence of chemicals used in aquaculture and fish wastes subjected to chemical treatment must be assessed prior to disposal (IMO 2005a).

### *Behavioral effects*

The presence of biodegradable tissue in the water column has the potential to alter the behavior of organisms in various ways, such as causing an attractant source for scavengers. This could alter the diet of individuals and interfere with trophic-level energy dynamics and community structure. The discharge of process water and biosolid wastes should be monitored carefully to ensure conditions within state and federal permits are met.

### *Conservation measures and best management practices for disposal of fish wastes*

1. Consider the practical availability of alternative methods of disposal to reuse, recycle, or treat the waste as a comparative risk assessment involving both ocean dumping and alternatives.
2. Perform site assessments of the proposed ocean disposal location prior to dumping, including the water depths, average velocities of tidal and nontidal currents, prevailing winds throughout the year, sediment and benthic habitat types, and nature of the sea floor (depositional versus dispersive). Information collected in the site assessment will be used in predictive models developed for the waste disposal activities. Existing uses of the site should be assessed, such as commercial and recreational fishing and whale watching vessels.
3. Use predictive models for plume dispersion and waste settlement based upon physical dynamics of the disposal area, nature of the fish waste, and the method of disposal. The models should be used to assess the probability of the waste plume reaching nearshore coastal waters or other protected areas, such as marine sanctuary waters. The models should also estimate the mass flux of nitrogen and organic carbon associated with the proposed discharges on a daily and annual basis, and how this input may affect phytoplankton production and benthic communities.
4. Dispose material at a steady rate while the vessel maintains headway speed (e.g., 3 nautical miles per hour) as opposed to dumping the entire load at once in a fixed location in order to provide better dilution of fish waste.
5. Grind organic materials to appropriate sizes (e.g., 0.5 inch) prior to discharge where they will be consumed or degraded in the water column dispersion field during and subsequent to their discharge. The intent should be to avoid water quality degradation and tissue deposition and accumulation on the seafloor.
6. Ensure that the waste will be rendered biologically inert during its residence time in the water column and avoid adverse effects on water quality, including reductions in dissolved oxygen concentrations and nutrient over-enrichment.
7. Require monitoring of the waste plume during and after discharge to verify model outputs and advance the knowledge regarding the practice of at-sea disposal of fish processing wastes.

## Vessel Disposal

### *Introduction*

When vessels are no longer needed, there are several options for their disposition, including reuse of the vessel or parts of the vessel, recycling or scrapping, creating artificial reefs, and disposal on land or sea (USEPA 2006). This section discusses the potential habitat and marine fisheries impacts associated with disposal at sea.

The disposal of vessels in the open ocean is regulated by the US EPA under section 102(a) of the MPRSA (Ocean Dumping Ban Act) and under 40 CFR § 229.3 of the US EPA regulations. In part, these regulations require that (1) vessels sink to the bottom rapidly and permanently and that marine navigation is not otherwise impaired by the sunk vessel; (2) all vessels shall be disposed of in depths of at least 1,000 fathoms (6,000 feet) and at least 50 nautical miles from land; and (3) before sinking, appropriate measures shall be taken to remove to the maximum extent practicable all materials which may degrade the marine environment, including emptying of all fuel tanks and lines so that they are essentially free of petroleum and removing from the hulls other pollutants and all readily detachable material capable of creating debris or contributing to chemical pollution.

The US EPA and US Department of Transportation Maritime Administration have developed national guidance, including criteria and best management practices for the disposal of ships at sea when the vessels are intended for creation or addition to artificial reefs (USEPA 2006). Vessels disposed of to create artificial reefs have historically been designed and intended to enhance fishery resources for recreational fishermen. However, in recent years artificial reefs have been constructed for a number of nonextractive purposes such as: (1) recreational SCUBA diving opportunities; (2) socioeconomic benefits to local coastal communities; (3) increase habitat to reduce user pressure on nearby natural reefs; (4) reduce user conflicts (e.g., diving in heavily fished areas), and; (5) provide mitigation or restoration to habitat loss for commercial activities (e.g., beach nourishment, dredging, pipeline routes) (NOAA 2007). Some vessels may be sunk to provide a combination of these purposes. Vessels prepared for use as artificial reefs should: (1) be "environmentally sound" and free from hazardous and potentially polluting materials; (2) have had resource assessments for the disposal locations conducted to avoid adverse impacts to existing benthic habitats; and (3) have had stability analyses for the sinking and the ship's ultimate location conducted to ensure there is minimal expectation of adverse impacts on adjacent benthic habitats. Several guidance documents have been developed for the planning and preparation of vessels as artificial reef material, including the National Artificial Reef Plan (NOAA 2007), Coastal Artificial Reef Planning Guide (ASMFC and GSMFC 1998), the Guidelines for Marine Artificial Reef Materials (ASMFC and GSMFC 2004), and the National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs (USEPA 2006). These documents should be consulted to ensure that conflicts with existing uses of the potential disposal site/artificial reef site are addressed and that materials onboard the vessel do not adversely impact the marine environment. Section 203 of the National Fishing Enhancement Act of 1984 (Title II of P.L. 98-623, Appendix C) established that artificial reefs in waters covered under the Act shall "be sited and constructed, and subsequently monitored and managed in a manner which will: (1) enhance fishery resources to the maximum extent practicable; (2) facilitate access and utilization by US recreational and commercial fishermen; (3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters; (4) minimize environmental risks and risks to personal health and property; and (5) be consistent with generally accepted principles of international law and shall not create any unreasonable obstruction to navigation."

The appropriate siting is vital to the overall success of an artificial reef. Considerations and options for site placement and function in the environmental setting should be carefully weighed to ensure program success. Since placement of a reef involves displacement and disturbance of the existing habitat, and building the reef presumably accrues some benefits that could not exist in the absence of the reef, documentation of these effects should be brought out in the initial steps to justify artificial reef site selection. Placement of a vessel to create an artificial reef should: (1) enhance and conserve targeted fishery resources to the maximum extent practicable; (2) minimize conflicts among competing uses of water and water resources; (3) minimize the potential for environmental risks related to site location; (4) be consistent with international law and national fishing law and not create an obstruction to navigation; (5) be based on scientific information; and (6) conform to any federal, state, or local requirements or policies for artificial reefs (USEPA 2006).

The Coastal Artificial Reef Planning Guide (ASMFC and GSMFC 1998) state that when an artificial reef has been constructed, another important phase of reef management begins: monitoring and maintenance. Monitoring provides an assessment of the predicted performance of reefs and assures that reefs meet the general standards established in the Section 203 of the National Fishing Enhancement Act as listed above. It also ensures compliance with the conditions of any authorizing permits. Artificial reef monitoring should be linked with performance objectives, which ensures that NOAA National Marine Fisheries Service responsibilities to protect, restore, and manage living marine resources, and to avoid and minimize any adverse effects on these resources are fulfilled.

### *Release of contaminants*

Ships disposed of at sea, including those intended to create artificial reefs, are often military and commercial vessels which typically contain various materials that, if released into the marine environment, could have adverse effects on the marine environment. Some of the materials of concern include fuels and oil, asbestos, polychlorinated biphenyl (PCB), paint, debris (e.g., vessel debris, floatables, introduced material), and other materials of environmental concern (e.g., mercury, refrigerants) (USEPA 2006). Depending upon the nature of the contaminant and the concentration and duration of the release of contaminant(s) adverse effects to marine organisms may be acute or chronic and either lethal or sublethal. Some contaminants, such as PCB and mercury, can be persistent and bioaccumulate in the tissues of organisms resulting in more serious impacts in higher trophic level organisms. The Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels prohibit materials containing contaminants which may impact the marine environment. The guidance documents provide detailed best management practices regarding recommended measures to remove and abate contaminants contained within and as part of a vessel.

### *Release of debris*

Debris, including solids and floatables, are materials that could break free from a vessel during transportation to the disposal site, and during and after sinking. The release of debris can adversely affect the ecological and aesthetic value of the marine environment. Debris released from vessels is generally categorized into vessel debris (material that was once part of the vessel) and clean-up debris (material that was not part of the vessel but was brought on board the vessel during preparation for disposal).

Some debris released from vessels is not highly degradable and can be persistent in the marine environment for long periods of time, increasing the threat it poses to the environment. Some of the impacts associated with debris include: (1) entanglement and/or ingestion, leading to injury, infection, or death of marine animals that may be attracted to or fail perceive the debris in the water; (2) alteration of the benthic floral and faunal habitat structure, leading to injury or mortality or indirect impact to other species linked in the benthic food web and; (3) elevation of the risk of spills and other environmental impacts caused by impacts with other vessels (e.g., hull damage, damage to cooling or propulsion systems) (USEPA 2006). The Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels require all debris to be removed from vessels prior to sinking. The guidance documents provide detailed best management practices regarding recommended measures to remove vessel and clean-up debris.

### *Conversion of substrate/habitat and changes in community structure*

Vessels that are sunk for the purpose of discarding obsolete or decommissioned ships, as well as those sunk to create an artificial reef, can convert bottom habitat type and alter the ecological balance of marine communities inhabiting the area. For example, placement of vessels over sand bottom can change niche space and predator/prey interactions for species or life history stages utilizing that habitat type. Large structures such as ships tend to attract adult fish and larger predators, which may increase predation rates on smaller and juvenile fish or displace smaller fish and juveniles to other areas (USEPA 2006). Large, anthropogenic structures, such as oil and gas platforms in the Gulf of Mexico, have been shown to affect the distribution of larval and juvenile fish (Lindquist et al. 2005). In addition, large structures tend to provide proportionally less shelter for demersal fishes and invertebrates than smaller, lower profile structures, while the surfaces of steel hull vessels are less ideal for colonization by epibenthos than are natural surfaces like rock (ASMFC and GSMFC 2004). Certain types of habitat and areas may be more susceptible to physical and chemical impacts from the placement of vessels, particularly those vessels sunk as artificial reefs. Generally, vessels sunk for disposal only are located in deeper water (> 6,000 feet) and very far offshore (> 50 nautical miles from land) and may have less impacts on sensitive benthic habitats. However, vessels sunk as artificial reefs are usually located in nearshore coastal waters that also support or are frequented by marine resources that may be adversely impacted by the placement of the structure. Artificial reefs should not be sited in sensitive areas that contain coral reefs or other reef communities, submerged aquatic vegetation, or habitats known to be utilized by endangered or threatened species (USEPA 2006). The Ocean Dumping Ban Act prohibits vessel disposal in areas that may adversely effect the marine environment.

### *Changes in bathymetry and hydrodynamics*

The location of a vessel on the ocean bottom will change the bathymetry and can potentially alter the current flow of the disposal area. A proposed disposal site should be assessed as to the effects the vessel disposal and subsequent bathymetry change may have on the hydrodynamics and geomorphology of the immediate and adjacent habitats. For example, even small vessels placed on the bottom can alter currents and create turbulence around the vessel that may scour existing soft substrates and adversely affect adjacent habitats and communities. In addition, the high vertical profile may cause some vessels to be prone to movement and structural damage from ocean currents and wave surge during storm events. For example, during Hurricane Andrew, a category 5 storm, in south Florida during 1992, nearly all steel-hulled vessels sunk as artificial reefs in the area of the storm's path sustained structural damage, and a number moved 100-700 m because of the storm surge (ASMFC and GSMFC 2004). The movement of vessels after disposal can impact adjacent habitats and relocate the vessels to areas that could alter the ecological balance of marine communities in the area. In addition, reductions in navigational clearance, either as a result of the vessel being sunk in the wrong location and in an area too shallow or because later movement of the vessel from storm surge or currents may increase the potential danger to vessel navigation (e.g., hull damage, damage to cooling or propulsion systems) which may cause further damage from oil/fuel spills or groundings (ASMFC and GSMFC 2004). To minimize the risk of alterations to the bathymetry and hydrodynamics of the disposal area and vessel movement, the Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels require a number of evaluations prior to dumping activities, including: (1) stability analyses; (2) assessments of the seabed, including topography and geological characteristics and; (3) assessment of mean direction and velocity of currents and storm-wave induced bottom currents (ASMFC and GSMFC 2004; IMO 2005b).

### *Deployment impacts*

Some risks to the marine environment exist during the deployment (i.e., sinking) of vessels for disposal or as an artificial reef. Some potential impacts that may occur during deployment include the release of contaminants accidentally left onboard the vessel, damage to adjacent benthic habitats from anchors and cables used to maintain the vessel position as it sinks, impacts to benthic habitats from a vessel accidentally sinking in an unintended location while being towed or from movement of the ship after deployment (ASMFC and GSMFC 2004). However, careful planning during the assessment stages and adherence to operational protocols can avoid impacts during deployment.

### *Conservation measures and best management practices for disposal of vessels*

1. Require that a vessel disposal site assessment adequately characterize the physical and biological environment of the site. In addition to identifying the habitat types and species utilizing the area and targeted for enhancement, ecological investigations should include community settlement and recruitment and predator/prey dynamics and anticipated changes in competition and niche space as a result of the vessel disposal (USEPA 2006).
2. Identify the locations of any sensitive marine habitats in the area. Potential vessel disposal sites should generally not be located near any of the following marine resources: coral reefs; significant beds of aquatic vegetation or macroalgae; oyster reefs; scallop, mussel, or clam beds; existing live bottom (i.e., marine areas supporting sponges, sea fans, corals, or other sessile invertebrates generally associated with rock outcrops); and habitats of endangered or threatened species (federal and state listed) (USEPA 2006).
3. Conduct vessel stability analysis to ensure the vessel is retained in the intended location, including characterization of anticipated weather conditions, tidal dynamics, mean direction and velocity of surface and bottom drifts and storm-wave induced currents, and general wind and wave characteristics (IMO 2005b).
4. Ensure that a thorough inventory and assessment of all potential contaminants on the vessel are completed and that all preplacement cleaning and inspections are completed thoroughly and effectively.
5. Avoid the use of explosives to the extent possible in sinking vessels under 150 feet in length where alternate methods (e.g., opening seacocks, flooding with pumps, etc.) are feasible (ASMFC and GSMFC 2004).
6. Monitor the disposal operation and the placement site for adherence to permit compliance and performance objectives.
7. Ensure that physical and biological monitoring plans for vessels disposed of as artificial reefs are developed as appropriate and that monitoring and reporting requirements are met throughout the designed timeframe.

## References for Offshore Dredging and Disposal

[ASMFC], [GSMFC] Atlantic and Gulf States Marine Fisheries Commissions. 1998. Coastal artificial reef planning guide. Washington (DC): Joint Artificial Reef Technical Committee of the Atlantic and Gulf States Marine Fisheries Commissions. 45 p.

[ASMFC], [GSMFC] Atlantic and Gulf States Marine Fisheries Commissions. 2004. Guidelines for marine artificial reef materials, 2nd ed. Washington (DC): Subcommittees of the Atlantic and Gulf States Marine Fisheries Commissions. Number 121. 198 p.

Barr BW, Wilk SJ. 1994. Sewage sludge and industrial waste dumping. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 41-4.

Battelle. 2004. Designating an ocean disposal site for dredged material. [Internet]. Columbus (OH): Battelle Memorial Institute; [cited 2007 Dec 21]. Available from: http://www.battelle.org/Environment/publications/EnvUpdates/summer2004/article1.stm.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth flatfish biology conference-poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Bohlen WF, Howard-Strobel MM, Cohen DR, Morton ET. 1996. An investigation of the dispersion of sediments resuspended by dredging operations in New Haven Harbor. Waltham (MA): New England Division, US Army Corps of Engineers. DAMOS Contribution #112. 12 p + appendices.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Burlas M, Ray GL, Clarke D. 2001. The New York District's biological monitoring program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section beach erosion control project. [Internet]. Final Report. Vicksburg (MS): US Army Corps of Engineers, New York and US Army Engineer Research and Development Center, Waterways Experiment Station. [cited 2007 Dec 21]. Available from: http://www.nan.usace.army.mil/business/prjlinks/coastal/asbury/index.htm.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New

England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Drucker BS, Waskes W, Byrnes MR. 2004. The US Minerals Management Service outer continental shelf sand and gravel program: environmental studies to assess the potential effects of offshore dredging operations in federal waters. Journal of Coastal Research 20(1):1-5.

Fredette TJ, French GT. 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Marine Pollution Bulletin 49(1-2):93-102.

Fredette TJ, Kullberg PG, Carey DA, Morton RW, Germano JD. 1993. Twenty-five years of dredged material disposal site monitoring in Long Island Sound: a long-term perspective. In: Van Patten MS, editor. Proceedings of the Long Island Sound Research Conference; 1992 Oct 23-24; New Haven, CT. Groton (CT): Connecticut Sea Grant Program, Publication No. CT-SG-93-03, p 153-61.

Germano JD, Rhoads DC, Lunz JD. 1994. An integrated, tiered approach to monitoring and management of dredged material sites in the New England region. Waltham (MA): US Army Corps of Engineers, New England Division. DAMOS Contribution No. 87, Report No. SAIC-90/7575&234. 55 p + appendices.

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hitchcock DR, Bell S. 2004. Physical impacts of marine aggregate dredging on seabed resources in coastal deposits. Journal of Coastal Research 20(1):101-114.

[ICES] International Council for the Exploration of the Sea. 1992. Report of the ICES working group on the effects of extraction of marine sediments on fisheries. Copenhagen (Denmark): ICES Cooperative Research Report # 182.

[IMO] International Maritime Organization. 2005a. Specific guidelines for assessment of fish wastes, or material resulting from industrial fish processing operations. [Internet]. London (England): IMO, Office for the London Convention 1972. [cited 2007 Dec 21]. 12 p. Available from: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D17022/3-FishWaste.pdf.

[IMO] International Maritime Organization. 2005b. Specific guidelines for assessment of vessels. [Internet]. London (England): IMO, Office for the London Convention 1972. [cited 2007 Dec 21]. 13 p. Available from: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D17023/4-Vessels.pdf.

Johnson SW, Stanley DR, Moles DA. 1998a. Effects of submarine mine tailings disposal on juvenile yellowfin sole (*Pleuronectes asper*): a laboratory study. Marine Pollution Bulletin 36(4):278-87.

Johnson SW, Stone RP, Love DC. 1998b. Avoidance behavior of ovigerous Tanner crabs (*Chionoecetes bairdi*) exposed to mine tailings: a laboratory study. Alaska Fishery Research Bulletin 5:39-45.

Kenny AJ, Rees HL. 1996. The effects of marine gravel extraction on the macrobenthos: results 2 years post-dredging. Marine Pollution Bulletin 32(8-9):615-22.

Kurland JM, Ludwig FM, Gorski SW, Mantazaris C. 1994. Dredging and dredged-material disposal. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 44-7.

Lindquist DC, Shaw RF, Hernandez FJ Jr. 2005. Distribution patterns of larval and juvenile fishes at offshore petroleum platforms in the north-central Gulf of Mexico. Estuarine, Coastal and Shelf Science 62(4):655-65.

Lohrer AM, Wetz JJ. 2003. Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek. Marine Pollution Bulletin 46(9):1156-63.

Malins DC, editor. 1977. Effects of petroleum on arctic and subarctic marine environments and organisms. New York (NY): Academic Press.

Messieh SN, Wildish DJ, Peterson RH. 1981. Possible impact from dredging and spoil disposal on the Miramichi Bay herring fishery. St. Andrews (New Brunswick): Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1008. iv + 33 p.

[MMS] Minerals Management Service. 2005a. Marine Minerals Program, offshore energy and minerals management. [Internet]. Herndon (VA): MMS, [updated 2007 Jun 28; cited 2007 Dec 21]. Available from: http://www.mms.gov/sandandgravel/.

[MMS] Minerals Management Service. 2005b. Offshore discharges from oil and gas development operations – FAQ. Gulf of Mexico Region, Offshore Information. [Internet]. New Orleans (LA): MMS. [updated 2001 June 6; cited 2007 Dec 21]. Available from: http://www.gomr.mms.gov/homepg/offshore/egom/factshee.html.

[NOAA] National Oceanic and Atmospheric Administration. 2007. National Artificial Reef Plan (as amended): guidelines for siting, construction, development, and assessment of artificial reefs. Washington (DC): US Department of Commerce, National Oceanic and Atmospheric Administration. 51 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Pacheco A. 1984. Seasonal occurrence of finfish and larger invertebrates at three sites in Lower New York Harbor, 1981-1982. Final report. Sandy Hook (NJ): NOAA/NMFS. Special report for USACE, New York District. 53 p.

Packer DB, Griesbach SJ, Berrien PL, Zetlin CA, Johnson DL, Morse WW. 1999. Essential fish habitat source document: summer flounder, *Paralichthys dentatus*, life history and habitat characteristics. [Internet]. Woods Hole (MA): NOAA, NMFS NER, NEFSC. NOAA Technical Memorandum NMFS-NE-151. [cited 2008 Jul 22]. 88 p. Available from: http://www.nefsc.noaa.gov/nefsc/publications/tm/tm151/tm151.pdf.

Palermo MR, Clausner JE, Rollings MP, Williams GL, Myers TE, Fredette TJ, Randall RE. 1998. Guidance for subaqueous dredged material capping. Vicksburg (MS): US Army Corps of Engineers, WES, Dredging Operations and Environmental Research (DOER). Technical Report DOER-1. 302 p.

Pearce JB. 1994. Mining of seabed aggregates. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum. NMFS-NE-106. p 48-50.

Rhoads DC. 1994. Analysis of the contribution of dredged material to sediment and contaminant fluxes in Long Island Sound. Special Technical Report. Waltham (MA): US Army Corps of Engineers, New England Division, Regulatory Division. DAMOS Contribution No. 88. 32 p.

Rhoads DC, Germano JD. 1982. Characterization of organism-sediment relations using sediment profile imaging: an efficient method of remote ecological monitoring of the seafloor (REMOTS ™ System). Marine Ecology Progress Series 8:115-28.

Rhoads DC, Germano JD. 1986. Interpreting long-term changes in benthic community structure: a new protocol. Hydrobiologia 142(1):291-308.

Rhoads DC, Kullberg PG, Fredette TJ. 1995. Dredged material disposal within an estuary: is it a significant source of sediment and contaminant fluxes? The case of Long Island Sound. In:

Knott MA, editor. Proceedings of the Conference for Ports '95, Volume 1; 1995 Mar 13-15; Tampa, FL. Reston (VA): American Society of Civil Engineers. p 428-39.

Scarrat DJ. 1987. Fisheries' interests and ocean mining. Marine Mining 6:141-7.

Stevenson DK, Scott ML. 2005. Essential fish habitat source document: Atlantic herring, *Clupea harengus*, life history and habitat characteristics (2nd ed). [Internet]. Woods Hole (MA): NOAA, NMFS, Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-NE-192. [cited 2008 Jul 22]. 94 p. Available from: http://www.nefsc.noaa.gov/nefsc/habitat/efh.

Stewart PL, Arnold SH. 1994. Environmental requirements Atlantic herring (*Clupea harengus harengus*) in eastern Canada and its response to human impacts. Dartmouth (Nova Scotia): Canadian Technical Report of Fisheries and Aquatic Sciences 2003: ix + 37p.

[URI] University of Rhode Island Coastal Institute. 2003. Designation of a long-term offshore disposal site for dredged material. [Internet]. [cited 2007 Dec 21]. Available from: http://www.ci.uri.edu/Projects/DD/.

[USACE] US Army Corps of Engineers. 1982. Final Supplemental Environmental Impact Statement for the designation of a disposal site for dredged material in Western Long Island Sound WLIS III. Waltham (MA): USACE, New England Division.

[USACE] US Army Corps of Engineers. 2001. Monitoring at the New London Disposal Site 1992-1998 Vol. I. [Internet]. Concord (MA): USACE, New England District. DAMOS Contribution No. 128, SAIC No. 515. [cited 2008 Jul 22]. 157 p + appendices. Available from: http://www.nae.usace.army.mil/damos/pdf/128.pdf.

[USACE] US Army Corps of Engineers. 2005a. HARS – Historic Area Remediation Site. [Internet]. [cited 2007 Dec 21]. Available from: http://www.nan.usace.army.mil/business/prjlinks/dmmp/benefic/hars.htm.

[USACE] US Army Corps of Engineers. 2005b. Managed dredged material disposal sites in the North Atlantic Division. [Internet]. [updated 2007 Apr 12; cited 2007 Dec 21]. Available from: http://www.nae.usace.army.mil/damos/maps.asp.

[USEPA] US Environmental Protection Agency. 1986. Ocean dumping site designation delegation handbook for dredged material. Washington (DC): US EPA Office of Marine and Estuarine Protection.

[USEPA] US Environmental Protection Agency. 1997. Supplemental to the Environmental Impact Statement on the New York dredged material disposal site designation for the designation of the Historic Area Remediation Site (HARS) in the New York Bight. New York (NY): US EPA.

[USEPA] US Environmental Protection Agency. 2003a. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: PAH mixtures. [Internet]. Washington (DC): US EPA Office of Research and

Development. Report No. EPA-600-R-02-013. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/PAHESB.pdf.

[USEPA] US Environmental Protection Agency. 2003b. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: dieldrin. [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-010. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/dieldrin.pdf.

[USEPA] US Environmental Protection Agency. 2003c. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: endrin. [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-009. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/endrin.pdf.

[USEPA] US Environmental Protection Agency. 2004. Rhode Island region long-term dredged material disposal site evaluation project. Boston (MA): US EPA, New England Region.

[USEPA] US Environmental Protection Agency. 2005a. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: metal mixtures (cadmium, copper, lead, nickel, silver, and zinc). [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-011. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/metalsESB_022405.pdf.

[USEPA] US Environmental Protection Agency. 2005b. Ocean dumping in the Southeast. [Internet]. [updated 2007 Nov 21; cited 2007 Dec 21]. Atlanta (GA): US EPA, Region 4. Available from: http://www.epa.gov/region4/water/oceans/.

[USEPA] US Environmental Protection Agency. 2005c. Disposal of fish waste. [Internet]. [updated 2007 Nov 1; cited 2007 Dec 21]. New York (NY): US EPA, Region 2. Available from: http://www.epa.gov/region2/water/oceans/fwaste.htm.

[USEPA] US Environmental Protection Agency. 2006. National guidance: best management practices for preparing vessels intended to create artificial reefs. [Internet]. Washington (DC): US EPA Office of Wetlands, Oceans, and Watersheds. EPA Report 842-B-06-002. [cited 2008 Jul 24]. 77 p. Available from: http://www.epa.gov/owow/oceans/habitat/artificialreefs/documents/0605finalreefguidance.pdf.

van Dalfsen JA, Essink K, Toxvig Madsen H, Birklund J, Romero J, Manzanera M. 2000. Differential responses of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. Copenhagen (Denmark): ICES Journal of Marine Science 57:1439-45.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center.

ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilber DH, Clarke DG, Ray GL, Burlas M. 2003. Response of surf zone fish to beach nourishment operations on the northern coast of New Jersey, USA. Marine Ecology Progress Series 250:231-46.

Wilk SJ, Barr BW. 1994. Multiple-use issues in estuarine and coastal habitat loss. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 51-3.

# CHAPTER SEVEN: CHEMICAL EFFECTS—WATER DISCHARGE FACILITIES

## Introduction

Disposal of various waste materials into rivers, estuaries, and marine waters is not a modern phenomenon; this practice has been used as a preferred disposal option virtually since the beginning of human civilization (Ludwig and Gould 1988; Islam and Tanaka 2004). Nevertheless, when the full spectrum of emissions from land-based activities is taken into account, the use of coastal waters as a repository for anthropogenic waste has not previously been practiced on as large or intense a global scale as in recent decades (Williams 1996). In the United States, growing human population densities in coastal communities have manifested a demonstrably adverse effect on aquatic resources. The scientific literature is replete with evidence of inorganic and organic pollutant accumulation in coastal waters from anthropogenic effluents (e.g., Ragsdale and Thorhaug 1980; Tessier et al. 1984; Phelps et al. 1985; Long E et al. 1995; Pastor et al. 1996; Smith et al. 1996; Chapman and Wang 2001; Hare et al. 2001; O'Connor 2002; Robinet and Fenteun 2002; Wurl and Obbard 2004). The federal Clean Water Act (CWA), enacted in 1972 to address many of these issues, eliminated certain types of disposal activities and otherwise induced improvements to the nation's surface water quality. Nonetheless, “despite reductions in pollution from municipal and industrial point sources more than one-third of the river miles, lake acres, and estuary square miles suffer [*sic*] some degree of impairment” (Ribaudo et al. 1999). To the extent that it may alter natural processes and natural resource communities, unabated degradation of the aquatic environment caused by a wide spectrum of human activities poses consequences for fishery resources and their habitats.

Contaminants enter our waterways through two generic vectors: point and nonpoint sources. Pollutants of nonpoint source origins tend to enter aquatic systems as relatively diffuse contaminant streams primarily from atmospheric and terrestrial sources (see Coastal Development chapter of this report for discussions on nonpoint source pollution). In contrast, point source pollutants generally are introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff in many urbanized portions of the northeastern United States are first intermingled and then subsequently released into aquatic habitats via combined sewer overflows (CSOs). Such point discharges collectively introduce a cocktail of inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

While all pollutants can become toxic at high enough levels, there are a number of compounds that are toxic even at relatively low levels. The US Environmental Protection Agency (US EPA) has identified and designated more than 126 analytes as “priority pollutants.” According to the US EPA, “priority pollutants” of particular concern for aquatic systems include: (1) dichlorodiphenyl trichloroethane (DDT) and its metabolites; (2) chlorinated pesticides other than DDT (e.g., chlordane and dieldrin); (3) polychlorinated biphenyl (PCB) congeners; (4) metals (e.g., cadmium, copper, chromium, lead, mercury); (5) polycyclic aromatic hydrocarbons (PAHs); (6) dissolved gases (e.g., chlorine and ammonium); (7) anions (e.g., cyanides, fluorides, and sulfides); and (8) acids and alkalis (Kennish 1998; USEPA 2003a). While acute exposure to these substances produce adverse effects of aquatic biota and habitats, chronic exposure to low concentrations probably is a more significant issue for fish population structure and may result in multiple substances acting in "an additive, synergistic or antagonistic manner" that may render impacts relatively difficult to discern (Thurberg and Gould 2005).

Determining the eventual fate and effect of naturally occurring and synthetic contaminants in coastal environments and biota is a highly dynamic proposition that requires interdisciplinary evaluation. It is essential that all processes sensitive to pollutants be identified and that investigators realize that the resulting adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Pollutant exposure can inhibit: (1) basic detoxification mechanisms, like production of metallothioneins or antioxidant enzymes; (2) the ability to resist diseases; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

The nature and extent of a pollutant's dispersal in our waterways are collectively dependent on a variety of factors including site-specific ecological conditions, the physical state in which the contaminant is introduced into the aquatic environment, and the inherent chemical properties of the substance in question. Soluble or miscible substances typically enter waterways in an aqueous phase and eventually become adsorbed onto organic and inorganic particles (Wu et al. 2005); however, contaminants may enter aquatic systems as either particle-borne suspensions or as solutes (Bishop 1984; Turner and Millward 2002). Dilution and settling out from such effluent streams initially are dictated by physical factors (e.g., the presence of significant currents or perhaps a strong thermocline or pycnocline) which predominantly influence the spatial extent of contaminant dispersal. In particular, turbulent mixing, or diffusion, disperses contaminant patches in coastal waters resulting in larger, comparatively diluted contaminant distributions further away from the initial point source (Bishop 1984). Biological activity and geochemical processes subsequently intercede and typically result in contaminant partitioning between the aqueous and particulate phases (Turner and Millward 2002).

While physical dispersion, biological activity, and other ecological factors clearly have important roles regarding the distribution of contaminants in aquatic habitats, contaminant partitioning is largely governed by certain ambient environmental conditions, notably salinity, pH, and the physical nature of local sediments (Turekian 1978; McElroy et al. 1989; Turner and Millward 2002; Leppard and Droppo 2003; Wu et al. 2005). Highly reactive suspended particles typically serve as important carriers of aquatic contaminants and largely are responsible for their bioavailability, transport, and ecological fate as they become dispersed in receiving waters (Turner and Millward 2002). In addition, hyporheic (i.e., the saturated zone under a river or stream, comprising substrate with the interstices filled with water) exchange between overlying water and groundwater can alter salinity, dissolved oxygen concentration, and other water chemistry aspects in ways that can influence the affinity of local sediment types for particular contaminants or otherwise affect contaminant behavior (Ren and Packman 2002).

Amendments to the CWA include important provisions to address acute or chronic water pollution emanating from discharge pipes and outfalls under the National Pollutant Discharge Elimination System (NPDES) program. Until the late 1980s, the NPDES program traditionally focused efforts on controlling industrial and municipal sewage discharges but has since expanded its purview to include storm water management (USEPA 1996). While the NPDES program has led to ecological improvements in waters of the United States, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels. Nonetheless, studies demonstrate that particle-associated contaminants collected in coastal depositional areas are preserved in chronological strata or horizons (Huntley et al. 1995; Chillrud et al. 2003). Consequently, historically deposited contaminants may be encountered when installing new outfalls or coastal infrastructure, especially near urbanized areas. Regardless of whether these pollutants were deposited recently or decades ago, dredging incidental to construction and related activities that enhance their potential biological availability can have adverse ecological implications.

The environmental dynamics of point source wastes are complex and involve a variety of physical, chemical, and biological processes simultaneously acting on the introduced suite of contaminants and their surrounding habitat. Because of the many competing variables involved, it is difficult to predict the ultimate fate and effects of anthropogenic wastes with great precision; however, local habitat characteristics in combination with the relative solubility, degree of hydrophobicity (i.e., tending to repel and not absorb water), and chemical reactivity of the introduced substances are important determining factors at the most basic level of analysis.

To minimize redundancy, all recommended conservation measures and best management practices for sewage discharge facilities, industrial discharge facilities, and combined sewer overflows have been included at the end of this chapter.

## Sewage Discharge Facilities

### *Introduction*

Sewage treatment plants introduce a host of contaminants into our waterways primarily through discharge of fluid effluents comprising a mixture of processed "black water" (sewage) and "gray water" (all other domestic and industrial wastewater). Such municipal effluents begin as a complex mixture of human waste, suspended solids, debris, and a variety of chemicals collectively derived from domestic and industrial sources. These contaminants include an array of suspended and dissolved substances, representing both inorganic and organic chemical species (Grady et al. 1998; Epstein 2002). These substances potentially include the full spectrum of EPA priority pollutants mentioned previously and many other contaminants of anthropogenic origin. However, the five constituents that are usually the most important in determining the type of treatment that will be required are: (1) organic content (usually measured as volatile solids); (2) nutrients; (3) pathogens; (4) metals; and (5) toxic organic chemicals (USEPA 1984).

Coastal communities rely on municipal wastewater treatment to contend with potential human health issues related to sewage and also to protect surface and groundwater quality. Municipal processing facilities typically receive raw wastewater from both domestic and industrial sources, and are designed to produce a liquid effluent of suitable quality that can be returned to natural surface waters without endangering humans or producing adverse aquatic effects (Grady et al. 1998; Epstein 2002). As it is currently practiced in the United States, wastewater treatment entails subjecting domestic and industrial effluents to a series of physical, chemical, or even biological processes designed to address or manipulate different aspects of contaminant mitigation. For both logistical and economic reasons, not all municipalities expend the same level of effort removing contaminants from their wastewater before returning it to a receiving aquatic habitat. The following discussion summarizes the different levels that municipal wastewater treatment and resulting water quality benefits derived from them.

Primary treatment, also known as "screen and grit," is only marginally effective at addressing sewage contaminants and simply entails bulk removal of "settleable" solids from the wastewater by sedimentation and filtration. Sometimes total suspended solids are further reduced in the initial effluent treatment phase by implementing another level of primary treatment, which entails using chemicals to induce coagulation and flocculation of smaller particles (Parnell 2003).

The resulting bio-solids must be disposed, and their final disposition could entail composting with subsequent use in agricultural applications, placement in a landfill, disposal at sea, or even incineration (Werther and Ogada 1999). Removal and appropriate disposal of sewage present in a solid phase are important steps, if elementary, in addressing human health and aesthetic issues surrounding sewage management because doing so removes visible substances that otherwise would accumulate in the aquatic environment at or near the discharge point. Unfortunately, primary treatment of municipal wastewater alone often fails to meet overall environmental goals of supporting important water-dependent uses like fishery resource production and recreational uses featuring primary contact with the water. As a consequence, coastal communities in the northeastern region process their wastewater through one or more additional treatment levels beyond bulk solids removal to address the environmental challenges of their sewage effluents more effectively.

Following bulk sludge removal, sewage treatment plants typically pass the highly organically-enriched water emerging from primary treatment through a second process that is intended to address biological oxygen demand (BOD), an indirect measure of the concentration of biologically degradable material present in organic wastes that reflects the amount of oxygen necessary to break down those substances in a set time interval. Such secondary treatment, which is required for all municipal wastewater treatment in the United States, involves removal of much of the remaining organic material by introducing aerobic microorganisms under oxygen-enriched conditions (Parnell 2003). The resulting microbial action breaks organic substrates into progressively simpler compounds, with the final waste components predominantly released as carbon dioxide. The bacteria subsequently are removed by chlorination before the secondarily-treated effluent is released into local surface waters or the secondarily treated wastewater is directed to another part of the sewage treatment plant for additional processing. Where practiced, such effluent-polishing or advanced treatment measures use any of several techniques to remove inorganic nitrogenous or phosphorous salts to reduce the final effluent's potential to cause excessive nutrient enrichment of the receiving waters (Epstein 2002; Parnell 2003).

Because of the large expense of tertiary sewage treatment, the public sector does not implement it as a uniform municipal wastewater treatment policy. Consequently, while secondary treatment is the standard operating procedure for municipal wastewater treatment in the northeastern United States, natural resource managers cannot assume that advanced, tertiary treatment is available to meet desired environmental goals. Recent point source management policy decisions by Boston, MA, area communities are a case in point. Rather than implementing more costly advanced treatment during system upgrades, these communities chose to address local municipal wastewater challenges by implementing primary and secondary treatment combined with source reduction of certain contaminants and offshore diversion of outfalls to encourage enhanced effluent dilution (Moore et al. 2005). Despite the added expense of implementing them, both secondary and advanced treatment processes are important potential habitat protection measures, particularly because they mitigate oxygen depletion events, eutrophication, and related phenomena that can result in adverse ecological conditions.

### *Release of nutrients and eutrophication*

Particularly under lesser levels of treatment, municipal sewage facilities discharge large volumes of nutrient-enriched effluent. While some level of readily available nutrients are essential to sustain healthy aquatic habitats and ecological productivity, excess concentrations result in eutrophication of coastal habitats. Elevated nitrogen and phosphorous concentrations in municipal wastewater effluents can cause pervasive ecological responses including: exaggeration of phytoplankton and macroalgal populations; initiation of harmful algal blooms (Anderson et al. 2002); adverse affects on the physiology, growth, and survival of certain ecologically important aquatic plants (Touchette and Burkholder 2000); reduction of water transparency with accompanying adverse effects to submerged and emergent vascular plants or other disruptions to the normal ecological balance among vascular plants and algae (Levinton 1982; Cloern 2001); hypoxic or anoxic events that may cause significant fish and invertebrate mortalities; disturbances to normal denitrification processes; and concomitant decrease in local populations of fishery resources and forage species (USEPA 1994). Sewage outfalls also may become an attraction nuisance in that they may at least initially attract fish around the point of discharge until hypoxia, toxin production, and algal bloom development render the aquatic area less productive (Islam and Tanaka 2004). Collectively, adverse chemical effects may be especially significant to aquatic resources in temperate regions because strong thermoclines and persistent ice cover restrict vertical mixing and exacerbate deteriorating habitat conditions at depth.

For additional information on the mechanisms involved in denitrification of organic and inorganic compounds, Korom's (1992) review of denitrification in natural aquifers is a concise and informative compilation of heterotrophic and autotrophic denitrifiers.

### *Release of contaminants*

Municipal treatment facilities discharge large volumes of effluent into the aquatic environment. The waste stream typically contains a complex mixture of domestic and industrial wastes that contain predominantly natural and synthetic organic substances, metals, and trace elements, as well as pathogens (Islam and Tanaka 2004). Similarly, introductions of certain pharmaceuticals via municipal wastewater discharges have become causes for concern because of their potential to act as endocrine disruptors in fish and other aquatic resources. Residence time of the different contaminant classes in aquatic environments is an important habitat management consideration. Some of these substances, such as volatile organic compounds, may have a relatively short residence time in the system and other, more persistent substances, such as synthetic organometallic compounds, may linger for decades after becoming associated with the substrate or concentrated in local biota. Such pollution has been associated with mortality, malformation, abnormal chromosome division, and higher frequencies of mitotic abnormality in adult fish from polluted areas compared with those from less polluted regions of the northwest Atlantic Ocean (Longwell et al. 1992).

Increased concentrations of the various contaminant classes associated with municipal wastewater can be highly ecologically significant. For instance, exposure to contaminants within these categories have been correlated with deleterious effects on aquatic life including larval deformities in haddock (*Melanogrammus aeglefinus*) (Bodammer 1981), reduced hatching success and increased larval mortality in winter flounder (*Pseudopleuronectes americanus*) (e.g., Klein-MacPhee et al. 1984; Nelson et al. 1991), skeletal deformities in Atlantic cod (*Gadus morhua*) (Lang and Dethlefsen 1987), inhibited gamete production and maturation in sea scallops (*Placopecten magellanicus*) (Gould et al. 1988), and reproductive impairment in Atlantic cod (Thurberg and Gould 2005).

Laboratory experiments with pesticides have shown a positive relationship between malformation and survival of embryos and larvae of Atlantic cod and concentration of DDT and its breakdown product dichlorodiphenyl dichloroethylene (DDE) (Dethlefsen 1976). The proportion of fin erosion in winter flounder collected on contaminated sediments was found to be greater in fish sampled with higher concentrations of PCB in muscle, liver, and brain tissues than in fish collected in reference sites (Sherwood 1982). Studies conducted in the harbor of New Haven, CT, found high occurrences of liver lesions, blood cell abnormalities, liver DNA damage, and liver neoplasms among winter flounder with high concentrations of organic compounds, metals, and PCB in their gonads (Gronlund et al. 1991). Such pollution also has been associated with mortality, malformation, abnormal chromosome division, and higher frequencies of mitotic abnormality in adult fish from polluted areas compared with those from less polluted regions of the northwest Atlantic Ocean (Longwell et al. 1992). Observed effects of fish exposed to PAH include decrease in growth, cardiac disfunction, lesions and tumors of the skin and liver, cataracts, damage to immune systems, estrogenic effects, bioaccumulation, bioconcentration, trophic transfer, and biochemical changes (Logan 2007).

For almost a century, sewage sludge (the solids extracted from raw wastewater during sewage treatment) was disposed of at sea. In the northeastern United States, a number of designated offshore sewage sludge dumpsites existed, including one in Boston Harbor, MA, and sites in the New York Bight and the Mid-Atlantic Bight (Barr and Wilk 1994). Not surprisingly, sediments sampled in the vicinity of sewage sludge dumpsites have contained higher levels of contaminants (e.g., PCB, PAH, chlorinated pesticides, and metals) than in control sites (Barr and Wilk 1994). Sewage sludge has been demonstrated to have adverse effects on aquatic organisms. For example, early life stages of Atlantic herring (*Clupea harengus*) have shown a series of developmental abnormalities, including premature hatching accompanied by reduced viability of emerging fry; poor larval survival; smothering or incapacitation of larvae by particle flocs; and fin damage (Urho 1989; Costello and Gamble 1992). The Ocean Dumping Ban Act of 1988 prohibited sewage sludge and industrial wastes from being dumped at sea after December 31, 1991. This law is an amendment to the Marine Protection, Research, and Sanctuaries Act of 1972, which regulates the dumping of wastes into ocean waters.

In addition to these diverse contaminant classes, wastewater facilities also discharge a host of synthetic hormones or other substances that could disrupt normal endocrine function in aquatic vertebrates, as well as introduce zoonotic viruses, bacteria, and fungi that may be present in raw human sewage. These chemicals act as "environmental hormones" that may mimic the function of the sex hormones (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Metals, PAHs, and other contaminants have been implicated in disrupting endocrine secretions of marine organisms (Brodeur et al. 1997; Thurberg and Gould 2005). However, the long-term effect of endocrine-disrupting substances on aquatic life is not well understood and demands serious attention by the scientific and resource policy communities. Refer to the Endocrine Disruptors subsection of this chapter for a broader discussion on this topic. Metals such as mercury are also capable of moving upward through trophic levels and can accumulate in fish (i.e., bioaccumulation) at levels which may cause health problems in human consumers.

While modern sewage treatment facilities undeniably reduce the noxious materials present in raw wastewater and some substances typical of processed effluents have their own inherent toxic effects, it also is important to recognize that secondary and advanced treatment can alter the chemistry of ordinarily benign materials in ways that initiate or enhance their toxicity. In particular, normally nonhazardous organic compounds present in wastewater potentially can be rendered toxic when raw municipal effluent is chlorinated in the sewage treatment process (NRC 1980; Epstein 2002). Other contaminants may become toxic to humans or many different aquatic resource taxa when these substances are methylated (addition of a $-CH_4$ group) or otherwise after having been chemically transformed into a harmful, biologically available molecular form.

The behavior and effects of trace chemicals in aquatic systems largely depend on the speciation and physical state of the pollutants in question. A detailed description concerning contaminant partitioning and bioavailability is beyond the scope of this technical discussion.

However, Gustafsson and Gschwend (1997) offer an excellent review of the matter in terms of how dissolved, colloidal and settling particle phases affect trace chemical fates and cycling in aquatic environments. While the observations provided by these Massachusetts Institute of Technology researchers pertain specifically to cycling of compounds in natural waters, the generic properties they discuss also would apply in the context of substances in treated wastewater since they are subject to the same physical and chemical forces. In addition, Tchobanoglous et al. (2002) may be consulted for an authoritative technical review of the environmental engineering aspects of wastewater treatment.

Exposure to potentially mutagenic or teratogenic pollutants and the resulting declines in viability at any life stage reduce the likelihood of maturation and eventual recruitment to adulthood or a targeted fishery. Literature on the aqueous and sedimentary geochemistry and physiological effects of contaminants on aquatic biota should be consulted to determine the fate of persistent compounds in local sediments and associated pore-water and the extent of acute or chronic toxic effects on affected aquatic biota (Varanasi 1989; Allen 1996; Langmuir 1996; Stumm and Morgan 1996; Tessier and Turner 1996; Paquin et al. 2003).

### *Alteration of water alkalinity*

Municipal sewage effluent that does not meet water quality standards can alter the alkalinity of riverine receiving waters. However, freshwater and low-salinity waters with low buffering capacity are more susceptible to acidification than are marine waters. Acidification of riverine habitats has been linked to the disruption of reproduction, development, and growth of anadromous fish (USFWS and NMFS 1999; Moring 2005). For example, osmoregulatory problems in Atlantic salmon (*Salmo salar*) smolts have been related to habitats with low pH (Staurnes et al. 1996). In estuarine waters, low pH has been shown to cause cellular changes in the muscle tissues of Atlantic herring which may lead to a reduction in swimming ability (Bahgat et al. 1989). However, all municipal sewage facilities are required to obtain water quality permits through the US EPA's NPDES program and must meet established pH standards for receiving waters. Acid precipitation from atmospheric sources is of concern in the northeastern United States. Refer to the Global Effects and Other Impacts chapter for more information regarding acid precipitation.

### *Impacts to submerged aquatic vegetation*

Submerged aquatic vegetation (SAV) requires relatively clear water in order to allow adequate light transmittance for metabolism and growth. Sewage effluent containing high concentrations of nutrients can lead to severely eutrophic conditions. The resulting depression of dissolved oxygen and diminished light transmittance through the water may result in local reduction or even extirpation of SAV beds that are present before habitat conditions become too degraded to support them (Goldsborough 1997). Examples of large scale SAV declines have been seen throughout the eastern coastal states, most notably in Chesapeake Bay, MD/VA, where overall abundance has been reduced by 90% during the 1960s and 1970s (Goldsborough 1997). Although a modest recovery of the historic SAV distribution has been seen in Chesapeake Bay over the past few decades, reduced light penetration in the water column from nutrient enrichment and sedimentation continues to impede substantial restoration. Primary sources of nutrients into Chesapeake Bay include fertilizers from farms, sewage treatment plant effluent, and acid rain (Goldsborough 1997). Short and Burdick (1996) correlated eelgrass losses in Waquoit Bay, MA, with anthropogenic nutrient loading primarily as a result of increased number of septic systems from housing developments in the watershed.

Eutrophication can alter the physical structure of SAV by decreasing the shoot density and blade stature, decreasing the size and depths of beds, and stimulating excessive growth of macroalgae (Short et al. 1993). An epidemic of an eelgrass wasting disease wiped out most eelgrass beds along the east coast during the 1930s, and although some of the historic distribution of eelgrass has recovered, eutrophication may increase the susceptibility of eelgrass to this disease (Deegan and Buchsbaum 2005).

### *Reduced dissolved oxygen*

The decline and loss of fish populations and habitats because of low dissolved oxygen concentrations is "one of the most severe problems associated with eutrophication in coastal waters" (Deegan and Buchsbaum 2005). The effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (Bejda et al. 1992). High nutrient loads into aquatic habitats can cause hypoxic or anoxic conditions, resulting in fish kills in rivers and estuaries (USEPA 2003b; Deegan and Buchsbaum 2005) and potentially altering long-term community dynamics (NRC 2000; Castro et al. 2003). Highly eutrophic conditions have been reported in a number of estuarine and coastal systems in the northeastern United States, including Boston Harbor, Long Island Sound, NY/CT, and Chesapeake Bay (Bricker et al. 1999). For the southern portions of the northeast coast (i.e., Narragansett Bay, RI, to Chesapeake Bay), O'Reilly (1994) described chronic hypoxia (low dissolved oxygen) as a result of coastal eutrophication in several systems. This author reported episodic, low dissolved oxygen conditions in some of the northern portions of the northeast coast, such as in Boston Bay/Charles River and the freshwater portion of the Merrimack River, MA/NH (O'Reilly 1994). Areas particularly vulnerable to hypoxia are those that have restricted water circulation, such as coastal ponds, subtidal basins, and salt marsh creeks (Deegan and Buchsbaum 2005). While any system can become overwhelmed by unabated nutrient inputs or nutrient enrichment, the effects of these generic types of pollution when experienced in temperate regions may be especially significant in the summer. This is primarily a result of stratification of the water column and higher water temperatures and metabolic rates during summer months (Deegan and Buchsbaum 2005).

### *Siltation, sedimentation, and turbidity*

Municipal sewage outfalls, especially those that release untreated effluent from storm drains, can release suspended sediments into the water column and the adjacent benthic habitat. Increased suspended particles within aquatic habitats can cause elevated turbidity levels, reduced light transmittance, and increased sedimentation of benthic habitat which may lead to the loss of SAV, shellfish beds, and other productive fishery habitats. Other affects from elevated suspended particles include respiration disruption of fishes, reduction in filtering efficiencies and respiration of invertebrates, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991; Barr 1993).

### *Introduction of pathogens*

Pathogens are generally a concern to human health because of consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). Microorganisms entering aquatic habitats in sewage effluents do pose some level of biological risk since they have been shown to infect marine mammals (Oliveri 1982; Bossart et al. 1990; Islam and Tanaka 2004). The degree to which anthropogenically-derived microbes may affect fish, shellfish, and other aquatic taxa remains an important research topic; however, some recently published observations concerning groundfish populations near the Boston sewage outfall into Massachusetts Bay are suggesting that appropriate management practices may address at least part of this risk (Moore et al. 2005). See also the chapters on Coastal Development and Introduced/Nuisance Species and Aquaculture for more information on the introduction of pathogens.

### *Introduction of harmful algal blooms*

Sewage treatment facilities releasing effluent with a high BOD that may enter estuarine and coastal habitats have been associated with harmful algal bloom events, which can deplete the oxygen in the water during bacterial degradation of algal tissue and result in hypoxic or anoxic "dead zones" and large-scale fish kills (Deegan and Buchsbaum 2005). There is evidence that nutrient overenrichment has led to increased incidence, extent, and persistence of nuisance and/or noxious or toxic species of phytoplankton; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from plankton algae (O'Reilly 1994).

Algal blooms may also contain species of phytoplankton such as dinoflagellates that produce toxins. Toxic algal blooms, such as red tides, can decimate large numbers of fish, contaminate shellfish beds, and cause health problems in humans. Shellfish sequester toxins from the algae and become dangerous to consume. Toxic algal blooms could increase in the future because many coastal and estuarine areas are currently moderately to severely eutrophic (Goldburg and Triplett 1997). Heavily developed watersheds tend to have reduced stormwater storage capacity, and the high flow velocity and pulse of contaminants from freshwater systems can have long-term, cumulative impacts to estuarine and marine ecosystems. Some naturally occurring microorganisms, such as bacteria from the genus, *Vibrio*, or the dinoflagellate, *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species will require additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997). See also the chapter on Introduced/Nuisance Species and Aquaculture for more information on harmful algal blooms.

### *Impacts to benthic habitat*

As discussed above, treated sewage effluent containing high concentrations of nutrients can lead to severely eutrophic conditions that can reduce or eliminate SAV beds (Goldsborough 1997). In addition, municipal sewage outfalls can release suspended sediments into the water column and the adjacent benthic habitat. Increased suspended particles within aquatic habitat can cause elevated turbidity levels, reduced light transmittance, which may lead to the reduction or loss of SAV, shellfish beds and other productive benthic habitats.

### *Changes in species composition*

Treated sewage effluent can contain, at various concentrations, nutrients, toxic chemicals, and pathogens that can affect the health, survival, and reproduction of aquatic organisms. These effects may lead to alterations in the composition of species inhabiting coastal aquatic habitats and can result in community and trophic level changes (Kennish 1998). For example, highly eutrophic water bodies have been found to contain exaggerated phytoplankton and macroalgal populations that can lead to harmful algal blooms (Anderson et al. 2002). Sewage treatment facilities may initially attract fish around the point of discharge until hypoxia, toxin production, and algal bloom development render the aquatic area less productive (Islam and Tanaka 2004). Reduced light penetration in the water column from nutrient enrichment and sedimentation has been shown to contribute to the loss of eelgrass beds in coastal estuaries in southern Massachusetts, Long Island Sound, and the Chesapeake Bay (Goldsborough 1997; Deegan and Buchsbaum 2005).

### *Contaminant bioaccumulation and biomagnification*

Sewage discharges can contain metals and other substances known to be toxic to marine organisms. Not surprisingly, the bays and estuaries of highly industrialized urban areas in northeastern US coastal areas, such as Boston Harbor, Portsmouth Harbor, NH/ME, Newark Bay,NJ, western Long Island Sound, and New York Harbor, have shown relatively high metal burdens in sampled sediments (Larsen 1992; Kennish 1998; USEPA 2004a). While industrial outfalls are responsible for metal contamination in some areas, sewage has been identified as one of the primary sources. For example, although lead contamination in coastal sediments can originate from a variety of sources, sewage is believed to be the primary source of silver contamination (Buchholtz ten Brink et al. 1996). Metals may move upward through trophic levels and accumulate in fish and some invertebrates (bioaccumulation) at levels which can eventually cause health problems in human consumers (Kennish 1998; NEFMC 1998). Other chemicals are known to bioaccumulate and biomagnify in the ecosystem, including pesticides (e.g., DDT) and PCB congeners (Kennish 1998). The National Coastal Condition Report (USEPA 2004a) reported that after metals, PCB congeners and DDT metabolites were responsible for most of the contaminant criteria exceedances in northeast coast samples. For example, sediment samples collected by NOAA's National Status and Trends (NS&T) Program found in some samples very high concentrations of chlorinated hydrocarbons such as PCBs, pesticides, and dioxins from the lower Passaic River, NJ, and Newark Bay in the Hudson-Raritan estuary (Long ER et al. 1995). Other locations in this estuary containing moderately to highly toxic samples in the NS&T Program included Arthur Kill, NY/NJ, and East River, NY.

### *Release of pharmaceuticals*

Concerns have been emerging over the past few years regarding the continual exposure of aquatic organisms to the complex spectrum of active ingredients in pharmaceuticals and personal care products (PPCP), which can persist in treated effluent from sewage facilities. PPCPs comprise thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, lotions, and cosmetics (Daughton and Ternes 1999; USEPA 2007). The concentrations of PPCP in the aquatic environment are generally detected in the range of parts per thousand to parts per billion and may not pose an acute risk. However, aquatic organisms may be adversely affected because they can have continual and multigenerational exposures, exposures at high concentrations from untreated water, and they may have low dose effects (Daughton and Ternes 1999; USEPA 2007). Some of these PPCPs include steroid compounds, which may act as endocrine disruptors by mimicking the functions of sex hormones (refer to the subsection below for more information on endocrine disruptors). The effects of antibiotics and antimicrobial drugs on aquatic organisms are also of concern. Although population level effects on aquatic organisms from PPCPs are inconclusive at this time, the growing evidence on this topic suggests further investigation is warranted.

### *Endocrine disruptors*

Another recent topic of concern involves a group of chemicals, called "endocrine disruptors," which interfere with the endocrine system of aquatic organisms. Growing concerns have mounted in response to the effects of endocrine-disrupting chemicals on humans, fish, and wildlife (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Several studies have implicated endocrine-disrupting chemicals with the presence of elevated levels of vitellogellin in male fish, a yolk precursor protein that is normally only found in mature female fish (Thurberg and Gould 2005). Some of the chemicals shown to be estrogenic include PCB congeners, dieldrin, DDT, phthalates, and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture and may be present in irrigation water and storm water runoff. Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997).

In summary, the chemical implications of sewage treatment plant effluents vary as a function of the effort taken to remove organic and inorganic contaminants collected by the wastewater treatment plant. Further complicating matters, while secondary treatment is the minimal acceptable standard treatment process in the northeastern United States, inadequately treated or even raw wastewater containing human sewage and attendant debris routinely passes into the aquatic environment from municipal processing plant outfalls when the flow and/or storage demands exceed design specifications. Such releases are commonly experienced when older sewer systems are inundated, particularly in conjunction with storm events. Accordingly, the types of treatment processes implemented, how effectively the wastewater treatment infrastructure is operating, and the salinity of the receiving waters (to the extent that it influences contaminant chemistry) are critical variables when considering the chemical implications of releasing treated wastewater into the aquatic environment.

### *Maintenance activities associated with sewage discharge facilities*

Maintenance activities associated with sewage treatment plants typically involve periodic application of chemicals to treat piping for colonization of biofouling organisms. Efforts to control fouling communities can produce larger field or even chronic disturbances that could adversely affect the aquatic environment. Under some circumstances, chemical treatments are not necessary and fouling communities may be removed mechanically using hot water under pressure. When this type of procedure is implemented, most of the direct impacts are physical. Although the use of pressurized, hot freshwater to mechanically remove fouling organisms may temporarily alter salinity and solute loads, some localized indirect thermodynamic effects that alter ambient chemistry could also occur in the dispersal plume until ambient temperature is restored. In addition, differences in the chemical composition of the source and receiving waters would be expected to have at least a minimal effect, particularly when chlorinated water is used to facilitate the removal of fouling organisms and when there is a significant difference in salinity between cleaning and receiving waters. Perhaps more typically, colonization of fouling communities is controlled through periodic use of antifouling paints, coatings, or other treatments. When conducted inappropriately, periodic applications of these substances can have chronic and potentially harmful effects in the aquatic environment.

Fortunately, application of biocides in aquatic systems is regulated under the CWA, which includes provisions to protect fishes and many invertebrate species to the extent practicable. Since local salinity ranges and diffusion rates at the outfall are important considerations in terms of eventual dispersion and relative toxicity of outfall maintenance materials, these and similar site-specific considerations often dictate which products may be used safely at a given project site. It is vital that only products designed and federally approved for use in and near aquatic habitats are deliberately allowed to enter US waterways under any circumstances.

In general, the most deleterious effects of sewage outfall maintenance probably revolve around fouling community control measures. That is because the underlying intent of such practices is to remove a large variety of plant, animal, and even bacterial populations from inhabiting the area surrounding the outfall. Biocide applications control undesirable organisms by chemical or biological means (Knight and Cooke 2002). Whether removed chemically or mechanically, the loss of these organisms at least initially may result in other forms of local ecological disturbance, such as reduced productivity and diminished prey and cover (Meffe and Carroll 1997). While outfall maintenance events individually result in an acute chemical impact to the environment and biota, it is important also to consider the cumulative effects of repeated applications over a project's maintenance cycle. Especially when undertaken regularly, the maintenance of outfall structures can create a chronic cycle of disturbance on resident biota, particularly sessile organisms.

Individual biocides and other contaminants released during outfall maintenance operations may have direct effects on local aquatic biota or they may act in an additive, synergistic, or antagonistic manner in concert with ambient physical and chemical habitat conditions. Such exposure to organic and inorganic pollutants may result in a spectrum of lethal and sublethal effects that may be discerned at every level of biological organization (Thurberg and Gould 2005). Wide distribution of contaminants, such as biocides and related outfall maintenance substances, can be facilitated through bioaccumulation in motile aquatic organisms that are capable of dispersing between riverine, estuarine, and marine habitats (Mearns et al. 1991). The pollutant-induced effects these substances engender are not limited to biochemical or physiological responses, as they may also disrupt a variety of complex behaviors which may be essential for maintaining fitness and survival (Atchison et al. 1987; Blaxter and Hallers-Tjabbes 1992; Kasumyan 2001; Scott and Sloman 2004).

In addition to measures to control fouling organisms in wastewater treatment facilities, maintenance activities also involve repairs and enhancements of structures associated with the facilities' infrastructure. Because they typically are undertaken on a relatively small scale, physical repairs of existing infrastructure usually produce impacts of lesser intensity and on a more limited spatial scale than those created during initial installation. In contrast, application of antifouling coatings or related treatments not only discourages settlement by aquatic organisms on the treated surface, but also releases biocide into the aquatic environment (Richardson 1997; Terlizzi et al. 2001). Depending on the individual case, such releases can range from very limited to extensive plumes, as measured by the volume of material emitted, and the distance broadcast away from the point source the substance may be detected in the water column.

Collectively, such releases degrade local water quality. Fortunately, chemical effects of sewage outfall maintenance in lotic coastal systems generally would be expected to dissipate relatively quickly because of dispersion by river flow or tidal action. For health and aesthetic reasons, municipal sewage outfalls should not be sited in quiescent waters. In addition, government-established protocols for biological control agents approved for applications in subaqueous discharges generally are applied in isolation within a capped pipe and are subsequently released after sufficient time has passed for the biocide properties to have abated, or more rarely after the bulk of the treating solution is siphoned off and dealt with offsite. Typically, such biocide solutions are designed to decompose into relatively benign constituent forms within hours and, when used properly, are thought not to pose a significant risk to nontarget organisms (Diderich 2002).

As is the case for initial outfall installation impacts, a variety of chemical and biological factors determine the extent to which the polluting substance affects the water column, sediments, and biota and the distance it migrates from the point source. Among them, salinity and carbonate alkalinity (i.e., carbonic acid and bicarbonate ion content) are especially important because of their respective roles in mediating chemical reactions in solution and in conferring the buffering capacity provided by marine and estuarine waters. Carbonate alkalinity, or water hardness, is an especially important property in riverine systems because the ambient carbonate concentrations regulate acid-base chemistry and other water quality parameters, which are thought to be important factors in the recovery of depleted salmonid populations in Maine (Johnson and Kahl 2005). While salmonids are particularly sensitive to degraded water quality, poor water quality is known to affect a wide variety of aquatic organisms (Tessier et al. 1984; Scott and Sloman 2004; Moore et al. 2005; Thurberg and Gould 2005).

### *Construction impacts associated with sewage discharge facilities*

The construction of municipal wastewater outfalls can have chemical effects that result from a number of activities, including releasing suspended sediments and associated pore-water in the construction zone; releasing drill mud or cuttings from a directional drilling operation; discharging substances from mechanized equipment (e.g., incidental discharges of hydrocarbons or hydraulic fluid); and introducing leachate from fresh and curing concrete, antifouling paints, and other construction materials. Contaminants initially reside in aquatic systems in either a dissolved phase in the water column or in a particulate phase when they have adsorbed onto sediments or other solids. Pollutants present in biologically-available forms subsequently become assimilated by aquatic biota and become biomagnified as they are taken up in successive trophic strata (Levinton 1982; Sigel and Sigel 2001).

While plume and sedimentation effects incidental to outfall construction do not always result in a readily observable ecological response, they commonly produce a range of direct and indirect effects to living aquatic resources and their habitats. Not all of the ecological implications of sediment resuspension and transport result in adverse effects to aquatic organisms (Blaber and Blaber 1980). These effects vary a great deal depending on which life history stages are affected (Wilber and Clarke 2001). As a general rule, however, the severity of adverse chemical effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996). In particular, predictive models of dose-response relationships corroborate that the eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Mitigative measures that limit the nature and extent of chemical impacts arising from outfall installation typically can and should be undertaken to avoid and minimize adverse construction effects.

From the standpoint of water quality, most chemical effects associated with outfall construction should be relatively acute and transitory. Adverse water quality impacts arising from outfall installation generally arise as a consequence of: (1) substances that have adsorbed onto resuspended particles; (2) pollutants that have dissolved or leached into the water column; or (3) contaminants that have been released directly by construction equipment. These pollutants may include substances that lead to nutrient enrichment; they may be chemically reduced; they may exhibit acidic or caustic properties; they may contain organometallic complexes or a variety of other natural or synthetic compounds; they may be hydrophobic or hydrophilic; or they otherwise may exhibit a diverse spectrum of chemical properties that affect their relative toxicity and dispersal in the water column.

While various physical, chemical, and biological factors come into play, the area into which such water quality impacts extend is largely dependent upon the length of time particles and solutes are held in the water column and the distance they are transported from the construction site. Grain size and ambient sediment structure characteristics have an important bearing on dispersal. As benthic material is disturbed during outfall installation and site preparation, resuspended particulate matter would settle predominantly in the immediate project vicinity. Remaining waterborne fractions subsequently would be transported over a distance and direction that are related to the grain size of disturbed sediments, the velocity of local water currents, and local wave action (Neumann and Pierson 1966). Contaminants mobilized in and subsequently deposited by the dispersal plume generated by construction activities are subject to complex biogeochemical processes that ultimately dictate their fate and ecological effects. For example, hydrogen sulfide released with pore-water from disturbed sediments depletes dissolved oxygen and results in locally hypoxic or anoxic conditions in the water column until the area engulfed within the dispersal plume becomes reoxygenated.

While important, it is essential to recognize that local sediment characteristics alone do not determine contaminant introduction or resuspension during outfall installation. The type of construction equipment used to build an outfall structure also has an important influence on the dispersion of disturbed bottom material. For traditional clamshell dredging, Tavolaro (1984) estimates a 2% loss of material through sediment resuspension at the dredge site. It is reasonable to conclude that similar losses would accrue when clamshells are used to install outfall pipes for sewage treatment facilities. In the same way, dredging methods that purposely fluidize sediments to facilitate their removal (e.g., hydraulic dredges, water jets) could result in even greater dispersion of resuspended sediment, especially when local waters are not quiescent or in situations where unfiltered return flow to the waterway is permitted. Since fine depositional sediments tend to have greater contaminant loads than do coarser sediments typical of higher energy areas, the chemical consequences of resuspending fine sediments during outfall installation are potentially greater since they are more likely to be associated with pollutants.

Likewise, water quality implications of outfall construction are not limited to sediment resuspension or releasing pore-water that contains hydrogen sulfide. Secondary vectors of chemical contamination during outfall installation include substances introduced into aquatic habitats by construction equipment and materials. Mechanized construction equipment may inadvertently or incidentally release a broad spectrum of chemicals, fuels, and lubricants into the waterway. Similarly, until the building material has completely cured or has leached out soluble contaminant fractions, subaqueous applications of wet concrete or grout, treated timber products, paints, and other construction materials would all potentially introduce pollutants into the surrounding water.

The chemical implications of constructing municipal outfalls to local substrates ultimately depend on whether (and to what extent) contaminants are released, become associated with, and accumulate in, sediments and surrounding pore-water. While sediment particles naturally exhibit cycles of exchange between the water column and bottom substrate materials (Turner and Millward 2002), dredging or outfall installation can be expected to disturb much deeper sediment horizons in a short period of time than would be expected from storms or in all but the most highly erosion prone coastal areas. As construction equipment disrupts sediment horizons at the project site, some fraction of the benthic substrate becomes resuspended into the water column (Tavolaro 1984).

Outfall construction for sewage treatment facilities can create measurable adverse impacts within the disturbed footprint, including the disruption of ambient sediment stratigraphy, cohesiveness, and geochemistry. These effects have geochemical consequences that may be particularly significant when construction activities are located in depositional or nutrient-enriched areas and where local sediments tend to be fine-grained and contain at least moderate levels of pollution. Regardless of the nature and concentration of substances adsorbed onto the sediment or sequestered in the pore-water, salinity may significantly affect local aqueous conditions, sedimentary geochemistry, and resulting ecological effects.

While it is critical to consider the impacts of outfall construction on physical habitat features, implications for resident and transitory biota also should be taken into account. Excavation and relocation of sediments, which may be performed incidental to outfall installation, would produce a sediment plume and create sedimentation effects that could result in detrimental effects on aquatic resources present in the affected area (Newcombe and Jensen 1996; Wilber and Clarke 2001; Berry et al. 2003; Wilber et al. 2005). Direct and indirect impacts related to the removal of benthic material can elicit a variety of responses from aquatic biota (Wilber and Clarke 2001) which have been addressed elsewhere in this report.

While many potential construction impacts clearly are physical in nature, the chemical effects are complex and may have important implications for biota present in the affected area. In addition to the physicochemical considerations already discussed above, the life history and ecological strategies characteristic of different species also are important considerations in assessing the potential chemical impacts of outfall installation. For instance, while highly motile adult and fish in juvenile life stages of most species could flee when construction is ongoing, those in egg and larval stages and nonmotile benthic organisms could not escape contaminant exposure. While some species like the sessile life stages of eastern oyster (*Crassostrea virginica*) have adapted to withstand some acute habitat disturbances (Galtsoff 1964; Levinton 1982), most benthic and slow-moving species would not be able to escape contaminant exposure and instead would exhibit adaptive physiological and biochemical responses to counter any pollutants present.

Contaminants released during outfall installation activities may have direct effects on local aquatic biota or they may act in an additive, synergistic, or antagonistic manner in concert with ambient physical and chemical habitat conditions. Such exposure to organic and inorganic pollutants may result in a spectrum of lethal and sublethal effects that can be discerned at the organismal, tissue, cellular, and subcellular levels of biological organization (Thurberg and Gould 2005). Wide distribution of contaminants can be facilitated through bioaccumulation in motile aquatic organisms that are capable of dispersing between riverine, estuarine, and marine habitats (Mearns et al. 1991).

Importantly, pollutant-induced effects are not limited to biochemical or physiological responses. Environmental pollutants such as metals, pesticides, and other organic compounds also have been shown to disrupt a variety of complex fish behaviors, some of which may be essential for maintaining fitness and survival (Atchison et al. 1987; Blaxter and Hallers-Tjabbes 1992; Kasumyan 2001; Scott and Sloman 2004). In particular, Kasumyan (2001) provided an excellent review of how chemical pollutants interfere with normal fish foraging behavior and chemoreception physiology, while Scott and Sloman (2004) have focused on the ways metals and organic pollutants have been shown to induce behavioral and physiological effects on fresh water and marine fishes.

## Industrial Discharge Facilities

### *Introduction*

Industrial wastewater facilities face many of the same engineering and environmental challenges as municipal sewage treatment plants. Industrial discharge facilities produce a wide variety of trace elements and organic and inorganic compounds. In the industrialized portions of the northeastern United States, such facilities include a variety of chemical plants, refineries, paper mills, defense factories, energy generating facilities, electroplating firms, mining operations, and many other high intensity industrial uses that generate large volumes of wastewater. In many situations, the sanitary and industrial process streams are intermingled and processed at the industrial facility's own treatment plant, requiring that the eventual effluent is treated to address water quality concerns from a fairly broad spectrum of contaminants. While the procedures involved are similar to those implemented at municipal treatment facilities, the specific levels and methods of wastewater treatment at industrial treatment plants vary considerably. While a detailed description of industrial wastewater engineering is well beyond the scope of this report, readers interested in specific technical information may consult portions of Tchobanoglous et al. (2002) or Perry (1997) for more information.

Like sewage plant outfalls, industrial discharge structures are point sources for a variety of environmental contaminants, particularly metals and other trace elements; nutrients; and persistent organic compounds such as pesticides and organochlorines. These substances tend to adhere to solid particles within the waste stream, become adsorbed onto finer sediment fractions once dispersed into coastal waters, and subsequently accumulate in depositional areas. Together with microbial action, local salinity and other properties of the riverine, estuarine, or marine receiving waters may alter the chemistry of these contaminant-particle complexes in ways that render them more toxic than their parent compounds. Upon entering the food web, such contaminants tend to accumulate in benthic organisms at higher concentrations than in surrounding waters (Stein et al. 1995) and may result in various physiological, biochemical, or behavioral effects (Scott and Sloman 2004; Thurberg and Gould 2005).

### *Release of metals*

Industrial discharge structures can release large volumes of effluent containing a variety of potentially harmful substances into the aquatic environment. Metals and other trace elements are common byproducts of industrial processes and as a consequence are anticipated to be components of typical industrial waste streams that may enter the aquatic environment (Kennish 1998). Metals may be grouped into transitional metals and metalloids. Transitional metals, such as copper, cobalt, iron, and manganese, are essential for metabolic function of organisms at low concentrations but may be toxic at high concentrations. Metalloids, such as arsenic, cadmium, lead, mercury, and tin, are generally not required for metabolic function and may be toxic even at low concentrations (Kennish 1998). Metals are known to produce skeletal deformities and various developmental abnormalities in marine fish (Bodammer 1981; Klein-MacPhee et al. 1984; Lang and Dethlefsen 1987). The early life history stages of fish can be quite susceptible to the toxic impacts associated with metals (Gould et al. 1994).

### *Release of organic compounds*

A variety of synthetic organic compounds are released by industrial facilities, find their way into aquatic environments and can be taken up by resident biota. These compounds are some of the most persistent, ubiquitous, and toxic pollutants known to occur in marine ecosystems (Kennish 1998). Organochlorines, such as DDT, chlordane, and PCBs, are some of the most highly toxic, persistent, and well documented and studied synthetic organic compounds. Others include dioxins and dibenzofurans that are associated with pulp and paper mills and wood treatment plants and have been shown to be carcinogenic and capable of interfering with the development of early development stages of organisms (Kennish 1998). Longwell et al. (1992) determined that dozens of different organic contaminants were present in ripe winter flounder eggs. Such accumulation can reduce egg quality and disrupt ontogenic development in ways that significantly depress survival of young (Islam and Tanaka 2004). Organic contaminants, such as PCBs, have been shown to induce external lesions (Stork 1983) and fin erosion (Sherwood 1982) and reduce reproductive success (Nelson et al. 1991) in marine fishes. In addition, suspicion is mounting that exposure to even very low levels of such persistent xenobiotic (i.e., foreign) compounds may disrupt normal endocrine function and lead to reproductive dysfunction such as reduced fertility, hatch rate, and offspring viability in a variety of vertebrates.

### Release of petroleum products

Oil, characterized as petroleum and any derivatives, consists of thousands of chemical compounds and can be a major stressor on inshore fish habitats (Kennish 1998). Industrial wastewater, as well as combined wastewater from municipal and storm water drains, contributes to the release of oil into coastal waters. Petroleum hydrocarbons can adsorb readily to particulate matter in the water column and accumulate in bottom sediments, where they may be taken up by benthic organisms (Kennish 1998). Petroleum products consist of thousands of chemical compounds that can be toxic to marine life including PAHs and water-soluble compounds, such as benzene, toluene, and xylene, which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). PAHs can be toxic to meroplankton, ichthyoplankton, and other pelagic life stages exposed to them in the water column (Kennish 1998). Short-term impacts include interference with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fishes, especially early life-history stages (Gould et al. 1994). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Refer to the chapters on Coastal Development, Energy-related Activities, and Marine Transportation for additional information on impacts associated with petroleum products and PAH.

### Alteration of water alkalinity

A major point of departure when comparing municipal sanitary treatment outfall and industrial plant effluents concerns the ability of some industrial discharges to affect carbonate alkalinity, or buffering capacity, of receiving waters. Both riverine and estuarine strata are particularly susceptible to point source acidification because their low buffering capacity can be quickly overwhelmed by acid discharges; however, even marine habitats can be significantly and adversely affected when continual influx of acidified liquid wastewater outstrips the natural buffering capability of seawater. In riverine systems, it has been postulated that locally reduced pH may be linked to impaired Atlantic salmon recovery (Johnson and Kahl 2005) and osmoregulatory problems (NRC 2004). Oulasvirta (1990) reported periodic massive mortalities of Atlantic herring eggs from effluent containing sulfuric acid and various other metals released at a titanium-dioxide plant in the Gulf of Bothnia, Finland. Low pH in estuarine waters may lead to cellular changes in muscle tissues, which could reduce swimming ability in herring (Bahgat et al. 1989). A variety of industrial operations, ranging from mining and metal production to certain industrial manufacturing activities, is known to release acid effluents that may have adverse effects on fish, shellfish, and their habitat. Collectively, such detrimental impacts can hinder the survival and sustainability of fishery resources and their prey. Point source pollution from industrial sources is currently regulated by the states or the US EPA through the NPDES permit program, which generally does not allow discharges of low pH water into estuaries and coastal waters of the United States.

### Release of nutrients and other organic wastes

Industrial facilities that process animal or plant by-products can release effluent with high BOD which may have deleterious affects to receiving waters. Wood processing facilities, paper and pulp mills, and animal tissue rendering plants can release nutrients, reduced sulfur and organic compounds, and other contaminants through wastewater outfall pipes. For example, wood processing plants and pulp mills release effluents with tannins and lignin products containing high organic loads and BOD into aquatic habitats (USFWS and NMFS 1999). The release of these contaminants in mill effluent can reduce dissolved oxygen in the receiving waters. In addition, paper and pulp mills can release a number of toxic chemicals used in the process of bleaching pulp for printing and paper products. The bleaching process may use chlorine, sulfur derivatives, dioxins, furans, resin acids, and other chemicals that are known to be toxic to aquatic organisms (Mercer et al. 1997). These chemicals have been implicated in various abnormalities in fish, including skin and organ tissue lesions, fin necrosis, gill hyperplasia, elevated detoxifying enzymes, impaired liver functions, skeletal deformities, increased incidence of parasites, disruption of the immune system, presence of tumors, and impaired growth and reproduction (Barker et al. 1994; Mercer et al. 1997). Because of concern about the release of dioxins and other contaminants, considerable improvements in the bleaching process have reduced or eliminated the use of elemental chlorine. According to the US EPA, all pulp and nearly all paper mills in the United States have chemical recovery systems in place and primary and secondary wastewater treatment systems installed to remove particulates and BOD (USEPA 2002). Approximately 96% of all bleached pulp production uses chlorine-free bleaching technologies (USEPA 2002).

### *Construction impacts of industrial discharge facilities*

The chemical impacts associated with constructing an industrial discharge are similar to those described for sewage treatment outfalls. Generally, such discharges predominantly entail suspending sediments and releasing pore-water in the construction zone, releasing drill mud or cuttings from horizontal directional drilling equipment, incidental discharges of fuels, lubricants and other substances from mechanized construction equipment, and leachates from construction materials. Since the substances encountered and circumstances of exposure would be the same regardless of the type of outfall being installed, the Construction Impacts Associated with Sewage Discharge Facilities subsection of this chapter should be reviewed for details regarding the impacts to the water column, sediment, and aquatic biota from the construction of industrial discharge facilities.

### *Maintenance impacts of industrial discharge facilities*

The chemical impacts of maintaining industrial discharge facilities are similar to those described for sewage treatment facilities. Generally, the impacts of performing structural repairs are expected to be similar to those experienced during initial outfall installation, but on a lesser scope and magnitude. Impacts associated with the removal and treatment of fouling communities would be similar to those described for the maintenance activities of sewage treatment facilities. The reader should review the previous subsection on Maintenance Activities Associated with Sewage Discharge Facilities for details on the implications of outfall maintenance on the water column, sediment, and aquatic biota.

## Combined Sewer Overflow (CSO)

The discussion of point source discharges would be incomplete without mention of CSOs, which are ubiquitous in urban and even suburban areas in New England and the Mid-Atlantic region. For a variety of reasons, many of these municipalities operate wastewater collection systems composed of “separate” and “combined” sewers. “Separate” sewers tend to be newer or replacement installations that have distinct piping components for stormwater and sanitary sewers.

Under storm or other high runoff conditions, the separate sewer system allows excess volumes of storm water to bypass sewage treatment facilities and discharge directly into the receiving water body constraining all sanitary waste to processing at the wastewater treatment plant. This prevents the excess volume of watershed runoff from overwhelming the operating capacity of the treatment facilities. Older systems tend to be "combined" sewer systems that commingle watershed runoff and sanitary waste streams.

Typical CSOs do not discharge effluent under dry conditions but may permit unprocessed sewage under high runoff events to enter the receiving waters completely or partially untreated. This occurs when large volumes of storm water and sewage overwhelm the treatment plant and untreated sewage is discharged prematurely. Some CSO discharges violate state and/or federal water quality standards, and each municipality must develop a plan to control and eliminate these CSOs. There is no precise estimate on the number of CSOs that exist or on how much untreated sewage is discharged from them each year. However, 828 separate NPDES permits were issued by the US EPA in 2004. There were a total 9,348 authorized discharges from CSOs nationally in 2004, with approximately one half located in the northeastern United States and the remaining half in the Great Lakes region (USEPA 2002; USEPA 2004b).

The chemical implications of CSOs are that they are potential sources of very large amounts of untreated nutrients and contaminating chemicals that degrade both the aesthetic and ecological conditions of affected habitats. In addition to the adverse effects mentioned for the other outfall types, CSOs can be important point sources for pesticides, herbicides, fertilizers, and other substances commonly applied to terrestrial habitats, ranging from rural farmland and suburban yards or golf courses to highly urbanized centers. In addition, they are sources of terrestrial particulates and may be a secondary source of atmospherically-deposited pollutants that have settled anywhere in the local watershed. While impacts associated with nonpoint sources are discussed elsewhere in this report, the sanitary sewer component of CSO effluents can be construed as an extension of the preceding discussions for municipal and industrial outfalls. The net effect of permitting untreated domestic wastewater to enter the receiving waterway is to diminish the effectiveness of wastewater treatment elsewhere. In so doing, CSOs contribute to increased pollution levels and related natural resource impairments. It is not possible to measure the resulting habitat damage and accompanying aquatic resource degradation in isolation from nonpoint pollution. However, it is important that resource managers consider that CSO discharges can and will occur and account for the added pollutant loads they generate when setting permissible local effluent limits or establishing priorities for replacing outmoded urban infrastructure.

### *Construction and maintenance impacts of CSOs*

The chemical impacts associated with construction and maintenance activities in CSOs are similar to those described for sewage treatment and industrial discharge facilities. Generally, discharges associated with construction activities may include releasing contaminants associated with suspended sediments, releasing pore-water and drill mud or cuttings from directional drilling, discharges of fuels, lubricants, and other substances from construction equipment. Maintenance activities may include the removal and treatment of fouling communities and releases of contaminants similar to those described above. The reader should refer to the Construction Impacts Associated with Sewage Discharge Facilities and the Maintenance Activities Associated with Sewage Discharge Facilities subsections of this chapter for additional information on this topic.

### *Conservation measures and best management practices for sewage and industrial discharge facilities and CSOs (adapted from Hanson et al. 2003)*

1. Locate discharge points in coastal waters well away from shellfish beds, submerged aquatic vegetation, reefs, fish spawning grounds, and similar fragile and productive habitats.
2. Determine benthic productivity by sampling prior to any construction activity related to installation of new or modified facilities. Implement all appropriate best management practices to maintain habitat quality during construction including any seasonal restrictions, use of cofferdams, working in the dry at low tide, etc., as is necessary and practicable.
3. Use seasonal restrictions during construction and maintenance operations to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods), when appropriate. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
4. Develop appropriate modeling studies for plume effects and other parameters of concern in cooperation with the involved resource agencies before finalizing outfall design. Any appropriate recommendations that involve agencies and developed as a consequence of the study results should be incorporated in the construction plans and operation plan for these facilities as enforceable permit conditions.
5. Institute all appropriate source control measures and/or elevate the treatment level to reduce the polluting substances in all effluents to the extent practicable. Ensure that discharge facilities obtain and adhere to NPDES program permits, as appropriate.
6. Ensure that maximum permissible discharges are appropriate for the given project setting and specify any and all operation procedures, performance standards, or best management practices that must be observed to address all reasonably foreseeable contingencies over the life of the project. Consider implementing an adaptive management plan that includes representatives from appropriate agencies to participate in future consultations for administering the management plan. Management plans should include monitoring protocols designed to measure discharge and potential impacts to sensitive resources and habitats.
7. Use best available technologies to treat discharges to the maximal effective and practicable extent, including measures that reduce discharges of biocides and other toxic substances.
8. Take precautions to mitigate the ecological damage arising from outfall maintenance activities. Facility maintenance plans should include measures such as: (a) ensuring biocides selected for a particular application are specifically designed for their intended use; (b) applying no more than the minimal effective dose, and; (c) closely following instructions for use in aquatic applications and ultimate disposal.
9. Use land treatment and upland disposal or storage for any sludge or other remaining wastes after wastewater processing is concluded. Use of vegetated wetlands as biofilters and pollutant assimilators for large-scale discharges should be limited only to circumstances where other less damaging alternatives are not available and the overall environmental suitability of such an action has been demonstrated.
10. Avoid locating pipelines and treatment facilities in wetlands and streams. Discharges should not be sited near eroding waterfronts or where receiving waters cannot reasonably assimilate the amount of anticipated discharge.
11. Ensure that the design capacity for all facilities will address present and reasonably foreseeable needs and that the best available technologies are implemented.
12. Encourage communities to reduce the volume of pollutants entering CSOs and reduce the number of CSO overflows during storm water runoff producing events. The US EPA provides recommended best management practices for communities (USEPA 1999), including: (a) reduce

and manage solid wastes streams; (b) encourage waste reduction and recycling; (c) reduce commercial and industrial pollution; (d) implement regular program of street cleaning; (e) maintain catch basins; (f) conserve water; (g) reduce unnecessary fertilizer and pesticide applications and; (h) control sediment and erosion.

## References for Chemical Effects: Water Discharge Facilities


Allen H, editor. 1996. Metal contaminated aquatic sediments. Boca Raton (FL): CRC Press. 292 p.

Anderson DM, Glibert PM, Burkholder JM. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25(4b):704-26.

Atchison G, Henry M, Sandheinrich M. 1987. Effects of metals on fish behavior: a review. Environmental Biology of Fishes 18:11-25.

Bahgat FJ, King PE, Shackley SE. 1989. Ultrastructural changes in the muscle tissue of *Clupea harengus* L. larvae induced by acid pH. Journal of Fish Biology 34:25-30.

Barker DE, Khan RA, Hooper R. 1994. Bioindicators of stress in winter flounder, *Pleuronectes americanus*, captured adjacent to a pulp and paper mill in St. George's Bay, Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 51(10):2203-9.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Barr BW, Wilk SJ. 1994. Sewage sludge and industrial waste dumping. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 41-4.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Berry W, Rubenstein N, Melzian B, Hill B. 2003. The biological effects of suspended and bedded sediments (SABS) in aquatic systems: a review. Narragansett (RI): Internal report to US EPA, Office of Research and Development. 58 p.

Bishop JM. 1984. Applied oceanography. McCormick ME, Bhattacharyya R, editors. New York (NY): John Wiley & Sons. 252 p.

Blaber S, Blaber T. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143-62.

Blaxter J, Hallers-Tjabbes C. 1992. The effect of pollutants on sensory systems and behaviour of aquatic animals. Netherlands Journal of Aquatic Ecology 26(1):43-58.

Bodammer JE. 1981. The cytopathological effects of copper on the olfactory organs of larval fish (*Pseudopleuronectes americanus* and *Melanogrammus aeglefinus*). Copenhagen (Denmark): ICES CM-1981/ E: 46.

Bossart G, Brawner T, Cabal C, Kuhns M, Eimstad E, Caron J, Trimm M, Bradley P. 1990. Hepatitis B-like infection in a Pacific whitesided dolphin (*Lagenorhynchus obliquidens*).

American Veterinary Medical Association 196:127-30.

Bricker SB, Clement CG, Pirhalla DE, Orlando SP, Farrow DRG. 1999. National estuarine eutrophication assessment: Effects of nutrient enrichment in the Nation's estuaries. Silver Spring (MD): NOAA, NOS, Special Projects Office and the National Centers for Coastal Ocean Science. 71 p.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Capuzzo JM, Sassner JJ Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Chapman P, Wang F. 2001. Assessing sediment contamination in estuaries. Bulletin of Environmental Contamination and Toxicology 20:3-22.

Chillrud S, Hemming S, Shuster E, Simpson H, Bopp R, Ross J, Pederson D, Chaky D, Tolley L, Estabrooks F. 2003. Stable lead isotopes, contaminant metals and radionuclides in upper Hudson River sediment cores: implications for improved time stratigraphy and transport processes. Chemical Geology 199(1-2):53-70.

Cloern J. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210:223-52.

Costello MJ, Gamble JC. 1992. Effects of sewage sludge on marine fish embryos and larvae. Marine Environmental Research 33(1):49-74.

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? [Internet]. Environmental Health Perspectives 107(S6): 907-38. [cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/pdf/errata.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dethlefsen V. 1976. The influence of DDT and DDE on the embryogenesis and the mortality of larvae of cod (*Gadus morhua* L.). Meereforshung 25(3-4):115-48.

Diderich R. 2002. Environmental safety and risk assessment. In: Knight D, Cooke M, editors. The biocides business. Wemheim (Federal Republic of Germany): Wiley-VCH. p 167-95.

Epstein E. 2002. Land applications of sewage sludge and biosolids. Boca Raton (FL): CRC Press. 216 p.

Galtsoff P. 1964. The American oyster *Crassostrea virginica* Gmelin. Fisheries Bulletin 64:1-480.

Goldburg R, Triplet T. 1997. Murky waters: environmental effects of aquaculture in the United States. Washington (DC): Environmental Defense Fund.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. 68 p + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Gould E, Thompson RJ, Buckley LJ, Rusanowsky D, Sennefelder GR. 1988. Uptake and effects of copper and cadmium in the gonad of the scallop *Placopecten magellanicus*: concurrent metal exposure. Marine Biology 97(2): 217-223.

Grady CPL, Daigger GT, Lim HC. 1998. Biological wastewater treatment. New York (NY): Marcel Dekker. 1076 p.

Gronlund W, Chan S, McCain B, Clark R, Myers M, Stein J, Brown D, Landahl J, Krahn M, Varanasi U. 1991. Multidisciplinary assessment of pollution at three sites in Long Island Sound. Estuaries 14(3):299-305.

Gustafsson Ö, Gschwend PM. 1997. Aquatic colloids: concepts, definitions, and current challenges. Limnology and Oceanography 42(3):519-28.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hare L, Tessier A, Warren L. 2001. Cadmium accumulation by invertebrates living at the sediment-water interface. Environmental Toxicology and Chemistry 20(4):880-9.

Huntley S, Wenning R, Bonnevie N, Paustenbach D. 1995. Geochronology and sedimentology of the lower Passaic River, New Jersey. Estuaries 18(2):351-61.

Islam MdS, Tanaka M. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin 48(7-8):624-49.

Johnson K, Kahl S. 2005. A systematic survey of water chemistry for Downeast area rivers (Final Report). [Internet]. Orono (ME): Senator George J. Mitchell Center for Environmental and Watershed Research, University of Maine. [cited 2007 Dec 21]. Available from: http://www.umaine.edu/waterresearch/research/nfwf_salmon_water_chemistry.htm.

Kasumyan A. 2001. Effects of chemical pollutants on foraging behavior and sensitivity of fish to food stimuli. Journal of Ichthyology 41(1):76-87.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C, and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Kennish MJ. 1998. Pollution impacts on marine biotic communities. Boca Raton (FL): CRC Press.

Klein-MacPhee G, Cardin JA, Berry WJ. 1984. Effects of silver on eggs and larvae of the winter flounder. Transactions of the American Fisheries Society 113(2):247-51.

Knight D, Cooke M, editors. 2002. The biocides business: regulation, safety and application. New York (NY): Wiley-Interscience. 404 p.

Korom S. 1992. Natural denitrification of the saturated zone: a review. Water Resources Research WRERAQ 28(6):1657-68.

Lang T, Dethlefsen V. 1987. Cadmium in skeletally deformed and normally developed Baltic cod (*Gadus morhua* L.). Copenhagen (Denmark): ICES CM-1987/ E: 30:18 p.

Langmuir D. 1996. Aqueous environmental geochemistry. New York (NY): Prentice-Hall. 600 p.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Leppard GG, Droppo IG. 2003. The need and means to characterize sediment structure and behaviour prior to the selection and implementation of remediation plans. Hydrobiologia 494:313-7.

Levinton J. 1982. Marine ecology. New York (NY): Prentice-Hall. 526 p.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Logan DT. 2007. Perspective on ecotoxicology of PAHs to fish. Human and Ecological Risk Assessment 13(2):302-316.

Long E, MacDonald D, Smith S, Calder F. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1):81-97.

Long ER, Wolfe DA, Scott KJ, Thursby GB, Stern EA, Peven C, Schwartz T. 1995. Magnitude and extent of sediment toxicity in the Hudson-Raritan Estuary. Silver Spring (MD): US Department of Commerce. NOAA/National Ocean Service/Office of Ocean Resources Conservation and Assessment. NOAA Technical Memorandum NOS ORCA 88. 134 p + append.

Longwell AC, Chang S, Hebert A, Hughes J, Perry D. 1992. Pollution and development abnormalities of Atlantic fishes. Environmental Biology of Fishes 35:1-21.

Ludwig M, Gould E. 1988. Contaminant input, fate and biological effects. In: Pacheco AL, editor. Woods Hole (MA): US Department of Commerce. NOAA/NMFS/Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-F/NEC 56. p 305-322.

Luoma SN. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. Journal of Experimental Marine Biology and Ecology 200:29-55.

McElroy A, Farrington J, Teal J. 1989. Bioavailability of polycyclic aromatic hydrocarbons in the aquatic environment. In: Varanasi U, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton (FL): CRC Press. p 2-39.

Mearns A, Matta M, Shigenaka G, MacDonald D, Buchman M, Harris H, Golas H, Laurenstein G. 1991. Contaminant trends in the southern California Bight: inventory and assessment. Silver Spring (MD): US Dept. Commerce, NOAA/NOS. NOAA Technical Memorandum NOS ORCA 62. 413 p.

Meffe G, Carroll C. 1997. Principles of conservation biology, 2nd ed. New York (NY): Sinauer Associates. 729 p.

Mercer IRG, Barker DE, Khan RA. 1997. Stress-related changes in cunner, *Tautogolabrus adspersus*, living near a paper mill. Bulletin of Environmental Contamination and Toxicology 58(3):442-7.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Moore M, Lefkovitz L, Hall M, Hillman R, Mitchell D, Burnett J. 2005. Reduction in organic contaminant exposure and resultant hepatic hydropic vacuolation in winter flounder (*Pseudopleuronectes americanus*) following improved effluent quality and relocation of the Boston sewage outfall into Massachusetts Bay, USA: 1987-2003. Marine Pollution Bulletin 50:156-66.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NRC] National Research Council. 1980. The chemistry of disinfectants in water: reactions and products. In: Drinking water and health, Vol. 2. Washington (DC): National Academy Press. p 139-250.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

[NRC] National Research Council. 2004. Atlantic salmon in Maine. Washington (DC): National Academy Press. 275 p.

Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). Estuaries 14(3):318-31.

Neumann G, Pierson WJ Jr. 1966. Principles of physical oceanography. Englewood Cliffs (NJ): Prentice-Hall International. 545 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

O'Connor T. 2002. National distribution of chemical concentrations in mussels and oysters in the USA. Marine Environmental Research 53:117-43.

Olivieri V. 1982. Bacterial indicators of pollution. In: Pipes W, editor. Bacterial indicators of pollution. Boca Raton (FL): CRC Press. p 21-41.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Oulasvirta P. 1990. Effects of acid-iron effluent from a titanium dioxide factory on herring eggs in the Gulf of Bothnia. Finnish Fisheries Research 11:7-15.

Paquin P, Ditoro D, Farley K, Santore R, Wu K-B, editors. 2003. Metals in aquatic systems: a review of exposure, bioaccumulation, and toxicity models. Pensacola (FL): Society of Environmental Toxicology and Chemistry (SETAC). 160 p.

Parnell P. 2003. The effects of sewage discharge on water quality and phytoplankton of Hawaiin coastal waters. Marine Environmental Research 55:293-311.

Pastor D, Boix J, Fernandez V, Albaiges J. 1996. Bioaccumulation of organochlorinated contaminants in three estuarine fish species (*Mullus barbatus, Mugil cephalus* and *Dicentrarcus labrax*). Marine Pollution Bulletin 32(3):257-62.

Perry RDWG. 1997. Perry's chemical engineer's handbook. New York (NY): McGraw-Hill Professional. 2640 p.

Phelps H, Wright D, Mihursky J. 1985. Factors affecting trace metal accumulation by estuarine oysters *Crassostrea virginica*. Marine Ecology Progress Series 22:187-97.

Ragsdale H, Thorhaug A. 1980. Trace metal cycling in the U.S. coastal zone: a synthesis. American Journal of Botany 67(7):1102-12.

Ren J, Packman A. 2002. Effects of background water composition on stream-subsurface exchange of submicron colloids. Journal of Environmental Engineering 128(7):624-34.

Ribaudo M, Horan R, Smith M. 1999. Economics of water quality protection from non-point sources: theory and practice. Washington (DC): US Department of Agriculture, Resource Economics Division, Economic Research Service. Report NR 782. 113 p.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Richardson H. 1997. Handbook of copper compounds and applications. New York (NY): Marcel Dekker. 432 p.

Robinet T, Feunteun E. 2002. Sublethal effects of exposure to chemical compounds: a cause for decline in Atlantic eels? Ecotoxicology 11:265-77.

Scott GR, Sloman KA. 2004. The effects of environmental pollutants on complex fish behaviour: integrating behavioural and physiological indicators of toxicity. Aquatic Toxicology 68:369-92.

Sherwood M. 1982. Fin erosion, liver condition, and trace contaminant exposure in fishes from three coastal regions. In: Mayer GG, editor. Ecological stress and the New York Bight: science and management. Columbia (SC): Estuarine Research Federation. p 359-77.

Short FT, Burdick DM. 1996. Quantifying, eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19(3):730-9.

Short FT, Burdick DM, Wolf JS, Jones GE. 1993. Eelgrass in estuarine research reserves along the East Coast, U.S.A. Part I: declines from pollution and disease and Part II: management of eelgrass meadows. Silver Spring (MD): NOAA-Coastal Ocean Program Publication. 107 p.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Sigel H, Sigel A, editors. 2001. Metal ions in biological systems: concepts on metal ion toxicity. New York (NY): Marcel Dekker. 416 p.

Smith S, MacDonald D, Keenleyside K, Ingersoll C, Field L. 1996. A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. Journal of Great Lakes Research 22(3):624-38.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Stein JE, Hom T, Collier T, Brown DR, Varanasi U. 1995. Contaminant exposure and biochemical effects in outmigrant juvenile chinook salmon from urban estuaries of Puget Sound, WA. Environmental Toxicology and Chemistry 14(6):1019-29.

Stiles S, Choromanski J, Nelson D, Miller J, Grieg R., Sennefelder G. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. Estuaries 14(3):332-42.

Stork T. 1983. PCB levels correlated with the ulcus-syndromes in cod (*Gadus morhua* L.). Copenhagen (Denmark): International Council for the Exploration of the Sea. ICES CM-1983/ E: 50:11 p.

Stumm W, Morgan J. 1996. Aquatic chemistry: chemical equilibria and rates in natural waters. New York (NY): John Wiley & Sons. 1005 p.

Tavolaro J. 1984. A sediment budget study of clamshell dredging and ocean disposal activities in the New York Bight. Environmental Geology and Water Science 6(3):133-40.

Tchobanoglous G, Burton F, Stensel H. 2002. Wastewater engineering: treatment and reuse. New York (NY): McGraw-Hill Professional. 1848 p.

Terlizzi A, Fraschetti S, Gianguzza P, Faimali M, Boero F. 2001. Environmental impact of antifouling technologies: state of the art and perspectives. Aquatic Conservation: Marine and Freshwater Ecosystems 11:311-7.

Tessier A, Campbell P, Auclair J, Bisson M. 1984. Relationship between the partitioning of trace metals in sediments and their accumulation in the tissues of the freshwater mollusc *Elliptio complanata* in a mining area. Canadian Journal of Fisheries and Aquatic Sciences 41:1463-72.

Tessier A, Turner D, editors. 1996. Metal speciation and bioavailability in aquatic systems. New York (NY): John Wiley and Sons. 696 p.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Touchette BW, Burkholder JM. 2000. Review of nitrogen and phosphorus metabolism in seagrasses. Journal of Experimental Marine Biology and Ecology 250:133-67.

Turekian K. 1978. The fate of estuaries. Washington (DC): US Environmental Protection Agency. EPA-600/9-78-038. p 27-38.

Turner A, Millward GE. 2002. Suspended particles: their role in estuarine biogeochemical cycles. Estuarine, Coastal and Shelf Science 55:857-83.

Urho L. 1989. Fin damage in larval and adult fishes in a polluted inlet in the Baltic [abstract]. In: Blaxter JHS, Gamble JC, Westernhagen HV, editors. The early life history of fish. Third ICES Symposium; 1988 Oct 3-5; Bergen, Norway. Copenhagen (Denmark): Rapports et Proces-Verbaux Des Reunions 191. International Council for the Exploration of the Sea. p 493-4.

[USEPA] US Environmental Protection Agency. 1984. Use and disposal of municipal wastewater sludge. Washington (DC): US EPA. 625/10-84-003.

[USEPA] US Environmental Protection Agency. 1994. The Long Island Sound Study: the comprehensive conservation and management plan. Stony Brook (NY): University of New York; Long Island Sound Office of the US EPA. 168 p.

[USEPA] US Environmental Protection Agency. 1996. Overview of the storm water management program. Washington (DC): US EPA Office of Water. EPA 833-R-96-008. 42 p.

[USEPA] US Environmental Protection Agency. 1999. Combined sewer overflow management fact sheet: pollution prevention. Washington (DC): US EPA Office of Water. EPA 832-F-99-038. 9 p.

[USEPA] US Environmental Protection Agency. 2002. Profile of the pulp and paper industry, 2nd ed. [Internet]. Washington (DC): US EPA Office of Compliance Sector Notebook Project. EPA-310-R-02-002. [cited 2008 Jul 24]. 135 p. Available from: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp.html.

[USEPA] US Environmental Protection Agency. 2003a. Guide for industrial waste management. Washington (DC): US EPA Office of Solid Waste. EPA-530-R-03-001.

[USEPA] US Environmental Protection Agency. 2003b. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Wetlands, Oceans, and Watersheds. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2004a. National coastal condition report II. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2004b. Report to Congress on the impacts and control of CSOs and SSOs. Washington (DC): US EPA Office of Water. EPA 833-R-04-001.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USEPA] US Environmental Protection Agency. 2007. Pharmaceuticals and personal care products (PPCP): frequent questions. [Internet]. Washington (DC): US EPA Office of Research and Development. [updated 2007 Dec 14; cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/faq.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Varanasi U, editor. 1989. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton (FL): CRC Press. 341 p.

Werther J, Ogada T. 1999. Sewage sludge combustion. Progress in Energy and Combustion Science 25(1):55-116.

Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energentics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) transplanted along a contamination gradient in Bermuda. Journal of Experimental Marine Biology and Ecology 138:99-117.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Williams C. 1996. Combatting marine pollution from land-based activities: Australian initiatives. Ocean & Coastal Management 33(1-3):87-112.

Wu Y, Falconer R, Lin B. 2005. Modeling trace metal concentration distributions in estuarine waters. Estuarine, Coastal and Shelf Science 64:699-709.

Wurl O, Obbard J. 2004. A review of pollutants in the sea-surface microlayer (SML): a unique habitat for marine organisms. Marine Pollution Bulletin 48(11-12):1016-30.

# CHAPTER EIGHT: PHYSICAL EFFECTS—WATER INTAKE AND DISCHARGE FACILITIES

## Introduction

Water intake and discharge facilities are typically municipal or industrial operations that use water for some processing purpose and/or release effluent water into the aquatic environment. Increased water diversion is associated with human population growth and development (Gregory and Bisson 1997). Some examples of facilities that use and discharge water include fossil-fuel and nuclear power plants, sewage treatment facilities, industrial manufacturing facilities, and domestic and agricultural water supply facilities. The construction and operation of water intake and discharge facilities can have a wide range of physical effects on the aquatic environment including changes in the substrate and sediments, water quality and quantity, habitat quality, and hydrology. Most facilities that use water depend upon freshwater or water with very low salinity for their needs. Reductions in the quality and quantity of freshwater to bays and estuaries have led to serious damage to estuaries in the northeast US region and worldwide (Deegan and Buchsbaum 2005). This chapter discusses the physical impacts associated with water discharge and intake facilities. Refer to the chapter on Chemical Affects: Water Discharge Facilities for information on chemical impacts.

## Intake Facilities

### *Introduction*

Water intake facilities can be located in riverine, estuarine, and marine environments and can include domestic water supply facilities, irrigation systems for agriculture, power plants, and industrial process users. Nearly half of US water withdrawals are attributed to thermoelectric power facilities, and about one-third are used for agriculture irrigation (Markham 2006). In freshwater riverine systems, water withdrawal for commercial and domestic water use supports the needs of homes, farms, and industries that require a constant supply of water. Freshwater is diverted directly from lakes, streams, and rivers by means of pumping facilities or is stored in impoundments or reservoirs. Water withdrawn from estuarine and marine environments may be used to cool coastal power generating stations, as a source of water for agricultural purposes, and more recently, as a source of domestic water through desalinization facilities. In the case of power plants and desalinization plants, the subsequent discharge of water with temperatures higher than ambient levels can also occur.

Water intake structures can interfere or disrupt ecosystem functions in the source waters, as well as downstream water bodies such as estuaries and bays. The volume and the timing of freshwater delivery to estuaries have been substantially altered by the production of hydropower, domestic and industrial use, and agriculture (Deegan and Buchsbaum 2005). Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life-stage, which affects recruitment and year-class strength (Travnichek et al. 1993). Water intake structures can result in adverse impacts to aquatic resources in a number of ways, including: (1) entrainment and impingement of fishes and invertebrates; (2) alteration of natural flow rates and hydroperiod; (3) degradation of shoreline and riparian habitats; and (4) alteration of aquatic community structure and diversity.

### *Entrainment and impingement*

Entrainment is the voluntary or involuntary movement of aquatic organisms from the parent water body into a surface diversion or through, under, or around screens and results in the loss of the organisms from the population. Impingement is the involuntary contact and entrapment of aquatic organisms on the surface of intake screens caused when the approach velocity exceeds the swimming capability of the organism (WDFW 1998). Most water-intake facilities have the potential to cause entrainment and impingement of some aquatic species when they are located in areas that support those organisms. Facilities that are known to entrain and impinge marine animals include power plants, domestic and agricultural water supplies, industrial manufacturing facilities, ballast water intakes, and hydraulic dredges. Some of these types of facilities need very large volumes and intake rates of water. For example, conventional 1,000-megawatt fossil fuel and nuclear power plants require cooling water rates of approximately 50 and 75 $m^3/s$, respectively (Hanson et al. 1977). Water diversion projects have been identified as a source of fish mortality and injury, and egg and larval stages of aquatic organisms tend to be the most susceptible (Moazzam and Rizvi 1980; NOAA 1994; Richkus and McLean 2000). Entrainment can subject these life stages to adverse conditions such as increased heat, antifouling chemicals, physical abrasion, rapid pressure changes, and other detrimental effects. Although some temperate species of fish are able to tolerate exposure to extreme temperatures for short durations (Brawn 1960; Barker et al. 1981), fish and invertebrates entrained into industrial and municipal water intake structures experience nearly 100% mortality from the combined stresses associated with altered temperatures, toxic effects of chemical exposure, and mechanical and pressure-related injuries (Enright 1977; Hanson et al. 1977; Moazzam and Rizvi 1980; Barker et al. 1981; Richkus and McLean 2000).

Both entrainment and impingement of fish and invertebrates in power plant and other water intake structures have immediate as well as future impacts to the riverine, estuarine, and marine ecosystems. Not only is fish and invertebrate biomass removed from the aquatic system, but the biomass that would have been produced in the future would not become available to predators (Rago 1984). Water intake structures, such as power plants and industrial facilities, are a source of mortality for managed-fishery species and play a role as one of the factors driving changes in species abundance over time (Richkus and McLean 2000).

Various physical impacts to fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, were reported by Dadswell and Rulifson (1994) and included mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found 21-46% mortality rates for experimentally tagged American shad (*Alosa sapidissima*) passing through the turbine. NOAA (1994) reported fish diverted into power turbines experience up to 40% mortality, as well as injury, disorientation, and delay of migration. An entrainment and impingment study for a once-through cooling system of an 848-megawatt electric generating plant on the East River (NY) concluded the reduction in biomass of spawners from an unfished stock in the Long Island Sound and New York-New Jersey estuary to be extremely small (i.e., 0.01% for Atlantic menhaden [*Brevoortia tyrannus*] and 0.09% for winter flounder [*Pseudopleuronectes americanus*]) compared to fishing mortality (Heimbuch et al. 2007).

Organisms that are too large to pass through in-plant screening devices become stuck or impinged against the screening device or remain in the forebay sections of the system until they are removed by other means (Hanson et al. 1977; Langford et al. 1978; Helvey 1985; Helvey and Dorn 1987; Moazzam and Rizvi 1980). They are unable to escape because the water flow either pushes them against the screen or prevents them from exiting the intake tunnel. This can cause injuries such as bruising or descaling, as well as direct mortality. The extent of physical damage to organisms is directly related to the duration of impingement, techniques for handling impinged fish, and the intake water velocity (Hanson et al. 1977). Similar to entrainment, the withdrawal of water can entrap particular species, especially when visual acuity is reduced (Helvey 1985) or when the ambient water temperature and the metabolism of individuals are low (Grimes 1975). This condition reduces the suitability of the source waters to provide normal habitat functions necessary for subadult and adult life stages of managed living marine resources and their prey. Increased predation can also occur. Intakes can stress or disorient fish through nonlethal impingement or entrainment in the facility and by creating conditions favoring predators such as larger fish and birds (Hanson et al. 1977; NOAA 1994).

### *Ballast water and vessel operations intake*

Vessels take in and release water in order to maintain proper ballast and stability, which is affected by the variable weight of passengers and cargo and sea conditions. In addition, water is used for cooling engines and other systems. While the discharge of ballast water can cause significant impacts on the aquatic environment, particularly through the introduction of invasive species as discussed below, the intake of water for ballast and vessel cooling can also cause entrainment and impingement impacts on aquatic organisms.

Depending upon the size of the vessel, millions of gallons of water and its associated aquatic life, particularly eggs and larvae, can be transferred to the ballast tanks of a ship at a rate of tens of thousands of gallons per minute. For example, large ships, such as those constructed to transport liquefied natural gas (LNG), need to take on ballast water to stabilize the ship during offloading of the LNG. A 200,000-$m^3$ capacity LNG carrier would withdraw approximately 19.8 million gallons of water over a 10-hour period at an intake rate of 2 million gallons per hour (FERC 2005). The use of water for ballast and vessel cooling at these volumes and rates has the potential to entrain and impinge large numbers of fish eggs and larvae. For example, a proposed offshore LNG degasification facility using a closed-loop system near Gloucester, MA, would have estimated annual mortality of eggs and larvae from vessel ballast and cooling water for Atlantic mackerel (*Scomber scombrus*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), and Atlantic cod (*Gadus morhua*) of 8.5 million, 7.8 million, 411,000, and 569,000, respectively (USCG 2006). Refer to the chapters on Energy-related Activities and Marine Transportation for additional information on vessel entrainment and impingement impacts.

### *Alteration of hydrological regimes/flow restrictions*

Water withdrawals for industrial or municipal water needs can have a number of physical effects to riverine systems, including altering stream velocity, channel depth and width, turbidity, sediment and nutrient transport characteristics, dissolved oxygen concentrations, and seasonal and diel temperature patterns (Christie et al. 1993; Fajen and Layzer 1993). These physical changes can have ecological impacts, such as a reduction of riparian vegetation that affects the availability of fish habitat and prey (Christie et al. 1993; Fajen and Layzer 1993; Spence et al. 1996). Alteration of freshwater flows is one of the most prevalent problems facing coastal regions and has had profound effects on riverine, estuarine, and marine fisheries (Deegan and Buchsbaum 2005). For example, water in the Ipswich River in Massachusetts has been reduced to 10% of historic natural flows because of increased water withdrawals, such as irrigation water during the growing season, power plant cooling water, and potable water for a growing human population (Bowling and Mackin 2003). Approximately one-half of the 45-mile long Ipswich River was reported to have gone completely dry in 1995, 1997, 1999, and 2002, and nearly one-half of the native fish populations have either been extirpated or severely reduced in size (Bowling and Mackin 2003). Many estuarine and diadromous species, such as American eel (*Anguilla rostrata*), striped bass (*Morone* *saxatilis*), white perch (*Morone americana*), Atlantic herring (*Clupea harengus*), blue crab (*Callinectes sapidus*), American lobster (*Homarus americanus*), Atlantic menhaden (*Brevoortia tyrannus*), cunner (*Tautogolabrus adspersus*), Atlantic tomcod (*Microgadus tomcod*), and rainbow smelt (*Osmerus mordax*), depend upon the development of a counter current flow set up by freshwater discharge to enter estuaries as larvae or early juveniles; reductions in the timing and volume of freshwater entering estuaries can reduce this counter current flow and disrupt larval transport (Deegan and Buchsbaum 2005).

### *Increased need for dredging*

The alteration of the hydrological regimes and reductions in flow in riverine and estuarine systems caused by water intake structures can result in the build-up of sediments and increase the need to dredge around the intake facilities in order to prevent the sediments from negatively affecting the operations of the facility. Dredging can cause direct mortality of the benthic organisms within the area to be dredged, result in turbidity plumes of suspended particulates that can reduce light penetration, interfere with respiration and the ability of site-feeders to capture prey, impede the migration of anadromous fishes, and affect the growth and reproduction of filter feeding organisms. For more detailed discussion on the impacts of dredging, refer to the chapters on Marine Transportation and Offshore Dredging and Disposal Activities.

### *Habitat impacts*

The operation of water intake facilities can have a broad range of adverse effects on fishery habitats, including the conversion and loss of habitat and the alteration of the community structure resulting from changes in the hydrological regimes, salinities, and flow patterns. Large withdrawals of freshwater from riverine systems above the tidal water influence can cause an upstream "relocation" of the salt wedge, altering an area's suitability for some freshwater species and possibly altering benthic community structure. In addition, reductions in the volume of freshwater entering estuaries can alter vertical and longitudinal habitat structure and disrupt larval transport (Deegan and Buchsbaum 2005). Water withdrawals during certain times of the year, such as the use of irrigation water during the growing season of crops, power plant cooling water used during high energy-demand periods, or for domestic water usage during dry, summer months can severely impact the ecological health of riverine systems. For example, the water withdrawal from the Ipswich River in Massachusetts increases by two-fold or more during summer months when natural river flows are lowest (Bowling and Mackin 2003). This has led to one-half of the river going completely dry in some years and has caused fish kills and habitat degradation (Bowling and Mackin 2003).

### *Construction-related impacts*

Impacts to aquatic habitats can result from construction-related activities (e.g., dewatering, dredging) as well as routine operation and maintenance activities for water intake facilities. Generally, these impacts are similar in nature to both water intake and discharge structures and facilities. There is a broad range of impacts associated with these activities depending on the specific design and needs of the system. For example, dredging activities associated with construction of pipelines, bulkheads and seawalls, and buildings for a facility can cause turbidity and sedimentation in nearby waters, degraded water quality, noise, and substrate alterations. Filling of the aquatic habitat may also be needed for the construction of the facilities. Excavation of sediments in subtidal and intertidal habitats during construction may have at least short-term impacts, but the recovery of the aquatic habitat for spawning and egg deposition is uncertain

(Williams and Thom 2001). Many of these impacts can be reduced or eliminated through the use of various techniques, procedures, or technologies such as careful siting of the facility, timing restrictions on in-water work, and the use of directional drilling for the installation of pipelines. Some impacts may not be fully eliminated except by eliminating the activity itself.

Turbidity plume and sedimentation effects incidental to facility construction commonly produce a range of direct and indirect effects to living aquatic resources and their habitats. However, not all of the ecological implications of sediment resuspension and transport result in adverse effects to aquatic organisms (Blaber and Blaber 1980). The life history and ecological strategies characteristic of different species also are important considerations in assessing potential physical impacts from facility installation. For instance, while highly motile adult and juvenile life stages of most fishes could flee when construction is ongoing, egg and larval stages as well as nonmotile benthic organisms will likely not be able to avoid impacts. As a general rule, the severity of adverse effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996). The eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Reductions in the hatching success of white perch and striped bass eggs were reported at suspended sediment concentrations of 1,000 mg/L, and the survival of striped bass and yellow perch (*Perca flavescens*) larvae were reduced at concentrations greater than 500 mg/L and for American shad larvae at concentrations greater than 100 mg/L (Auld and Schubel 1978). Nelson and Wheeler (1997) found reduced hatching success for winter flounder eggs exposed to suspended sediment concentrations as low as 75 mg/L. While some species like the sessile life stages of eastern oyster (*Crassostrea virginica*) have adapted to withstand some acute habitat disturbances such as sedimentation and turbidity (Galtsoff 1964; Levinton 1982), most benthic and slow-moving species would not be able to escape exposure and instead would exhibit adaptive physiological and biochemical responses to counter adverse effects to water quality.

The area affected by water quality impacts from the construction of a water intake facility is largely dependent on the nature of the resuspended sediments, the duration the sediments are held in the water column, and the factors contributing to the transport of the sediments from the site. As benthic material is disturbed during facility installation and site preparation, resuspended particulate matter settles predominantly in the immediate vicinity of the project. Remaining waterborne fractions subsequently would be transported from the site and dispersed according to the grain size of disturbed sediments, the velocity of local water currents, and local wave action (Neumann and Pierson 1966).

The construction of water intake facilities can create adverse impacts within the immediate vicinity of the construction, including disrupting ambient sediment stratigraphy, cohesiveness, and geochemistry. These effects have geochemical consequences that may be particularly significant when construction activities are located in depositional or nutrient-enriched areas and where local sediments tend to be fine-grained. While important, it is essential to recognize that local sediment composition is not the only factor which affects resuspension during water intake facility installation. The type of construction equipment used to build an intake structure also has an important influence on the dispersion of dredge material. For traditional clamshell dredging, Tavolaro (1984) estimates a 2% loss of material through sediment resuspension at the dredge site. Dredge equipment that fluidizes sediments to facilitate their removal (e.g., hydraulic dredges or water jets) could result in a greater dispersion of resuspended sediment, especially when local waters are not quiescent or in situations where unfiltered return flow to the waterway is permitted. While sediment particles naturally exhibit cycles of exchange between the water column and materials composing the bottom substrate (Turner and Millward 2002), mechanized equipment used to remove sediments can reasonably be expected to disturb much deeper sediment horizons in a short period of time than would be expected from storms or in all but the most highly erosion prone coastal areas.

Additional discussions of the effects of dredging, dredged material disposal, and coastal development can be found in the Marine Transportation, Coastal Development, and Offshore Dredging and Disposal chapters.

### *Conservation measures and best management practices for water intake facilities (adapted from Hanson et al. 2003)*

1. Locate facilities that rely on surface waters for cooling or ballast in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where important fishery species or their prey concentrate for spawning and migration.
2. Design and operate facilities to create flow conditions that provide for passage, water quality, proper timing of life history stages, and properly functioning channel, floodplain, riparian, and estuarine conditions.
3. Establish adequate instream flow conditions for anadromous fish.
4. Design intake structures to minimize entrainment or impingement. Velocity caps that produce horizontal intake/discharge currents should be employed, and intake velocities across the intake screen should generally not exceed 0.5 ft/s.
5. Use closed-loop cooling systems in facilities requiring water whenever practicable, especially in areas that would impinge and entrain large numbers of fish and invertebrates.
6. Screen water diversions on fish-bearing streams, as needed. In general, 2 mm wedge wire screens are recommended on intake facilities in areas that support anadromous fishes.
7. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems).
8. Assess existing and potential aquatic vegetation, the volume and depth of the water body, the amount and timing of freshwater inflow, the presence of upland rearing and spawning habitat, and the relative salinity of the water body.
9. Assess the hydrology of the regulated land's tolerance for increased water exchange. The assessment should account for active management of the water intake facility to allow increased water exchange during critical periods.
10. Install intake pipes and facilities during low flow periods and tidal stage; incorporate appropriate erosion and sediment control best management practices, and have an equipment spill and containment plan and appropriate materials onsite.
11. Monitor facility operations to assess impacts on water temperatures, dissolved oxygen, and other applicable parameters. Adaptive management should be designed to minimize impacts.

## Discharge Facilities

### *Introduction*

Although there are a number of potential impacts to aquatic resources from point-source discharges, it is important to be aware that not all point-source discharge results in adverse impacts to aquatic organisms or their habitats. Most point-source discharges are regulated by the US Environmental Protection Agency (US EPA) under the National Pollutant Discharge Elimination System (NPDES), and the effects on receiving waters are generally considered under this permitting program. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

Industrial, municipal, and other facilities must obtain permits if their discharges go directly into surface waters. In most cases, the NPDES permit program is administered by authorized state agencies.

Point source discharges may modify habitat by creating adverse impacts to sensitive areas such as freshwater, estuarine, and marine wetlands; emergent marshes; and submerged aquatic vegetation beds and shellfish beds. Extreme discharge velocities of effluent may also cause scouring at the discharge point as well as entrain particulates and thereby create turbidity plumes.

### *Habitat conversion and exclusion*

The discharge of effluent from point sources can cause numerous habitat impacts resulting from the changes in sediments, salinities, temperatures, and current patterns. These can include the conversion and loss of habitat as the salinities of estuarine areas decrease from the inflow of large quantities of freshwater or as areas become more saline through the discharge of effluent from desalinization plants. Temperature changes, increased turbidity, and the release of contaminants can also result in the reduced use of an area by marine and estuarine species and their prey and impede the migration of some diadromous fishes. Outfall pipes and their discharges may alter the structure of the habitats that serve as juvenile development habitat, such as eelgrass beds (Williams and Thom 2001). Power plants, for example, release large volumes of water at higher than ambient temperatures, and the area surrounding the discharge pipes may not support a healthy, productive community because of physical and chemical alterations of the habitat (Wilbur and Pentony 1999).

The accumulation of sediments at an outfall may alter the composition and abundance of infaunal or epibenthic invertebrate communities (Ferraro et al. 1991). These accumulated sediments can smother sessile organisms or force mobile animals to migrate from the area. If sediment characteristics are changed drastically at the discharge location, the benthic community composition may be altered permanently. This can lead to reductions in the biological productivity of the habitat at the discharge site for some aquatic resources as their prey species and important habitat types, such as aquatic vegetation, are no longer present. Outfall pipes can act as groins and interrupt sand transport, cause scour around the structures, and convert native sand habitat to larger course sediment or bedrock (Williams and Thom 2001). This can affect the spawning success of diadromous and estuarine species, many of which serve as prey species for other commercially or recreationally important species.

### *Alteration of sediment composition*

As discussed above, outfall pipes and their discharges may alter the composition of sediments that serve as juvenile development habitat through scouring or deposition of dissimilar sediments (Williams and Thom 2001). Outfalls that typically release water at high velocities may scour sediments in the vicinity of the outfall and convert the substrate to course sediments or bedrock. Conversely, outfalls that release water at lower velocities that contain fine grained, silt-laden sediments may accumulate sediments near the outfall and increase the need to dredge to remove sediment buildup (Williams and Thom 2001). This can lead to a change in the community composition because many benthic organisms are sensitive to grain size. The chronic accumulation of sediments can also bury benthic organisms that serve as prey and limit an area's suitability as forage habitat.

### *Substrate and sediment scouring*

The discharge of effluent from point sources can result in a variety of benthic habitat and water quality impacts relating to scouring of substrate and sediments at the discharge point.

Changes to the substrate from scouring may impact benthic invertebrate and shellfish community, as well as submerged aquatic vegetation, such as eelgrass (Williams and Thom 2001).

### *Turbidity and sedimentation effects*

Turbidity plumes of suspended particulates caused by the discharge of effluent, the scouring of the substrate at the discharge point, and even the repeated maintenance dredging of the discharge area can reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area while elevated turbidity persists. Fish and invertebrates in the immediate area may suffer a wide range of adverse effects, including avoidance and abandonment of the area, reduced feeding ability and growth, impaired respiration, a reduction in egg hatching success, and resistance to disease if high levels of suspended particulates persist (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; Wilber and Clarke 2001). Auld and Schubel (1978) reported reduced egg hatching success in white perch and striped bass at suspended sediment concentrations of 1,000 mg/L. They also found reduced survival of striped bass and yellow perch larvae at concentrations greater than 500 mg/L and for American shad at concentrations greater than 100 mg per liter (Auld and Schubel 1978). Short-term effects associated with an increase in suspended particles may include high turbidity, reduced light, and sedimentation, which may lead to the loss of benthic structure and disrupt overall productivity if elevated levels persist (USFWS and NMFS 1999; Newcombe and Jensen 1996). Other problems associated with suspended solids include reduced water transport rates and filtering efficiency of fishes and invertebrates and decreased foraging efficiency of sight feeders (Messieh et al. 1991; Wilber and Clarke 2001). Breitburg (1988) found the predation rates of striped bass larvae on copepods decreased by 40% when exposed to high turbidity conditions in the laboratory. In riverine habitats, Atlantic salmon (*Salmo salar*) fry and parr find refuge within interstitial spaces provided by gravel and cobble that can be potentially clogged by sediments, subsequently decreasing survivorship (USFWS and NMFS 1999).

### *Increased need for dredging*

The release of sediment from water discharge facilities, as well as increased turbidity and sedimentation resulting from high velocity outfall structures, can lead to a build-up of sediments. Over time this may increase the need to dredge around the discharge facility in order to prevent the sediments from negatively affecting the operations of the facility or interfering with vessel navigation. Dredging can cause direct mortality of the benthic organisms within the area to be dredged, as well as create turbidity plumes of suspended particulates that can reduce light penetration, interfere with respiration and the ability of site-feeders to capture prey, impede the migration of anadromous fishes, and affect the growth and reproduction of filter feeding organisms (Wilber and Clarke 2001). For more detailed discussion on the impacts of dredging, refer to the chapters on Marine Transportation and Offshore Dredging and Disposal Activities.

### *Reduced dissolved oxygen*

The contents of the suspended material can react with the dissolved oxygen in the water and result in oxygen depletion, which can impact submerged aquatic vegetation and benthos in the vicinity. Reduced dissolved oxygen (DO) can cause direct mortality of aquatic organisms or result in subacute effects such as reduced growth and reproductive success. Bejda et al. (1992) found that the growth of juvenile winter flounder was significantly reduced when DO levels were maintained at 2.2 mg/L or when DO varied diurnally between 2.5 and 6.4 mg/L for a period of 11 weeks.

## *Alteration of temperature regimes*

Sources of thermal pollution from water discharge facilities include industrial and power plants. Temperature changes resulting from the release of cooling water from power plants can cause unfavorable conditions for some species while attracting others. Altered temperature regimes have the ability to affect the distribution, growth rates, survival, migration patterns, egg maturation and incubation success, competitive ability, and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003). Increased water temperatures in the upper strata of the water column can result in water column stratification, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries (Kennedy et al. 2002). Because warmer water holds less oxygen than colder water does, increased water temperatures reduce the DO concentration in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. In addition, thermal stratification could also affect primary and secondary productivity by suppressing nutrient upwelling and mixing in the upper regions of the water column, potentially altering the composition of phytoplankton and zooplankton. Impacts to the base of the food chain would not only affect fisheries, but could impact entire ecosystems.

Elevated water temperature can alter the normal migration patterns of some species or result in thermal stress and mortality in individuals should the discharges cease during colder months of the year. Thermal effluents in inshore habitat can cause severe problems by directly altering the benthic community or killing marine organisms, especially larval fish. Temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969). Investigations to determine the thermal tolerances of larvae of Atlantic herring, smooth flounder (*Pleuronectes putnami*), and rainbow smelt suggests that these species can tolerate elevated temperatures for short durations which are near the upper limits of cooling systems of most normally operating nuclear power plants (Barker et al. 1981). However, a number of factors affected the survival of larvae, including the salinity the individuals were acclimated to and the age of the larvae.

Long-term thermal discharge may change natural community dynamics. For example, elevated water temperature has been identified as a potential factor contributing to harmful algae blooms (ICES 1991), which can lead to rapid growth of phytoplankton populations and subsequent oxygen depletion, sometimes resulting in fish kills. Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States caused by anthropogenic impacts may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005).

## *Alteration of salinity regimes*

The discharge of water with elevated salinity levels from desalination plants may be a potential source of impacts to fishery resources. Waste brine is either discharged directly to the ocean or passed through sewage treatment plants. Although some studies have found desalination plant effluent to not produce toxic effects in marine organisms (Bay and Greenstein 1994), there may be indirect effects of elevated salinity on estuarine and marine communities, such as forcing juvenile fish into areas that could increase their chances of being preyed upon by other species. Conversely, treated freshwater effluent from municipal wastewater plants can produce localized reductions in salinity and could subject juvenile fish to conditions of less than optimal salinity for growth and development (Hanson et al. 2003).

### *Changes in local current patterns*

In addition to changes in temperature and salinity, local current patterns can be altered by outfall discharges or by the structures themselves. These changes can be related to changes in the rate of sedimentation around the outfall, the volume of water discharged, and the size and location of the structures.

### *Release of radioactive wastes*

Both natural and anthropogenic sources of radionuclides exist in the environment (ICES 1991). Potential sources of anthropogenic radioactive wastes include nonpoint sources, such as storm water runoff and atmospheric sources (e.g., coal-burning power plants) and point sources, such as industrial facilities (e.g., uranium mining and milling fuel lubrication) and nuclear power plant discharges (ICES 1991; NEFMC 1998). Fish exposed to radioactive wastes can accumulate radioisotopes in tissues, causing toxicity to other marine organisms and consumers (ICES 1991). The identification of radioactive wastes from industrial and nuclear power plant discharges was a focus of concern during the 1980s (ICES 1991). However, most studies since then have found trends of decreasing releases of artificial radionuclides from industrial and nuclear power plant discharges and reduced tissue-burdens in sampled fish and shellfish to levels similar to naturally occurring radionuclides (ICES 1991).

### *Ballast water discharges*

Commercial cargo-carrying and recreational vessels are the primary type of vector that transports marine life around the world, some of which become exotic, invasive species that can alter the structure and function of aquatic ecosystems (Valiela 1995; Carlton 2001; Niimi 2004). Ballast water discharges, occurring when ships take on additional cargo while at a port, are one of the largest pathways for the introduction and spread of aquatic nuisance species (ANS). The introduction of ANS can have wide reaching impacts to the aquatic ecosystem, the economy, and human health. Many ANS species are transported and released in ballast in their larval stages, become bottom-dwelling as adults, and include sea anemones, marine worms, barnacles, crabs, snails, clams, mussels, bryozoans, sea squirts, and seaweeds (Carlton 2001). In addition, some species are transported and released as adults, including diatoms, dinoflagellates, copepods, and jellyfish (Carlton 2001). Invasive, exotic species can displace native species and increase competition with native species and can potentially alter nutrient cycling and energy flow leading to cascading and unpredictable ecological effects (Carlton 2001). Additional discussion of the effects of introduced species can be found in the chapters on Introduced/Nuisance Species and Aquaculture and Marine Transportation.

### *Behavioral effects*

Discharge facility effluents have the potential to alter the behavior of riverine, estuarine, and marine species by changing the chemical and physical attributes of the habitat and water column in the vicinity of the outfall. These include attractions to the increase in flow velocity and altered temperature regimes at the discharge point and changes in predator/prey interactions. Changes in temperature regimes can artificially attract species and alter their normal seasonal migration behavior, resulting in cold shock and mortality of fishes when ambient temperatures are colder and the flow of heated water is ceased during a facility shutdown (Pilati 1976). Shorelines physically altered with outfall structures may also disrupt the migratory patterns and pathways of fish and invertebrates (Williams and Thom 2001).

## *Physiological effects*

Point-source discharges can cause a wide range of physiological effects on aquatic resources including both lethal and sublethal effects. Alteration of temperature, salinity, and dissolved oxygen concentration regimes have been shown to effect the normal physiology of marine organisms and can retard or accelerate egg and larval development and time of hatching (Blaxter 1969). Fish subjected to abnormally cold or hot temperatures from water discharges will either leave the affected area or acclimate to the change if it is within the species' thermal tolerance zone (Pilati 1976). However, a sudden change in ambient temperature can cause thermal shock and result in death to the fish, or the thermal shock may debilitate a fish and make it susceptible to predation (Pilati 1976). Temperature plays an important role in determining the survival and fitness of coldwater species, such as Atlantic salmon, and can affect the normal growth and development of eggs and fry (Blaxter 1969; Spence et al. 1996).

Water intake and outfall facilities can also have widespread chemical effects on aquatic organisms. These effects are discussed in the Chemical Effects: Water Discharge Facilities chapter.

## *Construction-related impacts of water discharge facilities*

The physical effects of constructing water discharge facilities can result from a number of activities, including releasing suspended sediments and associated pore-water in the construction zone; removal of bottom sediments and subsequent suspended sediments; turbidity and alteration of benthic habitats from dredging; releasing drill mud or cuttings from a directional drilling operation; and the loss or conversion of the existing benthic habitat and water column from placement of fill pipelines, and shoreline stabilization structures (e.g., riprap, headwalls). The impacts associated with constructing water intake and discharge structures and facilities are similar in nature and have been discussed in more detail in the Intake Facilities section of this chapter.

## *Conservation measures and best management practices for discharge facilities (adapted from Hanson et al. 2003)*

1. Conduct a thorough environmental assessment of proposed site locations for water discharge facilities prior to granting any regulatory permits. The assessments should include detailed investigations on the utilization of the aquatic environment by resident and transient species, including the migratory pathways of marine and diadromous fishes. Physical and chemical parameters of the proposed site should be included, such as sediment and substrate characteristics, hydrological dynamics of tides and currents, and temperature and salinity regimes.
2. Develop outfall design (e.g., modeling concentrations within the predicted plume or likely extent of deposition within the zone of influence) by using site specific, hydrological data with input from appropriate resource agencies.
3. Select appropriate point-source discharge locations by using information on the concentrations of living marine resources based upon site-specific, biological assessments. Sensitive and highly productive areas and habitats, such as shellfish beds, sea grass beds, hardbottom reefs should be avoided. Reduce potentially high velocities by diffusing effluent to acceptable velocities.
4. Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter ambient temperatures and cause a change in species assemblages and ecosystem function in the receiving waters. Strategies should be implemented to diffuse the heated effluent.

5. Use land-treatment and upland disposal/storage techniques where possible. Use of vegetated wetlands as natural filters and pollutant assimilators for large-scale discharges should be limited to those instances where other less damaging alternatives are not available and the overall environmental and ecological suitability of such an action has been demonstrated.
6. Avoid siting pipelines and treatment facilities in wetlands and streams. Since pipeline routes and treatment facilities should not necessarily be water-dependent with regard to positioning, the priority should be to avoid their placement in wetlands or other fragile coastal habitats. Avoiding placement of pipelines within streambeds and wetlands will also reduce inadvertent infiltration into conveyance systems and retain natural hydrology of local streams and wetlands.
7. Ensure that all discharge water from outfall structures meets state and federal water quality standards. Whenever feasible, discharge pipes should extend a substantial distance offshore and be buried deep enough to not affect shoreline processes. Buildings and associated structures should be set well back from the shoreline to preclude the need for bank armoring.

## References for Physical Effects: Water Intake and Discharge Facilities


Auld AH, Schubel JR. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine and Coastal Marine Science 6(2):153-64.

Barker SL, Townsend DW, Hacunda JS. 1981. Mortalities of Atlantic herring, *Clupea h. harengus*, smooth flounder, *Liopsetta putnami*, and rainbow smelt, *Osmerus mordax*, larvae exposed to acute thermal shock. Fisheries Bulletin 79(1):1981.

Bay S, Greenstein D. 1994. Toxic effects of elevated salinity and desalination waste brine. In: Cross J, editor. Southern California coastal water research project. Annual report 1992-1993. Westminister (CA): SCCWRP. p 149-53.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Blaber S, Blaber T. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143-62.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology-Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New York (NY): Academic Press. p 177-252.

Bowling A, Mackin K. 2003. The state of the Ipswich River. Ipswich (MA): Ipswich River Watershed Association. 9 p.

Brawn VM. 1960. Temperature tolerance of unacclimated herring (*Clupea harengus* L.). Journal of the Fisheries Research Board of Canada 17(5):721-3.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Christie RW, Allen DE, Jobsis GJ. 1993. Diversions. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 181-6.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: a region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Enright JT. 1977. Power plants and plankton. Marine Pollution Bulletin 8(7):158-61.

Fajen OF, Layzer JB. 1993. Agricultural practices. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 257-67.

[FERC] Federal Energy Regulatory Commission. 2005. Draft environmental impact statement, Down Landing LNG and Logan Lateral projects. Washington (DC): FERC Office of Energy Projects.

Ferraro SP, Swartz C, Cole FA, Schults DW. 1991. Temporal changes in the benthos along a pollution gradient: discriminating the effects of natural phenomena from sewage-industrial wastewater effects. Estuarine, Coastal and Shelf Science 33:383-407.

Galtsoff P. 1964. The American oyster *Crassostrea virginica* Gmelin. Fisheries Bulletin 64:1-480.

Gregory SV, Bisson PA. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In: Stouder DJ, Bisson PA, Naiman RJ, editors. Pacific salmon and their ecosystems: status and future options. New York (NY): Chapman and Hall. p 277-314.

Grimes CB. 1975. Entrapment of fishes on intake water screens at a stream electric generating station. Chesapeake Science 16(3):172-7.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Heimbuch DG, Dunning DJ, Ross QE, Blumberg AF. 2007. Assessing potential effects of entrainment and impingement on fish stocks of the New York-New Jersey Harbor estuary and Long Island Sound. Transactions of the American Fisheries Society 136:492-508.

Helvey M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47:18-26.

Helvey M, Dorn PB. 1987. Selective removal of reef fish associated with an offshore cooling-water intake structure. Journal of Applied Ecology 24(1):1-12.

[ICES] International Council for the Exploration of the Sea. 1991. Report of the study group on ecosystem effects of fishing activities. 11-15 March 1991; Lowestoft, England. Copenhagen (Denmark): ICES C.M. 1991/G:7 Session Y.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Langford TE, Utting NJ, Holmes RHA. 1978. Factors affecting the impingement of fishes on power station cooling-water intake screens. In: McLusky DS, Berry AJ, editors. Physiology and behaviour of marine organisms. Oxford (England) and New York (NY): Pergamon Press. p 281-8.

Levinton J. 1982. Marine ecology. New York (NY): Prentice-Hall. 526 p.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Moazzam M, Rizvi SHN. 1980. Fish entrapment in the seawater intake of a power plant at Karachi coast. Environmental Biology of Fishes 5:49-57.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1994. Experimental fish guidance devices. Position statement. [Internet]. Long Beach (CA): National Marine Fisheries Service, Southwest Region. [cited 2008 Jul 24]. 7 p. Available from: http://swr.nmfs.noaa.gov/hcd/exprscrn.pdf.

Nelson DA, Wheeler JL. 1997. The influence of dredging-induced turbidity and associated contaminants upon hatching success and larval survival of winter flounder, *Pleuronectes americanus*, a laboratory study. Milford (CT): Connecticut Department of Environmental Protection. Final Report on Grant CWF #321-R. 57 p.

Neumann G, Pierson WJ Jr. 1966. Principles of physical oceanography. Englewood Cliffs (NJ): Prentice-Hall International. 545 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe CP, MacDonald DD. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11(1):72-82.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the

proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.
Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Pilati DA. 1976. Cold shock: biological implications and a method for approximating transient environmental temperatures in the near-field region of a thermal discharge. Science of the Total Environment 6(3):227-37.

Rago PJ. 1984. Production forgone: an alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. Ecological Modelling 24(1-2):79-111.

Richkus WA, McLean R. 2000. Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay. Environmental Science and Policy 3(Supplement 1):283-93.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Tavolaro J. 1984. A sediment budget study of clamshell dredging and ocean disposal activities in the New York Bight. Environmental Geology and Water Science 6(3):133-40.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

Turner A, Millward GE. 2002. Suspended particles: their role in estuarine biogeochemical cycles. Estuarine, Coastal and Shelf Science 55:857-83.

[USCG] US Coast Guard. 2006. Environmental impact statement/environmental impact report for the Neptune LNG deepwater port license application. Washington (DC): USCG-2005-22611.

[USEPA] US Environmental Protection Agency. 2003. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Valiela I. 1995. Marine ecological processes, 2nd ed. New York (NY): Springer-Verlag.

[WDFW] Washington Department of Fish and Wildlife. 1998. Fish passage technical assistance: surface diversion and fish screen terminology. [Internet]. Olympia (WA): Washington

Department of Fish and Wildlife; c1998-1999; [cited 2007 Dec 28]. Available from: http://wdfw.wa.gov/hab/engineer/scrnterm.htm.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. [cited 2008 Jul 9]. 99 p. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

# CHAPTER NINE: AGRICULTURES AND SILVICULTURE

## Croplands, Rangelands, Livestock, and Nursery Operations

### *Introduction*

Substantial portions of croplands, rangelands, and commercial nursery operations are connected, either directly or indirectly, to coastal waters where point and nonpoint pollution can have an adverse effect on aquatic habitats. According to the US Environmental Protection Agency's (US EPA) 2000 National Water Quality Inventory, agriculture was the most widespread source of pollution for assessed rivers and lakes (USEPA 2002a). In that report, agriculture was responsible for 18% of all river-mile impacts and 14% of all lake-acre impacts in the United States. In addition, 48% of all impaired river miles and 41% of all impaired lake acres were attributed to agriculture (USEPA 2002a). Impacts to fishery habitat from agricultural and nursery operations can result from: (1) nutrient loading; (2) introduction of animal wastes; (3) erosion; (4) introduction of salts; (5) pesticides; (6) sedimentation; and (7) suspended silt in water column (USEPA 2002a).

### *Release of nutrients/eutrophication*

Nutrients in agricultural land are found in several different forms and originate from various sources, including: (1) commercial fertilizers containing nitrogen, phosphorus, potassium, secondary nutrients, and micronutrients; (2) manure from animal production facilities; (3) legumes and crop residues; and (4) irrigation water (USEPA 2002a). In addition, agriculturals land are characterized by poorly maintained dirt roads, ditches, and drains that transport sediments and nutrients directly into surface waters. In many instances, headwater streams have been replaced by a constructed system of roads, ditches, and drains that deliver nutrients directly to surface waters (Larimore and Smith 1963). Worldwide, the production of fertilizers is the largest source of anthropogenic nitrogen mobilization, although atmospheric deposition exceeds fertilizer production as the largest nonpoint source of nitrogen to surface waters in the northeastern United States (Howarth et al. 2002). Human activity is estimated to have increased nitrogen input to the coastal water of the northeastern United States, specifically to Chesapeake Bay, MD/VA, by 6- to 8-fold (Howarth et al. 2002). Castro et al. (2003) estimated that the mid-Atlantic and southeast regions contained between 24-37% agricultural lands, with fertilizers and manure applications representing the highest nitrogen sources for those watersheds. The Pamlico Sound-Pungo River, NC, and Chesapeake Bay estuaries contained the highest percent of nitrogen sources coming from agriculture from the mid-Atlantic region (Castro et al. 2003). The second leading cause of pollution in streams and rivers in Pennsylvania has been attributed to agriculture, primarily nutrient loading and siltation (Markham 2006).

Nitrogen and phosphorus are the two major nutrients from agriculture sources which degrade water quality. The main forces controlling nutrient movement from land to water are runoff, soil infiltration, and erosion. Introduction of these nutrients into aquatic systems can promote aquatic plant productivity and decay leading to cultural eutrophication (Waldichuk 1993). Eutrophication can adversely affect the quality and productivity of fishery habitats in rivers, lakes, estuaries, and near-shore, coastal waters. Eutrophication can cause a number of secondary effects, such as increased turbidity and water temperature, accumulation of dead organic material, decreased dissolved oxygen, and the proliferation of aquatic vegetation. Cultural eutrophication has resulted in widespread damage to the ecology of the Chesapeake Bay, causing nuisance algal blooms, loss of productive shellfish and blue crab (*Callinectes sapidus*) habitat, and destruction of submerged aquatic vegetation (SAV) beds (Duda 1985). Nearly 80% of the nutrient loads intothe Chesapeake

Bay can be attributed to nonpoint sources, and agriculture accounted for the majority of those (USEPA 2003b). Agriculture accounts for approximately 40% and 48% of nitrogen and phosphorus loads, respectively, to the Chesapeake Bay (USEPA 2003b). Chronic eutrophication has severely impacted the historically productive recreational and commercial fisheries of the Chesapeake Bay.

While eutrophication generally causes increased growth of aquatic vegetation, it has been shown to be responsible for wide spread losses of SAV in many urbanized estuaries (Deegan and Buchsbaum 2005). By stimulating the growth of macroalgae, such as sea lettuce (*Ulva lactuca*), eutrophication can alter the physical structure of seagrass meadows, such as eelgrass (*Zostera marina*), by decreasing shoot density and reducing the size and depth of beds (Short et al. 1993; MacKenzie 2005). These alterations can result in the destruction of habitat that is critical for developing juvenile fish and can severely impair biological food chains (Hanson et al. 2003).

Groundwater is also susceptible to nutrient contamination in agricultural lands composed of sandy or other coarse-textured soil (USGS 1999). Nitrate, a highly soluble and mobile form of nitrogen, can leach rapidly through the soil profile and accumulate in groundwater, especially in shallow zones (USEPA 2003a). In the eastern United States, nitrogen contamination of groundwater is generally higher in areas that receive excessive applications of agriculture fertilizers and manure, most notably in mid-Atlantic states like Delaware, Maryland, and Virginia (i.e., the Delmarva Peninsula) (USEPA 2003a). When discharged through seeps and drains, or by direct subsurface flow to water bodies, groundwater can be a significant source of nutrients to surface waters (Hanson et al. 2003). Phosphorus from agricultural sources, such as manure and fertilizer applications and tillage, can also be a significant contributor to eutrophication in freshwater and estuarine ecosystems. Cultivation of agricultural land greatly increases erosion and with it the export of particle-bound phosphorus.

Livestock waste (manure), including fecal and urinary wastes of livestock and poultry, processing water and the feed, bedding, litter, and soil with which they become intermixed, is reported to be the single largest source of phosphorus contamination in the United States (Howarth et al. 2002). Because cattle are often allowed to graze in riparian areas, nutrients that are consumed elsewhere are often excreted in riparian zones that can impact adjacent aquatic habitats (Hanson et al. 2003). Because grazing processes remove or disturb riparian vegetation and soils, runoff that carries additional organic wastes and nutrients into aquatic habitats is accelerated (Hanson et al. 2003). Pollutants contained and processed in rangelands, pastures, or confined animal facilities can be transported by storm water runoff into aquatic environments. These pollutants may include oxygen-demanding substances such as nitrogen and phosphorus; organic solids; salts; bacteria, viruses, and other microorganisms; metals; and sediments that increase organic decomposition (USEPA 2003a). Increased nutrient levels resulting from processed water or manure causes excessive aquatic plant growth and algae. The decomposition of aquatic plants depletes dissolved oxygen in the water, creating anoxic or hypoxic conditions that can lead to fish kills. For example, six individual spills from animal waste lagoons in North Carolina during 1995 totaled almost 30 million gallons; including one spill that involved 22 million gallons of swine waste that was responsible for a fish kill along a 19-mile stretch of the New River (USEPA 2003a). Animal wastes from farms in the United States produce nearly 1.5 billion tons of nitrogen and phosphate-laden wastes each year that contribute to nutrient contamination in approximately 27,999 miles of rivers and groundwater (Markham 2006). The release of animal wastes from livestock production facilities have led to reductions in productivity of riverine, estuarine, and marine habitats because of eutrophication.

## *Introduction of pathogens*

Stormwater runoff from agriculture, particularly livestock manure, typically contains elevated levels of pathogens, including bacteria, viruses, and protozoa (USEPA 2003a). Pathogens are generally a concern to human health because of consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). While many pathogens affecting marine organisms are associated with upland runoff of fecal contamination, there are also naturally occurring marine pathogens that affect fish and shellfish (Shumway and Kraeuter 2000). Some naturally occurring pathogens, such as bacteria from the genus, *Vibrio*, or the dinoflagellate, *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species requires additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997). See also the chapter on Introduced/Nuisance Species and Aquaculture for more information on pathogens.

## *Reduced dissolved oxygen*

Reduced (hypoxic) or depleted (anoxic) oxygen conditions within estuarine waters as a result of cultural eutrophication may be one of the most severe problems facing coastal waters in the United States (Deegan and Buchsbaum 2005), and agriculture is a major contributing source in some areas. In general, extensive hypoxia has been more chronic in river-estuarine systems in the southern portion of the northeast coast (i.e., Narragansett Bay, RI, to Chesapeake Bay) than in the northern portion (Whitledge 1985; O'Reilly 1994; NOAA 1997). In 2001 approximately 50% of the deeper waters of the Chesapeake Bay had reduced dissolved oxygen concentrations (USEPA 2003b).

Warm temperatures, high metabolic sediment demand, and water column stratification, conditions that can be common at night during summer months, may lead to low dissolved oxygen concentrations in bottom waters (Deegan and Buchsbaum 2005). Hypoxia in estuaries north of Cape Cod, MA, are uncommon because of strong mixing and flushing characteristics of their waters in the northern New England region. However, high nutrient loads into aquatic habitats from livestock and croplands can cause hypoxic or anoxic conditions that can result in fish kills in rivers and estuaries in other areas of the northeast coast (USEPA 2003a; Deegan and Buchsbaum 2005), and they can potentially alter long-term community dynamics (NRC 2000; Castro et al. 2003). Chronic low-dissolved oxygen conditions can lower the growth and survivorship of finfish and shellfish. For example, the effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (*Pseudopleuronectes americanus*) (Bejda et al. 1992).

## *Altered temperature regimes*

Increased siltation in shallow aquatic habitats caused by erosion from croplands and livestock operations can result in increased water temperature (Duda 1985). In addition to accelerating bank erosion, loss of riparian vegetation resulting from livestock grazing can increase the amount of solar radiation reaching streams and rivers resulting in an increase in water temperatures (Moring 2005). Altered temperature regimes have the ability to affect the distribution, growth rates, survival, migration patterns, egg maturation and incubation success, competitive ability, and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003a). The temperature regimes of cold-water fish, such as Atlantic salmon (*Salmo salar*) and rainbow smelt (*Osmerus mordax*), may be exceeded in some rivers and streams of the northeastern United States and lead to local extirpation of these species. The removal of riparian vegetation can also lower water temperatures during winter, which can increase the formation of ice and delay the development of incubating fish eggs and alevins (Hanson et al. 2003). Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005). In the watersheds of eastern Maine, blueberry and cranberry processing plants discharge processing water into rivers important to Atlantic salmon spawning and migration. These facilities are permitted to discharge water at temperatures known to be lethal to both juvenile and adult Atlantic salmon (USFWS and NMFS 1999).

### *Siltation, sedimentation, and turbidity*

As discussed above, siltation, sedimentation, and turbidity impacts related to agricultural activities are generally a result of soil erosion. Agricultural lands are also characterized by poorly maintained dirt roads, ditches, and drains that transport sediments directly into surface waters. Suspended sediments in aquatic environments reduce the availability of sunlight to aquatic plants, cover fish spawning areas and food supply, interfere with filtering capacity of filter feeders, and can clog and harm the gills of fish, and when the sediments settle they can cover oysters and shells which prevents oyster larvae from settling on them (USEPA 2003a; MacKenzie 2007). The largest source of sediment into Chesapeake Bay, for example, is from agriculture. Approximately 63% of the over 5 million pounds of sediment delivered each year to tidal waters of the Chesapeake Bay comes from agricultural sources (MacKenzie 1983; USEPA 2003b) and results in devastating impacts to shellfish and SAV. Wide-spread agricultural deforestation during the 18$^{th}$ and 19$^{th}$ centuries contributed to large sediment loads in the James,VA; York, VA; Rappahannock,VA; Potomac, WV/VA/MD/DC; Patuxent, MD; Choptank, DE/MD; and Nanticoke, DE/MD, Rivers and which may have contributed to the decline of Atlantic sturgeon (*Acipenser oxyrinchus*) populations in the Chesapeake Bay watershed (USFWS and NMFS 1998).

In addition to the affects described in greater detail within the Bank and Soil Erosion subsection of this chapter, contaminants such as pesticides, phosphorus, and ammonium are transported with sediment in an adsorbed state, such that they may not be immediately available to aquatic organisms. However, alteration in water quality, such as decreased oxygen concentration or changes in water alkalinity, may cause these chemicals to be released from the sediment (USEPA 2003a). Consequently, the impacts to aquatic organisms associated with siltation and sedimentation may be combined with the affects of pollution originating from the agricultural lands.

### *Altered hydrological regimes*

There are both direct and indirect affects of agriculture activities on the hydrology of coastal watersheds. Direct alterations of hydrology can occur from water diversion projects used for crop irrigation and livestock operations. The volume and timing of freshwater delivery to estuaries can be altered by water diversions, such as for agriculture, which in turn can increase the salinity of coastal ecosystems and diminish the supply of sediments and nutrients to estuaries (Deegan and Buchsbaum 2005). Agriculture activities use large volumes of water for irrigation, accounting for one-third of all US water withdrawals in 2000 and the second largest source of total water use after thermoelectric energy (Markham 2006).

Water withdrawal for agriculture can have adverse affects on anadromous fish, particularly Atlantic salmon, which use rivers in the Gulf of Maine for spawning and migration. Water withdrawals pose a threat to life stages of Atlantic salmon and their habitat in the Machias, Pleasant, and Narraguagus Rivers in Maine (USFWS and NMFS 1999). Freshwater was diverted from eastern Maine watersheds in the late 1990s to irrigate approximately 6,000 acres of blueberry agricultural activities, and that acreage was expected to double by the year 2005 (USFWS and NMFS 1999). The withdrawal of water may also affect the productivity of oyster beds in the eastern United States, because the distribution of oysters is largely governed by water salinity. When water is withdrawn, oyster beds are forced to move upstream and into smaller areas and often closer to cities where pollution may affect commercial marketing of the oysters (MacKenzie 2007).

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and can increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002). Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005). In addition, counter current flows set up by freshwater discharges into estuaries are important for larvae and juvenile fish entering those estuaries. The diurnal behavioral adaptations of marine and estuarine species allow larvae and early juveniles to concentrate in estuaries. Reductions in freshwater flows caused by increased freshwater withdrawals can disrupt counter current flows and larval transport into estuaries (Deegan and Buchsbaum 2005). The quality and quantity of freshwater flows into estuaries are important in maintaining suitable conditions for spawning, egg, larval, and juvenile development for many estuarine-dependent species.

Indirect affects occur when sediments are transported from agricultural lands via soil erosion and are deposited in roadside ditches, streams, rivers, and navigation channels, which decrease the capacity of watersheds to attenuate the affects of flooding. The morphology of streams and rivers can be altered by eroded soil from improper livestock grazing and croplands, changing the stream width and depth and the timing and magnitude of stream flow (USEPA 2003a). In addition, sediment deposited in lakes and navigation channels reduces the storage capacity of those systems and necessitates more frequent dredging (USEPA 2003a).

### *Impaired fish passage*

Sediments transported from agricultural lands via soil erosion can change the morphology of streams and rivers. As a result, alteration of stream width and depth and the timing and magnitude of stream flow can impair the ability of anadromous fish to reach upstream spawning habitats. Roads that are constructed to access agriculture lands and for livestock may impede or prohibit migrating fish. For example, culverts constructed under roads to allow for water flow can alter the velocity and volume of water in streams and inhibit the ability of fish to migrate through the structure (Furniss et al. 1991). Additional information on fish passage impairments can be reviewed in the Alteration of Freshwater Systems chapter of this report.

### *Change in community structure and species composition*

Cropland and livestock operations can result in community-level impacts to riverine and estuarine ecosystems. As mentioned above, fertilizers applied to agricultural lands enter streams, rivers, and estuaries through stormwater runoff and groundwater sources (e.g., seeps and subsurface flows) and may result in eutrophication. Eutrophication can cause a number of secondary effects, such as increased turbidity and water temperature, accumulation of dead organic material, decreased dissolved oxygen, and the proliferation of macroalgae, such as sea lettuce (MacKenzie 2005). These alterations can then result in the destruction of habitat for small or juvenile fish and severely impair biological food chains (Hanson et al. 2003). For example, eelgrass beds growing in deeper areas of estuaries tend to be impacted more than shallower areas because those beds are very sensitive to light attenuation as a result of eutrophication (Deegan and Buchsbaum 2005). Species that depend upon eelgrass beds may be forced into shallower, potentially less desirable habitats. Declines in commercially and recreationally important finfish in Waquoit Bay, MA, have followed a concomitant decline in eelgrass beds for that area (Deegan and Buchsbaum 2005). Similarly, eelgrass wasting disease was documented to be responsible for severe declines in bay scallop (*Argopectin irradians*) landings along the east coast in the 1930s (Buchsbaum 2005).

Other impacts from agricultural activities such as soil erosion and release of fine sediments can alter aquatic communities through siltation and alteration of benthic substrates. Waldichuk (1993) identified a number of impacts to Pacific salmon (*Oncorhynchus* spp.) caused by activities related to agriculture, such as siltation in spawning, egg incubation and feeding habitats, impaired respiration and abrasion of gills from suspended particles, and failure of egg hatching resulting from low dissolved oxygen. The cumulative effect from the degradation of riverine habitats can inhibit or preclude restoration efforts of salmon populations to historic ranges by altering the community. Release of nutrients from fertilizers applied to croplands, livestock manure, and erosion of soils can reduce the dissolved oxygen levels in aquatic habitats through storm water runoff. Reduced dissolved oxygen in the water or sediments can change community composition to coastal habitats, particularly in areas with restricted water circulation such as coastal ponds, subtidal basins, and salt marsh creeks (Deegan and Buchsbaum 2005). Chronic hypoxia caused by cultural eutrophication can permanently alter the species composition and productivity of these areas.

### *Entrainment and impingement*

Water diverted and extracted for agriculture use can entrain (i.e., draw into flow system) and impinge (i.e., capture onto filter screens) aquatic organisms. Entrainment and impingement generally affects eggs, larvae, and early juvenile fish and invertebrates that cannot actively avoid the currents created at the water intake opening (ASMFC 1992). Long-term water withdrawal may adversely affect fish and invertebrate populations as well as their prey by adding another source of mortality to the early life stage which often determines recruitment and year-class strength (Hanson et al. 2003). Refer to the Physical Affects: Water Intake and Discharge Facilities chapter in this report for additional information on entrainment and impingement.

### *Bank and soil erosion*

Soil erosion in US farmland is estimated to occur seven times as fast as soil formation (Markham 2006). Soil erosion can lead to the transport of fine sediment that may be associated with a wide variety of pollutants from agricultural land into the aquatic environment. The presence of livestock in the riparian zone accelerates sediment transport rates by increasing surface soil erosion (Hanson et al. 2003), loss of vegetation caused by trampling, and streambank erosion resulting from shearing or sloughing (Platts 1991). Increased sedimentation in aquatic systems can increase turbidity and the temperature of the water, reduce light penetration and dissolved oxygen, smother fish spawning areas and food supplies, decrease the growth of SAV, clog the filtering capacity of filter feeders, clog and harm the gills of fish, interfere with feeding behaviors of certain species, cover shells on oyster beds, and significantly lower overall biological productivity (MacKenzie 1983; Duda 1985; USEPA 2003a). Soil eroded and transported from cropland usually contains a higher percentage of finer and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides, herbicides, trace metals, and nutrients (Duda 1985; USEPA 2003a). One of the consequences of erosional runoff from agricultural land is that it necessitates more frequent dredging of navigational channels (USEPA 2003a), which may result in transportation to and disposal of contaminated sediments in areas important to fisheries production and other marine biota (Witman 1996). Deposition of sediments from erosional runoff can also decrease the storage capacity of roadside ditches, streams, rivers, and navigation channels, resulting in more frequent flooding (USEPA 2003a).

### *Loss and alteration of riparian-wetland areas*

Functioning riparian-wetland areas require stable interactions between geology, soil, water, and vegetation in order to maintain productive riverine ecosystems. When functioning properly, riparian-wetland areas can: (1) reduce erosion and improve water quality by dissipating stream energy; (2) filter sediment and runoff from floodplain development; (3) support denitrification of nitrate-contaminated groundwater; (4) improve floodwater retention and groundwater discharge; (5) develop root masses that stabilize banks from scouring and slumping; (6) develop ponding and channel characteristics necessary to provide habitat for fish, waterfowl, and invertebrates; and (7) support biodiversity (USEPA 2003a). Agriculture activities have the potential to degrade riparian habitats. In particular, improper livestock grazing along riparian corridors can eliminate or reduce vegetation by trampling and increase streambank erosion by shearing or sloughing (Platts 1991). These effects tend to increase the streambank angle, which increases stream width, decreases stream depth, and alters or eliminates fish habitat (USEPA 2003a). As discussed above, the transport of eroded soil from the streambank to streams and rivers impacts water quality and aquatic habitats. Removing riparian vegetation also increases the amount of solar radiation reaching the stream and can result in higher water temperatures.

### *Reduced soil infiltration and soil compaction*

Tillage of croplands aerates the upper soil but tends to compact fine textured soils just below the depth of tillage, thus altering infiltration. Use of farm machinery on cropland and adjacent roads causes further compaction, reducing infiltration and increasing surface runoff (Hanson et al. 2003).

Johnson (1992) and Platts (1991) reviewed studies related to livestock grazing and concluded that heavy grazing nearly always decreases infiltration, reduces vegetative biomass, and increases bare soil. Compaction of rangelands generally increases with grazing intensity, although site-specific soil and vegetative conditions are also important factors in determining the effects of soil compaction (Kauffman and Krueger 1984). Reduced soil infiltration and compaction caused by agriculture are two of the factors that accelerate erosion and release of sediments and contaminants in aquatic habitats.

Salts are present in varying amounts in all soils because of the natural weathering process, but agricultural lands that have poor subsurface drainage can lead to high salt concentrations. Likewise, irrigation water, whether from ground or surface water sources has a natural base load of dissolved mineral salts. Irrigation return flows convey the salt to the receiving streams or groundwater reservoirs. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that aquatic functions are impaired. However, if the process of water diversion and the return flow of saline drainage water is repeated many times along a stream or river, downstream habitat quality can become progressively degraded (USEPA 2003a). The accumulation of salts, particularly on irrigated croplands, tends to cause soil dispersion, structure breakdown, and decreased infiltration (USEPA 2003a). While salts are generally a greater pollutant for freshwater ecosystems than for estuarine systems, they may adversely affect anadromous fish that depend upon freshwater systems for crucial portions of their life cycles (USEPA 2003a).

### Land-use change (post-agriculture)

When demands for developable land are sufficiently high, the value of land in developed use will exceed its value in agricultural use. In general, conversion of land from agricultural to urban uses is largely irreversible according to the US Department of Agriculture. In the continental United States, census data from urban areas have shown more than a doubling of agricultural land conversion from 25.5 million acres to 55.9 million acres between 1960 and 1990 (USDA 2005). While impacts on aquatic ecosystems from agriculture may be problematic in some areas, conversion of croplands and rangelands to urban and industrial uses may be more harmful in the long-term. Between 1992 and 1997 the state of New York lost approximately 90,000 acres of prime farmland to residential and commercial development, which was 140% faster than in the previous five years (Markham 2006). Refer to the Coastal Development chapter in this report for more information on the impacts of land-use change.

### Release of pesticides, herbicides, and fungicides

The term "pesticide" is a collective description of hundreds of chemicals used to protect crops from damaging organisms with different sources and fates in the aquatic environment and that have varying toxic effects on fish and other aquatic organisms (USEPA 2003a). Pesticides can be divided into four categories according to the target pest: insecticides, herbicides, fungicides, and nematicides (USEPA 2003a). Agricultural activities are a major nonpoint source of pesticide pollution in coastal ecosystems (Hanson et al. 2003). Large quantities of pesticides, perhaps 18-20 pounds of pesticide active ingredient per acre, are applied to vegetable crops in coastal areas to control insect and plant pests (Scott et al. 1999). Soil eroded and transported from croplands and rangelands usually contains a higher percentage of finer and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides and herbicides (Duda 1985; USEPA 2003a). In addition, agricultural lands are typically characterized by poorly maintained dirt roads, ditches and drains that transport sediments, nutrients, and pesticides directly into surface waters. In many instances, roads, ditches, and drains have replaced headwater streams, and these constructed systems deliver pollutants directly to surface waters (Larimore and Smith 1963). Pesticides are frequently detected in freshwater and estuarine systems that provide fishery habitat.

The most common pesticides include insecticides, herbicides, and fungicides. These are used for pest control on forested lands, agricultural crops, tree farms, and nurseries. Pesticides can enter the aquatic environment as single chemicals or complex mixtures. Direct applications, surface runoff, aerial drift, leaching, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems (Hanson et al. 2003).

Most studies evaluating pesticides in runoff and streams generally find that concentrations can be relatively high near the application site and soon after application but are significantly reduced further downstream and with time (USEPA 2003a). However, some pesticides used in the past, such as dichlorodiphenyl trichloroethane (DDT), are known to persist in the environment for years after application. Chlorinated pesticides, such as DDT, and some of the breakdown products are known to cause malformation and fatality in eggs and larvae, alter respiration, and disrupt central nervous system functions in fish (Gould et al. 1994). In addition, pesticides containing organochlorine compounds accumulate and persist in the fatty tissue and livers of fish and could be a threat to human health for those who consume contaminated fish (Gould et al. 1994).

Pesticides may bioaccumulate in organisms by first being adsorbed by sediments and detritus which are ingested by zooplankton and then eaten by planktivores, which in turn are eaten by fish (ASMFC 1992). For example, the livers of winter flounder from Boston and Salem Harbors, MA, contained the highest concentrations of DDT found on the east coast of the United

States and were ranked first and third, respectively, in the country in terms of total pesticides (Larsen 1992). In the Pocomoke River, MD/DE, a tributary of the Chesapeake Bay, agricultural runoff (primarily from poultry farms) was identified as one of the major sources of contaminants (Karuppiah and Gupta 1996). Blueberry and cranberry agriculture is an important land use in eastern Maine watersheds and involves the use of a number of pesticides, herbicides, and fungicides that may cause immediate mortalities to juvenile Atlantic salmon or can have indirect effects when chemicals enter rivers (USFWS and NMFS 1999). One study investigating the effects of two different classes of pesticides (organochlorines and organophosphates) in South Carolina estuaries found significant affects on populations of the dominant macrofauna species, daggerblade grass shrimp (*Palaemonetes pugio*), and mummichogs (*Fundulus heteroclitus*) (Scott et al. 1999). The study found impacts from pesticide runoff on daggerblade grass shrimp populations may cause community-level disruptions in estuaries; however, the authors concluded that implementation of integrated pest management, best management practices, and retention ponds could significantly reduce the levels of nonpoint source runoff from agriculture (Scott et al. 1999).

### *Endocrine disruptors*

Studies have recently focused on a group of chemicals, called "endocrine disruptors," that when present at extremely low concentrates can interfere with fish endocrine systems. Some of these chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Some of the chemicals shown to be estrogenic include some polychlorinated biphenyl (PCB) congeners, dieldrin, DDT, phthalates and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture. Several studies have found vitellogenin, a yolk precursor protein, in male fish in the North Sea estuaries (Thurberg and Gould 2005). Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997). However, the long-term effect of endocrine-disrupting substances on aquatic life is not well understood and demands serious attention by the scientific and resource policy communities.

### *Conservation measures and best management practices for croplands, rangelands, livestock, and nursery operations (adapted from Hanson et al. 2003)*

1. Recommend field and landscape buffers to provide cost-effective protection against the cumulative effects of multiple pollutant discharges associated with agricultural activities, including riparian forests, alley cropping, contour buffer strips, crosswind trap strips, field borders, filter strips, grassed waterways with vegetative filters, herbaceous wind barriers, vegetative barriers, and windbreak/shelterbelts.
2. Protect and restore soil quality with natural controls that affect permeability and water holding capacity, nutrient availability, organic matter content, and biological activity of the soil. Some examples of best management practices include cover cropping, crop sequence, sediment basins, contour farming, conservation tillage, crop residue management, grazing management, and the use of low-impact farming equipment.
3. Promote efficient use and appropriate applications of pesticides and irrigated water. Sound agricultural practices include use of integrated pest management, irrigation management, soil testing, and appropriate timing of nutrient applications.
4. Encourage protection and restoration of rangelands with practices such as rotational grazing systems or livestock distribution controls, exclusion of livestock from riparian and aquatic areas,

livestock-specific erosion controls, reestablishment of vegetation, or extensive brush management correction.
5. Avoid locating new confined animal facilities or expansion of existing facilities near riparian habitat, surface waters, and areas with high leaching potential to surface or groundwater. Ensure that adequate nutrient and wastewater collection facilities are in place.
6. Minimize water withdrawals for irrigation and promote water conservation measures, such as water reuse.
7. Site roads for agricultural lands to avoid sensitive areas such as streams, wetlands, and steep slopes.
8. Include best management practices (BMPs) for agricultural road construction plans, including erosion control, avoidance of side casting of road materials into streams, and using only native vegetation in stabilization plantings.
9. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

## Silviculture and Timber Harvest Activities

### *Introduction*

The growth and harvest of forestry products are major land-use types for watersheds along the east coast, particularly in New England, and can have short-term and long-term impacts to riverine habitat (USFWS and NMFS 1999). Forestry is the dominant land-use type in the watersheds of the Dennys, East Machias, Machias, Pleasant, and Narraguagus Rivers in Maine (USFWS and NMFS 1999). Forests that once covered up to 95% of the Chesapeake Bay watershed now cover only 58%, primarily because of land clearing for agriculture and timber (USEPA 2003b). Timber harvest generally removes the dominant vegetation; converts mature and old-growth upland and riparian forests to tree stands or forests of early seral stage; reduces the permeability of soils; increases sedimentation from surface runoff and mass wasting processes; alters hydrologic regimes; and impairs fish passage through inadequate design, construction, and maintenance of stream crossings (Hanson et al. 2003). Silviculture practices can also increase water temperatures in streams and rivers, increase impervious surfaces, and decrease water retention capacity in watersheds (USFWS and NMFS 1999). These watershed changes may result in inadequate river flows; increase stream bank and streambed erosion; sedimentation and siltation of riparian and stream habitat; increase the amount of woody debris; and increase of run-off and associated contaminants (e.g., from herbicides) (Sigman 1985; Hicks et al. 1991; Hanson et al. 2003). Debris (i.e., wood and silt) is released into the water as a result of timber harvest activities and can smother benthic habitat. Poorly placed or designed road construction can cause erosion, producing additional silt and sediment that can impact stream and riparian habitat. Deforestation can alter or impair natural habitat structures and dynamics of the ecosystem.

Four major categories of silviculture activities that can impact fishery habitat are: (1) construction of logging roads; (2) creation of barriers; (3) removal of streamside vegetation; and (4) input of pesticide and herbicide treatments to aquatic habitats.

### *Release of nutrients/eutrophication*

After logging activities, concentrations of plant nutrients in streams and rivers may increase for several years and up to a decade (Hicks et al. 1991). Excess nutrients, combined with increased light regimes caused by the removal of riparian vegetation, can stimulate algal growth; however, the effects of nutrient increases on salmonid populations are not well understood (Hicks et al. 1991). An estimated 41.5 million pounds of nitrogen per year from silviculture activities alone are released into the Chesapeake Bay watershed, contributing to phytoplankton blooms, chronic hypoxia (low dissolved oxygen concentrations), and die-off of SAV (USEPA 2003b).

### *Reduced dissolved oxygen*

Small wood debris and silt resulting from timber harvesting can smother benthic habitat and reduce dissolved oxygen levels in streams (Hicks et al. 1991; Hanson et al. 2003). Fine organic material introduced into streams following logging can result in increased oxygen demand and reduced exchange of surface and intergravel water (Hicks et al. 1991). While low oxygen conditions may not directly kill salmon embryos and alevins in streams after logging, emergent juveniles may have reduced viability (Hicks et al. 1991). Introduction of nutrients into aquatic systems can promote aquatic plant productivity and decay leading to cultural eutrophication (Waldichuk 1993). Anoxic (without oxygen) or hypoxic (low oxygen) conditions have caused widespread ecological problems for the Chesapeake Bay, resulting in a variety ecosystem impacts including the loss of shellfish beds and reductions of fish stocks in the Bay (USEPA 2003b). According to Chesapeake Bay Program modeling, approximately 15% of the nitrogen loads entering the Chesapeake Bay watershed each year are from forestry activities (USEPA 2003b).

### *Altered temperature regimes*

Removing streamside vegetation to construct logging access roads and logging adjacent to streams or rivers increase the amount of solar radiation reaching the water body and can increase water temperatures (Beschta et al. 1987; Hicks et al. 1991). In studies conducted in Alaska, researchers found that maximum temperatures in logged streams without riparian buffers exceeded that of unlogged streams by up to 5ºC, but did not reach lethal temperatures (Hanson et al. 2003). In cold climates, the removal of riparian vegetation can result in lower water temperatures during winter, increasing the formation of ice and damaging and delaying the development of incubating fish eggs and alevins (Hanson et al. 2003). In freshwater habitats of the northeastern United States, the temperature tolerances of cold-water fish such as Atlantic salmon and rainbow smelt may be exceeded leading to local extirpation of the species (USFWS and NMFS 1999). However, increased water temperatures can also increase primary and secondary production, which may lead to greater availability of food for fish (Hicks et al. 1991).

### *Siltation, sedimentation, and turbidity*

Sedimentation in streams resulting from timber harvesting activities can reduce benthic community production, cause mortality of incubating salmon eggs and alevins, reduce the amount of habitat available for juvenile salmon, and lower the productivity of oyster beds (MacKenzie 1983; Hicks et al. 1991; Hanson et al. 2003). Fine sediments deposited in salmon spawning gravel can reduce interstitial water flow, causing reduced dissolved oxygen concentrations, and they can physically trap emerging fry in the gravel (Hicks et al. 1991). Fine sediments on stream bottoms and in suspension can also reduce primary production and invertebrate abundance, reducing the availability of prey for fish (Hicks et al. 1991). Sedimentation in riparian habitat resulting from logging activities can reduce streamside vegetation that impacts bank stabilization, increasing solar radiation reaching the stream. In addition, suspended sediments can alter the behavior and feeding efficiencies of salmonids following timber harvesting (Hicks et al. 1991). Sawdust and pulp from sawmills and lumber companies can also enter streams and rivers and adversely affect benthic habitats of anadromous fish (Moring 2005).

Deforestation and silviculture activities have contributed to excessive amounts of sediments in Chesapeake Bay, which have led to adverse affects on benthic communities like SAV, oysters, and clams (USEPA 2003b). Nearly 1 million tons of sediments are estimated to enter the Chesapeake Bay each year from forestry activities alone, which accounts for approximately 20% of the total sediment loads into the Bay (USEPA 2003b).

### *Bank and soil erosion and altered hydrological regimes*

Timber harvesting may result in inadequate or excessive surface and stream flows, increased stream bank and streambed erosion, and the loss of complex instream habitats. Clear cutting large areas of forests can alter the hydrologic characteristics of watersheds, such as water temperature, and result in greater seasonal and daily variation in stream discharge and flows (Hicks et al. 1991; Hanson et al. 2003).

In addition, logging road construction can destabilize slopes and increase erosion and sedimentation. Mass wasting and surface erosion are the two major types of erosion that can occur from logging road construction. Mass movement of soils, commonly referred to as landslides or debris slides, is associated with timber harvesting and road building on high hazard soils and unstable slopes. The result is increased erosion and sediment deposition in down-slope waterways. Erosion from roadways is most severe when poor construction practices are employed that do not include properly located, designed, and installed culverts or when proper ditching is not utilized (Furniss et al. 1991).

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and can increase vertical stratification of the water column which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002).

### *Alteration and loss of vegetation*

By removing vegetation, timber harvesting tends to decrease the absorptive capability of the groundcover vegetation. This, in turn, increases surface runoff during periods of high precipitation. These effects can destabilize slopes, increase erosion, and cause sedimentation and debris input to streams (Hanson et al. 2003). Reductions in the supply of large woody debris to streams can result when old-growth forests are removed, with resulting loss of habitat complexity that is important for successful salmonid spawning and rearing (Hicks et al. 1991; Hanson et al. 2003). Removing riparian vegetation increases the amount of solar radiation reaching the stream and can result in higher water temperatures during summer months. A loss of riparian vegetation can also reduce stream water temperatures during the winter months (Beschta et al. 1987; Hicks et al. 1991).

### *Impaired fish passage*

Poorly placed or ill-designed culverts placed as part of road construction can negatively affect access to riverine habitat by fish. Stream crossings (e.g., bridges and culverts) on forest roads are often inadequately designed, installed, and maintained, and they frequently result in full or partial barriers to both the upstream and downsteam migration of adult and juvenile fish (Hanson et al. 2003). Perched culverts, in which the culvert invert at the downstream end is above the water level of the downstream pool, create waterfalls that can be physical barriers to migrating fish. Undersized culverts can accelerate stream flows to the point that these structures become velocity barriers for migrating fish. Blocked culverts can result in displacement of the stream from the downstream channel to the roadway or roadside ditch (Hanson et al. 2003). Blocked culverts often result from installation of undersized culverts or inadequate maintenance to remove debris. In addition, culverts and bridges deteriorate structurally over time, and failure to replace or remove them at the end of their useful life may cause partial or total blockage of fish passage.

### *Release of pesticides, herbicides, and fungicides*

Riparian vegetation is an important component of rearing habitat for fish, providing shade for maintaining cool water temperatures, food supply, channel stability, and structure (Furniss et al. 1991). Herbicides that are used to suppress terrestrial vegetation can negatively impact these habitat functions (USFWS and NMFS 1999). In addition, insecticides applied to forests to control pests can interfere with the smoltification process of Atlantic salmon, preventing some fish from successfully making the transition from fresh to salt water. Matacil, one pesticide used in the Maine timber industry, is known to contain an endocrine disrupting chemical (USFWS and NMFS 1999). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Refer to the Chemical Effects: Water Discharge Facilities chapter for more information on endocrine disruptors. Other possible affects to Atlantic salmon from pesticides may include altered chemical perception of home stream odor and osmoregulatory ability (USFWS and NMFS 1999).

### *Conservation measures and best management practices for silviculture and timber harvest activities*

1. Encourage timber operations to be located as far from aquatic habitats as possible. Buffer zones of 100 ft for first- and second-order streams and greater than 600 feet for fourth- and fifth-order streams are recommended.
2. Ensure that all silviculture and timber operations incorporate conservation plans that include control of nonpoint source pollution, protecting important habitat through landowner agreements, maintaining riparian corridors, and monitoring and controlling pesticide use.
3. Incorporate watershed analysis into timber and silviculture projects. Attention should be given to the cumulative effects of past, present, and future timber sales within a watershed.
4. Logging roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes.
5. Include BMPs for timber forest road construction plans, including erosion control, avoidance of side casting of road materials into streams, and using only native vegetation in stabilization plantings.
6. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

## Timber and Paper Mill Processing Activities

### *Introduction*

Timber and paper mill processing activities can affect riverine and estuarine habitats through both chemical and physical means. Timber and lumber processing can release sawdust and wood chips in riverine and estuarine environments where they may impact the water column and benthic habitat of fish and invertebrates. These facilities may also either directly or indirectly release contaminants, such as tannins and lignin products, into aquatic habitats (USFWS and NMFS 1999). Pulp manufacturing converts wood chips or recycled paper products into individual fibers by chemical and/or mechanical means, which are then used to produce various paper products. Paper and pulp mills use and can release a number of chemicals that are toxic to aquatic organisms, including chlorine, dioxins, and acids (Mercer et al. 1997), although a number of these chemicals have been reduced or eliminated from the effluent stream by increased regulations regarding their use.

### *Chemical contaminant releases*

Approximately 80% of all US pulp tonnage comes from kraft or sulfate pulping which uses sodium-based alkaline solutions, such as sodium sulfide and sodium hydroxide (USEPA 2002b). Kraft pulping reportedly involves less release of toxic chemicals, compared to other processes such as sulfite pulping (USEPA 2002b). Paper and pulp mills may also release a number of toxic chemicals used in the process of bleaching pulp for printing and wrapping paper products. The bleaching process may use chlorine, sulfur derivatives, dioxins, furans, resin acids, and other chemicals that are known to be toxic to aquatic organisms (Mercer et al. 1997). These chemicals have been implicated in various abnormalities in fish, including skin and organ tissue lesions, fin necrosis, gill hyperplasia, elevated detoxifying enzymes, impaired liver functions, skeletal deformities, increased incidence of parasites, disruption of the immune system, presence of tumors, and impaired growth and reproduction (Barker et al. 1994; Mercer et al. 1997). Because of concern about the release of dioxins and other contaminants, considerable improvements in the bleaching process have reduced or eliminated the use of elemental chlorine. Approximately 96% of all bleached pulp production uses chlorine-free bleaching technologies (USEPA 2002b).

An endocrine disrupting chemical, 4-nonylphenol, has been used in pulp and paper mill plants in Maine and has been shown to interfere with smoltification processes and the chemical perception of home range, and osmoregulatory ability in Atlantic salmon (USFWS and NMFS 1999). Other studies have implicated pulp and paper effluents in altered egg production, gonad development, sex steroids, secondary sexual characteristics, and vitellogenin concentration in male fish, which is considered to be an indicator of estrogenicity (Kovacs et al. 2005). A study investigating the prevalence of a microsporan parasite found in winter flounder in Newfoundland (Canada) waters observed infestations in the liver, kidney, spleen, heart, and gonads of fish collected downstream from pulp and paper mills, whereas fish collected from pristine sites harbored cysts of the parasite in only the digestive wall (Khan 2004). In addition, flounder with a high prevalence of parasite infections throughout multiple organs were found to have significant impairments to growth, organ mass, reproduction, and survival that were not observed in fish sampled from pristine locations, suggesting a link between those affects and effluent discharged by the pulp and paper mills (Khan 2004).

### *Entrainment and impingement*

Pulp and paper mills require large amounts of water and energy in the manufacturing process. For example, a bleached kraft pulp mill can utilize 4,000-12,000 gallons of water per ton of pulp produced (USEPA 2002b). Diverting water from streams, rivers, and estuaries for pulp and paper mills can entrain and impinge eggs, larvae, and juveniles and may impact local populations of fish and invertebrates. Information is not available on the potential magnitude of entrainment and impingement impacts from wood, pulp, and paper mills. Refer to Physical Effects: Water Intake and Discharge Facilities for more information on entrainment and impingement impacts.

### *Thermal discharge*

Pulp and paper production involves thermal and chemical processing to convert wood fibers to pulp or paper and may result in the release of effluent water with higher than ambient temperatures. There is a potential for cold-water fish such as Atlantic salmon and rainbow smelt to be adversely affected by these facilities. However, information is not available on the potential magnitude of thermal discharge impacts from wood, pulp, and paper mills.

### *Reduced dissolved oxygen*

Pulp and paper mill wastewaters generally contain sulfur compounds with a high biological oxygen demand (BOD), suspended solids, and tannins (USEPA 2002b). The release of these contaminants in mill effluent can reduce dissolved oxygen in the receiving waters. According to the US EPA, however, all kraft pulp mills and nearly all US paper mills have chemical recovery systems in place and primary and secondary wastewater treatment systems installed to remove particulates and BOD (USEPA 2002b).

### *Conversion of benthic substrate*

Sawdust and pulp from sawmills and lumber processing facilities can enter streams and rivers, adversely affecting benthic habitats for anadromous fish (Moring 2005). Pulp and paper mill effluent can contain solid particulates and a high BOD that can alter the benthic habitat of receiving water bodies. The impacts to benthic habitat from past practices of wood, pulp, and paper mills are evident today in some streams and rivers of Maine, including the Penobscot River from Winterport to Bucksport (USFWS and NMFS 1998). Most of the bottom substrate in this stretch of the Penobscot River is covered by bark and sawdust, which substantially reduces the diversity of benthic organisms (USFWS and NMFS 1998). However, chemical recovery systems and wastewater treatment systems should reduce or eliminate most solid wastes from the effluent stream.

### *Alteration of light regimes*

Lumber, pulp, and paper mills releasing effluent containing solids, a high BOD, and tannins can reduce water clarity and alter the light regimes in receiving waters. This can adversely affect primary production and SAV in riverine and estuarine habitat where these facilities are located. Information is not available on the potential magnitude of light regime impacts from wood, pulp, and paper mills.

### *Conservation measures and best management practices for timber and paper mill processing activities*

1. Ensure that lumber, pulp, and paper mills have adequate chemical recovery systems and wastewater treatment systems installed to reduce or eliminate most toxic chemicals and solid wastes from the effluent stream. Ensure that effluent streams do not elevate the ambient water temperatures of the receiving water bodies.
2. Discourage the construction of new lumber, pulp, and paper mills adjacent to riverine and estuarine waters that contain productive fisheries resources. New facilities should be sited so as to avoid the release of effluents in wetlands and open water habitats.
3. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

4. Incorporate watershed analysis into new lumber, pulp, and paper mill facilities, with consideration for the cumulative effects of past, present, and future impacts within the watershed.

## References for Agriculture and Silviculture


[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

Barker DE, Khan RA, Hooper R. 1994. Bioindicators of stress in winter flounder, *Pleuronectes americanus*, captured adjacent to a pulp and paper mill in St. George's Bay, Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 51(10):2203-9.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Beschta RL, Bilby RE, Brown GW, Holtby LB, Hofstra TD. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo EO, Cundy TW, editors. Streamside management: forestry and fishery interactions. Seattle (WA): University of Washington, College of Forest Resources. p 191-232.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Buchsbaum R. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Duda AM. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Water Resources Bulletin 21(2):225-34.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19 ed. Bethesda (MD): American Fisheries Society. p 297-323.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hicks BJ, Hall JD, Bisson PA, Sedell JR. 1991. Responses of salmonids to habitat changes. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitat. Special Publication 19 ed. Bethesda (MD): American Fisheries Society. p 483-518.

Howarth RW, Sharpley A, Walker D. 2002. Sources of nutrient pollution to coastal waters in the United States: implications for achieving coastal water quality goals. Estuaries 25(4b):656-76.

Johnson KL. 1992. Management for water quality on rangelands through best management practices: the Idaho approach. In: Naiman RJ, editor. Watershed management: balancing sustainability and environmental change. New York (NY): Springer-Verlag. p 415-41.

Karuppiah M, Gupta G. 1996. Impact of point and nonpoint source pollution on pore waters of two Chesapeake Bay tributaries. Ecotoxicology and Environmental Safety 35:81-5.

Kauffman JB, Krueger WC. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management 37(5):430-8.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Khan RA. 2004. Effect, distribution, and prevalence of *Glugea stephani* (Microspora) in winter flounder (*Pleuronectes americanus*) living near two pulp and paper mills in Newfoundland. Journal of Parasitology 90(2):229-33.

Kovacs T, Martel P, Ricci M, Michaud J, Voss R. 2005. Further insights into the potential of pulp and paper mill effluents to affect fish reproduction. Journal of Toxicology and Environmental Health 68(Part A):1621-41.

Larimore RW, Smith PW. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Illinois Natural History Survey Bulletin 28:299-382.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

MacKenzie CL Jr. 1983. To increase oyster production in the northeastern United States. Marine Fisheries Review 45(3):1-22.

MacKenzie CL Jr. 2005. Removal of sea lettuce, *Ulva* sp., in estuaries to improve the environments for invertebrates, fish, wading birds, and eelgrass, *Zostera marina*. Marine Fisheries Review 67(4):1-8.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

Mercer IRG, Barker DE, Khan RA. 1997. Stress-related changes in cunner, *Tautogolabrus adspersus*, living near a paper mill. Bulletin of Environmental Contamination and Toxicology 58(3):442-7.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1997. NOAA's estuarine eutrophication survey. Vol. 2: Mid-Atlantic Region. Silver Spring (MD): Office of Ocean Resources Conservation and Assessment. 51p.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Platts WS. 1991. Livestock grazing. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 389-423.

Scott GI, Fulton MH, Moore DW, Wirth EF, Chandler GT, Key PB, Daugomah JW, Strozier ED, Devane J, Clark JR, and others. 1999. Assessment of risk reduction strategies for the management of agricultural non-point source pesticide runoff in estuarine ecosystems. Toxicology and Industrial Health 15:200-13.

Short FT, Burdick DM, Wolf JS, Jones GE. 1993. Eelgrass in estuarine research reserves along the East Coast, U.S.A. Part I: declines from pollution and disease and Part II: management of eelgrass meadows. Silver Spring (MD): NOAA Coastal Ocean Program Publication. 107 p.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Sigman M. 1985. Impacts of clearcut logging on the fish and wildlife resources of southeast Alaska. Juneau (AK): Alaska Dept. of Fish and Game, Habitat Division. Technical Report 85-3.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

[USDA] US Department of Agriculture. 2005. Land use, value, and management: urbanization and agricultural land. [Internet]. Washington (DC): Economic Research Service. [updated 2005 Jun 28; cited 2007 Dec 21]. Available from: http://www.ers.usda.gov/Briefing/LandUse/urbanchapter.htm.

[USEPA] US Environmental Protection Agency. 2002a. National water quality inventory: 2000 Report to Congress. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-R-02-001. [cited 2008 Jul 9]. Available from: http://www.epa.gov/305b/2000report/.

[USEPA] US Environmental Protection Agency. 2002b. Profile of the pulp and paper industry, 2nd ed. [Internet]. Washington (DC): US EPA Office of Compliance Sector Notebook Project. EPA-310-R-02-002. [cited 2008 Jul 24]. 135 p. Available from: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp.html.

[USEPA] US Environmental Protection Agency. 2003a. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2003b. Technical support document for identification of Chesapeake Bay designated uses and attainability. [Internet]. Annapolis (MD): US EPA, Region III, Chesapeake Bay Program Office. EPA 903-R-03-004. [cited 2008 Jul 24]. 207 p. Available from: http://www.epa.gov/region03/chesapeake/uaasupport.htm.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). [Internet]. Hadley (MA): USFWS. [cited 2008 Jul 24]. 93 p. + appendices. Available from: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon.pdf.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

[USGS] US Geological Survey. 1999. The quality of our Nation's waters: nutrients and pesticides. [Internet]. Reston (VA): USGS Circular 1225. 82 p. [cited 2007 Dec 28]. Available from: http://pubs.usgs.gov/circ/circ1225/pdf/index.html.

Waldichuk M. 1993. Fish habitat and the impact of human activity with particular reference to Pacific salmon. In: Parsons LS, Lear WH, editors. Perspectives on Canadian marine fisheries management. Canadian Bulletin of Fisheries and Aquatic Sciences 226: 295-337.

Whitledge TE. 1985. Nationwide review of oxygen depletion and eutrophication in estuarine and coastal waters: Northeast region. Upton (NY): Brookhaven National Laboratory.

Witman JD. 1996. Dynamics of Gulf of Maine benthic communities. In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Darmouth College Regional Association for Research on the Gulf of Maine (RARGOM). Report 96-1. p 51-69.

# CHAPTER TEN: INTRODUCED/NUISANCE SPECIES AND AQUACULTURE

## Introduced/Nuisance Species

### *Introduction*

Introductions of nonnative invasive species into marine and estuarine waters are a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species can be released intentionally (i.e., fish stocking and pest control programs) or unintentionally during industrial shipping activities (e.g., ballast water releases), aquaculture operations, recreational boating, biotechnology, or from aquarium discharge (Hanson et al. 2003; Niimi 2004). Hundreds of species have been introduced into US waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001).

In New England and the mid-Atlantic region, a number of fish, crabs, bryozoans, mollusks, tunicates, and algae species have been introduced since colonial times (Deegan and Buchsbaum 2005). New introductions continue to occur, such as *Convoluta convoluta*, a small carnivorous flatworm from Europe that has invaded the Gulf of Maine (Carlton 2001; Byrnes and Witman 2003); *Didemnum* sp., an invasive species of tunicate that has invaded Georges Bank and many coastal areas in New England (Pederson et al. 2005); the Asian shore crab (*Hemigrapsus sanguineus*) that has invaded Long Island Sound, NY/CT, (Carlton 2001) and other coastal areas; and *Codium fragile* spp. *tomentosoides,* an invasive algal species from Japan that has invaded the Gulf of Maine (Pederson et al. 2005).

Introduced species may thrive best in areas where there has been some level of environmental disturbance (Vitousek et al. 1997; USFWS and NMFS 1999; Minchinton and Bertness 2003). For example, in riverine systems alteration in temperature and flow regimes can provide a niche for nonnative species to invade and dominate over native species such as salmon (USFWS and NMFS 1999). Invasive species introductions can result in negative impacts to the environment and to society, with millions of dollars being expended for research, control, and management efforts (Carlton 2001).

The impacts associated with introduced/nuisance species can involve habitat, species, and genetic-level effects. Introduced/nuisance species can impact the environment in a variety of ways, including: (1) habitat alterations; (2) trophic alterations; (3) gene pool alterations; (4) alterations to communities and competition with native species; (5) introduced diseases; (6) changes in species diversity; (7) alteration in the health of native species; and (8) impacts to water quality. The following is a review of the potential environmental impacts associated with the introduction of nonnative aquatic invasive/nuisance species into marine, estuarine, and freshwater ecosystems.

### *Habitat alterations*

Introduced species can have severe impacts on the quality of habitat (Deegan and Buchsbaum 2005). Nonnative aquatic plant species can infest water bodies, impair water quality, cause anoxic conditions when they die and decompose, and alter predator-prey relationships. Fish may be introduced into an area to graze and biologically control aquatic plant invasions. However, introduced fish may also destroy habitat, which can eliminate nursery areas for native juvenile fishes, accelerate eutrophication, and cause bank erosion (Kohler and Courtenay 1986).

Habitat has been altered by the introduction of invasive species in New England. For example, the green crab (*Carcinus maenus*) an exotic species from Europe, grazes on submerged aquatic vegeation and can interfere with eelgrass restoration efforts (Deegan and Buchsbaum 2005). *Didemnum* sp. is an invasive tunicate that has colonized the northern edge of Georges Bank, as well as many coastal areas in New England. This filter-feeding organism forms dense mats that encrust the seafloor, which can prevent the settlement of benthic organisms, reduce food availability for juvenile scallops and groundfish, and smother organisms attached to the substrate (e.g., Atlantic sea scallops [*Placopectin magellanicus*] in spat and juvenile stages) (Pederson et al. 2005; Valentine et al. 2007) and could have impacts to productive fishing grounds in New England and elsewhere. There is no evidence at this time that the spread of the tunicate on Georges Bank will be held in check by natural processes other than smothering by moving sediments; however, its offshore distribution may be limited by temperatures too low for reproduction (Valentine et al. 2007).

An invasive species of algae from Japan, *Codium fragiles* spp. *tomentosoides*, also referred to as deadman's fingers, has invaded subtidal and intertidal marine habitats in the Gulf of Maine and mid-Atlantic. Deadman's fingers can outcompete native kelp and eelgrass, thus destroying habitat for finfish and shellfish species (Pederson et al. 2005). The common reed (*Phragmites australis*) a nonnative marsh grass, has invaded coastal estuaries and can exclude native brackish and salt marsh plant species such as smooth cordgrass (*Spartina alterniflora*) from their historic habitat (Burdick et al. 2001; Minchinton and Bertness 2003; Deegan and Buchsbaum 2005). *Phragmites* invasions can increase the sedimentation rate in marshes and reduce intertidal habitat available for fish species in New England (Deegan and Buchsbaum 2005).

### *Trophic alterations and competition with native species*

Introduced species can alter the trophic structure of an ecosystem via increased competition for food and space between native and nonnative species (Kohler and Courtenay 1986; Caraco et al. 1997; Strayer et al. 2004; Deegan and Buchsbaum 2005) as well as through predation by introduced species on native species (Kohler and Courtenay 1986). Competition may result in the displacement of native species from their habitat or a decline in recruitment, which are factors that can collectively contribute to a decrease in population size (Kohler and Courtenay 1986). For example, introductions of the invasive zebra mussel (*Dreissena polymorpha*) in the Hudson River, NY/NJ, estuary coincided with a decline in the abundance, decreased growth rate, and a shift in the population distribution of commercially and recreationally important species (Strayer et al. 2004). Zebra mussels have altered trophic structure in the Hudson River estuary by withdrawing large quantities of phytoplankton and zooplankton from the water column, thus competing with planktivorous fish. Phytoplankton is the basis of the food web, and altering the trophic levels at the bottom of the food web could have a detrimental, cascading effect on the aquatic ecosystem. Increased competition for food between the zebra mussel and open-water commercial and recreational species such as the American shad (*Alosa sapidissima*) and black sea bass (*Centropristis striata*) has been associated with large, pervasive alterations in young-of-the-year fish, which can result in interspecies competition and alterations in trophic structure (Strayer et al. 2004; Deegan and Buchsbaum 2005).

Predation on native species by nonnative species may increase the mortality of a species and could also alter the trophic structure (Kohler and Courtenay 1986). Whether the predation is on the eggs, juveniles, or adults, a decline in native forage species can affect the entire food web (Kohler and Courtenay 1986). For example, the Asian shore crab invaded Long Island Sound and has an aggressive predatory behavior and voracious appetite for crustaceans, mussels, young clams, barnacles, periwinkles, polychaetes, macroalgae, and salt marsh grasses. The removal of the forage base by this invasive crab could have a ripple effect throughout the food web that could restructure communities along the Atlantic coast (Tyrrell and Harris 2000; Brousseau and Baglivo 2005).

### *Alterations to communities*

Introductions of nonnative species may result in alterations to communities and an increase in competition for food and habitat (Deegan and Buchsbaum 2005). For example, the green crab is an exotic species from Europe which preys on native soft-shelled clams and newly settled winter flounder (*Pseudopleuronectes americanus*) (Deegan and Buchsbaum 2005).

Nonnative marsh grass introductions can alter habitat conditions, resulting in changes in the fauna of salt marsh habitat. Alterations to communities have been noted in areas in which native marsh cordgrass habitat has been invaded by the invasive, exotic *Phragmites* (Posey et al. 2003). *Phragmites* has been implicated in alteration of the quality of intertidal habitats, including: lower abundance of nekton in *Phragmites* habitat; reduced utilization of this habitat by other species during certain life stages (Weinstein and Balletto 1999; Able and Hagan 2000); decreased density of gastropods, oligochaetes, and midges (Posey et al. 2003); decreased bird abundance and species richness (Benoit and Askins 1999); and avoidance of *Phragmites* by juvenile fishes (Weis and Weis 2000).

### *Gene pool alterations*

Native species may hybridize with introduced species that have a different genetic makeup (Kohler and Courtenay 1986), thus weakening the genetic integrity of wild populations and decreasing the fitness of wild species via breakup of gene combinations (Goldburg et al. 2001). Aquaculture operations have the potential to be a significant source of nonnative introductions into North American waters (Goldburg and Triplett 1997; USCOP 2004). Escaped aquaculture species can alter the genetic characteristics of wild populations when native species interbreed with escaped nonnative or native aquaculture species (USFWS and NMFS 1999).

In the Gulf of Maine, the wild Atlantic salmon (*Salmo salar*) population currently exhibits poor marine survival and low spawning stock and is in danger of becoming extinct, which makes the species particularly vulnerable to genetic modification via interbreeding with escaped aquaculture species. Any genetic modification combined with other threats such as reduced water levels, parasites and diseases, commercial and recreational fisheries, loss of habitat, poor water quality, and sedimentation may threaten or potentially extirpate the wild salmon stock in the Gulf of Maine (USFWS and NMFS 1999). Refer to the Aquaculture section of this chapter for a more detailed discussion on impacts from aquaculture operations.

### *Introduced diseases*

Introduced aquatic species are often vectors for disease transmittal that represent a significant threat to the integrity and health of native aquatic communities (Kohler and Courtenay 1986). Bacteria, viruses, and parasites may be introduced advertently or inadvertently and can reduce habitat quality (Hanson et al. 2003). The introduction of pathogens can have lethal or sublethal effects on aquatic organisms and has the potential to impair the health and fitness level of wild fish populations. Sources of introduced pathogens include industrial shipping, recreational boating, dredging activities, sediment disposal, municipal and agricultural runoff, wildlife feces, septic systems, biotechnology labs, aquariums, and transfer of oyster spat and other species to new areas for aquaculture or restoration purposes (ASMFC 1992; Boesch et al. 1997).

Parasite and disease introductions into wild fish and shellfish populations can be associated with aquaculture operations. These diseases have the potential to lower the fitness level of native species or contribute to the decline of native populations (USFWS and NMFS 1999). Examples include the MSX (multinucleated sphere unknown) oyster disease introduced through the Pacific oyster (*Crassostrea gigas*) which contributed to the decline of native oyster (*Crassostrea virginica*) populations in Delaware Bay, DE/NJ, and Chesapeake Bay, MD/VA, (Burreson et al. 2000; Rickards and Ticco 2002) and the Infectious Salmon Anemia (ISA) that has spread from salmon farms in New Brunswick, Canada, to salmon farms in Maine (USFWS and NMFS 1999). Refer to the Aquaculture section of this chapter for more information regarding diseases introduced through aquaculture operations.

### *Changes in species diversity*

Introduced species can rapidly dominate a new area and can cause changes within species communities to such an extent that native species are forced out of the invaded area or undergo a decline in abundance, leading to changes in species diversity (Omori et al. 1994). For example, changes in species distribution have been seen in the Hudson River, where the invasion of zebra mussels caused localized changes in phytoplankton levels and trophic structure that favored littoral zone species over open-water species. The zebra mussel invasion resulted in a decline in abundance of open-water fishes (e.g., American shad) and an increase in abundance for littoral zone species (e.g., sunfishes) (Strayer et al. 2004). Shifts in the distribution and abundance of species caused by introduced species can effect the diversity of species in an area.

Alterations in species diversity have been noted in areas in which native *Spartina alterniflora* habitat has been invaded by the exotic haplotype, *Phragmites australis* (Posey et al. 2003). *Phragmites* can rapidly colonize a marsh area, thus changing the species of marsh grass present at that site. In addition, *Phragmites* invasions have been shown to change species use patterns and abundance at invaded sites, potentially causing a cascading of effects to the species richness and diversity of a community.

Benthic species diversity can be altered by the introduction of shellfish for aquaculture purposes (Kaiser et al. 1998) and for habitat restoration projects. Cultivation of shellfish such as hard clams often requires the placement of gravel or crushed shell on the substrate. Changes in benthic structure can result in a shift in the community at that site (e.g., from a polychaete to a bivalve and nemertean dominated benthic community) which may have the effect of reduced diversity (Simenstad and Fresh 1995; Kaiser et al. 1998). However, community diversity may be enhanced by the introduction of aquaculture species and/or the modification of the substrate (Simenstad and Fresh 1995). In addition, changes in species diversity may occur as a result of oyster habitat restoration. Oyster reefs provide habitat for a variety of resident and transient species (Coen et al. 1999), so restoration activities that introduce oysters into an area may result in localized changes in species diversity, as reef-building organisms and fish are attracted to the restoration site. Refer to the section on Aquaculture of this chapter for more information regarding altered species diversity caused by aquaculture activities.

### *Alterations in the health of native species*

The health of native species can be impaired by the introduction of new species into an area. A number of factors may contribute to reduced health of native populations, including: (1) competition for food may result in a decrease in the growth rate and local abundance (Strayer et al. 2004) or the decline in the entire population (USFWS and NMFS 1999) of native species; (2) aggressive and fast growing nonnative predators can reduce the populations of native species (Pederson et al. 2005); (3) diseases represent a significant threat to the integrity and health of native aquatic communities and can decrease the sustainability of the native population (Kohler and

Courtenay 1986; USFWS and NMFS 1999; Rickards and Ticco 2002; Hanson et al. 2003); and (4) the genetic integrity of native species may be compromised through hybridization with introduced species (Kohler and Courtenay 1986), which can also decrease the fitness of wild species via breakup of gene combinations (Goldburg et al. 2001). The factors listed above, in combination with potential impact on the habitats of native species, can collectively result in long-term impacts to the health of native species (Burdick et al. 2001; Minchinton and Bertness 2003; Deegan and Buchsbaum 2005; Pederson et al. 2005).

### *Impacts to water quality*

Invasive species can affect water quality in marine, estuarine, and riverine environments because they have the potential to outcompete native species and dominate habitats. For example, nonnative aquatic plant species, which may not have natural predators in their new environments, can proliferate within water bodies, impair water quality, and cause anoxic conditions when they die and decompose. Fish species such as grass carp (*Ctenopharyngodon idella*) and tilapia (Cichlidae), introduced to control noxious weeds, can accelerate eutrophication through fecal decomposition of nutrients previously stored in the plants (Kohler and Courtenay 1986). In addition, fish introduced to control invasive plant species can increase turbidity in the water column from the grazing behavior itself (Kohler and Courtenay 1986).

Introduced nonnative algal species from anthropogenic sources such as ballast water and shellfish transfer (e.g., seeding) combined with nutrient overloading may increase the intensity and frequency of algal blooms. An overabundance of algae can degrade water quality when they die and decompose, which depletes oxygen levels in an ecosystem. Oxygen depletion can result in ecological "dead zones," reduced light transmittance in the water column, seagrass and coral habitat degradation, and large-scale fish kills (Deegan and Buchsbaum 2005).

### *Conservation measures and best management practices for impacts on aquatic habitats from introduced/nuisance species*

1. Do not introduce exotic species for aquaculture purposes unless a thorough scientific evaluation and risk assessment is performed. Aquaculturist should be encouraged to only culture native species in open-water operations.
2. Prevent or discourage boaters, anglers, aquaculturists, traders, and other potential handlers of introduced species from accidental or purposeful introduction of species into ecosystems where these species are not native. In addition, measures should be taken to prevent the movement or transfer of exotic species into other waters.
3. Encourage vessels to perform a ballast water exchange in marine waters (in accordance with the US Coast Guard's voluntary regulations) to minimize the possibility of introducing exotic species into estuarine habitats. Ballast water taken on in marine waters will contain fewer organisms, and these organisms will be less likely to become invasive in estuarine conditions than are species transported from other estuaries.
4. Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
5. Require vessels brought from other areas over land via trailering to clean any surfaces that may harbor nonnative plant or animal species (e.g., propellers, hulls, anchors, fenders). Bilges should be emptied and cleaned thoroughly with hot water or a mild bleach solution. These activities should be performed in an upland area to prevent introduction of nonnative species to aquatic environments during the cleaning process.

6. Encourage natural resource managers to provide outreach materials on the potential impacts resulting from releases of nonnative species into the natural environment.
7. Limit importation of ornamental fishes to licensed dealers.
8. Use only local, native fish for live seafood or bait.
9. Encourage natural resource managers to identify areas where invasive species have become established at an early time in the infestation and pursue efforts to remove them, either manually or by other methods.
10. Encourage natural resource managers to identify methods that eradicate or reduce the spread of invasive species (e.g., reducing *Phragmites* in coastal marshes by mitigating the effects of tidal restrictions).
11. Treat effluent from public aquaria displays, laboratories, and educational institutes that are using exotic species prior to discharge for the purpose of preventing the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.

# Aquaculture

## *Introduction*

Aquaculture is defined as the controlled cultivation and harvest of aquatic organisms, including finfish, shellfish, and aquatic plants (Goldburg et al. 2001, 2003). Aquaculture operations are conducted at both land and water facilities. Land-based aquaculture systems include ponds, tanks, raceways, and water flow-through and recirculating systems. Water-based aquaculture systems include netpens, cages, ocean ranching, longline culture, and bottom culture (Goldburg and Triplett 1997).

Aquaculture can provide a number of socio-economic benefits, including food provision, improved nutrition and health, generation of income and employment, diversification of primary products, and increased trade earnings through the export of high-value products (Barg 1992). Aquaculture can also provide environmental benefits by supporting stocking and release of hatchery-reared organisms, countering nutrient and organic enrichment in eutrophic waters from the culture of some mollusk and seaweed species, and because aquaculture operations relies on good water quality, the prevention and control of aquatic pollution (Barg 1992).

However, freshwater, estuarine, and marine aquaculture operations have the potential to adversely impact the habitat of native fish and shellfish species. The impact of aquaculture facilities varies according to the species cultured, the type and size of the operation, and the environmental characteristics of the site. Intensive cage and floating netpen systems typically have a greater impact because aquaculture effluent is released directly into the environment. Pond and tank systems are less harmful to the environment because waste products are released in pulses during cleaning and harvesting activities rather than continuously into the environment (Goldburg et al. 2001). The relative impact of finfish and shellfish aquaculture differs depending on the foraging behavior of the species. Finfish require the addition of a large amount of feed into the ecosystem, which can result in environmental impacts impacts from the introduction of the feed, but also from the depletion of species harvested to provide the feed. Bivalves are filter feeders and typically do not require food additives; however, fecal deposition can result in benthic and pelagic habitat impacts, changes in trophic structure (Kaspar et al. 1985; Grant et al. 1995), and nutrient and phytoplankton depletion (Dankers and Zuidema 1995).

Similar to the introduced/nuisance species section of this chapter, aquaculture activities can effect fisheries at both a habitat and species-level. Typical environmental impacts resulting from aquaculture production include: (1) impacts to the water quality from the discharge of organic wastes and contaminants; (2) seafloor impacts; (3) introductions of exotic invasive species; (4) food web impacts; (5) gene pool alterations; (6) changes in species diversity; (7) sediment deposition; (8) introduction of diseases; (9) habitat replacement or exclusion; and (10) habitat conversion. The following is a review of the known and potential environmental impacts associated with the cultivation and harvest of aquatic organisms in land- and water-based aquaculture facilities.

### *Discharge of organic wastes*

Aquaculture operations can degrade the quality of the water column and the benthic environment via the discharge of organic waste and other contaminants (Goldburg et al. 2001; USCOP 2004). Organic waste includes uneaten fish food, urine, feces, mucus, and byproducts of respiration, which can have an adverse effect on both benthic and pelagic organisms when released into marine, estuarine, and riverine environments.

Uneaten fish food can contribute a significant amount of nutrients to the ecosystem at aquaculture sites (Kelly 1992; Goldburg and Triplett 1997). Farmed fish are typically fed "forage fish" of low economic value, such as anchovies (Engraulidae) and menhaden (*Brevoortia* sp.), which are either fed directly to aquaculture species or processed into dry feed pellets. However, these "forage fish," while having low economic value, may be highly important to other species and the aquatic ecosystem. A large percentage of nutrients contained in farmed fish food are lost to the environment through organic waste. As much as 80% of total nitrogen and 70% of total phosphorus fed to farmed fish may be released into the water column through fish wastes (Goldburg et al. 2001).

In New England, the majority of aquaculture operations are located in Maine, with Cobscook Bay being the primary site of finfish aquaculture operations. Recent research in Cobscook Bay and in neighboring waters of New Brunswick, Canada, has shown the primary sources of nutrients in the area are finfish aquaculture operations and the open ocean (Goldburg et al. 2001). Research conducted at an aquaculture facility with 200,000 salmon has revealed that the amount of nitrogen, phosphorus, and feces discharged from the facility are equivalent to that released from untreated sewage produced by 20,000, 25,000, and 65,000 people, respectively (Goldburg et al. 2001).

The release of high concentrations of nutrients can negatively affect an aquatic system through eutrophication. Eutrophication of an aquatic system can occur when nutrients, such as nitrogen and phosphorus, are released in high concentrations and over long periods of time. Eutrophication can stimulate the growth of algae and other primary producers and, in some cases, may develop into "algal blooms" (Hopkins et al. 1995; Goldburg et al. 2001; Deegan and Buchsbaum 2005). Although the effects of eutrophication are not necessarily always adverse, they are often extremely undesirable and include: (1) increased incidence, extent, and persistence of noxious or toxic species of phytoplankton; (2) increased frequency, severity, spatial extent, and persistence of low oxygen conditions; (3) alteration in the dominant phytoplankton species and the nutritional-biochemical "quality" of the phytoplankton community; and (4) increased turbidity of the water column because of the presence of algae blooms (O'Reilly 1994).

Oxygen can be depleted in the water column during bacterial degradation of algal tissue or when algal respiration exceeds oxygen production and can result in hypoxic or anoxic "dead zones," reduced water clarity, seagrass habitat degradation, and large-scale fish kills (Deegan and Buchsbaum 2005). Algal blooms may contain species of phytoplankton such as dinoflagellates that can produce toxins, cause toxic blooms (e.g., red tides), kill large numbers of fish, contaminate shellfish beds, and cause health problems in humans. Coastal and estuarine ecosystems in the United States are already moderately to severely eutrophic (Goldburg et al. 2001; Goldburg and

Triplett 1997) and are expected to worsen in 70% of all coastal areas over the next two decades (USEPA 2001). Consequently, the frequency and severity of toxic algal blooms could increase in the future. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for more information on eutrophication and harmful algal blooms.

### *Discharge of contaminants*

In addition to organic waste, chemicals and other contaminants that are discharged as part of the aquaculture process can affect benthic and pelagic organisms (Hopkins et al. 1995; Goldburg and Triplett 1997). Chemicals are typically released directly into the water, including antibiotics that fight disease; pesticides that control parasites, algae, and weeds; hormones that initiate spawning; vitamins and minerals to promote fish growth; and anesthetics to ease handling of fish during transport. These chemical agents are readily dispersed into marine, estuarine, and freshwater systems and can be harmful to natural communities. Few chemicals have been approved for disease treatment in US aquaculture operations, although veterinarians can prescribe human and animal drugs use in food fish (Goldburg et al. 2001).

Antibiotics are given to fish and shrimp via injections, baths, and oral treatments (Hopkins et al. 1995; Goldburg and Triplett 1997). The most common method of oral administration is the incorporation of drugs into feed pellets, which results in a greater dispersion of antibiotics in the marine environment. Antibiotics, including those toxic to humans, typically bind to sediment particles, may remain in the environment for an extended period of time, can accumulate in farmed and wild fish and shellfish populations, and can harm humans when ingested.

Herbicides are chemicals used to control aquatic weeds in freshwater systems, and algicides are herbicides specifically formulated to kill algae; dissolved oxygen levels in ponds can be reduced when the algae die and decompose. A common ingredient in algicides is copper, which is toxic to aquatic organisms. Applications of herbicides or algicides must be carefully considered for their toxicity to aquaculture organisms and to humans, as well as their tendency to bioaccumulate in fish and shellfish tissues (Goldburg and Triplett 1997). While these chemicals may not be applied within riverine or estuarine systems, they may find their way there through stormwater runoff. Pesticides must also be carefully monitored for their effects on aquatic organisms and habitat. For example, antifouling compounds such as copper and organic tin compounds were historically used in the aquaculture industry to prevent fouling organisms from attaching to aquaculture structures. These chemicals accumulate in farmed and wild organisms, especially in shellfish species, and the use of organic tin compounds is now banned for use in both Washington and Maine. Aquaculturalists have used the insecticide, Sevin, for 35 years in Willapa Bay, WA, to control burrowing shrimp that destabilize sediment. Sevin kills other organisms such as the Dungeness crab (*Cancer magister*), and it should be used in moderation to minimize the impacts of the aquaculture industry on other important commercial fisheries (Goldburg and Triplett 1997). For additional information on the release of pesticides, refer to the Agriculture and Silviculture and Coastal Development chapters of this report.

### *Seafloor impacts*

Aquaculture operations not only can cause environmental impacts through the discharge of contaminants and organic wastes, but these operations can also affect the seafloor as a result of the deposition of waste products, the placement of aquaculture structures on the seafloor, and the harvesting of aquaculture species.

Aquaculture operations can have a wide range of biological, chemical, and physical impacts on seafloor habitat stemming from organic material deposition, shading effects, damage to habitat from aquaculture structures and operations, and harvesting with rakes and dredges (USFWS and NMFS 1999; Goldburg et al. 2001). Organic material deposition beneath netpens and cages can smother organisms, change the chemical and biological structure of sediment, alter species biomass and diversity, and reduce oxygen levels. The physical and chemical conditions present at the aquaculture site will influence the degree to which organic waste affects the benthic community. At aquaculture sites with slower currents and softer sediments, benthic community impacts will generally be localized; whereas sites with stronger currents and coarser sediments will generally have widely distributed but less intense benthic community effects downstream of the site.

At both land-based and water-based aquaculture facilities, accumulations of large amounts of carbon and nutrient-rich sediment may produce anaerobic conditions in sediments and cause the release of hydrogen sulfide and methane, two gases toxic to fish (Goldburg and Triplett 1997). In Maine, seafloor impacts resulting from sediment deposition at salmon farms include the growth of the bacterial mold *Beggiatoa* sp., which degrades water quality and subsequently lowers species diversity and biomass beneath the pens (Goldburg and Triplett 1997).

Suspended shellfish culture techniques may cause changes in benthic community structure similar to those conditions found under netpens. Filter-feeding shellfish "package" phytoplankton and other food particles into feces and pseudofeces, which are deposited on the seafloor and may cause local changes in benthic community structure (Grant et al. 1995; Goldburg and Triplett 1997). In Kenepuru Sound, New Zealand, a mussel aquaculture site consistently showed a higher organic nitrogen pool than at the reference site, indicating that organic nitrogen was accumulating in the sediments below the mussel farm (Kaspar et al. 1985). The benthic community at the mussel farm was composed of species adaptable to low-oxygen levels that live in fine-textured, organically rich sediments, while the reference site consisted of species that typically reside in highly oxygenated water (Kaspar et al. 1985).

Aquaculture structures can have direct impacts on seafloor habitat, including shading of seafloor habitat by netpens and cages (NEFMC 1998; USFWS and NMFS 1999). Shading can impede the growth of SAV that provides shelter and nursery habitat to fish and their prey species (Barnhardt et al. 1992; Griffin 1997; Deegan and Buchsbaum 2005). Seagrasses and other sensitive benthic habitats may also be impacted by the dumping of shells onto the seafloor for use in shellfish aquaculture operations (Simenstad and Fresh 1995). Shell substratum helps to stabilize the benthos and improve growth and survival of the cultured shellfish species. The placement of this material on the bottom not only causes a loss in seagrass and other habitat, but substrate modification also induces a localized change in benthic community composition (Simenstad and Fresh 1995).

Harvesting practices also have the potential to adversely affect seafloor habitat. Perhaps the most detrimental is the mechanical harvesting of shellfish (e.g., the use of dredges). Polychaete worms and crustaceans may be removed or buried during dredging activities (Newell et al. 1998). Mechanical harvesting of shellfish may also adversely affect benthic habitat through direct removal of seagrass and other reef-building organisms (Goldburg and Triplett 1997).

### *Introductions of exotic invasive species*

Aquaculture operations have the potential to be a significant source of nonnative introductions into North American waters (Goldburg and Triplett 1997; USCOP 2004). The cultivation of nonnative species becomes problematic when fish escape or are intentionally released into the marine environment. As discussed in the above section on introduced/nuisance species, introduced species can reduce biodiversity, alter species composition, compete with native species for food and habitat, prey on native species, inhibit reproduction, modify or destroy habitat, and introduce new parasites or diseases into an ecosystem (Goldburg and Triplett 1997; USFWS and

NMFS 1999). Impacts from introduced aquaculture species may result in the displacement or extinction of native species, which is believed to be a contributing factor in the decline of seven endangered or threatened fish species populations listed under the Endangered Species Act (Goldburg and Triplett 1997).

In Maine, escaped aquaculture salmon can disrupt redds (i.e., spawning nests) of wild salmon, transfer disease or parasites, compete for food and habitat, and interbreed with wild salmon (USFWS and NMFS 1999). Escaped aquaculture salmon represent a significant threat to wild salmon in Maine because even at low levels of escapement, aquaculture salmon can represent a large proportion of the salmon returns in some rivers. Escaped Atlantic salmon have been documented in the St. Croix, Penobscot, East Machias, Dennys, and Narraguagus rivers in Maine. Escapees represented 89% and 100% of the documented runs for the Dennys River in 1994 and 1997, respectively, and 22% of the documented run for the Narraguagus River in 1995 (USFWS and NMFS 1999). In 2000, only 22 wild Atlantic salmon in Maine were documented as returning to spawn in their native rivers; however, total adult returning spawners may have numbered approximately 150 fish (Goldburg et al. 2001).

Cultivating a reproductively viable European stock of Atlantic salmon in Maine waters poses a risk to native populations because of escapement and the subsequent interbreeding of genetically divergent populations (USFWS and NMFS 1999). The wild Atlantic salmon population in the Gulf of Maine currently exhibits poor marine survival and low spawning stock size, is particularly vulnerable to genetic modification, and is in danger of becoming extinct. Dilution of the gene pool, when combined with environmental threats such as reduced water levels, parasites and diseases, commercial and recreational fisheries, loss of habitat, poor water quality, and sedimentation could extirpate the wild salmon stock in the Gulf of Maine (USFWS and NMFS 1999). For additional discussions on this topic, refer to the subsection in this chapter on Gene Pool Alterations.

### *Food web impacts*

Aquaculture operations have the potential to impact food webs via localized nutrient loading from organic waste and by large-scale removals of oceanic fish for dry-pellet fish feed (Goldburg and Triplett 1997). As reviewed in previous sections of this chapter, nutrients in discharged organic waste may affect local populations by changing community structure and biodiversity. These localized changes may have broader implications to higher trophic level organisms. For example, biosedimentation at a mussel aquaculture site had a strong effect on benthic community structure both below and adjacent to mussels grown on rafts (Kaspar et al. 1985). Benthic species located beneath and adjacent to mussel rafts included sponges, tunicates, and calcareous polychaete worms, while benthic species at the reference site included bivalve mollusks, brittle stars, crustaceans, and polychaete worms. The shift in benthic community structure at the shellfish aquaculture site may have had implications in higher trophic levels in the ecosystem.

Large-scale removals of anchovy, herring, sardine, jack mackerel, and other pelagic fishes for the production of fish feed has an impact on the food web. Approximately 27% (31 million metric tons) of the world's fish harvest is now used to produce fish feeds, and about 15% of this is used in aquaculture production (Goldburg and Triplett 1997). Feeding fish to other fish on a commercial scale is highly energy-inefficient and may have environmental implications and impacts on other species. Higher trophic levels depend on small pelagic fishes for growth and survival, so the net removal of protein can have significant effects on sea birds, mammals, and commercially important fish species (Goldburg and Triplett 1997).

## *Gene pool alterations*

Escaped aquaculture species can alter the genetic characteristics of wild populations when native species interbreed with escaped nonnative or native aquaculture species or escaped genetically engineered aquaculture species (USFWS and NMFS 1999; Goldburg et al. 2001; USCOP 2004). Interbreeding of the wild population with escaped nonnative species is problematic, as discussed in the Introduced/Nuisance Species section of this chapter. Interbreeding of the wild population with escaped, native species may also be problematic because of the genetic differences between the escaped native and the wild native populations. Aquaculture operations often breed farmed fish for particular traits, such as smaller fins, aggressive feeding behavior, and larger bodies. Therefore, the genetic makeup of escaped native and wild native fish may be different, and interbreeding may decrease the fitness of wild populations through the breakup of gene combinations and the loss of genetic diversity (Goldburg et al. 2001).

Atlantic salmon aquaculture in New England has been established from Cape Cod, MA, north to Canada, although most of this activity is clustered at the Maine-New Brunswick border. In 1994, thousands of Atlantic salmon escaped from an aquaculture facility during a storm event; many of these fish spread into coastal rivers in eastern Maine (Moring 2005). In 2000, a similar storm event in Maine resulted in the escapement of 100,000 salmon from a single farm, which is more than 1,000 times the documented number of native adult Atlantic salmon. Canada is experiencing similar problems with aquaculture escapees and the interbreeding of wild and farmed salmon populations. In 1998, 82% of the young salmon leaving the Magaguadavic River in New Brunswick originated from aquaculture farms (Goldburg et al. 2001). Escapees can and do breed with wild populations of Atlantic salmon, which is a concern because interbreeding can alter the genetic makeup of native stocks (Moring 2005).

Escaped genetically engineered aquaculture species may exacerbate the problem of altering the gene pool of native fish stocks. Genetically engineered (i.e., transgenic) species are being developed by inserting genes from other species into the DNA of fish for the purpose of altering performance, improving flesh quality, and amplifying traits such as faster growth, resistance to diseases, and tolerance to freezing temperatures (Goldburg and Triplett 1997; Goldburg et al. 2001). For example, genetically engineered Atlantic salmon have an added hormone from chinook salmon that promotes faster growth, which may reduce costs for growers (Goldburg et al. 2001, 2003). Although no transgenic fish products are commercially available in the United States, at least one company has applied for permission through the Food and Drug Administration to market a genetically-engineered Atlantic salmon for human consumption (Goldburg et al. 2001, 2003). Transgenic aquaculture escapees could impair wild Atlantic salmon stocks via competition, predation, and expansion into new regions. Interbreeding could weaken the genetic integrity of wild salmon populations and have long-term, irreversible ecological effects (Goldburg et al. 2001).

## *Impacts to the water column and water quality*

Aquaculture may impact the water column via organic and contaminant discharge from land- and water-based aquaculture sites (NEFMC 1998). As discussed in other sections of this chapter, aquaculture discharges include nutrients, toxins, particulate matter, metabolic wastes, hormones, pigments, minerals, vitamins, antibiotics, herbicides, and pesticides. Water quality in the vicinity of finfish aquaculture operations may be impaired by the discharge of these compounds. The water column may become turbid as a result of this discharge, which can degrade overall habitat conditions for fish and shellfish in the area. Discharge may contribute to nutrient loading, which may lead to eutrophic conditions in the water column. Eutrophication often results in oxygen depletion, finfish and shellfish kills, habitat degradation, and harmful algal blooms that may impact human health.

Shellfish aquaculture operations have the potential to improve water quality by filtration of nutrients and suspended particles from the water column (Newell 1988). However, bivalves may contribute to the turbidity of the pelagic environment via their waste products (Kaspar et al. 1985; Grant et al. 1995). These waste products are expelled as feces and pseudofeces, which can be suspended into the water column, thus contributing to nutrient loads near aquaculture sites. Nutrient overenrichment often results in oxygen depletion, toxic gas generation, and harmful algal blooms, thus impairing the water quality near shellfish aquaculture sites. Therefore, both finfish and shellfish aquaculture operations have the potential to adversely affect water quality beneath aquaculture structures and in the surrounding environment. For additional information on discharge of nutrients and its subsequent effects on the water column via eutrophication and algal blooms, see the subsections on the Discharge of Organic Wastes and Discharge of Contaminants in this chapter, as well as the chapters on Agriculture and Silviculture, Coastal Development, and Alteration of Freshwater Systems of this report.

### *Changes in species diversity*

Species diversity and abundance may change in the vicinity of aquaculture farms as a result of effluent discharges or habitat modifications that alter environmental conditions. Changes in species diversity may occur through increased organic waste in pelagic and benthic environments, modification to bottom habitat, and the attraction of predators to the farmed species. Accumulated organic waste beneath aquaculture structures may change benthic community structure. In Maine, salmon netpen aquaculture can alter the benthos by shifting microbial and macrofaunal species to those adapted to enriched organic sediments. At one netpen site, epibenthic organisms were more numerous near the pen than at reference sites, suggesting that benthic community structure can be altered by salmon aquaculture in coastal Maine waters (Findlay et al. 1995).

Cultivated mussels can alter species diversity via biodeposition. Benthic habitat can shift from communities of bivalve mollusks, brittle stars, crustaceans, and polychaete worms to communities of sponges, tunicates, and calcareous polychaete worms beneath mussel aquaculture sites. The difference between the two sites represents a change in species diversity from those that typically reside in highly oxygenated water to those species adaptable to low-oxygen levels that can live in areas with fine-textured, organically rich sediments (Kaspar et al. 1985).

Benthic habitat modification at shellfish aquaculture sites can alter species diversity (Kaiser et al. 1998). Cultivation of shellfish such as hard clams requires the placement of gravel or crushed shell on the substrate. Seed clams are placed on the substrate in bags or directly on substrate covered with protective plastic netting. Benthic structure at shellfish aquaculture sites can therefore shift from polychaete-dominated communities to bivalve and nemertean-dominated communities, which could have repercussions for other trophic levels (Simenstad and Fresh 1995; Kaiser et al. 1998). However, community diversity may be enhanced by the introduction of aquaculture species and the modification of the substrate. For example, the placement of gravel in the intertidal area, the placement of substrates suitable for macroalgal attachment, or predator exclusion nets in some habitats may enhance epibenthos diversity and standing stock (Simenstad and Fresh 1995).

Open water netpens may alter species diversity by attracting wild fish or other predators to the aquaculture site (Vita et al. 2004). Wild benthic and pelagic species are attracted to uneaten pellet feed and other discharged effluent, which can result in impacts to the food web (Vita et al. 2004). Predators such as seals, sea lions, and river otters may also be attracted to aquaculture pens to feed on farmed species, which can alter communities in the vicinity of aquaculture sites (Goldburg et al. 2001).

### *Sediment deposition*

The effects of sediment deposition include eutrophication of the water column; toxic algal blooms; hypoxic or anoxic zones caused by microbial degradation; and the spread of contaminants such as antibiotics, herbicides, pesticides, hormones, pigments, minerals, and vitamins. The impacts of sediment deposition from discharged organic waste and contaminants on the water column and on the seafloor have been discussed in the Discharge of Organic Wastes, Discharge of Contaminants, Seaflood Impacts, Food Web Impacts, Changes in Species Diversity, and Habitat Exclusion and Replacement/Conversion subsections of this chapter.

### *Introduction of diseases*

Parasite and disease introductions into wild fish and shellfish populations are often associated with aquaculture operations and have the potential to lower the fitness level of native species or contribute to the decline of native populations. For example, in the 1940s and 1950s, scientists inadvertently introduced a new disease into eastern US waters when they attempted to restore declining populations of the eastern oyster (*Crassostrea virginica*) via the introduction of the Pacific oyster (*Crassostrea gigas*) (Burreson et al. 2000; Rickards and Ticco 2002). *Haplosporidium nelsoni* is a protistan parasite that causes MSX oyster disease and was present amongst the Pacific oysters introduced in east coast waters. MSX spread from Delaware Bay to the Chesapeake Bay and contributed to the decline in the native oyster population. MSX and another pathogenic disease, Dermo (*Perkinsus marinus*), have collectively decimated the native oyster population remaining along the much of the eastern US coast (Rickards and Ticco 2002).

In eastern Maine and New Brunswick, an outbreak of two diseases in both wild and cultured stocks of Atlantic salmon suggests that cultured stocks are acting as reservoirs of diseases and are now passing them on to wild stocks (Moring 2005). In addition to diseases, sea lice are a flesh-eating parasite that has been passed from farmed salmon to wild salmon when wild salmon migrate through coastal waters. Sea lice also can serve as a host for Infectious Salmon Anemia (ISA), which is a virus that has spread from salmon farms in New Brunswick to salmon farms in Maine (USFWS and NMFS 1999). The ISA virus causes fatalities in salmon at aquaculture facilities, and this virus has been detected in both escaped farmed salmon and wild salmon populations. ISA first appeared in New Brunswick in 1996, was detected in the United States in 2001, and represents a significant threat to wild salmon populations (Goldburg et al. 2001).

### *Habitat exclusion and replacement/conversion*

Aquaculture operations require the use of space, which results in the conversion of natural aquatic habitat that could have been used by native organisms for spawning, feeding, and growth. Approximately 321,000 acres of fresh water habitat and 64,000 acres of salt-water habitat have been converted for use in aquaculture operations in the United States (Goldburg et al. 2001). Aquaculture facilities may exclude aquatic organisms from their native habitat through the placement of physical barriers to entry or through changes in environmental conditions at aquaculture sites. Nets, cages, concrete, and other barriers exclude aquatic organisms from entering the space in which the aquaculture structures are placed. By effectively acting as physical barriers for wild populations, these formerly usable areas are no longer available as habitat for fish and shellfish species to carry out their life cycles. Aquaculture facilities may physically exclude wild stocks of fish, such as Atlantic salmon, from reaching critical spawning habitat upstream of the facilities (Goldburg et al. 2001).

Changes in environmental conditions at the aquaculture site may also exclude aquatic organisms from their native habitat. Discharge of organic waste and contaminants beneath aquaculture netpens and cages may render pelagic and benthic habitat unusable through nutrient loading and the subsequent effects of eutrophication. Low dissolved oxygen caused by eutrophication may force native species out of their habitat, while harmful algal blooms can cause widespread fish kills or exclude fish from areas affected by the outbreak (Goldburg and Triplett 1997). In the case of large shellfish aquaculture operations, filtering bivalves can also decrease the amount and type of nutrients and phytoplankton available to other species. This reduction in nutrients and phytoplankton can stimulate competition between populations of cultured and native species (Dankers and Zuidema 1995). Nutrient and phytoplankton removal could have a cascade effect on the trophic structure of the ecosystem (NEFMC 1998), which may eventually cause mobile species to relocate to other areas. Nonetheless, bivalves grown in open-water mariculture facilities can provide similarily beneficial filtering functions as native bivalves by contributing to the control nutrients, suspended sediments, and water column phytoplankton dynamics.

Aquaculture can result in the replacement or conversion of the natural benthic and pelagic community in the area surrounding the facility. For example, shellfish aquaculture can eliminate seagrass beds when shell material is dumped on the seafloor (Simenstad and Fresh 1995). Seagrass beds in the vicinity of shellfish culture operations may be eliminated during harvesting, which may temporarily reduce levels of biodiversity by reducing habitat for other marine species. Habitat conversion also takes place at netpen sites in which sediment deposition causes underlying habitat to become eutrophic. Sensitive benthic habitats beneath the netpens, such as seagrasses, may be eliminated or degraded by poor water quality conditions, thus converting viable habitat to unusable or less productive seafloor area (Goldburg and Triplett 1997).

Although the effects of replacement and exclusion of habitat by aquaculture facilities are often negative, there may be some positive effects of the structures. For example, cages, anchoring systems, and other devices can increase the structural complexity to the benthic and pelagic environment, which can provide shelter and foraging habitat for some native species. Open-water shellfish mariculture operations can provide some of the same habitat benefits as natural shellfish beds, such as refugia from predation and feeding habitat for juvenile and adult mobile species. Under some conditions, seafloor productivity may increase near aquaculture sites.

### *Conservation measures and best management practices for aquaculture*

1. Assess the aquatic resources in the area when siting new aquaculture facilities, including benthic communities, the proximity to wild stocks, migratory corridors, competing resource uses (e.g., commercial fishing, recreational uses, other aquaculture facilities), hydrographic conditions, and upstream habitat uses.
2. Avoid siting of aquaculture operations in or near sensitive benthic communities, such as submerged aquatic vegetation.
3. Avoid enclosing or impounding tidally influenced wetlands for mariculture purposes.
4. Ensure that aquaculture operations adequately address disease issues to minimize risks to wild stocks.
5. Employ methods to minimize escape from culture facilities to minimize potential genetic impacts and to prevent disruption of natural aquatic communities.
6. Design aquaculture facilities to meet applicable environmental standards for wastewater treatment and sludge control.

7. Locate aquaculture facilities to minimize discharge effects on habitat and locate water intakes to minimize entrainment of native fauna.
8. Evaluate and control the use of antibiotics, pesticides, and herbicides in aquaculture operations. Avoid direct application of carbaryl or other pesticides in water.
9. Consider biological controls to reduce pest populations, such as small, native species that feed on sea lice and fouling organisms.
10. Reduce the metabolic stress of aquaculture species in order to eliminate or reduce the need for using chemicals. Measures to reduce stress include improving water quality, lowering stock densities, and minimizing handling of fish.
11. Use aquaculture gear designed to minimize entanglement of native species attracted to the aquaculture operation (e.g., predators, such as marine mammals and birds).
12. Exclude exotic species from aquaculture operations until a thorough scientific evaluation and risk assessment is performed.
13. Locate aquaculture facilities rearing nonnative species upland and use closed-water circulation systems.
14. Treat effluent from public aquarium displays, laboratories, and educational institutes that are using exotic species prior to discharge for the purpose of preventing the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.
15. Consider growing several cultured species together, such as finfish, shellfish, algae, and hydroponic vegetables to reduce nutrient and sediment loads on the ecosystem.
16. Develop a monitoring program at the site to evaluate habitat and water quality impacts and the need for corrective measures through adaptive management.

## References for Introduced/Nuisance Species and Aquaculture

Able KW, Hagan SM. 2000. Effects of common reed (*Phragmites australis*) invasion on marsh surface macrofauna: response of fishes and decapod crustaceans. Estuaries 23:633-46.

[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

Barg UC. 1992. Guidelines for the promotion of environmental management of coastal aquaculture development. [Internet]. Rome (Italy): Food and Agriculture Organization of the United Nations (FAO). FAO Fisheries Technical Paper 328. [cited 2008 Jul 24]. 122 p. Available from: http://www.fao.org/docrep/T0697E/t0697e01.htm.

Barnhart RA, Boyd MJ, Pequegnat JE. 1992. The ecology of Humboldt Bay, California: an estuarine profile. Arcata (CA): US Fish and Wildlife Service. USFWS Biological Report 1. 121 p.

Benoit LK, Askins RA. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut marshes. Wetlands 19:194-208.

Boesch DF, Anderson DM, Horner RA, Shumway SE, Tester PA, Whitledge TE. 1997. Harmful algal blooms in coastal waters: options for prevention, control and mitigation. Silver Spring (MD): NOAA Coastal Ocean Office. NOAA Coastal Ocean Program Decision Analysis Series No. 10. 46 p + appendix.

Brousseau DJ, Baglivo JA. 2005. Laboratory investigations of food selection by the Asian shore crab, *Hemigrapsus sanguineus*: algal versus animal preference. Journal of Crustacean Biology 25(1):130-4.

Burdick DM, Buchsbaum R, Holt E. 2001. Variation in soil salinity associated with expansion of *Phragmites australis* in salt marshes. Environmental and Experimental Botany 46(3):247-61.

Burreson EM, Stokes NA, Friedman CS. 2000. Increased virulence in an introduced pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern oyster *Crassostrea virginica*. Journal of Aquatic Animal Health 12(1):1-8.

Byrnes J, Witman JD. 2003. Impact assessment of an invasive flatworm, *Convoluta convoluta*, in the southern Gulf of Maine. Journal of Experimental Marine Biology and Ecology 293(2):173-91.

Caraco NF, Cole JJ, Raymond PA, Strayer DL, Pace ML, Findlay SEG, Fischer DT. 1997. Zebra mussel invasion in a large, turbid river: phytoplankton response to increased grazing. Ecology 78(2):588-602.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Coen LD, Luckenback MW, Breitburg DL. 1999. The role of oyster reefs as essential fish habitat: A review of current knowledge and some new perspectives. In: Benaka LR, editor. Proceedings of the Sea Grant symposium on fish habitat and rehabilitation. Bethesda (MD): American Fisheries Society Symposium, No. 22. p 438-54.

Dankers N, Zuidema DR. 1995. The role of the mussel (*Mytilus edulis* L.) and mussel culture in the Dutch Wadden Sea. Estuaries 18(1A):71-80.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Drake LA, Jenkins PT, Dobbs FC. 2005. Domestic and international arrivals of NOBOB (no ballast on board) vessels to lower Chesapeake Bay. Marine Pollution Bulletin 50(5):560-5.

Findlay RH, Watling L, Mayer M. 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: a case study. Estuaries 18(1A):145-79.

Goldburg RJ, Elliott MS, Naylor RL. 2001. Marine aquaculture in the United States: environmental impacts and policy options. Arlington (VA): Pew Oceans Commission.

Goldburg RJ, Elliott MS, Naylor RL. 2003. Guiding sustainable marine aquaculture. In: Pew Ocean Commission. America's living oceans: charting a course for sea change. Arlington (VA): Pew Oceans Commission. p 73-79.

Goldburg R, Triplet T. 1997. Murky waters: environmental effects of aquaculture in the United States. Washington (DC): Environmental Defense Fund.

Grant J, Hatcher A, Scott DB, Pocklington P, Schafer CT, Winters GV. 1995. A multi-disciplinary approach to evaluating impacts of shellfish aquaculture on benthic communities. Estuaries 18(1A):124-44.

Griffin K. 1997. Commercial oyster cultivation and eelgrass ecology in Tillamook Bay, Oregon: a literature review and synthesis. Garibaldi (OR): Tillamook Bay National Estuary Project. 36 p.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hopkins JS, Sandifer PA, Devoe MR, Holland AF, Browdy CL, Stokes AD. 1995. Environmental impacts of shrimp farming with special reference to the situation in the continental United States. Estuaries 18(1A):25-42.

Kaiser MJ, Laing I, Utting SD, Burnell GM. 1998. Environmental impacts of bivalve mariculture. Journal of Shellfish Research 17(1):59-66.

Kaspar HF, Gillespie PA, Boyer IC, MacKenzie AL. 1985. Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. Marine Biology 85:127-36.

Kelly LA. 1992. Dissolved reactive phosphorus release from sediments beneath a freshwater cage aquaculture development in West Scotland. Hydrobiologia 235/236:569-72.

Kohler CC, Courtenay WR Jr. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries 11(2):39-42.

Minchinton TE, Bertness MD. 2003. Disturbance-mediated competition and the spread of *Phragmites australis* in a coastal marsh. Ecological Applications 13(5):1400-16.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

Newell RIE. 1988. Ecological changes in Chesapeake Bay: are they the result of overfishing the American Oyster, *Crassostrea virginica*? In: Understanding the estuary: advances in Chesapeake Bay research: proceedings of a conference; 1988 Mar 29-31; Baltimore, MD. Edgewater (MD): Chesapeake Research Consortium Publication 129. p 536-46.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Pederson J, Bullock R, Carlton J, Dijkstra J, Dobroski N, Dyrynda P, Fisher R, Harris L, Hobbs N, Lambert G, and others. 2005. Marine invaders in the Northeast: rapid assessment survey of non-native and native marine species of floating dock communities. Report of the August 3-9, 2003 Survey. Cambridge (MA): MIT Sea Grant College, Publication No. 05-3. 40 p.

Posey MH, Alphin TD, Meyer DL, Johnson JM. 2003. Benthic communities of common reed *Phragmites australis* and marsh cordgrass *Spartina alterniflora* marshes in Chesapeake Bay. Marine Ecology Progress Series 261:51-61.

Rickards WL, Ticco PC. 2002. The Suminoe oyster, *Crassostrea ariakensis*, in Chesapeake Bay: current status and near-term research activities. Charlottesville (VA): University of Virginia, Virginia Sea Grant.

Simenstad CA, Fresh KL. 1995. Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries: scales of disturbance. Estuaries 18(1A):43-70.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Tyrrell MC, Harris LG. 2000. Potential impact of the introduced Asian shore crab, *Hemigrapsus sanguineus*, in northern New England: diet, feeding preferences, and overlap with the green crab, *Carcinus maenas*. In: Pederson J, editor. Marine bioinvasions: proceedings of the 1st National Conference; 1999 Jan 24-27; Cambridge (MA): MIT SeaGrant College Program. p 208-20.

[USCOP] US Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century. Final report. [Internet]. Washington (DC): USCOP. [cited 2008 Jul 24]. Available from: http://www.oceancommission.gov.

[USEPA] US Environmental Protection Agency. 2001. National coastal condition report. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-01/005. [cited 2008 Jul 24]. Available from: http://www.epa.gov/owow/oceans/nccr/downloads.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Valentine PC, Collie JS, Reid RN, Asch RG, Guida VG, Blackwood DS. 2007. The occurrence of the colonial ascidian *Didemnum* sp. on Georges Bank gravel habitat–ecological implications and potential effects on groundfish and scallop fisheries. Journal of Experimental Marine Biology and Ecology 342(1):179-181.

Vita R, Marin A, Madrid JA, Jimenez-Brinquis B, Cesar A, Marin-Guirao L. 2004. Effects of wild fishes on waste exportation from a Mediterranean fish farm. Marine Ecology Progress Series 277:253-61.

Vitousek PM, D' Antonio CM, Loope LL, Rejmanek M, Westbrooks R. 1997. Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21(1):1-16.

Weinstein MP, Balletto JH. 1999. Does the common reed, *Phragmites australis*, affect essential fish habitat? Estuaries 22:793-802.

Weis JS, Weis P. 2000. Behavioral responses and interactions of estuarine animals with an invasive plant: a laboratory analysis. Biological Invasions 2:305-14.

# CHAPTER ELEVEN: GLOBAL EFFECTS AND OTHER IMPACTS

## Climate Change

### *Introduction*

The earth's climate has changed throughout geological history because of a number of natural factors that affect the radiation balance of the planet, such as changes in earth's orbit, the output of the sun, and volcanic activity (IPCC 2007a). These natural changes in the earth's climate have resulted in past ice ages and periods of warming that take place over several thousand years. An example of changes to earth's climate over recent geological timeframes caused by natural factors has been observed in slowly rising global temperatures and sea levels since the end of the Pleistocene epoch (about 10,000 years before present). However, the rate of warming observed over the past 50 years is unprecedented in at least the previous 1,300 years (IPCC 2007a). The Intergovernmental Panel on Climate Change (IPCC) concludes that recent human-induced increases in atmospheric concentrations of greenhouse gases are expected to cause much more rapid changes in the earth's climate than have previously been experienced (IPCC 2007a). The buildup of greenhouse gases (primarily carbon dioxide) is a result of burning fossil fuels and forests and from certain agricultural activities. Other greenhouse gases released by human activities include nitrous oxide, methane, and chlorofluorocarbons. The global atmospheric concentration of carbon dioxide has increased from about 280 ppm during preindustrial times to 379 ppm in 2005, which far exceeds the natural range over the last 650,000 years (180-300 ppm) as determined from ice cores (IPCC 2007a).

In the Fourth Assessment Report of the IPCC, the Contribution of Working Group I issued the following conclusions (IPCC 2007a):

> Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.

In order to consider various possible futures for climate change effects, the IPCC developed a series of models, or scenarios, based upon different levels of greenhouse gas emissions. The higher-emissions scenario represented fossil fuel-intensive economic growth and global human population that peaks around 2050 and then declines. This model assumes atmospheric carbon dioxide concentrations to reach about 940 ppm by 2100, or about three times preindustrial levels (Frumhoff et al. 2007). The lower-emissions scenario also represents a global human population that peaks around 2050 but assumes a much faster shift to less fossil fuel-intensive industries and more resource-efficient technologies. This model assumes carbon dioxide concentrations to peak around 2050 and then to decline to about 550 ppm by 2100, which is about double preindustrial levels (Frumhoff et al. 2007).

Based on current global climate models for greenhouse gas emission scenarios, some of the 2007 IPCC report conclusions were:

1. By 2100 average global surface air temperatures will increase by 1.8°C (lower-emissions scenario) to 4.0°C (higher-emissions scenario) above 2000 levels. The most drastic warming will occur in northern latitudes in the winter.
2. Sea level rose 12-22 cm in the 20th century and may rise another 18-38 cm (lower-emissions scenario) and as high as 26-59 cm (higher-emissions scenario) by 2099. However, these projections were based upon contributions from increased ice flow from Greenland and Antarctica at rates observed for the 1993-2003 period. If this contribution were to grow linearly with global average temperature change, the upper ranges for sea level rise would increase by an additional 10-20 cm.
3. Global precipitation is likely to increase, with more precipitation and more intense storms in the mid to high latitudes in the northern hemisphere.
4. Increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100, adding to the present decrease of 0.1 units since preindustrial times.

The average annual atmospheric temperature across the northeastern United States has risen by approximately 0.8ºC since 1900, although this warming trend has increased to approximately 0.3ºC per decade since 1970 (Frumhoff et al. 2007). Most climate models indicate the region will experience continued increased warming over the next century (Frumhoff et al. 2007; IPCC 2007a). Climate change models predict increased warming under the lower-emissions scenario to be 2.2-4.2°C and 3.8-7.2°C under the higher-emissions scenario by 2100 in New England and eastern Canada (Frumhoff et al. 2007). Over the next several decades, the greatest temperature changes are expected to be in the wintertime and early spring with warm periods expected to increase in frequency and duration (Nedeau 2004). For example, the average winter temperature in over the next few decades are expected to increase 1.4-2.2°C under both emission scenarios, while average summer temperature increases are expected to be 0.8-1.9°C (Frumhoff et al. 2007). However, by the end of the century, the average winter temperature is expected to increase 4.4-6.7°C under the higher-emissions scenario, while summer temperature is expected to increase 3.3-7.8°C (Frumhoff et al. 2007). Long-term increases in average temperatures, the frequency and intensity of extreme temperature and climatic events, and the timing of seasonal temperature changes can have adverse effects on ecosystem function and health. Combined with extreme precipation and drought and rising sea levels, these effects have the potential to result in considerable adverse changes to the northeast region's ecosystems.

Primary impacts of global climate change that may threaten riverine, estuarine, and marine fishery resources include:

1. Increasing rates of sea-level rise and intensity and frequency of coastal storms and hurricanes will increase threats to shorelines, wetlands, and coastal ecosystems;
2. Marine and estuarine productivity will change in response to reductions in ocean pH and alterations in the timing and amount of freshwater, nutrients, and sediment delivery;
3. High water temperatures and changes in freshwater delivery will alter estuarine stratification, residence time, and eutrophication and;
4. Increased ocean temperatures are expected to cause poleward shifts in the ranges of many marine organisms, including commercial species, and these shifts may have secondary effects on their predators and prey.

These affects may be intensified by other ecosystem stresses (pollution, harvesting, habitat destruction, invasive species), leading to more significant environmental consequences. It should be noted that while the general consensus among climate scientists today indicates a current and future warming of the earth's climate caused by emissions of greenhouse gases from anthropogenic sources, the anticipated effects at regional and local levels are less understood. Consequently, there are degrees of uncertainty regarding the specific effects to marine organisms and communities and their habitats from climate change. For example, although most climate models predict an increase in extreme rainfall events in the northeast region of the United States, the regional projections for average annual precipitation and runoff vary considerably (Scavia et al. 2002).

This section attempts to address some of the possible effects of global climate change to fishery resources in the northeast region of the United States. The effects discussed in this report reflect the general topics identified by participants of the Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities. However, other possible effects and consequences of climate change have been suggested, some of which may be inconsistent with those described in this report. A complete and thorough discussion of this rapidly-developing area of science is beyond the scope of this report. For a more thorough assessment of impacts caused by climate change, we recommend the reader refer to the publications cited in this chapter, as well as new research that will emerge subsequent to this report.

### *Alteration of hydrological regimes*

The hydrologic cycle controls the strength, timing, and volume of freshwater input, as well as the chemical and sediment load to estuaries and coastal waters (Scavia et al. 2002). Precipitation across the continental United States has increased by about 10% in the past 100 years or so, primarily reflected in the heavy and extreme daily precipitation events (Karl and Knight 1998; USGS 2005). This trend is also evident in the northeastern US region, which has experienced an increase in annual average precipitation by about 5-10% since 1900 (Frumhoff et al. 2007). In addition, increased early spring streamflows have occurred over the past century in New England, possibly a result of earlier melting of winter snowpack caused by increased air temperatures and/or greater rainfall (Hodgkins and Dudley 2005).

The IPCC Working Group II Report on Climate Change Impacts, Adaptation, and Vulnerability (IPCC 2007b) concluded that by mid-century average annual river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics. For the northeastern United States, climate change models indicate an increase in precipitation over the next 100 years (Frumhoff et al. 2007; IPCC 2007b). By the end of the century, the average annual precipitation is expected to increase by about 10%; however, the average winter precipitation is expected to increase 20-30%, and a much greater proportion of the precipitation would be expected to fall as rain rather than snow (Frumhoff et al. 2007; IPCC 2007b). Climate models also predict more frequent, heavy-precipitation events, which are expected to increase the probability of high-flow events in Maine, New Hampshire, and Vermont streams and rivers by about 80% during late winter and spring (Frumhoff et al. 2007). These changes in the intensity and frequency of high-flow events have the potential to increase the export of nutrients, contaminants, and sediments to our estuaries. Climate-related changes in the northeast region may alter the timing and amount of water availability. For example, increased temperatures during summer months can increase evapotranspiration rates. Combined with reduced summer rainfall, these changes can cause reductions in soil moisture and streamflows that may lead to seasonal drought (Frumhoff et al. 2007).

Accelerated sea-level rise resulting from climate change threatens coastal wetlands through inundation, erosion, and saltwater intrusion (Kennedy et al. 2002; Scavia et al. 2002). The quantity of freshwater discharges affects salt marshes because river flow and runoff deliver sediments that are critical for marshes to maintain or increase its elevation. An increase in freshwater discharge could increase supply of sediment and allow coastal wetlands to cope with sea-level rise (Scavia et al. 2002). However, some coastal areas may experience a decrease in precipitation and freshwater runoff, causing salt marsh wetlands to become sediment-starved and ultimately lost as sea levels rise and marshes are drowned (Kennedy et al. 2002). Greater periods of drought leading to a decrease in freshwater discharge might also cause salinity stress in salt marshes. Rising sea levels will also allow storm surges to move further inland and expose freshwater wetlands to high salinity waters.

Estuaries may be affected by changes in precipation and freshwater discharge from rivers and runoff from land. Precipitation patterns and changes in freshwater inflow can influence water residence time, salinity, nutrient delivery, dilution, vertical stratification, and phytoplankton growth and abundance (Scavia et al. 2002). Patterns of more frequent heavy-precipitation events during winter and spring months and increased temperature and reduced rainfall during summer months may exacerbate existing nutrient over-enrichment and eutrophication conditions that already stress estuarine systems (Scavia et al. 2002; Frumhoff et al. 2007).

A decline in the atmospheric pressure at the sea surface in the central Arctic during the late 1980s led to increased delivery of warmer, higher-salinity Atlantic water into the Arctic Ocean, mainly via the Barents Sea (Greene and Pershing 2007). In addition, there has been an increase in continental melting of permafrost, snow, and ice which, combined with increased precipitation, has resulted in greater river discharge into the Arctic Ocean over the past three decades. This is believed to have led to accelerated sea ice melting and reductions in Arctic sea ice. Although the relative importance of human versus natural climate forces in driving the observed changes in atmospheric and ocean circulation patterns continues to be debated, it has led to an enhanced outflow of low-salinity waters from the Arctic and general freshening of shelf waters from the Labrador Sea to the Mid-Atlantic Bight beginning in the early 1990s (Greene and Pershing 2007). Increased freshwater input in the upper layers of the ocean results in increased stratification, which suppresses upwelling of nutrients into the upper regions of the ocean and generally reduces the productivity of phytoplankton (Kennedy et al. 2002). Conversely, increased freshwater flux and stratification could also lead to enhanced biological productivity in some systems by enabling organisms to remain longer in the photic zone (Scavia et al. 2002). Greene and Pershing (2007) reported enhanced ocean stratification caused by increased freshwater outflow from the Arctic during the 1990s. They attributed increased phytoplankton and zooplankton production and abundance during the autumn, a period when primary production would otherwise be expected to decline, with enhanced freshening of the Northwest Atlantic shelf (Greene and Pershing 2007). Although some climate models predict a net decrease in global phytoplankton productivity under doubled atmospheric carbon dioxide conditions caused by increased thermal stratification and reduced nutrient upwelling, simple extrapolation to particular northeast marine waters is difficult (Kennedy et al. 2002). The climatic variability associated with natural, large-scale phenomena such as the El Nino-Southern Oscillation and the North Atlantic Oscillation/Northen Hemisphere Annular Mode effects water column mixing and stratification on regional and global scales and has implications on the productivity of the oceans. These natural phenomena may act in tandem with, or in opposition to, anthropogenic climate change (Kennedy et al. 2002).

A number of computer climate models indicate a slowing of the “overturning” process of ocean waters, known as the thermohaline circulation (THC). This phenomenon appears to be driven by a reduction in the amount of cold and salty, and hence, more dense water sinking into the depths of the ocean. In fact, surface waters of the North Atlantic Ocean have been warming in recent decades and parts of the North Atlantic Ocean are also becoming less salty (Nedeau 2004).

In the North Atlantic, a weakening of the THC is related to wintertime warming and increased freshwater flow into the Arctic Ocean and the North Atlantic Ocean (Nedeau 2004). An increased weakening of the THC could lead to a complete shut down or southward shift of the warm Gulf Stream, as was experienced during the last glacial period (Nedeau 2004). However, the response of the THC to global climate change remains uncertain, and predictions are dependent upon future greenhouse gas emissions and temperature increases (Kennedy et al. 2002). On a regional level, changes in ocean current circulation patterns may alter temperature regimes, vertical mixing, salinity, dissolved oxygen, nutrient cycles, and larval dispersal of marine organisms in the northeast coastal region, ultimately leading to a net reduction in oceanic productivity (Nedeau 2004).

### *Alteration of temperature regimes*

Sea surface temperatures of the northeastern US coast have increased more than 0.6°C in the past 100 years, and are projected to increase by another 3.8-4.4°C under the high-emissions scenario and by 2.2-2.8°C under the lower-emissions scenario over the next 100 years (Frumhoff et al. 2007). The IPCC Working Group II Report (IPCC 2007b) concluded there is "high confidence" that observed changes in marine and freshwater biological systems are associated with rising water temperatures, including: (1) shifts in ranges and changes in algal, plankton, and fish abundance in high-latitude oceans; (2) increased algal and zooplankton abundance in high-latitude and high-altitude lakes; and (3) range changes and earlier migrations of fish in rivers.

Temperature affects nearly every aspect of marine environments, from cellular processes to ecosystem function. The distribution, abundance, metabolism, survival, growth, reproduction, productivity, and diversity of marine organisms will all be affected by temperature changes (Kennedy et al. 2002; Nedeau 2004). Most marine organisms are able tolerate a specific temperature range and will become physiologically stressed or die after exposure to temperatures above or below the normal range. At sublethal levels, temperature extremes can effect the growth and metabolism of organisms, as well as behavior and distribution patterns. Reproduction timing and the rates of egg and larval development are dependent upon water temperatures. The reproductive success of some cold water fish species may be reduced if water temperatures rise above the optimum for larval growth (Mountain 2002). For example, cold-adapted species, such as winter flounder (*Pseudopleuronectes americanus*), Atlantic cod (*Gadus morhua*), Atlantic salmon (*Salmo salar*), and ocean quahog (*Artica islandica*) may not be able to compete with warm-adapted species if coastal water temperatures increase, particularly for those populations that may be living near the southern distribution limit (Kennedy et al. 2002).

The predicted increase in water temperatures resulting from climate change, combined with other factors such as increased precipitation and runoff, may alter seasonal stratification in the northeast coastal waters. Stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton, thus affecting the growth and survival of fish larvae (Mountain 2002). In the northeast Atlantic, studies have found shifts in the timing and abundance of plankton populations with increasing ocean temperatures (Edwards and Richardson 2004; Richardson and Schoeman 2004). Edwards and Richardson (2004) found long term trends in the timing of seasonal peaks in plankton populations with increasing sea surface temperatures. However, the magnitude of the shifts in seasonal peaks were not equal among all trophic groups, suggesting alterations in the synchrony of timing between primary, secondary, and tertiary production. Richardson and Schoeman (2004) reported effects of increasing sea surface temperatures on phytoplankton abundances in the North Sea. Phytoplankton production tended to increase as cooler ocean areas warmed, probably because higher water temperatures boost phytoplankton metabolic rates. However, in warmer ocean areas phytoplankton became less abundant as sea surface temperatures increased further, possibly because warm water blocks nutrient-rich deep water from rising to the upper strata where phytoplankton exist (Richardson and Schoeman 2004). These effects have been implicated as a factor in the decline in North Sea cod stocks (Edwards and Richardson 2004; Richardson and Schoeman 2004). Impacts to the base of the food chain would not only affect fisheries but will impact entire ecosystems.

Mountain (2002) predicted a northward shift in the distributional patterns of many species of fish because of increasing water temperatures in the Mid-Atlantic region as a result of climate change. Nearly thirty years of standardized catch data on the northeast continental shelf revealed significant surface and bottom water temperature anomalies that resulted in changes to the distribution of 26 out of 30 fish species examined (Mountain and Murawski 1992). Increased water temperatures were correlated with fish moving northward or shallower to cooler water (Mountain and Murawski 1992). Perry et al. (2005) investigated the distributional patterns of demersal fish species in the North Sea and found two-thirds of all species examined shifted in latitude or depth or both in response to increasing water temperatures. This study reported that most of the species with shifting distributions had moved north or to greater depths in areas of cooler waters. Temperature induced shifts in the distribution of fish have implications for stock recruitment success and abundance. Based on the projected sea surface temperature increases under the higher-emission scenarios, Frumhoff et al. (2007) predicted bottom temperatures by the year 2100 on Georges Bank would approach the 30ºC threshold of thermally-suitable habitat and practical limit of Atlantic cod distribution. The 26ºC threshold for the growth and survival of young cod would be exceeded by the end of the century under both emission scenarios on Georges Bank (Frumhoff et al. 2007).

The frequency of diseases and pathogens may increase with warming ocean temperatures caused by climate change. For example, Dermo, a disease that affects commercially valuable oysters, exhibits higher infection rates with increased temperature and salinity. Warm, dry periods (e.g., summer drought) may make oysters more susceptible to this disease. Extremely warm waters in New England and the mid-Atlantic regions are suspected as playing a role causing disease and mortality events in American lobsters (*Homarus americanus*), including lobster-shell disease, parasitic paramoebiasis, and calcinosis (Frumhoff et al. 2007). The eelgrass wasting disease pathogen (*Labyrinthula zosterae*) has reduced eelgrass beds throughout the east coast in the past and may become more problematic because of its preference for higher salinity waters and warmer water (both of which are expected in some estuaries because of sea-level rise) (Nedeau 2004).

### *Changes in dissolved oxygen concentrations*

Dissolved oxygen concentrations are influenced by the temperature of the water. Because warmer water holds less oxygen than does colder water, increased water temperatures will reduce the dissolved oxygen in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. Increased precipitation and freshwater runoff into estuaries would effect water residence time, temperature and salinity, and increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries with excess nutrients (Kennedy et al. 2002; Scavia et al. 2002; Nedeau 2004). Increased vertical stratification of the water column occurs with increasing freshwater inflow and decreasing salinities, resulting from greater precipitation and storm water input. In addition, increased water temperatures in the upper strata of the water column also increase water column stratification.

Some species may be adversely affected by increasing surface water temperatures caused by climate change as they seek cooler and deeper waters. Deeper areas may be susceptible to hypoxic conditions near the bottom in stratified, poorly mixed estuarine and marine environments and would be unfavorable to many species. The habitats of aquatic species may be "squeezed" by warming surface waters and hypoxic bottom waters, resulting in greater physiologic stress and metabolic costs or death if the stress does not abate (Kennedy et al. 2002). However, an increase in coastal storm frequency and intensity, as predicted with some climate models, may contribute to some increase in vertical mixing of shallow habitats and reduce the effects of stratification.

Some phytoplankton populations may respond positively to increases in water temperatures and available carbon dioxide, which most climate models project are likely as a result of global warming (IPCC 2007a). Increased precipitation and runoff can increase the nutrient loads entering estuaries and marine waters that further exacerbate the proliferation of algae in nearshore waters. As algae die and begin to sink to the bottom, the decomposition of this increased organic material will consume more oxygen in the water, increasing the occurrence of hypoxic and anoxic conditions in coastal waters (Nedeau 2004).

### *Nutrient loading and eutrophication*

Nitrate driven eutrophication is one of the greatest threats to the integrity of many estuaries in the northeast region (NRC 2000; Cloern 2001; Howarth et al. 2002). Increases in the amount of precipitation are very likely in northern latitudes (IPCC 2007a), and excess nutrients exported from watersheds and delivered to estuarine and marine waters may increase if freshwater flow from rivers and stormwater discharges are greater. Higher nutrient loads may increase the incidence of eutrophication and harmful algal blooms, which can cause hypoxia or anoxia in nearshore coastal waters. These effects on water quality can also negatively impact benthic communities and submerged aquatic vegetation (SAV). The environmental effects of excess nutrients or sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

### *Release of contaminants*

Increased precipitation and freshwater runoff may increase because of climate change and may lead to increased contaminant loading in coastal waters. Contaminants, such as hydrocarbons, metals, organic and inorganic chemicals, sewage, and wastewater materials, can be flushed from the watershed and exported to coastal waters, especially if the frequency and intensity of storms and floods are affected (Kennedy et al. 2002). These contaminants may be stored in coastal sediments or taken up directly by biota (e.g., bacteria, plankton, shellfish, or fish) and could ultimately affect fisheries and human health. Sea-level rise would inundate lowland sites near the coast, many of which contain hazardous substances that could leach contaminants into nearshore habitats (Bigford 1991).

### *Loss of wetlands and other fishery habitat*

Global warming is expected to accelerate the rate of sea-level rise by expanding ocean water and melting alpine glaciers over the next century (Schneider 1998; IPCC 2007a). Average global sea levels rose 12-22 cm between 1900 and 2000 and are expected to rise another 18-38 cm (lower-emissions scenario) and as high as 26-59 cm (higher-emissions scenario) by 2100 (IPCC 2007a). In the US Atlantic coast, relative sea levels over the last century have risen approximately 18 cm in Maine and as much as 44 cm in Virginia (Zervas 2001). Sea-level rise may affect diurnal tide ranges, causing coastal erosion, increasing salinity in estuaries, and changing the water content of shoreline soils. Accelerated sea-level rise threatens coastal habitats with inundation, erosion, and saltwater intrusion (Scavia et al. 2002; Frumhoff et al. 2007). Sea-level rise may indundate salt marshes and coastal wetlands, at which point shorelines will either need to build upward (accrete) to keep pace with rising sea levels or migrate inland to keep pace with drowning/erosion on the seaward edge. In cases where the upland edge is blocked by steep topography (e.g., bluffs) or human development (e.g., shoreline protection structures) coastal wetlands including salt marsh will be lost (Scavia et al. 2002; Frumhoff et al. 2007; IPCC 2007b). Conservative estimates of losses to saline and freshwater wetlands from sea-level rise range from 47-82% of the nation's coastal wetlands, or approximately 2.3-5.7 million acres (Bigford 1991). Shoreline protection structures can also prevent the shoreward migration of SAV necessitated by sea-level rise (Orth et al. 2006).

Worldwide distribution, productivity, and function of SAV may be effected by climate change. Perhaps most critical to SAV are impacts from increases in seawater temperature resulting from the greenhouse gas effect; secondary impacts of changing water depths and tidal range caused by sea-level rise, altered current circulation patterns and current velocities; changes in salinity regimes; and potential impacts on plant photosynthesis and productivity resulting from increased ultraviolet-B radiation and carbon dioxide concentrations (Short and Neckles 1999).

The distribution and productivity of coastal wetlands may be effected by rising sea levels, altered precipitation patterns, changes in the timing and delivery of freshwater and sediment, and increases in atmospheric carbon dioxide and temperature (Scavia et al. 2002). Increased atmospheric carbon dioxide could increase plant production for some coastal wetland species, assuming other factors such as nutrients and precipitation are not limiting. However, rising sea levels may inhibit the growth of some brackish and freshwater marshes and swamps.

### *Shoreline erosion*

Millions of cubic yards of sand are placed on northeast coastal beaches each year by state and federal governments to combat shoreline erosion. In addition, a variety of hard structures such as seawalls, revetments, groins, and jetties have been installed to protect eroding shorelines. Yet some areas of the northeast, such as Cape Cod, MA, Long Island, NY/CT, and coastal New Jersey, continue to experience a net loss of shoreline and have been identified by the US Geological Survey as being particularly at risk from sea-level rise (Frumhoff et al. 2007). It is uncertain how these engineering measures might affect the ability of natural processes to respond to future sea-level rise (Gutierrez et al. 2007). There exists a high degree of uncertainty in predicting long-term shoreline changes because of the uncertainty of the rate of future sea-level rise and the complex interactions of regional sediment budgets, coastal geomorphology, and anthropogenic influences, such as beach nourishment and seawall construction. However, Gutierrez et al. (2007) reported an increased likelihood for erosion and shoreline retreat for all types of mid-Atlantic coastal shorelines, including an increased likelihood for overwash and inlet breaching and the possibility of segmentation or disintegration of some barrier islands.

An increase in freshwater discharge, storm frequency and intensity, and sea-level rise can lead to increased erosion rates along coastal shorelines (Scavia et al. 2002). The loss of riparian and salt marsh vegetation because of climate change effects could serve as a feedback loop that reduces the ability of wetlands to withstand further increases in sea level and storm effects, which may exacerbate the effects of coastal erosion.

### *Alteration of salinity regimes*

Vertical mixing in coastal waters is influenced by several factors, including water temperatures and freshwater input, so warmer temperatures may affect the thermal stratification of estuaries (Nedeau 2004). Climate models project increased average temperatures and precipitation, particularly during the winter, in the northeastern US region (Frumhoff et al. 2007). Hotter and drier summers and warmer, wetter winters will alter the timing and volume of freshwater runoff and river flows. If freshwater flow from rivers is reduced or increased, salinities in rivers and estuaries will be altered which will have profound affects on the distribution and life history requirements of coastal fisheries. For example, increased freshwater input into estuaries would lower salinities in salt marsh habitat which could enhance conditions for invasive exotic plants that prefer low-salinity conditions, such as *Phragmites* or purple loosestrife (*Lythrum salicaria*). Increased freshwater runoff will increase vertical stratification of estuaries and coastal waters, which could have indirect effects on estuarine and coastal ecosystems (Kennedy et al. 2002). For example, upwelling of deep, nutrient-rich seawater could be reduced, leading to reductions in primary productivity in coastal waters. Rising sea levels could cause estuarine wetlands to be inundated with higher salinity seawater, altering the ecological balance of highly productive fishery habitat.

### *Alteration of weather patterns*

Numerous long-term changes in climate have already been observed at continental, regional, and ocean basin scales, including changes in Arctic temperatures, ice, ocean salinity, wind patterns; and increased occurrences of extreme weather events including droughts, heavy precipitation, heat waves, and intensity of tropical cyclones (IPCC 2007a).

There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since the 1970s, correlated with increased tropical sea-surface temperatures (IPCC 2007a). Increases in the amount of precipitation are very likely in high latitudes, and extra-tropical storms are projected to move poleward (Frumhoff et al. 2007; IPCC 2007a). Although there continues to be debate over the link between global warming and increased hurricane frequency, observed ocean warming is a key condition for the formation and strengthening of hurricanes (Frumhoff et al. 2007). The integrity of shorelines and wetlands would be threatened by increased intensity and frequency of coastal storms and hurricanes resulting from climate change. The loss of coastal wetland vegetation and increased erosion of shorelines and riparian habitats caused by storms would have an adverse effect on the integrity of aquatic habitats. Reductions in dissolved oxygen concentrations and salinity are phenomena associated with coastal storms and hurricanes, and most aquatic systems require weeks or months to recover following severe storms (Van Dolah and Anderson 1991). Increased frequency and intensity of storms could lead to chronic disturbances and have adverse consequences on the health and ecology of coastal rivers and estuaries.

### *Changes in water alkalinity*

Increasing atmospheric carbon dioxide concentrations can alter seawater carbonate chemistry by lowering seawater pH, carbonate ion concentration, and carbonate saturation state and by increasing dissolved carbon dioxide concentration (Riebesell 2004). According to the IPCC Working Group I Fouth Asssessment, increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100 (IPCC 2007a). The uptake of anthropogenic carbon since 1750 has led to an average decrease in pH of 0.1 units; however, the effects of observed ocean acidification on marine ecosystems are unclear at this time (IPCC 2007b).

Increased acidity in oceans is expected to effect calcium carbonate availability in seawater, which would lower the calcification rates in marine organisms (e.g., mollusks and crustaceans, some plankton, hard corals) (IPCC 2007b). Alteration of water alkalinity could have severe impacts on primary and secondary production, which have implications at the ecosystem level (Orr et al. 2005). Increasing atmospheric carbon dioxide concentrations and altered seawater carbonate chemistry could have a range of effects, including physiological changes to marine plankton on the organismal level, changes in ecosystem structure and regulation, and large scale shifts in biogeochemical cycling (Riebesell 2004). For example, increased carbon dioxide concentrations are predicted to decrease the carbonate saturation state and cause a reduction in biogenic calcification of corals and some plankton, including coccolithophorids and foraminifera; however, increasing carbon dioxide concentrations could increase the rates of photosynthetic carbon fixation of some calcifying phytoplankton (Riebesell 2004).

### *Changes in community and ecosystem structure*

The geographic distributions of species may expand, contract, or otherwise adjust to changing oceanic temperatures, creating new combinations of species that could interact in unpredictable ways. Fish communities are likely to change. For example, warming oceans may cause the southern range of northern species, such as Atlantic cod, American plaice (*Hippoglossoides platessoides*), haddock (*Melanogrammus aeglefinus*), and Atlantic halibut (*Hippoglossus hippoglossus*), to shift north as will the northern range limit of southern species, such as butterfish (*Peprilus triacanthus*) and menhaden (*Brevoortia tyrannus*) (Nedeau 2004; Frumhoff et al. 2007). Mountain and Murawski (1992) reported changes in the distribution of selected fish stocks in the northeast continental shelf that were attributed to changes in surface and bottom water temperatures. Distributional changes attributed to increased water temperatures were observed in 26 out of the 30 species examined and resulted in fish moving northward or shallower towards cooler water (Mountain and Murawski 1992). Temperature induced shifts in the distribution of fish have implications for stock recruitment success and abundance. Short-lived fish species may show the most rapid demographic responses to temperature changes, resulting in stronger distributional responses to warming (Perry et al. 2005). Range shifts could create new competitive interactions between species that had not evolved in sympatry, causing further losses of competitively inferior or poorly adapted species.

Because of changes in the atmospheric and oceanic circulation patterns in the Arctic Ocean, the Northwest Atlantic shelf waters became fresher during the 1990s relative to the 1980s (Greene and Pershing 2007). This freshening was believed to have enhanced stratification of shelf waters and led to greater phytoplankton and zooplankton production and abundance during the autumn, a period when primary production would otherwise be expected to decline (Greene and Pershing 2007). Although it is uncertain as to whether the increased abundances of plankton during the 1990s were solely attributed to enhanced stratification caused by greater inflow of freshwater (bottom-up control), overfishing of large predators, such as Atlantic cod (top-down control) or some combined effect, it is clear that changes in climate and oceanic circulation patterns can have profound effects on ecosystem functions and productivity (Greene and Pershing 2007). Mountain (2002) proposed several possible effects to fish stocks in the mid-Atlantic region in response to increased water temperatures, increased seasonal stratification of the water column, and changes in regional ocean circulation patterns. Direct effects included northward shift in stock distributions and reduced reproductive success for some cold water species because of increased water temperatures; indirect effects included changes in phytoplankton productivity and species composition that can impact the lower trophic levels affecting recruitment success of fish stocks (Mountain 2002).

Migratory and anadromous fish such as salmon and shad may be affected by climate change because they depend on the timing of seasonal temperature-related events as cues for migration. Ideal river and ocean temperatures may be out of synch as climate changes, making the saltwater-to-freshwater transition difficult for spawning adults or the freshwater-to-saltwater transition difficult for ocean-bound juveniles. Migration routes, timing of migration, and ocean growth and survival of fish may also be affected by altered sea-surface temperatures (Nedeau 2004).

Invasive species may flourish in a changing climate when shifting environmental conditions give certain species a foothold in a community and a competitive advantage over native species. Species inhabiting northern latitude islands may be particularly vulnerable as nonnative organisms adapted to warmer climates take advantage of changing climatic conditions (Scavia et al. 2002; IPCC 2007b).

Increases in the severity and frequency of coastal storms may result in cumulative losses of coastal marshes by eroding the seaward edge, causing flooding further inland, changing salinity regimes and marsh hydrology, and causing vegetation patterns to change. Healthy salt marshes can buffer upland areas (including human structures) from storm damage, and this ecosystem function will be impaired if marshes are destroyed or degraded. Increased sea-surface temperatures, sea-level rise, and intensity of storms and associated surge and swells, combined with more localized effects such as nutrients and increased loading of sediments, have had demonstrable impacts on SAV beds worldwide (Orth et al. 2006). The loss or degradation of freshwater, brackish, and salt marsh wetlands, SAV and shellfish beds, and other coastal habitats will affect critical habitat for many species of wildlife, which may ultimately affect biodiversity, coastal ecosystem productivity, fisheries, and water quality.

### *Changes in ocean/coastal uses*

Commercial fisheries could be impacted by the cumulative effects of climate change, including rising sea levels and water temperatures and habitat degradation in estuaries, rivers, and coastal wetlands. Approximately 32% of species important to fisheries in New England are dependent upon estuaries during some portion of their life histories (Nedeau 2004). Climate change could also affect human health and the use of ocean resources if the frequency and intensity of harmful algal blooms, fish and shellfish diseases, coastal storms, and impacts to coastal wetlands increase. These effects, combined with sea-level rise, may result in a loss or inability to utilize coastal resources. Climate-induced changes to marine ecosystems will require consideration of longer time-scale effects in fisheries and coastal management strategies.

The IPCC Working Group II Report (IPCC 2007b) concluded there is “high confidence” that climate change will cause regional changes in the distribution and production of particular fish species, with adverse effects projected for aquaculture and fisheries. Conservative predictions of impacts to fisheries resources from sea-level rise and habitat loss from climate change would likely dwarf those impacts now attributed to direct human activities, like water quality degradation, coastal development, and dredging (Bigford 1991). It is possible that nonclimate stresses will increase the vulnerability to climate change impacts by reducing resilience and adaptive capacity (IPCC 2007b). However, it is likely that sustainable development, along with implementing strategies of climate change mitigation and adaptation, technological development (to enhance adaptation and mitigation), and research (on climate science, impacts, adaptation, and mitigation) can minimize some of the risks associated with climate change (IPCC 2007b).

The development of strategic mitigation and adaptation measures to address global climate change are beyond the scope of this report. However, conservation measures and best management practices that are consistent with sound coastal management and sustainable development may help mitigate some of the effects of global warming.

### *Conservation measures and best management practices for climate change impacts to aquatic habitat*

1. Promote soft shore protection techniques, such as salt marsh restoration and creation and beach dune restoration, as alternatives to hard-armoring approaches.
2. Consider vertical structures such as concrete bulkheads for shoreline stabilization only as a last resort.
3. Establish setback lines for coastal development and rolling easements based on sea-level rise and subsidence projections that include local land movement.
4. Avoid development projects that involve wetland filling and increase impervious surfaces.
5. Improve land use practices, such as more efficient nutrient management and more extensive restoration and protection of riparian zones and wetlands.
6. Encourage the development and use of renewable, nongreenhouse gas emitting energy technologies, whenever practicable and feasible.
7. Encourage local, regional, and federal agencies to consider implications of climate change in their decision-support analysis and documents (e.g., National Environmental Policy Act) regarding permit decisions and funding programs.
8. Encourage the use of energy efficient technologies to be integrated into commercial and residential construction, including renewable energy and energy efficient heating and cooling systems and insulation.
9. Encourage the use of fuel-efficient vehicles and mass transportation systems.
10. Encourage communities and states to develop and implement strategies for sustainable development and greenhouse gas reduction initiatives, such as through the International Council for Local Environmental Initiatives (ICLEI).

## Ocean Noise

### *Introduction*

Sound is the result of energy created by a mechanical action dispersed from a source at a particular velocity and causes two types of actions: an oscillation of pressure in the surrounding environment and an oscillation of particles in the medium (Stocker 2002). Because water is 3500 times denser than air, sound travels five times faster in water (Stocker 2002). The openness of the ocean and relative density of the ocean medium allow for the transmission of sound energy over long distances. Factors that affect density include temperature, salinity, and pressure. These factors are relatively predictable in the open ocean but highly variable in coastal and estuarine waters. As a result of these factors along with water depth and variable nearshore bathymetry, sound attenuates more rapidly with distance in shallow compared to deep water (Rogers and Cox 1988).

Noise in the ocean environment can be categorized as natural and anthropogenic sources. Naturally generated sounds come from wind, waves, ice, seismic activity, tides and currents, and thunder, among other sources. Many sea animals use sound in a variety of ways; some use sound passively and others actively. Passive use of sound occurs when the animal does not create the sound that it senses but responds to environmental and ambient sounds. These uses include detection of predators, location and detection of prey, proximity perception of cospecies in schools or colonies, navigation, and perception of changing environmental conditions such as seismic movement, tides, and currents. Animals also create sounds to interact with their environment or other animals in it. Such active uses include sonic communication with cospecies for feeding and spawning (e.g., oyster toadfish [*Opsanus tau*]), territorial and social interactions, echolocation (e.g., marine mammals), stunning and apprehending prey, long distance navigation and mapping (e.g., sharks and marine mammals), and the use of sound as a defense against predators (e.g., croakers) (Stocker 2002).

The degree to which an individual fish exposed to noise will be affected is dependent upon a number of variables, including: (1) species of fish; (2) fish size; (3) presence of a swimbladder; (4) physical condition of the fish; (5) peak sound pressure and frequency; (6) shape of the sound wave (rise time); (7) depth of the water; (8) depth of the fish in the water column; (9) amount of air in the water; (10) size and number of waves on the water surface; (11) bottom substrate composition and texture; (12) tidal currents; and (13) presence of predators (Hanson et al. 2003).

Anthropogenic sources of noise include commercial shipping, seismic exploration, sonar, acoustic deterrent devices, and industrial activities and construction. The ambient noises in an average shipping channel are a combination of propeller, engine, hull, and navigation noises. In coastal areas the sounds of cargo and tanker traffic are multiplied by complex reflected paths – scattering and reverberating because of littoral geography. These cargo vessels are also accompanied by all other manner of vessels and watercraft: commercial and private fishing boats, pleasure craft, personal watercraft (e.g., jet skis) as well as coastal industrial vessels, public transport ferries, and shipping safety and security services such as tugs boats, pilot boats, US Coast Guard and coastal agency support craft, and of course all varieties of US Navy ships – from submarines to aircraft carriers. In large part, anthropogenic activities creating ocean noise are concentrated in coastal and nearshore areas. The most pervasive anthropogenic ocean noise is caused by transoceanic shipping traffic (Stocker 2002). The average shipping channel noise levels are 70-90 dB, which is as much as 45 dB over the natural ocean ambient noise in surface regions (Stocker 2002). Ships generate noise primarily by propeller action, propulsion machinery, and hydraulic flow over the hull (Hildebrand 2004). Considering all of these noises together, noise generated from a large container vessel can exceed 190 dB at the source (Jasny et al. 1999). Refer to the Marine Transportation chapter for additional information on ocean noises generated from vessels.

The loudest noises may be the sounds of marine extraction industries such as oil drilling and mineral mining (Stocker 2002). The most prevalent sources of these sounds are from "air guns" used to create and read seismic disturbances. Air guns are used in seismic exploration to create a sound pressure wave that aids in reflection profiling of underlying substrates for oil and gas. These devices generate and direct huge impact noises into the ocean substrate. Offshore oil and gas exploration generally occurs along the continental margins; however, a recent study indicated that air gun activity in these areas propagates into the deep ocean and is a significant component of low frequency noise (Hildebrand 2004). Peak source levels of air guns typically are 250-255 dB. Following the exploration stage, drilling, coring, and dredging are performed during extraction which also generates loud noises. Acoustic telemetry is also associated with positioning, locating, equipment steering, and remotely operated vessel control to support extraction operations (Stocker 2002).

Sonar systems are used for a wide variety of civilian and military operations. Active sonar systems send acoustic energy into the water column and receive reflected and scattered energy. Sonar systems can be classified into low (<1 kHz), mid (1-20 kHz), and high frequency (>20 kHz). Most vessels have sonar systems for navigation, depth sounding, and "fish finding." Some commercial fishing boats also deploy various acoustic aversion devices to keep dolphins, seals, and turtles from running afoul of the nets (Stocker 2002).

Because the ocean transfers sound over long distances so effectively, various technologies have been designed to make use of this feature (e.g., long distance communication, mapping, and surveillance). Since the early 1990s, it has been known that extremely loud sounds could be transmitted in the deep-ocean isotherm and could be coherently received throughout the seas. Early research in the use of deep-ocean noise was conducted to map and monitor deep-ocean water temperature regimes. Since the speed of sound in water is dependent on temperature, this characteristic was used to measure the temperature of the deep water throughout the sea. This technology has been used to study long-term trends in deep-ocean water temperature that could give a reliable confirmation of global warming. This program, Acoustic Thermometry of Ocean Climates (ATOC), uses receivers stationed throughout the Pacific Basin from the Aleutian Islands to Australia. ATOC is a long wavelength, low frequency sound in the 1-500 Hz band and is the first pervasive deep-water sound channel transmission, filling an acoustical niche previously only occupied by deep sounding whales and other deep water creatures (Stocker 2002). Concurrent with the development of ATOC, the US Navy and other North American Treaty Organization (NATO) navies have developed other low frequency communications and surveillance systems. Most notable of these is low frequency active sonar (LFAS) on a mobile platform, or towed array (Stocker 2002). Recently, the use of LFAS for military purposes has received considerable attention and controversy because of the concerns that this technology has resulted in injury and death to marine mammals, particularly threatened and endangered whales. Fernandez et al. (2005) found the occurrence of mass stranding events of beaked whales in the Canary Islands to have a temporal and spatial coincidence with military exercises using mid-frequency sonar. Beaked whales that died after stranding were found to have injuries to tissues consistent with acute decompression-like illness in humans and laboratory animals. Additional monitoring and research will need to be conducted to determine the degree of threat sonar has on marine organisms, particularly marine mammals. The effects of LFAS on bony fish and elasmobranches are unknown at this time.

Industrial and construction activities concentrated in nearshore areas contribute to ocean noise. Primary activities include pile driving, dredging, and resource extraction and production activities. Pile driving activities, which typically occur at frequencies below 1000 Hz, have led to mortality in fish (Hastings and Popper 2005). Intensity levels of pile driving have been measured up to 193 dB in certain studies (Hastings and Popper 2005). Refer to the chapter on Coastal Development for additional information on the affects of pile driving.

Underwater blasting with explosives is used for a number of development activities in coastal waters. Blasting is typically used for dredging new navigation channels in areas containing large boulders and ledges; decommissioning and removing bridge structures and dams; and construction of new in-water structures such as gas and oil pipelines, bridges, and dams. The potential for injury and mortality to fish from underwater explosives has been well-documented (Hubbs and Rechnitzer 1952; Teleki and Chamberlain 1978; Linton et al. 1985; and Keevin et al. 1999). Generally, aquatic organisms that possess air cavities (e.g., lungs, swim bladders) are more susceptible to underwater blasts than are those without. In addition, smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and the eggs and embryos tend to be particularly sensitive (Wright 1982). However, fish larvae tend to be less sensitive to blasts than are eggs or post-larval fish, probably because the larval stages do not yet possess air bladders (Wright 1982). Impacts to fishery habitat from underwater explosives may include sedimentation and turbidity in the water column and benthos and the release of contaminants (e.g., ammonia) in the water column with the use of certain types of explosives.

Noise generated from anthropogenic sources covers the full frequency of bandwidth used by marine animals (0.001-200 kHz), and most audiograms of fishes indicate a higher sensitivity to sound within the 0.100-2 kHz range (Stocker 2002). Evidence indicates that fish as a group have very complex and diverse relationships with sound and how they perceive it. It should be noted that relatively little direct research has been conducted on the impacts of noise to marine fish. However, some studies and formal observations have been conducted that elucidate general categories of impacts to fish species. Noise impacts to fish can generally be divided into four categories: (1) physiological; (2) acoustic; (3) behavioral; and (4) cumulative.

### *Physiological impacts to fish*

Increased pressure from high noise levels may have impacts on other nonauditory biological structures such as swim bladders, the brain, eyes, and vascular systems (Hastings and Popper 2005). Any organ that reflects a pressure differential between internal and external conditions may be susceptible to pressure-related impacts. Some of the resulting affects on fish include a rupturing of organs and mortality (Hastings and Popper 2005). Sounds within autonomic response ranges of various organisms may trigger physiological responses that are not environmentally adapted in healthful ways (Stocker 2002).

The lethality of underwater blasts on fish is dependent upon the detonation velocity of the explosion; however, a number of other variables may play an important role, including the size, shape, species, and orientation of the organism to the shock wave, and the amount, type of explosive, detonation depth, water depth, and bottom type (Linton et al. 1985). Fish with swimbladders are the most susceptible to underwater blasts, owing to the effects of rapid changes in hydrostatic pressures on this gas-filled organ. The kidney, liver, spleen, and sinus venosus are other organs that are typically injured after underwater blasts (Linton et al. 1985).

### *Acoustic impacts to fish*

Acoustic impacts include damage to auditory tissue that can lead to hearing loss or threshold shifts in hearing (Jasny et al. 1999; Heathershaw et al. 2001; Hastings and Popper 2005). Temporary threshold shifts and permanent threshold shifts may result from exposure to low levels of sound for a relatively long period of time or exposure to high levels of sound for shorter periods. Threshold shifts can impact a fish's ability to carry out its life functions.

### *Behavioral impacts to fish*

While tissue damage would be a significant factor in compromising the health of fish, other effects of anthropogenic noise are more pervasive and potentially more damaging. For example, masking biologically significant sounds by anthropogenic interference could compromise acoustical interactions from feeding to breeding, to community bonding, to schooling synchronization, and all of the more subtle communications between these behaviors. Anthropogenic sounds that falsely trigger these responses may have animals expend energy without benefits (Stocker 2002). With respect to behavioral impacts on fish, studies in this area have been limited. Clupeid fish, including Atlantic herring (*Clupea harengus*) are extremely sensitive to noise, and schools have been shown to disperse when approached by fishing gear, such as trawls and seines (NOAA Fisheries 2005). Several studies indicate that catch rates of fish have decreased in areas exposed to seismic air gun blasts (Engås et al. 1996; Hastings and Popper 2005). These results imply that fish relocate to areas beyond the impact zone. One study indicated that catch rates increased 30-50 km away from the noise source (Hastings and Popper 2005). Several studies have indicated that increased background noise and sudden increases in sound pressure can lead to elevated levels of stress in many fish species (Hastings and Popper 2005). Elevated stress levels can increase a fish's vulnerability to predation and other environmental impacts. New studies are addressing the masking effects by background noise on the ability of fish to understand their surroundings. Because fish apparently rely so heavily on auditory cues to develop an "auditory scene," an increase in ambient background noise can potentially reduce a fish's ability to receive those cues and respond appropriately (Jasny et al. 1999; Scholik and Yan 2002; Hastings and Popper 2005). Furthermore, the auditory threshold shifts of fish exposed to noise may not recover even after termination of the noise exposure (Scholik and Yan 2002).

### Cumulative impacts to fish

Few research efforts have focused on the cumulative effects of anthropogenic ocean noise on fish. Subtle and long-term effects on behavior or physiology could result from persistent exposure to certain noise levels leading to an impact on the survival of fish populations (Jasny et al. 1999; Hastings and Popper 2005).

### Conservation measures and best management practices for ocean noise

1. Develop mitigation strategies for noise impacts to consider the frequency, intensity, and duration of exposure and evaluate possible reductions of each of these three factors. Mitigation strategies for ocean noise are challenged by the fact that a sound source may move in addition to the movement of affected fish in and out of the insonified region.
2. Assess the "acoustic footprint" of a given sound source and develop standoff ranges for various impact levels. Standoff ranges can be calculated by using damage risk criteria for species exposure, source levels, sound propagation conditions, and acoustic attenuation models. Development of standoff ranges implies that sound sources be relocated or reduced since the sound receptors (fish) are more difficult to control. Because the potential number of species affected and their location is most likely unknown, development of a generic approach for mitigation by using the species with the most sensitive hearing would produce a precautionary approach to reducing impacts on all animals (Heathershaw et al. 2001).
3. Recommend an assessment and designation of "acoustic hotspots" that are particularly susceptible to acoustic impacts and reducing sound sources around them. These hotspots may include seasonal areas for particularly susceptible life history activities like spawning or breeding (Jasny et al. 1999).
4. Recognize that reducing noise intensity at the source primarily relies on technological solutions. These options include the use of "quiet" technology in marine engines and using bubble curtains for activities such as pile driving.
5. Encourage the use of sound dampening technologies for vessels and port/marine infrastructure to reduce ocean noise impacts to aquatic organisms.
6. Manage the duration of sound when the source level of a sound cannot be reduced in order to reduce impacts. Underwater sounds should be avoided during sensitive times of year (e.g., upstream and downstream river migrations, spawning, and egg and larvae development).
7. Avoid using underwater explosives in areas supporting productive fishery habitats. The use of less destructive methods should be encouraged, whenever possible. In some cases, the use of mechanical devices (e.g., ram hoe, clamshell dredge) may reduce impacts associated with rock and ledge removal.
8. Investigate options to mitigate the impacts associated with underwater explosives. Avoiding use during sensitive periods (e.g., upstream and downstream river migrations, spawning, and egg and larvae development) may be one of the most effective means of minimizing impacts to fishery resources. Other methods may include the use of bubble curtains; stemming (back-filling charge holes with gravel); delayed charges (explosive charges broken down into a series of smaller charges); and the use of repelling charges (small explosive charges used to frighten and drive fish away from the blasting zone) (Keevin 1998).

# Atmospheric Deposition

## *Introduction*

Pollutants travel through the atmosphere for distances of up to thousands of miles, often times to be deposited into rivers, estuaries, and nearshore and offshore marine environments. Substances such as sulfur dioxide, nitrogen oxide, carbon monoxide, lead, volatile organic compounds, particulate matter, and other pollutants are returned to the earth through either wet or dry atmospheric deposition. Wet deposition removes gases and particles in the atmosphere and deposits them to the earth's surface by means of rain, sleet, snow, and fog. Dry deposition is the process through which particles and gases are deposited in the absence of precipitation. Deposition of nutrients (i.e., nitrogen and phosphorous) and contaminants (e.g., polychlorinated biphenyl [PCB] and mercury) into the aquatic system are of particular concern because of the resulting impacts to fisheries and health-risks to humans.

Atmospheric inputs of nutrients and contaminants differ from riverine inputs in the following ways: (1) riverine inputs are delivered to the coastal seas at their margins, whereas atmospheric inputs can be delivered directly to the surface of the central areas of coastal seas and hence exert an impact in regions less directly affected by riverine inputs; (2) atmospheric delivery occurs at all times, whereas riverine inputs are dominated by seasonal high-flows and coastal phytoplankton activity; (3) atmospheric inputs are capable of episodic, high deposition events associated with natural or manmade phenomena (e.g., volcanic eruptions, forest fires); and (4) atmospheric inputs of nitrogen are chemically different from river inputs in that rivers are dominated by nitrous oxides, phosphorus, and silica, while atmospheric inputs include reduced and oxidized nitrogen, but no significant phosphorus or silica (Jickells 1998). While there is little information on the direct effects of atmospheric deposition on marine ecosystems, management strategies must attempt to address these variations in inputs from terrestrial and atmospheric pathways.

## *Nutrient loading and eutrophication*

Nutrient pollution is currently the largest pollution problem in the coastal rivers and bays of the United States (NRC 2000). Nitrogen inputs to estuaries on the Atlantic and Gulf Coasts of the United States are now 2-20 times greater than during preindustrialized times (Castro et al. 2003). Sources of nitrogen include emissions from automobiles, as well as urban, industrial, and agricultural sources. Atmospheric deposition is one means of nitrogen input into aquatic systems, with atmospheric inputs delivering 20 to greater than 50% of the total input of nitrogen oxide to coastal waters (Paerl 1995). One of the most rapidly increasing means of nutrient loading to both freshwater systems and the coastal zone is via atmospheric pathways (Anderson et al. 2002).

Precipitation readily removes most reactive nitrogen compounds, such as ammonia and nitrogen oxides, from the atmosphere. These compounds are subsequently available as nutrients to aquatic and terrestrial ecosystems. Because nitrogen is commonly a growth-limiting nutrient in streams, lakes, and coastal waters, increased concentrations can lead to eutrophication, a process involving excess algae production, followed by depletion of oxygen in bottom waters. Hypoxic and anoxic conditions are created as algae die off and decompose. Harmful algal blooms associated with unnatural nutrient levels have been known to stimulate fish disease and kills. In addition, phytoplankton production increases the turbidity of waters and may result in a reduced photic zone and subsequent loss of submerged aquatic vegetation. Anoxic conditions, increased turbidity, and fish mortality may result from increased nitrogen inputs into the aquatic system, potentially altering long-term community dynamics (NRC 2000; Castro et al. 2003). Refer to the chapters on

Agriculture and Silviculture, Coastal Development, Alteration of Freshwater Systems, and Chemical Effects: Water Discharge Facilities for further discussion on impacts to fisheries from eutrophication.

The atmospheric component of nitrogen flux into estuaries has often been underestimated, particularly with respect to deposition on the terrestrial landscape with subsequent export downstream to estuaries and coastal waters (Howarth et al. 2002). The deposition of nitrogen on land via atmospheric pathways impacts aquatic systems when terrestrial ecosystems become nitrogen saturated. Nitrogen saturation means that the inputs of nitrogen into the soil exceed the uptake ability by plants and soil microorganisms. Under conditions of nitrogen saturation, excess nitrogen leaches into soil water and subsequently into ground and surface waters. This leaching of excess nitrogen from the soils degrades water quality. Such conditions have been known to occur in some forested watersheds in the northeastern United States, and streams that drain these watersheds have shown increased levels of nitrogen from runoff (Williams et al. 1996).

In one study, quantifying nitrogen inputs for 34 estuaries on the Atlantic and Gulf Coasts of the United States, atmospheric deposition was the dominant nitrogen source for three estuaries, and six estuaries had atmospheric contributions greater than 30% of the total nitrogen inputs (Castro et al. 2003). In the northeastern United States, atmospheric deposition of oxidized nitrogen from fossil-fuel combustion may be the major source of nonpoint input. Evidence suggests a significant movement of nitrogen in the atmosphere from the eastern United States to coastal and offshore waters of the North Atlantic Ocean where it is deposited (Holland et al. 1999). Nitrogen fluxes in many rivers in the northeastern United States have increased 2- to 3-fold or more since 1960, with much of this increase occurring between 1965 and 1988. Most of this increase in nitrogen was attributed to increased atmospheric deposition originating from fossil-fuel combustion onto the landscape (Jaworski et al. 1997).

### *Mercury loading/bioaccumulation*

Mercury is a hazardous environmental contaminant. Mercury bioaccumulates in the environment, which means it can collect in the tissues of a plant or animal over its lifetime and biomagnify (i.e., increases in concentration within organisms between successive trophic levels) within the food chain. Fish near the top of the food chain often contain high levels of mercury, prompting the United States and Canada to issue health advisories against consumption of certain fish species. The US Food and Drug Administration reports certain species, including sharks, swordfish (*Xiphias gladius*), king mackerel (*Scombermorus cavalla*), and tilefish (*Lopholatilus chamaeleonticeps*), to have typically high concentrations of mercury (USFDA 2004).

One of the most important anthropogenic sources of mercury pollution in aquatic systems is atmospheric deposition (Wang et al. 2004). The amount of mercury emitted into the atmosphere through natural and reemitted sources was estimated to be between 1500-2500 metric tons/year in the late 20$^{th}$ century (Nriagu 1990). Industrial activities have increased atmospheric mercury levels, with modern deposition flux estimated to be 3-24 times higher than preindustrial flux (Bindler 2003). More than half of the total global mercury emissions are from incineration of solid waste, municipal and medical wastes, and combustion of coal and oil (Pirrone et al. 1996).

Studies strongly support the theory that atmospheric deposition is an important (sometimes even the predominant) source of mercury contamination in aquatic systems (Wang et al. 2004). Mercury exists in the atmosphere predominately in the gaseous form, although particulate and aqueous forms also exist (Schroeder et al. 1991). Gaseous mercury is highly volatile, remaining in the atmosphere for more than one year, making long-range atmospheric transport a major environmental concern (Wang et al. 2004).

Concentrations of mercury in the atmosphere and flux of mercury deposition vary with the seasons, and studies suggest that atmospheric mercury deposition is greatest in summer and least in winter (Mason et al. 2000). Different, site-specific factors may influence the transport and transformation of mercury in the atmosphere. Wind influences the direction and distance of deposition from the source, while high moisture content may increase the oxidation of mercury, resulting in the rapid settlement of mercury into terrestrial or aquatic systems. Mercury that is deposited on land can be absorbed by plants through their foliage and ultimately be passed into watersheds by litterfall (Wang et al. 2004).

Mercury and other metal contaminants are found in the water column and persist in sediments (Buchholtz ten Brink et al. 1996). Mercury is toxic in any form according to some scientists, but when absorbed by certain bacteria such as those in marine sediments, it is converted to its most toxic form, methyl mercury. Methyl mercury can cause nerve and developmental damage in humans and animals. Mercury inhibits reproduction and development of aquatic organisms, with the early life-history stages of fish being the most susceptible to the toxic impacts associated with metals (Gould et al. 1994). Metals have also been implicated in disrupting endocrine secretions of aquatic organisms, potentially disrupting natural biotic properties (Brodeur et al. 1997). Direct mortality of fish and invertebrates by lethal concentrations of metals may occur in some instances. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for more information on impacts from mercury contamination.

### *PCB and other contaminants*

PCB congeners are a group of organic chemicals which can be odorless or mildly aromatic and exist in solid or oily-liquid form. They were formerly used in the United States as hydraulic fluids, plasticizers, adhesives, fire retardants, way extenders, dedusting agents, pesticide extenders, inks, lubricants, cutting oils, manufacturing of heat transfer systems, and carbonless reproducing paper. Most uses of PCB were banned by the US Environmental Protection Agency in 1979; however this persistent contaminant continues to enter the atmosphere mainly by cycling from soil to air to soil again. PCB is also currently released from landfills, incineration of municipal refuse and sewage sludge, and improper (or illegal) disposal of PCB-contaminated materials, such as waste transformer fluid, to open areas (USEPA 2005a).

PCB compounds are a mixture of different congeners of chlorobiphenyl. In general, the persistence of PCB increases with an increase in the degree of chlorination. Mono-, di- and trichlorinated biphenyls biodegrade relatively rapidly, tetrachlorinated biphenyls biodegrade slowly, and higher chlorinated biphenyls are resistant to biodegradation. If released to the atmosphere, PCB will primarily exist in the vapor-phase and have a tendency to become associated with the particulate-phase as the degree of chlorination of the PCB increases. Physical removal of PCB from the atmosphere is accomplished by wet and dry deposition (USEPA 2005b).

Although restrictions were first placed on the use of PCBs in the United States during the 1970s, lipid-rich finfish and shellfish tissues have continued to accumulate PCBs, dichlorodiphenyl trichloroethane (DDT), and chlordane from the environment (Kennish 1998). PCB congeners are strongly lipophilic and accumulate in fatty tissues including egg masses, affecting the development of fish as well as posing a threat to human health through the consumption of contaminated seafood. Refer to the chapters on Coastal Development and Chemical Effects: Water Discharge Facilities for more additional information on PCB contamination.

### *Alteration of ocean alkalinity*

The influx of acid to the aquatic environment occurs through the atmospheric precipitation of two predominant acids, sulfuric acid and nitric acid, making up acid rain (i.e., pH less than 5.0). Sulfur dioxide is produced naturally by volcanoes and decomposition of plants, while the main anthropogenic source is combustion, especially from coal-burning power plants. In eastern North America, acid rain is ubiquitous because of the presence of coal-burning power plants (Baird 1995). Other sources of sulfuric acid in the atmosphere include oil refinement, cleaning of natural gas, and nonferrous smelting. Affects on biological life depend strongly on soil composition. Granite and quartz have little capacity to neutralize acid, while limestone or chalk can efficiently neutralize acids. Under acidic conditions, aluminum is leached from rocks. Both acidity and high concentrations of dissolved aluminum are responsible for decreases in fish populations observed in many acidified water systems (Baird 1995).

The freshwater environment does not have the buffering capacity of marine ecosystems, so acidification has serious implications on riverine habitat. Low pH (below 5.0) has been implicated with osmoregulation problems (Staurnes et al. 1996), pathological changes in eggs (Peterson et al. 1980; Haines 1981), and reproduction failure in Atlantic salmon (Watt et al. 1983). Cumulative, long-term deposition of acid into the aquatic environment can hinder the survival and sustainability of fisheries by disrupting and degrading important fish and shellfish habitat. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for additional information on the affects of acidification of aquatic habitats.

### *Conservation measures and best management practices for atmospheric deposition*

1. Install scrubbers for flue-gas desulfurization in electricity generating powerplants, oil refineries, nonferrous smelters, and other point sources of sulfur dioxide emissions.
2. Use integrated, gas-scrubbing systems on municipal waste combustion units.
3. Reduce sulfur dioxide emissions by substituting natural gas or low-sulfur coal for high-sulfur coal at power plants.
4. Encourage renewable energy generation using wind, solar, and geothermal technologies.
5. Encourage the use of fuel-efficient vehicles and mass transportation systems.
6. Encourage the separation of batteries from the waste stream to reduce the release of mercury vapors through waste incineration.
7. Lower volatization and/or erosion and resuspension of persistent compounds through remediation at waste sites.

## Military/Security Activities

The operations of the US military span the globe and are carried out in coastal, estuarine, and marine habitats. Military operations have the potential to adversely impact fish habitat through training activities conducted on land bases as well as in coastal rivers and the open ocean. Military operations also impact fish habitat and larger ecological communities during wars (Literathy 1993).

Because many military bases and training activities are located in coastal areas and oftentimes directly on shorelines, they can cause impacts similar to those mentioned in other parts of this document (e.g., coastal development, dredging, sewage discharge, road construction, shoreline protection, over-water structures, pile driving, port and marina operations, and vessel operations). In addition to these conventional activities, the military often stockpiles and disposes of toxic chemicals on base grounds. Toxic dumping on base grounds has led to the contamination of groundwater at Otis Air National Guard Base on Cape Cod, MA, (NRDC 2003) and in Vieques, Puerto Rico.

The United States Navy also uses sonar systems that create large amounts of noise in ocean waters. The Surveillance Towed Array Sensor System (SURTASS) low frequency active sonar produces extremely loud low frequency sound that can be heard at 140 dB from 300 miles away from the source (NRDC 2004). Sixty percent of the US Navy's 294 ships are equipped with mid-frequency sonar devices that can produce noise above 215 dB (NRDC 2002). The intensity of these noises in the water column can cause a variety of impacts to fish, marine mammals, and other marine life such as behavior alterations, temporary and permanent impairments to hearing, and mortality. Other sources of underwater noise from military activities may include explosive devices and ordnances during training exercises and during wartime. Refer to the Ocean Noise section in this chapter for more information on impacts associated with sonar, as well as the Marine Transportation and Coastal Development chapters for information related to blasting impacts.

## Natural Disasters and Events

### *Introduction*

Natural events and natural disasters of greatest concern for the northeastern United States include hurricanes, floods, and drought. These events may impact water quality, alter or destroy habitat, alter hydrological regimes, and result in changes to biological communities. Natural disasters have the potential to impact fishery resources, such as displacing plankton and fish from preferred habitat and altering freshwater inputs and sediment patterns. While these effects may not themselves pose a threat to coastal ecosystems, they may have additive and synergistic effects when combined with anthropogenic influences such as the release of agricultural and industrial pollutants in storm water.

### *Water quality impacts*

Water quality degradation by hurricanes can be exacerbated by human activities. Hurricanes and posthurricane flooding have been known to result in large freshwater inputs and high concentrations of nutrients into river and estuarine waters, causing reductions in water quality and massive fish kills (Mallin et al. 1999). For example, when Hurricane Fran struck North Carolina in the Cape Fear River area in 1996, the following impacts were reported as a result of the hurricane: (1) power failures caused the diversion of millions of liters of raw and partially treated human waste into rivers when sewage treatment plants and pump stations were unable to operate; (2) dissolved oxygen concentrations decreased in parts of the Cape Fear River for more than three weeks following the hurricane; (3) ammonium and total phosphorous concentrations were the highest recorded in 27 years of monitoring in Northeast Cape Fear River following the hurricane and; (4) sediment-laden waters flowing into Cape Fear River increased turbidity levels (Mallin et al. 1999).

Generally, high rates of flushing and reduced water residence times will inhibit the formation of algal blooms in bays and estuaries. However, the input of large amounts of human and animal waste can greatly increase the biological oxygen demand and lead to hypoxic conditions in aquatic systems. In addition to the diversion of untreated waste from sewage treatment plants during Hurricane Fran, several swine waste lagoons were breached, overtopped, or inundated, discharging large quantities of concentrated organic waste into the aquatic environment (Mallin et al. 1999). Other sources of nutrient releases during storms and subsequent flooding events include septic systems on private residences built on river and coastal floodplains.

Natural disasters, such as hurricanes, may also put vessels (e.g., oil tankers) and coastal industrial facilities (e.g., liquefied natural gas [LNG] facilities, nuclear power plants) at risk of damage and contaminant spills. Tanker ship groundings generally occur during severe storms, when moorings are more susceptible to being broken and the control of a vessel may be lost or compromised. The release of toxic chemicals from damaged tanks, pipelines, and vessels threaten aquatic organisms and habitats.

### *Changes to community composition*

Major storm events may impact benthic communities through a variety of mechanisms, including increased sedimentation, introduction of contaminants, reduction in dissolved oxygen, short-term changes in salinity, and disturbance from increased flow. Monitoring of environmental impacts following Hurricane Fran in 1996 indicated that significant declines in benthic organism abundance were observed up to three months after the storm. However, significant declines in benthic abundance generally did not occur in areas where levels of dissolved oxygen recovered quickly after the storm (Mallin et al. 1999). Poorly flushed bays and inland river floodplains are areas that typically exhibit greater magnitude and duration of storm-related impacts.

### *Loss/alteration of habitat*

The rate of accretion and erosion of coastal areas is influenced by wave energy impacting the shoreline, and natural events such as hurricanes will accelerate this process. Erosion may occur as a function of hydraulic scour produced by hurricane overwash and offshore-directed wave energy. Accretion of materials resulting from overwash deposition may result in subsequent flood tidal delta development. Extreme climatic events, such as hurricanes and tsunamis, can have large-scale impacts on submerged aquatic vegetation communities (Orth et al. 2006). Loss or alteration of coastal habitat as a result of storms may be exacerbated by the effects of shoreline development and erosion control measures. For example, the creation of hardened shoreline structures (e.g., seawalls, jetties) and storm-water control systems can focus storm energy and redirect storm water to wetlands, resulting in increased erosion and habitat loss in productive fishery habitat.

### *Alteration of hydrological regimes*

Hurricane and flood events result in large volumes of water delivered to the watershed in a relatively short period of time. These events can alter the hydrology of wetlands, streams, and rivers by increasing erosion and overwhelming flood control structures. Freshwater flows into rivers draining into Charleston Harbor in South Carolina increased as much as four times the historical average after Hurricane Hugo in 1989 (Van Dolah and Anderson 1991). Reduced dissolved oxygen concentrations were observed in all portions of the Charleston Harbor estuary following Hurricane Hugo, with hypoxic conditions in some of the rivers in the watershed. The decomposition of vegetation and the failure of septic and sewer systems overflowing into the watershed as a result of this hurricane was identified as the primary cause of the high organic loads (Van Dolah and Anderson 1991). At the other extreme, drought will result in reduced run-off and low flows in streams and rivers that drain into estuaries and bays. Low freshwater input resulted in dramatic reductions in phytoplankton and zooplankton in San Francisco Bay, CA, reducing pelagic food for fish populations (Bennett et al. 1995). Larval starvation may limit recruitment. During low-flow years, toxins from agricultural and urban runoff are less diluted which can also harm fish.

### *Conservation measures and best management practices for natural disasters and events*

1. Require backup generating systems for publicly owned waste treatment facilities.
2. Prohibit development of high-risk facilities, such as animal waste lagoons, storage of hazardous chemicals within the 100-year floodplain.
3. Ensure that all industrial and municipal facilities involving potentially hazardous chemicals and materials have appropriate emergency spill response plans, including emergency notification systems and spill cleanup procedures, training, and equipment.
4. Encourage the protection and restoration of coastal wetlands and barrier islands, which buffer the affects of storm events by dissipating wave energy and retaining floodwaters.
5. Discourage new construction and development in or near coastal and riparian wetlands.
6. Discourage the use of "hard" shoreline stabilization, such as seawalls and bulkheads.
7. Limit emergency authorizations (e.g., federal Clean Water Act permits) for reconstruction projects to replacing structures that were in-place and functional at the time of the natural disaster/event and do not include the expansion of structures and facilities.

## Electromagnetic Fields

Anthropogenic activities are responsible for the majority of the overall electromagnetic fields (EMF) emitted into the environment, with natural sources making up the remainder. Levels of EMF from anthropogenic sources have increased steadily over the past 50-100 years (WHO 2005). Anthropogenic sources of EMF include undersea power cables, high voltage power lines, radar, FM radio and TV transmitters, cell phones, high frequency transmitters for atmospheric research, and solar power satellites. The EMF created by undersea power cables may have some adverse affect on marine organisms. Undersea power cables transfer electric power across water, usually conducting very large direct currents (DC) of up to a thousand amperes or more. It has been inferred that undersea cables can interfere with the prey sensing or navigational abilities of animals in the immediate vicinity of the sea cables (See also the Cables and Pipelines section of the Energy-related Activities chapter). Few published, peer reviewed scientific articles on the environmental effects of electromagnetic fields on aquatic organisms exist. However, the World Health Organization cosponsored an international seminar in October 1999 entitled "Effect of Electromagnetic Fields on the Living Environment" to focus attention on this subject. A review of the information presented at the seminar was prepared by Foster and Repacholi (2000).

Electromagnetic fields are the product of both natural and artificial sources. Natural sources of EMF include radiation from the sun, the earth's magnetic fields, the atmosphere (e.g., lightning discharges), and geological processes (WHO 2005). Marine animals are also exposed to natural electric fields caused by sea currents moving through the geomagnetic field. Examples of anthropogenic sources of EMF include undersea power cables and US Navy submarine communication systems (Foster and Repacholi 2000). Mild electroreception by teleost (bony) fishes occurs through external pit organs that interpret minute electrical currents in the water (Moyle and Cech 1988). However, elasmobranches (i.e., sharks, skates, and rays) are unique in that they possess well-developed electroreceptive organs, called Ampullae of Lorenzini, that enable them to detect weak electric fields in the surrounding seawater as low as 0.01 μV/m (Kalmijn 1971). Elasmobranchs are able to receive information about the positions of their prey, the drift of ocean currents, and their magnetic compass headings from electric fields in their surrounding environment.

Most aquatic organisms emanate low-frequency electric fields that can be detected by fish, such as skates and rays, through a process known as "passive electrolocation" or "passive electroreception." Passive electroreception allows animals to sense electric fields generated in the environment, thereby allowing predators to detect prey by the electric fields that individual fauna emanate. Elasmobranchs have demonstrated during controlled experiments the ability to detect artificially created electric fields (1-5 μA) that are similar to those produced by prey (Kalmijn 1971). The other form of electroreception is "active electroreception" and occurs when an animal detects changes in their own electric field caused by the electric field produced by prey in the vicinity. This ability to detect disturbances to an individual's own electric field is rare, occurring only in a few families of weakly electric fish, none of which are found in the Northwest Atlantic Ocean.

There is evidence that elasmobranches also use their ability to detect electric fields for the purpose of navigation. For example, blue sharks (*Prionace glauca*) have been observed migrating in the North Atlantic Ocean maintaining straight courses for hundreds of kilometers over many days (Paulin 1995). The two modes of detection used for navigation are: (1) passive detection (when an animal estimates its drift from the electrical fields produced by interactions of tidal and wind-driven currents and the vertical component of the earth's magnetic field); or (2) active detection (when the animal derives its magnetic compass heading from the electrical field it generates by its interaction with the horizontal component of the earth's magnetic field) (Gill and Taylor 2001).

### *Changes in migration of marine organisms*

Anthropogenic sources of EMFs may affect social behavior, communications, navigation, and orientation of those animals that rely on the earth's magnetic field. Certain fish rely on the natural (geomagnetic) static magnetic field as one of a number of parameters believed to be used as orientation and navigational cues. For example, stingrays have demonstrated their ability during training experiments to orient relative to uniform electric fields similar to those produced by ocean currents (Kalmijn 1982). In addition, the small-spotted catshark (*Scyliorhinus canicula*) and the thornback skate (*Raja clavata*) have shown a remarkable sensitivity to electric fields (Kalmijn 1982). However, studies demonstrating an impact on the ability of marine organisms to migrate because of anthropogenic sources of EMFs have not been found. Foster and Repacholi (2000) noted the sensitivity of sharks to low frequency electric fields and a potential mechanism for adverse effects from DC fields but made no mention of adverse effects from EMFs.

### *Changes to feeding behavior*

Electric or magnetic fields near sea cables may affect prey sensing of electrically or magnetically sensitive species. Submarine cables may attract species when the field intensity approximates that of their natural prey. Smooth dogfish (*Mustelus canis*) and the blue shark have been observed to execute apparent feeding responses to dipole electric fields designed to mimic prey (Kalmijn 1982). Less is known about how elasmobranches respond in the presence of stronger EMFs that exist closer to the cable. Depending on the presence and strength of electric fields, the feeding behavior of elasmobranches could be altered by submarine cables.

The possible affects of exposure to EMF depend on a coupling between the external field and the body of the animal and the biological response mechanisms. The size of the animal, frequency of the field, and whether the pathway of exposure is via air or water will determine effects to the animal. It has been suggested that monopolar power links are more likely to affect aquatic animals than bipolar links do because they produce perceptible levels of fields over larger distances from the cables (Kalmijn 2000). Sea cables are isolated from the surrounding water by layers of insulation and metal sheathing, yet electric fields that can exceed natural ambient levels remain detectable (Foster and Repacholi 2000). The flow of seawater past the cables can create electric fields by magnetic induction. The resulting field strength in the seawater can exceed naturally occurring levels and depends on the flow velocity, whether or not the observer is moving with respect to the water, and on the electrical conductivity of nearby surfaces (Foster and Repacholi 2000).

Further directed research should be conducted to examine the effect of EMFs from underwater transmission lines on marine organisms. Increased understanding is needed about the effects of cable burial within different substrata and the range of frequencies and sensitivities of electric fields that marine species are capable of detecting.

### *Conservation recommendations and best management practices for electromagnetic fields*

1. Map proposed submarine cable routes with marine resource utilization in a geographic information system database to provide information on potential interference with elasmobranch fishes and other organisms. Particular attention should be paid to known nursery and pupping grounds of coastal shark species.
2. Bury submarine cables below the seafloor to potentially reduce possible interference with the electroreception of fishes. However, the benefits of cable burial to minimize potential impacts to elasmobranchs should be weighed with the adverse effects associated with trenching on the seafloor.
3. Place new submarine electric transmission lines within existing transmission corridors to minimize the cumulative effect of transmission lines across the ocean bottom to the extent practicable.

## References for Global Effects and Other Impacts


Anderson DM, Glibert PM, Burkholder JM. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25(4b):704-26.

Baird C. 1995. Ground-level air chemistry and air pollution. In: Environmental Chemistry. New York (NY): W. H. Freeman and Company. p 90-9.

Bennett WA, Ostrach DJ, Hinton DE. 1995. Larval striped bass condition in a drought-stricken estuary: evaluating pelagic food-web limitation. Ecological Applications 5(3):680-92.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Bindler R. 2003. Estimating the natural background atmospheric deposition rate of mercury utilizing ombrotrophic bogs in southern Sweden. Environmental Science and Technology 37:40-6.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Cloern J. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210:223-52.

Edwards M, Richardson A. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430(7002):881-4.

Engås A, Lokkeborg S, Ona E, Soldal AV. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Sciences 53:2238-49.

Fernandez A, Edwards JF, Rodriguez F, Espinosa De Los Monteros A, Herraez P, Castro P, Jaber JR, Martin V, Arbelo M. 2005. ‘‘Gas and fat embolic syndrome’’ involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. Veterinary Pathology 42:446-57.

Foster KR, Repacholi MH. 2000. Environmental impacts of electromagnetic fields from major electrical technologies. In: Matthes R, Bernhardt JH, Repacholi MH, editors. Proceedings of the international seminar on effects of electromagnetic fields on the living environment; 1999 Oct. 4-5; Ismaning, Germany. Munich (Germany): International Commission on Non-Ionizing Radiation Protection. World Health Organization (WHO). 17 p.

Frumhoff PC, McCarthy JJ, Melillo, SC, Moser SC, Wuebbles DJ. 2007. Confronting climate change in the U.S. Northeast: science, impacts, and solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge (MA): Union of Concerned Scientists (UCS). 146 p.

Gill AB, Taylor H. 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. University of Liverpool: Research project for Countryside Council of Wales. CCW Science report No. 488. 73 p.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Greene CH, Pershing AJ. 2007. Oceans: climate drives sea change. Science 315:1084-5.

Gutierrez BT, Williams SJ, Thieler ER. 2007. Potential for shoreline changes due to sea-level rise along the U.S. mid-Atlantic region. [Internet]. Reston (VA): US Geological Survey Open-File Report 2007-1278. [cited 2008 July 28]. 26 p. Available from: http://pubs.er.usgs.gov/usgspubs/ofr/ofr20071278.

Haines TA. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110(6):669-707.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hastings MC, Popper AN. 2005. Effects of sound on fish. Sacramento (CA): Jones & Stokes. CADOT Contract No. 43A0139, Task Order 1. 82 p.

Heathershaw AD, Ward PD, David AM. 2001. The environmental impact of underwater sound. Proceedings of the Institute of Acoustics 23(4).

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hodgkins GA, Dudley RW. 2005. Changes in the magnitude of annual and monthly streamflows in New England, 1902-2002. Denver (CO): US Department of the Interior, US Geological Survey. Scientific Investigations Report 2005-5135. 23 p. plus appendices.

Holland TA, Dentener FJ, Braswell BH, Sulzman JM. 1999. Contemporary and pre-industrial global reactive nitrogen budgets. Biogeochemistry 46:7-43.

Howarth RW, Sharpley A, Walker D. 2002. Sources of nutrient pollution to coastal waters in the United States: implications for achieving coastal water quality goals. Estuaries 25(4b):656-76.

Hubbs CL, Rechnitzer AB. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38:333-66.

[IPCC] Intergovernmental Panel on Climate Change. 2007a. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 996 p. Available from: http://www.ipcc.ch.

[IPCC] Intergovernmental Panel on Climate Change (IPCC). 2007b. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 976 p. Available from: http://www.ipcc.ch.

Jasny M, Reynolds J, Horowitz C, Wetzler A. 1999. Sounding the depths: supertankers, sonar, and rise of undersea noise. Los Angeles (CA): Natural Resources Defense Council. Marine Mammal Protection Project. 38 p.

Jaworski NA, Howarth RW, Hetling LJ. 1997. Atmospheric deposition of nitrogen oxides onto the landscape contributes to coastal eutrophication in the northeast United States. Environmental Science and Technology 31:1995-2004.

Jickells TD. 1998. Nutrient biogeochemistry of the coastal zone. Science 281(5374):217-22.

Kalmijn AJ. 1971. The electric sense of sharks and rays. Journal of Experimental Biology 55:371-83.

Kalmijn AJ. 1982. The electric and magnetic field detection in elasmobranch fishes. Science 218(4575):916-18.

Kalmijn AJ. 2000. Detection and processing of electromagnetic and near-field acoustic signals in elasmobranch fishes. Biological Sciences 335(1401):1135-41.

Karl TR, Knight RW. 1998. Secular trends in precipitation amount, frequency, and intensity in the United States. Bulletin of the American Meteorological Society 79(2):231-41.

Keevin TM. 1998. A review of natural resource agency recommendations for mitigating the impacts of underwater blasting. Reviews in Fisheries Science 6(4):281-313.

Keevin TM, Gaspin JB, Gitschlag GR, Hempen GL, Linton TL, Smith M, Wright DG. 1999. Underwater explosions: natural resource concerns, uncertainty of effects, and data needs. In: Proceedings of the twenty-fifth annual conference on explosives and blasting technique; 1999 Feb 7-10; Nashville, TN. Cleveland (OH): International Society of Explosive Engineers. p 105-16.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Kennish MJ, Ruppel BE. 1998. Organochlorine contamination in selected estuarine and coastal marine finfish and shellfish of New Jersey. Water, Air, and Soil Pollution 101(1-4):123-36.

Linton TL, Landry AM Jr, Buckner JE Jr, Berry RL. 1985. Effects upon selected marine organisms of explosives used for sound production in geophysical exploration. The Texas Journal of Science 37(4):341-53.

Literathy P. 1993. Considerations for the assessement of environmental consequences of the 1991 Gulf War. Marine Pollution Bulletin 27:349-56.

Mallin MA, Posey MH, Shank GC, McIver MR, Ensign SH, Alphin TD. 1999. Hurricane effects on water quality and benthos in the Cape Fear watershed: natural and anthropogenic impacts. Ecological Applications 9(1):350-62.

Mason RP, Lawson NM, Sheu GR. 2000. Annual and seasonal trends in mercury deposition in Maryland. Atmospheric Environment 34:1691-701.

Mountain DG. 2002. Potential consequences of climate change for the fish resources in the Mid-Atlantic region. In: McGinn NA, editor. Fisheries in a changing climate. Bethesda (MD): American Fisheries Society, Symposium 32.

Mountain DG, Murawski SA. 1992. Variation in the distribution of fish stocks on the northeast continental shelf in relation to their environment, 1980-1989. ICES Marine Science Symposia 195:424-432.

Moyle P, Cech J. 1988. Fishes: an introduction to ichthyology. Englewood Cliffs (NJ): Prentice-Hall. 559 p.

[NOAA] National Oceanic and Atmospheric Administration. 2005. Final environmental impact statement for minimizing impacts of the Atlantic herring fishery on essential fish habitat. Gloucester (MA): National Marine Fisheries Service, Northeast Regional Office. 274 p.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

[NRDC] Natural Resource Defense Council. 2002. Federal court blocks full deployment of navy low frequency active sonar system. [Internet]. NRDC Press Archive, October 31, 2002. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/021031.asp.

[NRDC] Natural Resource Defense Council. 2003. Above the law? The Pentagon is taking aim at America's public health and environmental protections. [Internet]. NRDC Backgrounder, March 12, 2003. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/030312.asp.

[NRDC] Natural Resources Defense Council. 2004. Coalition warns navy over destructive use of mid-frequency sonar. [Internet]. NRDC Press Archive, July 15, 2004. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/040715.asp.

Nedeau E. 2004. Effects of climate change on the Gulf of Maine region. [Internet]. Gulf of Maine Council on the Marine Environment. [cited 2008 Jul 9]. 12 p. Available from: http://www.gulfofmaine.org/summit/ClimateChangeKbase.pdf.

Nriagu JO. 1990. Global metal pollution. Poisoning the biosphere? Environment 32:7-33.

Orr JC, Fabry VJ, Aumont O, Bopp L, Doney SC, Feely RA, Gnanadesikan A, Gruber N, Ishida A, Joos F, and others. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-6.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, and others. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Paerl HW. 1995. Coastal eutrophication in relation to atmospheric nitrogen deposition: current perspectives. Ophelia 41:237-59.

Paulin MG. 1995. Electroreception and the compass sense of sharks. Journal of Theoretical Biology 174(3):325-39.

Perry AL, Low PJ, Ellis JR, Reynolds JD. 2005. Climate change and distribution shifts in marine fisheries. Science 308:1912-5.

Peterson RH, Daye PG, Metcalfe JL. 1980. Inhibition of Atlantic salmon (*Salmo salar*) hatching at low pH. Canadian Journal of Fisheries and Aquatic Sciences 37:770-4.

Pirrone N, Keeler GJ, Nriagu JO. 1996. Regional differences in worldwide emissions of mercury to the atmosphere. Atmospheric Environment 30:2981-7.

Richardson A, Schoeman D. 2004. Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305(5690):1609-12.

Riebesell U. 2004. Effects of $CO_2$ enrichment on marine phytoplankton. Journal of Oceanography 60:719-29.

Rogers PH, Cox M. 1988. Underwater sound as a biological stimulus. In: Atema J, Fay RR, Popper AN, Tavolga WN, editors. Sensory biology of aquatic animals. New York (NY): Springer-Verlag. p 131-49.

Scavia D, Field JC, Boesch DF, Buddemeier RW, Burkett V, Cayan DR, Fogarty M, Harwell MA, Howart RW, Mason C, and others. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25(2):149-64.

Schneider D. 1998. The rising seas. Oceans; Scientific American Quarterly 9(3):28-35.

Scholik AR, Yan HY. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63:203-9.

Schroeder WH, Yarwood G, Niki H. 1991. Transformation processes involving mercury species in the atmosphere-results from a literature survey. Water, Air, and Soil Pollution 56:653-66.

Short FT, Neckles HA. 1999. The effects of global climate change on seagrasses. Aquatic Botany 63 (3-4): 169-96.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Stocker M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America 112(5):2431.

Teleki GC, Chamberlain AJ. 1978. Acute effects of underwater construction blasting on fishes in Long Point Bay, Lake Erie. Journal of the Fisheries Research Board of Canada 35:1191-8.

[USEPA] US Environmental Protection Agency. 2005a. Technical factsheet on polychlorinated biphenyls (PCBs). [Internet]. Washington (DC): US EPA. [updated 2006 Nov 28; cited 2007 Dec 21]. Available from: http://www.epa.gov/safewater/dwh/t-soc/pcbs.html.

[USEPA] US Environmental Protection Agency (USEPA). 2005b. Consumer factsheet on polychlorinated biphenyls (PCBs). [Internet]. Washington (DC): US EPA Office of Groundwater and Drinking Water. [updated 2006 Nov 28; cited 2007 Dec 21]. Available from: http://www.epa.gov/OGWDW/dwh/c-soc/pcbs.html.

[USFDA] US Food and Drug Adminstration. 2004. What you need to know about mercury in fish and shellfish. [Internet]. Washington (DC): US Department of Health and Human Services and US Environmental Protection Agency. EPA-823-R-04-005. [cited 2008 Jul 28]. Available from: http://www.cfsan.fda.gov/~dms/admehg3.html.

[USGS] US Geological Survey. 2005. Streamflow trends in the United States. Reston (VA): US Department of the Interior, US Geological Survey. USGS Fact Sheet 2005-3017. 3 p.

Van Dolah RF, Anderson GS. 1991. Effects of Hurricane Hugo on salinity and dissolved oxygen conditions in the Charleston Harbor estuary. Journal of Coastal Research Special Issue 8:83-94.

Wang Q, Kim D, Doinysiou DD, Sorial GA, Timberlake D. 2004. Sources and remediation for mercury contamination in aquatic systems-a literature review. Environmental Pollution 131(2004):323-36.

Watt WD, Scott CD, White WJ. 1983. Evidence of acidification of some Nova Scotia rivers and its impact on Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences 40:462-73.

Williams MW, Baron JS, Caine N, Sommerfield R, Sanford RJ. 1996. Nitrogen saturation in the Rocky Mountains. Environmental Science and Technology 30:640-6.

[WHO] World Health Organization. 2005. Electromagnetic fields and public health: Effects of EMF on the environment. [Internet]. Munich (Germany): WHO. Fact sheet No. 296. 2005 Dec. [cited 2008 Jul 28]. Available from: http://www.who.int/mediacentre/factsheets/fs296/en/.

Wright DG. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Winnipeg (Manitoba): Western Region, Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1052. 16 p.

Zervas C. 2001. Sea level variations of the United States 1854-1999. [Internet]. Silver Spring (MD): National Ocean Service. NOAA Technical Report NOS CO-OPS 36. [cited 2008 Aug 12]. 66 p. Available from: http://tidesandcurrents.noaa.gov/publications/techrpt36doc.pdf.

# CHAPTER TWELVE: COMPENSATORY MITIGATION

## Introduction

The purpose of this chapter is to describe the need for and use of compensatory mitigation within the context of regulatory review of proposed coastal development activities. This topic has purposefully been included in a separate chapter of this report to reflect NOAA National Marine Fisheries Services' view that compensatory mitigation is a process that is distinct and separate from impact avoidance and minimization. Only a cursory discussion of compensatory mitigation has been attempted in this report because of the complexity and depth that would be required to cover this topic. We have provided a list of websites and publications that the reader may want to refer to for more detailed discussion of compensatory mitigation.

Compensatory mitigation is a means of offsetting unavoidable impacts to natural resources. It cannot be stressed strongly enough that compensatory mitigation should not be considered until a thorough and exhaustive assessment of project alternatives that may be less environmentally damaging and options for avoiding and minimizing impacts has been completed, and all remaining impacts are "unavoidable." The term "unavoidable impacts" is used ubiquitously in environmental impact assessments developed to meet various requirements of the National Environmental Policy Act (NEPA), Clean Water Act (CWA), Magnuson-Stevens Fishery Conservation and Management Act (MSA), Fish and Wildlife Coordination Act, and other laws and regulations.

The MSA identified the continuing loss of marine, estuarine, and other aquatic habitats to be one of the greatest long-term threats to the viability of commercial and recreational fisheries. The consultation requirements of §305(b)(4)(A) of the MSA require that NOAA National Marine Fisheries Service provide recommendations, which may include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on essential fish habitat (EFH), to federal or state agencies for activities that would adversely effect EFH.

According to NEPA regulations, environmental assessments and environmental impact statements must include a discussion of the means to mitigate adverse environmental impacts. However, according to NEPA guidance, the term "mitigation" includes avoidance and minimization in addition to compensatory mitigation, and NEPA does not strictly require agencies to first avoid and minimize before utilizing compensatory mitigation to offset adverse effects. NEPA regulations do, however, require agencies to assess and discuss the environmental effects of all reasonable alternatives, including the means to mitigate any adverse effects.

The Federal CWA 404(b)(1) guidelines prohibit the discharge of dredge or fill material in waters of the United States if there is a practicable alternative. The 404(b)(1) guidelines also require that all waters of the United States will be accorded the full measure of protection under the CWA, including the requirements for appropriate and practicable mitigation. "Appropriate" is based on the values and functions of the aquatic resource that will be impacted, and "practicable" is defined as that which is available and capable of being done after taking into consideration the cost, existing technology, and logistics in light of overall project purposes. The Memorandum of Agreement (MOA) between the US Environmental Protection Agency and the Department of the Army Concerning the Determination of Mitigation under the Clean Water Act Section 404(b)(1) Guidelines states, "Appropriate and practicable compensatory mitigation is required for unavoidable adverse impacts which remain after all appropriate and practicable minimization has been required." This MOA established a three-part sequential process to help guide mitigation decisions, which includes: (1) avoidance – adverse impacts are to be avoided and no discharge shall be permitted if there is a practicable alternative with less adverse impact; (2) minimization – if impacts cannot be avoided, appropriate and practicable steps to minimize adverse impacts must be taken; and (3) compensation – appropriate and practicable compensatory mitigation is required for unavoidable adverse impacts which remain (USDOA and USEPA 1989).

The need for exhausting all practicable alternatives to avoid and minimize adverse impacts prior to consideration of compensatory mitigation is necessary because of the inherent risks associated with compensatory mitigation. Establishing (creating), reestablishing (restoring), and rehabilitating (enhancing) degraded wetlands and/or aquatic habitats have inherent risks. Replicating or restoring the physical and chemical characteristics of fishery habitat, including soil/sediment hydrology and chemistry, hydrologic connections, and water quality are complex undertakings and can require years to achieve desired results. Replicating and restoring the full ecological functions and values of fishery habitat may not occur without additional effort and cost, and there are no assurances of success. In addition, evaluating mitigation performance and success can require considerable pre- and postconstruction monitoring and assessment, which can be time consuming and costly. For these and other reasons, compensatory mitigation should be viewed as a "last resort" option to achieve effective mitigation, with avoidance and minimization of impacts being the initial focus during the impact assessment process.

Once all practicable alternatives have been considered satisfactorily and a least damaging practicable alternative has been selected that effectively avoids and minimizes adverse effects to the maximum extent practicable, measures to offset unavoidable impacts should be assessed and utilized. Compensatory mitigation can be accomplished on-site or off-site (i.e., in relation to the area being impacted) and can either be in-kind or out-of-kind (i.e., compensation with the same or different ecological functions and values). Generally, in order to achieve the functional replacement of the same or similar ecological resources, in-kind should be considered over out-of-kind compensatory mitigation. However, compensatory mitigation decisions are often made in the context of landscape and watershed implications, as well as logistical and technological limitations. Out-of-kind mitigation, should it be considered, should provide services of equal or greater ecological value and should only be employed if in-kind mitigation is deemed impracticable, unfeasible, or less desirable in the watershed context. However, replacing lost or degraded tidal wetlands or other intertidal/subtidal habitats with nontidal (e.g., freshwater) wetlands should not occur.

Compensatory mitigation can be broadly categorized as restoration, creation, enhancement, and preservation (USACE 2002). Restoration includes reestablishment of a wetland or other aquatic resource with the goal of returning natural or historic functions and characteristics to a former or degraded habitat. Restoration may result in a net gain in ecological function and area. Creation or establishment consists of the development of a wetland or other aquatic resource through manipulation of the physical, chemical, or biological characteristics where a wetland did not previously exist. Creation results in a net gain in ecological function and area. Enhancement or rehabilitation includes activities within existing wetlands that heighten, intensify, or improve one or more ecological functions. Enhancement may result in improved ecological function(s), but does not result in a gain in area. Preservation is designed to protect important wetland or other aquatic resources into perpetuity through implementation of appropriate legal and physical mechanisms (i.e., conservation easements, title transfers). Preservation may include protection of upland areas adjacent to wetlands or other aquatic resources. Preservation does not result in a net gain of wetland acres or other aquatic habitats and should only be used in exceptional circumstances. Preservation is best applied in conjunction with restoration and/or enhancement of ecological functions and values and rarely as the sole means of compensation.

Compensatory mitigation can be provided in the form of project-specific mitigation, mitigation banking, or in-lieu fee mitigation (USEPA 2003). Project-specific mitigation is generally undertaken by a permittee or agency in order to compensate for resource impacts resulting from a specific action or permit. The permittee or agency performs the mitigation and is ultimately responsible for implementation and success of the mitigation. Mitigation banking is a wetland area that has been restored, created, or enhanced, which is then set aside ("banked") to compensate for future impacts to wetlands or other aquatic resources. The value of a bank is determined by quantifying the resource functions restored or created in terms of "credits," which can be acquired, upon the approval of regulatory agencies, to meet a project's requirements for compensatory mitigation. The bank sponsor is ultimately responsible for the success of the project. In-lieu fee mitigation involves a program where funds are paid to a natural resource management entity by a permittee or agency to meet their requirements of compensatory mitigation. The fees are used to fund the implementation of either specific or general wetland or other aquatic resource conservation projects. The management entity may be a third party (e.g., nongovernmental organizations, land trusts) or a public agency that specializes in resource conservation, restoration, and enhancement programs.

Below are some general topics and recommendations regarding the assessment and implementation of compensatory mitigation for actions that may adversely affect fishery resources. It may be necessary to include some of these measures as permit conditions or in decision documents in order to ensure that compensatory mitigation is completed satisfactorily and within the agreed upon timeframes.

### *Baseline information*

The primary purpose of providing effective compensatory mitigation should be to restore or replace the ecological functions and values of resources. In order to assess the effectiveness of compensatory mitigation, the baseline or existing functions and values of the project impact site must be known, as well as the target functions and values for the completed compensatory mitigation site. This can only be accomplished through site-specific monitoring and resource assessments. There are a number of assessment methodologies available to accomplish this, and it is important to determine the method(s) that should be used in advance because it will be necessary for the performance evaluation of the completed mitigation site.

Generally, compensatory mitigation should be provided for direct and indirect impacts, as well as short-term, long-term, and cumulative impacts to fishery resources. Indirect, long-term, and cumulative impacts of a development project may be more difficult to identify and quantify than short-term impacts, but they are no less important. In some cases, the adverse effects on aquatic resources from indirect, long-term, and cumulative impacts may be greater than the direct, short-term construction-related impacts. For example, the direct construction-related impacts of deepening a navigation channel for the purpose of expanding a commercial marina may only involve the removal of bottom sediments in the existing channel. Even so, the dredging project may also result in other short-term impacts to benthic resources from sedimentation and turbidity and anchor damage from vessels. Expansion of a marina operation may result in long-term and cumulative impacts to seagrass and riparian vegetation from vessel wakes and prop scour and in chronic turbidity and sedimentation from larger and more frequent vessel activity. Long-term and cumulative impacts from a development project may also determine whether compensatory mitigation is more appropriately located on-site or off-site.

### *Compensatory mitigation plan*

A clear and concise description of the specific habitats and the functions and values that are intended to be restored should be provided in the mitigation plan. Wetlands and other aquatic habitats provide numerous functions and values within an ecosystem, so it is important to identify the specific functions and values that the compensatory mitigation is intended to restore or replace. Performance criteria should be established (e.g., 80% vegetation cover by target species by the end of the second growing season), and specific monitoring and analytical methods to assess the success of the mitigation should be stipulated in advance.

Adaptive management should be incorporated into mitigation plans, when appropriate. While clear and concise performance criteria are important in all compensatory mitigation plans, monitoring data and predetermined ecological indicators should be used to guide the progress of the mitigation and ensure mitigation objectives are met. Effective compensatory mitigation plans should recognize the importance of adaptive management and allow for corrective action when performance measures are not being met.

A compensatory mitigation plan should include requirements for monitoring and performance reporting, including the content and frequency of reports and who should receive the reports. Generally, the reports should be provided concurrently with the completion of performance monitoring to allow for corrective actions to be taken should success criteria not be met. Other features of a mitigation plan may include measures to ensure mitigation site protection, financial assurances, and a description of long-term maintenance requirements, if necessary, and the party or parties responsible for completing the mitigation requirements.

### *Contingency plans*

Contingency plans for the mitigation plan may be necessary to ensure that adequate compensation is provided, particularly for mitigation that is considered a high-risk endeavor, such as restoration of eelgrass beds. The contingency plan may be necessary to extend the completion of the mitigation plan, and it may require supplemental effort (e.g., planting) or call for alternative mitigations (e.g., out-of-kind). If it is determined that mitigation contingencies are necessary, they should be specified in the permit or decision documents.

### *Mitigation timing*

To minimize the time lag between the loss of wetlands or other aquatic resources and the completion of the compensatory mitigation project, implementation of mitigation construction should begin as soon as possible. For example, if mitigation construction must begin during a specific time of year or the ecological functions and values at the mitigation site require multiple years before being realized, it may be desirable for the compensatory mitigation project to begin before the resource impacts occur.

### *Interim losses*

In situations where there will be delays in implementation of compensatory mitigation or a compensatory mitigation project requires several years to complete, interim or temporal losses of ecological functions and values may be substantial. In these cases, compensation of the interim losses of ecological functions and values should be included in the compensatory mitigation plan. There are a number of ways in which compensation of interim losses can be assessed, such as increasing the ratio of acreage lost to acreage replaced. However, “loss of services” analyses, such as the Habitat Equivalency Analysis (HEA), have been used successfully in a number of restoration projects (NOAA 2006). The HEA assumes there is a one-to-one tradeoff between the resource services at the compensatory restoration site and the resource impact site. In other words, it assumes that the resources can be compensated for past losses through habitat replacement projects providing the replacement resources are the same type as the lost or damaged resources (i.e., in-kind mitigation).

For more information and a more detailed discussion about compensatory mitigation, the reader may refer to the following resources.

### *General compensatory mitigation guidelines*

http://www.epa.gov/wetlandsmitigation
http://www.epa.gov/owow/wetlands/guidance
http://www.nap.usace.army.mil/cenap-op/regulatory/draft_mit_guidelines.pdf
http://www.mitigationactionplan.gov/Preservation_8-27-04.htm

### *Mitigation banking and in-lieu fee programs*

http://www2.eli.org/wmb/backgroundb.htm
http://www.gao.gov/new.items/d01325.pdf

### *Habitat equivalency analysis*

http://www.csc.noaa.gov/coastal/economics/habitatequ.htm
http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

## References for Compensatory Mitigation

[NOAA] National Oceanic and Atmospheric Administration. 2006. Habitat equivalency analysis: an overview. [Internet]. Washington (DC): US Department of Commerce, NOAA, Damage Assessment and Restoration Program.[cited 2008 Jul 28]. 24 pp. Available from: http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

[USACE] US Army Corps of Engineers. 2002. Guidance on compensatory mitigation projects for aquatic resource impacts under the Corps regulatory program pursuant to Section 404(a) of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. [Internet]. Washington DC): USACE. Regulatory Guidance Letter No. 02-2, 2002 Dec 24. [cited 2008 Jul 28]. Available from: http://www.usace.army.mil/cw/cecwo/reg/rgls/RGL2-02.pdf.

[US Army], [USEPA] US Department of the Army, US Environmental Protection Agency. 1989. Memorandum of agreement between the Department of the Army and the Environmental Protection Agency concerning the determination of the Section 404 Program and the application of the exemptions under Section 404(F) of the Clean Water Act. [Internet]. Washington (DC): US Army and US EPA. [cited 2008 Jul 28]. Available from: http://www.usace.army.mil/cw/cecwo/reg/mou/404f.htm.

[USEPA] US Environmental Protection Agency. 2003. Wetlands compensatory mitigation. [Internet]. Washington (DC): US EPA, Office of Wetlands, Oceans, and Watersheds. EPA Report EPA-843-F-03-002. [cited 2008 Jul 28]. Available from: http://www.epa.gov/owow/wetlands/pdf/CMitigation.pdf.

# CONCLUSIONS AND RECOMMENDATIONS

The purpose of this chapter is to synthesize the information discussed in the previous chapters of this report and to identify topics for future research and focus. In addition, the participants of the technical workshop on nonfishing impacts identified activities that are known or suspected to have adverse impacts on fisheries habitat, and we have attempted to draw some conclusions (based upon the effects scores) concerning those activities and effects that deserve further scrutiny and discussion. While many of these activities clearly have known direct, adverse impacts on the quantity and quality of fisheries habitat, their effects at the population and ecosystem level are not well known or understood. For example, there are a number of ports and harbors in the northeast region that have been identified as the most contaminated sites in US coastal waters for polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, and trace metals (USEPA 2004; Buchsbaum 2005). Although many of the effects of these pollutants at the cellular, physiological, and whole organism level are known, information on the effects at the population and ecosystem level is less understood.

There were some noteworthy results from the technical workshop, particularly regarding the geographic areas that scored high for some of the activity types and effects. As one might expect, the workshop participants considered impacts on fisheries habitats to be generally focused in nearshore coastal areas. These results are not particularly surprising considering the proximity of riverine and nearshore habitats to industrial facilities, shipping, and other coastal development. Rivers, estuaries, and coastal embayments are essential for fisheries because they serve as nurseries for the juvenile stages of species harvested offshore or as habitats for the prey of commercially important species (Deegan and Buchsbaum 2005). Estuarine and wetland dependent fish and shellfish species account for about 75% of the total annual seafood harvest of the United States (Dahl 2006). In the workshop session on alteration of freshwater systems, several effects scored high in the estuarine/nearshore ecosystem in addition to the riverine ecosystem. For example, impaired fish passage and altered temperature regimes scored high for the riverine and estuarine/nearshore ecosystems in the dam construction/operation and water withdrawal activity types, suggesting that the participants viewed these activities to have broad ecosystem impacts.

Most effects in both the chemical and physical effects workshop sessions scored high in the riverine and estuarine/nearshore ecosystems. In addition, a few of these effects also scored high in the marine/offshore ecosystem. For the chemical effects session, the release of nutrients/eutrophication, release of contaminants, development of harmful algal blooms, contaminant bioaccumulation/biomagnification, and all effects under the combined sewer overflows impact type scored high in all ecosystem types. The concern of the workshop participants regarding these impacts seems to reflect recently published assessments on threats to coastal habitats (USEPA 2004; Deegan and Buchsbaum 2005; Lotze et al. 2006). For example, the 2004 National Coastal Condition Report (USEPA 2004) assessed the condition of estuaries in the northeast to be poor, with 27% of estuarine area as impaired for aquatic life, 31% impaired for human use, and an additional 49% as threatened for aquatic life use. One of the primary factors contributing to poor estuarine conditions in the northeast region is poor water quality, which is typically caused by high total nitrogen loading, low dissolved oxygen concentrations, and poor water clarity. In the northeast region, the contributing factors associated with nutrient enrichment are principally high human population density and, in the mid-Atlantic states, agriculture (USEPA 2004). In addition, harmful algal blooms (HABs) have been associated with eutrophication of coastal waters, which can deplete oxygen in the water, result in hypoxia or anoxia, and lead to large-scale fish kills (Deegan and Buchsbaum 2005). HABs may also contain species of algae that produce toxins, such as red tides, that can kill or otherwise negatively affect large numbers of fish and shellfish, contaminate shellfish beds, and cause health problems in humans. The extent and severity of coastal eutrophication and HABs will likely continue and may worsen as coastal human population density increases. Considerable attention should be focused on the effects of eutrophication on habitat and water quality, the populations of fish and shellfish, and the role of natural versus anthropogenic sources of nutrients in the occurrence of HABs.

For the workshop session on physical effects, entrainment and impingement effects scored high in all ecosystem types. Entrainment and impingement of eggs, larvae, and juvenile fish and shellfish are increasingly being identified as potential threats to fishery populations from a wide variety of activities, including industrial and municipal water intake facilities, electric power generating facilities, shipping, and liquefied natural gas facilities (Hanson et al. 1977; Travnichek et al. 1993; Richkus and McLean 2000; Deegan and Buchsbaum 2005). Future research is needed to assess the long-term and cumulative effects that entrainment and impingement from these activities have on fish stocks, their prey, and higher trophic levels of the marine ecosystem.

The participants of the workshop session on global effects and other impacts scored most effects in the estuarine/nearshore ecosystem as high. However, several effects of climate change scored high for all ecosystems, including alteration of temperature and hydrological regimes, alteration of weather patterns, and changes in community structure. The effects of climate change related to commercial and recreational fisheries have not as of yet been the focus of extensive research. However, greater emphasis on this topic will likely be necessary as the effects of global warming become more pronounced (Bigford 1991; Frumhoff et al. 2007).

A number of activities and effects were identified during the workshop and in the preparation of this report that may pose substantial threats to fisheries habitat, but the extent of the problems they represent and their implications to aquatic ecosystems are not well understood. Some of these activities and effects have only recently been recognized as potential threats, such as the effects of endocrine disrupting chemicals on aquatic organisms and the threats to fisheries from global warming and will require additional research to have a clearer understanding of the mechanism and scope of these problems. However, other effects such as sedimentation on benthic habitats and biota have been the focus of considerable research and attention, but questions remain as to the lethal and sublethal thresholds of sedimentation effects on individual species and its effects on populations. For example, although sedimentation caused by navigation channel dredging is known to adversely affect the demersal eggs of winter flounder (*Pseudopleuronectes americanus*) (Berry et al. 2004; Klein-MacPhee et al. 2004; Wilber et al. 2005) a better understanding of how the intensity and duration of egg burial effects mortality is needed (i.e., lower lethal thresholds). In addition, how do grain size, the type and amount of contamination, and background suspended sediment concentrations affect egg and larvae survival rates, and what are the implications at the population level?

A number of energy-related activities were assessed for adverse effects on fisheries habitat in the technical workshop and in the corresponding report chapter, including offshore liquefied natural gas platforms, wind turbines, and wave and tidal energy facilities. Although various impacts were discussed, there have not been any facilities of this type constructed in the northeast region of the United States at the time of this report. Although we believe the resource assessments for these types of facilities have been based upon the best available information, further monitoring and assessments will be necessary once they are constructed.

The workshop participants identified a number of chemical effects in several sessions that may have a high degree of impact on fisheries, such as endocrine disrupting chemicals and pharmaceuticals in treated wastewater. Pharmaceuticals and personal care products (PPCP) can persist in treated wastewater and have been found in natural surface waters at concentrations of parts per thousand to parts per billion (Daughton and Ternes 1999). Although the range of concentrations of PPCPs may not pose an acute risk, because aquatic organisms may be exposed continually and for multi-generations, the effects on coastal aquatic communities are a major concern (USEPA 2007). Some of these PPCPs include steroid compounds, which may also be endocrine disruptors. Endocrine disruptors can mimic the functions of sex hormones, androgen and estrogen, and can interfere with reproductive functions and potentially result in population-level impacts. Some chemicals shown to be estrogenic include polychlorinated biphenyl (PCB) congeners, pesticides (e.g., dieldrin, dichlorodiphenyl trichloroethane [DDT]), and compounds used in some industrial manufacturing (e.g., phthalates, alkylphenols) (Thurberg and Gould 2005). In addition, some metal compounds have also been implicated in disrupting endocrine secretions of marine organisms (Brodeur et al. 1997). Additional investigation into the effects of PPCPs and endocrine disruptors on aquatic organisms and their potential impacts at the population and ecosystem level is needed.

In addition, the workshop participants identified a number of adverse effects on aquatic ecosystems from introduced/nuisance species, particularly in the estuarine/nearshore ecosystem. Introduction of nonnative invasive species into marine and estuarine waters poses a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species introductions occur through a wide range of activities, including hull fouling and ballast water releases from ships, aquaculture operations, fish stocking and pest control programs, and aquarium discharges (Hanson et al. 2003; Niimi 2004). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001). Increased research focused towards reducing the rate of nonnative species introductions is needed, in addition to a better understanding of the effects of nonnative species on fisheries in the United States.

Overfishing, including fishing effects on habitat, is likely the greatest factor in the decline of groundfish species in New England (Buchsbaum 2005) and is responsible for the majority of fish and shellfish species depletions and extinctions worldwide (Lotze et al. 2006). However, habitat loss and degradation through nonfishing activities (including pollution, eutrophication, and sedimentation) closely follow exploitation as a causative agent in fishery declines and may be equally or more important for some species such as Atlantic salmon (*Salmo salar*) (Buchsbaum 2005; Lotze et al. 2006). Cumulative effects likely play a role in a large majority of historic changes in fish stocks. Worldwide, nearly half of all marine and estuarine species depletions and extinctions involve multiple human impacts, most notably exploitation and habitat loss (Lotze et al. 2006). It is imperative that management measures intended to reduce exploitation, increase habitat protection, and improve water quality be applied holistically and that the cumulative effects of multiple human interactions be considered in both management and conservation strategies (Lotze et al. 2006). The challenges of quantifying the cumulative effects of nonfishing impacts are vast and complex. Nonetheless, the importance of nonfishing impacts on the coastal ecosystem will likely become greater in the future, and we believe fishery managers would be well served by beginning to collaborate with coastal resource managers and integrate signals from nonfishing effects and stresses on the ecosystem with traditional stock assessment models.

## References for Conclusions and Recommendations


Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth f latfish biology conference-poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchsbaum RN. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Dahl TE. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. [Internet]. Washington (DC): US Department of the Interior; Fish and Wildlife Service. [cited 2008 Jul 21]. 112 p. Available from: http://wetlandsfws.er.usgs.gov/status_trends/National_Reports/trends_2005_report.pdf.

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? [Internet]. Environmental Health Perspectives 107(S6): 907-38. [cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/pdf/errata.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Frumhoff PC, McCarthy JJ, Melillo, SC, Moser SC, Wuebbles DJ. 2007. Confronting climate change in the U.S. Northeast: science, impacts, and solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge (MA): Union of Concerned Scientists (UCS). 146 p.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Klein-MacPhee G, Macy WK, Berry W. 2004. *In situ* effects of suspended particulate loads produced by dredging on eggs of winter flounder (*Pseudopleuronectes americanus*). In: Ninth flatfish biology conference-oral presentation; 2004 Dec 1-2; Water's Edge Resort, Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-9.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Richkus WA, McLean R. 2000. Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay. Environmental Science and Policy 3(Supplement 1):283-93.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

[USEPA] US Environmental Protection Agency. 2004. National coastal condition report II. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2007. Pharmaceuticals and personal care products (PPCP): frequent questions. [Internet]. Washington (DC): US EPA Office of Research and Development. [updated 2007 Dec 14; cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/faq.html.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

# APPENDIX

## Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities, January 10-12, 2005 in Mystic, CT

*Attendee List*

| Name | Organization/Affiliation | City and State |
|---|---|---|
| Michael Johnson | National Marine Fisheries Service | Gloucester, MA |
| Sean McDermott | National Marine Fisheries Service | Gloucester, MA |
| Chris Boelke | National Marine Fisheries Service | Gloucester, MA |
| Marcy Scott | National Marine Fisheries Service | Gloucester, MA |
| Lou Chiarella | National Marine Fisheries Service | Gloucester, MA |
| David Tomey | National Marine Fisheries Service | Gloucester, MA |
| Jennifer Anderson | National Marine Fisheries Service | Gloucester, MA |
| Mike Ludwig | National Marine Fisheries Service | Milford, CT |
| Diane Rusanowsky | National Marine Fisheries Service | Milford, CT |
| Anita Riportella | National Marine Fisheries Service | Highlands, NJ |
| Stan Gorski | National Marine Fisheries Service | Highlands, NJ |
| Andy Draxler | National Marine Fisheries Service | Highlands, NJ |
| Ric Ruebsamen | National Marine Fisheries Service | St. Petersburg, FL |
| Jeanne Hanson | National Marine Fisheries Service | Anchorage, AK |
| Heather Ludemann | National Marine Fisheries Service | Silver Spring, MD |
| Kimberly Lellis | National Marine Fisheries Service | Silver Spring, MD |
| David Wiley | Stellwagen Bank National Marine Sanctuary | Situate, MA |
| Leslie-Ann McGee | New England Fishery Management Council | Woods Hole, MA |
| Sally McGee | New England Fishery Management Council | Mystic, CT |
| Eric Nelson | US Environmental Protection Agency | Boston, MA |
| Phil Colarusso | US Environmental Protection Agency | Boston, MA |
| Cathy Rogers | US Army Corps of Engineers | Concord, MA |
| Michael Hayduk | US Army Corps of Engineers | Philadelphia, PA |
| Brenda Schrecengost | US Army Corps of Engineers | Philadelphia, PA |
| Steven Mars | US Fish and Wildlife Service | Trenton, NJ |
| Michelle Dione | Wells National Estuarine Research Reserve | Wells, ME |
| John Sowles | Maine Dept. of Marine Resources | W. Boothbay Harbor, ME |
| Brian Swan | Maine Dept. of Marine Resources | Augusta, ME |
| Ray Grizzle | University of New Hampshire | Durham, NH |
| Mashkoor Malik | University of New Hampshire | Durham, NH |
| Vincent Malkoski | Massachusetts Division of Marine Fisheries | Boston, MA |
| Stephanie Cunningham | Massachusetts Division of Marine Fisheries | Gloucester, MA |
| Tony Wilbur | Massachusetts Office of Coastal Zone Management | Boston, MA |
| Joe Pelczarski | Massachusetts Office of Coastal Zone Management | Boston, MA |
| Chris Powell | Rhode Island Division of Fish & Wildlife | Jamestown, RI |
| Mark Johnson | Connecticut Dept. of Environmental Protection | Hartford, CT |
| Karen Chytalo | New York State Dept. of Environmental Conservation | East Setauket, NY |
| Drew Carey | Coastal Vision | Newport, RI |
| Donna Bilkovic | Virginia Institute of Marine Science | Gloucester Point, VA |
| Robert Van Dolah | South Carolina Dept. of Natural Resources | Charleston, SC |
| Trevor Kenchington | Gadus Associates/Fisheries Survival Fund | Nova Scotia, Canada |
| Phil Ruhle | New England Fishery Management Council/ F/V Sea Breeze | Newport, RI |
| Gib Brogan | Oceana | Mystic, CT |

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

**Refer to NMFS No:**
**2008/03298**

August 13, 2008

Cayla Morgan
Seattle Airports District Office
Federal Aviation Administration
1601 Lind Avenue SW, Suite 250
Renton, Washington 98055-4056

Re: Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Coos Bay Airport Expansion in North Bend (HUC: 171003040303), Coos County, Oregon

Dear Ms. Morgan:

The enclosed document contains a biological opinion (Opinion) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of the Federal Aviation Administration's (FAA) proposal to fund the Coos Bay Airport Expansion in North Bend (HUC: 171003040303), in Coos County, Oregon. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), or result in the destruction or adverse modification of designated critical habitat for OC coho salmon. This Opinion also concludes the proposed action is not likely to jeopardize the continued existence of the southern distinct population segment of North American green sturgeon (*Acipenser medirostris*).

As required by section 7 of the ESA, NMFS is providing an incidental take statement (ITS) for OC coho salmon with the Opinion. The ITS describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The ITS sets forth nondiscretionary terms and conditions, including reporting requirements, that the FAA and their applicant must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of ESA-listed species.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes two conservation recommendations to avoid, minimize or otherwise offset potential adverse effects on EFH. These conservation recommendations are a subset of the terms and conditions found in the ITS. Section 305(b)(4)(B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations.

If the response is inconsistent with the EFH conservation recommendations, the FAA must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, in your statutory reply to the EFH portion of this consultation, please clearly identify the number of conservation recommendations accepted.

If you have questions regarding this consultation, please contact Ken Phippen, Branch Chief of the Southwest Oregon Habitat Branch of the Oregon State Habitat Office, at 541.957.3385.

Sincerely,

Michael Tehan

for D. Robert Lohn
Regional Administrator

cc: Teena Monical, Corps.
Casey Storey, W & H Pacific
Southwest Oregon Regional Airport

# Endangered Species Act Section 7 Consultation
# Biological Opinion

and

# Magnuson-Stevens Fishery Conservation and Management Act
# Essential Fish Habitat Consultation

Coos Bay Airport Expansion in North Bend (HUC: 171003040303)
Coos County, Oregon

Lead Action Agency: Federal Aviation Administration

Consultation Conducted By: National Marine Fisheries Service
Northwest Region

Date Issued: August 13, 2008

Issued by: for Michael Tehan
D. Robert Lohn
Regional Administrator

**NMFS No.:** **2008/03298**

## TABLE OF CONTENTS

# INTRODUCTION

This document contains a biological opinion (Opinion) and incidental take statement (ITS) prepared in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, *et seq.*), and implementing regulations at 50 C.F.R. 402. The National Marine Fisheries Service (NMFS) also completed an essential fish habitat (EFH) consultation, prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq.*) and implementing regulations at 50 CFR 600.

The docket for this consultation is on file at the Southwest Oregon Habitat Branch in Roseburg, Oregon.

## Background and Consultation History

On December 1, 2006, NMFS received a letter and biological assessment (BA) from the Seattle Airports District Office of the Federal Aviation Administration (FAA), requesting consultation on the effects of funding a construction project at the Southwest Oregon Regional Airport in North Bend, Oregon. The request for consultation was made pursuant to section 305(b)(2) of the MSA. The funding would allow the Southwest Oregon Regional Airport to improve airport safety and meet FAA design requirements by expanding an existing taxiway and adding a new air traffic control tower. The proposed changes will require that a 1,000-foot long by 65-foot wide section of Coos Bay be filled to accommodate the expansion.

The Southwest Oregon Regional Airport (formerly known as the North Bend Municipal Airport) began in 1936 as a local Work Project Administration (WPA) project. The airfield became an Auxiliary Air Facility in 1942. In 1947, the airfield was deeded to the City of North Bend. The most recent airport expansion occurred in 1988, and extended Runway 4-22. The airport is currently owned and operated by the Coos County Airport District (CCAD). It is the only commercial airport on the Oregon Coast.

A field trip was held on November 1, 2006, to visit the construction site and nearby mitigation site. Representatives from W&H Pacific (consultant), the U.S. Army Corps of Engineers, the Ocean and Coastal Program of the Oregon Land Conservation and Development Commission, Oregon Department of Fish and Wildlife (ODFW), and the Southwest Oregon Regional Airport attended the field trip.

On July 16, 2007, the Southwest Oregon Habitat Branch of the NMFS received the final Environmental Assessment (EA) for the project. This final assessment provided key information that outlined the proposed activities at the Mangan mitigation site on Haynes Inlet.

On October 5, 2007, NMFS issued an EFH consultation (refer to NMFS No.: 2006/06108) completing MSA consultation to the Federal Aviation Administration (FAA) for their proposed funding of the Coos Bay Airport Expansion and provided two conservation recommendations to avoid, minimize or otherwise offset potential adverse effects to EFH. Some upland work has occurred to prepare the site, but project area work previously permitted and with the potential to impact EFH has not been completed. Deployment of temporary coffer-dams was attempted before the lapse of the in-water work period, but was discontinued due to delays encountered while deploying the coffer dam, as described below. Wetland and estuarine habitat mitigation construction has taken place at the Mangan mitigation site, but elements including the breech of the dike and installation of work area isolation structures associated with this activity, have not taken place.

The relocation of taxiway C at the Southwest Oregon Regional Airport requires the placement of fill material into the Coos Bay estuary. The erosion control plan called for the installation of a temporary cofferdam with a minimum 10 feet of clearance between the toe of slope and the back of the cofferdam. Removal of existing riprap along the old embankment, compaction of the proposed fill area, and filling/completion of the proposed taxiway and new embankment were to be completed only after this structure had been installed.

Due to the nature of substrate in the project area and the isolation structure, a standard cofferdam was deemed to be inappropriate for the project area by cofferdam suppliers and the contractor. In response, the contractor selected a water-filled temporary dam for work area isolation. Such a structure typically produces fewer impacts, requires less installation time, and does not require stable foundation substrate-as was the case with other cofferdams.

The water-filled dam was received at the project site in early January, 2008. Deployment of the dam began soon after its arrival at the site. Delays and problems with the deployment of the water dam began almost immediately. Tidal timing, rupture of internal bladders, and long delays in receiving replacement parts and technical staff from the suppliers added to multiple delays. Finally, after additional deployment attempts and structure failures, the water filled dams were abandoned as viable options for work area isolation. At this time, the in-water work period at the project site had lapsed and plan changes were deemed necessary.

Multiple conference calls were conducted between personnel from W&H Pacific, ODFW, and NMFS personnel to discuss the project status and consultation strategy. On May 27, 2008, the FAA transmitted a letter to the NMFS requesting reinitiation of the MSA consultation due to changes in the proposed work. The FAA also requested initiation of formal consultation under the ESA for the newly-listed Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) and its designated critical habitat, and for the newly-listed Southern distinct population segment (DPS) of the North American green sturgeon (*Acipenser medirostris*). Southern DPS green sturgeon individuals were recently determined to inhabit Coos Bay, therefore the FAA chose to initiate ESA consultation on this ESA-listed species.

The FAA concluded that funding the proposed action may adversely affect OC coho salmon, critical habitat for OC coho salmon, southern DPS green sturgeon and EFH designated for Pacific salmon and groundfish.

**Description of the Proposed Action**

The proposed action is to fund the remaining elements of an expansion of a runway and taxiway at the Southwest Oregon Regional Airport in North Bend, Coos County, Oregon. The expansion will improve airport safety but will not increase the operational capacity of the airport, nor will it allow larger aircraft to use the airport.

The following descriptions summarize the proposed project changes that remain to be completed at the Airport and the Mangan mitigation site that are pertinent to review and consultation by NMFS. The summary includes the proposed changes to timing and staging.

**Taxiway C Relocation – Southwest Oregon Regional Airport.** In response to a need for plan changes, an alternative isolation method for the site has been devised. This method involves the construction of a coarse gravel pier extending eastward to westward from the existing embankment near the current stormwater discharge and then north to the existing taxiway C embankment as depicted in the Embankment Plan – Sheet C-15A. The pier will match the toe of slope of the final grade proposed for the fill area in the original plan. The pier will be constructed in the following order:

1. Work will commence from east to west, and then north.
2. Geotextile fabric will be placed on the bay bottom.
3. Aggregate will be placed on the geotextile fabric to a height of 6.62 feet, the elevation of highest measured tide.
4. Geotextile fabric will be wrapped around the aggregate and secured.
5. The closure of the pier will be completed at low tide to avoid fish entrapment within the structure.

Dewatering of the fill area will pump water into the existing stormwater containment pond for sediment control. Fill activities will be conducted during low and low slack tides to reduce the generation of local turbidity. The pier construction process and general work conditions during filling will be monitored for sediment and fish entrapment. In the event of fish salvage behind the pier structure, beach seines and dip nets will be utilized to remove fish to bay waters. Fish salvage is expected to be conducted by a W&H Pacific biologist.

Following completion of compaction and filling in the internal fill area, the pier will be capped with additional fill materials to the proposed final elevation of the new taxiway alignment and previously specified riprap will be installed on the bay-side face of the pier. See Sheet C-22A for a detail of the sequence of fill and pier (embankment) construction.

Construction of the pier work containment structure constitutes in-water work, but does not constitute a difference in fill volumes or the final development footprint. The estimated time for construction of the pier is expected to be no more than 2 weeks. Following recommendations and considering environmental conditions, construction of the structure will not commence until after June 30, 2008. This timing is out of the in-water work period for the watershed, but is during the driest time of the year for the region and is out of the expected peak outmigration time for OC coho salmon smolts.

**Mangan Mitigation Site – Taxiway C Wetland Impacts Mitigation Site.** The creation of the Mangan mitigation site involves the restoration of mud flats and salt marsh from diked agricultural lands. The primary element of the mitigation site is the removal of an existing levee to introduce tidal action to the site. As specified in the original demolition plan, the levee removal work was to be isolated by a temporary coffer dam as designed for the taxiway. Following failure of the water-dam at the Airport site, the device was rejected for work area isolation at the Mangan site as well.

In lieu of utilizing the water-dam, the levee removal work will be isolated from the Haynes Inlet by the deployment of two 5-foot tall silt fences spaced 5 feet apart. These silt fences would be installed as close to the toe of the existing levee as practical. See Existing Conditions Demolition Plan Sheets WL-02 and WL-03 for details. All excavation at elevations within tidal influence will be conducted when tidal waters are not in the project area.

Upon complete removal of the existing levee, both silt fences will be removed from the project area. The site will be monitored for fish stranding and turbidity while the silt fences are deployed. In the event that fish are stranded behind the silt fences and in the work area, W&H Pacific biologists will coordinate salvage efforts with ODFW. Stranded fish will be removed from the work area with beach seines and dip nets and returned to Haynes Inlet.

Demolition of the levee (in-water work) is expected to take no more than 5 days – with excavated materials being used to add to the new levee elevation. All other work besides installation of salt marsh plantings is completed to date and does not require in-water work. The proposed in-water work at the site is expected to be conducted after June 30, 2008, for the same reasons specified for the pier construction at the airport. The site will be monitored for sedimentation and fish entrapment while the sediment barriers are deployed.

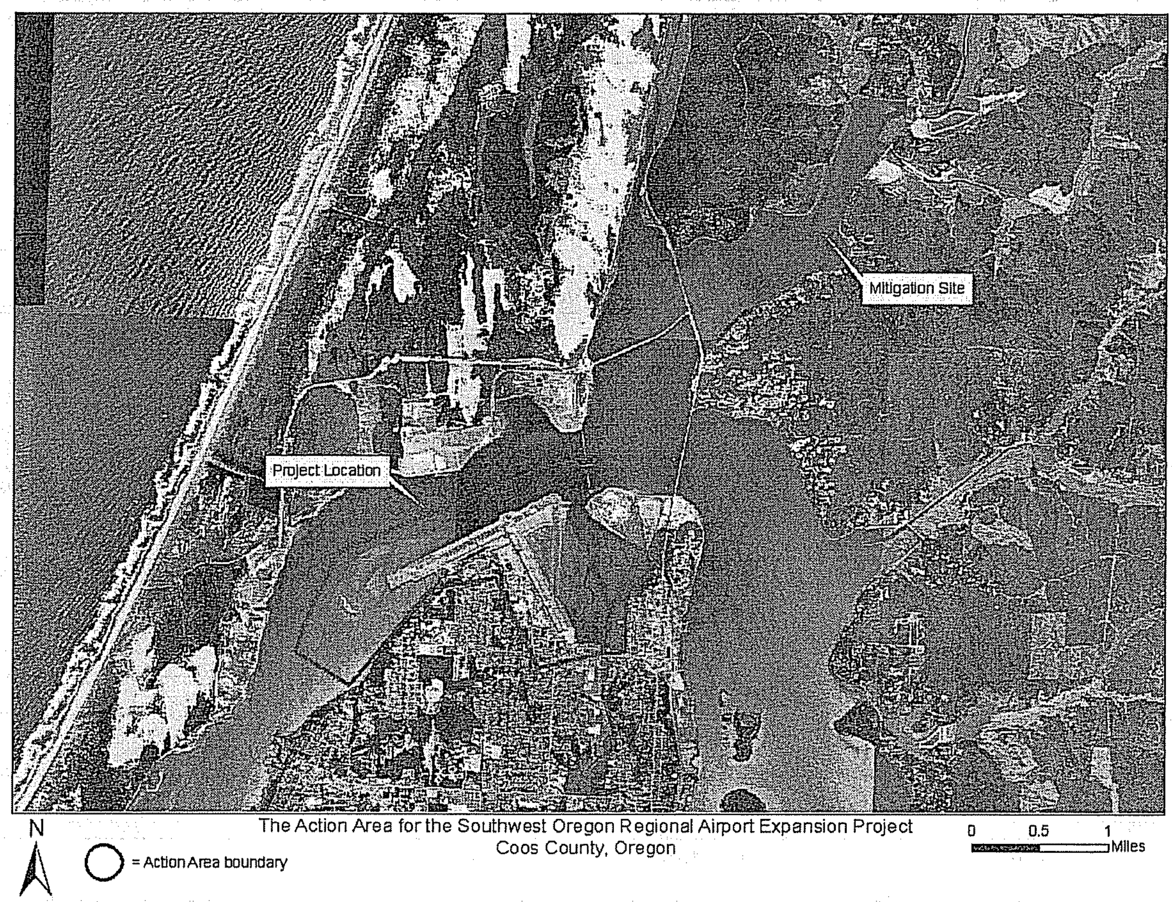
The impact reduction measures, described here as part of the proposed action, are intended to reduce adverse effects on ESA-listed species and their habitats. The NMFS regards these impact reduction measures as integral components of the proposed action and expects that all proposed project activities will be completed consistent with those measures. We have completed our effects analysis accordingly. Any project activity that deviates from these impact reduction measures will be beyond the scope of this consultation and will not be exempted from the prohibition against take as described in the attached ITS. Further consultation will be required to determine what effect the modified action may have on listed species or critical habitats.

The NMFS relied on the foregoing description of the proposed action, including all stated impact reduction measures, to complete this consultation. To ensure that this consultation remains valid, NMFS requests that the action agency or applicant keep NMFS informed of any changes to the proposed action.

**Action Area**

'Action area' means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area is defined as the footprint of the existing airport and adjacent bank, substrate, and aquatic areas of the Coos Bay Estuary and Pony Slough. The action area extends 500 feet upstream from the project site and 1,500 feet downstream from the downstream end of the project site in Coos Bay due to potential impacts from stormwater discharge, turbidity and contaminant dispersion, and habitat loss. The action area also incorporates the mitigation site which includes the immediate footprint of the site and the waters of Haynes Inlet surrounding the site out to a distance of approximately 300 feet. The airport is on Coos Bay in North Bend, Coos County, Oregon. The site is in Township 25 South, Range 13 West, Sections 8, 9, and 10.

**Figure 1.** Location of the two construction areas within Coos Bay for the Southwest Oregon Regional Airport Expansion Project.




The Pacific Fishery Management Council (PFMC) designated EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon (*O. tshawytscha*), coho salmon, and Puget Sound pink salmon (PFMC 1999). The action area includes areas designated as EFH for various life-history stages of groundfish, coastal pelagics, and Chinook salmon and coho salmon (Table 1).

The action area is used by adult and juvenile OC coho salmon for migration and making the transition between the marine and freshwater environments. The OC coho salmon were listed under the ESA, protective regulations were issued and critical habitat was designated on February 4, 2008 (70 FR 7816).

**Table 1.** Species with designated EFH found in waters of Oregon and Washington

| **Groundfish Species** | Blue rockfish (*S. mystinus*) | Rougheye rockfish (*S. aleutianus*) | Flathead sole (*Hippoglossoides elassodon*) |
|---|---|---|---|
| Leopard shark (*Triakis semifasciata*) | Bocaccio (*S. paucispinis*) | Sharpchin rockfish (*S. zacentrus*) | Pacific sanddab (*Citharichthys sordidus*) |
| Soupfin shark (*Galeorhinus zyopterus*) | Brown rockfish (*S. auriculatus*) | Shortbelly rockfish (*S. jordani*) | Petrale sole (*Eopsetta jordani*) |
| Spiny dogfish (*Squalus acanthias*) | Canary rockfish (*S. pinniger*) | Shortraker rockfish (*S. borealis*) | Rex sole (*Glyptocephalus zachirus*) |
| Big skate (*Raja binoculata*) | Chilipepper (*S. goodei*) | Silvergray rockfish (*S. brevispinus*) | Rock sole (*Lepidopsetta bilineata*) |
| California skate (*R. inornata*) | China rockfish (*S. nebulosus*) | Speckled rockfish (*S. ovalis*) | Sand sole (*Psettichthys melanostictus*) |
| Longnose skate (*R. rhina*) | Copper rockfish (*S. caurinus*) | Splitnose rockfish (*S. diploproa*) | Starry flounder (*Platyichthys stellatus*) |
| Ratfish (*Hydrolagus colliei*) | Darkblotched rockfish (*S. crameri*) | Stripetail rockfish (*S. saxicola*) | |
| Pacific rattail (*Coryphaenoides acrolepsis*) | Grass rockfish (*S. rastrelliger*) | Tiger rockfish (*S. nigrocinctus*) | **Coastal Pelagic Species** |
| Lingcod (*Ophiodon elongatus*) | Greenspotted rockfish (*S. chlorostictus*) | Vermillion rockfish (*S. miniatus*) | Northern anchovy (*Engraulis mordax*) |
| Cabezon (*Scorpaenichthys marmoratus*) | Greenstriped rockfish (*S. elongatus*) | Widow Rockfish (*S. entomelas*) | Pacific sardine (*Sardinops sagax*) |
| Kelp greenling (*Hexagrammos decagrammus*) | Longspine thornyhead (*Sebastolobus altivelis*) | Yelloweye rockfish (*S. ruberrimus*) | Pacific mackerel (*Scomber japonicus*) |
| Pacific cod (*Gadus macrocephalus*) | Shortspine thornyhead (*Sebastolobus alascanus*) | Yellowmouth rockfish (*S. reedi*) | Jack mackerel (*Trachurus symmetricus*) |
| Pacific whiting (Hake) (*Merluccius productus*) | Pacific Ocean perch (*S. alutus*) | Yellowtail rockfish (*S. flavidus*) | Market squid (*Loligo opalescens*) |
| Sablefish (*Anoplopoma fimbria*) | Quillback rockfish (*S. maliger*) | Arrowtooth flounder (*Atheresthes stomias*) | |
| Aurora rockfish (*Sebastes aurora*) | Redbanded rockfish (*S. babcocki*) | Butter sole (*Isopsetta isolepsis*) | **Salmon** |
| Bank Rockfish (*S. rufus*) | Redstripe rockfish (*S. proriger*) | Curlfin sole (*Pleuronichthys decurrens*) | Coho salmon (*Oncorhynchus kisutch*) |
| Black rockfish (*S. melanops*) | Rosethorn rockfish (*S. helvomaculatus*) | Dover sole (*Microstomus pacificus*) | Chinook salmon (*O. tshawytscha*) |
| Blackgill rockfish (*S. melanostomus*) | Rosy rockfish (*S. rosaceus*) | English sole (*Parophrys vetulus*) | Pink salmon (*O. gorbuscha*) |

The NMFS listed southern DPS green sturgeon as threatened under the ESA on April 7, 2006 (71 FR 17757). Southern DPS green sturgeon use the action area as habitat for growth and development to adulthood and for adult feeding. The NMFS has not designated critical habitat for southern DPS green sturgeon, or issued protective regulations under section 4(d) of the ESA.

## ENDANGERED SPECIES ACT

Section 7(a)(2) of the ESA requires Federal agencies to consult with NMFS to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The Opinion that follows records the results of the interagency consultation for this proposed action. An ITS is provided after the Opinion that specifies the impact of any taking of OC coho salmon that will be incidental to the proposed action, reasonable and prudent measures that NMFS considers necessary and appropriate to minimize such impact, and nondiscretionary terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agencies, applicants, or both, to carry out the reasonable and prudent measures.

### Biological Opinion

To complete the jeopardy analysis presented in this Opinion, NMFS reviewed the status of each listed species considered in this consultation, the environmental baseline in the action area, the effects of the action, and cumulative effects (50 CFR 402.14(g)). From this analysis, NMFS determined whether effects of the action were likely, in view of existing risks, to appreciably reduce the likelihood of both the survival and recovery of the affected listed species.

For the critical habitat adverse modification analysis, NMFS considered the status of the entire designated area of the critical habitat considered in this consultation, the environmental baseline in the action area, the likely effects of the action on the function and conservation role of the affected critical habitat, and cumulative effects. The NMFS used this assessment to determine whether, with implementation of the proposed action, critical habitat would remain functional, or retain the current ability for the primary constituent elements (PCEs) to become functionally established, to serve the intended conservation role for the species (Hogarth 2005).

#### Status of the Species and Critical Habitat

This section defines the biological requirements of the species, and reviews the status of the species and affected critical habitat relative to those requirements. The present risk of extinction faced by the listed species informs NMFS' determination of whether additional risk will 'appreciably reduce' the likelihood that they will survive or recover in the wild. The greater the present risk, the more likely it is that any additional risk resulting from the proposed action's effects on the population size, productivity (growth rate), distribution, or genetic diversity of the species (McElhany *et al.* 2000), or on the conservation value of critical habitat, will be an appreciable reduction.

**OC Coho Salmon**. This species includes all naturally-spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco, and progeny of five artificial propagation programs. The Oregon Coast Technical Recovery Team (OC-TRT) identified 56 historical populations, grouped into five major "biogeographic strata," based in consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Lawson *et al.* 2007).

The OC-TRT concluded that, if recent past conditions continue into the future, OC coho salmon are moderately likely to persist over a 100-year period without artificial support, and have a low to moderate likelihood of being able to sustain their genetic legacy and long-term adaptive potential for the foreseeable future (Wainwright *et al.* 2007).

The following factors were identified by NMFS (2007) as limiting the recovery of OC coho salmon: Degraded floodplain connectivity and function, degraded channel structure and complexity, degraded riparian areas and large wood debris recruitment, degraded stream substrate, degraded water quality, predation, competition, and disease.

***Coos River population***. OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population (Lawson *et al.* 2007). An independent population is defined as having minimal demographic influence from adjacent populations and is viable-in-isolation. An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations (McElhany *et al.* 2000). The Coos River Population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU (Lawson *et al.* 2007).

Annual spawning surveys document the Coos River population's annual abundance varies considerably from year to year (Tables 2 and 3). The recent negative trend in abundance demonstrated at the ESU level is reflected at the population level as well (Table 3). Preliminary conclusions for the 2007 spawner abundance places last year's spawner abundance at a very low level.

The number of OC coho salmon juvenile outmigrants from the Coos River population has not been studied enough to provide a reliable estimate. However, it can be back-calculated by dividing the number of returning adults by marine survival. Marine survival predictions averaged 4%, with a range of 0.5% and 11.7%, between 1970 and 1999 (PMFC 2000). In the years of overlapping data (1990-1999), the average number of outmigrants estimated by this back-calculation is 123,625, with a range of 72,067 to 1,686,360.

**Table 2.** Annual estimates of wild OC coho salmon spawner abundance in the Coos Bay system based on monitoring data collected by ODFW.

| Year | Coos Bay & Big Creek |
|---|---|
| 1990 | 2,273 |
| 1991 | 3,813 |
| 1992 | 16,545 |
| 1993 | 15,284 |
| 1994 | 14,685 |
| 1995 | 10,351 |
| 1996 | 12,128 |
| 1997 | 1,127 |
| 1998 | 3,167 |
| 1999 | 4,945 |
| 2000 | 5,386 |
| 2001 | 43,301 |
| 2002 | 35,429 |
| 2003 | 29,559 |
| 2004 | 24,116 |

**Table 3.** Estimated wild OC coho salmon abundance estimates and 95% confidence interval (CI) from the 2002 through 2007 spawning survey seasons for Coos River. Included are the number of surveys and miles surveyed.

| Year | Number Surveys | Miles | Estimate | 95% CI |
|---|---|---|---|---|
| 2002 | 32 | 29.4 | 35,688 | 13,258 |
| 2003 | 33 | 30.9 | 29,559 | 11,486 |
| 2004 | 34 | 31.8 | 24,116 | 7,446 |
| 2005 | 9 | 7.3 | 17,048 | 9,170 |
| 2006 | 23 | 20.0 | 11,266 | 4,243 |
| 2007 | 31 | 30.1 | 1,414 | 459 |

**Southern DPS Green Sturgeon.** Green sturgeon are a widely-distributed and marine-oriented species found in nearshore waters from Baja California to Canada (NMFS 2008). There are two distinct population segments defined for green sturgeon – a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NMFS 2008). The southern DPS includes all spawning populations of green sturgeon south of the Eel River in California, of which only the Sacramento River currently contains a spawning population. McLain (2006) noted that southern DPS green sturgeon were first determined to occur in Oregon and Washington waters in the late 1950s when tagged San Pablo Bay green sturgeon were recovered in the Columbia River estuary (CDFG 2002).

The green sturgeon biological review team (BRT) convened a status review update in November 2004 (BRT 2005). The majority of the BRT concluded that southern DPS green sturgeon is likely to become endangered in the foreseeable future and only one member concluded that the southern DPS is not in danger of extinction or likely to become endangered in the foreseeable future. Weighing heavily in this decision was the fact that this species only spawns in one area, the Sacramento River. The BRT felt that the blockage of green sturgeon spawning from what were certainly historic spawning areas above Shasta Dam and the accompanying decrease in spawning area with the loss of the Feather River spawning area make green sturgeon in the southern DPS at risk of extinction in the foreseeable future.

The distribution of green sturgeon is not well known, although southern DPS green sturgeon are reported to congregate in coastal waters and estuaries, including non-natal estuaries, such as Coos Bay. Beamis and Kynard (1997) suggested that green sturgeon move into estuaries of non-natal rivers to feed. Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Green sturgeon are known to enter Washington estuaries during summer (Moser and Lindley 2007). Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are likely to be present in these estuaries from June until October (Moser and Lindley 2007).

***Coos Bay.*** Total population estimates are not available for abundance of either DPS of green sturgeon in Coos Bay; southern DPS individuals were documented to occur by sampling in a 2006 study (Israel and May 2006). Because Coos Bay is not their natal stream, southern DPS green sturgeon are likely to be present from June through October. While in the Coos Bay estuary, they are likely feeding and seeking out the deepest habitats.

**Status of OC Coho Salmon Critical Habitat.** The NMFS reviews the status of critical habitat affected by the proposed action by examining the condition and trends of PCEs of critical habitat throughout the designated area. Within the action area, critical habitat has been designated for OC coho salmon. The PCEs consist of the physical and biological elements identified as essential to the conservation of the species in the documents identifying critical habitat (Table 4).

**Table 4.** Sites (types of habitats), essential physical and biological features named as PCEs, and affected life history events in all salmon critical habitat designations.

| Site | Essential Physical and Biological Features | Affected Life History Event |
|---|---|---|
| Estuarine | Free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover[a]; and forage[b]. | Juvenile and adult mobility and survival |

[a] Natural cover includes submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.

Critical habitat was designated for OC coho salmon, and the action area contains one or more PCEs within the acceptable range of values required to support the biological processes for which the species use that habitat. The specific unit of OC coho salmon critical habitat that will be affected by the proposed action is the Coos Bay 5th field hydraulic unit code (HUC5

#1710030403). This watershed contains PCEs necessary for spawning, rearing and migration. The action area is identified as estuarine habitat and contains the PCEs necessary for juvenile and adult mobility and survival (Table 4). The NMFS Critical Habitat Analytical Review Team (CHART) identified the key management activities with the potential to affect the PCEs as forestry and urbanization. The CHART rated the conservation values of the HUC5 and the migratory corridor as high.

OC coho salmon adult and smolts considered in this Opinion migrate through the action area and use the area to make the physiological transition between marine and freshwater environments. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile coho salmon for migration and to make the transition between these two environments (Table 4). Loss of estuarine wetlands caused by diking and filling to make those areas suitable for agricultural use, urbanization, and industrialization is the most important factor limiting salmon habitat value in the Coos Bay estuary.

**Environmental Baseline for the Action Area**

The NMFS describes the environmental baseline in terms of the biological requirements for habitat features and processes necessary to support all life stages of ESA-listed species within the action area. When the environmental baseline departs from those biological requirements, the adverse effects of a proposed action on the species or its habitat are more likely to jeopardize the listed species or result in destruction or adverse modification of a critical habitat (NMFS 1999).

The Coos Bay estuary is the second largest estuary in Oregon. It is approximately 13,300 acres in size, averaging nearly 0.6 mile wide by 15 miles long. The bay has approximately 30 tributaries. The major tributary flowing into Coos Bay is the Coos River. The Coos Bay estuary is classified as a drowned river mouth-type estuary, where winter flows discharge high volumes of sediment through the estuary. In summer, when discharge is lower, seawater inflow dominates this type of estuary. Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary. Approximately 90% of Coos Bay marshes have been lost to dikes and landfills (Proctor *et al.*1980). Approximately 72,000 tons of sediment, mainly silts and clays, pour into the Coos Bay estuary every year (Schultz 1990).

The waters surrounding the airport site consist of mostly shallow tidal mudflats that are exposed during most low tide occurrences. Habitat typing and mapping identified the area around the airport as: (1) Intertidal with sand and mud flats; (2) undifferentiated aquatic bed; and (3) seagrass aquatic bed. These three habitat types comprise 57.3% of the total 8,582 acres of intertidal zone within Coos Bay.

### Effects of the Action

'Effects of the action' means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). The effects analysis presented in this section is based on information developed with the FAA and the applicants during the consultation process and provided by the applicants BA and supplemental information.

Based on information provided in the BA, NMFS concludes that the proposed action will have adverse effects on the aquatic environment in the action area. Two distinct areas exist in the action area. The taxiway C relocation and the Mangan mitigation site are the two areas with very distinct actions and effects on the environment. The NMFS believes the action, as proposed, is reasonably likely to have the following direct and indirect effects on the ESA-listed species and their aquatic environment: (1) Increased turbidity; (2) chemical contamination from materials staging and construction activities; (3) loss of benthic and shoreline habitat; (4) restoration of estuary functions; and (5) injury due to fish salvage.

Changes in stormwater generation and management are not expected to result in adverse effects to the local aquatic environment. Increased impervious surface and resulting stormwater management will result in discharged stormwater to Coos Bay and Pony Slough, but the proposed level of treatment and water management results in a negligible probability of an adverse effect on OC coho salmon and southern DPS green sturgeon. Approximately 76,595 square feet of increased impervious surface will result from the proposed action. The development of grassy swales, retention ponds, and an infiltration collection system will treat the 6-month, 24-hour storm; that is 90 to 95% of the annual runoff volume. Discharge will occur into Coos Bay and Pony Slough, which will have some low-intensity but insignificant effects on flow and potential contaminants.

#### <u>Effects on the Aquatic Environment</u>.

***Turbidity.*** Elevated turbidity levels will result from actions taken in both areas of the project. Actions associated with the taxiway C relocation that will cause elevated turbidity include the construction of the gravel pier. Dike removal at the Mangan mitigation site will also result in elevated turbidity.

Dry season construction of the pier will equate to less opportunity for precipitation-generated turbidity from the structure and fill area and will reduce the chances of smolts entering the work area. Construction of the pier within the early portion of the in-water work period would present a more significant delay from that already incurred by the project and would increase the likelihood of fall and winter storms affecting the work area and potentially increasing local turbidity.

During the gravel pier construction that will be used to isolate the work area, geotextile fabric will be placed during low tide and filled with unwashed aggregate. Each day the fabric will be folded up and closed around the aggregate to prevent tidal action from washing dirt off of the aggregate. It is expected that some turbidity will be generated through this process. Elevated turbidity levels will occur along the outside of the geotextile fabric from two causes: primarily due to wave action at the base of the structure, and secondarily from fine sediments escaping the geotextile fabric.

This elevated turbidity is expected to be localized, but to develop cumulatively along the face of the pier. Elevated turbidity levels will accumulate fine material and travel along the face of the pier in the direction of the water current. Turbidity plume directional movement and disbursement will be dependent on current flow. The outgoing tidal flows, combined with outgoing river flows, will carry the turbidity approximately 1,500 feet downstream from the end of the gravel pier. The gravel pier is inside a cove, therefore incoming tides will carry along the face of the pier into the back end of the cove. Most turbidity movement will be parallel to the gravel pier and then dispersed out from the pier to settle at the end of the cove. The cove area where elevated turbidity is expected to be observed is approximately 3.8 acres (185 feet wide and 900 feet long). During the incoming tide, the NMFS expects any increase in turbidity to not be detectable beyond this area. Tidal fluctuations and wind will drive the currents and disperse the suspended sediments away from the pier. Elevated turbidity levels will occur over a short time, lasting a few hours immediately after the work area is inundated by the incoming high tide. The elevated turbidity levels will occur over the 2 weeks of in-water work, twice each day in relation to the high tide cycle.

The dike removal process will create elevated turbidity in the immediate vicinity of the work. Although the removal work will occur at low tide, inundation of the work area during the high tide cycle will suspend sediments and create elevated turbidity. The placement of two silt fences will aid in controlling the suspended sediment spread, but not eliminate elevated turbidity. It is expected that the elevated turbidity levels will be observed up to 300 feet from the dike removal area. The elevated turbidity levels will occur over the 5 days of in-water work, twice each day in relation to the high-tide cycle.

**Chemical Contamination.** As with all construction activities, accidental release of fuel, oil, and other contaminants may occur as the presence of construction equipment near sensitive habitats, such as the estuary and wetlands, creates the potential for introduction of toxic materials from accidental spills, improper storage of petrochemicals, or mechanical failure. Operation of back-hoes, excavators, and other equipment requires the use of fuel, lubricants, *etc*., which, if spilled into the channel of a waterbody or into the adjacent riparian zone, can injure or kill aquatic organisms.

Based on experience with construction activities, the probability of a fuel spill, equipment malfunction, or accident is more than negligible. However, this is likely to be a short-term effect. Short-term effects of a spill could be extremely detrimental to aquatic habitat within the action area. Petroleum-based contaminants, such as fuel, oil, and some hydraulic fluids, contain poly-cyclic aromatic hydrocarbons (PAHs) which can be acutely toxic to the aquatic environment for fishes and can also cause lethal and chronic sublethal effects to aquatic organisms (Neff 1985).

Accidental spills may occur, allowing chemicals to reach Coos Bay, resulting in impacted water quality and reduced feeding opportunities for aquatic species within the action area. The large volume of water in the bay, the strong water currents and wind action, and the conservation measures proposed to minimize the amount and distance of a toxicant material spread will result in the dilution of any spill to undetectable levels in a few hours. Potential water contamination from construction activities will be controlled by the implementation of a spill containment plan. However, depending on the timing, weather conditions, and response and clean-up efficiency, adverse impacts may still occur due to the proximity to aquatic habitat.

**Loss of Benthic and Shoreline Habitat.** The fill will permanently destroy 1.23 acres of tidal estuarine habitat in Coos Bay. Habitat typing and mapping identified the area around the airport as: (1) Intertidal with sand and mud flats; (2) undifferentiated aquatic bed; and (3) seagrass aquatic bed. This proposed action will fill 1.23 acres of the total 8,582 acres of these three habitat types in the intertidal zone of Coos Bay. This loss will result in reduced abundance and diversity of prey for species inhabiting the immediate surrounding area of the Coos Bay estuary. The loss of shallow-water and benthic habitat from construction operations will eliminate the physical habitat space and the biotic community living in the 1.23 acres. Macroinvertebrates move, rest, find shelter, and feed on the substrate and organic material, as well as live within the substrate. The proposed project will physically disturb channel bottoms, eliminate the aquatic habitat, eliminate or displace established benthic communities and reduce prey availability in the vicinity of the fill placement.

**Restoration of Estuary Functions.** The applicant proposes to provide approximately 10 acres of estuarine compensatory mitigation at the Mangan mitigation site on Haynes Inlet, in the town of North Bend in Coos County, Oregon. This mitigation area is currently a 35-acre diked freshwater wetland and has been used to graze livestock since the 1940s. The mitigation action will restore portions of the area and provide similar estuarine habitat function to those that will be lost due to the filling of 1.23 acres of intertidal estuarine habitat; the conversion of 1.39 acres of freshwater wetland to intertidal wetland; and the 1.13 acres of freshwater wetland lost from the new dike construction. Approximately 8.6 acres of the total 10-acre intertidal mitigation site will function as a tidal mud flat, supporting mats of green and brown algae and provide support for a mud flat biotic community. Establishing approximately 1.44 acres of salt marsh in the mitigation area will be accomplished by planting plugs of Lyngbye's sedge (*Carex lygbyei*) and seeding of redtop (*Agrostis alba*), which are both salt marsh species. This salt marsh complex provides productive nutrient cycling and forage production in the estuarine ecosystem. Full conversion of this area will likely take several years for the salt tolerant plants to establish and mature. This is also the likely time line for most of the other estuarine biotic community.

**Effects on Species.**

***Fish salvage.*** Project activities will create fish entrapment conditions. This activity is proposed for July, but may occur in August, depending on action approval. During July and August, very few OC coho salmon smolts are expected to inhabit the action area. Adult coho salmon are not expected to be in the action area at that time. Adult southern DPS green sturgeon occurring in the action area are not likely to occur in the areas immediately adjacent to the project where fish salvage will occur, and are not likely to be entrapped or require capture.

Fish salvage is proposed to occur in the taxiway relocation area and in the Mangan mitigation area. In the taxiway C relocation area, proposed activities include constructing a gravel pier to serve as an in-water work enclosure. An area of approximately 1.23 acres will be enclosed and require fish salvage. In the process of isolating the work area, fish entrapment conditions are created and the proposed action includes seining the entrapment area to recover fish. Enclosure of the isolation area will occur at low tide and this should result in fewer trapped fish than if the entire area was enclosed at a higher tide. Some juvenile coho salmon will likely evacuate the areas to be isolated in response to disturbance of the areas and as the tide recedes, but it is reasonably certain that some smolts will be stranded or trapped and will require handling. All captured fish will be released in the open bay. Approximately 0.25 acre of intertidal area will be enclosed with the two silt curtains at the Mangan mitigation site. As stated, few coho salmon smolts are expected to be in the area during the proposed in-water work period. Seining and dip-netting are proposed methods of capture for any fish entrapped within the silt curtain deployment.

The NMFS assumes that any coho salmon smolts salvaged would experience high stress with the possibility of up to a 5% direct or delayed mortality due to injury and stress experienced in the fish salvage process. Although work area isolation is a conservation measure intended to reduce adverse effects from in-water work activities, some OC coho salmon smolts are likely to be subjected to incidental harassment, injury or death.

Based on an average of 4% survival from smolts to returning adults, back-calculated estimates from recent (last 6 years, Table 3) return numbers would suggest 35,000 to 875,000 smolts pass through the action area. It is expected almost all smolts from the Coos River OC coho salmon population will move through the estuary and into the ocean prior to this work area isolation activity (July and August); therefore, only a very small proportion of the number of individuals in the Coos population will be exposed to adverse effects. Based on experience with smolt outmigration timing and the proposed in-water work timing in July and August, the NMFS expects 0.5 % of the total smolts to still be in Coos Bay; therefore 175 to 4,375 smolts could inhabit the bay at the time work area isolation will occur. Of these smolts, few are expected to occur in the action area and the NMFS expects a smaller number to actually be trapped in the isolation areas.

The two isolation areas will have different probabilities of entrapping coho salmon smolts. At the airport site, the NMFS expects 450 smolts (10% of the highest estimate) to be entrapped with up to 23 (approximately 5%) of these dying from stress and injury due harassment from being captured and handled. At the Mangan site, the NMFS expects 219 smolts (5% of the highest estimate) to be entrapped with up to 11 (approximately 5%) of these dying from stress and injury due harassment from being captured and handled.

***Turbidity.*** Elevated turbidity levels will be the result of in-water work. The two regions of the action area will have differing causes and patterns of generating elevated turbidity. Increases in suspended sediment at a concentration of 53.5 milligrams per liter (mg/L) for a 12-hour period caused physiological stress and changes in behavior in coho salmon (Berg 1983). The NMFS expects the OC coho salmon smolts would react quicker with higher concentrations.

At the taxiway relocation area, the initial installation of the gravel pier will result in disturbance of the substrate from installation of the geotextile fabric and then placement of the coarse gravel and the resulting increased suspended sediment will reach concentrations that are likely to cause physiological stress to smolt coho salmon residing in the area. Most work will occur at low tide and the step-wise procedures described in the proposed action are intended to minimize turbidity by covering the unwashed gravel with the geotextile. Some turbidity creation will occur during this process, but NMFS expects the turbidity to be localized. Disturbed substrate at the outside base of the gravel pier will be suspended by wave action created from tidal influence, wind action, and ship wakes. This elevated turbidity will move directionally with the current and wave action.

During the outgoing tide, elevated turbidity levels are expected to be observed up to 1,500 feet from the downstream end of the gravel pier where it will disperse to an undetectable level. At the downstream end of the gravel pier and for the first 300 feet of this 1,500 feet turbidity plume, turbidity concentrations may approach and likely exceed the 53.5 mg/L levels that could cause gill irritation and behavioral response.

During the incoming tide, the highest concentrations will occur along the base of the gravel pier and as the suspended sediment is carried back into the cove, thereby limiting its dispersal. The NMFS expects the elevated turbidity concentrations within the cove will reach levels that are likely to cause gill irritation and behavioral response over approximately 3.8 acres. Turbidity will be highest at the back of the cove and dissipate as the currents flow back outwards

Any coho salmon smolts exposed to these high turbidity levels are likely to display behavioral effects, such as reduced feeding and gill-flaring, in response to pulses of suspended sediment (Berg and Northcote 1985). Gill irritation can result in increased disease exposure resulting in higher mortality rates. OC coho salmon smolts exposed to these elevated concentrations will likely move out of the area, thus forced to seek other suitable habitat. This may make them more vulnerable to predators, although the lower water visibility will assist their avoidance of predators. Adult southern DPS green sturgeon are most likely to inhabit deeper waters where project caused elevated turbidity levels are not expected to reach concentrations that would adversely affect this species.

At the Mangan mitigation site, turbidity generation will occur from the removal of the existing dike. Equipment operation and actual fill removal will occur at low tide intervals, but the work site will be inundated during each high tide event. This inundation will mobilize disturbed and exposed fine sediments during the fill removal process. Deploying two silt screens, set five feet apart, will filter some of the fine sediments. This control measure will maintain some control of the turbidity distribution, but turbidity concentrations are expected to reach gill irritation levels inside the silt screened area and the first 200 feet outside of the last screen. Any OC coho salmon smolts within this area exposed to these high levels will experience gill irritation and make a behavioral avoidance response. These smolts will likely move out to the outer edge of the turbidity line to avoid the irritation. This may make them more vulnerable to predators, although the lower water visibility will assist their avoidance of predators. Adult southern DPS green sturgeon are most likely to inhabit deeper waters where project caused elevated turbidity levels are not expected to reach concentrations that would adversely affect this species.

In July and August, when the turbidity causing project activities will occur, few (175 to 4,375) OC coho salmon smolts will occur in the bay, with even fewer in the action area. Some smolts that are late in leaving the Coos Estuary could be exposed to higher turbidity concentrations, therefore the potential for exposure and subsequent adverse effects that may lead to increased mortality due to vulnerability to predation and disease cannot be discounted. In conclusion, only a very small portion (0.5%) of the total smolts from the Coos River population of OC coho salmon will be exposed to elevated turbidity levels cause by the project. Therefore, it is reasonably certain that these effects are not likely to be significant at the population level.

***Chemical contamination.*** The potential extent of a chemical spill from the proposed project is limited because of work area isolation for construction activities and proposed conservation measures. Additionally, all work is proposed to occur during the late summer when the fewest amount of coho salmon will be present due to their limited use of the estuary at that time. Nonetheless, any exposure to these toxic chemicals could be extremely detrimental to juvenile coho salmon within the action area.

Petroleum-based contaminants, such as fuel, oil, and some hydraulic fluids, contain PAHs which can kill salmonids at high levels of exposure and can also cause lethal and sublethal adverse effects to aquatic organisms (Neff 1985). The action area is a large open bay with sufficient open space for the fish to quickly move from the toxicants. Each compound has its own specific characteristics related to mobility, toxicity, and density, therefore some compounds that may move through the water column more rapidly will expose more fish to toxic chemicals.

Mortality, harm and harassment, including reduced or less aggressive feeding, reduced growth, increased disease susceptibility and reduced survival of OC coho salmon smolts is reasonably certain to occur from chemical contamination from accidental spills, but the extent of this exposure will be limited to the few individuals in the immediate area of the spill. It is expected that the conservation measures employed to contain any spill and the large volume of water of Coos Bay will result in limiting adverse concentrations of these chemicals to 300 feet around the gravel pier. Potential dispersal patterns are expected to those described in the turbidity section. A large fuel spill is unlikely, but would degrade water quality from the spill location up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Based on the few OC coho salmon smolts that potentially could be exposed to the contaminants, only a very small proportion of the Coos River population's total smolts will be exposed to chemical contamination. Therefore it is reasonably certain that these effects are not likely to be significant at the population level.

***Loss of benthic and shoreline habitat.*** Adult, smolt, and juvenile coho salmon from the Coos River population of OC coho salmon will be exposed to the loss of estuarine habitat resulting in impacts to available forage and decreased cover from predators. Juvenile salmonids feed on a range of invertebrates. In winter, aquatic larval forms of organisms dominate the food source (Brown 2002) while the benthic invertebrates most commonly consumed by rearing and migrating coho juvenile salmonids in an estuary are *Corophium salmonis* and *Corophium spinicorne* (amphipods) and adult *Diptera* (Bottom *et al.* 2001). Areas with rooted vegetation provide a greater density of food sources than bare mud (Brown 2002). The fill will permanently destroy approximately 1.23 acres of tidal estuarine habitat in Coos Bay and will result in reduced abundance and diversity of prey for juvenile coho salmon inhabiting the Coos Bay estuary. Habitat typing and mapping identified the area around the airport as intertidal with sand and mud flats; undifferentiated aquatic bed; and seagrass aquatic bed. Aquatic seagrass provides natural cover for coho salmon smolts. Coho salmon smolts will be more vulnerable to predation with the loss of cover.

Increased predation is also likely with the change to a riprapped shoreline that favors some predatory fish species. All Coos River population individuals whose natal streams are upstream of the project site will have some exposure to this component of the proposed action resulting in lost estuarine habitat and reduced forage. With the exception of South Slough and a few other smaller tributaries, the majority of OC coho salmon in this population are from upstream of this action area. Based on estimates from the last 6 years, the estimated number of adult OC coho salmon exposed to the lost habitat is from 1,400 to 35,000 individuals per year. OC coho salmon outmigrant numbers vary significantly depending on the year and the environmental conditions determining the survival rates. Based on an average of 4% survival from smolts to returning adults, back-calculated estimates from these return numbers would suggest 35,000 to 875,000 smolts would be exposed to this lost habitat per year.

Little is known about green sturgeon feeding other than general information. The 2002 status review (Adam *et al.* 2002) described benthic invertebrates, mollusks, and small fish as potential forage for green sturgeon. All of these prey species are likely to inhabit the habitat to be filled. Specific information about southern DPS green sturgeon use of this habitat is not known, but permanently lost habitat will result in some level of reduced forage available for green sturgeon in the airport area.

***Restoration of estuary functions.*** Proposed compensatory mitigation is expected to result in long-term beneficial habitat restoration for OC coho salmon and southern DPS green sturgeon. Full conversion of this area will likely take several years for the salt tolerant plants to establish and mature and the ecological functioning of the area to reach full potential. Forage production, nutrient cycling, water quality maintenance, natural cover through submerged plant growth; and other biotic and abiotic components of the estuarine ecosystem will be improved by re-introducing this diked pasture to tidal flushing. When this tidal flat and salt marsh reach their full ecological potential, the result for OC coho salmon and southern DPS green sturgeon is an increase in forage production, water quality, and coho salmon natural cover. This mitigation site is located in Haynes Inlet, which is approximately 2.7 miles upstream from the taxiway relocation, and in an arm of Coos Bay that is not necessarily directly benefiting all upstream segments of the Coos River coho salmon population. The resulting habitat increase from the mitigation site will provide benefits to the population overall by increasing natural cover and forage production in Haynes Inlet. Fewer individuals of the Coos River population will be exposed to this habitat, but it is likely the increased quantity of habitat will offset the losses from the airport site.

Distribution of green sturgeon in Coos Bay is likely independent of the Coos Bay tributaries. The NMFS assumes any green sturgeon inhabiting Coos Bay that would be impacted by the loss of the intertidal zone at the airport will also be benefitted by the benefits from the Mangan mitigation site due to the overall increase in forage production within this area of the bay.

***Summary of effects to OC coho salmon and southern DPS green sturgeon.*** Project-caused effects on OC coho salmon and southern DPS green sturgeon will reach adverse levels. Direct and indirect effects from project actions will adversely affect OC coho salmon due to fish salvage efforts, turbidity, chemical contamination, and habitat loss. The proposal to complete in-water work between July 1 and August 31 results in fewer OC coho salmon exposed to the activities and serves to minimize, but not eliminate, exposure to direct adverse conditions. Salvage will occur in two separate areas that will have differing probabilities of entrapping coho salmon smolts. A total of 669 OC coho salmon smolts are expected to be harassed and captured during fish salvage operations. Up to 34 of these smolts are expected to die due to injury and stress related factors. Southern DPS green sturgeon occurring in the action area are expected to inhabit the deeper waters of the bay, depending on the time of day, tidal cycle, and activity. Adverse effects from project caused elevated turbidity or chemical contamination are discountable due to green sturgeon spatial distribution. Southern DPS green sturgeon in the area are adult fish residing and feeding in the estuary. It is unlikely and considered discountable that any individuals will be captured during the fish salvage effort. Both OC coho salmon and southern DPS green sturgeon will lose habitat at the airport taxiway expansion resulting in adverse effects to both species due to permanent loss of forage at the airport site. Beneficial actions are proposed to compensate for the loss of forage and ecological functions by re-introducing approximately 10 acres of intertidal habitat to tidal flushing, but a delay of several years before the area reaches full ecological potential is expected.

**Effects on OC Coho Salmon Critical Habitat.** The action area in Coos Bay, which is designated as critical habitat for OC coho salmon, provides habitat to support successful estuarine life history requirements. OC coho salmon adults and smolts use the action area for migration and to make the physiological transition between marine and freshwater environments. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile coho salmon for migration and to make this transition between these two environments. These PCEs include water quality, salinity conditions, natural cover, and forage which support juvenile and adult physiological transitions between fresh- and saltwater. The likely effects of the project on these essential features are described below.

1. Water Quality. Suspended sediment levels will be increased over background due to fine sediment mobilized by construction activities. While the impact on habitat is great enough to adversely affect some OC coho salmon smolts, it will not occur on a large enough spatial or temporal scale to significantly disrupt their normal behavioral patterns. Few smolts will occur in the action area at the time elevated turbidity levels will occur and the elevated turbidity levels will be short-term, lasting a few hours at a time during the two weeks of in-water work. A large fuel spill is unlikely, but would degrade water quality from the spill location up to 300 feet for up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Because these impacts are short term and temporary or are unlikely, the water quality PCE will not be functionally changed.

2. Salinity Conditions. Salinity conditions will be improved within the Haynes Inlet portion of the Coos Bay 5th field due to the Mangan mitigation site development. This area is not accessible to OC coho salmon unless this proposed action occurs. The mitigation site

is located in Haynes Inlet where reintroduction of river flows and tidal currents to approximately 10 acres of previously inaccessible intertidal habitat will provide a complex and varying salinity gradient, which is necessary to aid adult and smolt OC coho salmon making the transition between the marine and freshwater environments.

3. Natural Cover. 1.23 acres of natural cover will be permanently lost due to the filling of intertidal habitat. An additional area (10 acres) will be restored at the Mangan mitigation site. The additional acres of habitat reintroduced to tidal influence is likely a reasonable offset to the acres lost at the airport site.

4. Forage. Food resources will be permanently lost in the 1.23 acres of the airport fill site. Additional forage production will be available in the Mangan mitigation site once the area reaches functioning condition, perhaps in 1 to 2 years. While the impact on habitat is great enough to result in some OC coho salmon smolts being adversely affected, it will not disrupt normal behavior patterns. Because the mitigation site will provide additional benthic habitat in the Coos Bay 5th field watershed, the food resources PCE will not be functionally changed.

***Summary of effects to OC coho salmon critical habitat.*** Information presented in the status and baseline sections of this opinion show that the Coos Bay estuary has been altered, but conditions still support successful migration and transition from freshwater to saltwater environments. Four PCEs will be affected, but will not be functionally changed because effects will be small-scale, short-term, unlikely, or sufficiently offset by the proposed mitigation. Potential short-term effects to the water quality PCE include increased turbidity concentrations and toxic material contamination from PAHs due to spill, equipment failure, or accident. These are expected to be short-term and localized. Salinity conditions will be improved in the action area at the Mangan mitigation site where tidal flow and fluctuation will be reintroduced to 10 acres of intertidal habitat. Forage production and natural cover will be lost from the filling of 1.23 acres and this will be replaced with the 10 acre mitigation site within the same watershed. Since the effects will not adversely change the habitat functions at the site scale, the effects from the proposed project will not adversely change functions at the 5th field watershed scale either.

**Cumulative Effects**

Between 2000 and 2006, the population of Coos County increased by 3.2%.[1] Thus, NMFS assumes that future private and state actions will continue within the action area, increasing as population density rises. As the human population in the action area continues to grow, demand for agricultural, commercial, or residential development is also likely to grow. The effects of new development caused by that demand are likely to reduce the conservation value of the habitat within the action area. However, NMFS is not aware of any specific future non-Federal activities within the action area that would cause greater effects to a listed species or a designated critical habitat than presently occurs.

---

[1] U.S. Census Bureau, State and County Quickfacts, Curry County. Available at: http://quickfacts.census.gov/qfd/

## Conclusion

After reviewing the status of OC coho salmon and designated critical habitat, the environmental baseline for the action area, the effects of the proposed action, and cumulative effects, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of southern DPS green sturgeon or OC coho salmon, and is not likely to destroy or adversely modify OC coho salmon designated critical habitat. These conclusions are based on the following considerations.

The suspended sediment and contaminant spill threats from the proposed action will expose OC coho salmon smolts to adverse water quality conditions that may reduce survival due to increased susceptibility to disease, predation, and physiological response to toxicants. However, only a very small percentage of Coos River coho salmon smolts will still be in the estuary during July and August. These two threats to southern DPS green sturgeon are discountable because of their deep-water habitat use.

The proposed action will result in harassment of up to 669 smolt OC coho salmon due to capture and handling. Effects on abundance and productivity at the population scale will be insignificant because such a small proportion of the total Coos River population's smolt population will be affected (approximately 0.07 to 1.9%, based on 6-year high and low population estimates). No specific future non-Federal activities have been identified within the action area that would cause greater effects to a listed species or a designated critical habitat than presently occurs.

The limiting factor to OC coho salmon that will be affected from this project is the loss of intertidal estuarine habitat including sand and mud flats, undifferentiated aquatic bed, and seagrass aquatic bed. As proposed, 1.23 acres of intertidal habitat will be permanently filled and approximately 10 acres of intertidal habitat will be restored for fish use by relocating a dike. Within these 10 acres of intertidal habitat, the potential exists for all three habitat types to develop after several years of tidal flow exposure. As part of the proposed action, this habitat replacement is expected to offset the habitat loss at the taxiway relocation site; therefore, the proposed action will not result in a net decrease in intertidal habitat. The lag time between the mitigation site reaching its full ecological potential and the immediate habitat loss will cause adverse impacts to OC coho salmon and southern DPS green sturgeon due to loss of available cover for OC coho salmon and reduced forage available to both species.

Four critical habitat PCEs will be affected, but will not be functionally changed because effects will be localized and short-term, beneficial, or replaced by compensatory mitigation in the same watershed. The actions will not adversely affect the estuary habitat functions within the 5$^{th}$ field watershed. The critical habitat would remain functional and retain its current ability for the PCEs to become functionally established.

## Reinitiation of Consultation

Reinitiation of formal consultation is required and shall be requested by the Federal agency or by NMFS where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) If the amount or extent of taking specified in the ITS is exceeded;

(b) if new information reveals effects of the action that may affect listed species or designated critical habitat in a manner or to an extent not previously considered; (c) if the identified action is subsequently modified in a manner that has an effect to the listed species or designated critical habitat that was not considered in the biological opinion; or (d) if a new species is listed or critical habitat is designated that may be affected by the identified action (50 CFR 402.16).

To reinitiate consultation, contact the Oregon State Habitat Office of NMFS and refer to the NMFS Number assigned to this consultation (2008/03298).

**Incidental Take Statement**

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering. Harass is defined by Fish and Wildlife Service as an intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA, provided that such taking is in compliance with the terms and conditions of this ITS.

**Amount or Extent of Take**

The NMFS has not prohibited take of southern DPS green sturgeon. However, the effects of the proposed action will overlap in time and space with the presence of adult and smolt OC coho salmon, and are reasonably likely to result in take of some juveniles. The action area is used as a migration corridor and as an area that both life stages use to acclimate while making the physiological transition between freshwater and saltwater. The action area is defined as the footprint of the existing airport and adjacent bank, substrate, and aquatic areas of the Coos Bay Estuary and Pony Slough. The action area extends 500 feet upstream from the project site and 1,500 feet downstream from the downstream end of the project site in Coos Bay due to potential impacts from turbidity, contaminant dispersion, and habitat loss. The mitigation site includes the immediate footprint of the site and the waters of Haynes Inlet surrounding the site out to a distance of approximately 300 feet. The Coos Bay estuary plays a critical role in the survival and recovery of ESA-listed OC coho salmon by providing refuge, nutrients and conditions in which juvenile and adult salmon change physiologically.

While adults will not be present in the bay during construction and very few smolts are expected, both life-stages will be exposed to the long-term, continuing adverse effects of the project. The action area provides migration and vital estuarine habitat in fair condition. Incidental take caused by the adverse short- and long-term effects will include the following: (1) Death or injury of smolts from work area isolation and fish salvage; (2) increased vulnerability to predation of juvenile coho salmon displaced from the action area during construction, changed habitat characteristics favoring predators, and lost natural cover; (3) death or significant impairment of essential behaviors from increased turbidity and exposure to PAHs; and (4) reduced growth and survival from reduced feeding opportunities due to lost forage production in the area until the mitigation site's ecological potential is reached in 2 years. Outmigrating OC coho salmon smolts from most of the Coos River population use the action area for migration and to acclimate to saltwater conditions. Within this action area, the area that incidental take may occur includes an area 300 feet downstream from the gravel pier construction, approximately 3.8 acres inside the cove adjacent to the gravel pier, and approximately 200 feet outside the silt screen placement surrounding the Mangan mitigation site. Incidental take within that area that meets the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

Some coho salmon smolts will likely evacuate the action area in response to work area isolation activities, but it is reasonably certain that some individuals will be trapped within the work isolation area. These trapped individuals will be stranded during dewatering. Death and injury of captured smolts is reasonably certain to occur. However, only a small number of individuals are likely to be exposed to or displaced by work area isolation due to the July and August implementation. The process of work area isolation for the proposed action is reasonably certain to cause incidental take (capture) of 669 individual OC coho salmon smolts, up to 34 of which may die.

The distribution and abundance of fish that occur within an action area are affected by habitat quality, competition, predation and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, the distribution and abundance of fish within the action area cannot be attributed entirely to habitat conditions, nor can NMFS precisely predict the number of fish that are reasonably certain to be injured or killed if their habitat is modified or degraded by the proposed action.

Here, the best available indicators for the extent of take is the 1.23 acres of intertidal aquatic habitat that is to be permanently modified by the action, and increased turbidity measured within the 3.8 acres of the cove at 300 feet downstream from the end of the gravel pier and 200 feet outside the last silt screen at the Mangan site. These are the best indicators of the likely take pathways associated with this action, are proportional to the anticipated amount of harm and harassment, and are the most practical and feasible indicators to measure.

In the accompanying Opinion, NMFS determined that this level of incidental take is not likely to jeopardize OC coho salmon. The area of intertidal habitat modified, extent of suspended sediment, and the number of juveniles captured or killed by work area isolation (up to 669 smolts captured or 34 smolts killed) are the thresholds for reinitiating consultation. Exceeding any of these limits will trigger the reinitiation provisions of this Opinion.

### Reasonable and Prudent Measures

The following measures are necessary and appropriate to minimize the impact of incidental take of listed species from the proposed action:

The FAA shall:

1. Minimize incidental take from construction by applying permit conditions to avoid or minimize disturbance to aquatic habitats.

2. Avoid or minimize the likelihood of incidental take caused by work area isolation.

3. Avoid or minimize long-term take from the loss of eel grass by planting eel grass in the mitigation area.

4. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this incidental take statement are effective in minimizing incidental take.

### Terms and Conditions

The measures described below are non-discretionary, and must be undertaken by the FAA or, if an applicant is involved, must become binding conditions of any permit or grant issued to the applicant, for the exemption in section 7(o)(2) to apply. The FAA has a continuing duty to regulate the activity covered by this incidental take statement. If the FAA (1) fails to assume and implement the terms and conditions or (2) fails to require an applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, the FAA or applicant must report the progress of the action and its impact on the species to the NMFS as specified in the incidental take statement.

1. To implement reasonable and prudent measure number 1 (construction), the FAA shall ensure that:

    a. <u>Timing of In-water Work</u>. Work below the oridinary high tide will be completed during the period of July 1 through August 31. All in-water work must be completed within these dates unless otherwise approved in writing by NMFS.
    b. <u>Minimum Area.</u> Construction impacts are confined to the minimum area necessary to complete the project.
    c. <u>Cessation of Work</u>. Project operations will cease under high flow conditions that may inundate the project area, except for efforts to avoid or minimize resource damage.

d. Fish Screens. All water intakes used, including pumps used to isolate any in-water work area, will have a fish screen installed, operated and maintained according to NMFS' fish screen criteria.[2]

e. Pollution and Erosion Control Plan. A pollution and erosion control plan will be prepared and carried out to prevent pollution related to construction operations. The plan must be available for inspection upon request by the FAA or NMFS.

   i. Plan contents. The pollution and erosion control plan must contain the pertinent elements listed below, and meet requirements of all applicable laws and regulations.

      1. Practices to prevent erosion and sedimentation associated with access roads, stream crossings, construction sites, haul roads, equipment and material storage sites, fueling operations and staging areas.
      2. A description of any hazardous products or materials that will be used, including procedures for inventory, storage, handling, and monitoring.
      3. A spill containment and control plan with notification procedures, specific clean up and disposal instructions for different products, quick response containment and clean up measures that will be available on the site, proposed methods for disposal of spilled materials, and provisions for employee training on spill containment.
      4. Practices to prevent construction debris from dropping into any stream or waterbody, and to remove any material that does drop with a minimum disturbance to the streambed and water quality.

   ii. Inspection of erosion controls. During construction, all erosion controls must be inspected daily to ensure they are working adequately.[3] If inspection shows that the erosion controls are ineffective, work crews must be mobilized immediately to make repairs, install replacements, or install additional controls as necessary.

   iii. Sediment must be removed from each erosion control once it has reached 1/3 of the exposed height of the control.

f. Pre-construction Activity. Before significant[4] alteration of the project area, the following actions must be completed:

   i. Marking. Flag the boundaries of clearing limits associated with site access and construction to prevent ground disturbance of riparian vegetation, wetlands, and other sensitive features beyond the flagged boundary.

   ii. Emergency erosion controls. Ensure that the following materials for emergency erosion control are on site:

---

2 National Marine Fisheries Service, *Juvenile Fish Screen Criteria* (revised February 16, 1995) and *Addendum: Juvenile Fish Screen Criteria for Pump Intakes* (May 9, 1996) (guidelines and criteria for migrant fish passage facilities, and new pump intakes and existing inadequate pump intake screens) *(http://www.nwr.noaa.gov/1hydrop/hydroweb/ferc.htm).*

3 'Working adequately' means no turbidity plumes are evident during any part of the year.

4 'Significant' means an effect can be meaningfully measured, detected or evaluated.

1. A supply of sediment control materials (*e.g.*, silt fence, straw bales).[5]
2. An oil-absorbing floating boom whenever surface water is present.

g. Heavy Equipment. Use of heavy equipment will be restricted as follows:
   i. Select equipment that will have the least adverse effects on the environment (*e.g.*, minimally-sized, low ground pressure equipment).
   ii. Ensure that only enough supplies and equipment to complete a specific job will be stored on site.
   iii. Complete vehicle cleaning, maintenance, refueling and fuel storage in the vehicle staging area placed 150 feet or more from any stream, waterbody or wetland.
   iv. Inspect all vehicles operated within 150 feet of any stream or wetland daily for fluid leaks before leaving the vehicle staging area. Repair any leaks detected in the vehicle staging area before the vehicle resumes operation. Document inspections in a record that is available for review on request by FAA or NMFS.
   v. Before operations begin, and as often as necessary during operation, steam clean all equipment that will be used below ordinary high water until all visible external oil, grease, mud, and other visible contaminants are removed. Complete all cleaning in the vehicle staging area.

h. Vehicle staging. Vehicle staging, cleaning, maintenance, refueling, and fuel storage must take place in a vehicle staging area placed 150 feet or more from any stream, waterbody or wetland.

i. Stationary power equipment. Stationary power equipment (*e.g.*, generators, cranes) operated within 150 feet of any stream, waterbody or wetland must be diapered to prevent leaks, unless otherwise approved in writing by NMFS.

j. Site Preparation. Native materials will be conserved for site restoration. If possible, native materials must be left where they are found. Materials that are moved, damaged or destroyed must be replaced with a functional equivalent during site restoration.

k. Earthwork. Earthwork (including excavation, filling and compacting) will be completed as quickly as possible.

l. Site Stabilization. Stabilize all disturbed areas, including obliteration of temporary roads, following any break in work unless construction will resume within 4 days.

m. Source of Materials. Boulders, rock, woody materials, and other natural construction materials used must be obtained outside riparian areas.

---

[5] When available, certified weed-free straw or hay bales must be used to prevent introduction of noxious weeds.

2. To implement reasonable and prudent measure number 2 (work area isolation), the FAA shall ensure that:

   a. Fish Salvage. Before, and intermittently during, isolation of in-water work areas, fish trapped in the area must be captured using a hand-net, seine, or other methods as are prudent to minimize risk of injury, then released at a safe release site under the supervision of a qualified fishery biologist.
      i. If an isolated pool is affected by work area isolation the entire pool must be salvaged for fish prior to isolation.
      ii. Handle ESA-listed fish with extreme care, keeping fish in water to the maximum extent possible during seining or hand-netting and transfer procedures to prevent the added stress of out-of-water handling.
      iii. Ensure water quality conditions are adequate in buckets or tanks used to transport fish by providing circulation of clean, cold water, using aerators to provide dissolved oxygen, and minimizing holding times.
      iv. Release fish into a safe release site as quickly as possible, and as near as possible to capture sites.
      v. Do not transfer ESA-listed fish to anyone except NMFS personnel, unless otherwise approved in writing by NMFS.
      vi. Obtain all other Federal, state, and local permits necessary to conduct the capture and release activity.
   b. Salvage Notice. The following notice is included as a permit condition and shall be provided to the applicant and the contractor and posted at the work site:

      NOTICE: If a sick, injured or dead specimen of a threatened or endangered species is found in the project area, the finder must notify NMFS through the contact person identified in the transmittal letter for this Opinion, or through the NMFS Office of Law Enforcement at 1-800-853-1964, and follow any instructions. If the proposed action may worsen the fish's condition before NMFS can be contacted, the finder should attempt to move the fish to a suitable location near the capture site while keeping the fish in the water and reducing its stress as much as possible. Do not disturb the fish after it has been moved. If the fish is dead, or dies while being captured or moved, report the following information: (1) NMFS consultation number; (2) the date, time, and location of discovery; (3) a brief description of circumstances and any information that may show the cause of death; and (4) photographs of the fish and where it was found. The NMFS also suggests that the finder coordinate with local biologists to recover any tags or other relevant research information. If the specimen is not needed by local biologists for tag recovery or by NMFS for analysis, the specimen should be returned to the water in which it was found, or otherwise discarded.

3. To implement reasonable and prudent measure number 3 (eel grass planting), the FAA shall ensure that:

    a. Identify areas within the Mangan mitigation site that are suitable for eel grass production.
    b. Plant eel grass in the identified suitable habitat.

4. To implement reasonable and prudent measure number 4 (monitoring and reporting) the FAA shall:

    a. Turbidity Monitoring. Complete turbidity monitoring as follows.
        i. Equipment. Use an appropriate and regularly calibrated turbidometer to quantify change as nephelometic turbidity units (NTU), or use a visual observation based on any detectable change.
        ii. Interval. A turbidometer reading, or visual observation, must be taken as often as necessary to ensure that each work area is not contributing excessive sediment to the stream.
            1. Whenever in-water work is in progress, or when precipitation has occurred within seven days, a sample must be taken at least twice each day, at approximately 10:00 a.m. and again at 2:00 p.m.
            2. When in-water work is not in progress and no precipitation has occurred within the previous seven days, a sample may be taken once each day, at approximately 2:00 p.m.
            3. Sites. Each sample consists of a turbidometer reading, or a visual observation, made at a baseline site upstream of each work area, and a corresponding reading or observation made within the 3.8 acres of the cove, within 300 feet downstream from the end of the gravel pier and 200 feet outside the last silt screen at the Mangan site.
        iii. Compliance.
            1. Compare results from the baseline and compliance sites for each sample to determine whether turbidity increased below the work area.
            2. If turbidity increased by 5 NTUs, or to any visible extent, take corrective action to reduce turbidity, including any work necessary to repair, replace or reinforce sediment controls, and continue to monitor every 4 hours.
            3. If the turbidity does not return to baseline level within 24 hours, contact NMFS and cease work until turbidity returns to baseline.
        iv. Reporting. Prepare and submit a summary of the turbidity monitoring, including a photograph of the baseline and compliance sites; a copy of turbidity measurements or observations with the date and time that each was taken; other relevant sampling conditions; and description of any sediment control failure, sediment release, and correction efforts.
    b. Implementation Monitoring Report. Complete implementation monitoring and submit a monitoring report to NMFS describing the FAA' progress and success in

meeting the terms and conditions contained in this Opinion by March 1 of the year following construction. The content of the monitoring report will include:

- i. Project name
- ii. Project location by 6th field HUC
- iii. FAA contact person(s)
- iv. Starting and ending dates for work completed
- v. Photos, within construction areas, of the riparian vegetation and the stream channel before, during, and after project completion.
  1. Include general views and close-ups showing details of the project and project area, including pre- and post-construction.
  2. Label each photo with date, time, project name, and a comment about the subject.
- vi. Other data as follows:
  1. A summary of pollution and erosion control inspection results, including a description of any erosion control failure, contaminant release, and efforts to correct such incidences.
  2. Dates work ceased due to high flows.
  3. Status of compliance with NMFS' fish screen criteria.
  4. Isolation of in-water work area and fish capture and release.
     - a. Supervisory fish biologist – name and contact information.
     - b. Methods of work area isolation and take minimization.
     - c. Habitat conditions before, during and within 1 week after completion of work area isolation.
     - d. Means of fish capture.
     - e. Number of OC coho salmon captured.
     - f. Location and condition of OC coho salmon released.
     - g. Any incidence of observed injury or mortality.

c. Site Restoration.

- i. Post-construction report showing as-built conditions, including photo points, construction and any variation from the approved plan, to be submitted within 60 days of the completion of construction.
- ii. Final area reintroduced to tidal flow at the Mangan mitigation site.
- iii. Final linear distance breached in the dike.
- iv. Planting composition and density.
- v. Copy of the legal agreement conveying mitigation site responsibilities.

d. Extent of Take. At project completion, report the total acres of intertidal habitat filled, the total acres of estuary restored, all turbidity measurements and the results of fish salvage operations.

e. Reporting. On an annual basis for 5 years after completing the proposed action, the FAA shall ensure submittal of a monitoring report to NMFS describing the applicant's success in meeting their habitat restoration goals of intertidal habitat restoration. This report will include the following information:

i. Project identification.

- (1). Project name.
- (2) Starting and ending dates of work completed for this project.
- (3) The FAA contact person.

ii. Intertidal and freshwater habitat development at the Mangan site. Documentation of the following conditions:

(1) Any changes in survival and coverage of the willow plantings.
(2) A plan to inspect and, if necessary, replace failed plantings.
(3) Intertidal habitat rehabilitation will be documented by mapping habitats established for 5 years.
(4) Monitoring report of survival and spread of Lyngbye's sedge and redtop.
(5) Report the identified potential eel grass habitat in #ii(3) and monitoring survival and spread of eel grass.
(6) Benthic invertebrate monitoring to document colonization of the mitigation area with marine/estuarine species.
(7) Tidal influence area achieved based on the highest measured tide.

iii. A plan to inspect and, if necessary, replace failed plantings to achieve 100% survival at the end of the first year, and 80% survival or 80% coverage after 5 years (including both plantings and natural recruitment) of native species in the salt marsh area; control invasive non-native vegetation; and protect plantings from wildlife damage and other harm.

f. Monitoring reports shall be submitted to:

Oregon State Habitat Office
National Marine Fisheries Service
Attn: 2008/03298
1201 NE Lloyd Blvd., Ste. 1100
Portland, OR 97232-2182

## MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions, or proposed actions that may adversely affect EFH. Adverse effects include the direct or indirect physical, chemical or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that may be taken by the action agency to conserve EFH.

The Pacific Fishery Management Council (PFMC) designated EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon, coho salmon, and Puget Sound pink salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999).

Based on information provided in the BA and the analysis of effects presented in the ESA portion of this document, NMFS concludes that proposed action will have the following adverse effects on EFH designated for groundfish, coastal pelagic species, and Chinook salmon and coho salmon:

1. Water Quality. Suspended sediment levels will be increased over background due to fine sediment mobilized by construction activities. While the impact on habitat is great enough to adversely affect some MSA-managed species, it will not occur on a large enough spatial or temporal scale to significantly disrupt their normal behavioral patterns. The elevated turbidity levels will be short-term, lasting a few hours at a time during the 2 weeks of in-water work. A large fuel spill is unlikely, but would degrade water quality from the spill location up to 300 feet for up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Because these impacts are short term and temporary or are unlikely, the water quality of the action area will not be functionally changed.

2. Salinity Conditions. Salinity conditions will be improved within the Haynes Inlet portion of the Coos Bay 5th field due to the Mangan mitigation site development. This area is not accessible to MSA-managed species unless this proposed action occurs. The mitigation site is located in Haynes Inlet where reintroduction of river flows and tidal currents to approximately 10 acres of previously inaccessible intertidal habitat will provide a complex and varying salinity gradient, which is necessary to aid adult and smolt salmon making the transition between the marine and freshwater environments. Other MSA-managed species will have access to this intertidal habitat.

3. Natural Cover. An unknown area of eelgrass beds, which is natural cover for MSA-managed species, will be permanently lost due to the filling of intertidal habitat. This could be up to 1.23 acres of natural cover. An additional area, possibly up to 10 acres, will be developed at the Mangan mitigation site. Although neither maximum is likely, the additional acres of habitat reintroduced to tidal influence is likely a reasonable offset to the acres lost at the airport site.

4. Forage. Food resources will be permanently lost in the 1.23 acres of airport relocation fill site. Additional forage production will be available in the Mangan mitigation site once the area reaches functioning condition, perhaps in 1 to 2 years. While the impact on habitat is great enough to result in some MSA-managed species being adversely affected, it will not disrupt normal behavior patterns. Because the mitigation site will provide additional benthic habitat in the Coos Bay 5th field watershed, the food resources for MSA-managed species will not be functionally changed.

**EFH Conservation Recommendations**

The following two conservation measures are necessary to avoid, mitigate or offset the impact of the proposed action on EFH. These conservation recommendations are a subset of the ESA terms and conditions.

1. Minimize adverse effects from construction by applying permit conditions to avoid or minimize disturbance to aquatic habitats as described in Term and Condition 1 in the accompanying Opinion.
2. Ensure completion of a monitoring and reporting program as described in Term and Condition 3, except for 3.b.vi.4 (isolation of in-water work area and fish capture and release), in the accompanying Opinion to confirm the action is meeting its objective of minimizing habitat modification from permitted activities. Recommended EFH monitoring and reporting components are pollution and erosion control, final area of intertidal habitat filled; area of intertidal habitat reintroduced to tidal influence, success of plant establishment, and species composition and abundance of invertebrates in the intertidal mitigation site.

**Statutory Response Requirement**

Federal agencies are required to provide a detailed written response to NMFS' EFH conservation recommendations within 30 days of receipt of these recommendations [50 CFR 600.920(j) (1)]. The response must include a description of measures proposed to avoid, mitigate or offset the adverse affects of the activity on EFH. If the response is inconsistent with the EFH conservation recommendations, the response must explain the reasons for not following the recommendations. The reasons must include the scientific justification for any disagreements over the anticipated effects of the proposed action and the measures needed to avoid, minimize, mitigate or offset such effects.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, in your statutory reply to the EFH portion of this consultation, we ask that you clearly identify the number of conservation recommendations accepted.

**Supplemental Consultation**

The FAA must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations [50 CFR 600.920(k)].

## DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity and objectivity. This section of the Opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this EFH consultation has undergone pre-dissemination review.

**Utility:** Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable and beneficial to the intended users.

This consultation concludes that the Coos Bay airport expansion will adversely affect EFH, and includes conservation recommendations to the action agency to avoid, minimize or otherwise offset those adverse modifications. The FAA may authorize and fund this action in accordance with its authority to oversee aviation guidelines. The intended users are the FAA and the Southwest Oregon Regional Airport.

Individual copies were provided to the above-listed entities. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

**Integrity:** This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

**Objectivity:**

***Information Product Category:*** Natural Resource Plan.

***Standards:*** This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq.*, and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

***Best Available Information:*** This consultation and supporting documents use the best available information, as referenced in the Literature Cited section. The analyses in this Opinion/EFH consultation contain more background on information sources and quality.

***Referencing:*** All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

***Review Process:*** This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

## LITERATURE CITED


Adams, P.B., C.B. Grimes, S.T. Lindley, and M.L. Moser. 2002. Status Review for North American Green Sturgeon, *Acipenser medirostris*. National Marine Fisheries Service. Santa Cruz, CA. June 2002.

BRT (Biological Review Team). 2005. Green Sturgeon (*Acipenser medirostris*) Status Review Update. Santa Cruz, CA. December 2004.

Beamis, W.E. and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. *Environmental Biology of Fishes* 48:167-183.

Berg, L. 1983. Effects of short-term exposure to suspended sediments on the behavior of juvenile coho salmon. Master's Thesis. University of British Columbia, Vancouver, B.C. Canada.

Berg, L. and T.G. Northcote. 1985. Changes In Territorial, Gill-Flaring, and Feeding Behavior in Juvenile Coho Salmon (*Oncorhynchus kisutch*) Following Short-Term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Bottom, D.L., C.A. Simenstad, A.M. Baptista, D.A. Jay, J. Burke, K.K. Jones, E. Casillas and M.H. Schiewe. 2001. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. January 2001.

Brown, T.G. 2002. Floodplains, flooding, and salmon rearing habitats in British Columbia: A review. Canadian Science Advisory Secretariat Research Document 2002/007. 155 p.

CDFG (California Department of Fish and Game). 2002. California Department of Fish and Game comments to NMFS regarding green sturgeon listing.

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

Hogarth, W.T. 2005. Memorandum from William T. Hogarth, to Regional Administrators, Office of Protected Resources, NMFS, Regarding Application of the "Destruction or Adverse Modification" Standard Under Section 7(a)(2) of the Endangered Species Act, 3p. November 7.

Israel, J.A. and B. May. 2006. Mixed stock analysis of green sturgeon from Washington State coastal aggregations. Final Report. Genomic Variation Laboratory Department of Animal Science, University of California at Davis.

Lawson, P.W., E. Bjorkstedt, M. Chilcote, C. Huntington, J. Mills, K. Moore, T. Nickelson, G.H. Reeves, H.A. Stout and T.C. Wainwright. 2007. Identification of historical populations of coho salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit. U. S. Department of Commerce, Technical Report of the Oregon Coast Workgroup, Oregon and Northern California Coasts. Technical Recovery Team, NOAA-NMFS-NWFSC.

McElhany, P., M. Ruckleshaus, M.J. Ford, T. Wainwright and E. Bjorkstedt. 2000. Viable Salmon Populations and the Recovery of Evolutionarily Significant Units. U. S. Department of Commerce, National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memorandum NMFS-NWFSC-42. 156 p.

McLain, J. December 18, 2006. Memorandum: The likely distribution of the Southern Distinct Population Segment of North American green sturgeon in SWR waters. National Marine Fisheries Service, Sacramento CA.

Moser, M. and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/sl0641-006-9028-1.

NMFS (National Marine Fisheries Service). 1999. The Habitat Approach. Implementation of Section 7 of the Endangered Species Act for Actions Affecting the Habitat of Pacific Anadromous Salmonids. Northwest Region, Habitat Conservation and Protected Resources Divisions, Portland, Oregon (August 26).

NMFS (National Marine Fisheries Service). 2007. Pacific coastal salmon recovery fund, fiscal year 2000-2006.

NMFS (National Marine Fisheries Service). 2008. Species of Concern - Green Sturgeon (*Acipenser medirostris*) Northern DPS.

Neff, J.M. 1985. Polycyclic aromatic hydrocarbons. *In*: Fundamentals of aquatic toxicology, G.M. Rand and S.R. Petrocelli, p. 416-454. Hemisphere Publishing, Washington, D.C.

PFMC (Pacific Fishery Management Council). 1998. The coastal pelagic species fishery management plan: Amendment 8. Portland, Oregon.

PFMC (Pacific Fishery Management Council). 1999. Amendment 14 to the Pacific Coast Salmon Plan. Appendix A: Description and Identification of Essential Fish Habitat, Adverse Impacts and Recommended Conservation Measures for Salmon. Pacific Fishery Management Council, Portland, Oregon (March).

PFMC (Pacific Fishery Management Council). 2000. 2000 Review of Amendment 13 to the Pacific Coast Salmon Plan. Pacific Fishery Management Council, Portland, Oregon (October).

PFMC (Pacific Fishery Management Council). 2005. Amendment 19 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon (November).

Proctor, C.M., C. Garcia, D.V. Galvin, G.B. Lewis and L.C. Loehr. 1980. An ecological characterization of the Pacific Northwest coastal region. U.S. Fish and Wildlife Service. FWS/OBS-79/15.

Schultz, S.T. 1990. The northwest coast: A natural history. Timber Press, Inc. Portland, Oregon.

Wainwright T.C., M.C. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout and L.A. Weitkamp. 2007. Biological recovery criteria for the Oregon coast coho salmon evolutionarily significant unit, public review draft.

NOAA Technical Memorandum NMFS-NWFSC-105

# Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

March 2010

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service

**NOAA Technical Memorandum**
**NMFS-NWFSC Series**

The Northwest Fisheries Science Center of the National Marine Fisheries Service, NOAA, uses the NOAA Technical Memorandum NMFS-NWFSC series to issue scientific and technical publications. Manuscripts have been peer reviewed and edited. Documents published in this series may be cited in the scientific and technical literature.

The NMFS-NWFSC Technical Memorandum series of the Northwest Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest & Alaska Fisheries Science Center, which has since been split into the Northwest Fisheries Science Center and the Alaska Fisheries Science Center. The NMFS-AFSC Technical Memorandum series is now being used by the Alaska Fisheries Science Center.



**This document should be referenced as follows:**

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 p.

NOAA Technical Memorandum NMFS-NWFSC-105

# Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

Richard G. Gustafson, Michael J. Ford,
David Teel*, and Jonathan S. Drake

Northwest Fisheries Science Center
Conservation Biology Division
2725 Montlake Boulevard East
Seattle, Washington 98112

* Northwest Fisheries Science Center
Conservation Biology Division
Manchester Research Station
7305 East Beach Drive
Port Orchard, Washington 98366

March 2010

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service

**Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov)**

Copies are also available from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone orders (1-800-553-6847)
e-mail orders (orders@ntis.fedworld.gov)

# Table of Contents

# List of Figures

# List of Tables

# Executive Summary

On 27 November 2007, the National Marine Fisheries Service (NMFS) received a petition seeking to list southern eulachon (*Thaleichthys pacificus*), as a threatened or endangered species under the Endangered Species Act (ESA) of 1973. NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated an updated status review of eulachon in Washington, Oregon, and California.

The Eulachon Biological Review Team (BRT)—consisting of scientists from the Northwest Fisheries Science Center, Alaska Fisheries Science Center, Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted from state agencies and other interested parties were also considered. The BRT also reviewed additional information submitted to the ESA Administrative Record.

The BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.
2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is: at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or

chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.

5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the species to which it belongs and significant to the species to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

After consideration of the all available scientific data, the eulachon BRT has determined that the petitioned unit of eulachon that spawn in rivers in Washington, Oregon, and California is not a species under the ESA, as it does not meet all the biological criteria to be considered a DPS as defined by the joint USFWS-NMFS 1996 policy on vertebrate populations. However, the BRT has determined that eulachon spawning in Washington, Oregon, and California rivers are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT found it difficult to establish a clear northern terrestrial or river boundary for this DPS in light of the fact that the BRT believes the northern boundary is essentially determined by oceanographic processes. However, it was the majority opinion of the BRT that the northern boundary of the DPS is south of the Nass River on the north coast of British Columbia. The BRT proposes that this DPS be termed the southern DPS of eulachon. The BRT also concluded that the eulachon spawning in the Nass River and further north consist of at least one additional (northern) DPS.

The BRT qualitatively ranked threats to the southern DPS of eulachon subpopulations that spawn in the Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. In each case, the BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon. Climate change impacts on freshwater habitat and eulachon bycatch were scored as moderate to high risk in all subareas of the DPS, and dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers were also ranked within the top four threats in their respective regions.

The BRT was concerned that although eulachon are a relatively poorly monitored species, the weight of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. Considering this large decline, in addition to other risk factors, the BRT determined that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range.

# Acknowledgments

The status review of eulachon (*Thaleichthys pacificus*) was conducted by a team of scientists. NMFS gratefully acknowledges the commitment and efforts of the Eulachon Biological Review Team (BRT) members and thanks them for generously contributing their time and expertise to the development of this status review.

The Eulachon BRT relied on comments and informational reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), California Department of Fish and Game, and Department of Fisheries and Oceans Canada (DFO).

Numerous individual fishery scientists and managers provided information that aided in preparation of this document and deserve special thanks. We particularly thank Dr. Doug Hay, Nearshore Consulting, Nanaimo, British Columbia (Scientist Emeritus, Pacific Biological Station, DFO); Brad James, WDFW; Olaf Langness, WDFW; and Tom Rien, ODFW; for information, data, opinions, and advice.

We also thank Megan Moody, Nuxalk Nation, Bella Coola, British Columbia; Andy Lecuyer, Environmental Advisor, Rio Tinto Alcan Inc., Kemano, British Columbia; Michael R. Gordon, M. R. Gordon & Associates Ltd., North Vancouver, British Columbia; and Irene Martin, Skamokawa, Washington, for providing documents or steering us toward those who could.

We also thank five anonymous scientists whose peer review of an earlier version of this document provided added clarity.

# Introduction: Summary of Information Presented by the Petitioner

In 1999 the National Marine Fisheries Service (NMFS) received a petition (Wright 1999) to list eulachon (*Thaleichthys pacificus*) in the Columbia River and its tributaries as a threatened or endangered species under the U.S. Endangered Species Act (ESA) of 1973. NMFS determined that the 1999 eulachon petition failed to present substantial scientific and commercial information indicating that the petitioned action may be warranted (NMFS 1999).

On 27 November 2007, NMFS received a new petition seeking to list eulachon in Washington, Oregon, and California as a threatened or endangered species under the ESA (Cowlitz Indian Tribe 2007). NMFS evaluated the petition to determine whether the petitioner provided substantial information to list a species as required by the ESA. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated a status review of eulachon in Washington, Oregon, and California (NMFS 2008).

A Eulachon Biological Review Team (BRT)[1]—consisting of scientists from the Northwest Fisheries Science Center (NWFSC), Alaska Fisheries Science Center (AFSC), Southwest Fisheries Science Center, U.S. Fish and Wildlife Service (USFWS), and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted to the ESA Administrative Record from state agencies and other interested parties were also considered.

The BRT proceeded on the directives included in the Draft BRT Eulachon Instructions Memo that was received from the NMFS Northwest Region on 19 May 2008. In the memo the BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.

[1] The Eulachon BRT consisted of: Jonathan Drake, Robert Emmett, Kurt Fresh, Richard Gustafson, Mindy Rowse, and David Teel, NWFSC; Matthew Wilson, AFSC; Peter Adams, SWFSC; Elizabeth A. K. Spangler, USFWS; and Robert Spangler, U. S. Forest Service.

2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.
5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

The Eulachon BRT submitted a summary status review document (BRT 2008) to the NMFS Northwest Region in December 2008. In April 2009 we asked a number of scientists with expertise in eulachon biology or viability analysis to review that document (BRT 2008). Substantial scientific comments received from five peer reviewers and our responses to these comments can be found in Appendix E. Numerous changes have been incorporated into the present document in response to suggestions made by the peer reviewers.

## The DPS Question: Evidence for Discreteness and Significance

The petitioner noted that early mitochondrial DNA (mtDNA) genetic information (McLean et al. 1999) suggested that eulachon did not exhibit genetic discreteness and gave little support for subdivision of population structure throughout the species' range. However, other biological data including the number of vertebrae, size-at-maturity, fecundity, river-specific spawning times, and population dynamics indicated that there is substantial local stock structure (Hart and McHugh 1944, Hay and McCarter 2000). The petitioner described these latter observations as consistent with the hypothesis that there is local adaptation and genetic differentiation among populations. Recent microsatellite genetic work (Beacham et al. 2005) appears to confirm the existence of significant differentiation among populations. The petitioner summarized these findings as indicating that although the Fraser River, mainstem Columbia River, and Cowlitz River spawning populations are genetically distinct from each other, they are more closely related to one another than either population is to the more northerly British Columbia populations (Beacham et al. 2005). Although the petitioner felt that the available information is inconclusive, the petitioner noted that eulachon may be composed of several DPSs separated by differences in run timing, spawn timing, meristics, and genetic characteristics.

The petitioner concluded that the available genetic, meristic, and life history information is inconclusive regarding the discreteness of eulachon populations. However, the petitioner argued that under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively discrete from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. The petitioner noted that the United States and Canada differ in their regulatory control of commercial, recreational, and tribal or First Nations eulachon harvest, and also differ in their management of eulachon habitat. The petitioner concluded that there is no assurance that the United States and Canada will coordinate management and regulatory efforts sufficiently to conserve eulachon and their habitat, and thus the DPS should be delineated at the border between Washington and British Columbia.

The petitioner argued that the southern eulachon population segment is significant under the DPS policy because the loss of the discrete population segment would cause a significant gap in the taxon's range. The petitioner stated that eulachon have largely disappeared in rivers throughout the southern portion of their range, and that eulachon in the Columbia River probably represent the southernmost extant population for the species. The petitioner argued that the loss of the Columbia River eulachon population and any dependent coastal spawning populations could represent the loss of the species throughout its range in the United States, as well as the loss of a substantial proportion of its historical range.

## Summary of Abundance and Population Trends

The petitioner stated that although eulachon abundance exhibits considerable year-to-year variability, nearly all spawning runs from California to southeastern Alaska have declined in the past 20 years, especially since the mid-1990s (Hay and McCarter 2000). Historically, the Columbia River has exhibited the largest returns of any spawning population throughout the species' range. The petitioner noted that from 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 1.9 million pounds (lb). From 1993 to 2006, the median catch had declined to approximately 43,000 lb, representing a 97.7% reduction in catch from the prior period. Although there was an increasing trend in Columbia River eulachon catch from 2000 to 2003, recent catches have been extremely low. The petitioner also presented catch per unit effort (CPUE) and larval survey data (JCRMS 2006) for the Columbia River and tributaries in Oregon and Washington that similarly reflect the depressed status of Columbia River eulachon during the 1990s, a relative increase during 2001 to 2003, and a decline back to low levels in recent years.

The petitioner also noted that eulachon returns in the Fraser River showed a similar pattern to those in the Columbia River; a rapid decline in the mid-1990s, increased returns during 2001 to 2003, and a recent decline to low levels. The petitioner stated that egg and larval surveys conducted in the Fraser River since 1995 also demonstrate that, despite the implementation of fishing restrictions in British Columbia, the stock has not recovered from its mid-1990s collapse and remains at a precariously low level. An offshore index of Fraser and

Columbia rivers eulachon biomass, calculated from eulachon bycatch in an annual trawl survey of shrimp biomass off the west coast of Vancouver Island, illustrates highly variable biomass over the time series since 1973, but also reflects stock declines in the mid-1990s and in recent years, according to the petitioner. With respect to eulachon populations further south in the species' range, the petitioner noted that populations in the Klamath River, Mad River, Redwood Creek, and Sacramento River are likely extirpated or nearly so.

## Summary of Risk Factors

The petitioner described a number of threats facing eulachon range-wide and facing populations in U.S. rivers in particular. The petitioner expressed concern that habitat loss and degradation threaten eulachon, particularly in the Columbia River basin. The petitioner argued that hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation.

The petitioner expressed strong concern regarding the siltation of spawning substrates in the Cowlitz River due to altered flow management and the accumulation of fine sediments from the Toutle River. The petitioner believes that efforts to retain and stabilize fine sediments generated by the 1980 eruption of Mount St. Helens are inadequate. The petitioner noted that the release of fine sediments from behind a U.S. Army Corps of Engineers (USACE) sediment retention structure (SRS) on the Toutle River has been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later. The petitioner also expressed concern that dredging activities in the Cowlitz and Columbia rivers during the eulachon spawning run may entrain and kill fish, or otherwise result in decreased spawning success.

The petitioner also noted that eulachon have been shown to carry high levels of chemical pollutants (EPA 2002), and although it has not been demonstrated that high contaminant loads in eulachon result in increased mortality or reduced reproductive success, such effects have been shown in other fish species (Kime 1995). The petitioner concluded that no evidence suggests that disease currently poses a threat to eulachon, but noted that information presented in the 1999 petition (Wright 1999) to list eulachon suggested that predation by pinnipeds may be substantial.

The petitioner expressed concern that depressed eulachon populations are particularly susceptible to overharvest in fisheries where they are targeted or taken as bycatch. The petitioner acknowledged that eulachon harvest has been curtailed significantly in response to population declines, and that were it not for continued low levels of harvest, there would be little or no status information available for some populations. However, the petitioner concluded that existing regulatory mechanisms have proven inadequate in recovering eulachon stocks, and that directed harvest and bycatch may be important factors limiting the recovery of impacted stocks. The petitioner emphasized the need for further fishery-independent monitoring and research.

Finally, the petitioner concluded that global climate change is one of the greatest threats facing eulachon, particularly in the southern portion of its range where ocean warming trends may be the most pronounced. The petitioner felt that the risks facing southerly eulachon populations in Washington, Oregon, and California will be exacerbated by such a deterioration of marine conditions. According to the petitioner, these southerly populations, already exhibiting dramatic declines and impacted by other threats (e.g., habitat loss and degradation), might be at risk of extirpation if unfavorable marine conditions predominate in the future.

# The Species Question

As amended in 1978, the ESA allows listing of DPSs of vertebrates as well as named species and subspecies. Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS (1996) policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the taxon to which it belongs and significant to the taxon to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the [Endangered Species] Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

The interagency policy states that international boundaries within the geographical range of the species may be used to delimit a distinct population segment in the United States. This criterion is applicable if differences in the control of exploitation of the species, the management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment in the United States. However, in past assessments of DPSs of marine fish, NMFS has placed the emphasis on biological information in defining DPSs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological information in identifying whether DPSs of eulachon could be delineated.

# Eulachon Life History and Ecology

## Taxonomy and Species Description

### Scientific Nomenclature

Eulachon are an anadromous smelt in the family Osmeridae and are distinguished from other osmerids by having 4–6 gill rakers on the upper half of the arch (others have 8–14 gill rakers), distinct concentric striae on the operculum and suboperculum (other osmerids lack these concentric striae), and 8–11 pyloric caeca (others have 0–8 pyloric caeca) (McAllister 1963, Hart 1973, Mecklenburg et al. 2002). McAllister (1963) provides a taxonomic synonymy for the species, which was originally described from the Columbia River as *Salmo (Mallotus) pacificus* by Richardson (1836). The genus *Thaleichthys* has only one species and valid subspecies have not been described (McAllister 1963). The binomial species name is derived from Greek roots; *thaleia* meaning rich, *ichthys* meaning fish, and *pacificus* meaning of the Pacific (Hart 1973).

### Common Names

#### Native, Indian, and First Nations languages

The common name officially recognized by the American Fisheries Society (Nelson et al. 2004) for *Thaleichthys pacificus* is eulachon (pronounced you-la-kon in the United States), which is originally derived from the Chinook Indian trade language of the lower Columbia River (Hart and McHugh 1944, Moody 2008). Numerous variations include hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon, oulacon, ulchen, ulichan, uthlecan, yshuh (Hart and McHugh 1944), ooligan, olachen, and olachon (Moody 2008). The Yurok Tribe of the lower Klamath River call eulachon quat-ra (Larson and Belchik 1998) and the Quinault Tribe named the fish páagwáls (Olson 1936). Each First Nations group in British Columbia has a unique name for eulachon (Hay and McCarter 2000, Moody 2008). The First Nations of the lower Fraser River called eulachon swavie or chucka (Hart and McHugh 1944); and the Haisla and Tlingit of Alaska call it juk'wan or za'xwen and ssag or saak, respectively (Krause 1885, Betts 1994, Willson et al. 2006).

#### English

Besides eulachon, *Thaleichthys pacificus* is known by numerous local common English names including candlefish, small fish, savior fish, salvation fish, little fish, fathom fish (because it was sold by the fathom) (Hart and McHugh 1944), and Columbia River smelt.

# Eulachon and Human Cultural History

Eulachon were, and still are, highly important ceremonially, nutritionally, medicinally, and economically to First Nations people in British Columbia and Native American tribes in northern California and the Pacific Northwest. Many ethnographers and historians have stressed the cultural and nutritional importance of eulachon to the Tlingit of Southeast Alaska (Mills 1982, Olson and Hubbard 1984, Krause 1885, Betts 1994), Tsimshians of the north coast of British Columbia (Stewart 1975, Halpin and Seguin 1990, Martindale 2003), Haisla of Douglas Channel and Gardner Canal of British Columbia (Hawthorn et al. 1960, Hamori-Torok 1990), Haihais and Oowekeeno of Rivers Inlet in British Columbia (Hilton 1990), Nuxalk (formerly known as the Bella Coola) of the central coast of British Columbia (Kuhnlein et al. 1982, Kennedy and Bouchard 1990), Kwakwaka'wakw (formerly known as the Kwakiutl) of the north and central coast of British Columbia (Curtis 1915, Rohner 1967, Macnair 1971, Mitchell 1983, Codere 1990), Stó:lō of the Fraser River (Duff 1952), Quinault of the Washington coast (Willoughby 1889, Olson 1936), Chinook and Cowlitz on the lower Columbia River (Boyd and Hajda 1987, Byram and Lewis 2001), and Yurok on the Klamath River (Pilling 1978, Byram and Lewis 2001). In many areas, eulachon returned in the late winter and early spring when other food supplies were scarce and were known, for this reason, as savior or salvation fish (Boyd and Hajda 1987, Byram and Lewis 2001).

Major aboriginal subsistence fisheries for eulachon reportedly occurred on the Stikine, Nass, Skeena, Kitimat, Bella Coola, Kingcome, Klinaklini, Fraser (Macnair 1971, Kuhnlein et al. 1982, Mitchell 1983), and Columbia rivers (Boyd and Hajda 1987). Eulachon were eaten fresh, smoked, dried, and salted, and rendered as oil or grease. Especially to the north of the Fraser River, the fat of the eulachon was rendered into oil, or what is commonly called grease, which is solid at room temperature and was a common traditional year-round condiment with many foods, as well as a medicine for skin rashes and internal ailments among First Nations people on the central and north coasts of British Columbia and in some parts of Alaska (Kuhnlein et al. 1982). Kuhnlein et al. (1982, p. 155) stated that:

> The cultural significance of ooligan grease cannot be underestimated, as it was (and continues to be) a prominent food and gift during feasts and potlatch ceremonies. Early ethnographers among the Nuxalk and Kwakiutl people noted that it was a sign of poverty for a family to be without ooligan grease.

Eulachon grease was widely traded to First Nations such as the Haida and Nootka of Vancouver Island and First Nations in the interior of British Columbia that had no rivers with eulachon runs (Krause 1885, Green 1891, Martindale 2003). Sutherland (2001, p. 8) has stated that "by trading the grease [First Nations people] obtained wealth, prestige, and power." Ancient trade routes up the Nass and Bella Coola river valleys, in particular, and through the mountains, became known as "grease trails" after the traffic in eulachon grease, packed in wooden boxes (Collison 1941, Hart and McHugh 1944, Stewart 1977, Byram and Lewis 2001, Hirch 2003). Numerous sources describe the methods, which varied slightly from area to area, of extracting the oil by boiling the fish bodies (MacFie 1865, Lord 1866, Swan 1881, Krause 1885, Green 1891, Macnair 1971, Stewart 1977).

The largest and most important eulachon fisheries for grease production were on the Nass and Klinaklini rivers of British Columbia (Stacey 1995), although grease was produced by all the First Nations with fishing rights on eulachon rivers north of the Fraser River (Swan 1881, Macnair 1971). As many as 2,000 people annually migrated to the eulachon fishing grounds (Tsawatti) on the Klinaklini River at the head of Knight Inlet (Macnair 1971, Mitchell 1983, Stacey 1995), some traveling from as far as 402 km (250 miles) away by canoe (Codere 1990). The assemblage on the Klinaklini River included nine winter village groups of the Southern Kwakwaka'wakw (formerly known as the Southern Kwakiutl) (Mitchell 1983). A comparable assemblage of five other Southern Kwakwaka'wakw winter village groups and the bulk of the Nimpkish First Nation people from Vancouver Island congregated at Quaee at the head of Kingcome Inlet on the Kingcome River to harvest the spring run of eulachon (Mitchell 1983). Kennedy and Bouchard (1990, p. 325) in an ethnographic summary of the Bella Coola First Nation noted that "Because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola."

# Historical and Current Distribution

### Freshwater Spawning Distribution

Eulachon spawn in the lower portions of certain rivers draining into the northeastern Pacific Ocean ranging from northern California to the southeastern Bering Sea in Bristol Bay, Alaska (Hubbs 1925, Schultz and DeLacy 1935, McAllister 1963, Scott and Crossman 1973, Willson et al. 2006) (Table A-1 in Appendix A, Figures 1 through 3). This distribution coincides closely with the distribution of the coastal temperate rain forest ecosystem on the west coast of North America (Figure 1). Both Willson et al. (2006) and Moody (2008) have recently reviewed the coast-wide spawning distribution of eulachon in North America.

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of fishes in U.S. West Coast estuaries (see Table A-2) and based on the references cited therein described adult eulachon as common in Grays Harbor and Willapa Bay on the Washington coast, abundant in the Columbia River, common in Oregon's Umpqua River, and abundant in the Klamath River in northern California. In addition, a number of estuaries where eulachon were thought to occur in rare relative abundance included Puget Sound and Skagit Bay in Washington; Siuslaw River, Coos Bay, and Rogue River in Oregon; and Humboldt Bay in California (Monaco et al. 1990, Emmett et al. 1991). Hay and McCarter (2000) and Hay (2002) identified 33 eulachon spawning rivers in British Columbia and 14 of these were classified as supporting regular yearly spawning runs. Willson et al. (2006) and Moody (2008) list numerous rivers that support eulachon runs in Southeast and Southcentral Alaska and on the coastline of Alaska in the southeastern Bering Sea (Table A-1). McPhail and Lindsey (1970, p. 198) suggested that eulachon "apparently survived glaciation south of the ice sheet along the Pacific coast of North America" and likely "entered the Bering Sea from the south" following the Wisconsian glaciation.

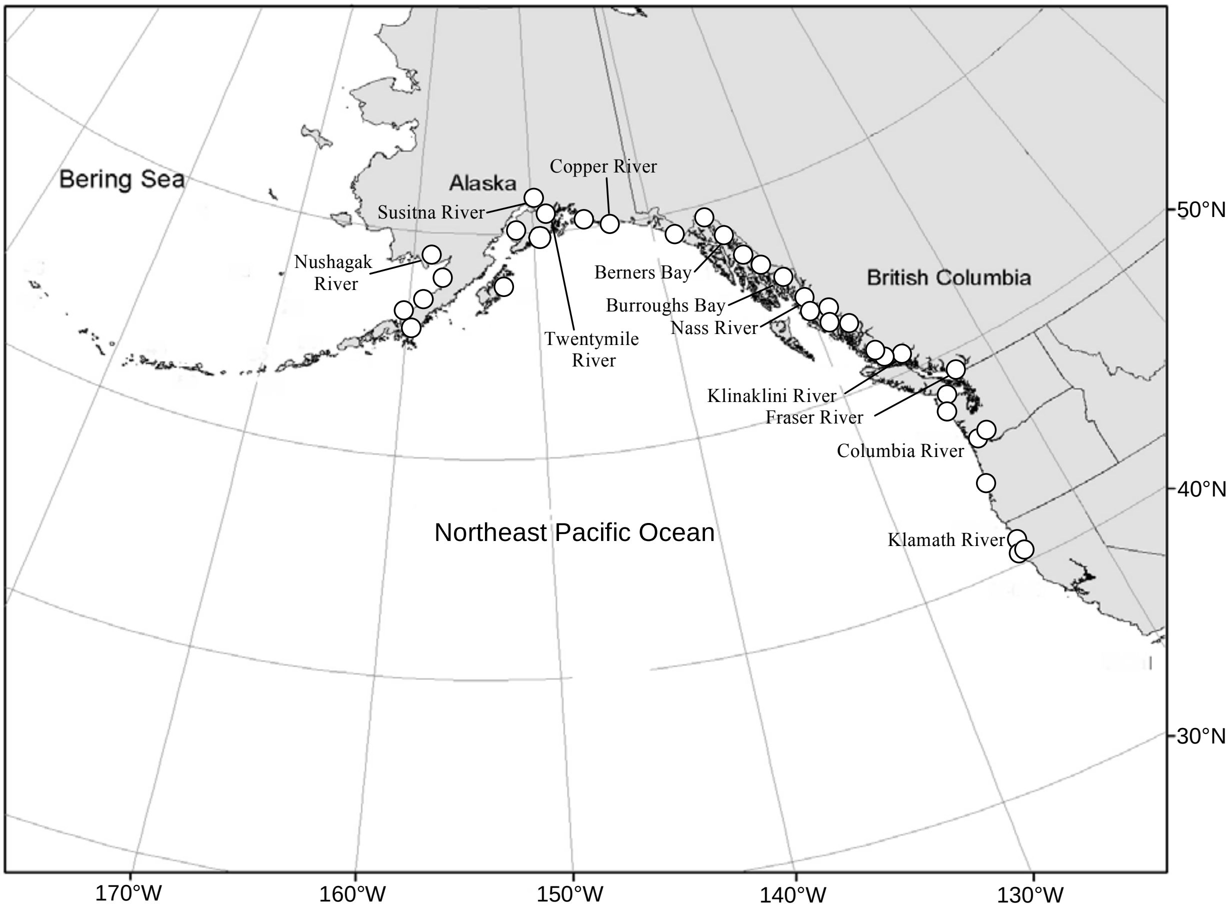



Figure 1. Distribution of eulachon spawning rivers (open circles) in the Northeast Pacific Ocean.

## California

Hubbs (1925) and Schultz and DeLacy (1935), leading ichthyologists of their day, described the Klamath River in northern California as the southern limit of the range of eulachon. Miller and Lea (1972, p. 62) in the California Department of Fish and Game's (CDFG) Guide to the Coastal Marine Fishes of California reported that the eulachon "spawns in rivers from Mad River north." More recent compilations state that large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Ridenhour and Hofstra 1994, Moyle et al. 1995) (Table A-1, Figure 2).

In addition, Moyle et al. (1995) and Moyle (2002) state that small numbers of eulachon have been reported from the Smith River (Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) states that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries. The California

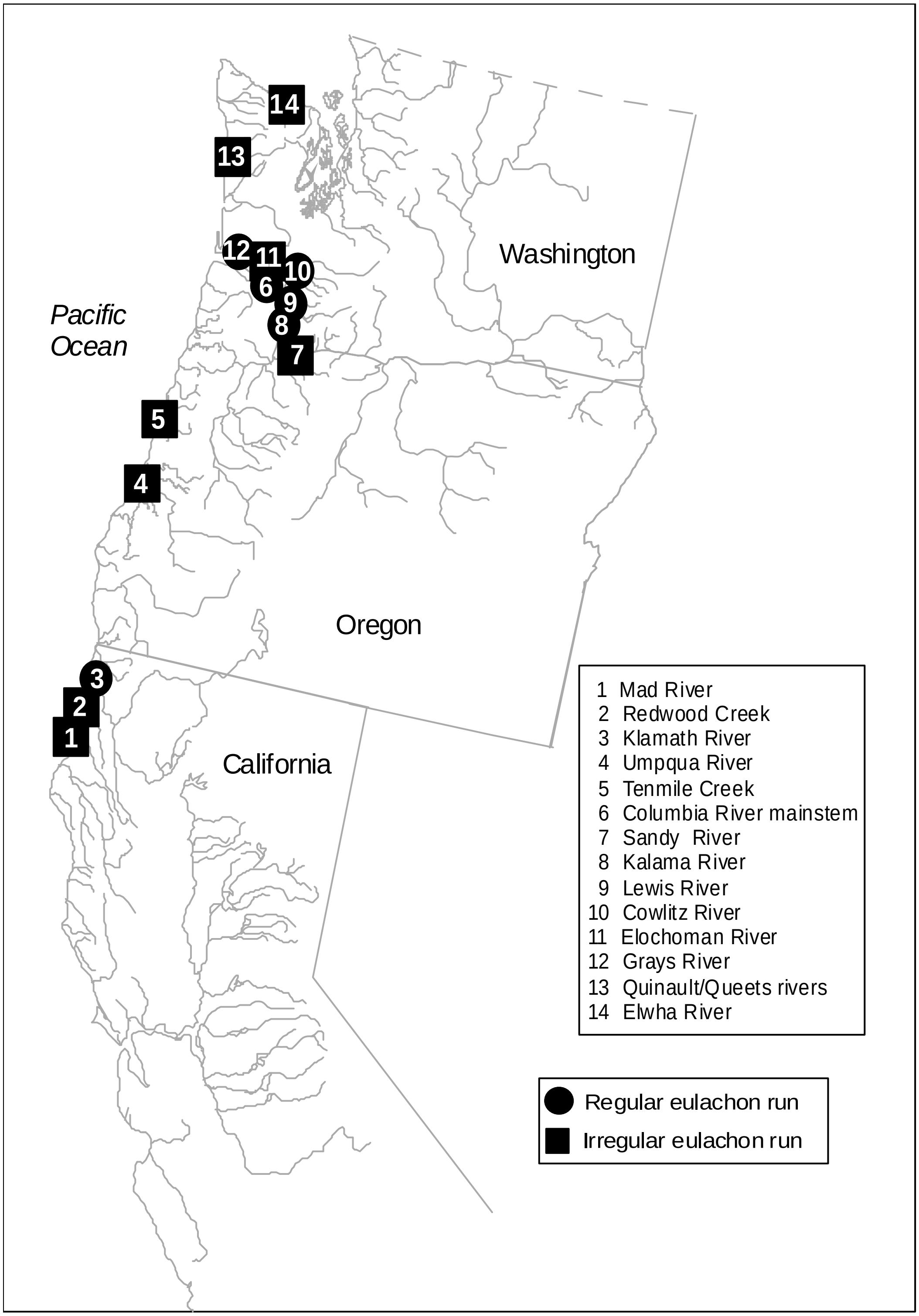



Figure 2. Eulachon spawning areas mentioned in the text in the conterminous United States.

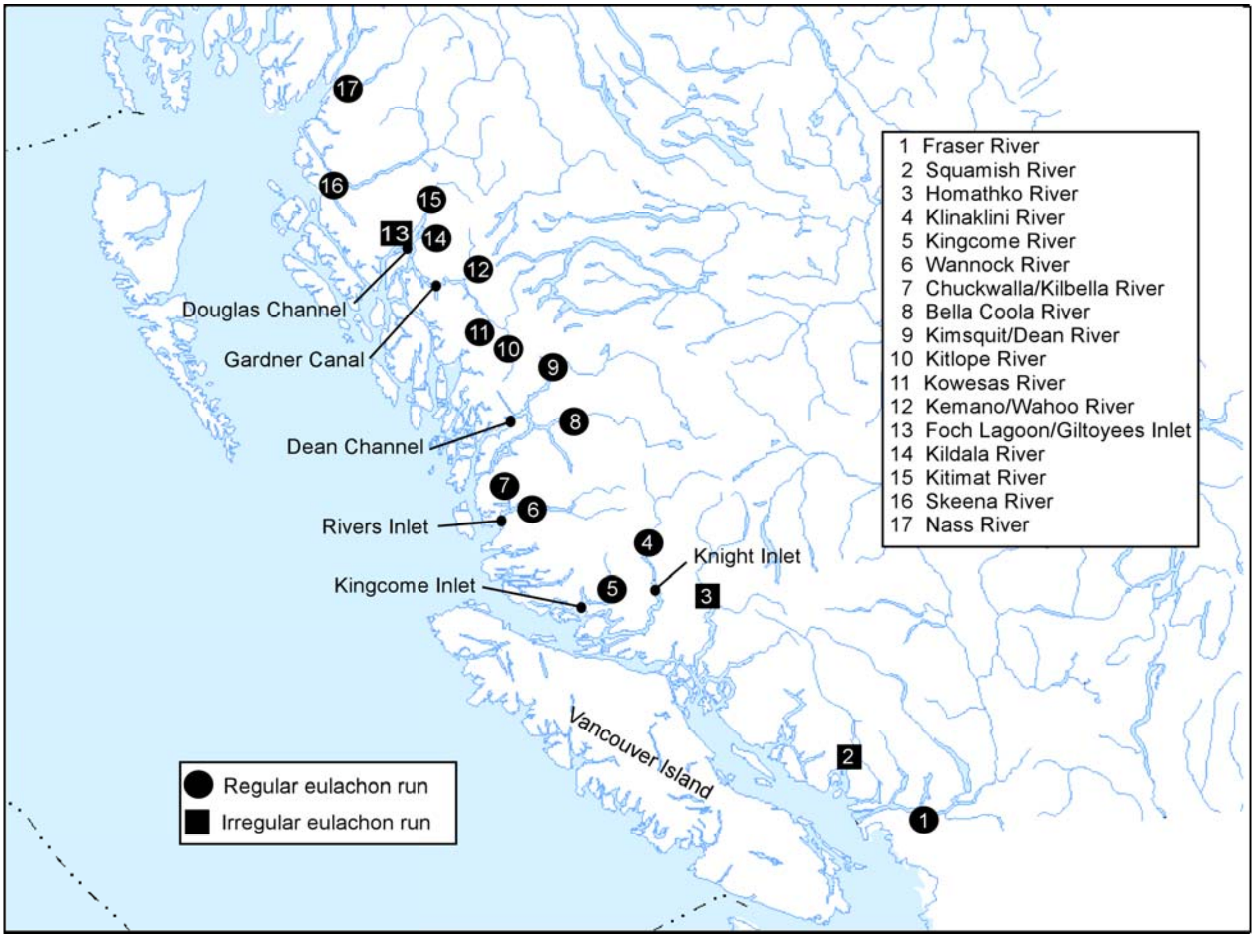



Figure 3. Major known eulachon spawning rivers in British Columbia (based on Hay and McCarter 2000 and Hay 2002).

Academy of Sciences (CAS) ichthyology collection database (online at http://research .calacademy.org/research/Ichthyology/collection/index.asp) lists eulachon specimens collected from the Klamath River in February 1916, March 1947, and March 1963, and in Redwood Creek in February 1955.

A search of available online digital newspaper resources (listed in Table B-1) revealed an early account of eulachon (aka candlefish in northern California) in the Klamath River in a newspaper article in 1879 (Appendix B). Runs large enough to be noted in available local newspaper articles occurred in the Klamath River in February 1919, March 1968, April 1963, and April 1969, in Redwood Creek in April 1963 and April 1967, and in the Mad River in April 1963 (Table A-3 and Appendix B). An early memoir by a traveler surveying timber resources on the Klamath River reported eulachon being harvested (15–20 lb in a single dip net haul) by Yurok tribal members in the early 1890s (Pearsall 1928) (Appendix C). Petersen (2006) reported on interviews with Yurok and Karuk tribal fishers on the lower Klamath River that indicated eulachon were abundant in the river in the 1960s. Petersen (2006, p. 88) stated that "one fisher remembered picking up 75 pounds of fish in one dip" and that another remembered "filling the back of a pickup truck in one hour" with eulachon in 1966.

Young (1984) collected eulachon in Redwood Creek in April 1978 and in the Klamath River in April 1978, March and April of 1979, and 1980. Bowlby (1981) documented eulachon in the diet of California sea lions (*Zalophus californianus*) through gastrointestinal content analysis and in harbor seals (*Phoca vitulina*) through scat analysis and gastrointestinal content analysis in the Klamath River during spring 1978 and 1979. One California sea lion contained 186 eulachon in its gut on 10 April 1978 when the carcass was recovered 1 km upriver from the river mouth, and sea lions "were observed at Klamath Glenn, 9.6 km upriver, while fishermen dipnetted these congregating fish from shore" (Bowlby 1981, p. 59). Eulachon have been reported to spawn at least as far as 40 km upstream on the Klamath River (Fry 1979, Hamilton et al. 2005). Larson and Belchik (1998, p. 5) noted that "In the Klamath, adults generally migrate as high as Pecwan Creek …, have been witnessed as high as Weitchpec …, but specific spawning areas are unknown."

Eulachon have been occasionally reported from other freshwater streams of California. Fry (1979, p. 90) reported that the largest eulachon run in California occurred in the Klamath River, and that eulachon occurred in "fresh water from the Gualala River, California, northward." Although Odemar (1964) has been cited as evidence that eulachon occurred in the Russian River, Odemar (1964) actually stated that "No runs of *T. pacificus* have been reported in the Russian River, or in any river south of the Mad River, and it does not appear that the fish examined off the Russian River in May 1963 were destined to spawn there."

Eulachon were not observed by Eldridge and Bryan (1972) in a larval fish survey of Humboldt Bay, California, and Barnhart et al. (1992, p. 101) stated that eulachon are "not reported in Humboldt Bay tributaries," although they are occasionally recorded in Humboldt Bay itself. Monaco et al. (1990) described eulachon as rare in Humboldt Bay and, in addition to several personal communications, cited Gotshall et al. (1980) and Young (1984) as supporting references (Table A-2). Gotshall et al. (1980, p. 229) recorded eulachon as an "occasional visitor" in winter to Humboldt Bay, California. Young (1984) stated that:

> Specimens [of eulachon] have occasionally been taken, during the spawning season, in Jolly Giant and Jacoby creeks (George Allen, pers. comm., 1980). Both of these streams empty into Humboldt Bay.

Jennings (1996) reported on observations of adult eulachon in creeks tributary to Humboldt Bay, California, in May 1977. A single spawned-out adult male eulachon was collected in a downstream migrant trap on Jolly Giant Creek, approximately 7 km south of Mad River, and a total of seven adult eulachon were observed in another downstream migrant trap in Jacoby Creek, located 8.5 km south of Mad River (Jennings 1996).

Although Minckley et al. (1986, their Table 15.1, p. 541) indicate that eulachon were native to the Sacramento River and drainages within the south California Coastal to Baja California region, no verifying references for these assertions were given. Recently, Vincik and Titus (2007) reported on the capture of a single mature male eulachon in a screw trap at RKM 228 (RM 142) on the Sacramento River.

## Coastal Oregon

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of eulachon in major Oregon estuaries and listed the Rogue River, Coos Bay, Siuslaw River, and Umpqua River as possessing records of eulachon presence. More recently, Willson et al. (2006, p. 36–37) listed the following drainages on the coast of Oregon as supporting eulachon spawning runs (based on Emmett et al. [1991] and personal communications with fish biologists of ODFW): Winchuck, Chetco, Pistol, Rogue, Elk, Sixes, Coquille, Coos, Siuslaw, Umpqua, and Yaquina rivers; and Hunter, Euchre, Tenmile (draining Tenmile Lake), and Tenmile (near Yachats, Oregon) creeks (Table A-1).

Monaco et al. (1990) described eulachon as rare in the Rogue River and, in addition to a personal communication, cited Ratti (1979b) as a supporting reference (Table A-2). Although smelt and surf smelt (*Hypomesus pretiosus*) were reported from the Rogue River estuary by Ratti (1979b), no specific mention of eulachon occurs in this report. Roffe and Mate (1984) reported the presence of otoliths representing at least 120 eulachon from harbor seal scat collected in April 1978 on the Rogue River, which represented 16.7% of the identified harbor seal prey.

Reimers and Baxter (1976) reported that adult eulachon were caught in a downstream migrant trap in the lower portion of the Sixes River in Oregon between 1964 and 1972, although dates of occurrence or numbers caught were not provided. Reimers and Baxter (1976) suggested that these adults had possibly been spawning and were headed downstream at the time of capture.

Gaumer et al. (1973) recorded the taking of 28 eulachon in June 1971 by recreational fishers at the city docks of Bandon, Oregon, in the Coquille River estuary. Kreag (1979) also lists eulachon as occurring in the marine portion of the Coquille River estuary.

Monaco et al. (1990) described eulachon as rare in Coos Bay, Oregon, and, in addition to a personal communication, cited Cummings and Schwartz (1971), Hostick (1975), Roye (1979), and Wagoner et al. (1988) as supporting references (Table A-2). Cummings and Schwartz (1971) included eulachon in their list of fishes occurring in Coos Bay and indicated that eulachon were found up to 11 km (6.8 miles) upstream of the mouth of the bay. Although whitebait smelt (*Allosmerus elongatus)* and surf smelt were reported from Coos Bay by Hostick (1975), no specific mention of eulachon occurs in this report. Roye (1979, p. 36) referenced Cummings and Schwartz (1971) in describing eulachon as occurring in the lower 14.5 km (9 miles) of the Coos Bay estuary. The final version of the draft report, cited by Monaco et al. (1990) as Wagoner et al. (1988), stated that "eulachon may have occurred in large numbers in past years [in the Coos Bay estuary], but they have apparently not been abundant enough in recent years to attract an active dipnet fishery" (Wagoner et al. 1990, p. 100). More recently, Miller and Shanks (2005) surveyed the distribution of 28 identified larval and juvenile fish species in Coos Bay for more than three years between 1998 and 2001, but did not encounter eulachon.

Two reports (Gestring 1991, ODFW 1991) were found that list eulachon as a native fish species occurring in Tenmile and North Tenmile lakes, although no further information on frequency of occurrence or abundance were provided in these reports.

OFC (1970) reported that from 4,000 to 5,000 lb of eulachon were landed by two commercial fishermen in the Umpqua River during 31 days of drift gill net fishing from late December 1966 to mid-March 1967. OFC (1970, p. 34) stated that "The fishing area extended from the Highway 101 bridge at Reedsport upstream about 4 miles." A sport fishery for eulachon also operated over this period in the Umpqua River (OFC 1970). Monaco et al. (1990) described eulachon as common in the Umpqua River estuary and, in addition to a personal communication, cited Mullen (1977), Ratti (1979a), and Johnson et al. (1986) as supporting references (Table A-2). Neither Mullen (1977) nor Ratti (1979a) mention eulachon and Johnson et al. (1986, their Table 1) list eulachon as occurring in trace amounts in their trawl and beach-seine samples from April 1977 to January 1986.

Williams (2009, p. 2) reported that the Oregon Department of Fish and Wildlife (ODFW) has "no direct observations of eulachon spawning in the Umpqua" River, but provided additional information "on eulachon observations and captures during inventories." Williams (2009, p. 2) noted that:

> two random observations of eulachon [were reported] from Little Mill Creek [a tributary of the lower Umpqua River] on December 8, 1954 and January 26, 1955. The fish found in 1954 measured 6 inches in total length.

Williams (2009, p. 3) also reported on the results of seine collections conducted during March to November from 1995 to 2003 in Winchester Bay estuary on the Lower Umpqua River, which documented the

> presence … [of eulachon] in 4 of the last 14 years. Forty-four fish were found in May 1995, 80 fish during April and July 1998, 54 fish during March and May 1999, and 2 fish during June 2003. Seining was also conducted in the lower Smith River estuary [a tributary of the Lower Umpqua] at three sites during 1999 during February and March, but no eulachon were captured.

A search of available online digital newspaper resources (listed in Appendix B) revealed anecdotal evidence that an extensive recreational fishery for eulachon occurred in the lower Umpqua River at least from 1969 to 1982 during January to April. The last reference to eulachon in the Umpqua River in these digital newspaper resources occurred in 1989 (Appendix B).

Monaco et al. (1990) described eulachon as rare in the Siuslaw River estuary and, in addition to a personal communication, cited Hutchinson (1979) as a supporting reference (Table A-2); however, we have been unable to locate a copy of this document.

WDFW and ODFW (2008) describe the occasional occurrence of small numbers of eulachon in Tenmile Creek (not be confused with the Tenmile Lakes Basin), just south of Yachats, Oregon. Between 1992 and 2008, a total of 75 eulachon were caught in traps designed to catch outmigrating salmonid smolts located 0.8 km upstream from the ocean. Eulachon were caught in 1992 (24), 1993 (6), 1994 (1), 1995 (1), 1996 (1), 2001 (26), 2003 (3), 2005 (10), 2007 (1), and 2008 (2). As reported in WDFW and ODFW (2008):

> Eulachon were seen in February (3 years), March (6 years), April (7 years) and May (1 year). The earliest observed arrival was the week of February 3 in 1992.

> The latest observed presence was the week of May 21 in 2001. Fish lengths (annual averages) ranged from 155 to 208 mm FL. Local biologists suspect the eulachon spawn in the creek based on the trapping location, fish size, and that some fish appear to be spawned out.

Although Monaco et al. (1990) describe eulachon as not found in the Yaquina River (based on several personal communications) (Table A-2), Borgerson et al. (1991) list eulachon as occurring in the Yaquina River basin, but do not elaborate further on the evidence for this opinion.

**Columbia River**

Large spawning runs of eulachon occur in the mainstem lower Columbia River and the tributary Cowlitz, Lewis, Sandy (Craig and Hacker 1940), Grays (Smith and Saalfeld 1955), Kalama, and Elochoman (DeLacy and Batts 1963) rivers and Skamokawa Creek (WDFW and ODFW 2001, 2008). Smith and Saalfeld (1955) stated that eulachon were occasionally reported to spawn up to the Hood River on the Oregon side of the Columbia River prior to the construction of Bonneville Dam in the 1930s. In times of great abundance (e.g., 1945, 1953), eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, WDFW and ODFW 2008) and may extend above Bonneville Dam by passing through the ship locks (Smith and Saalfeld 1955). Eulachon likely reached the Klickitat River on the Washington side of the Columbia River in 1945 via this route (Smith and Saalfeld 1955).

On average, the highest incidence of spawning occurs in the Cowlitz River (Smith and Saalfeld 1955, Wydoski and Whitney 2003), although on occasion eulachon may avoid the Cowlitz entirely, due to unfavorable environmental conditions (Wydoski and Whitney 2003). Sporadic spawning runs occur in the Grays, Elochoman, Kalama, Lewis, and Sandy rivers (JCRMS 2007, 2008, 2009). Stockley (1981, p. 1) stated that "occasionally, with very large runs, smelt ascend and enter the Washougal" River on the Washington side of the Columbia River at RKM 195. Stockley and Ellis (1970) suggested that in years of low abundance eulachon may not enter the Columbia River tributaries but remain within the mainstem Columbia River. In 2001 eulachon migrated upstream to Bonneville Dam at RKM 234 and spawned in all the major tributaries of the lower Columbia River, including the Sandy River (Howell et al. 2001). In 1953 eulachon were observed spawning in Tanner Creek on the Oregon side of the Columbia River near the base of Bonneville Dam (OFC 1953, WDFW and ODFW 2008).

Craig and Suomela (1940, p. 11) stated that "smelt are reported to confine their spawning activities to the lower 5 miles of the [Sandy] river" and that "this section is characterized, especially near the mouth, by moderate riffles and an abundance of glacial silt and sand." Anderson (2009) noted that eulachon have been observed on the Sandy River, Oregon, as far upstream as Gordon Creek at RKM 20.9 (RM 13). In addition, ODFW (Williams 2009, p. 1) stated that:

> The Sandy River in Oregon is the only Oregon tributary known to support a run of eulachon. However, it is sporadic and none have been seen in the last 6 to 8 years. … Based on observed sport fishing activity in the Sandy, we believe that spawning took place from the mouth up to RM 2.5.

Williams (2009) also reported on the onetime observation by an ODFW stream surveyor in February 1991 of eulachon in Conyers Creek, a tributary of the Clatskanie River, which is in turn a tributary of the lower Columbia River on the Oregon side of the river. The stream surveyor reported that eulachon were seen holding in pools within the lower 0.8 km (0.5 mile) of Conyers Creek during a daytime flood tide, but none were observed in the main stem of the Clatskanie River.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [Grays River] more frequently than commercial landings would suggest." Furthermore, Anderson (2009, his Table 1, p. 2) stated that the normal extent of eulachon spawning on the Grays River extended to the "covered bridge (RKM 17.4)."

Smith and Saalfeld (1955, p. 22) reported that:

> The lowest suitable spawning ground on the Cowlitz is located just below Kelso and the upper limit of spawning was noted in 1946, when smelt eggs were found in river bottom samples taken upstream almost to the mouth of the Toutle River, 20 river miles [32.2 km] from the Columbia.

In describing the principle spawning reaches of eulachon in the Cowlitz River, WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 16 miles [25.7 km] (Castle Rock/Toutle River mouth area), often up to 34 miles [54.7 km] (Toledo area), and on occasion up to 50 miles [80.5 km] upstream (Cowlitz Salmon Hatchery barrier dam). … Upstream movement during the past 15 years or so has apparently been limited to the Castle Rock/Toutle River mouth area.

Stockley (1981, p. 1) indicated that eulachon "have been known to ascend the Toutle River [tributary of the Cowlitz River] occasionally," particularly before the 1980 eruption of Mount St. Helens (WDFW and ODFW 2008). Anderson (2009, p. 3) stated that:

> Adult eulachon were observed to enter the Toutle River prior to the eruption of Mount St. Helens. … Though the Washington Department of Fish and Wildlife (WDFW) has no reports of eulachon using the Toutle River since the eruption … WDFW considers the Toutle River as potential primary habitat due to its past use and vicinity to primary Cowlitz River spawning grounds.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [the Kalama River] more frequently than commercial landings would suggest." In addition, Anderson (2009, his Table 1, p. 2) said that the normal extent of eulachon spawning on the Kalama River extended "downstream of Modrow Bridge (RKM 4.5)."

Anderson (2009, his Table 1, p. 2) indicated that the normal extent of eulachon spawning on the Lewis River extended to the "upper end of Eagle Island (RKM 18.8)." WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 10 miles [on the Lewis River] but on occasion upstream 19.5 miles [31.4 km] to Ariel [aka Merwin] Dam. … Biologists believed that a natural sediment blockage prevented upstream movement past river mile 7

> [11.3 km] for a number of years, from 1977 until the mid-1980s. Spawning eulachon have since been observed upstream of river mile 7 [11.3 km].

Anderson (2009, p. 2) noted that “eulachon spawn within the main stem of the Columbia River, but spawning ground locations are not well known.” Smith and Saalfeld (1955) reported that spawned out and partially spawned out eulachon captured near Eagle Cliff on the main stem of the Columbia River identified this area as a eulachon spawning ground. Howell et al. (2001, p. 12) also noted that Eagle Cliff at RKM 82 “on the Washington shore [is] historically recognized as a major mainstem eulachon spawning area” and that “spawning in the main stem of the Columbia River has never been recorded upstream of Martin’s Bluff” at RKM 117. Romano et el. (2002) collected eulachon eggs between RKM 56 and RKM 118 on the Washington side of the main stem of the Columbia River; however, mapping the extent of spawning on the main stem will require much additional sampling (Anderson 2009). Anderson (2009, p. 3) noted that:

> In years of very high eulachon abundance, spawning has been observed in the main stem of the Columbia River upstream of RKM 137 as eulachon travel to the Lewis and Sandy rivers and as far as Bonneville Dam on rare occasion. Primary spawning habitat could, therefore, extend from the estuary upstream to at least as far as the Sandy River (RKM 193).

The earliest mention of eulachon in the Columbia River occurs in the journals of members of the Lewis and Clark Expedition during February and March 1806 (Gass 1807, Moulton 1990, Moring 1996) (Appendix C). Throughout the 1810s–1820s, the journals of several fur trappers and explorers (e.g., Gabriel Franchère [Franchère 1967, 1968, 1969], Robert Stuart [Rollins (ed.) 1995], Wilson Price Hunt [Rollins (ed.) 1995], Alexander Henry [Gough (ed.) 1992], and Alexander Ross [Ross 1849]) describe the appearance of large eulachon runs in the lower Columbia River and their importance to the local Native American tribes (Appendix C).

Subsequently, several contemporary references (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963) (Appendix C) indicate a major decline in Columbia River eulachon abundance occurred between the mid to late 1830s and mid to late 1860s. Similarly, several secondary references (Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008, 2009) cite additional sources that indicate eulachon were at low levels of abundance prior to about 1867, when eulachon were once again seen in large numbers. Anderson (1872, footnote on p. 30–31) (Appendix C) stated that eulachon:

> were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence-forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

Subsequently, Anderson (1877, p. 345) (Appendix C) said:

> Formerly resorting in enormous shoals to the estuary of the Columbia River, [eulachon] disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore.

Similarly, Lord (1866, p. 96) (see Appendix C) observed that:

> Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together.

An early settler on the Cowlitz River, Edwin Huntington (Huntington 1963, p. 5) (Appendix C), recalled that:

> Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. … After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife) having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

Summers (1982, p. 31) in a local history of the town of Kelso, Washington, at the confluence of the Cowlitz and Columbia rivers, related that:

> The earliest record of a smelt run was found in a 1867 diary written by W. A. L. McCorkle, a settler at Lexington. He tells of small silvery fish coming into the Cowlitz during that year and that no smelt had been observed by Americans earlier than that. Settlers came beginning 1850. Of course, the Cowlitz Indians and other tribes had caught smelt in the Cowlitz many years before the Americans came.

However, a memoir written by Peter W. Crawford (Crawford 1878, p. 369) indicates that early settlers were aware of "small numbers" of eulachon on the Cowlitz River, and that large runs were noted, after an absence of 17 years, in the spring of 1865. Crawford (1878, p. 369) (Appendix C) stated that:

> In Feby and March 1865 there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. … The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

Hinrichsen (1998, p. 16) reported that "According to historian Duncan Stacey, Hudson's Bay Company documents describe very low returns in the Columbia River from about 1835 to 1865." However, examination of microfilmed records from the Hudson's Bay Company Archives (Fort Vancouver Report 1826–1845 [reel #1M783] and Fort Vancouver Post Journal

1825–1836 [reel # 1M148]) did not reveal any reference to eulachon or smelt in these records. Fort Vancouver was a Hudson's Bay Company post from 1825 to 1860 near the present location of Vancouver, Washington, on the lower Columbia River. Another early reference (Swan 1881, p. 258) mentions that "eulachon are found in limited numbers at certain seasons in the Columbia River."

A search of available online digital newspaper resources (listed in Appendix B) revealed mention of eulachon in the Columbia River or "smelt" as items for sale in local fish markets in the spring of 1867. A two sentence article in the Vancouver Register (Vancouver, Washington Territory) for 6 April 1867 (Appendix B) indicates that large numbers of "smelt" were present in the Columbia River off the city of Vancouver (at about RKM 170) at that time. This newspaper article said that previously "this … fish ... [had] never before been known to come up higher than Lewis River," which indicates that eulachon were known to occur in some numbers prior to 1867 in the Lewis River or in the Columbia River, downstream of the Lewis River.

Two advertisements of "smelt" for sale in Portland, Oregon, fish markets appeared in early newspapers, one in April 1867 and another in April 1868. Since April is near the tail end of the traditional period for eulachon run timing in the Columbia River, and other species of smelt are available at that time, it is uncertain whether these advertisements (Appendix B) refer to eulachon or some other species of smelt. An advertisement of eulachon for sale (referred to as Oak Point smelt) in a local fish market appeared on 15 January 1869 in the Daily Oregonian (Portland) (Appendix B). In later years the eulachon commercial fishery commonly operated in the vicinity of Oak Point on the Lower Columbia River indicating that this advertisement of "Oak Point smelt" likely refers to eulachon and not some other smelt species.

A newspaper article published in the Daily Oregonian on 13 March 1885 (Appendix B) reported that:

> a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years.

**Coastal Washington**

Outside of the Columbia River Basin, eulachon have been occasionally reported from other coastal Washington rivers. Swan (1881, p. 258) noted that "eulachon are found in limited numbers at certain seasons in … Shoalwater bay [Willapa Bay], Gray's Harbor, and at the mouth of various small streams of the coast." WDFW and ODFW (2001) stated that "Washington rivers outside the Columbia Basin where eulachon have been known to spawn include the Bear, Naselle, Nemah, Wynoochee, Quinault, [and] Queets … rivers." Willson et al. (2006) listed Willapa Bay (North, Naselle, Nemah, Bear, and Willapa rivers), Grays Harbor (Humptulips, Chehalis, Aberdeen, and Wynoochee rivers), and the Copalis, Moclips, Quinault, Queets, and Bogachiel rivers as supporting eulachon spawning runs.

Monaco et al. (1990) described eulachon as common in Willapa Bay based on a personal communication (Table A-2). Smith (1941) noted that:

> A small smelt run was noted in the north fork of the Nemah River on 7 February 1941. The fish ascended the Nemah River as far as the mouth of Williams Creek, which stream they entered for a distance of about 100 yards. … An old resident of the community reported that this was the first smelt run that had occurred during his 48 years in the section.

According to WDFHMD (1992), adult eulachon "were found in the Naselle and Bear rivers, tributaries of Willapa Bay (B. Dumbauld, WDF, pers. comm.)" in 1992. WDFW and ODFW (2001, p. 12) reported "that in 1993, when the eulachon run into the Columbia River was delayed (presumably due to cold water conditions), they were noted in large abundance in the Quinault and Wynoochee rivers, outside the Columbia Basin."

Monaco et al. (1990) described eulachon as "common" in Grays Harbor and, in addition to a personal communication, cited Deschamps et al. (1970) as a supporting reference (Table A-2). Deschamps et al. (1970, p. 16) reported the capture of a single adult eulachon in a seine catch in March 1966 and stated that "It is unlikely that the Chehalis system [which drains into Grays Harbor] has a run of any consequence, although strays or feeding fish from other areas probably visit the upper harbor at times." WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the … Wynoochee" River, a tributary of the Chehalis River, in 1993. Simenstad et al. (2001) recorded eulachon as of "rare" occurrence in sloughs of the Chehalis River estuary in 1990 and 1995.

Willoughby (1889) and Olson (1936) record the Quinault Indian Tribe as taking eulachon in the lower Quinault River with dip nets. Olson (1936, p. 36) stated that:

> The people of the lower villages often came down to the river mouth to catch smelt (komólnil) and candlefish (páagwáls). Both were taken in the surf of the beach, though the candlefish often ascend the river for several miles. There was usually a big run every three or four years, when the water was literally filled with fish. The time of the run varied, usually occurring between January and April.

The Washington Department of Fisheries annual report for 1960 (Starlund 1960) and statistical report for 1970 (Ward et al. 1971) listed commercial eulachon landings in the Quinault River in 1936 (36,315 lb [16,507 kg]), 1940 (6,917 lb [3,144 kg]), 1953 (93,387 lb [42,449 kg]), 1958 (34,387 lb [15,630 kg]), 1960 (135 lb [61 kg]), and 1961 (1,051 lb [ 477 kg]). Fiedler (1939, p. 213) also records 36,300 lb (16,500 kg) of eulachon taken by dip net in the coastal district of Washington State in 1936. WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the Quinault" River in 1993. Quotations from unattributed sources were presented in Workman (1997) that described eulachon occurring in and about the Quinault River in January 1936 and February 1993. NWIFC (1998, p. 11) reported that "candlefish, or Columbia River smelt, were caught in significant numbers at the mouth of the Queets River for the second time in 5 years in late January [1998]." A noticeable number of eulachon make an appearance in the Queets, Quinault, and occasionally, the Moclips rivers at 5–6 year intervals and were last observed in the Quinault River in the winter of 2004–2005.[2]

Shaffer et al. (2007) reported on the capture of 58 adult eulachon in the Elwha River on Washington's Olympic Peninsula (Figure 2) between March 18 and June 28, 2005. This was the first formal documentation of eulachon in the Elwha River, although anecdotal observations suggest that eulachon "were a regular, predictable feature in the Elwha until the mid 1970s" (Shaffer et al. 2007, p. 80). Other Olympic Peninsula rivers draining into the Strait of Juan de Fuca have been extensively surveyed over many years for salmonid migrations; however, eulachon have not been observed in any of these other systems (Shaffer et al. 2007).

## Puget Sound

Girard (1858) based his description of a new species *Thaleichthys stevensi* (later synonymized with *Salmo* [*Mallotus*] *pacificus* Richardson, 1836 as *T. pacificus* [Richardson, 1836] [McAllister, 1963]) on a single specimen collected in Puget Sound by George Suckley. The published figure (Girard 1858, his Plate LXXV, his Figure 1 through Figure 4) of this single specimen is detailed enough to be identifiable as a eulachon. Later, Suckley (1860, p. 348–349) in his Report Upon the Fishes Collected on the Survey (text republished in Suckley and Cooper 1860) stated that eulachon were "a very delicious fish, in some years coming in great shoals in the bays in the lower part of Puget Sound, and along the coast near the mouth of Frazer's River." Suckley (1860, p. 348–349) also stated that eulachon were "abundant in Puget Sound" and that "several eulachon in the recent state [dried] were obtained by me from different portions of the lower end of Puget Sound;" however, these specimens were lost when in transit to "Washington city" and their identification cannot be verified. Similarly, Lord (1866, p. 96), in his The Naturalist in Vancouver Island and British Columbia, stated that "the eulachon has also disappeared from Puget's Sound."

Curiously, although these early authorities (Girard 1858, Suckley 1860, Lord 1866) describe Pacific herring (*Clupea pallasii*) and eulachon as occurring in Puget Sound, they make no mention of surf smelt, longfin smelt (*Spirinchus thaleichthys*), or Pacific sand lance (*Ammodytes hexapterus*) in Puget Sound. Swan (1881, p. 258) also stated that eulachon were found "in limited numbers at certain seasons … in the waters of Puget Sound" and they are "found on Puget Sound occasionally with the sand-smelt *Hypomesus olidus*." Since *H. olidus*, or pond smelt, is a freshwater species, Swan may have meant to refer to the abundant surf smelt.

Jordan and Starks (1895, p. 793) also listed eulachon as "abundant in spring" in Puget Sound, although they did not obtain specimens themselves. They cite a local fisherman as reporting "that this species buries itself in the sand of the beach," which indicates that the fish referred to by the local fisherman were not eulachon, but were possibly either surf smelt or Pacific sand lance. Both surf smelt and Pacific sand lance are currently common in Puget Sound and spawn on Puget Sound beaches, and Pacific sand lance are locally known as "candlefish" (Penttila 2007). Therefore, there is substantial reason to believe that mention of abundant eulachon in Puget Sound in some nineteenth century references (Suckley 1860, Lord 1866,

[2] L. Gilbertson, Quinault Indian Nation, Taholah, WA. Pers. commun., 27 June 2008.

Jordan and Starks 1895) results from misidentification with either the common longfin smelt or surf smelt, neither of which were mentioned in Suckley (1860) or Lord (1866).

DeLacy et al. (1972) gathered available fish collection records for Puget Sound from academic and fisheries agencies sources and indicated that between 10 and 49 reports of eulachon exist in these records for the San Juan Islands. However, no more than 10 reports of eulachon specimens exist for each of the Juan de Fuca Strait, Everett, Seattle, central Puget Sound, and south Puget Sound regions (DeLacy et al. 1972). Monaco et al. (1990) described eulachon as rare in Puget Sound and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference. Miller and Borton (1980) list five eulachon specimens collected in Puget Sound (one each in Port Susan, off Everett, and in Carr Sound, and two at Carkeek Park), which are deposited in the University of Washington Fish Collection, and seven eulachon specimens reported in the University of Washington Boat Log (one each at Golden Gardens, Port Madison, Herron Island, Penn Cove, and three in or near Carr Inlet). Currently, 12 specimens of eulachon collected in Puget Sound are deposited in the University of Washington Fish Collection (searchable database at http://www.washington.edu/burkemuseum/collections/ichthyology/index.php).

Miller and Borton (1980) also reported a personal communication dated 22 April 1976 from a biologist with the Puyallup Tribe indicating that eulachon "spawn in Wapato Creek, 1 mile upstream from the mouth of the Puyallup River." Fiedler (1941, p. 463) recorded 10,200 lb (4,636 kg) of eulachon landed in Puget Sound in 1938 in a commercial fishery using drag bag net gear. The precise location of this fish catch is not recorded (Fiedler 1941).

There are some records of transplant efforts to Puget Sound rivers from Columbia River source populations. An article in a Centralia, Washington, newspaper in 1932 (Centralia Daily Chronicle, 1 February 1932, p. 2, col. 8) (Appendix B) reported that:

> Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama river and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful.

Similarly, Wendler and Nye (1962, p. 9) stated that:

> A smelt transplant was initiated in 1959 from the Lewis River to the Puyallup River.... Approximately 4,500 fish were transplanted with an estimated egg potential of 40 million. This was considered a minimal number to plant for a species which requires mass spawning for successful reproduction. However, a measure of success may be seen if Columbia River smelt are present in the Puyallup during the spring of 1962.

A recent WDFW technical report entitled Marine Forage Fishes in Puget Sound (Penttila 2007, p. 19) presents detailed data on the biology, status, and trends of surf smelt and longfin smelt in Puget Sound, but states that "there is virtually no life history information within the

Puget Sound basin" available for eulachon. Similarly, detailed notes provided by WDFW and ODFW (2008) as part of this review, do not provide evidence of spawning stocks of eulachon in Puget Sound rivers. Interestingly, a newspaper account in The Daily Oregonian of Portland for 4 March 1876, cautions the public "against buying Puget Sound smelt [a likely reference to surf smelt] for Columbia River smelt [eulachon]" (Appendix B).

Monaco et al. (1990) described eulachon as rare in Skagit Bay and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference (Table A-2). Miller and Borton (1980) report on a total of 20 eulachon specimens collected in the San Juan Islands, southern Strait of Georgia, and Strait of Juan de Fuca and recorded in boat logs and museum collection records; however, samples from Skagit Bay were not included in this list.

The Nooksack River has been frequently listed as supporting a run of eulachon (WDFW and ODFW 2001, Wydoski and Whitney 2003, Willson et al. 2006, Moody 2008); however, Anchor Environmental (2003, p. 27) stated that:

> Longfin smelt [*Spirinchus thaleichthys*] are also called "hooligans" and are sometimes mistaken for eulachon. Eulachon occurrence and spawning has not [been] documented in the Nooksack River.

The run of hooligans into the Nooksack River commonly occurs in November, which is outside of the normal spawn timing period for eulachon, and these fish have recently been positively identified as longfin smelt.[3]

**British Columbia**

Hay and McCarter (2000, their Table 1) listed a total of 33 eulachon spawning rivers in British Columbia; however, only about 14 of these river systems were thought to have regular yearly eulachon returns (Table A-1). These 14 river systems and the estuaries or inlets they are associated with from south to north are the Fraser River (Strait of Georgia), Klinaklini River (Knight Inlet), Kingcome River (Kingcome Inlet), Wannock River (Rivers Inlet), Chuckwalla/Kilbella rivers (Rivers Inlet), Kimsquit and Dean rivers (Dean Channel), Bella Coola River (Dean Channel), Kemano/Wahoo rivers (Gardner Canal), Kowesas River (Gardner Canal), Kitlope River (Gardner Canal), Kildala River (Douglas Channel), Kitimat River (Douglas Channel), Skeena River (Chatham Sound), and Nass River (Portland Inlet) (Hay and McCarter 2000, Hay 2002).

Many of these distributions were discovered or verified during a series of ichthyoplankton surveys of eulachon larvae on the mainland coast of British Columbia (McCarter and Hay 1999). These surveys "suggested the occurrence of eulachon spawning in … rivers not previously known to support eulachon spawning" (McCarter and Hay 1999, p. 8). In particular, small spawning runs of eulachon may be detected through ichthyoplankton surveys "that might be missed by conventional fishing techniques (gill nets or seine nets) on adults" (McCarter and Hay 2003, p. 17). Willson et al. (2006) and Moody (2008) recently listed numerous rivers in British Columbia thought to support eulachon runs and these distribution data, essentially the same as in Hay and McCarter (2000), are provided in Table A-1.

---

[3] G. Bargmann, WDFW, Olympia, WA. Pers. commun., June 2008.

**Fraser River**—Early reference to eulachon being caught by First Nations groups on the Fraser River in 1827–1830 appear in the journals of the Hudson's Bay Company post Fort Langley, located on the south bank of the lower Fraser River near the Salmon River (MacLachlan 1998) (Appendix C). According to Swan (1881, p. 258) eulachon "taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized."

Recent surveys of the Fraser River indicate that eulachon primarily spawn in the lower 50 km (Hay et al. 2002), although earlier studies reported spawning occurred at least up to RKM 100 (McHugh 1940), and perhaps as far upstream as Hope, more than 150 km from Vancouver, British Columbia (Moody 2008). McHugh (1940) surveyed eulachon egg distribution in the Fraser River using a bottom dredge and determined that spawning in 1940 occurred mainly between the towns of Mission and Chilliwack, over a distance of about 13 km. Samis (1977, p. 1) stated that "localized areas of spawning may occur in the north and south arms of the Fraser River, in the Pitt and Alouette rivers, and in other tributaries." However, similar to the findings of Hart and McHugh (1944), Samis (1977) found the highest concentration of eulachon eggs in the Fraser River in May 1976 to occur upstream of Mission, adjacent to Nicomen Island. Higgins et al. (1987, p. 2) noted that "potential [eulachon] spawning sites exist in the lower Fraser River adjacent to Barnston, McMillan, and Matsqui islands (Samis 1977), which are approximately 100 km, 130 km, and 175 km from the Fraser River mouth, respectively." Interannual variation in spawning locations in the Fraser River occur (Hay and McCarter 2000, Hay et al. 2002), with most spawning being above New Westminster in 1995, below New Westminster in 1996, and in the tributary Pitt River in 1999 (Hay and McCarter 2000).

**Other British Columbia rivers**—Outside of the Fraser River, only limited aspects of the biology of eulachon have been studied in other spawning rivers in British Columbia, including: the Kingcome (Berry and Jacob 1998), Wannock (Berry and Jacob 1998, Moody 2008), Bella Coola (Moody 2008), Kemano (Lewis et al. 2002, Ecometrix 2006), Kitimat (Pedersen et al. 1995, Kelson 1997, Ecometrix 2006), Skeena (Lewis, 1997, Stoffels 2001), and Nass (Langer et al. 1977) rivers.

Eulachon were normally located no further upstream in the Kemano River, British Columbia, than RKM 2.7, about 1.5 km above saltwater, although they have been rarely observed up to RKM 4.3 (Lewis et al. 2002). Eulachon spawning is limited to the lower 1.6 km of the nearby Wahoo River (Lewis et al. 2002). Stoffels (2001, p. 4) described areas of the lower mainstem Skeena River and several tributaries (Table A-1) and stated that:

> The eulachon spawn in the main stem Skeena, with high value spawning grounds around the lower Skeena River Islands and around the mouth of the Kwinitsa River (D. De Leeuw, WLAP, pers. comm.). Eulachon also spawn throughout the Ecstall River system, almost up to Johnston Lake and in the Khyex, the Scotia, the Khtada, Kasiks, Gitnadoix and other tributaries in the vicinity (Don Roberts, Terrace, pers. comm.).

Eulachon reportedly spawn upriver in the Nass River to about RM 32 (RKM 51.5), which is the near the limit of tidal influence (Langer et al. 1977).

Although eulachon are not thought to maintain populations in island rivers (Hay and McCarter 2000), anomalous spawning events have reportedly occurred in the Somass, Nimpkish (Hay and McCarter 2000), and Kokish rivers (Willson et al. 2006) on Vancouver Island, as well as in "unnamed rivers on Haida G'waii [Queen Charlotte Islands]" (Willson et al. 2006, p. 35).

**Alaska**

Moffitt et al. (2002) indicated that at least 35 rivers in Alaska have spawning runs of eulachon, including one in a glacial stream on Unimak Island, the first island in the Aleutian Island chain off the western end of the Alaska Peninsula. According to Moffitt et al. (2002, p. 3), "this is probably the only island in Alaska with a glacial river of the type similar to mainland systems used for spawning." Armstrong and Hermans (2007, p. 2) stated that "no eulachon runs in island rivers have been reported in Southeast [Alaska]." Aspects of the biology of eulachon have been studied in the following Alaska rivers: the Stikine (Franzel and Nelson 1981), Taku (Flory 2008b), Chilkoot (Betts 1994), Chilkat (Mills 1982, Betts 1994), Copper (Moffitt et al. 2002), Eyak, Alaganik (Moffitt et al. 2002, Joyce et al. 2004), Twentymile (Kubik and Wadman 1977, 1978, Spangler 2002, Spangler et al. 2003), and Susitna (Barrett et al. 1984, Vincent-Lang and Queral 1984).

Both Willson et al. (2006) and Moody (2008) listed numerous other Alaska rivers thought to support eulachon runs and these distribution data are provided in Table A-1. In some years, commercial harvests have occurred on eulachon in the Copper, Stikine, Unuk, Chickamin, and Bradfield rivers (Moffitt et al. 2002, Armstrong and Hermans 2007). Jordan and Gilbert (1899, p. 439) indicated that eulachon occurred in the "Nushagah [Nushagak] River" that flows into Alaska's Bristol Bay in the southeastern Bering Sea. Other more recent compilations also list the Nushagak River as supporting a run of eulachon (Mecklenburg et al. 2002, Willson et al. 2006). The Nushagak River is the northern most system reported to support a run of eulachon.

Larval plankton surveys suggest that the upstream limit of eulachon distribution in the Taku River occurs at about RKM 44 (Flory 2008b). During exceptionally large runs, eulachon have reportedly been seen "at Bull Slough, near the Tulsequah River in Canada" (Flory 2008b, p. 16). Tidal influence affects the Taku River up to about RKM 35 (Flory 2008b). Eulachon were observed from the mouth of the Susitna River up to about RKM 80 in 1982 and 1983, although the greatest concentration of spawning occurred within the lower 46.6 km of the main channel of the Susitna River (Barrett et al. 1984).

**Physical characteristics of spawning rivers**

Hay and McCarter (2000, p. 12) noted that some eulachon rivers are "large or turbid, with high sediment loads; others are small and clear." Despite these apparent differences, they recognized that "virtually all [eulachon rivers] have spring freshets, which are characteristic of rivers draining large snow packs or glaciers." Although this is true of most rivers supporting eulachon in British Columbia and Alaska (Hay et al. 2002), many eulachon rivers in the lower Columbia River basin and on the coasts of California, Oregon, and Washington are not fed by extensive snowmelt or glacial runoff. However, most systems that support eulachon and are not fed by snowmelt still possess extensive spring freshets. Hay and McCarter (2000, p. 12) suggested that the apparent requirement for snow pack or glacier-fed spring freshets may be the reason why "there are no known eulachon spawning rivers found on any large coastal islands, including Vancouver Island, Queen Charlotte Islands, Kodiak, or any of the small coastal islands in northern British Columbia or southeastern Alaska."

The lack of eulachon larvae in waters examined during ichthyoplankton surveys off Vancouver Island and the Queen Charlotte Islands in April and May (Hay and McCarter 1997) "reinforce the conclusion that eulachon spawning is mainly confined to coastal rivers that have a distinct spring freshet and drain major glaciers or snowpacks" (McCarter and Hay 2003, p. 16). Typically, eulachon spawn well before the spring freshet, near the seasonal flow minimum, especially on the mainland coast of British Columbia (Lewis et al. 2002); however, Fraser River eulachon appear to spawn during the height of the freshet (Stables et al. 2005). In many rivers, eulachon spawning appears to be timed so that egg hatching will coincide with peak spring river discharge (Flory 2008b).

## Marine Distribution

Although they spend 95–98% of their lives at sea (Hay and McCarter 2000), little is known concerning the saltwater existence of eulachon. They are reported to be present in the "food rich" and "echo scattering layer" of coastal waters (Barraclough 1964, p. 1,337), and "in near-benthic habitats in open marine waters" of the continental shelf between 20 and 150 m depth (Hay and McCarter 2000, p. 14). Hay and McCarter (2000, their Figure 5) illustrated the offshore distribution of eulachon in British Columbia as determined in research trawl surveys, which indicate that most eulachon were taken at around 100 m depth, although some were taken as deep as 500 m and some at less than 10 m. Schweigert et al. (2007, p. 11) stated that "the marine distribution of adults in British Columbia includes the deeper portions of the continental shelf around Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island, generally at depths of 80–200 m." Mueter and Norcross (2002) reported eulachon were present in 32% of triennial bottom trawl surveys on the upper slope and continental slope in the Gulf of Alaska between 1984 and 1996 and were caught at depths down to 500 m in the Kodiak, Yakutat, and southeast areas of Alaska. Armstrong and Hermans (2007) indicated that eulachon are commonly caught in trawls in the coastal fjords of Southeast Alaska. Further information on eulachon distribution in research bottom trawl surveys is below and in Table A-4 and Table A-5.

Smith and Saalfeld (1955, p. 12) reported the occasional capture of eulachon in the offshore "otter trawl fishery," particularly in November to January near the mouth of the Columbia River "as the mature smelt approach the Columbia River." Emmett et al. (2001) reported the capture of small numbers of eulachon by nighttime surface trawls targeted on pelagic fishes off the Columbia River in April to July of 1998 and 1999. About 10% of hauls in 1999 contained from one to a maximum of eight eulachon (Emmett et al. 2001). Eulachon also occur as bycatch in some U.S.-based groundfish fisheries (Bellman et al. 2008) off the U.S. West Coast and more commonly in the California and Oregon ocean shrimp (*Pandalus jordani*) fisheries (NWFSC 2008). The Pacific Fishery Management Council has prohibited at-sea directed harvest of eulachon in U.S. West Coast waters and eulachon are not an actively managed or monitored species (PFMC 2008); therefore there is a paucity of data on at-sea distribution of eulachon off the U.S. West Coast.

## U.S. West Coast groundfish trawl surveys

Fishery-independent surveys conducted off the U.S. West Coast that provide data on distribution or abundance of eulachon in the ocean are very limited (Table A-4). The Northwest and Alaska Fisheries Center (NWAFC, before it split into NWFSC and AFSC) and AFSC conducted groundfish trawl surveys on the continental slope (at depths of 184–1,280 m) periodically from 1984 to 1987, and annually beginning in 1988. Continental shelf (at depths of 55–183 m) surveys were conducted triennially from 1977 to 2001 by the NWAFC and AFSC. The NWFSC assumed responsibility for the slope portion of the groundfish survey starting in 1998 and expanded the depth coverage to include the continental shelf as well as the continental slope in 2003. Many of these groundfish surveys report catch as occurring in one of five International North Pacific Fisheries Commission (INPFC) statistical areas. These INPFC areas from north to south are: 1) Vancouver (U.S.-Canada border to lat 47°30′N), 2) Columbia (lat 47°30′ to 43°00′N), 3) Eureka (lat 43°00′ to 40°30′N), 4) Monterey (lat 40°30′ to 36°00′N), and 5) Conception (lat 36°00′N to the U.S.-Mexico border) (Figure 4).

Eulachon were reported in the triennial groundfish bottom trawl surveys on the U.S. West Coast continental shelf in 1977 (Gabriel and Tyler 1980), 1980 (Coleman 1986), 1983 (Weinberg et al. 1984), 1986 (Coleman 1988), 1989 (Weinberg et al. 1994a, 1994b), 1992 (Zimmermann 1994, Zimmermann et al. 1994), 1995 (Wilkins 1998, Wilkins et al. 1998), 1998 (Shaw et al. 2000, Wilkins and Shaw 2000), and 2001 (Weinberg et al. 2002, Wilkins and Weinberg 2002) (Table A-4). These surveys targeted rockfish from 1977 to 1986, and were subsequently designed to estimate Pacific hake (*Merluccius productus*) and juvenile sablefish (*Anoplopoma fimbria*) abundance, as well as other commercially important groundfish (Weinberg et al. 1994a). However, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

The 1977 shelf groundfish survey recorded eulachon in six of nine assemblages off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m) off Oregon (Gabriel and Tyler 1980). Trawl surveys in 1980–1986 occurred between Monterey Bay, California, and either Northern Vancouver Island (1980), Estevan Point, Vancouver Island (1983), or the U.S.-Canada border (1986) at depths of 55–366 m (Coleman 1986, 1988, Weinberg et al. 1984). From 1989 to 2001 triennial groundfish bottom trawl surveys covered all West Coast INPFC areas from Vancouver to Monterey, inclusive. In 1980 eulachon were recorded as the fifteenth most common fish encountered at depths of 55–183 m in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986).

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in the triennial surveys from 1989 to 2001 are provided in Table A-4. Eulachon were found into the far south Monterey INPFC area in the 1989 survey but were not recorded in either the Monterey or Eureka INPFC areas in surveys conducted between 1992 and 2001. Mean depth of occurrence of eulachon in these surveys varied between 137 and 147 m, with minimum depths of 59–79 m and maximum depths of 322–466 m (Table A-4).

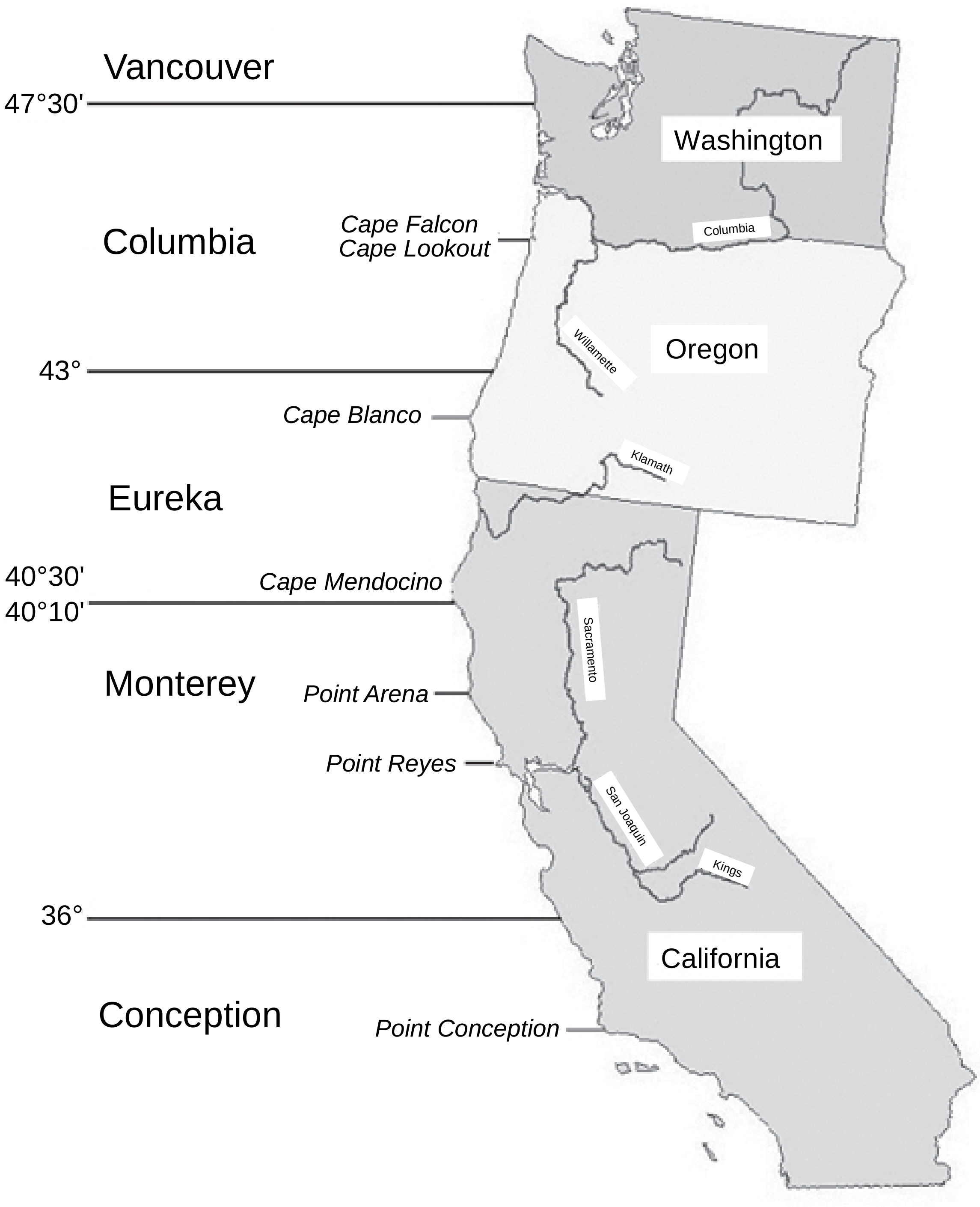



Figure 4. INPFC statistical areas off the U.S. West Coast. Modified from Pacific Fishery Management Council Web site at http://www.pcouncil.org/wp-content/uploads/georock.pdf.

Eulachon were occasionally sampled in West Coast upper continental slope groundfish trawl surveys conducted between 1984 and 1999 by the NWAFC and AFSC (Raymore and Weinberg 1990, Parks et al. 1993, Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000) and between 1999 and 2002 by the NWFSC (Builder Ramsey et al. 2002, Keller et al. 2005, 2006a, 2006b). These surveys covered habitat between 183 and 1,280 m from the U.S.-Canada border to lat 30°30′N (Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000, Keller et al. 2005, 2006a, 2006b), although annual surveys prior to 1997 covered only a portion of the area each year (Table A-4). This depth range is deeper than is preferred by eulachon (Hay and McCarter 2000), so these surveys likely missed the vast majority of eulachon, which occur on the continental shelf and not the slope.

Minimum, maximum, and mean depths of eulachon captured during the 1989–2002 survey years are given in Table A-4; however, eulachon were seldom encountered at these depths (below 183 m) and their reported occurrence in trawl hauls ranged from 6% of trawls conducted between 1989 and 1993 to fewer than 1% of all trawls in 2001. Presumably, eulachon were not encountered during the NWFSC 1999 bottom survey of the U.S. West Coast continental slope, as this species is not included in the comprehensive list of species encountered (Builder Ramsey et al. 2002). Eulachon were captured as deep as 608 m during the 2001 survey (Keller et al. 2005).

Starting in 2003, the NWFSC conducted combined slope and shelf surveys for groundfish between depths of 55 and 1,280 m (Keller et al. 2007a, 2007b, 2008) off the U.S. West Coast (Table A-4). Sampling in these slope and shelf surveys, in contrast to the NWAFC and AFSC triennial bottom trawl surveys (discussed above), did not extend into the Canadian portion of the Vancouver INPFC area where the triennial surveys had encountered the majority of eulachon. Currently, eulachon abundance in the Canadian portion of the Vancouver INPFC is tracked by the Department of Fisheries and Oceans Canada (DFO) during the annual surveys of shrimp biomass off the west coast of Vancouver Island (DFO 2008a). Eulachon were found at depth extremes of 51 to 237 m in the NWFSC surveys, with mean depths of 119 to 130 m during the three survey years (Table A-4) (Keller et al. 2007a, 2007b, 2008); however, eulachon biomass estimates were not presented in these survey documents. Some eulachon were found as far south as 34°N in the INPFC Conception area in 2003 and 2004 (Keller et al. 2007a, 2007b), a southern distribution that had not been recorded in groundfish surveys since 1989 (Weinberg et al. 1994a) (Table A-4). Pacific hake trawl surveys in U.S. and Canadian waters off the Pacific Coast have also reported incidental catch of eulachon (Fleischer et al. 2005, 2008), although details on catch location were not provided.

### Alaska trawl surveys

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in AFSC bottom trawl surveys in the Gulf of Alaska (triennially from 1984 to 1996, biennially from 1999 to 2007), Eastern Bering Sea (annually from 1982 to 2008), and Aleutian Islands (triennially from 1983 to 1997, biennially from 2000 to 2006) regions of Alaska are summarized in Table A-5. Eulachon are a common species in the Gulf of Alaska trawl surveys (Stark and Clausen 1995, Martin and Clausen 1995, von Szalay et al. 2008) and are particularly abundant in the Chirikof and Kodiak INPFC areas (von Szalay et al. 2008). In the

2007 trawl survey, eulachon were present in about 31% of the hauls under 300 m deep and 9% of hauls below that depth, although none were seen deeper than 700 m (von Szalay et al. 2008).

Eulachon distribution and abundance were also incidentally reported in two summer echo integration-trawl (EIT) surveys of prespawning walleye pollock (*Theragra chalcogramma*) on the Gulf of Alaska continental shelf in 2003 (Shumagin Islands to Prince William Sound) and 2005 (Islands of Four Mountains to south Prince William Sound) (Guttormsen and Yasenak 2007). Eulachon were the fourth and third most abundant species by numbers of fish caught in midwater trawls in the Gulf of Alaska in 2003 (10% of total) and 2005 (18% of total), respectively. Eulachon constituted 6.6% of the fish caught during EIT bottom trawls in 2003 in the Gulf of Alaska, but were not recorded in bottom trawls in 2005 (Guttormsen and Yasenak 2007).

Marine distribution maps of eulachon captured in AFSC research bottom trawl surveys of the Eastern Bering Sea continental shelf between 2001 and 2007 are provided in Nebenzahl (2001), Acuna et al. (2003), Acuna and Kotwicki (2004, 2006), Lauth and Acuna (2007a, 2007b), and Acuna and Lauth (2008). Abundance estimates for eulachon are not generally provided in these documents as they are "not adequately represented in the samples," which is "due to the bottom sampling nature of the survey" (Nebenzahl 2001, p. 27).

**Ichthyoplankton surveys**

Ichthyoplankton surveys in the northeastern Pacific Ocean commonly report the capture of osmerid larvae, but few studies have identified smelt larvae to the species level (Waldron 1972, Richardson and Pearcy 1977, Doyle et al. 2002, Auth and Brodeur 2006, Parnell et al. 2008). It is also possible that by the time eulachon reach the open ocean where these ichthyoplankton surveys occur, they may have grown sufficiently to be able to avoid capture in slowly towed, fine-mesh ichthyoplankton nets.

**Mixed stock genetic analysis**

Beacham et al. (2005) used variation at 14 microsatellite DNA loci to examine the stock composition of trawl and research surveys in marine areas off British Columbia. Using a genetic baseline data set of eulachon populations in eight rivers in Washington and British Columbia, they estimated the proportional composition of three marine-caught samples. A sample of 184 eulachon was collected during a shrimp research survey near Nootka Sound off the west coast of Vancouver Island in May of 2000. The largest proportions of fish were estimated to be from the Columbia River (56.6%, SD = 10.4) and Fraser River (37.5%, SD = 10.1). Populations in other rivers were estimated to contribute less than 6% to the sample. A sample of 100 eulachon sampled as bycatch in a shrimp trawl fishery near Chatham Sound (off British Columbia's north coast) in March 2001 was estimated to be largely fish from the British Columbia central mainland (51.6%, SD = 13.8) and from the Nass River (37.4%, SD = 10.9). Columbia (1.7%, SD = 2.4) and Fraser (2.1%, SD = 3.6) rivers contributed a small fraction to the sample. A third sample of 200 fish taken in research shrimp surveys in Queen Charlotte Sound in March 2001 was comprised of substantial proportions of Columbia, Fraser, British Columbia central mainland, and Skeena rivers, all contributing between 22.1% (SD = 5.9) and 27.1% (SD = 6.9).

Beacham et al. (2005) concluded that although eulachon marine migrations are largely unknown, there is spatial structure to the distributions of fish from different rivers. Their data indicate that Queen Charlotte Sound is an area inhabited by eulachon from very diverse origins including fish from nearby rivers as well as from more northern and southern sources. Analysis of samples in the south (off Vancouver Island) were dominated by Columbia River and Fraser River fish, whereas eulachon in the most northern marine region sampled, Chatham Sound, were largely from British Columbia coastal rivers north of the Fraser River.

# Life History Stages

### Eggs

Eulachon eggs from the Columbia River are reported to be approximately 1 mm in diameter (Parente and Snyder 1970, WDFW and ODFW 2001). In the Fraser River, eggs have been variously reported to "have an average diameter between 0.03 and 0.04 inches [0.76–1.02 mm] after preservation in formalin" (Hart and McHugh 1944, p. 9), to measure " less than 1.0 mm diameter" (Hay and McCarter 2000, p. 18), or to be "small (≈0.8 mm)" (Hay et al. 2002, p. 20). According to Garrison and Miller (1982, p. 119), "the eggs show considerable irregularity in shape and have numerous oil globules in the yolk." This irregularity in shape likely refers to unfertilized eggs.

Mature eggs are reported to have an outer sticky membrane that turns inside out after the broadcast spawned eggs are fertilized and remains attached to the egg by a short stalk, which serves to adhere the egg to particles of sand or other substrates (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Hay and McCarter 2000). Hay et al. (2002, p. 18) speculated that as eulachon eggs may attach to small sediment particles and appear to develop while being actively carried downstream by river currents that "the mobile incubation (or 'tumble' incubation) may even have a selective advantage because it may spread the eggs over a broad space, thereby reducing predation and optimizing environmental conditions."

Pedersen et al. (1995) found no significant relationship between egg weight and female body length in the Kitimat River, British Columbia. Eggs weighed 0.26–0.58 mg with a mean and standard error of 0.43 ± 0.01 mg (n = 58) (Pedersen et al. 1995). Similarly, Hay and McCarter (2000) reported eggs from the Fraser River to weigh 0.36–0.68 mg (0.51 ± 0.01 mg, n = 106) in 1995 and 0.30–0.68 mg (0.44 ± 0.01 mg, n = 100) in 1996 in the Fraser River. Mean eulachon egg weight in the Kemano River, British Columbia, was estimated at 0.43 mg (± 0.16 SD, n = 429) (Lewis et al. 2002).

Smith and Saalfeld (1955) reported that eulachon eggs from the Columbia River required 388, 378, and 370 daily cumulative degree Fahrenheit days (equivalent to 198, 192, and 188 degree Celsius days) to hatch in the Naselle River Hatchery, Kalama River Hatchery, and the University of Washington School of Fisheries hatchery, respectively. In hatchery conditions, Smith and Saalfeld (1955) reported eggs taken from the Cowlitz River hatched in 19 days at temperatures that varied from 9.4 to 12.7ºC. These data led Smith and Saalfeld (1955) to estimate that eulachon eggs would hatch in 30–40 days, given the usual water temperatures in February and March in the Cowlitz River. Assuming similar thermal requirements for incubation, Langer et al. (1977) estimated that it would take 30–40 days for eulachon eggs to hatch in the Nass River, British Columbia. Artificially spawned and incubated eulachon eggs from the Cowlitz River hatched in 21–25 days when reared at 6.5–9.0ºC (Parente and Snyder 1970). Berry and Jacob (1998 p. 4) reported the incubation period in the Kingcome River in Kingcome Inlet, British Columbia "to be approximately 21 days." Flory (2008b, p. 3) cited a personal communication indicating that the incubation period for eulachon in Southeast Alaska ranges from four to six weeks, longer than the typical three to five weeks common in more southern regions.

Lewis et al. (2002) estimated that the number of accumulated thermal units (ATUs, one ATU equal to one degree Celsius for one day) between the peak of adult spawning and larval migration for eulachon in the Kemano River, British Columbia, in 1990 to be 204 degree-days based on daily recorded temperatures. In 1997 the number of ATUs to reach 50% larval hatch were estimated to be 340 in the Kemano River and 235 in the nearby Wahoo River (Lewis et al. 2002). Duration of egg incubation in the Kemano River was calculated at 50 days (Lewis et al. 2002). Similarly, 51% of eulachon larvae hatched in the Kitimat River, British Columbia, in 1993 after accumulating 258 ATUs and 87% of hatch occurred at an estimated 307 ATUs (Pedersen et al. 1995). The shortest duration of incubation of eulachon eggs from deposition to hatch was 35–39 days, the earlier time period equating to approximately 168 ATUs (Pedersen et al. 1995).

In the Twentymile River in Southcentral Alaska, incubation was estimated during three time periods at 47–50 days, which equated to between 294 and 321 ATUs, based on calculations using mean daily water temperatures (Spangler 2002, Spangler et al. 2003). Moody (2008, p. 3) reported that earlier studies had found eulachon eggs from the Bella Coola River hatched in 54 days at about 6ºC, equivalent to about 340 ATUs. Howell (2001) reported that 400ºC ATUs (752ºF ATUs) were accumulated prior to hatching, after a minimum of 47 days, by eulachon eggs stripped from Cowlitz River broodstock and incubated at a constant temperature of 48ºC under artificial hatchery conditions. The anomalously high number of ATUs required for hatching in this experiment may have been an artifact of the experimental conditions (Howell 2001).

Pedersen et al. (1995) postulated that incubation requirements may vary with latitude, and Spangler (2002) and Spangler et al. (2003) noted that, in general, the number of ATUs required for eulachon egg incubation appears to increase with increasing latitude.

Parente and Snyder (1970) provide the only published observations on eulachon embryonic development, which is typical of teleost fishes. In laboratory conditions at temperatures ranging from 6.5°C to 9°C; a blastodisc appears at 3 hours after fertilization, cleavage is occurring by 30 hours, invagination of the gastrula is in process at 60 hours, and the head and auditory capsule are apparent at 120 hours. At 300 hours (12–13 days) a weak heart beat is present, which is stronger by 400 hours. By this time the yolk sac is about one-half its original size. The active embryo begins hatching at about 500 hours (20–21 days) and all eggs under observation hatched within 5 days of each other (Parente and Snyder 1970).

## Larvae

Newly hatched larvae are transparent, slender, and about 4–8 mm in length in the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001), 4.0–6.5 mm in the Fraser River (Hay et al. 2002), and 4–6 mm in the Kemano River (Lewis et al. 2002). Eulachon larvae are reported to be feeble swimmers and are rapidly carried downstream to estuarine portions of rivers and inlets within hours or days of hatching (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Parente and Snyder 1970, Samis 1977, Howell 2001). In the Columbia River, larval eulachon are usually located near the bottom during their downstream migration (Smith and Saalfeld 1955, Howell et al. 2001). Larval nutrition is provided by the yolk sac prior to first feeding (WDFW and ODFW 2001). Spangler et al. (2003) detected higher levels of downstream drifting larval eulachon during low light intensity periods at night than during the day in the Twentymile River, Alaska. Care must be taken in many parts of the range that larval eulachon in rivers are not confused with superficially similar cottid (sculpin) larvae (Kelson 1997, Flory 2008b).

Ichthyoplankton surveys indicate that larval eulachon may be retained for weeks or months in estuaries (McCarter and Hay 1999, 2003), especially in inlets or fjords on the British Columbia mainland coast (McCarter and Hay 2003). These surveys also indicate that eulachon larvae are mostly present in the top 15 m of the water column, with few larvae occurring below 20 m (McCarter and Hay 1999, Hay and McCarter 2000). Hay and McCarter (2000, p. 19) showed that newly hatched larvae were about 3.6–8 mm in length and that in mainland inlets on the British Columbia coast “mean eulachon larval size (mm) generally increased at each sampling station in a seaward direction away from eulachon spawning rivers.” Although larvae disperse seaward from their spawning rivers, they also “appear to be retained in inlets” and fjords to some degree on the British Columbia coast (Hay and McCarter 2000, p. 21). Ichthyoplankton surveys also showed that larvae were smaller in shallow water than those captured in deeper depths (McCarter and Hay 1999, Hay and McCarter 2000). During the period from April to August, larval eulachon on the central British Columbia coast were estimated to grow from an initial size of 3–4 mm to 30–35 mm in length (McCarter and Hay 1999, 2003).

Robinson et al. (1968b, their Table I) determined that almost all eulachon larvae in the Strait of Georgia, off the Fraser River during daylight on 6 June 1967, were distributed in the top 6.5 m of the water column, with the greatest density (50–150 larvae/$m^3$) occurring between 1.7 and 3.5 m depth. McCarter and Hay (1999) found that eulachon larvae (mostly ≤15 mm in length) in mainland inlets on the central coast of British Columbia were mainly found within the top 15 m of the water column during springtime plankton tows and suggested that larval densities were greater near the surface at night than during daytime tows.

## Juveniles

Information on the distribution and ecology of juvenile eulachon is scanty, owing to these fish being too small to occur in most fisheries and too large to occur in ichthyoplankton surveys (Hay and McCarter 2000). Eulachon that range 30–100 mm in length, exhibit schooling behavior, and have developed pigmentation and lateral scales are generally classified as juveniles (Hay and McCarter 2000). Barraclough (1964) sampled juvenile eulachon in the Strait of Georgia in winter and spring with midwater trawls and shrimp trawls and indicated that Fraser

River eulachon may spend their first year of life in the Strait of Georgia; however, observer data indicate that virtually no eulachon were caught as bycatch in the late 1990s in the Strait of Georgia shrimp fishery (Hay et al. 1999a). A larger mesh size is used in commercial shrimp trawls, compared to the mesh size used in Barraclough's (1964) studies (Hay and McCarter 2000), suggesting that juvenile eulachon may be present in coastal waters but are difficult to detect without a directed effort. Hay and McCarter (2000, p. 22) reported that "it seems that … [juveniles] disperse to open, marine waters within the first year of life and perhaps within the first few months."

## Adults and Spawners

### Age composition

The two common methods of estimating age in eulachon, either through counting rings on scales or on otoliths, have not been validated for any population of eulachon (Ricker et al. 1954, DeLacy and Batts 1963, Higgins et al. 1987, Hay and McCarter 2000, Moffitt et al. 2002, Clarke et al. 2007). Age as determined from scales is typically one to three years less than age determined from otolith increments (Ricker et al. 1954, Langer et al. 1977, Higgins et al. 1987). Several early studies expressed doubt as to the reliability of using otolith rings to determine eulachon age (Smith and Saalfeld 1955, DeLacy and Batts 1963). Consequently, the determination of age from scales and otoliths are not considered reliable methods by many researchers (Ricker et al. 1954, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007). Clarke et al. (2007, p. 1,480) noted that many dark bands or pseudo-annuli are present in whole and polished otoliths "that have been interpreted as winter growth zones in past ageing attempts" and that "sectioned otoliths viewed under transmitted light can reveal fewer zones," indicating some of the problems with this ageing methodology.

In some cases "there is no corresponding increase in size (length or weight) with putative [increase in] age" (Hay and McCarter 2000, p. 15). Higgins et al. (1987) also reported overlap in fork lengths (FL) between putative age classes of eulachon. However, in the Twentymile River, Alaska, eulachon body length has been shown to increase with age in both males and females, as expected (Spangler 2002). Beamish and McFarlane (1983) highlighted the importance of proving that a technique for ageing a species is accurate (age validation). Age validation "requires either a mark-recapture study or the identification of known-age fish in the population" (Beamish and McFarlane 1983, p. 741). It is important to point out that age validation is different than determining the precision of an ageing technique by assessing the level of agreement among several age readers. Despite the acknowledged problems with age determination in eulachon, numerous studies have reported age composition of spawning populations of eulachon based on examination of growth increments on either scales or otoliths and these data are presented in Table A-6.

Although age determination of eulachon is admittedly difficult and uncertain, adult spawners are variously reported to be 3–4 years old (Smith and Saalfeld 1955) or 3–5 years old (WDFW and ODFW 2001) in the Columbia River; 2–3 years old (McHugh 1939, Ricker et al. 1954) or mostly 3 years old, with some 2-, 4-, and 5-year-olds in the Fraser River (Hay et al. 2005); and mostly age 3 (Hay and McCarter 2000, Hay 2002) or 2–5 years old (Schweigert et al. 2007) in British Columbia. The majority of adult eulachon on the Columbia River are reported to return at age 3, although some are purported to be up to 9 years old (WDFW and ODFW 2001). Wydoski and Whitney (2003, p. 106) also stated that some eulachon "may live for 9 years;" however, these age estimates are based on the unvalidated otolith methodology.

Clarke et al. (2007) examined seasonal changes in trace elements incorporated into otoliths to estimate age structure of eulachon populations in the Columbia, Fraser, Kemano, Skeena, and Copper rivers. It has been shown that barium (Ba) and calcium (Ca) are incorporated into the aragonitic matrix of fish otoliths in proportion to their concentration in the environment (Bath et al. 2000). Barium concentrations are normally about three times greater in deep ocean waters than in surface waters; however, for about 3 months during the summer, wind-driven upwelling of deep barium-rich waters occurs off the west coast of North America and "these upwelling events should therefore impart a seasonal barium peak … in … [eulachon] otoliths" (Clarke et al. 2007, p. 1,481). As expected, Clarke et al. (2007) found that eulachon otoliths had low Ba:Ca levels in the outer region of the otolith in February and March and high levels in the summer. Clarke et al. (2007, p. 1,488) used laser-ablation inductively coupled plasma mass spectrometry to reconstruct the Ba:Ca profile of eulachon otoliths and stated that:

> a single age class of fish was observed to spawn in the systems examined in this study. Only 3-year-old eulachon were observed from the spawning populations in the Fraser and Kemano rivers, and the majority of fish for the Columbia, Skeena, and Copper rivers were also composed of a single age class; 2-, 3- and 4-year-olds from the Columbia, Skeena, and Copper rivers, respectively.

These data suggest that populations to the south spawn at an earlier age than more northern populations. Clarke et al. (2007, p. 1,489) concluded that "seasonal fluctuations in Ba:Ca observed in this study suggests that, to date, many eulachon have been aged incorrectly" and that "Ba:Ca variations appear to match expected annual shifts in ambient chemistry and so offer a more reliable annual marker for ageing."

Analyses of size frequencies have also been used to estimate age of at-sea (Ricker et al. 1954, Barraclough 1964, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007) and in-river (McHugh 1939) eulachon. These methods have identified age 1+ and age 2+ eulachon in the ocean (Barraclough 1964, Hay et al. 2003) and indicate that "the largest size mode [in the ocean] corresponds to the size modes observed in spawning rivers" (Hay et al. 2003, p. 5). Size frequency analysis indicates that most eulachon in British Columbia are spawning at age 3 (Hay and McCarter 2000).

**Body size**

Eulachon are reportedly the largest species of smelt in the family Osmeridae on the west coast of North America (Scott and Crossman 1973). Published reports of maximum eulachon body length of 305 mm (Clemens and Wilby 1967, Miller and Lea 1972) are likely in error (Miller and Lea 1976, Mecklenburg et al. 2002). Specimens of 254 mm (Miller and Lea 1976, Mecklenburg et al. 2002) from the Bering Sea represent the maximum known length for eulachon. Mean lengths of male and female eulachon in the Twentymile and Susitna rivers of Southcentral Alaska are greater than 200 mm FL (Table A-7), much larger than mean lengths in rivers further south (Spangler 2002, Spangler et al. 2003). These authors also noted that the mean weight of eulachon in the Susitna and Twentymile rivers was greater than in eulachon spawning in more southern rivers (Spangler 2002, Spangler et al. 2003) (Table A-8).

Moffitt et al. (2002) found mean length of male eulachon on the Copper River to be significantly longer than females in all years analyzed from 1998 to 2002. There were also significant differences in length among years for both male and female eulachon from the Copper River. Male eulachon were also found to be significantly longer and heavier than female eulachon in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Male eulachon were significantly larger than females in the Kemano River, British Columbia, and both sexes were significantly longer than eulachon in the nearby Wahoo River (Lewis et al. 2002).

Length of pelvic and pectoral fins of female eulachon from the Fraser River were both 14.3% of the standard body length, compared to 17.6% for pelvic fins and 15.8% for pectoral fins in male eulachon (McHugh 1939, Hart and McHugh 1944). By comparison, Langer et al. (1977) found that lengths of pelvic and pectoral fins of female eulachon in the Nass River were 11.1% and 11.8% of the standard body length, compared to 13.4% for pelvic fins and 12.7% for pectoral fins in male eulachon. Both sexes of eulachon in the Nass River apparently possess "relatively smaller fins than do Fraser fish" (Langer et al. 1977, p. 33). Craig (1947, p. 3) stated that among Columbia River tributaries:

> fishermen consistently claim to find larger smelt in the runs comprising the Lewis and Sandy river populations than those in the Cowlitz River stocks. Such size variation has been statistically proven sound in 1946 when large samples of fish were measured from both the Cowlitz and Sandy rivers.

Clarke et al. (2007, p. 1,484) found significant differences in length and weight of eulachon from five river systems (Columbia, Fraser, Kemano, Skeena, and Copper) and found a trend towards larger fish in more northerly populations "and the largest fish were from Alaska and northern British Columbia." Clarke et al. (2007) suggested that eulachon likely spawn after reaching a minimum fork length of 160 mm and a body weight greater than 30 g and that these size thresholds are obtained at an earlier age in southern latitudes and later in the far north. Available data on eulachon body length and weight from throughout the species' range are compiled in Table A-7 and Table A-8, respectively.

### Vertebrae meristics

Hart and McHugh (1944) and DeLacy and Batts (1963) attempted to identify stocks of eulachon based on differences in the number of vertebrae present in adult fish on the spawning grounds. Hart and McHugh (1944, p. 6) counted vertebrae, which varied from 65 to 72 per fish, in eulachon samples from the Nass River, Rivers Inlet, Knight and Kingcome inlets, and Fraser River and found:

> the Fraser river run to differ in average vertebral number from the runs to the more northern parts of the province.… This indicates that mixing between the runs to the Fraser and more northerly rivers cannot be extensive because, if it were, any differences in vertebral count would soon be eliminated.

Similarly, DeLacy and Batts (1963, p. 33) counted vertebrae, which also varied from 65 to 72 per fish, in eulachon samples taken between 1953 and 1962 in the lower Columbia River and its tributaries and reported that "an indication of heterogeneity was found among eight collections of smelt made in 1956 from the Cowlitz, Kalama, and Sandy rivers." Based on these data, DeLacy and Batts (1963, p. 33) stated that their study found "scant evidence of heterogeneity in the total Columbia River smelt population;" however, "there is enough suggestion of heterogeneity to justify further exploration of the possibility that smelt do move to the spawning grounds in some nonrandom fashion."

### Sexual dimorphism

There are a number of morphological differences between male and female eulachon at maturity. Mean length is in general longer in males than in females (McHugh 1939, Higgins et al. 1987, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003, Cambria Gordon 2006). Although age-2 males were statistically greater in length than the same age females on the Nass River in 1971, length of age-3 through age-5 fish did not vary between the sexes (Langer et al. 1977). Mean weight of males was statistically greater than that of females in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003) and in the Kemano River, British Columbia, from 1988 to 1998 (Lewis et al. 2002). However, mean lengths and weights of male and female eulachon in the Fraser River from 1995 to 2001 as reported by Hay et al. (2002, their Table 3) did not show consistent differences between the sexes. McHugh (1939) was also unable to detect significant difference in size between males and female eulachon from the Fraser River.

Males differ from females in having numerous tubercles on the body, head, and fins, and particularly along the lateral line (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003). In males, "the muscles of the body wall have undergone considerable development, so that the body wall is considerably thicker, and the whole fish is more firm and rigid than the female" (McHugh 1939, p. 21). Females are smoother in appearance with far fewer tubercles and do not possess the mass of muscle along the lateral line (McAllister 1963, Spangler et al. 2003). The pelvic fins are also larger at the base and longer in male compared to female eulachon; the ends of the pelvic fins often reach as far posterior as the level of the anus in males, but are much shorter in females (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003, Cambria Gordon 2006). Hart and McHugh (1944, p. 4) reported that female eulachon have a more tapered form than male eulachon. Spangler (2002) found females retained teeth to a greater degree (84.0–96.9%) than did males (3.4–32.4%) in the Twentymile River, Alaska.

### Proximate analysis

The very high fat content of eulachon led many Native American tribal groups in Southeast Alaska and First Nations in British Columbia, especially to the north of the Fraser River, to render the fat of the eulachon into oil or "grease" (Kuhnlein et al. 1982, Hay and McCarter 2000). Several early studies investigated the chemical characteristics of eulachon oil with regard to its nutritional qualities (Brocklesby and Denstedt 1933, Brocklesby 1941, Bailey et al. 1952). However, Clark and Clough (1926, p. 505) were the first to publish on the proximate composition of eulachon flesh and they reported that a single sample of the edible portion of fresh eulachon from the Columbia River contained 11.2% fat, 13.2% protein, and 1.4% ash. Although Clark and Clough (1926) studied the composition of Columbia River eulachon, these results were subsequently republished in Babcock (1927) as typical for British Columbia. Stansby (1976) found the mean (and range) of percent moisture, oil, protein, and ash in the raw muscle of 16 eulachon specimens from the Columbia River to be 79.6% (76.5–81.3), 6.3% (4.6–9.0), 14.6% (13.2–15.3), and 1.3% (1.1–1.4), respectively. Stansby's (1976) data were also reported in Sidwell (1981).

Whole unprocessed eulachon sampled in Knights Inlet on the British Columbia coast contained 16.7% fat and 72.3% moisture (Kuhnlein et al. 1996). Mean percent values for eulachon caught at sea in the Gulf of Alaska were 18.8% oil (as total lipid), 11.9% protein, 1.6% ash, and 68.1% moisture (Payne et al. 1999). Similar mean values for sea-caught eulachon in the eastern Bering Sea were 19.9% oil (as total lipid), 12.5% protein, 1.5% ash, and 66.7% moisture (Payne et al. 1999). Of 14 species of forage fish in the Gulf of Alaska and Bering Sea, eulachon had the highest oil content (16.8–21.4%) and the lowest moisture content (64.6–70.8%) (Payne et al. 1997, 1999). No significant differences in composition of eulachon were seen between the Gulf of Alaska and the Bering Sea when fish of a common size range collected in the same season of the year were compared (Payne et al. 1999).

In the Gulf of Alaska, eulachon were found to have the lowest mean moisture content (64%), lowest mean ash content as a percentage of dry mass (4%), highest dry mass energy value (7.7 kcal/g), and highest wet mass energy value (2.6 kcal/g) among 18 fish and 5 squid species analyzed (Perez 1994). These energetic values were obtained using bomb calorimetry (Perez 1994). Payne et al. (1999) derived a mean value for eulachon wet mass energy of 2.47 kcal/g derived from calculations of caloric content using energy coefficients for protein and oil from Gulf of Alaska eulachon. These eulachon energy values were the highest in relation to moisture content of the 13 forage fish analyzed (Payne et al. 1999). Similarly, Anthony et al. (2000) reported that eulachon had the highest mean lipid content (50% of dry mass) among 39 forage fish species analyzed in the Gulf of Alaska. Eulachon also had a much higher water content as a percent of wet mass (71%) than would be expected given its high lipid content (Anthony et al. 2000). A sample of 34 eulachon (141–202 mm standard length [SL]) also had the second highest mean energy density, after northern lampfish (*Stenobrachius leucopsarus*): 6.5 kcal/g (27.2 kJ/g) dry mass or 1.8 kcal/g (7.49 kJ/g) wet mass (Anthony et al. 2000).

Iverson et al. (2002) examined fat content and fatty acid composition in 26 species of fish and invertebrates in Prince William Sound, Alaska. Fat content of 20 eulachon samples taken in spring were uniformly the highest in fat content and ranged 15–25% fat with a mean value of 19% fat (Iverson et al. 2002). The next highest fat content was found in adult herring, which ranged 7–20% fat with a mean value of 14% fat (Iverson et al. 2002). Eulachon possessed unique fatty acid signatures that "differed most from all other finfish, cephalopod, or crustacean species studied" (Iverson et al. 2002, p. 177). Eulachon in Prince William Sound had "extremely high levels of 18:1n-9, moderately high levels of 14:0 and 16:1n-7, and extremely low levels of polyunsaturated fatty acids such as 20:5n-3 and 22:6n-3" (Iverson et al. 2002, p. 177). The dietary source of this unique fatty acid signature in eulachon is currently unknown (Iverson et al. 2002).

The apparent differences in fat content between eulachon samples in the Columbia River (6.3% fat; Stansby 1976), Knight Inlet on the British Columbia coast (16.7% fat, Kuhnlein et al. 1996), and in the Gulf of Alaska (19% fat, Payne et al. 1999, Iverson et al. 2002) likely had a significant impact on American Indian and First Nations uses for these fish. MacLachlan (1998, p. 183) stated that:

> On the northern coast, eulachon were a major source of oil, but on the Fraser, as on the Columbia, they were eaten fresh or smoked whole. A difference in oil content may have been the basis of this difference in use.

# Reproduction and Development

### Sex Ratio

Many studies have reported that sex ratios in eulachon are either biased in favor of males (Smith and Saalfeld 1955, Kubik and Wadman 1977, 1978, Franzel and Nelson 1981, Higgins et al. 1987, Lewis 1997, Lewis et al. 2002, Moffitt et al. 2002, Spangler 2002, Spangler et al. 2003) or are highly variable depending on time and location of sampling (McHugh 1939, Hart and McHugh 1944, Langer et al. 1977, Pedersen et al. 1995). On the other hand, Hay and McCarter (2000) and Hay et al. (2002) report that the ratio of spawning male to female eulachon in their gill net samples from the Fraser River in 1995–2002 was approximately 1 to 1, with the exception of 1998 when the sex ratio was 1.7 to 1.

All reports of eulachon sex ratio should be viewed with caution, as proportions of male to female eulachon have been reported to vary with fishing gear type, distance upriver, distance from the river shoreline, time of the day, and migration time (McHugh 1939, Langer et al. 1977, Moffit et al. 2002, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003). Langer et al. (1977, p. 33) reported that "sex ratios varied with location, within the duration of the run, and between years in the Nass River." Lewis (1997) suggested that sex ratios skewed in favor of males may be due to longer residence time of male eulachon in freshwater compared to females. Moffit et al. (2002) postulated that as spawning commences, females may avoid the riverbank and disperse to the center of the river, thus skewing sex ratios calculated from dip net sampling along riverbanks. Spangler (2002) and Spangler et al. (2003) reported that sampling with different gear types (gill nets versus dip nets) resulted in different sex ratios in the Twentymile River, Alaska. However, Franzel and Nelson (1981) reported that fishing gear did not significantly change the sex ratio of eulachon captured in the Stikine River, Alaska.

Mc Hugh (1939) and Hart and McHugh (1944) reported that the sex ratio varied during the fishing season in 1939 and 1941 in the Fraser River; males predominated in the early part of the eulachon run, but in the latter part females came to predominate. A similar situation may obtain in the Columbia River basin, where WDFW and ODFW (2001, p. 15) stated that analysis of sex ratios indicated that "female return timing is skewed later than that of males," although females never appear to dominate. Pedersen et al. (1995, p. 16) reported that earlier studies in the Nass River had found "a changing sex ratio during the spawning season," whereas another study based on daily monitoring had found 55% males and 45% females. Lewis et al. (2002) also reported changing sex ratios over the duration of the eulachon run in the Kemano River, British Columbia; however, there appeared to be two pulses of female returns, and males rather than females appeared to dominate the later part of the run. The proportion of males was also found to increase as the run progressed in 1971 on the Nass River (Langer et al. 1977) and at Flag Point Channel on the Copper River in 1998 and 2000–2002 (Moffit et al. 2002).

The overall sex ratio reported by Smith and Saalfeld (1955) for the Columbia River basin was 4.5 males to 1 female. Similarly, Higgins et al. (1987) and Rogers et al. (1990) found a sex ratio of 3.4 males to 1 female in Fraser River samples collected in April 1986 and Rogers et al. (1990) reported the ratio to be 5.9 to 1 in 1988. Sex ratios in the early 1930s in Cowlitz River dip net, Lewis River dip net, and Columbia River gill net samples were 3.2 to 1, 12.3 to 1, and 6.8 to 1, respectively (Smith and Saalfeld 1955). In 1946 sex ratios in commercial fisheries were 10.5 to 1 in the Cowlitz River and 2.8 to 1 in the Sandy River, which may reflect the bias in the fishery for the more marketable male eulachon (Smith and Saalfeld 1955). Since males dominate the early part of the run in the Columbia River, they are more prevalent in both the sport and commercial fisheries, which preferentially target the first fish to return (WDFW and ODFW 2001).

Sex ratio of male to female eulachon in the Kemano River, British Columbia, ranged from 1.1 to 1 to 10.7 to 1 with a mean of 4.4 to 1 between 1989 and 1997; however, when weighted by fish abundance over the duration of the run, the true sex ratio was estimated at 1.6 to 1 (Lewis et al. 2002, p. 72). Males predominated in upriver locations in both 1970 and 1971 in the Nass River (Langer et al. 1977). However, in the Fraser River the proportion of male to female eulachon was independent of the distance of upriver capture (along a 31 km gradient) among April 1986 (Higgins et al. 1987, Rogers et al. 1990) and April/May 1988 (Rogers et al. 1990) samples.

Franzel and Nelson (1981) found that gill net–sampled eulachon in the Stikine River, Alaska, over two years had a sex ratio of males to females of 17.5 to 1. Eulachon sex ratios on the Copper River, Alaska, and nearby systems were also dominated by males in all samples (Moffitt et al. 2002). The percentages of males at Flag Point Channel on the Copper River in 1998, 2000, 2001, and 2002 were 78%, 60%, 72%, and 69%, respectively. At 60-km Channel on the Copper River in 2002, males represented 61%–85% of the captured eulachon (Moffit et al. 2002). On the Copper River delta, the percentages of males in 1998 and 2000 were 91% and 66%, respectively, in Alaganik Slough and ranged from 82% to 98% in January to February 2001 in Ibeck Creek (Moffit et al. 2002). Eulachon collected in Twentymile River, Alaska, from May 15 to June 2, 1976, and from April 29 to June 5, 1977, had a cumulative sex ratio of 5 males to 1 female (n = 204) (Kubik and Wadman 1977) and 7.4 males to 1 female (n = 408) (Kubik and Wadman 1978), respectively. Sampling by dip net in the Twentymile River resulted in male to female ratios of 6.7 to 1 in 2000 (n = 394) and 2.1 to 1 in 2001 (n = 2,711) (Spangler 2002, Spangler et al. 2003). Barrett et al. (1984) reported average male to female sex ratios of prespawning eulachon of 1.6 to 1 in late May 1982, 1.3 to 1 in early June 1982, 1.2 to 1 in mid-May 1983, and 0.6 to 1 in mid-May and early June 1983. Spawning and postspawning ratios were higher due to the shorter stream residence time of female eulachon (Barrett et al. 1984).

Smith and Saalfeld (1955, p. 22) first hypothesized “that the type of spawning of smelt may necessitate an excess of males.” Moffitt et al. (2002, p. 26) postulated that in the case of eulachon, which broadcast-spawn eggs and sperm in fast moving rivers, “a large number of males upstream may increase the probability of egg fertilization.” Spangler et al. (2003, p. 46) also postulated that a sex ratio skewed in favor of males "may be a key element to successful spawning" and that "fertilization would increase with more available milt in the water increasing the probability of eggs being fertilized." Hay and McCarter (2000, p. 23) stated that spawning involves groups of fish and eulachons must closely synchronize the timing of spawning between sexes, because the duration of sperm viability in freshwater is short, perhaps only minutes. Interestingly, Langer et al. (1977, p. 32) reported on a second-hand observation of spawning in eulachon, suggesting that a group of males simultaneously released milt upstream of a group of females that laid their eggs as the milt drifted over the downstream female eulachon. Lewis et al. (2002, p. 83) observed spawning eulachon in the Kemano River, British Columbia and reported that:

> At night in the riffles, males lay next the females, beside them and on top of them. We observed small puffs of milt and eggs drifting in the water. We interpret this behaviour as egg laying behaviour because we had not seen it during the day and because we examined rocks at the site during daylight hours … and discovered eggs adhering to the rocks.

### Fecundity

Hart and McHugh (1944) noted that fecundity in the Fraser River ranged about 17,300–39,600 eggs in female eulachon measuring 145–188 mm SL. Average fecundity was about 25,000 eggs per female (Hart and McHugh 1944, Hart 1973). Smith and Saalfeld (1955, p. 22) report a fecundity of 20,000–60,000 for female eulachon ranging 140–195 mm length from the Columbia River. Both Clemens and Wilby (1967) and McPhail and Lindsey (1970) report fecundity to be about 25,000 eggs in an average size female. Hay and McCarter (2000) reported total fecundity range of 20,000–40,000 eggs, the number generally increasing with fish size. Depending on fish size, fecundity can range 7,000–31,000 eggs on the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001).

Mean total fecundity in Fraser River eulachon ranged from a low of about 31,200 to a high of about 34,100 when estimated between 1995 and 1998 (Hay et al. 2002). Mean relative fecundity (total fecundity divided by female body weight) of Fraser River eulachon ranged from a low of 683 eggs/g in 1995 to a high of 898 eggs/g in 1997 (Hay et al. 2002). There are significant differences in fecundity among years in Fraser River eulachon, which are likely related to "significant interannual differences in mean size (length and weight)" (Hay et al. 2002, p. 11).

Mean fecundity of 58 eulachon from the Kitimat River, British Columbia, in 1993 was about 22,900 eggs with a range of 3,242 to 47,798 (Pedersen et al. 1995). Relative fecundity in the Kitimat River was calculated at 504 eggs/g female body weight (Pedersen et al. 1995). Based on 5 years of data, mean eulachon fecundity in Kemano River, British Columbia, was about 27,000 and ranged 6,744–57,260 eggs. Mean relative fecundity of Kemano River eulachon over this 5-year data set was 544 eggs/g female body weight (Lewis et al. 2002).

Mean fecundity of eulachon in the Copper River, Alaska, was estimated at about 35,520 (range: 12,202–52,722) in 2000 and 36,200 (range: 18,645–62,855) in 2001 (Moffitt et al. 2002). From these data, Moffitt et al. (2002) estimated relative fecundity of eulachon from the Copper River in 2000 and 2001 as 790 and 792 eggs/g female body weight, respectively. Fecundity in the Twentymile River, Alaska, ranged from as low as 8,530 to as high as 67,510 and reportedly increased with increasing length, weight, and age (as determined by otolith increment analysis) (Spangler 2002, Spangler et al. 2003).

### Homing

Smith and Saalfeld (1955, p. 12) examined migration behavior of eulachon in the Columbia River and its tributaries and stated that:

> The so-called "homing instinct," influencing fish to return as adults to the stream in which they were hatched, has not been established for smelt. … The irregularity of the runs into the various tributaries virtually precludes the existence of a home tributary influence.

McCarter and Hay (1999) and Hay and McCarter (2000) argue that both the short time eulachon larvae spend in the natal freshwater environment and their small size would preclude their ability to imprint on a spawning river. Eulachon larvae are very small, 4–6 mm in length, weigh only a few mg at hatching, and are flushed into the estuarine environment almost as soon as they rise into the water column. Hay and McCarter (2000, p. 13) noted that eulachon larvae are so small that they "may lack the necessary physiological tissue (i.e., olfactory rosette and associated nervous system memory capacity)" to imprint on the freshwater natal spawning river. However, eulachon larvae may spend weeks to months in nearby estuarine environments where they grow significantly in size and may develop the capacity to imprint on large estuaries and eventually home to these areas as adults (McCarter and Hay 1999, Hay and McCarter 2000). These considerations would suggest that large river estuaries, inlets, and fjords may serve as the smallest stock structure unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005).

### Spawn Timing

McCarter and Hay (1999, p. 12) emphasized that:

> Based on concepts developed from observation of spawning of Pacific salmon, the timing of [eulachon] spawning runs should be biologically adapted to each river. If so, and if the same model is applied to eulachons, then each population would be adapted to each river.

However, several authors emphasize that there is no clear latitudinal (Hay and McCarter 2000, Cambria Gordon 2006) or other pattern (Hay et al. 2002) apparent in eulachon spawn timing (Table A-9, Figure 5). Over the whole range of eulachon from northern California to the southeastern Bering Sea, Hay and McCarter (2000, p. 17) noted that:

> the most southern runs (i.e., the California and the Columbia River runs) are early, beginning in late January, whereas some of the Alaska runs are much later (May), although not too dissimilar to [eulachon in] the Fraser [River, which run in April through May].

However, eulachon have been known to spawn as early as January in rivers on the Copper River delta of Alaska (Moffitt et al. 2002), as late as May in northern California, and from January to April in various subbasins of the Columbia River (Table A-9, Figure 5, and Figure 6). Analysis

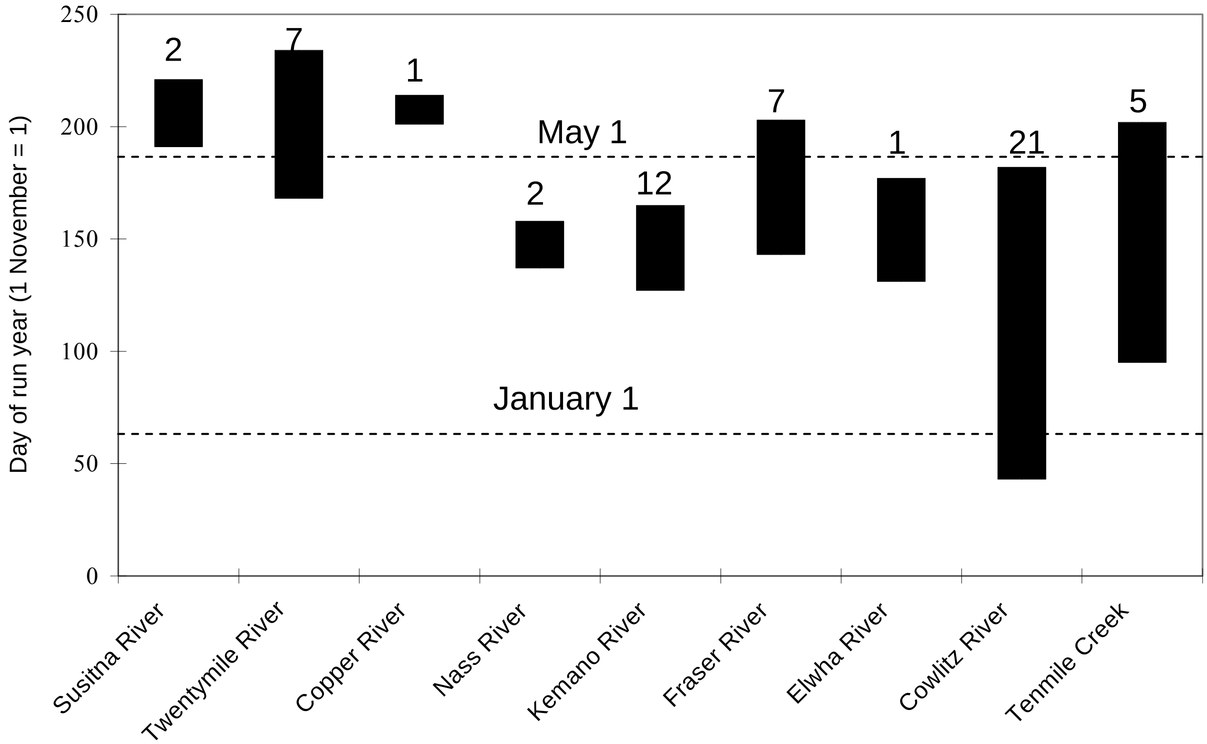



Figure 5. Duration of reported eulachon spawn timing in various river systems arranged north to south from left to right on the x-axis. Dates of spawn timing have been converted relative to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each system. Data from Barrett et al. (1984, reported in Spangler et al. 2003), ADFG (1972, 1973, 1974, reported in Spangler et al. 2003), Kubik and Waldman (1977, 1978), Spangler (2002), Spangler et al. (2003), Morstad (1998, reported in Spangler et al. 2003), Langer et al. (1977), Lewis et al. (2002), Hay et al. (2003), Shaffer et al. (2007), B. James,[4] and WDFW and ODFW (2008).

of spawn timing as a stock identifier in eulachon is also complicated by observed variation in the duration of spawn timing from year to year, the presence of multiple spawning runs in some rivers, and observations of eulachon returning earlier in recent years in some systems relative to historical data (Moody 2008).

## California

Historically, eulachon runs in northern California were said to start as early as December and January and peak in abundance during March and April (Table A-9). Larson and Belchik (1998, p. 5) reported that:

> The timing of the Klamath, Redwood Creek, and Mad River spawning migrations were similar to the Columbia's runs, which usually begin in December and January (S. King, ODFW, pers. comm.). The Klamath run continued until around May with peak occurrence between March and April.

[4] B. James, WDFW, Vancouver, WA. Pers. commun., 12 May 2008.

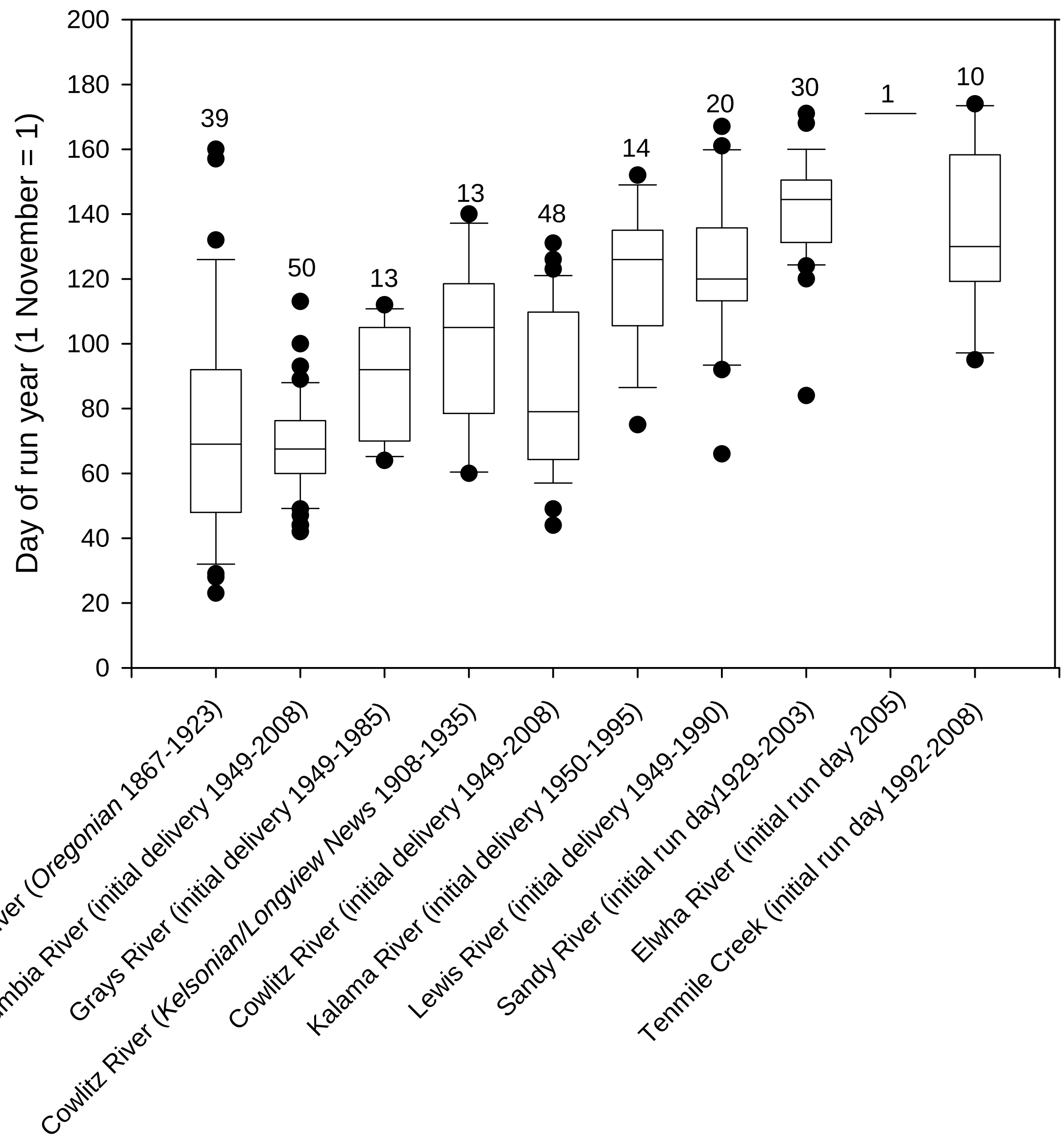



Figure 6. Box plots of the initial day of river entry in various river systems as reported in local newspapers (Appendix B and Smith et al. 1953), commercial fishery deliveries (B. James[5]), Shaffer et al. (2007), and WDFW and ODFW (2008). Dates of initial river entry or fishery delivery have been converted to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each data set.

Similarly, Young (1984) reported on the collection or observation of adult eulachon in the Klamath River and Redwood Creek in April 1978 and in the Klamath River in March and April in both 1979 and 1980. Young (1984, p. 62) further stated that eulachon begin their migration in the Klamath River "in January in small numbers well before the main spawning runs (more than one may occur) in March and April, and then continuing on a smaller scale."

[5] See footnote 4.

**Columbia River and tributaries**

Smith and Saalfeld (1955, p. 24) noted that eulachon "may be found in the Columbia River between late December and mid-May." Howell and Uusitalo (2000, p. 3) documented that historically eulachon migration into the Columbia River "begins in December, peaks in February, and continues through May." Bargmann et al. (2005, p. 22) stated that "peak [eulachon] abundance [in the Columbia River] is usually in February, but may be as late as April."

Initial arrival of eulachon in the Columbia River and its tributaries can be estimated from historical landings data in the commercial fishery (WDFW,[6] Howell and Uusitalo 2000) (Figure 6). Documented eulachon landings in the Columbia River have occurred as early as December 13 and as late as February 21 with an average date of around January 8 for the years 1949 to 2008, based on data supplied by WDFW.[7] Based on newspaper accounts of eulachon in the fish markets of Portland, Oregon, from 1867 to 1923 (Appendix B), the earliest date of appearance of eulachon in the Portland markets was November 23 and the mean date of initial appearance was February 12 (Figure 6).

Similarly, documented eulachon landings in the Cowlitz River have occurred as early as December 13 and as late as March 11 with an average date of around January 25 for the years 1949 to 2008, based on data supplied by WDFW.[8] Newspaper accounts of initial appearance of eulachon in the Cowlitz River between 1908 and 1935 were summarized in Smith et al. (1953) and give the earliest date of January 30. In the Grays River between 1949 and 1985, initial eulachon landings occurred as early as January 3 with an average initial date of February 20, based on data supplied by WDFW.[9] In the Kalama River between 1950 and 1995, initial eulachon landings occurred as early as January 14 with an average initial date of April 1, based on data supplied by WDFW.[10] In the Lewis River between 1949 and 1990, initial eulachon landings occurred as early as January 5 with an average initial date of April 16, based on data supplied by WDFW.[11]

WDFW and ODFW (2008) provided the initial arrival dates of eulachon in the Sandy River, Oregon, for the years 1929 to 2008, although no run was recorded in 48 of the 79 years. The earliest appearance of eulachon on the Sandy River occurred on January 23 (the next earliest being February 28) and the latest on April 21, with an average data of initial appearance of about March 21 (Figure 6). Craig (1947, p. 3) stated that eulachon "runs into the Sandy and Lewis rivers normally occur later than those in the Cowlitz." Smith and Saalfeld (1955, p. 13) also noted that "the Cowlitz fish [appear] in the early part of the season, and the Sandy fish nearly two months later." Comparison of average dates of initial landings in the commercial fishery in the Cowlitz River (January 25) and in the Sandy River (March 21) confirm that a nearly two-month period separates the average run timing in these two tributaries (Figure 6).

[6] Statewide eulachon landings database, B. James, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.
[7] See Footnote 6.
[8] See Footnote 6.
[9] See Footnote 6.
[10] See Footnote 6.
[11] See Footnote 6.

## British Columbia

On the mainland coast of British Columbia, earliest eulachon spawning occurs in the far north in February to early March in the Nass River, and the latest spawning occurs in April and May in the Fraser River in the far south (Table A-9, Figure 5). This pattern of spawn timing is reversed from the apparent overall range-wide pattern of eulachon spawning earlier in the south and later in the north (Hay and McCarter 2000). Early researchers variously stated that eulachon enter and spawn in rivers in British Columbia "from the middle of March to the middle of May" (Hart and McHugh 1944, p. 7) or "during March, April, and May" (Clemens and Wilby 1967, p. 123). Hart and McHugh (1944, p. 7) also affirmed that "The time of appearance is fairly constant from year to year in each locality and the runs are apparently of progressively shorter duration from south to north." Similarly, McCarter and Hay (2003, p. 16) noted that:

> In some rivers, such as the Kitimat or Kemano, the time of spawning is relatively early, beginning in early March and in others, such as the Fraser or Klinaklini, the timing is later, beginning in April or May.

**Fraser River**—The early journals of Fort Langley, a Hudson's Bay Company post on the lower Fraser River, indicate that eulachon were observed in the Fraser River on 28–29 April 1828, 14 April 1829, and 4 May 1830 (MacLachlan 1998) (Appendix C). McHugh (1939) suggested that the presence of spent fish in the catch indicated that spawning may occur throughout the two-month period from early April until late May in the Fraser River. Hart and McHugh (1944) sampled eulachon on the Fraser River 12 April–19 May 1939 and 4 April–8 May 1940. Ricker et al. (1954, p. 1) noted that historically the eulachon fishery operated in the Fraser River "between the middle of March and the middle of May, from the mouth of the river up to Mission and Matsqui." More recently, Hay et al. (2002, p. 20) stated that eulachon enter the Fraser River "in late March and April to spawn" and Stables et al. (2005) recorded the capture of eulachon by trawl net in late April and early May of both 2001 and 2002.

**Kitimat River**—In 1993 eulachon spawned in the lower 4 km of the Kitimat River March 20–30 (Pedersen et al. 1995). Peak spawning in 1997 occurred March 7–19 (Kelson 1997).

**Kemano River**—Lewis et al. (2002) reported that eulachon run timing in the Kemano River extended from late March to early April in 1980 and typically lasted from March 22 to April 10 between the years 1988 and 1998. Females entered the Kemano River in two distinct pulses separated in time by from several days up to 10 days (Lewis et al. 2002). Typically the run duration was about 15 days in the Kemano River, "ranging from 4 to 20 days" and "over the 11 year study [1988–1998] there was a trend for the eulachon run to begin and end earlier" perhaps in "response to changing sea temperatures" (Lewis et al. 2002, p. 68).

**Skeena River**—Adult eulachon were present in the Skeena River March 10–20, 1997 (Lewis 1997). Historically, the Skeena River eulachon run was reported to occur between early February and late March (Lewis 1997).

**Nass River**—Swan (1881) noted that two spawning runs of eulachon appear in the Nass River, one that normally begins between March 16 and 22, but sometimes occurs as late as March 28 to April 4, and a second run that enter the river towards the end of June. Langer et al.

(1977, p. 45) verified that eulachon typically enter the Nass River in mid-March, peaking in late March, and the run may extend into mid-April and may consist of "two overlapping spawning waves."

### Alaska

Moffitt et al. (2002, p. 3) stated that "eulachon enter river systems from January through early July" in Alaska. Eulachon typically spawn in early April in the Taku River in Southeast Alaska and may migrate beneath river ice to reach the spawning grounds (Flory 2008b). Franzel and Nelson (1981) reported that the eulachon run in the Stikine River, Alaska, in 1979 and 1980 occurred in early April soon after spring breakup and lasted for up to 3 to 4 weeks. Marston et al. (2002, p. 231) reported that eulachon spawning runs in 1995–1997 in the Antler and Berners rivers in Berners Bay in Southeast Alaska began between May 3–6 and lasted 10–12 days, "although spent fish or a few late spawners remained in the rivers until the end of May." More recently, eulachon have spawned in mid to late April in Berners Bay rivers (Flory 2008a), spawning 26 April–14 May 2004 in the Antler River in particular (Eller and Hillgruber 2005).

**Chilkat and Chilkoot rivers**—Krause (1885) indicated that two runs of eulachon occurred in the Chilkat River region of Southeast Alaska, a February run and a separate run in late April to mid-May. The later run was characterized as larger in both numbers and individual fish size (Krause 1885). Mills (1992, p. 8) stated that the main eulachon run occurred "between mid and late May" on the Chilkat River. Betts (1994, p. 19) reported that both the Chilkat and Chilkoot rivers supported two runs of eulachon, "a small run in February, and en masse most commonly in mid-May." Eulachon harvest on the Chilkat River occurred 1–7 May 1990 and 6–16 May 1991 (Betts 1994). On the nearby Chilkoot River, harvest occurred 6–9 May 1990 and 9–16 May 1991 (Betts 1994). Betts (1994) also reported that salmon fishwheels on the Chilkat River caught eulachon 7 May–17 June 1991. Eulachon reportedly spawn in several rivers in the Yakutat region of Alaska in March to early June (Rogers et al. 1980).

**Copper River delta**—Eulachon run timing in the Copper River, Alaska, and in nearby rivers of the Copper River delta is variable, and in many cases two runs separated by weeks to months have been observed in the same rivers (Moffitt et al. 2002, Joyce et al. 2004) (Table A-9). Eulachon were observed in the Eyak River on the western Copper River delta 16–23 June 2002, but did not appear in Ibeck Creek in 2002, a tributary of the Eyak (Joyce et al. 2004). In 2003 there were two separate eulachon runs observed in the Eyak River, February 15–22 and June 9–13. Eulachon were observed in the tributary Ibeck Creek 28 January–17 March 2001 (Moffitt et al. 2002) and 15 February–1 March 2003 (Joyce et al. 2004). On the central Copper River delta, eulachon were present in Alaganik Slough as early as 9 February 2001 (Moffitt et al. 2002), 9–16 June 2002, and during two periods in 2003, February 23–26 and May 29 to June 15 (Joyce et al. 2004). In the Copper River itself, eulachon were present as early as May 19 and as late as May 24 at Flag Point Channel between 1998 and 2002, and the duration of the run lasted 8–14 days (Moffitt et al. 2002). Eulachon were present at Flag Point 20 May–2 June 1998, 19–28 May 2000, 19–30 May 2001, 24 May–6 June and 16–24 June in 2002, and 1–5 March and 17–19 April 2003 (Joyce et al. 2004). Eulachon were also present at 37-mile Bridge on the Copper River 16–23 June 2003 (Joyce et al. 2004).

**Twentymile River**—The eulachon run in the Twentymile River "spanned a period of 25 days between May 13 and June 6" in 1976 (Kubik and Wadman 1977, p. 37) and "44 days from April 23 to June 5" in 1977 (Kubik and Wadman 1978, p. 54) (Table A-9). Spangler (2002) and Spangler et al. (2003) cited an additional 7 years of observations in the Twentymile River where the spawn period ranged 18–54 days. Eulachon were captured in the Twentymile River by dip nets 4 May–21 June and 17 April–9 June in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Spangler (2002, p. 27) stated that "the eulachon run lasts over a longer period of time in the Twentymile River than in any other river for which data are available." In contrast, other researchers have stated that the duration of eulachon spawning migrations decreases from south to north (Hart and McHugh 1944, Scott and Crossman 1973).

**Susitna River**—Based on the presence of adults, two runs of eulachon were observed on the Susitna River in Southcentral Alaska in 1982 (May 16–30 and June 1–8) and 1983 (May 10–17 and May 19 to June 8) (Barrett et al. 1984, Vincent-Lang and Queral 1984). Initial eulachon run timing likely precedes these early dates for the first run, as fish were present as soon as sampling was possible following ice breakup in both years (Vincent-Lang and Queral 1984). Actual spawning occurred on the Susitna River May 21–31 and June 4–9 in 1982, and May 15–22 and May 23 to June 5 in 1983 (Barrett et al. 1984).

### Multiple spawning runs

A number of rivers are reported to have two or even more separate spawning runs of eulachon, including the Chilkat River (Krause 1885, Betts 1994), Chilkoot River (Betts 1994), Copper River (Moffitt et al. 2002, Joyce et al. 2004), and Susitna River (Vincent-Lang and Queral 1984) in Alaska, and the Nass River (Swan 1881, Langer et al. 1977) and Kingcome River (Berry and Jacob 1998) in British Columbia. Based on adult run timing, Langer et al. (1977) suggested there could be up to three waves of spawning on the Nass River. Berry and Jacob (1998, p. 4) reported that there appeared to be four waves of eulachon spawning activity in the Kingcome River, British Columbia, in 1997, "with peaks on April 2, April 15, April 21, and May 2." There may also have been an earlier eulachon spawning event in March and a later one in early June in the Kingcome River (Berry and Jacob 1998), based on the presence of eggs and larvae; however, experience in other river systems raises the possibility that some of these eggs and larvae may have been confused with those of sculpins (cottids) (Kelson 1997). Indications of eulachon spawning in May and June, based on egg and larval presence, in the Kitimat (Pedersen et al. 1995), Skeena (Lewis 1997), and other rivers on the central and north coast of British Columbia are suspect, due to the presence of sculpin larvae in these rivers that may have been misidentified as eulachon larvae (Kelson 1997).

## Semelparity versus Iteroparity

Numerous references (McPhail and Lindsey 1970, Hart 1973, Scott and Crossman 1973, Samis 1977, Garrison and Miller 1982, Lewis et al. 2002) cite Barraclough (1964) as evidence that eulachon may be iteroparous. In fact, Barraclough (1964, p. 1,337) noted that the presence of dead eulachon found in the Columbia and Fraser rivers indicates many die after spawning. The evidence in Barraclough (1964, p. 1,337) that eulachon may be iteroparous occurs in the statement that: "spent eulachon in good condition caught by trawlers in the Strait of Georgia off the mouth of the Fraser River suggest that some eulachon recover after spawning, and may spawn a second time." However, it is uncertain whether the spent eulachon observed at the mouth of the Fraser River, as reported by Barraclough (1964), recovered and lived long enough to spawn in a subsequent season. Some additional secondary sources indicate that some eulachon are iteroparous (WDFW and ODFW 2001, Mecklenburg et al. 2002, LCFRB 2004b). According to WDFW and ODFW (2001, p. 4), "although adults can repeatedly spawn, most die after spawning." Mecklenburg et al. (2002, p. 175) stated that "most [eulachon] die after spawning, but some survive to spawn once more."

Earlier authorities (McHugh 1939, Hart and McHugh 1944, Clemens and Wilby 1946, Ricker et al. 1954, Smith and Saalfeld 1955) reported that eulachon were semelparous (spawn once in their lifetime and die soon after spawning). McHugh (1939) and Hart and McHugh (1944) noted that the outer edge of the scales in spawning eulachon in the Fraser River were resorbed and showed a characteristic clear margin. This region of the scale is commonly called a spawning mark or spawning check. However, these authors found no eulachon with a previous year's spawning check and "concluded that none of the fish examined had spawned in a previous year" (McHugh 1939, p. 21). Similarly, Langer et al. (1977, p. 39) stated that "since no spawning checks were noted on any scales from the Nass River, repeat spawning is probably minor or nonexistent on the Nass." Eulachon in the Kemano River also showed no evidence of spawning checks on the otoliths (Lewis et al. 2002). Smith and Saalfeld (1955, p. 25) reported that:

> All available evidence indicates that smelt die after one spawning. In all spawning studies where live smelt were allowed to spawn in the confines of [a] hatchery trough, death followed extrusion of the spawn. In addition, commercial fisherman, who fish in the Columbia River after the smelt run, report the tremendous abundance of dead smelt on the river bottom.

The evidence is strong that most, if not all, eulachon in the southern portion of the range (south of about 54°N latitude) are semelparous (Hay and McCarter 2000, Hay 2002, Hay et al. 2002, 2003), "although there may be some iteroparity (survive spawning) at higher latitudes, in Alaska" (Hay et al. 2003, p. 2). Hay et al. (2002, 2003) presented three lines of evidence for semelparity in eulachon from British Columbia: 1) direct observation of postspawning mortality in the form of beached and floating carcasses in many rivers, 2) only eulachon with well developed teeth are found at sea, whereas all spawning eulachon observed in the Fraser River have undergone substantial tooth loss and resorption, and 3) the largest size class of eulachon in British Columbia are found in rivers during the spawning runs and are much larger than any eulachon caught anywhere in the nearby ocean. However, retention of teeth in significant numbers of spawning eulachon in the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003), indicates that some of these fish may survive spawning, return to the sea, and begin feeding again. Teeth retention rates in spawning eulachon in the Twentymile River were 84% and 97% for females, and 3% and 32% for males in 2000 and 2001, respectively (Spangler 2002, Spangler et al. 2003).

Although age determination in eulachon has not been validated (see above discussion in the Age Composition subsection, p. 35), Lewis et al. (2002) examined age composition as estimated from otolith increments of prespawning eulachon captured in a fishery and postspawning carcasses on the Kemano River and reported that the carcass sample had:

> a greater proportion of fish age 5 years [than did the prespawning sample] (31% versus 21%) and a lower proportion age 3 (18% versus 41%) and 4 years (51% versus 38%). Based on these data, we reject the null hypothesis that Kemano River eulachon are semelparous.

However, Clarke et al. (2007) reported that the pattern of seasonal oscillations in barium and calcium deposited in eulachon otoliths (see discussion in Age Composition subsection on page 36) and the lack of a freshwater strontium signal in otoliths of spawners indicate that eulachon are semelparous. Comparison of length frequencies of eulachon at sea and in the Kemano River also indicate that Kemano River eulachon are semelparous, and are estimated to spawn at age 3 (Clarke et al. 2007). Otoliths of eulachon that had spawned in freshwater in a previous season would be expected to show a corresponding decrease in the strontium to calcium ratio representative of this time spent in freshwater; however, this was not evident in otolith samples from any of five river systems (Clarke et al. 2007). Strontium to calcium ratios are much higher in bony structures of fish secreted while in the marine compared to freshwater environment, have been used to detect migration of fish between these two environments in many studies, and can detect exposure to freshwater conditions of as little as 6 hours. This study "supports the hypothesis that [eulachon] are semelparous" (Clarke et al. 2007, p. 1,490).

## Spawn Behavior

### Selection of spawn substrate

Eulachon eggs were reportedly preferentially laid on sand in both the Fraser (McHugh 1940, Hay et al. 2002) and Nass rivers (Langer et al. 1977). Eggs were primarily found attached to pea-sized gravel and only secondarily on sand in the Columbia River (Smith and Saalfeld 1955). Eggs laid in areas of silt or organic debris reportedly suffer much higher mortality than those laid over sand or gravel (Langer et al. 1977). Although eulachon eggs are most commonly laid on a sand substrate, eggs have been found on silt, gravel to cobble–sized rock, and organic detritus (Smith and Saalfeld 1955, Langer et al. 1977, Vincent-Lang and Queral 1984, Lewis et al. 2002).

### Estuary spawning

Based on movements of adult eulachon tracked with gastrically implanted radio tags in the Twentymile River, Spangler (2002) and Spangler et al. (2003) speculated that a portion of the eulachon population in this river may have spawned in the estuary. Some tagged fish moved in and out of the lower river and did not move upstream of the tagging site. Spangler et al. (2003, p. 52) stated that "if fish are capable of spawning in the estuary, larval sampling [and thus abundance estimation methodology] could be missing a segment of the population leading to erroneous results." However, Armstrong and Hermans (2007, p. 4) cite an unpublished study indicating that eulachon egg survival is reduced on exposure to salinities of 16 ppt and greater, and thus successful spawning in estuarine salinities greater than this is unlikely.

### Spawn migration

According to Spangler et al. (2003, p. 2), "There are no consistently reported environmental factors known to influence spawning run timing of adult eulachon throughout their range." These factors include water temperature, tide height, and river discharge rates (Spangler 2002, Spangler et al. 2003). However, both water temperature and river discharge rate are cited as factors that may initiate upriver migration of eulachon in local river basins (Ricker et al. 1954, Smith and Saalfeld 1955, Langer et al. 1977).

**Spawn temperature**

It is apparent that "the temperature at which eulachon spawning runs commence varies by geographic area" (Spangler 2002, p. 71); however, a clear pattern is not readily discernible. Columbia River eulachon are reported to spawn at temperatures between 4ºC and 10ºC and that the spawning migration is inhibited at temperatures less than 4ºC (WDFW and ODFW 2001). In 2001, most eulachon avoided the Columbia River until mid-February when the temperature rose above 4ºC (Howell et al. 2001). Spawning in the Fraser River reportedly occurs "at temperatures exceeding 6 or 7ºC whereas temperatures in northern rivers, which sometimes are ice covered during spawning, are much lower" (Hay et al. 2003, p. 2). Mean, minimum, and maximum water temperatures during spawning in the Kemano River in March-April between 1992 and 1998 were 3.1ºC, 1.1ºC, and 6.5ºC, respectively (Lewis et al. 2002). Langer et al. (1977, p. 18) reported that "1971 temperature records from the Nass [River] indicated that peak [eulachon] migration was occurring at temperatures as low as 0–1°C." During the 8-day peak eulachon migration in the Nass River in 1971, the mean daily water temperature ranged from 0.3 to 2.0°C (Langer et al. 1977, their Table 6). Temperature at the onset of the eulachon run in the Twentymile River, Alaska, ranged 2.8–6.0°C (Spangler 2002, Spangler et al. 2003); however, over the entire spawning run temperatures varied "from 1.6°C to 12.7°C in 2000 and from 0.5°C to 10.7°C in 2001" (Spangler et al. 2003, p. 28). Eulachon spawned in the Susitna River, Alaska, in 1982 and 1983 when temperatures ranged about 6–11°C (Barrett et al. 1984, Vincent-Lang and Queral 1984).

**Spawning under ice**

Swan (1881, p. 260) stated that eulachon arrive in the Nass River "about the time the ice begins to break up" and that in "some years the ice remains solid until after the fish are caught, in which case holes have to be cut in the ice to put down the nets." Langer et al. (1977, p. 43) documented this under-ice eulachon fishery on the Nass River in 1969 and stated that "adult migration occurs at colder river temperatures than previously recorded." Hay and McCarter (2000) also noted that spawning may occur under the ice in some northern British Columbia rivers. Eulachon reportedly migrate, and presumably spawn, under the ice on the Unuk River in Southeast Alaska, and this under-ice migratory behavior may have also occurred in the past on the Twentymile River in Southcentral Alaska (Spangler 2002, Spangler et al. 2003). Flory (2008b) reported that in April 2006 on the Taku River in Southeast Alaska, "eulachon schools were observed up river [before ice break up], indicating the fish moved underneath the ice [to] access spawning grounds (E. Jones, pers. comm.)."

**Spawning at night or under low light levels**

Several authors indicate that eulachon mainly spawn at night (Smith and Saalfeld 1955, Parente and Snyder 1970, Lewis 1997) or under low light conditions (Spangler 2002), and this has been suggested as possible predator avoidance behavior (Spangler et al. 2003). Smith and

Saalfeld (1955) reported that captive eulachon always deposited eggs at night, and when partially spent eulachon were captured at night in the Cowlitz River, freshly deposited eggs were sampled on the river bottom the next morning. Lewis et al. (2002, p. 74) reported that "female eulachon migrated into the [Kemano] river to spawn in darkness on high tides, retreating by day to the lower river" and that egg drift was greatest at night in the Kemano River.

#### Tidal level during spawning

Periods of low river discharge and high tides are associated with peak adult eulachon migration in both the Nass River, British Columbia (Langer et al. 1977), and the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003). Higgins et al. (1987, p. 6) were unable to discriminate between interacting effects of light and tide on eulachon migration in the Fraser River but did note that fishing success was best "at dusk on the high slack tide." Lewis et al. (2002) also suggested that eulachon spawning may be tied to nighttime high tides, and noted that "higher tides reduced water velocity, allowing eulachon to swim further upstream."

#### Flow velocity and depth during spawning

In the Kemano River, British Columbia, eulachon preferred water velocities from 0.1 to 0.7 m/s (Lewis et al. 2002). Earlier studies on Kemano eulachon indicated that many eulachon are unable to maintain long-term position in the stream at flow velocities greater than 0.3 m/s (Lewis et al. 2002). In the Susitna River, Alaska, "water velocities ranging from 0.5 to 2.5 feet/s [0.2–0.8 m/s] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

McHugh (1940) found the heaviest concentration of eulachon eggs in the Fraser River at a depth of 25 feet (7.6 m). Likewise, Langer et al. (1977) reported eggs to be more abundant at depths greater than 4 m than in shallower waters in the Nass River, British Columbia. In the Columbia River, larval eulachon were recovered in waters from 3 inches (0.1 m) to more than 20 feet (6.1 m) in depth and spent adults have been caught as deep as 75 feet (22.9 m) (Smith and Saalfeld 1955). However, eulachon may live long enough after spawning to be swept far downstream from the spawning grounds, so the presence of spent eulachon may not indicate that spawning occurred in the vicinity. In the Kemano River, British Columbia, eulachon preferred depths between 0.5 and 2.3 m, but used available habitat from 0.2 to more than 4 m in depth (Lewis et al. 2002). In the Susitna River, Alaska, "depths ranging from 0.5 to 3.0 feet [0.2–0.9 m] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

## Trophic Interactions

### Diet

Larval and juvenile eulachon are planktivorous (WDFW and ODFW 2001). Barraclough (1967) and Robinson et al. (1968b) examined stomach contents of larval (5–15 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June of 1966 and 1967, respectively. Although 5–8 mm FL larvae still possessed a yolk sac, larvae as small as 6 mm FL had fed on copepod nauplii. Other stomach contents of larval (≤15 mm FL) eulachon in the Strait of Georgia included phytoplankton, centric diatoms, copepod metanauplii, copepod eggs, barnacle eggs, rotifers, cladocerans (*Podon* sp.), ostracods, and polychaete larvae (Barraclough 1967, Robinson et al. 1968b).

Barraclough (1967), Barraclough and Fulton (1967), and Robinson et al. (1968a, 1968b) examined stomach contents of postlarval and juvenile (20–69 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June 1966, July 1966, May 1967, and June 1967. Stomach contents of eulachon in the Strait of Georgia included phytoplankton, barnacle eggs, barnacle nauplii, copepod eggs, copepod nauplii, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Acartia* sp., *Microcalanus pygmaeus*, *Calanus* sp.), cladocerans, ostracods, mysiids, larvaceans (*Oikopleura* sp.), and in one case a larval eulachon (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968a, 1968b). Larger specimens of eulachon (91–157 mm FL) collected in the Strait of Georgia had consumed barnacle eggs, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Calanus* sp.), cladocerans, and gammaridean amphipods (Robinson et al. 1968a, 1968b).

Smith and Saalfeld (1955, p. 12) stated that the only recognizable prey found in stomachs of adult eulachon captured off Washington in 1948 were abundant "remains of the cumacean, *Cumacea dawsoni*." Other authorities have reported that juvenile and adult eulachon eat primarily "euphausiids and copepods" (Hart 1973, p. 149) or "euphausiids, crustaceans, and cumaceans" (Scott and Crossman 1973, p. 323). Hay (2002, p. 100) stated that "eulachon stomachs from offshore waters indicate that [they] mainly consume the euphausiid *Thysanoessa spinifera*." Yang et al. (2006) examined the stomach contents of 39 eulachon from a single haul in the Gulf of Alaska in 2001 that ranged in size from 160 to 210 mm FL. Food items and their percent of total stomach content weight included mysids (2.7%), cumaceans (2.1%), hyperiid amphipods (5.9%), the euphausiid *T. inermis* (25.8%), other euphausiids (40.8%), larvaceans (1.7%), teleost fish (13.8%), undetermined fish remains (2.6%), and unidentified material (4.6%) (Yang et al. 2006).

## Predators

### Marine mammals

Numerous pinnipeds prey on eulachon both at sea and during eulachon spawning runs, including: 1) Stellar sea lions (*Eumetopias jubatus*) (Beach et al. 1981, 1985, Jeffries 1984, Bigg 1988, Marston et al. 2002, Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009), 2) California sea lions (Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984), 3) northern fur seals (*Callorhinus ursinus*) (Clemens et al. 1936, Spalding 1964, Antonelis and Fiscus 1980, Antonelis and Perez 1984), and 4) harbor seals (Fisher 1947, 1952, Spalding 1964, Pitcher 1980, Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984, Roffe and Mate 1984, Olesiuk 1993, Marston et al. 2002). Other nonpinniped marine mammal predators on eulachon include baleen whales, beluga whales (*Delphinapterus leucas*) (Moore et al. 2000, Rugh et al. 2000, Speckman and Piatt 2000), humpback whales (*Megaptera novaeangliae*) (Marston et al. 2002, Witteveen et al. 2004), killer whales (*Orcinus orca*), harbor porpoises (*Phocoena phocoena*) (Jeffries 1984), Dall's porpoises (*Phocoenoides dalli*) (Kajimura et al. 1980, Stroud et al. 1981, Jeffries 1984), and white-sided dolphins (*Lagenorhyncus obliquidens*) (Morton 2000).

## Birds

Numerous authors (WDFW and ODFW 2001, Spangler 2002, Willson and Marston 2002, Marston et al. 2002, Maggiulli et al. 2006) report large numbers of gulls (*Larus* spp.), terns (*Sterna* spp.), ducks (Anatidae), bald eagles (*Haliaeetus leucocephalus*), shorebirds (Scolopacidae), corvids, and other birds feeding on live and dead eulachon during spawning events. Documented bird predators on spawning aggregations of eulachon in various river systems are summarized in Table A-10.

Ormseth et al. (2008, their Table 2) listed the estimates of eulachon contribution to seabird diets (percent weight of eulachon in the predator's diet) based on a mass-balance ecosystem model derived from predator diet data in the Gulf of Alaska for the following birds: kittiwakes (*Rissa* spp.) (4.3%), murres (*Uria* spp.) (3.0%), puffins (*Fratercula* spp.) (6.1%), cormorants (*Phalacrocorax* spp.) (3.0%), gulls (*Larus* spp.) (8.2%), shearwaters (*Puffinus* spp.) (5.0%), and albatross/jaeger (3.5%).

## Fish

Numerous fish species have been recorded as consuming eulachon, including spiny dogfish (*Squalus acanthias*) (Chatwin and Forrester 1953, Jones and Geen 1977), green sturgeon (*Acipenser medirostris*) (Fry 1979), Pacific cod (*Gadus macrocephalus*) (Hart 1949, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), walleye pollock (Yang 1993, Yang and Nelson 2000, Yang et al. 2006), Pacific halibut (*Hippoglossus stenolepis*) (Scott and Crossman 1973, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), sablefish (Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006), Pacific hake (Alton and Nelson 1970, Outram and Haegele 1972, Livingston 1983, McFarlane and Beamish 1985, Rexstad and Pikitch 1986, Buckley and Livingston 1997, Buckley et al. 1999), rougheye rockfish (*Sebastes aleutianus*) (Yang and Nelson 2000), and arrowtooth flounder (*Atheresthes stomias*) (Kabata and Forrester 1974, Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006).

Larval and juvenile eulachon have also been reported to be the occasional prey of Pacific herring, surf smelt, Pacific sand lance, kelp greenling (*Hexagrammos decagrammus*), threespine stickleback (*Gasterosteus aculeatus*), steelhead (*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*) salmon in the Strait of Georgia (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968b). Juvenile white sturgeon (*Acipenser transmontanus*) in the Columbia River are known to consume large quantities of eulachon eggs during spawning events (McCabe et al. 1993). Marston et al. (2002) reported that coho salmon and Dolly Varden (*Salvelinus malma*) may also feed on eulachon eggs and larvae. In addition, juvenile eulachon may occasionally consume larval eulachon (Barraclough 1967, p. 26).

## Other predators

Marston et al. (2002) noted that terrestrial mammals such as bears (*Ursus* spp.), wolves (*Canis lupus*), river otters (*Lontra canadensis*), and mink (*Mustela vison*) likely prey on eulachon either during or after spawning events.

### Parasites

Compilations of parasites and fish hosts in British Columbia (Margolis and Arthur 1979, Kabata 1988, McDonald and Margolis 1995, Gibson 1996) listed two trematodes (*Pronoprymna petrowi* and *Lecithaster gibbosus*), a cestode (*Phyllobothrium* sp.), a nematode (*Contracaecum* sp.), and a parasitic pennellid copepod (*Haemobaphes disphaerocephalus*) as known parasites on eulachon. The trematode *L. gibbosus* was found in stomachs of juvenile eulachon collected in the Strait of Georgia with 29–59 mm FL (Robinson et al. 1968a, 1968b, Barraclough 1967). Similarly, the trematode *P. petrowi* was found in the stomachs of juvenile eulachon collected in the Strait of Georgia with 32–38 mm FL (Barraclough 1967). Arai (1967, 1969) reported the trematode *L. gibbosus*, a larval cestode *Phyllobothrium* sp, and a larval nematode *Contracaecum* sp. in eulachon from Burke Channel, an inlet on the south mainland coast of British Columbia. Hoskins et al. (1976) reported the occurrence of the parasitic copepod *Haemobaphes diceraus* on a eulachon host, from Port Hardy on Vancouver Island, British Columbia. Kabata (1988) and McDonald and Margolis (1995) described another pennellid copepod (*H. disphaerocephalus*) as parasitic on eulachon from British Columbia. Kabata (1988) noted that the report of *H. diceraus* infecting eulachon by Hoskins et al. (1976) occurred before *H. disphaerocephalus* was described as a separate species. The pennellid copepods in the genus *Haemobaphes* attach themselves headfirst to the bulbous arteriosus of the host fish with the body protruding from the gill arch (McDonald and Margolis 1995).

## Information Relating to the Species Question

### Approaches to Addressing Discreteness and Significance

The BRT considered several kinds of information to delineate potential DPS structure in eulachon. To address the discreteness criteria, the BRT primarily considered patterns of genetic variation among eulachon sampled from various locations along the coast, patterns of variation in life history and morphology, and ecological and environmental differences between eulachon populations. Comparison of spawning distribution, spawn timing, meristic variation in vertebral counts, elemental analysis of otoliths, and genetic variation have also been cited as evidence for stock discrimination in eulachon (Hay and McCarter 2000, Beacham et al. 2005, Hay and Beacham 2005). For the significance criteria, the BRT focused primarily on ecological differences among populations and on whether loss of such populations would create a significant gap in the range of the species.

#### Life history and morphology

Isolation between populations may be reflected in several variables, including differences in life history variables (e.g., spawning timing, seasonal migrations), spawning location, parasite incidence, growth rates, morphological variability (e.g., morphometric and meristic traits), and demography (e.g., fecundity, age structure, length and age at maturity, mortality rates), among others. Although some of these traits may have a genetic basis, they are usually also strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and can sometimes be used to infer the degree of independence among populations or subpopulations. Begg et al. (1999) have emphasized the necessity to examine the temporal stability of life history characteristics in order to determine whether differences between populations persist across generations.

### Persistence of spawn location and spawn timing

Eulachon generally spawn in rivers that are glacier fed or have peak spring freshets. It has been argued that the rapid movement of eggs and larvae by these freshets to estuaries makes it likely that eulachon imprint and home to an estuary into which several rivers drain rather than to individual spawning rivers (McCarter and Hay 1999, Hay and McCarter 2000). Thus the estuary has been invoked as the likely geographic stock unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005) (Table A-1).

Variation in spawn timing among rivers has been cited as indicative of local adaptation in eulachon (Hay and McCarter 2000), although the wide overlap in spawn timing and river entry timing among rivers makes it difficult to discern distinctive geographic patterns in this trait. In general, eulachon spawn earlier in southern portions of their range than in rivers to the north. River entry and spawning begins as early as December and January in the Columbia River system and as late as June in Southcentral Alaska (Table A-9, Figure 5, and Figure 6). However, they have been known to spawn as early as January in rivers on the Copper River delta of Alaska and as late as May in northern California. The general spawn timing pattern is reversed along the coast of British Columbia, where the earliest spawning occurs in the Nass River in the far north in February to early March and the latest spawning occurs in the Fraser River in April and May in the far south (Table A-9, Figure 5). There is also some evidence that different waves or runs of eulachon may occur in some basins, based on run-time separation (Table A-9).

These differences in spawn timing result in some populations spawning when water temperatures are as low as 0–2°C, and sometimes under ice (Nass River, Langer et al. 1977), whereas other populations experience spawning temperatures of 4–7°C (Cowlitz River, Smith and Saalfeld 1955) (Table A-11).

### Morphology

Differences in the mean number of vertebrae in eulachon from northern and southern rivers in British Columbia have been cited as indicative of population separation (Hart and McHugh 1944, Hay and McCarter 2000), although no differences were evident in population means between the Fraser and Columbia rivers (Hay and McCarter 2000) (Figure 7). However, meristic differences such as these can vary with environmental conditions and it is impossible to determine the underlying causes of these differences from the available data. It has often been shown that the number of vertebrae formed during early development is subject to modification by temperature such that the average vertebral number in fish populations is greater in the northern versus the southern portion of the range and the mean vertebral number in a population may also vary from year to year within a population (McHugh 1954, Waldman 2005). In addition, morphometric and meristic differences between groups of fish are often subtle and relating such differences to a specific degree of isolation among populations can be difficult.

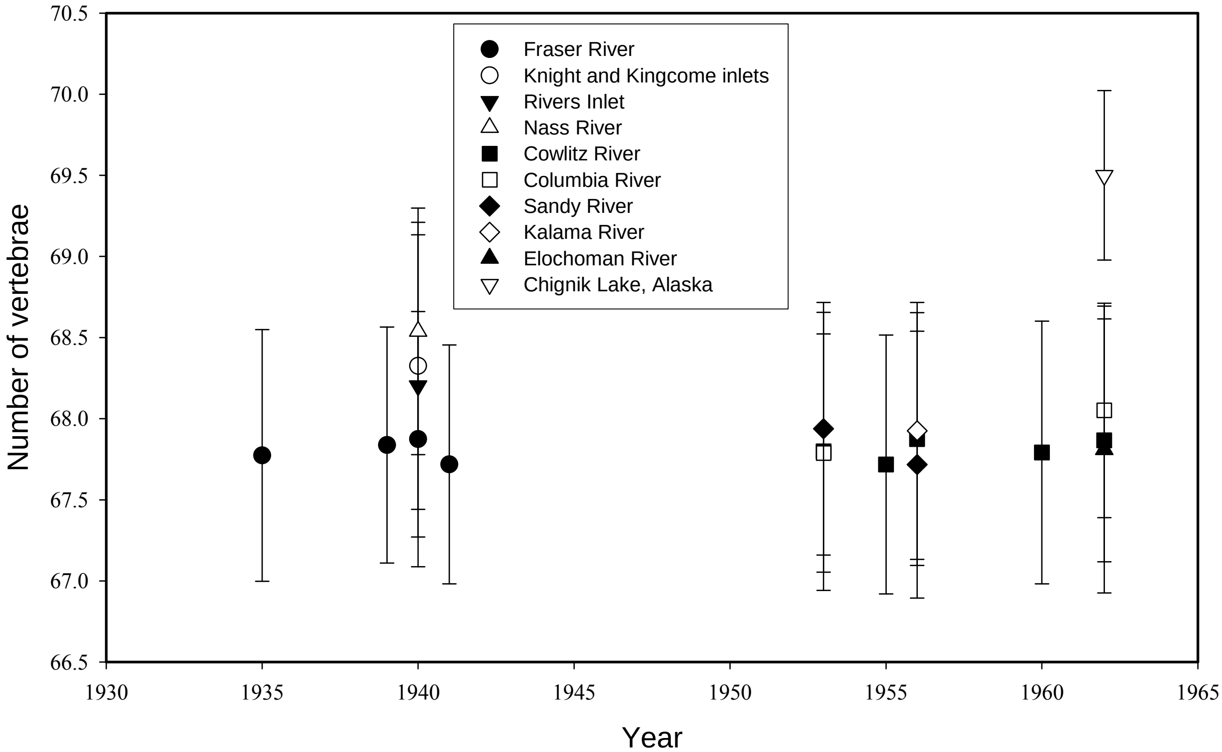



Figure 7. Comparison of mean and standard deviations of eulachon vertebral counts in various rivers. Data from DeLacy and Batts (1963) for the Columbia River, its tributaries, and Chignik Lake. Data from Hart and McHugh (1944) for rivers in British Columbia.

Coastwide, there appears to be an increase in both mean length and weight of eulachon at maturity with an increase in latitude (Table A-7, Table A-8, and Figure 8). Mean eulachon fork length and weight at maturity range from upwards of 215 mm and 70 g in the Twentymile River in Alaska to 175 mm and 37 g in the Columbia River. Although eulachon obtain a larger body size in the northern portion of their range compared to populations in the south, this relationship may be somewhat obscured by problems associated with the ageing of this species (Hay and McCarter 2000). Most Pacific herring also exhibit a latitudinal cline in mean size-at-age, such that Pacific herring in southern locations (e.g., California) exhibit small size and Pacific herring in the north (e.g., Bering Sea) obtain a far larger size at a similar age (Stout et al. 2001a, Gustafson et al. 2006). This pattern is typical of many vertebrate ectotherms where higher rearing temperatures result in reduced size at a given stage of development (Lindsey 1966, Atkinson 1994).

### Otolith chemistry

Hay and McCarter (2000) and Hay and Beacham (2005) reported on attempts to use differences in the elemental makeup of eulachon otoliths (earbones) to detect stock structure among various rivers on the coast of British Columbia. Significant variation occurred in the elemental analysis associated with the date of the laboratory elemental analysis. Despite these sources of potential error, the results indicated that there were differences in the elemental

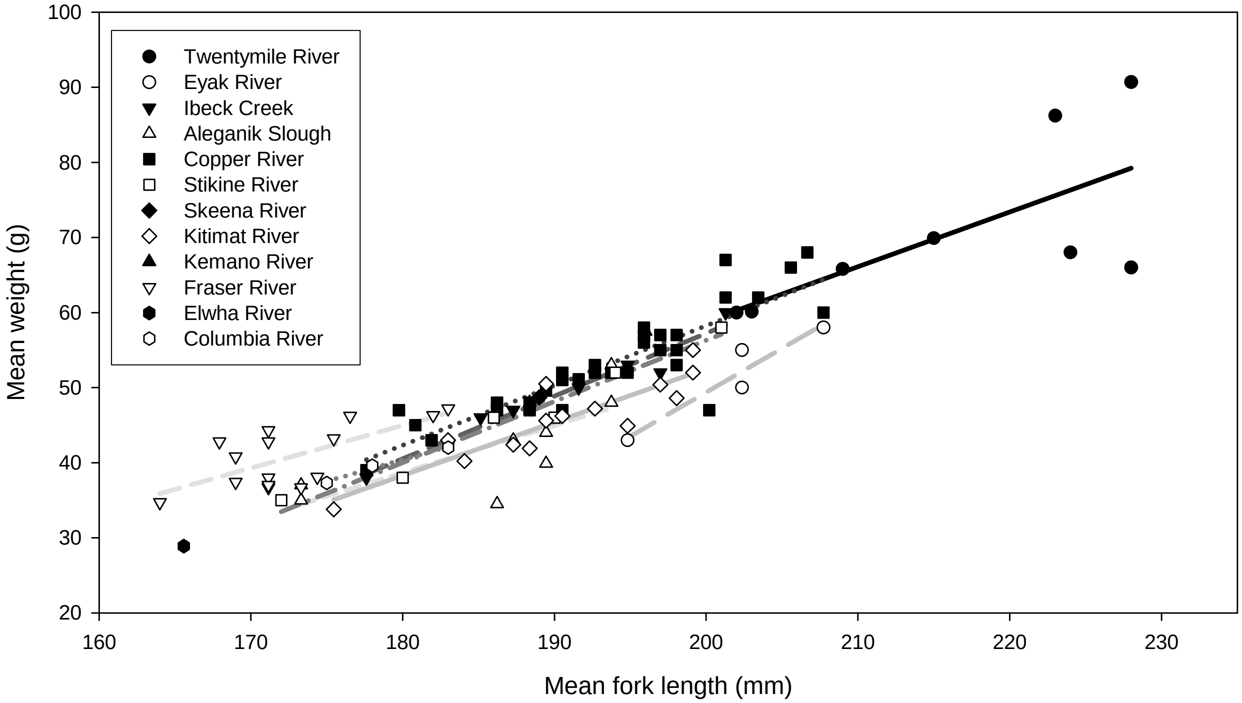



Figure 8. Length-weight relationship of eulachon from various rivers. Standard linear regressions fit the data to lines for each population that has multiple observations. Standard lengths and total lengths have been converted to fork length using equations published in Buchheister and Wilson (2005).

composition of eulachon otoliths over a broad geographic range, but that "elemental analysis was not useful to distinguish between closely adjacent stocks" (Hay and Beacham 2005, p. 10).

## Age composition

Age determination of eulachon has been difficult to validate and estimates of age based on otolith or scale increments may not be accurate (Ricker et al. 1954, Hay and McCarter 2000). However, in general, studies using otolith aging techniques have concluded that some eulachon spawn at age 2 or age 5, but most are age 2 or age 3 at spawning (Willson et al. 2006). Recently, Clarke et al. (2007) pioneered a method to estimate eulachon age at spawning from analysis of variations in barium and calcium in the otoliths. This study indicated that age structure of spawners in the southern areas may be limited to one, or at most, two year classes (Clarke et al. 2007). According to Clarke et al. (2007):

> The number of Ba:Ca peaks measured in the eulachon populations varied; eulachon captured in Barkley Sound, located off the west coast of Vancouver Island (ocean), had 1.5 and 2.5 peaks, Fraser River eulachon were all characterized by 3 peaks, and Columbia River eulachon exhibited 2 or 3 peaks. All of the fish in the Kemano and Skeena rivers examined were characterized by 3 peaks in Ba:Ca with the exception of two Skeena River fish that had 4 peaks. Fish collected from the Copper River in Alaska had 3 or 4 peaks. The number of

peaks in Ba:Ca observed in eulachon otoliths increased with increasing latitude, suggesting that the age at maturity is older for northern populations.

## Genetic differentiation

The analysis of the geographical distribution of genetic variation is a powerful method of identifying discrete populations. In addition, such analysis can sometimes be used to estimate historical dispersals, equilibrium levels of migration (gene flow), and past isolation. Commonly used molecular genetic markers include protein variants (allozymes), microsatellite loci (variable numbers of short tandem DNA repeats), and mtDNA.

One widely used method of population analysis is sequence or restriction fragment length polymorphism (RFLP) analysis of mtDNA, which codes for several genes that are not found in the cell nucleus. mtDNA differs from nuclear DNA (nDNA) in two ways. One way is that recombination is lacking in mtDNA, so that gene combinations (haplotypes) are passed unaltered from one generation to the next, except for new mutations. A second way is that mtDNA is inherited from only the maternal parent in most fishes, so that gene phylogenies correspond to female lineages. These characteristics permit phylogeographical analyses of mtDNA haplotypes, which can potentially indicate dispersal pathways for females and the extent of gene flow between populations (Avise et al. 1987). Although the lack of recombination allows for some types of analysis that are difficult to conduct with other markers (e.g., microsatellites), inferences of population structure (or lack thereof) from mtDNA are limited by the fact that the entire mitochondrial genome is inherited genetically as a single locus. Mitochondrial studies are therefore most useful for detecting deep patterns of population structure, and may not be very powerful for detecting structure among closely related populations.

Microsatellite DNA markers can potentially detect stock structure on finer spatial and temporal scales than can other DNA or protein markers, because of higher levels of polymorphism found in microsatellite DNA (reflecting a high mutation rate). Relatively high levels of variation can increase the statistical power to detect stock structure, particularly among closely related populations. In addition, microsatellite studies usually involve analysis of multiple genetic loci, which increases the power to detect differentiation among populations.

The BRT reviewed four published genetic studies of genetic population structure in eulachon. One of these studies (McLean et al. 1999) used RFLP analysis to examine variation in mtDNA. The other studies (McLean and Taylor 2001, Kaukinen et al. 2004, Beacham et al. 2005) analyzed microsatellite loci. Additional detail on two of these studies can be found in McLean (1999).

McLean et al. (1999) examined mtDNA variation in two fragments (each containing two genes NADH-5/NADH-6 and 12S/16S rRNA) in 285 eulachon samples collected at 11 freshwater sites ranging from the Columbia River to Cook Inlet, Alaska, and also in 29 ocean-caught fish captured in the Bering Sea. Samples were taken at two sites (Columbia and Cowlitz rivers) in two years and all other locations were sampled in single years. Overall, 37 mtDNA composite haplotypes were observed in the study. Two haplotypes were found in all sampling locations and together accounted for approximately 67% of the samples in the study. Eight additional haplotypes were present at multiple sites and the remaining 27 haplotypes were "private" (found only in one location).

An analysis of the nucleotide substitutions separating the 37 haplotypes revealed that the haplotypes were all closely related, with the number of substitutions ranging between 1 and 13. The mtDNA haplotypes clustered into two major groups and the frequencies of the two haplotype groups differed among sampling sites, particularly in the Alaska and Bering Sea collections compared to samples from further south, although these differences were not statistically significant. Approximately 97% of mtDNA variation occurs within populations and about 2% is found among regions ($F_{ST} = 0.023$). McLean et al. (1999) also found that genetic distance among sampling locations was correlated with geographic distance ($r^2 = 0.22$, $P = 0.0001$). Based on these results, McLean et al. (1999) concluded that there was little genetic differentiation among distinct freshwater locations throughout the eulachon range. However, McLean et al. (1999) noted that association of geographic distance and genetic differentiation among eulachon populations suggested an emerging population subdivision throughout the range of the species.

In a later study, McLean and Taylor (2001) used five microsatellite loci to examine variation in the same set of populations as McLean et al. (1999). The populations in the Columbia and Cowlitz rivers were represented by 2 years of samples with a total sample size of 60 fish from each river. However, several populations were represented by very few samples including just 5 fish from the 3 rivers in Gardner Canal and just 10 fish from the Fraser River. Results from a hierarchical analysis of molecular variance test were similar to that of the McLean et al. (1999) mtDNA study, with 0.85% of variation occurring among large regions and 3.75% among populations within regions.

Tests of differentiation were significant among several pairs of populations in the microsatellite study (27% of tests after correction for multiple comparisons), particularly comparisons that included populations in the Columbia and Cowlitz rivers and those with the Nass River sample and samples taken further south. $F_{ST}$ (a commonly used metric to evaluate population subdivision) was estimated as 0.047 when sample sites were considered separately, and was significantly different from zero. In contrast to the mtDNA analysis, genetic distances among populations using these five microsatellite loci were not correlated with geographic distances. Overall, however, McLean and Taylor (2001) concluded that their microsatellite results were mostly consistent with the mtDNA findings of McLean et al. (1999) and that both studies indicated that eulachon have some degree of population structure.

The most extensive study of eulachon, in terms of sample size and number of loci examined, is that of Beacham et al. (2005). Beacham et al. (2005) examined microsatellite DNA variation in eulachon collected at 9 sites ranging from the Columbia River to Cook Inlet, Alaska, using the 14 loci developed by Kaukinen et al. (2004). Sample sizes per site ranged from 74 fish in the Columbia River to 421 from the Fraser River. Samples collected in multiple years were analyzed from populations in the Bella Coola and Kemano rivers (2 years of sampling) and also in the Nass River (3 years of sampling).

Beacham et al. (2005) observed much greater microsatellite diversity within populations than that reported by McLean and Taylor (2001) and all loci were highly polymorphic in all of the sampled populations. Significant genetic differentiation was observed among all comparisons of the nine populations in the study and $F_{ST}$ values for pairs of populations ranged from 0.0014 to 0.0130. A cluster analysis of genetic distances showed genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples being approximately 3–6 times more divergent from samples further to the north than they were to each other (Figure 9). Similar to the mtDNA study of McLean et al. (1999), Beacham et al. (2005) also found that genetic differentiation among populations ($F_{ST}$) was correlated with geographic distances (r = 0.34, $P < 0.05$).

Beacham et al. (2005) found stronger evidence of population structure than the earlier genetic studies, and concluded that their results indicated that management of eulachon would be appropriately based at the level of the river drainage. In particular, the microsatellite analysis showed that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels. The authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish, but less than that observed in most salmon species.

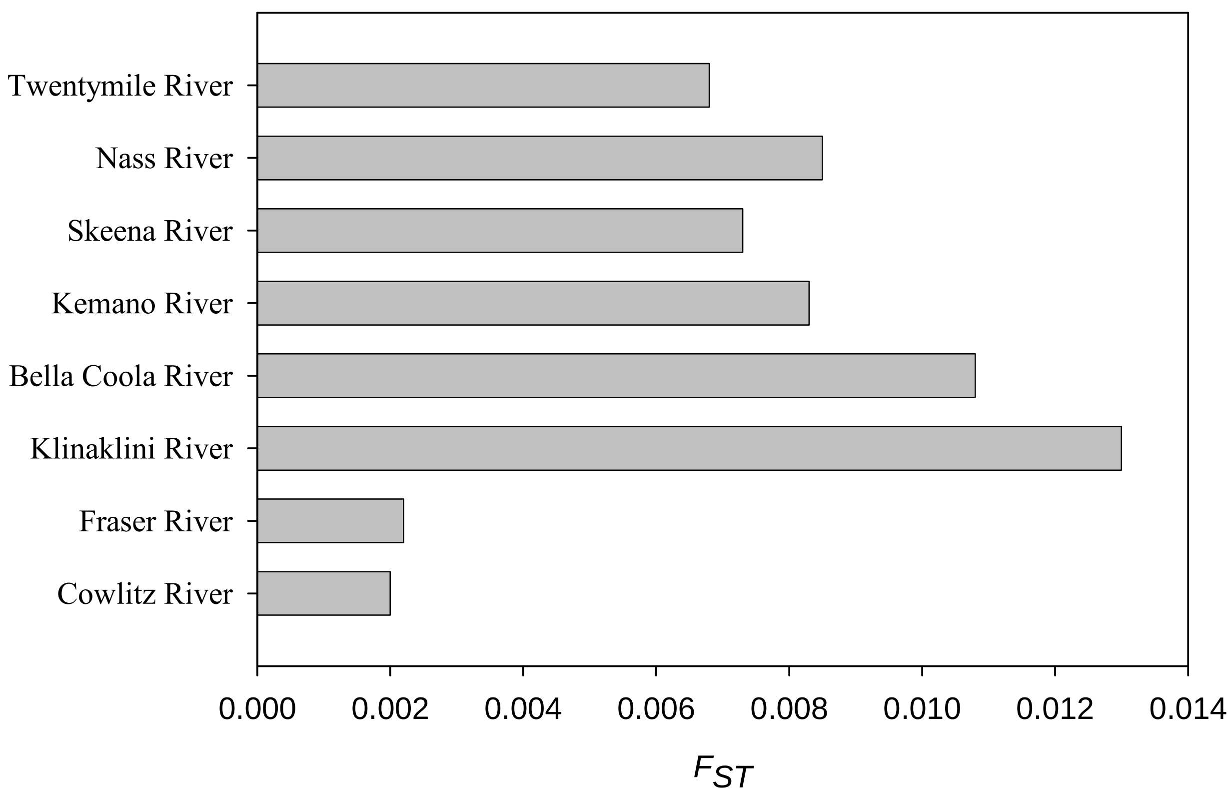



Figure 9. Comparison of $F_{ST}$ (a measure of genetic distance) values of the Columbia River eulachon sample to other samples. Data are from Beacham et al. (2005, their Table 4). See Beacham et al. (2005, their Figure 1) for sampling locations.

Although Beacham et al. (2005) found clear evidence of genetic structure among eulachon populations, the authors also noted that important questions remained unresolved. The most important one in terms of identifying a DPS or DPSs for eulachon is the relationship between temporal and geographic patterns of genetic variation. In particular, Beacham et al. (2005) found that year-to-year genetic variation within three British Columbia coastal river systems was similar to the level of variation among the rivers, which suggests that patterns among rivers may not be temporally stable. However, in the comparisons involving the Columbia River samples, the variation between the Columbia samples and one north-of-Fraser sample from the same year was approximately five times greater than a comparison within the Columbia from two different years. Taken together, there appears to be little doubt that there is some genetic structure within eulachon and that the most obvious genetic break appears to occur in southern British Columbia north of the Fraser River. To fully characterize genetic relationships among eulachon populations, additional research will be needed to identify appropriate sampling and data collection strategies.

### Ecological features

The analysis of ecological features or habitat characteristics may be informative in identifying population segments that occupy unusual or distinctive habitats, relative to the biological species as a whole. One of the criteria that may be useful for evaluating discreteness as articulated in the joint DPS policy (USFWS-NMFS 1996) relates to the population being "markedly separated from other populations of the same taxon as a consequence of … ecological … factors." In addition, the persistence of a discrete population segment in an ecological setting unusual or unique for the taxon is also a factor identified in the joint DPS policy that may provide evidence of the population's significance. Oceanographic and other ecological features may also contribute to demographic isolation between marine populations.

**Freshwater (spawning) environment**—The presumed fidelity with which eulachon return to their natal river, estuary, inlet, or area implies a close association between a specific stock and its freshwater or estuarine environment. Differences in life history strategies among eulachon populations or stocks may have arisen, in part, in response to selective pressures of different freshwater and estuarine environments. If the boundaries of distinct freshwater or estuarine habitats coincide with substantial differences in life histories, it would suggest a certain degree of local adaptation. Therefore, identifying distinct freshwater, terrestrial, and climatic regions may be useful in identifying eulachon DPSs.

The Environmental Protection Agency has established a system of ecoregion designations based on soil content, topography, climate, potential vegetation, and land use for the conterminous United States (Omernik 1987) and Alaska (Gallant et al. 1995). Historically, the distribution of eulachon in Washington, Oregon, and California corresponds closely with the Coastal Range Level III Ecoregions as defined in Omernik and Gallant (1986) and Omernik (1987). Similarly, Environment Canada (2008) has established a system of ecozones and ecoregions in Canada. Ecozones in Canada have been described as "areas of the earth's surface representative of large and very generalized ecological units characterized by interactive and adjusting abiotic and biotic factors." Each ecozone consists of numerous ecoregions that are described as "a part of a province characterized by distinctive regional ecological factors, including climatic, physiography, vegetation, soil, water, fauna, and land use" (Environment Canada 2008).

**Coastal range ecoregions of the United States**—Extending from the Olympic Peninsula through the Coast Range proper and down to the Klamath Mountains and the San Francisco Bay area, this region is influenced by medium to high rainfall levels due to the interaction between marine weather systems and the mountainous nature of the region. Topographically, the region averages about 500 m in elevation, with mountain tops under 1,200 m. These mountains are generally rugged with steep canyons. Between the ocean and the mountains lies a narrow coastal plain composed of sand, silt, and gravel. Tributary streams are short and have a steep gradient; therefore, surface runoff is rapid and water storage is relatively short term during periods of no recharge.

These rivers are especially prone to low flows during times of drought. Regional rainfall averages 200–240 cm per year, with generally lower levels along the southern Oregon coast. Average annual river flows for most rivers in this region are among the highest found on the West Coast when adjusted for watershed area. Peak flow of coastal rivers occurs during winter rain storms common in December and January. Snow melt adds to the surface runoff in the spring, providing a second flow peak (spring freshet), and there are long periods when the river flows are maintained at a level of at least 50% of peak flow. During July or August there is usually little or no precipitation; this period may expand to 2 or 3 months every few years. River flows are correspondingly at their lowest and temperatures at their highest during August and September, with the exception of glacier fed systems. The region is heavily forested primarily with Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Forest undergrowth is composed of numerous types of shrubs and herbaceous plants.

**Terrestrial ecozones and ecoregions of Canada**—All rivers that support regular runs of eulachon in British Columbia are within the Pacific Maritime Ecozone, which consists of 14 ecoregions (Figure 10). The Lower Mainland, Pacific Ranges, and Coastal Gap ecoregions contain rivers supporting regular runs of eulachon as defined in Hay and McCarter (2000) and Hay (2002), and two rivers, the Nass and the Skeena, drain out of the Nass Basin Ecoregion (Environment Canada 2008).

The Lower Mainland Ecoregion (196 in Figure 10) is dominated by the Fraser River and occupies the Fraser River valley from Chilliwack and the Cascade Range foothills downstream to the Fraser River delta and northward from there to incorporate the Sunshine Coast. Mean summer and winter air temperatures in this region are 15°C and 3.5°C, respectively. At sea level, less than 10% of winter precipitation falls as snow, although maximum precipitation occurs in the winter. Mean annual precipitation in the Fraser River valley ranges from 200 cm in the Cascade foothills to 85 cm at the river's mouth. Douglas fir (*Pseudotsuga menziesii*) dominates native forest stands with an understory typically containing hollyleaved barberry, aka tall Oregon grape (*Mahonia aquifolium*), salal (*Gaultheria shallon*), and mosses. Disturbed sites are commonly dominated by stands of red alder (*Alnus rubra*). Drier natural sites consist of mixed stands of Pacific madrone (*Arbutus menziesii*), Douglas fir, western hemlock, and occasionally, Pacific dogwood (*Cornus nuttallii*). Wetter areas contain mixtures of western red cedar, Douglas fir, and western hemlock. Soils consist of unconsolidated clay-like and silty

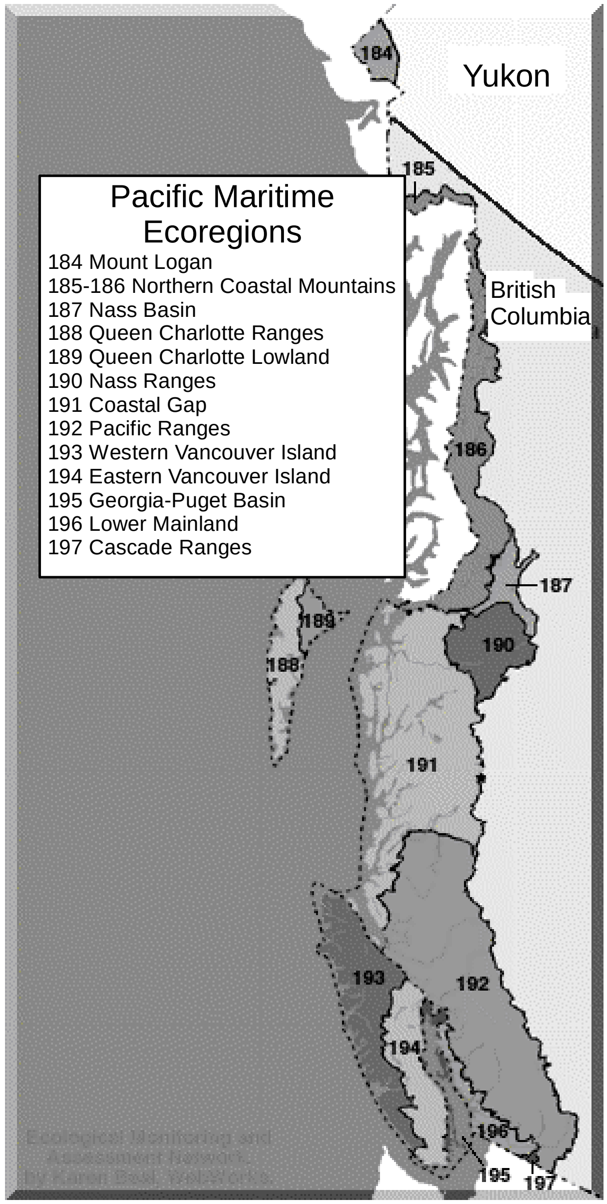



Figure 10. Ecoregions in the Pacific Maritime Ecozone of British Columbia. Map modified from online source: http://ecozones.ca/english/zone/PacificMaritime/ecoregions.html.

marine deposits, silty alluvium, glacial till, and glaciofluvial deposits. Eastern hills in the ecoregion up to 310 m in height are formed from bedrock outcrops of Mesozoic and Paleozoic age.

The Pacific Ranges Ecoregion (192 in Figure 10) extends from the southern extent of the steeply sloping irregular Coast Mountains at the U.S.-Canada border to Bella Coola in the north. These mountains range from sea level to as high as 4,000 m and are made up of granite and crystalline gneisses. Many rivers in this region originate in expansive ice fields, and numerous glaciers extend into the lowlands. Many steep-sided, transverse valleys bisect these mountains and terminate in inlets or fjords. Mean summer and winter air temperatures in this region are

13.5°C and –1°C, respectively. Mean annual precipitation in this ecoregion ranges from 340 cm at high elevations to 150 cm at sea level. This ecoregion consists of three main regions distinguished by altitude: an alpine zone above 1,800 m, a subalpine zone between 900 and 1,800 m, and a coastal forest zone below 900 m. The coastal forest zone is dominated by stands of western red cedar, western hemlock, and Pacific silver fir (*Abies amabilis*) and in drier sites by Douglas fir and western hemlock.

The Coastal Gap Ecoregion (191 in Figure 10) extends from Dean Channel north to the border between British Columbia and Alaska and is bounded by the taller Pacific Ranges to the south and the Boundary Ranges to the north. The low-relief mountains in this ecoregion consist of the Kitimat Ranges, which rarely reach higher than 2,400 m and are made up of granitic rocks and crystalline gneisses. Although many inlets and fjords bisect this mountainous coastline and terminate in steep-sided, transverse valleys, glaciers are less common and smaller than in areas to the south and north of this ecoregion. Mean summer and winter air temperatures are 13°C and –0.5°C, respectively. This ecoregion has the highest mean annual precipitation in British Columbia, ranging from 200 cm on the coast to more than 450 cm at high elevations. At sea level, the forests are dominated by western red cedar, yellow cedar (*Chamaecyparis nootkatensis*), and western hemlock. Some Sitka spruce and shore pine (*Pinus contorta* var. *contorta*) are also present with red alder being common on disturbed sites. Low-lying bogs and stream fens are common types of wetlands. Forests in upland areas are dominated by western red cedar and western hemlock, whereas Pacific silver fir and western hemlock are found in areas with poorer drainage.

The Nass Basin Ecoregion (187 in Figure 10) lies between the interior and coastal portions of the Coast Mountains in west-central British Columbia and is an area of low relief composed of folded Jurassic and Cretaceous sediments that is almost encircled by mountains. The Nass Basin is drained by the Nass and Skeena rivers to the ocean through large gaps in the Coast Mountains and consists of a gently rolling landscape generally below 750 m in altitude. Mean summer and winter air temperatures in this region are 11.5°C and –9.5°C, respectively. Mean annual precipitation ranges up to 250 cm at higher elevations to 150 cm in the lowlands. The moist montane zone is dominated by western red cedar and western hemlock, whereas forests in the subalpine zone contain subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta* var. *latifolia*), and Engelmann spruce (*Picea engelmannii*).

**Oceanic environment**—Ware and McFarlane (1989) built on previous descriptions of oceanic domains in the northeast Pacific Ocean by Dodimead et al. (1963) and Thomson (1981) to identify three principal fish production domains: 1) a southern Coastal Upwelling Domain, 2) a northern Coastal Downwelling Domain, and 3) a central Subarctic Domain (aka the Alaskan Gyre) (Figure 11). The boundary between the Coastal Upwelling Domain and Coastal Downwelling Domain occurs where the eastward flowing Subarctic Current (aka the North Pacific Current) bifurcates to form the north-flowing Alaska Current and the south-flowing California Current in the vicinity of a transitional zone between the northern tip of Vancouver Island and the northern extent of the Queen Charlotte Islands (Figure 11). Similarly, Longhurst (2006) identifies an Alaska Downwelling Coastal Province and a California Current Province within the Pacific Coastal Biome.

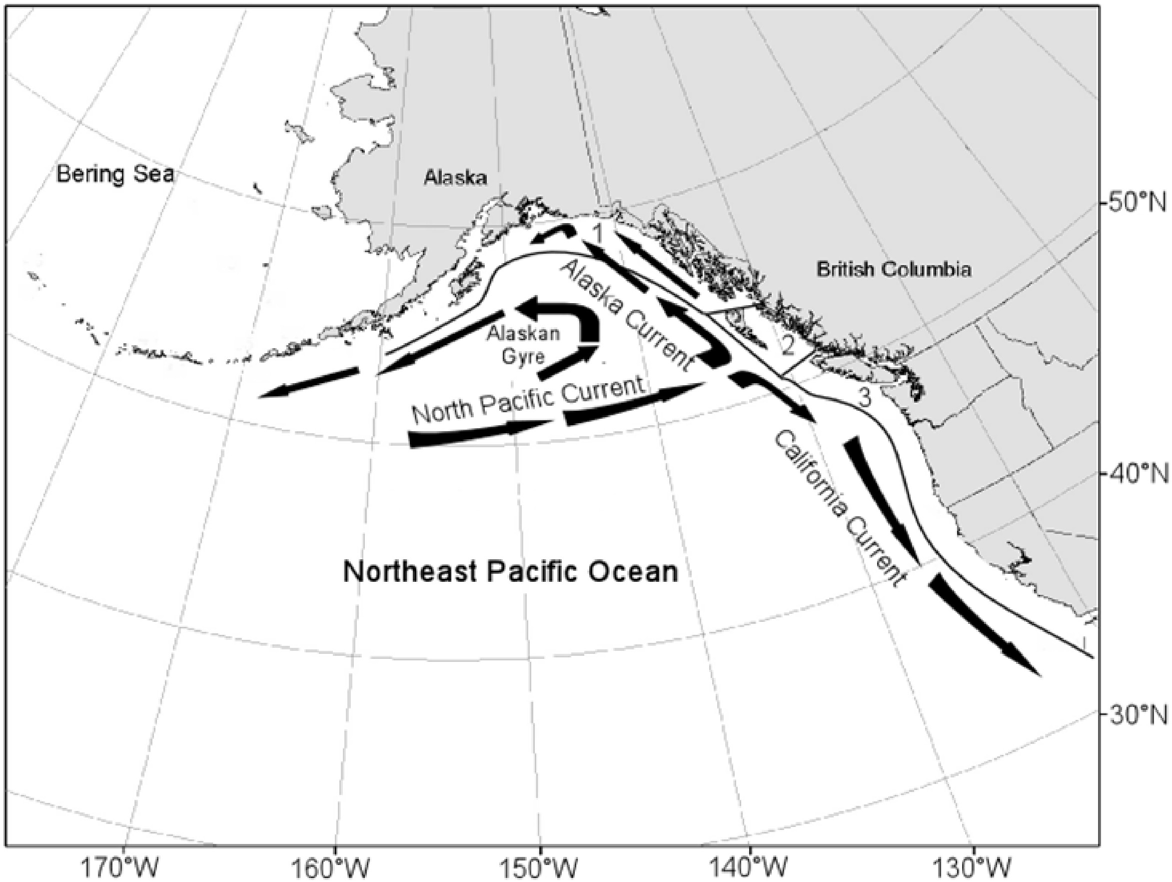



Figure 11. Approximate locations of oceanographic currents, oceanic domains (Ware and McFarlane 1989), and coastal provinces (Longhurst 2006) in the Northeast Pacific Ocean. 1–Alaska Coastal Downwelling Province (aka Coastal Downwelling Domain), 2–Transition Zone, and 3–California Current Province (aka Coastal Upwelling Domain).

Longhurst's (2006) work provides a worldwide ecological geography of the sea that identifies 4 primary oceanic biomes and 51 biogeochemical provinces based mainly on differences in regional physical processes that act on regional patterns of phytoplankton growth that are partially defined by "the interaction between light, nutrients, mixing, and stability in the upper part of the water column." This scheme to partition the ocean into provinces differs from previous attempts by relying on oceanographic features that drive phytoplankton ecology rather than on biogeography of species or water current patterns alone (Longhurst 2006). The steps taken and data analyzed to define biogeochemical provinces in the ocean are detailed in Longhurst (2006).

Within Longhurst's (2006) Pacific Coastal Biome, ocean distribution of eulachon spans the Alaska Downwelling Coastal Province and the northern portion of the California Current Province (Figure 11). Longhurst (2006) places the boundary between the Alaska Coastal Downwelling Province and the California Current Province between the Queen Charlotte Islands at 53°N latitude and the northern end of Vancouver Island at 47–48°N latitude, where the eastward flowing North Pacific Current encounters the North American continent and bifurcates to form the north-flowing Alaska Current and south-flowing California Current. Different modes of physical forcing and nutrient enrichment characterize these provinces.

The Alaska Coastal Downwelling Province spans the coastal boundary region from the Aleutian Islands east and south to the Queen Charlotte Islands (Haida Gwai'i) at about 53°N latitude and extends seaward to the Alaska Current velocity maximum (Longhurst 2006). The continental shelf in this region is dominated by nearly year-round onshore downwelling winds. Large amounts of precipitation and runoff from melting glaciers along the mountainous Alaska coast is another feature of this province. In summer and fall, when runoff is at maximum, waters in the fjord-like coastline and in the Alaska Coastal Current are usually highly stratified in both temperature and salinity. Following the spring phytoplankton bloom, stratification in the top layers of the water column limits nutrient availability and leads to subsequent nutrient depletion. Occasional wind events lead to temporary local upwelling of nutrients and subsequent phytoplankton blooms.

The northern extent of the California Current Province (aka California Upwelling Coastal Province) begins where the eastward flowing North Pacific Current splits near Vancouver Island near 47–48°N latitude, creating the southward flowing California Current and northward flowing Alaska Coastal Current (Longhurst 2006). The southern boundary of this province occurs off the southwest tip of Baja California, where the North Equatorial Current begins. Seasonal wind-driven upwelling is a dominate feature of this province, especially in the northern portion of the province. This process carries nutrients onshore where they are upwelled along the coast, leading to high primary production that lasts through much of the spring and summer. Nearshore upwelling also results in higher salinities and lower temperatures compared to offshore locations.

A widely recognized Transition Pacific Zone (Ware and McFarlane 1989, BC Ministry of Sustainable Resource Management 2002) occurs between the Alaska Coastal Downwelling and California Current provinces whose "northern boundary is indistinct and approximately coincident with the southern limit of the Alaskan Current" (BC Ministry of Sustainable Resource Management 2002, p. 35). This zone is characterized as a mixing area between boreal plankton communities to the north and temperate plankton communities to the south, and incorporates the waters of Queen Charlotte Sound and Hecate Strait (i.e., north of Vancouver Island and inshore of the Queen Charlotte Islands). In the summer, the California Current may affect the southern portion of this transition zone with the inshore Davidson Current flowing south in the summer and north in the winter (BC Ministry of Sustainable Resource Management 2002).

### Marine zoogeographic provinces

Marine zoogeography attempts to identify regional geographic patterns in marine species' distribution and delineate faunal provinces or regions based largely on the occurrence of endemic species and of unique species' assemblages (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988). These province boundaries are usually coincident with changes in the physical environment such as temperature and major oceanographic currents. Similar to the above ecological features category, boundaries between zoogeographic provinces may indicate changes in the physical environment that are shared with the species under review.

Ekman (1953), Hedgpeth (1957), and Briggs (1974) summarized the distribution patterns of coastal marine fishes and invertebrates and defined major worldwide marine zoogeographic zones or provinces. Along the coastline of the boreal eastern Pacific, which extends roughly from Point Conception, California, to the eastern Bering Sea, numerous schemes have been proposed for grouping the faunas into zones or provinces. A number of authors (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988) have recognized a zoogeographic zone within the lower boreal eastern Pacific that has been termed the Oregonian Province.

Another zone in the upper boreal eastern Pacific has been termed the Aleutian Province (Briggs 1974). However, exact boundaries of zoogeographic provinces in the eastern boreal Pacific are in dispute (Allen and Smith 1988). Briggs (1974) and Allen and Smith (1988) reviewed previous literature from a variety of taxa and from fishes, respectively, and found the coastal region from Puget Sound to Sitka, Alaska, to be a gray zone or transition zone that could be classified as part of either of two provinces: Aleutian or Oregonian (Figure 12). The southern boundary of the Oregonian Province is generally recognized as Point Conception, California, and the northern boundary of the Aleutian Province is similarly recognized as Nunivak in the Bering Sea or perhaps the Aleutian Islands (Allen and Smith 1988).

Briggs (1974) placed the boundary between the Oregonian and Aleutian provinces at Dixon Entrance, based on the well-studied distribution of mollusks, but indicated that distributions of fishes, echinoderms, and marine algae gave evidence for placement of this

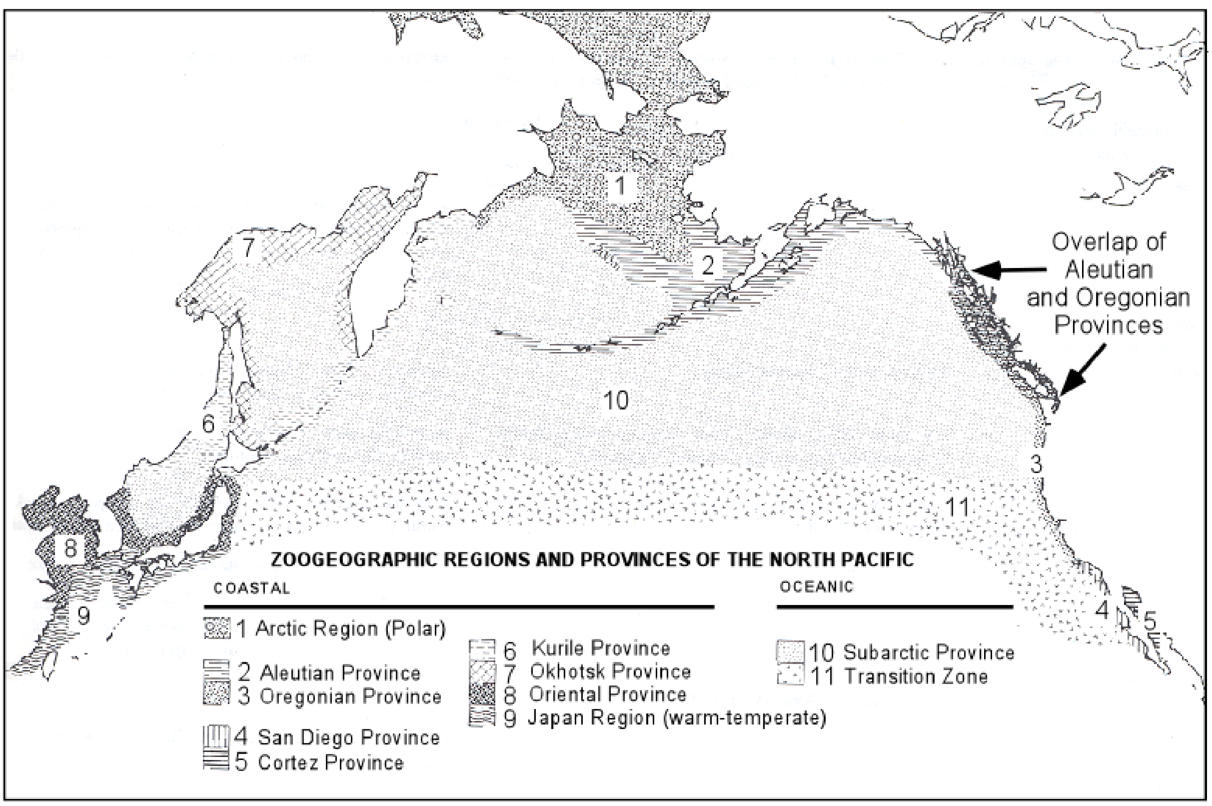



Figure 12. Marine zoogeographic provinces of the North Pacific Ocean. Modified after Allen and Smith (1988).

boundary in the vicinity of Sitka, Alaska. Briggs (1974) placed strong emphasis on the distribution of littoral mollusks (due to the more thorough treatment this group has received) in placing a major faunal break at Dixon Entrance. The authoritative work by Valentine (1966) on distribution of marine mollusks of the northeastern Pacific shelf showed that the Oregonian molluscan assemblage extended to Dixon Entrance with the Aleutian fauna extending northward from that area. Valentine (1966) erected the term Columbian Subprovince to define the zone from Puget Sound to Dixon Entrance.

Several lines of evidence suggest that an important zoogeographic break for marine fishes occurs in the vicinity of Southeast Alaska. Peden and Wilson (1976) investigated the distributions of inshore fishes in British Columbia and found Dixon Entrance to be of minor importance as a barrier to fish distribution. A more likely boundary between these fish faunas was variously suggested to occur near Sitka, Alaska, off northern Vancouver Island, or off Cape Flattery, Washington (Peden and Wilson 1976, Allen and Smith 1988). Chen (1971) found that of the more than 50 or more rockfish species belonging to the genus Sebastes occurring in northern California, more than two-thirds do not extend north of British Columbia or Southeast Alaska. Briggs (1974, p. 278) stated that “about 50 percent of the entire shore fish fauna of western Canada does not extend north of the Alaskan Panhandle.” In addition, many marine fish species common to the Bering Sea extend southward into the Gulf of Alaska, but apparently occur no further south (Briggs 1974). Allen and Smith (1988, p. 144) noted that “the relative abundance of some geographically displacing [marine fish] species suggest that the boundary between these provinces [Aleutian and Oregonian] occurs off northern Vancouver Island.”

Blaylock et al. (1998) examined the distribution of more than 25 species of parasites in 432 juvenile and adult Pacific halibut sampled over much of its North American range and found evidence of three zoogeographic zones as determined by parasite clustering; northern, central, and southern. Similar to studies with other invertebrates, Blaylock et al. (1998, p. 2,269) found a breakpoint between zoogeographic zones in the vicinity of the Queen Charlotte Islands.

### Other marine fish DPS designations

It is also useful to briefly review the size and complexity of other designated DPSs of marine fish that have undergone the status review process and have thus been considered both discrete and significant to their respective biological species. DPSs have been designated for portions of the range of Pacific herring (NMFS 2000, 2005, 2008b), Pacific hake, Pacific cod, walleye pollock (NMFS 2000), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*), brown rockfish (*S. auriculatus*) (NMFS 2001), bocaccio (*S. paucispinis*) (NMFS 2002), and smalltooth sawfish (*Pristis pectinata*) (NMFS 2003).

Several marine fish DPSs cover large geographic areas (e.g., Pacific cod and walleye pollock DPSs extend from Puget Sound to Southeast Alaska, two West Coast DPSs of bocaccio rockfish were designated off Washington and Oregon [the northern DPS] and off California and Mexico [the southern DPS], and all smalltooth sawfish in U.S. waters were designated a separate DPS). At slightly smaller geographic scales, a Southeast Alaska Pacific herring DPS (Carls et al. 2008) and DPSs of Pacific hake and Pacific herring in Georgia Basin (Puget Sound and the straits of Georgia and Juan de Fuca) were established as separate from coastal hake and herring (Gustafson et al. 2000, Stout et al. 2001a) (Figure 13). Three DPSs each of copper and quillback rockfish (Puget Sound Proper DPS, Northern Puget Sound DPS, and Coastal DPS) and two of brown rockfish (Puget Sound Proper DPS and Coastal DPS) have also been delineated (Stout et al. 2001b). Many of these marine fish DPSs include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008).

## Evaluation of Discreteness and Significance for Eulachon

In past evaluations of distinct population boundaries for marine fish (Gustafson et al. 2000, 2006, Stout et al. 2001a), spawn timing, spawning distribution, tagging, biogeography, ecological factors, seasonal migration patterns, parasite incidence, genetic population structure, morphometrics, meristics, and demographic data (growth rate, fecundity, etc.) have been evaluated for evidence of DPS discreteness and significance. The BRT examined similar evidence for eulachon and found evidence that was informative included genetic data, differences in spawning temperatures and length-at-maturity and weight-at-maturity of eulachon between northern and southern rivers, ecological features of both the oceanic and terrestrial environments occupied by eulachon, and biogeography.

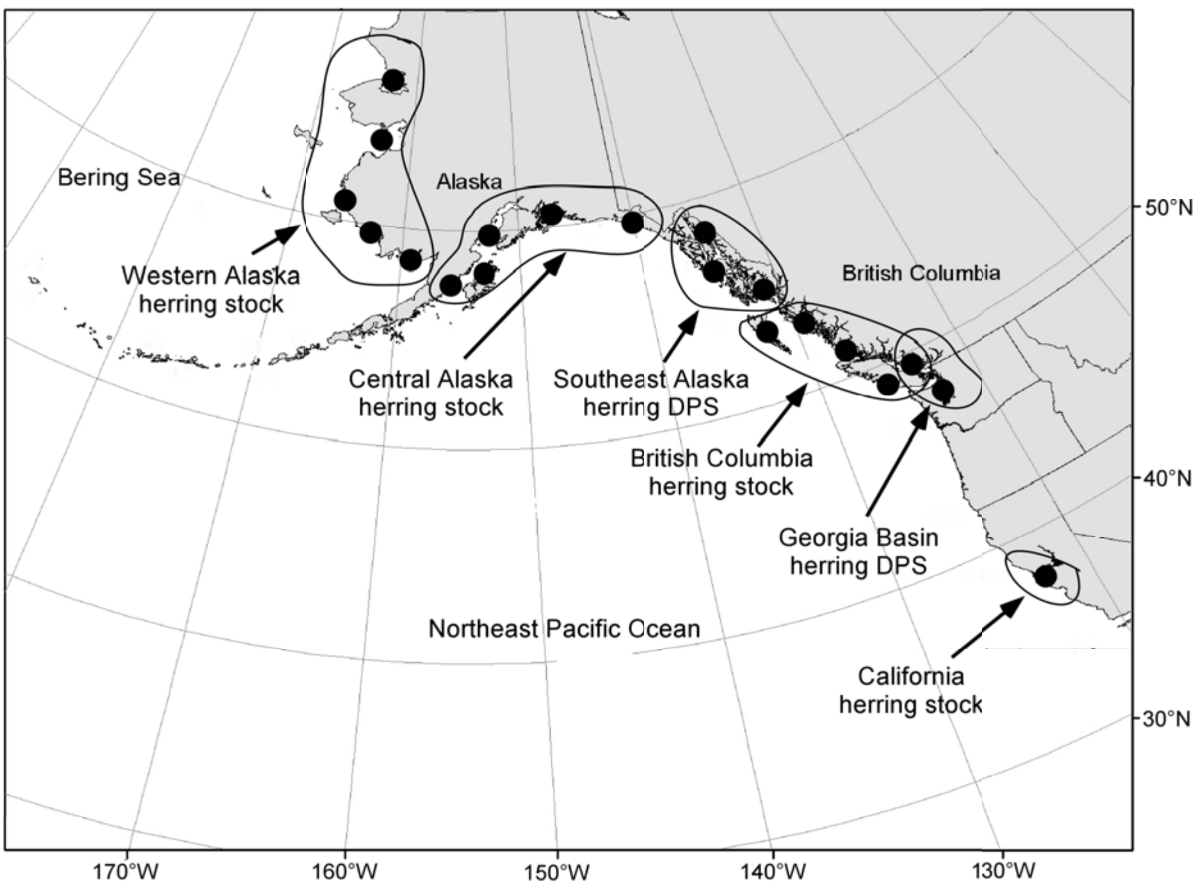



Figure 13. Major stocks of Pacific herring in the Northeast Pacific in relation to the Georgia Basin Pacific herring DPS (Stout et al. 2001a, Gustafson et al. 2006) and the Southeast Alaska Pacific herring DPS (Carls et al. 2008).

To allow for expressions of the level of uncertainty in identifying the boundaries of a discrete and significant eulachon population, the BRT adopted a likelihood point method, often referred to as the FEMAT method, because it is a variation of a method used by scientific teams evaluating options under the Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT) (FEMAT 1993). This method was previously used in the DPS decisions for Southern Resident killer whales (Krahn et al. 2004) and Pacific herring (Gustafson et al. 2006). In this approach, each BRT member distributes 10 "likelihood" points among a number of proposed DPSs, reflecting their opinion of how likely that proposal correctly reflects the true DPS boundary. Thus if a member were certain that the DPS that contains eulachon from California, Oregon, and Washington included all spawning aggregations from the Fraser to the south, he or she could assign all 10 points to that proposal. A member with less certainty about DPS boundaries could split the points among two, three, or even more DPS proposals (Table 1).

The BRT ultimately considered six possible DPS configurations or scenarios that might conceivably incorporate eulachon that spawn in Washington, Oregon, and California rivers. Each BRT member distributed his or her 10 likelihood points amongst these six scenarios. Other possible geographic configurations that incorporated the petitioned unit were contemplated but not seriously considered by the BRT. The BRT did not attempt to divide the entire species into DPSs, but rather focused on evaluating whether a DPS could be identified that contains eulachon that spawn in Washington, Oregon, and California. The geographic boundaries (Figure 14) of possible DPSs considered in this evaluation were:

1. The entire biological species is the ESA species (i.e., there is no apparent DPS structure)
2. One DPS inclusive of eulachon in Southeast Alaska to northern California
3. One DPS south of the Nass River/Dixon Entrance
4. One DPS inclusive of eulachon in the Fraser River to California
5. One DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California)
6. Multiple DPSs of eulachon in Washington, Oregon, and California

The distribution of likelihood points among these six scenarios is presented in Table 1. Scenario 1 (no DPS structure) received about 12% of the total likelihood points. Scenarios 2 (one DPS inclusive of eulachon in Southeast Alaska to northern California) and 5 (one DPS south of the Fraser River) received no support on the BRT. There was also very little support on the BRT for multiple DPSs of eulachon in the conterminous United States; only about 4% of the likelihood points were placed in scenario 6 (multiple DPSs of eulachon in Washington, Oregon, and California).

All remaining likelihood points (84%) were distributed among scenarios supporting a DPS at a level larger than the petitioned unit of Washington, Oregon, and California. Scenario 3 (one DPS south of the Nass River/Dixon Entrance) received about 57% of the total likelihood points and all but one BRT member placed between 5 and 10 points in this DPS scenario. Scenario 4 (one DPS inclusive of eulachon in the Fraser River to California) received significant

Table 1. Worksheet for evaluating potential of DPS or DPSs of eulachon (*Thaleichthys pacificus*) that incorporate spawning populations in California, Oregon, and Washington using the "likelihood point" method (FEMAT 1993).

| | Likelihood points | |
|---|---|---|
| **Scenario** | **Number[a]** | **Percentage[b]** |
| 1) Entire species (no DPS structure) | 11 | 12.2 |
| 2) One DPS south of Yakutat Forelands | — | — |
| 3) One DPS south of Nass River and Dixon Entrance | 51 | 56.7 |
| 4) One DPS, Fraser River and south | 24 | 26.7 |
| 5) One DPS south of Fraser River | — | — |
| 6) Multiple DPSs in Washington, Oregon, and California | 4 | 4.4 |

[a]Each BRT member distributes 10 likelihood points among the 6 DPS scenarios. Placement of all 10 points in a given scenario reflects 100% certainty that this is the DPS configuration that incorporates eulachon from Washington, Oregon, and California. Distributing points between scenarios reflects uncertainty in whether a given scenario reflects the true DPS delineation.
[b]Nine of 10 BRT members in attendance.

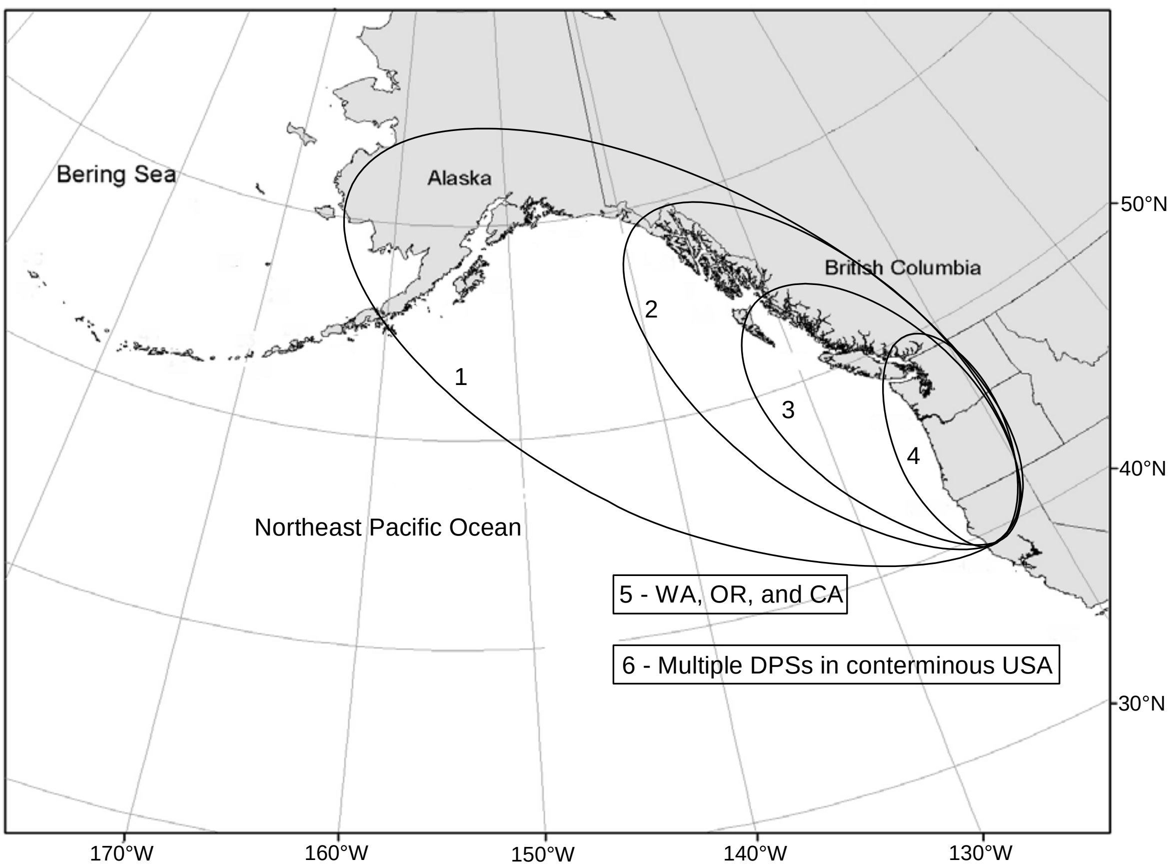



Figure 14. Geographic boundaries of possible eulachon DPSs considered by the BRT: 1) the entire biological species is one DPS, 2) one DPS south of the Yakutat Forelands (Southeast Alaska to northern California), 3) one DPS south of the Nass River (i.e., south of Dixon Entrance), 4) one DPS that includes the Fraser River and south, 5) one DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California), and 6) multiple DPSs of eulachon in Washington, Oregon, and California.

support with about 27% of all points placed in this scenario and all but two members placed from 2 to 5 of their likelihood points in this DPS scenario. In discussing the evidence for these alternative scenarios, the BRT focused on the following factors.

In considering the discreteness and significance criteria (USFWS-NMFS 1996), the BRT concluded that the weight of the available evidence indicated that there are multiple discrete populations of eulachon. In particular, the most comprehensive genetic study of eulachon that has been published to date (Beacham et al. 2005) found reasonably strong evidence of a genetic break between eulachon spawning in the Fraser and Columbia rivers compared to those spawning in rivers further north in British Columbia and Alaska, and also found that nearly all sampled populations were differentiated statistically from each other. Earlier genetic studies (McLean et al. 1999, McLean and Taylor 2001) also found some evidence of population structure, although the evidence was less compelling than that reported by Beacham et al. (2005). However, these earlier studies were characterized by fewer loci and smaller sample sizes than the later study and therefore likely had less power to detect population structure. Overall, the BRT believed the results to be largely consistent among the studies, when differences in sample size and power are taken into account. The BRT did note, however, that there was some uncertainty about the genetic population structure due to the small number of temporally replicated samples in all of the studies, and this uncertainty is reflected in the proportion of the likelihood points that were placed in the no DPS structure category (Table 1).

In addition to the genetic data, the BRT considered the strong ecological and environmental break that occurs between the California Current and Alaska Current oceanic domains as contributing evidence for discreteness, a factor that was also important for identifying DPS structure in Pacific cod (Gustafson et al. 2000), killer whales (Krahn et al. 2004), and Southeast Alaska Pacific herring (Carls et al. 2008). The BRT also considered, but did not weigh heavily, the latitudinal differences in spawn timing, body size, and vertebral counts among samples from different rivers. Similar latitudinal patterns in life history characters were considered but did not weigh heavily in DPS decisions for Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a). Overall, the BRT believed the genetic and ecological data provided strong evidence that eulachon south of the Nass River were discrete from those in the Nass River and northward, but that there was also evidence (from the genetic data) suggesting that Fraser and Columbia River groups may be discrete from more northern groups.

In evaluating the significance criteria, the BRT focused primarily on criteria 1 (ecological setting), criteria 2 (evidence that loss would result in a significant gap in the range of the species), and criteria 4 (markedly differs in genetic characteristics). After carefully discussing all of the available data, the BRT concluded that there was evidence supporting the significance criteria under either scenario 3 (one DPS south of the Nass River/Dixon Entrance) or scenario 4 (one DPS inclusive of eulachon in the Fraser River to California). In particular, there is evidence under either scenario for a significant break in ecological setting, and loss of a putative DPS defined by either boundary would without question result in a significant gap (or reduction) in the range of the overall species. The BRT also considered whether the available genetic data provided any evidence for “markedly different” populations, but concluded that although the genetic data provides evidence for discreteness (lack of gene flow) there was little evidence to support the existence of deep intraspecific phylogenetic breaks that the BRT believed were necessary to be considered “marked.”

In summary, the BRT believed the evidence most strongly supported scenario 3, but that there was also some evidence for scenarios 4 and 1. The factors supporting each of the top three scenarios are summarized below.

### Scenario 3

This scenario designated one DPS south of the Nass River/Dixon Entrance (57% support). Supporting factors were:

1. Beacham et al. (2005) found strong evidence that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels and the authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish but less than that observed in most Pacific salmon species.
2. A major ecological break occurs in the coastal ocean biome between the Coastal Downwelling Province (Ware and McFarlane 1989, Longhurst 2006) to the north and the California Current Province (Ware and McFarlane 1989, Longhurst 2006) to the south. The northern boundary of the transition zone that separates these provinces occurs in the vicinity of the Dixon Entrance at the northern end of the Queen Charlotte Islands. The coastal distribution of eulachon south of the Dixon Entrance occupies an ecologically discrete area that is a combination of this transition zone and the northern California Current Province (Longhurst 2006).
3. Dixon Entrance is also the approximate northern boundary that separates two major marine zoogeographic provinces (Oregonian and Aleutian Provinces) (Briggs 1974), further supporting the ecological discreteness of marine waters south of Dixon Entrance.
4. Stocks of eulachon from the Columbia River to the Klinaklini River in British Columbia experienced a nearly simultaneous collapse in 1994 (Hay and McCarter 2000, Hay 2002), stayed at low levels throughout the 1990s, experienced a rebound in 2001–2003, and subsequently declined to near record low levels of abundance (Hay 2002, JCRMS 2007). The nearly synchronous demographic responses of all eulachon stocks south of the Nass River to what are likely coast-wide changes in ocean condition, strongly suggest that these stocks occupy a common ocean rearing environment. Stocks of eulachon from the Nass River and north remained relatively healthy throughout this period of decline of more southern stocks. Not until 2003 did eulachon stocks in southern Southeast Alaska begin to show serious declines. These demographic patterns are similar to those seen in Pacific salmon stock abundance that fluctuates in opposite directions in the Alaska and California Current domains (Hare et al. 1999), which has been correlated with the Pacific Decadal Oscillation (PDO) (Mantua and Hare 2002).
5. A major break in terrestrial ecoregions also occurs along the north coast of British Columbia in the vicinity of the Nass River, with both the Nass and Skeena rivers draining the interior Nass Basin Ecoregion (Environment Canada 2008). Evidence of a natural biological boundary coinciding with the international boundary separating Southeast Alaska and British Columbia (Dixon Entrance/Nass River) also supported delineation of

- Different biological zones are apparent along the coast, probably a result of both thermal (north-south) and salinity (east-west) gradients.
- A thermal gradient is clearly evident through British Columbia and Southeast Alaska.
    - o Temperatures in Southeast Alaska are colder than in British Columbia.
    - o Southeast Alaska has tidewater glaciers, British Columbia does not, chilling the water and increasing turbidity and possibly nutrients.
    - o Southeast Alaska mainland topography is heavily influenced by snowfields and glaciers; this is less prevalent in British Columbia.

6. Eulachon spawning in rivers on the north coast of British Columbia (e.g., Nass River) experience significantly colder temperatures at spawning (often spawning under ice) than eulachon spawning to the south, particularly in the Klinaklini, Fraser, and Columbia rivers (Hay and McCarter 2000) (Table A-11). Hochachka and Somero (2002, p. 292, 317) emphasized that habitat temperature plays a "strong and frequently dominant role … in governing the distribution patterns of organisms" and that "temperature differences of a few degrees Celsius have sufficient effects on proteins to favor adaptive change." The dominant role that temperature plays on ectothermic organisms, affecting "essentially every aspect of an organism's physiology" (Hochachka and Somero 2002, p. 290), suggests that these 2–4°C temperature differences experienced by adult eulachon and their gametes during spawning (Table A-11) are a strong indicator of potential physiological differences between eulachon south of the Nass River and those in the Nass River and northward.

Items 2–5 above support a discrete and significant eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of ecological features" and Item 6 supports a discrete eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of physiological features."

### Scenario 4

This scenario designated one DPS inclusive of eulachon in the Fraser River to California (27% support). Supporting factors were:

1. The available genetic data indicate that a substantial genetic break occurs between eulachon populations from the Fraser River and those from rivers further to the north (see Genetic Differentiation subsection, p. 61). In particular, the largest genetic discontinuity appears to be in southern British Columbia rather than northern British Columbia.
2. In contrast to systems to the north of the Fraser River, the Columbia, Fraser, and Klamath rivers have many physiographic and habitat features in common; all three are large rivers with wide valleys, drain extensive interior basins, are fed by spring snow melt, and do not drain off extensive ice sheets.

Average length-at-maturity and weight-at-maturity in eulachon from the Columbia and Fraser rivers and southern rivers in general are smaller than eulachon from more northern rivers (Figure 8). However, this pattern is typical in many vertebrate poikilotherms (ectotherms), where higher temperatures lead to reduced size at a given stage of development (Atkinson 1994, Lindsey 1966), so the BRT did not weight this evidence very heavily.

**Scenario 1**

This scenario designated no DPS structure (12% support). Supporting factors were:

1. There was a lack of apparent discrete differences in many eulachon life history traits (Hay and McCarter 2000, Hay and Beacham 2005); however, similar uniformity in life history characters over large geographic distances was evident in previous marine fish reviews of Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a).
2. Another reason BRT members put some support in this scenario was uncertainty about how strongly to weight the genetic study of Beacham et al. (2005). In particular, although the BRT concluded that the study as a whole clearly supported the existence of discrete genetic populations of eulachon, the BRT was also somewhat concerned about the limited temporal replication in the study.

Given the previous DPS structure established for marine fishes, such as Pacific herring, Pacific cod, Pacific hake, and walleye pollock (Gustafson et al. 2000, 2006, Stout et al. 2001a), it seems unlikely that there would be an absence of DPS structure across the more than 2,800 km range of eulachon, an anadromous species with similar among-population genetic differentiation, as these purely marine fishes. Pacific herring, which exhibit genetic variation similar to eulachon when compared over the same geographic range (Beacham et al. 2002, 2005, Small et al. 2005), have had DPSs delineated at the geographic level of the Georgia Basin (Stout et al. 2001a) and Southeast Alaska (Carls et al. 2008), based to a large degree on marked differences in ecological features of their habitats. For example, the estimated mean $F_{ST}$ value for Pacific herring over 13 microsatellite DNA loci and 83 sampling sites ranging from California to Southeast Alaska was 0.0032 (Beacham et al. 2002), whereas a similar estimated mean $F_{ST}$ value over 14 loci and 9 eulachon sampling sites ranging from the Columbia River to Southcentral Alaska was 0.0046 (Beacham et al. 2005).

Although nowhere near the same quantity or quality of data exists for eulachon as for the economically more valuable Pacific herring, it is likely that if data comparable to that for Pacific herring were available, an even finer DPS structure for the anadromous eulachon might become apparent. In addition, the biological heterogeneity of eulachon as seen in “the geographical discontinuity of different spawning runs, different spawning times, and the apparent homing of each run to individual rivers” (Hay and McCarter 2000, p. 36) strongly argues against the lack of DPS structure.

## BRT DPS Determination

In conclusion, it was the majority opinion of the BRT that eulachon from Washington, Oregon, and California are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT proposes that this DPS be termed the southern DPS of eulachon. Although it was not the

BRT's objective to subdivide the entire biological species of eulachon into DPSs throughout their range, the identification of a southern DPS of eulachon indicates that at least one, and possibly more than one, additional DPS or DPSs of eulachon occur north of the Skeena River on the north coast of British Columbia and in Alaska.

Although the BRT could not with any certainty identify multiple populations or DPSs of eulachon within the region south of Dixon Entrance/Nass River, it acknowledged the possibility that significant stock structuring does exist within this region and that a finer DPS structure might be revealed by further information on the behavior, ecology, and genetic population structure of eulachon. The BRT also recognized that the DPS that includes eulachon from California, Oregon, and Washington may represent fish that are uniquely adapted to survive at the southern end of the species' range.

# The Extinction Risk Question

Information considered in evaluating the status of a DPS can generally be grouped into two categories: 1) demographic information reflecting the past and present condition of subpopulations (e.g., data on population abundance or density, population trends and growth rates, number and distribution of populations, exchange rates of individuals among populations, and ecological, life history, or genetic diversity among populations) and 2) information on past factors for decline as well as threats faced by the DPS (e.g., habitat loss and degradation, overutilization, disease, climate change). The demographic risk data reviewed by the BRT are summarized in this document. This document also contains a narrative summary of threats faced by the DPS.

Evaluating extinction risk of a species includes considering the available information concerning the abundance, growth rate and productivity, spatial structure and connectivity, and diversity of a species and assessing whether these demographic criteria indicate that it is at high risk of extinction, at moderate risk, or neither. A species at very low levels of abundance and with few populations will be less tolerant to environmental variation, catastrophic events, genetic processes, demographic stochasticity, ecological interactions, and other processes (e.g., Gilpin and Soulé 1986, Meffe and Carroll 1994, Caughley and Gunn 1996). A rate of productivity that is unstable or declining over a long period of time may reflect a variety of causes, but indicates poor resiliency to future environmental variability or change (e.g., Lande 1993, Foley 1997, Middleton and Nisbet 1997).

For species at low levels of abundance, in particular, declining or highly variable productivity confers a high level of extinction risk. A species that is not widely distributed across a variety of well-connected habitats will have a diminished capacity for recolonizing locally extirpated populations and is at increased risk of extinction due to environmental perturbations and catastrophic events (Schlosser and Angermeier 1995, Hanski and Gilpin 1997, Tilman and Lehman 1997, Cooper and Mangel 1999). A species that has lost locally adapted genetic and life history diversity may lack the characteristics necessary to endure short-term and long-term environmental changes (e.g., Hilborn et al. 2003, Wood et al. 2008).

The demographic risk criteria described above are evaluated based on the present species status in the context of historical information, if available. However, there may be threats or other relevant biological factors that might alter the determination of the species' overall level of extinction risk. These threats or other risk factors are not yet reflected in the available demographic data because of the time lags involved, but are nonetheless critical considerations in evaluating a species' extinction risk (Wainwright and Kope 1999).

Forecasting the effects of threats and other risk factors into the foreseeable future is rarely straightforward, and usually necessitates qualitative evaluations and the application of informed professional judgment. This evaluation highlights those factors that may exacerbate or ameliorate demographic risks so that all relevant information may be integrated into the determination of overall extinction risk for the species. Examples of such threats or other relevant factors may include climatic regime shifts that portend favorable temperature and marine productivity conditions, an El Niño event that is anticipated to result in reduced food quantity or quality, or recent or anticipated increases in the range or abundance of predator populations.

In considering the status of eulachon, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments of the status of eulachon populations by agencies, reviewed below. Additional information presented by the petitioners was considered, as discussed under the Introduction: Summary of Information Presented by the Petitioner section above.

## Abundance and Carrying Capacity

### Absolute Numbers

The absolute number of individuals in a population is important in assessing two aspects of extinction risk. For small populations that are stable or increasing, population size can be an indicator of whether the population can sustain itself into the future in the face of environmental fluctuations and small-population stochasticity; this aspect is related to the concept of minimum viable populations (MVP) (Gilpin and Soulé 1986, Thompson 1991). For a declining population, present abundance is an indicator of the expected time until the population reaches critically low numbers; this aspect is related to the concept of "driven extinction" (Caughley 1994). In addition to total numbers, the spatial and temporal distribution of adults is important in assessing risk to a species or DPS.

Several aspects of eulachon biology indicate that large aggregations of adult eulachon are necessary for maintenance of normal reproductive output. Eulachon are a short-lived, high-fecundity, high-mortality forage fish, and such species typically have extremely large population sizes. Research from other marine fishes (Sadovy 2001) suggests that there is likely a biological requirement for a critical threshold density of eulachon during spawning to ensure adequate synchronization of spawning, mate choice, gonadal sterol levels, and fertilization success. Since eulachon sperm may remain viable for only a short time, perhaps only minutes, sexes must synchronize spawning activities closely, unlike other fish such as Pacific herring (Hay and McCarter 2000, Willson et al. 2006).

In most samples of spawning eulachon, males greatly outnumber females (although many factors may contribute to these observations) (Willson et al. 2006), and in some instances congregations of males have been observed simultaneously spawning upstream of females that laid eggs as milt drifted downstream (Langer et al. 1977). Sadovy (2001, p. 100) noted that "the idea that, if a population drops below some critical density, the intrinsic rate of population increase may not be realized because breeding activity may cease, cannot be readily dismissed and a number of possible Allee effects have been noted" in marine fishes. Sadovy (2001, p. 101) further noted that "aggregating behaviour presumably reflects some biological imperative for sociality during the reproductive season."

In addition, the genetically effective population size of eulachon may be much lower than the census size. Although eulachon exhibit high fecundity (7,000–60,000 eggs; mean ≈30,000), survival from egg to larva may vary widely (3–5% in the Kemano River to approximately 1% in the Wahoo River [Willson et al. 2006]) and may be less than 1% in large egg masses. Larvae are small (4–8 mm long), are rapidly carried by currents to the sea, and rear in the pelagic zone similarly to many marine pelagic fish larvae where the extent of mortality during the transition phase from larva to juvenile is high. In marine species, under conditions of high fecundity and high mortality associated with pelagic larval development, local environmental conditions may lead to random "sweepstake recruitment" events where only a small minority of spawning individuals contribute to subsequent generations (Hedgecock 1994). Hauser and Carvalho (2008) report that "data available so far suggest that the scope for sweepstake recruitment may be higher in larger populations, as the $N_e/N$ [ratio of effective size to census size] is lower in larger populations."

Large spawning aggregations of adult eulachon may also be necessary to withstand predation pressure associated with large congregations of predators that target returning adults, and to produce enough eggs and pelagic larvae to swamp out predation in the ocean (Bailey and Houde 1989). Multiple species of predators (sea lions, harbor seals, gulls, bald eagles, ducks, sturgeon, porpoises, killer whales, etc.) commonly congregate at eulachon spawning runs and "local observers often judge arrival of fish by the conspicuous arrival of many predators" (Willson et al. 2006).

## Historical Abundance and Carrying Capacity

Knowing the relationship of present abundance to present carrying capacity is important for evaluating the health of populations, but the fact that a population is near its current capacity does not necessarily signify full health. A population near capacity implies that short-term management may not be able to increase fish abundance.

The relationship of current abundance and habitat capacity to historical levels is an important consideration in evaluating risk. Knowledge of historical population conditions provides a perspective for understanding the conditions under which present populations evolved. Historical abundance also provides the basis for scaling long-term trends in populations. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation. For eulachon, current and historical abundance data and information was available in the form of spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish), offshore juvenile eulachon biomass estimates (metric tons), mean eulachon larval density, CPUE, commercial-recreational-subsistence fisheries landings, ethnographic studies, and anecdotal qualitative information.

## Trends in Abundance

Short-term and long-term trends in abundance are primary indicators of risk. Trends may be calculated from a variety of quantitative data, which are discussed in detail in specific subsections below. Interpretation of trends in terms of population sustainability is difficult for several reasons. First, eulachon are harvested in fisheries and shifting harvest goals or market conditions directly affect trends in spawning abundance and catch. Second, environmental fluctuations on short timescales affect trend estimates, especially for shorter trends.

## Recent Events

A variety of factors, both natural and human-induced, affect the degree of risk facing eulachon populations. Because of time lags in these effects and variability in populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus consideration of these effects must go beyond examination of recent abundance and trends, but forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgment. Events affecting populations may include natural changes in the environment or human-induced changes, either beneficial or detrimental. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis, but we have considered documented changes in the natural environment. A key question regarding the role of recent events is: Given our uncertainty regarding the future, how do we evaluate the risk that a population may not persist?

It is generally accepted that important shifts in ocean-atmosphere conditions occurred about 1977 and again in 1998 that affected North Pacific marine ecosystems. Several studies have described decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua and Hare 2002). These changes have been associated with recruitment patterns of several groundfish species and Pacific herring (McFarlane et al. 2000). As discussed in this report, increases in eulachon in the Columbia, Fraser, and Klinaklini rivers in 2001–2002 may be largely a result of the more favorable ocean conditions for eulachon survival during the transition from larvae to juvenile when these broods entered the ocean in 1998–2000.

One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index; Figure 15 shows that from fall 2007 to mid-summer 2009 (time period E on the graph) monthly PDO values were negative, whereas PDO values were mostly positive in time period D from 2002 to fall of 2007 and during most of the previous two decades (time period B). One exception is time period C, which corresponds with 1998–2000 when good ocean conditions for survival of larval eulachon led to the increased run strength noted in 2001–2002. PDO values were generally negative for a long period from the 1950s to the late 1980s (time period A). Recently negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest and positive values are associated with warmer, less productive conditions (Mantua and Hare 2002).

Coupled changes in climate and ocean conditions have occurred on several different time scales and have influenced the geographical distributions, and hence local abundance, of marine fishes. On time scales of hundreds of millennia, periodic cooling produced several glaciations in the Pleistocene Epoch (Imbrie et al. 1984, Bond et al. 1993). Since the end of this major period of cooling, several population oscillations of pelagic fishes, such as anchovies (*Engraulis mordax*) and sardines (*Sardinops sagax*), have been noted on the west coast of North America (Baumgartner et al. 1992). These oscillations, with periods of about 100 years, have presumably occurred in response to climatic variability. On decadal time scales, climatic variability in the North Pacific and North Atlantic oceans has influenced the abundances and distributions of widespread species, including several species of Pacific salmon (*Oncorhynchus* spp.) (Francis et

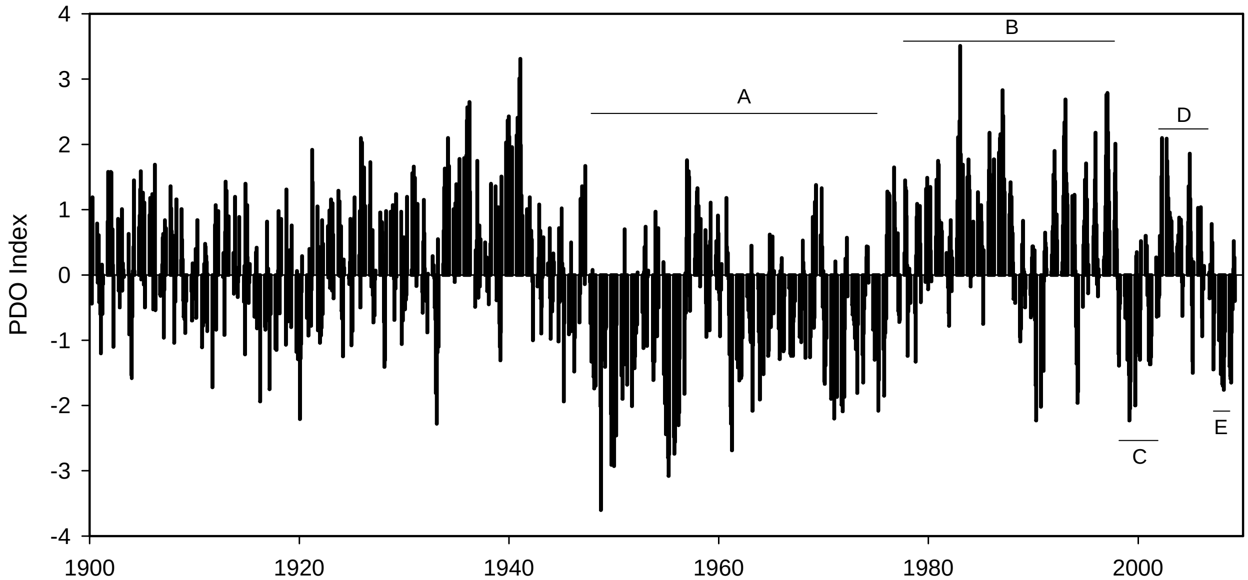



Figure 15. Monthly values for the PDO index, which is based on sea surface temperatures in the North Pacific Ocean, poleward of 20º N. A through E are time periods discussed in the text. Data source: online at http://jisao.washington.edu/pdo/PDO.latest.

al. 1998, Mantua et al. 1997) in the North Pacific, and Atlantic herring (*Clupea harengus*) (Alheit and Hagen 1997) and Atlantic cod (*Gadus morhua*) (Swain 1999) in the North Atlantic. At this time, we do not know whether recent shifts in climate and ocean conditions represent a long-term shift in conditions that will continue affecting stocks into the future or short-term environmental fluctuations that can be expected to be reversed in the near future. Although recent conditions appear to be within the range of historic conditions under which eulachon populations have evolved, the risks associated with poor climate conditions may be exacerbated by human influence on these populations (Lawson 1993).

None of the elements of risk outlined above are easy to evaluate, particularly in light of the great variety in quantity and quality of information available for various populations. Two major types of information were considered: previous assessments that provided integrated reviews of the status of eulachon in our region and data regarding individual elements of population status, such as abundance, trend, and habitat conditions.

A major problem in evaluations of risk for eulachon is combining information on a variety of risk factors into a single overall assessment of risk facing a population. Conducting an overall assessment of extinction risk involves the consideration of a wide variety of qualitative and quantitative information concerning the threats and demographic risks affecting a species' persistence. Moreover, the type and spatial-temporal coverage of the information available often varies within and among populations. This presents a substantial challenge of integrating disparate types of information into an assessment of a species' overall level of extinction risk. Usually such assessments necessitate qualitative evaluations based on informed professional judgment. In this review, we have used a risk-matrix approach through which the BRT members applied their best scientific judgment to combine qualitative and quantitative evidence regarding multiple risks into an overall assessment.

# Status Assessments

### Official Status in California, Oregon, and Washington

In California eulachon are classified on the Fish Species of Special Concern List as a Class 3 Watch List species (see http://www.dfg.ca.gov/wildlife/nongame/ssc/fish.html). This list was most recently updated in 1995. Class 3 Watch List species are defined as:

> taxa occupying much of their native range, but were formerly more widespread or abundant within that range. … The populations of such species need to be assessed periodically (i.e., every 5 years) and included in long-term plans for protected waterways (e.g., ADMAs [aquatic diversity management areas]).

In Oregon, eulachon are not listed as a state threatened, endangered, or candidate species, nor are they on the state sensitive species list. However, eulachon are on the list of Strategy Species in Oregon's Nearshore Strategy (ODFW 2006, p. 26). These species are defined in the following manner:

> Strategy species are nearshore species that were identified by the Nearshore Team to be in greatest need of management attention. Identification as a strategy species does not necessarily mean the species is in trouble. Rather, those identified as a strategy species have some significant nearshore management/conservation issue connected to that species that is of interest to managers.

ODFW (2006, p. 28) further refers to eulachon under the category of Notes on Conservation Needs as:

> Forage fish. Vulnerable freshwater spawning and nursery grounds. Columbia River population has declined. Other distinct population segments (DPS) may have experienced similar declines.

In Washington, eulachon are classified by the WDFW (online at http://wdfw.wa.gov/wlm/diversty/soc/candidat.htm) as a State Candidate Species, which are defined as:

> fish and wildlife species that the department will review for possible listing as State Endangered, Threatened, or Sensitive. A species will be considered for designation as a State Candidate if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened, or Sensitive.

### Status in Canada

The Province of British Columbia examined the conservation status of eulachon in 2000 and again in 2004 and in both instances assigned eulachon to its blue list. According to the British Columbia Conservation Data Centre (2008, online at http://www.env.gov.bc.ca/atrisk/red-blue.html) the blue list:

> Includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered, or Threatened.

Eulachon are also considered a Group 1 high priority candidate species for review in British Columbia by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). According to the COSEWIC Web site (http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm), "Group 1 contains species of highest priority for COSEWIC assessment. Wildlife species suspected to be extirpated from Canada would also be included in this group." A recent bid to conduct a COSEWIC review has been awarded in Canada and a final product is due in November 2010 (see information online at http://www.cosewic.gc.ca/eng/sct2/sct2_4_e.cfm).

Pickard and Marmorek (2007) reported out the results of a DFO workshop whose purpose was to determine research priorities and recovery strategies for eulachon in the wake of the recent coastwide decline. They stated that:

> Recent information indicates that eulachon are declining in many parts of the west coast of North America, though the reasons for this decline and possible remedies are not well understood. In 1994 the Columbia, Fraser, and Klinaklini rivers suffered sudden drastic declines (Hay 1996). Since then First Nations have reported that fish are absent or at very low levels in many other British Columbia eulachon spawning rivers including: the Kemano, Kitimat, Wannock, Bella Coola, Nass, Skeena, Chilcoot, Unuk, Kitlope, and Stikine (Moody 2007, Hay 2007).

According to Schweigert et al. (2007, p. 13):

> In recent years, particularly since 1994, eulachon abundance has declined synchronously in many rivers and virtually disappeared in California. This decrease has been noticeable in the PNCIMA [Pacific North Coast Integrated Management Area] region, with very poor runs in Douglas Channel, Gardner Canal, Dean/Burke channels, and Rivers Inlet areas in the past 5 years. It is suspected that these declines may be related to large-scale climate change. Recent studies suggest rivers that normally experience spring freshet events may gradually be changing to summer and fall freshets that may impair eulachon spawning runs.

### Other Status Assessments

Musick et al. (2000, p. 11) assessed the status of eulachon following American Fisheries Society criteria to define extinction risk in marine fishes (Musick 1999), and classified eulachon in the Columbia River as threatened based on "commercial landings [that] have declined from average of 2.1 million lb annually from 1938 to 1989 to 5,000 lb in 1999, a decline > 0.99." In addition, Musick et al. (2000, p. 11) stated that "other DPSs from British Columbia to northern California may have declines similar to that observed in the Columbia River."

Hay and McCarter (2000) conducted a review of the status of eulachon for the Canadian Stock Assessment Secretariat of Fisheries and Oceans Canada and concluded at that time that "the widespread decline in the southern part of the range warrants a COSEWIC classification of 'threatened' in Canadian waters." This conclusion was based on:

> Available evidence [which] suggests that several rivers in the central coast of British Columbia may be extirpated, while others have declined severely. Only the Nass maintains normal or near-normal runs, although the Fraser, while markedly lower in recent decades and especially since 1994, still has regular, but diminished runs. The Columbia River, with the world's largest eulachon run, declined sharply in 1993, and has remained low since. Apparently all runs in California have declined and several runs that once were large have not been seen in more than 20 years.

## General Demographic Indicators

Within the range of the DPS, the BRT examined abundance related information in the published literature; data provided by DFO, WDFW, and ODFW; analyses of available abundance data both past and present summarized in Moody (2008); and information and presentations provided by eulachon experts from DFO, WDFW, ODFW, the Cowlitz Indian Tribe, and the Yurok Indian Tribe assembled during a scientific technical meeting at the NWFSC in June 2008. Information on eulachon abundance fell into the general categories of 1) fisheries-independent scientific surveys of adults, offshore juveniles, and outmigrant larvae; 2) commercial fisheries-dependent landings; 3) recreational fisheries-dependent landings; 4) First Nations subsistence fisheries landings; 5) ethnographic studies; 6) anecdotal qualitative information; and 7) traditional ecological knowledge.

In addition, the BRT reviewed the results of a fuzzy logic expert system developed by Moody (2008) to estimate a past and present relative abundance status index for eulachon in several areas of the southern DPS of eulachon. Moody's (2008) expert system uses catch data to determine the exploitation status of a fishery and combines this with other data sources such as spawning stock biomass estimates, CPUE data, test fishery catches, larval survey data, or anecdotal comments on run size to estimate the relative abundance status index. This index was produced using designed heuristic rules and by adjusting weighting parameters (Moody 2008).

Although humans have exploited eulachon populations for centuries, the perceived abundance of the resource and its low commercial value has resulted in limited regulation of past commercial and recreational fisheries, limited recording of past catches, and until recently a lack of assessment surveys of spawning abundance. The BRT recognized that the lack of direct estimates of eulachon abundance based on fishery-independent surveys (spawning stock biomass estimates or escapement counts) prior to 1993 makes it very difficult to quantify trends in eulachon abundance. Since the mid-1990s, monitoring of this resource has improved and a handful of data sets are now available that track eulachon spawning stock abundance and offshore juvenile abundance or provide an indication of run strength in several subareas of the DPS.

## Data Availability

### Fisheries-independent scientific surveys

There are few direct estimates of spawning biomass of eulachon from rivers within the DPS, although all of these data sets began to be collected after the perceived decline in run sizes occurred in the early 1990s. Spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish) are available for the Fraser River (1996–2009), Klinaklini River (1995), Kingcome River (1997), Wannock/Kilbella rivers (2005–2006), Bella Coola River (2001–2004), Kitimat River (1993–1996, 1998–2005), and Skeena River (1997). Even though the results of most of these studies are only available in gray literature reports, they were regarded by the BRT as constituting the best scientific and commercial data available for recent eulachon abundance in the DPS and were heavily weighted in the BRT's risk analysis. The BRT was cognizant of the fact that abundance estimates always contain observational error. These factors were taken into account when evaluating the data sets.

Offshore juvenile eulachon biomass estimates were available for Queen Charlotte Sound (1998–2009), West Coast Vancouver Island (1973, 1975–1983, 1985, 1987–2009), and the U.S. West Coast (1995, 1998, 2001). Data for Queen Charlotte Sound and West Coast Vancouver Island were collected by DFO as part of offshore shrimp biomass assessments. Eulachon juvenile biomass data for the U.S. West Coast were available from AFSC triennial groundfish bottom trawl surveys on the continental shelf (55–500 m) in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

CPUE data for eulachon were also available off the U.S. West Coast in AFSC triennial groundfish bottom trawl surveys over the continental shelf in depths of 55–366 m (1989, 1992) or 55–500 m (1995, 1998, 2001) and in certain INPFC statistical areas in AFSC groundfish bottom trawl surveys over the continental slope in depths of 183–1,280 m (1989–1999). However, as mentioned previously, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

Mean eulachon larval density data were available in the mainstem Columbia River (1996–2009), Cowlitz River (1986, 1994–2004, 2006–2009), Grays River (1998–2001, 2004–2006, 2008, 2009), Elochoman River (1997–2001, 2003, 2008), Kalama River (1995–2002), Lewis River (1997–2003, 2007–2009), and Sandy River (1998–2000, 2003).

Data from a Fraser River test fishery were available for the years 1995–1998 and 2000–2005 and are reported as number of fish caught. CPUE data were available from the Columbia River (1988–2008), Kemano River (1988–2006), and Kitimat River (1994–2006).

### Commercial fisheries–dependent landings

Commercial fisheries landings in pounds or metric tons of eulachon were available for the Klamath River (1963), Umpqua River (1967), Columbia River (1888–1892, 1894–1913, 1915–2009), Fraser River (1881–1996), Kitimat River (1969–1971), and Skeena River (1900–1916, 1919, 1924, 1926–1927, 1929–1932, 1935, 1941).

In some areas of the southern DPS of eulachon where escapement counts or estimates of spawning stock biomass are unavailable, catch statistics provide the only available quantitative data source that defines the relative abundance of eulachon occurrence that may be otherwise evident only by simple run-strength observation. However, inferring population status or even trends from yearly changes in catch statistics requires assumptions that are seldom met, including similar fishing effort and efficiency, assumptions about the relationship of the harvested portion to the total portion of the stock, and statistical assumptions such as random sampling.

**First Nations and Indian tribal subsistence fisheries landings**

First Nations subsistence fisheries landings in pounds or metric tons of eulachon were available for a number of rivers in British Columbia including the Fraser River (1975–1987, 1991), Klinaklini River (1947, 1949, 1950, 1952, 1959–1973, 1977), Kingcome River (1950, 1957, 1960, 1961, 1963, 1966), Wannock River (1967, 1968, 1971), Bella Coola River (1945, 1946, 1948–1989, 1995, 1998), Kemano River (1969–1973, 1988–2006), and Kitimat River (1969–1972).

**Recreational fisheries–dependent landings**

Recreational fisheries for eulachon are even more poorly documented that those for commercial and subsistence purposes. A popular recreational dip net fishery for eulachon has a long history on the Columbia River, particularly in tributary rivers such as the Cowlitz and on occasion the Sandy River. Catch records are not maintained for this fishery, although it has been estimated at times to equal the commercial catch (WDFW and ODFW 2001). A similar recreational dip net fishery occurred in the past on the Fraser River, and landings data exist for a portion of this fishery in the vicinity of Mission, British Columbia, for the years 1956, 1963–1967, and 1970–1980 (Moody 2008, p. 49, her Figure 2.22).

**Ethnographic studies**

Numerous ethnographic studies emphasize the nutritional and cultural importance of eulachon to coastal mainland Indian tribes and First Nations. The BRT examined ethnographic sources that describe historical distributions and relative abundance of eulachon fisheries within the boundaries of the DPS. Many of the statements in these sources as to the historical distribution and abundance of eulachon consisted of traditional ecological knowledge or were anecdotal in nature.

**Anecdotal qualitative information**

Anecdotal information is defined in the present context as information based on personal observation, case study reports, or random investigations rather than systematic scientific evaluation. This category includes memoirs of pioneers, fur trappers, and explorers; newspaper articles; and interviews with local fishers.

The BRT examined a variety of primary sources (e.g., accounts of early explorers, surveyors, fur trappers, and settlers and newspaper articles) and secondary sourced (e.g., agency fisheries reports and journal articles that cite personal communications) that describe historical distributions and relative abundance of eulachon within the boundaries of the DPS. The BRT also examined documents (e.g., Larson and Belchik 1998, Hay and McCarter 2000, Moody 2008) that cited interviews with local fishers or personal communications from local fisheries managers in their attempt to qualitatively characterize eulachon run strength. Many statements in these sources as to the historical distribution of eulachon were largely anecdotal in nature.

### Traditional ecological knowledge

Although there is a largely untapped store of knowledge on eulachon residing in the culture and traditions of Native American Indian Tribes and First Nations in Canada, the BRT did not separately consider traditional ecological knowledge sources in its deliberations; however, the BRT did examine secondary sources that presented information on eulachon presence and run size that was gathered from interviews with traditional local fishers.

## Summary of Regional Demographic Data

To facilitate evaluation of eulachon distribution and abundance, the BRT analyzed the available demographic information on a subpopulation basis, arranged geographically into separate major estuaries, which have been postulated to be the smallest area that likely supports a biological stock (McCarter and Hay 1999, Hay and McCarter 2000, Hay 2002). These major areas are 1) Klamath River, 2) Columbia River (Cowlitz, Grays, Lewis, Kalama, Sandy rivers, etc.) in the United States, 3) Fraser River, 4) Knight Inlet (Klinaklini River), 5) Kingcome Inlet (Kingcome River), 6) Rivers Inlet (Wannock and Kilbella/Chuckwalla rivers), 7) Dean Channel (Bella Coola and Kimsquit rivers), 8) Gardner Canal (Kemano, Kowesas, and Kitlope rivers), 9) Douglas Channel (Kitimat and Kildala rivers), and 10) Skeena River in British Columbia.

Eulachon are periodically noted in small numbers in several rivers and creeks on the Washington and Oregon coast. Documentation of these irregular occurrences of eulachon is usually anecdotal and it is uncertain how these fish are related demographically to eulachon in rivers such as the Fraser and Columbia where consistent annual runs occur. Occasionally large runs are noticed, usually by the abundance of predatory birds and marine mammals that accompany these runs, in coastal rivers such as the Queets and Quinault. Usually these large run events are separated in time by periods greater than the generation time of eulachon. We do not know enough about the biology of eulachon to know if these eulachon run events represent self-sustaining populations or are simply stray individuals from larger eulachon systems. It is possible that these populations may exist at levels of abundance that would not be detected by the casual observer, only to become noticed in years of high abundance. Further research on the source and sustainability of eulachon that occasionally appear in these coastal creeks and rivers is needed to fully assess the status of these eulachon aggregations.

### Offshore juvenile abundance estimates

Four fisheries-independent indices of juvenile offshore biomass are available that indicate status of stock mixtures: 1) a West Coast Vancouver Island eulachon biomass index (Figure 16); 2) a Queen Charlotte Sound eulachon biomass index (Figure 17); 3) estimates of CPUE, biomass, or number of eulachon reported in a series of groundfish bottom trawl surveys conducted on the continental shelf and slope of the U.S. West Coast by NMFS's NWAFC and

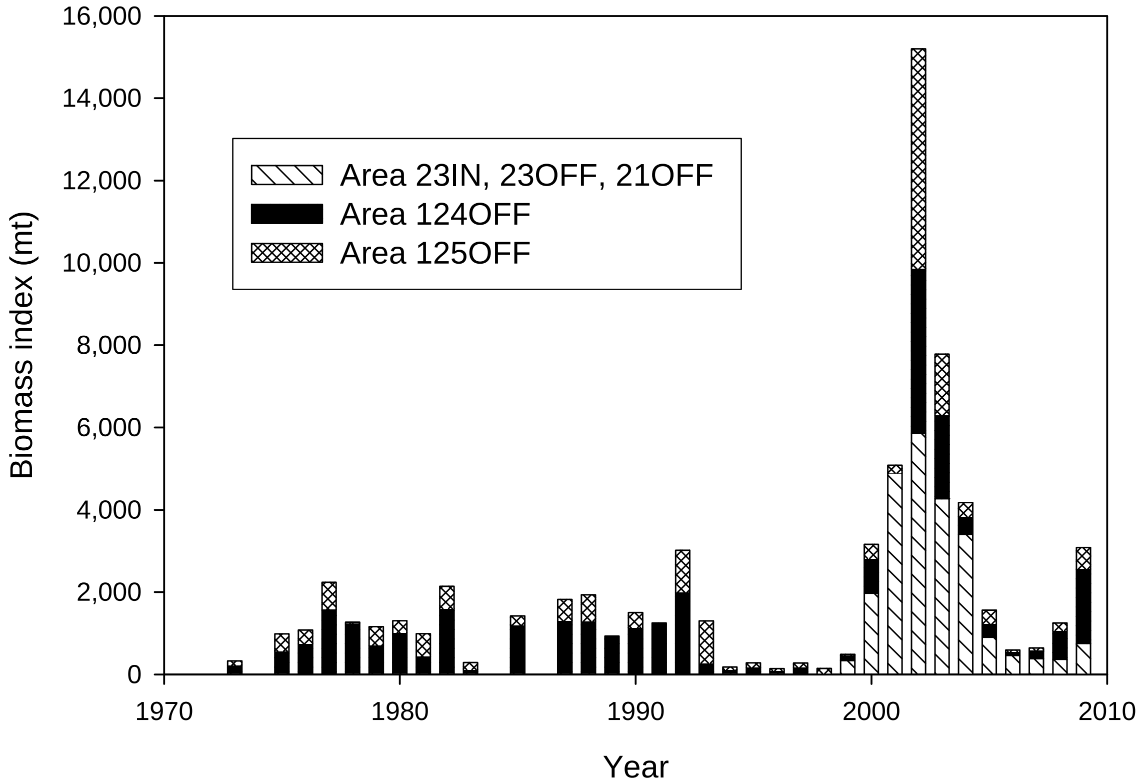



Figure 16. West coast Vancouver Island offshore eulachon biomass index. See Figure 21 for geographic locations of DFO shrimp management areas 23IN, 23OFF, 21OFF, 124OFF, and 125OFF. Data from Hay et al. (2003) and DFO west coast Vancouver Island shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

AFSC and more recently by NWFSC (Table 2 through Table 5, Figure 18, and Figure 19); and 4) the AFSC Gulf of Alaska bottom trawl biomass estimates for eulachon (Figure 20). The latter two groundfish surveys were designed to sample bottom-dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon. In addition, none of these four indices provides information on spawning stock biomass and each incorporates juvenile biomass derived from 2 to 4 broodyears; however, these indices are useful predictors for potential future run sizes.

DFO (2008a, p. 11) describes the west coast Vancouver Island eulachon biomass index as follows (Figure 16):

> The offshore biomass index is based on an annual trawl survey conducted in late April or early May by Fisheries and Oceans Canada, Science Branch. The survey initially was designed to index shrimp abundance but since eulachon also are caught by this survey, a eulachon index is possible. It is important to note that this is a biomass index and not a biomass estimate and that eulachon caught in this survey include stocks from both the Fraser River, and the Columbia River, and possibly other areas. This survey has been conducted since 1973 and provides an annual index of offshore abundance for the lower west coast Vancouver Island (areas 121, 23, 123, 124, and 125) [Figure 21].

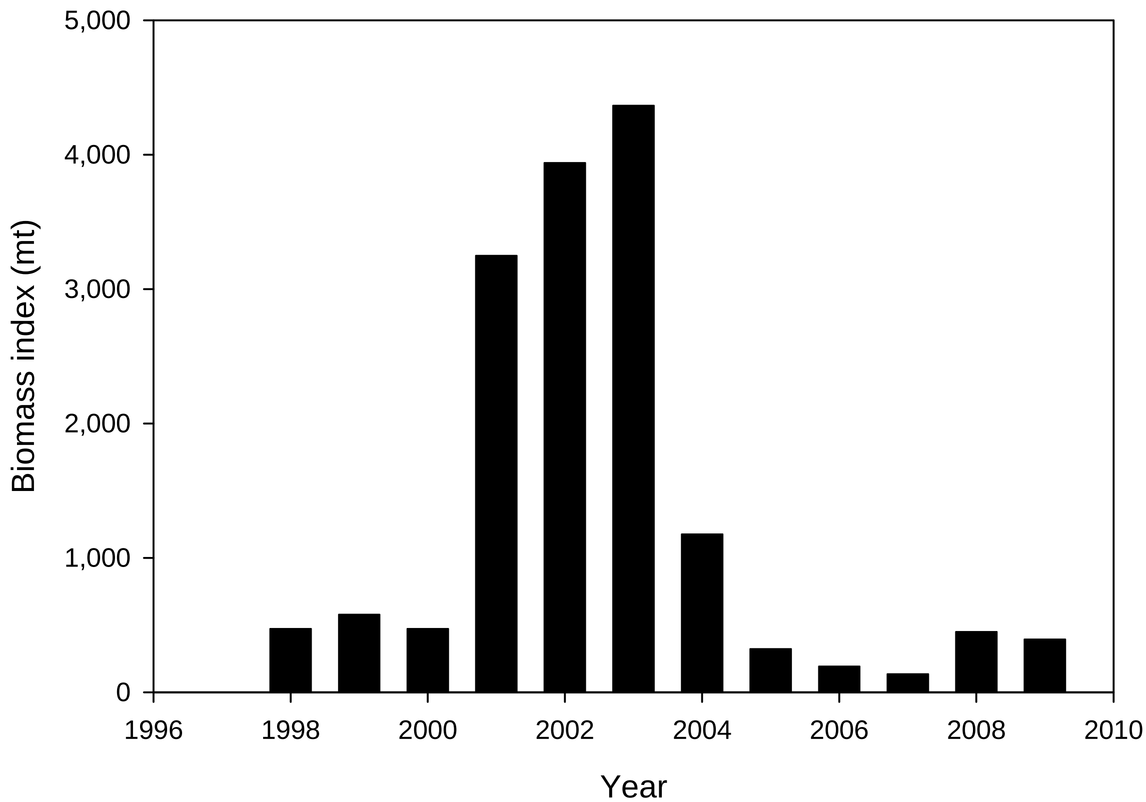



Figure 17. Queen Charlotte Sound offshore eulachon biomass index. Data from DFO Queen Charlotte Sound shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

DFO (2009a, p. 3) stated that "the eulachon biomass indices for 2009 increased in all SMAs [shrimp management areas] surveyed [off west coast Vancouver Island] compared to 2008 indices" (Figure 16). Biomass increased "from 353.7 t in 2008 to 720.8 t in 2009" in SMAs 23OFF+21OFF, "from 697.8 t in 2008 to 1810.1 t in 2009" in SMA 124OFF, and "from 184.9 t in 2008 to 520.0 t in 2009" in SMA 125OFF (DFO 2009a, p. 3) (Figure 21).

In a similar manner, a Queen Charlotte Sound eulachon biomass index (Figure 17) is derived from eulachon caught in the fishery-independent shrimp survey that is conducted in May of each year in SMA Queen Charlotte Sound. Data indicate that "the 2008 estimate of 451.5 t is a significant increase from the record low 137.1 t in 2007" (DFO 2008b, p. 2); however, "eulachon biomass on the shrimp grounds decreased slightly to 394.8 t in 2009 from 451.5 t in 2008" (DFO 2009b, p. 2). As reported in DFO (2009b, p. 3) "the shrimp trawl fishery in SMA Queen Charlotte Sound will remain closed due to eulachon conservation concerns in central British Columbia rivers" (Figure 21).

The history and location of groundfish trawl surveys conducted by the NWAFC, AFSC, and NWFSC in Alaska and off the U.S. West Coast were described in the above Marine Distribution subsection. Mean CPUE (kg/ha) data for eulachon in select INPFC statistical areas (Table 2) were published in various AFSC groundfish bottom trawl surveys conducted between

Table 2. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC groundfish bottom trawl surveys on the continental slope in depths of 183 to 1,280 m. ND (for no data) indicates that no survey occurred in a certain area and a dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1989[a] | ND | ND | ND | 2.296 | ND | ND | ND | ND | ND |
| 1990[a] | ND | ND | ND | ND | 0.487 | ND | ND | ND | ND |
| 1991[a] | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 1992[a] (183–366 m) | ND | 0.003 | ND | 0.032 | ND | ND | ND | ND | ND |
| 1992[a] (367–549) | ND | 0.004 | ND | 0.002 | ND | ND | ND | ND | ND |
| 1993[a] (183–366 m) | ND | ND | ND | 0.001 | ND | ND | ND | ND | ND |
| 1993[a] (367–549 m) | ND | ND | ND | 0.001 | ND | ND | ND | ND | ND |
| 1996[b] (183–366 m) | ND | — | ND | — | ND | ND | ND | ND | ND |
| 1996[b] (367–549 m) | ND | — | ND | 0.002 | ND | ND | ND | ND | ND |
| 1997[c] (183–366 m) | ND | — | ND | 0.002 | — | — | — | 0.001 | ND |
| 1997[c] (367–549 m) | ND | — | ND | 0.003 | — | — | — | 0.001 | ND |
| 1999[d] (183–366 m) | ND | — | ND | 0.006 | 0.007 | — | — | 0.003 | ND |

[a] Lauth et al. 1997
[b] Lauth 1997b
[c] Lauth 1999
[d] Lauth 2000

Table 3. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 366 m (1989 and 1992) or 55 to 500 m (1995–2001). A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1989[a] | 0.723 | 0.259 | 0.557 | 0.438 | 0.458 | 0.014 | 0.169 | 0.295 | 0.368 |
| 1992[b] | 3.115 | 0.010 | 1.933 | 0.188 | 0.226 | — | — | 0.114 | 0.604 |
| 1995[c] | 1.118 | 0.094 | 0.761 | 0.027 | 0.001 | — | — | 0.019 | 0.169 |
| 1998[d] | 0.127 | 0.007 | 0.077 | 0.009 | Trace | — | — | 0.004 | 0.018 |
| 2001[e] | 13.251 | 0.362 | 6.888 | 0.253 | 0.013 | — | — | 0.135 | 1.172 |

[a] Weinberg et al. 1994, [b] Zimmerman 1994, [c] Wilkins 1998, [d] Wilkins and Shaw 2000, [e] Wilkins and Weinberg 2002

Table 4. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1995[a] | 1,137 | 85 | 1,221 | 59 | 1 | — | — | 145 | 1,281 |
| 1998[b] | 123 | 9 | 132 | 20 | — | — | — | 30 | 153 |
| 2001[c] | 12,186 | 717 | 12,903 | 558 | 9 | — | — | 1,284 | 13,470 |

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

Table 5. Estimated number of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1995[a] | 39,912,489 | 2,475,680 | 42,579,382 | 1,552,718 | 16,787 | — | — | 4,045,185 | 44,148,887 |
| 1998[b] | 7,811,913 | 595,554 | 8,407,466 | 1,150,452 | 5,297 | — | — | 1,751,303 | 9,653,216 |
| 2001[c] | 340,794,386 | 22,481,691 | 363,276,077 | 22,146,832 | 808,073 | — | — | 45,436,595 | 386,230,981 |

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

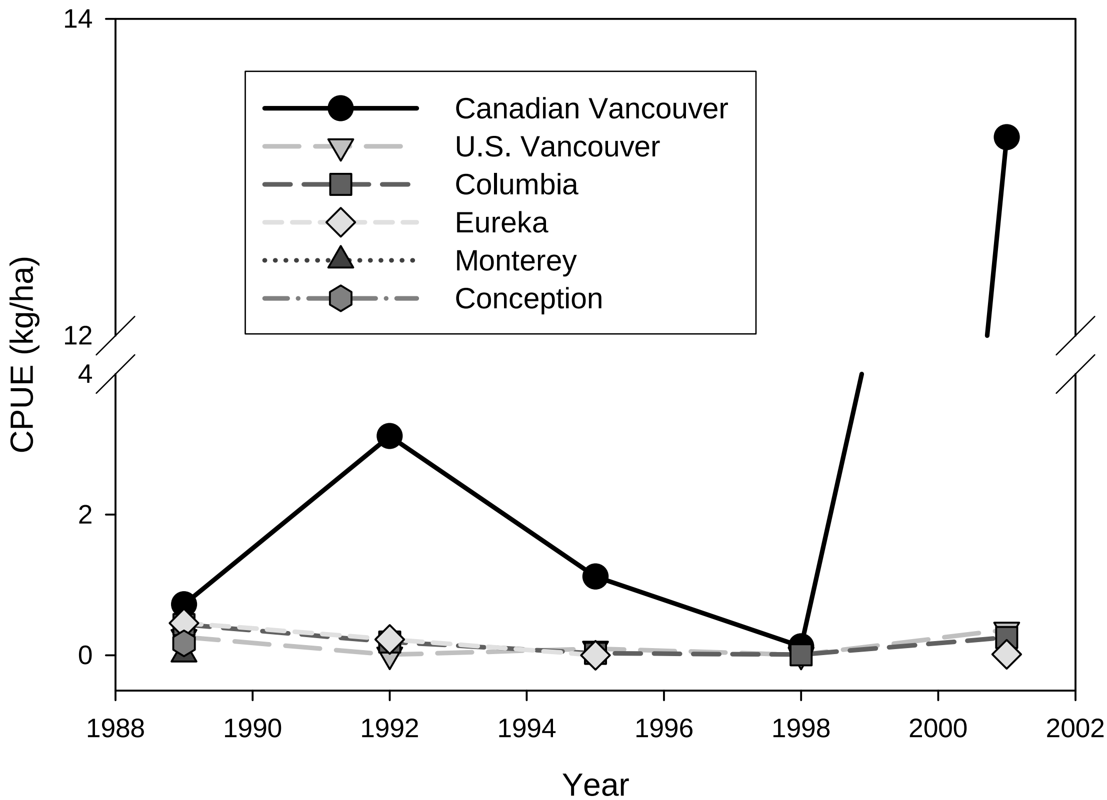



Figure 18. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast, as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–366 m (1989 and 1992) or 55–500 m (1995–2001) in 1989 (Weinberg et al. 1994), 1992 (Zimmermann 1994), 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

1989 and 1999 on the U.S. West Coast continental slope between depths of 183 and 1,280 m (Lauth et al. 1997, Lauth 1997b, 1999, 2000).

As mentioned previously, this depth range is deeper than preferred by eulachon and it is likely that these continental slope surveys missed the vast majority of eulachon in the area. The 1977 triennial groundfish survey recorded eulachon in six of nine assemblages on the continental shelf off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m), where they constituted 3.5% of the total biomass and had a mean CPUE of 28.6 lb/haul (13 kg/haul) (Gabriel and Tyler 1980). In 1980 eulachon were recorded as the 15th most common fish encountered (0.69 kg/ km trawled) in the shallow stratum (55–183 m) in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986). Triennial surveys conducted in 1989–2001 provided mean CPUE (kg/ha) data for eulachon (Table 3, Figure 18) in INPFC statistical areas off the U.S. West Coast (Weinberg et al. 1994b, Zimmermann 1994, Wilkins 1998, Wilkins and Shaw 2000, Wilkins and Weinberg 2002).

Biomass and total number of fish (Table 5) estimates for eulachon were published for surveys conducted in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins

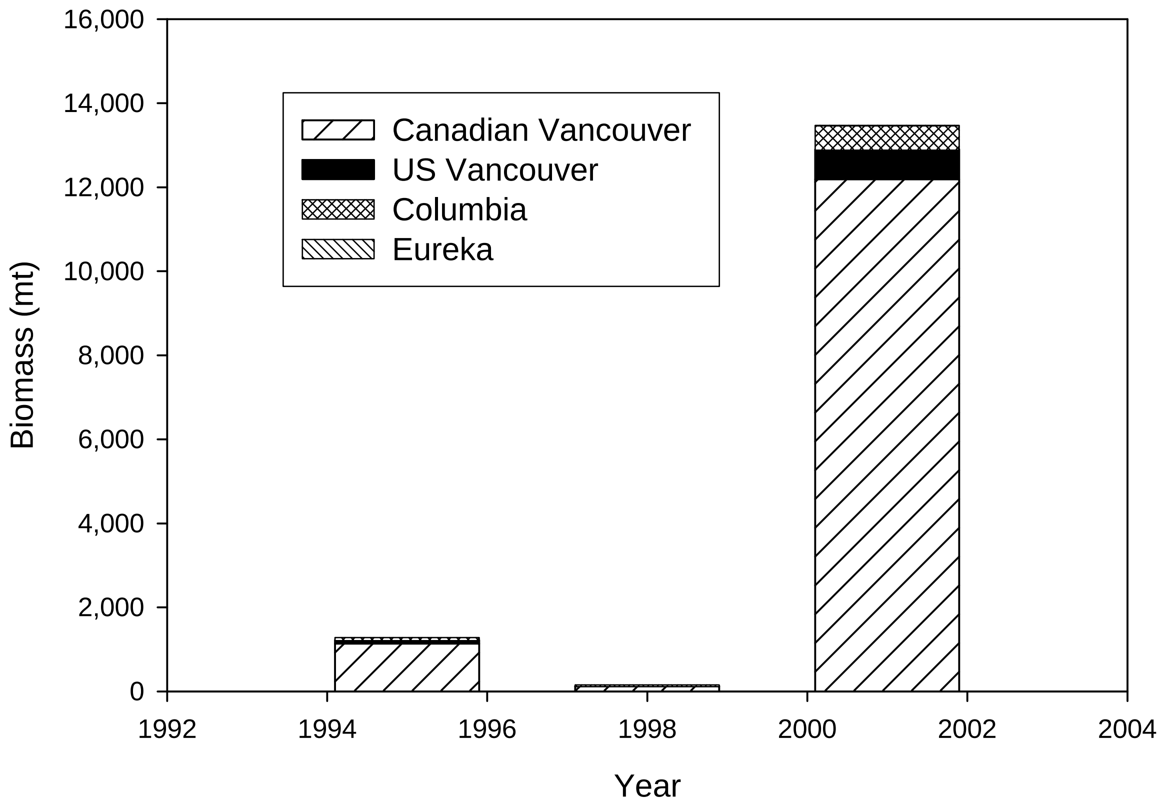



Figure 19. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–500 m in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

and Weinberg 2002). Between 80% and 90% of the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 19). As stated previously, these groundfish surveys were designed to sample bottom-dwelling species and only capture a small and erratic portion of the pelagic distribution of eulachon.

Although unlikely to include eulachon from the southern DPS, the AFSC Gulf of Alaska bottom trawl estimates for eulachon (Figure 20) are a useful indicator of fluctuations in abundance in the Alaska Current for comparison with conditions in the California Current.

**Oregon marine recreational fisheries survey data**

ODFW (Williams 2009) (Table 6) provided a:

> summary for catches of eulachon in the marine sport fishery. The Oregon Recreational Boat Survey (ORBS) is our ocean boat sampling project. The survey is responsible for sampling sport catches from boats, focusing on ocean catches. Estimates of harvest are produced based on this sampling and are used for in-season management of quota species. Sampling takes place at a lesser extent in estuaries and that information is catalogued, but not used routinely. The

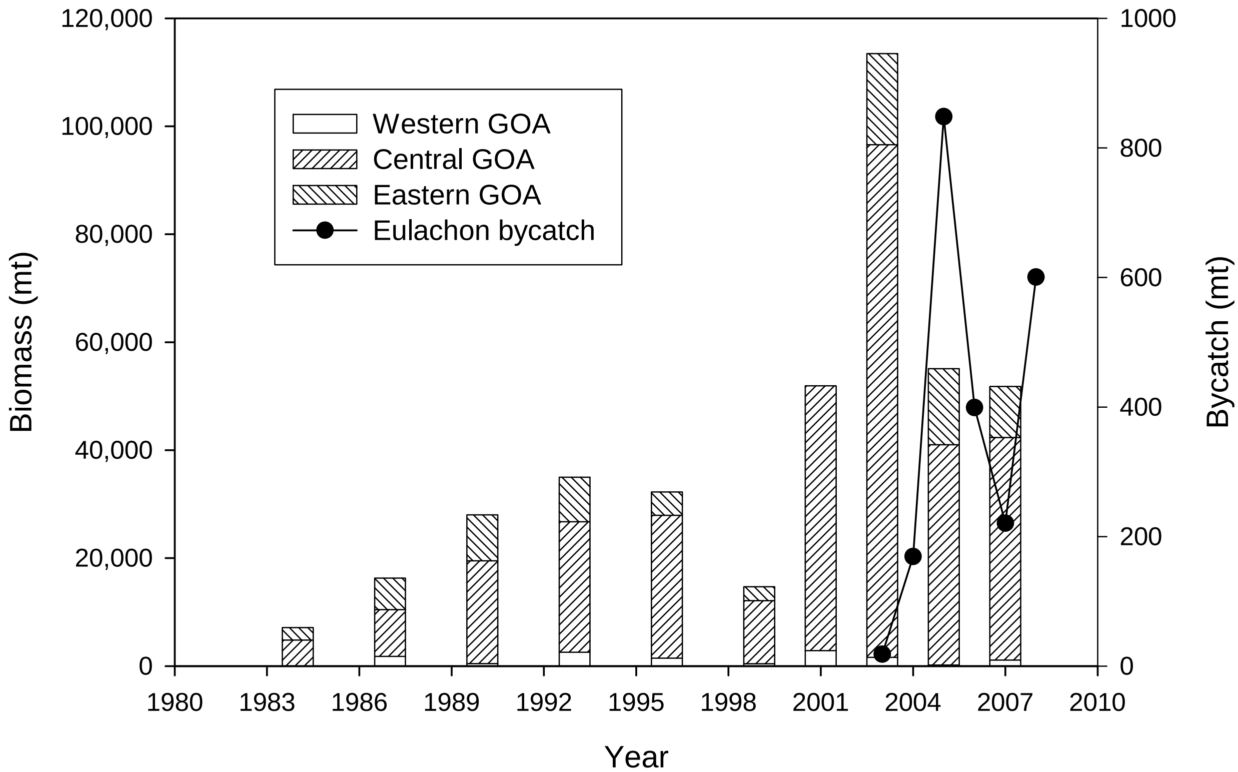



Figure 20. AFSC bottom trawl survey biomass estimates for eulachon and fishery incidental catch (bycatch) of eulachon in the Gulf of Alaska. Data from Ormseth and Vollenweider (2007) and Ormseth et al. (2008).

> Marine Recreational Finfish Statistical Survey (MRFSS) was formed by NMFS and operated by the Pacific States Marine Fisheries Commission. This survey was conducted at all saltwater access points including beaches, estuaries, man-made structures (e.g., jetties), and docks. It was a comprehensive survey that was intended to produce harvest trends over a number of years. … Beginning in 1994, ORBS estimates for ocean boats superseded those generated by the old MRFSS program because ORBS methodology generates more accurate estimates. In particular, MRFSS is weak in capturing pulse, or short-term, fisheries like smelt (the PSE [proportional statistical error] for the annual eulachon estimates range from 73 to 100). Hence, the summary is best regarded as an indicator of eulachon presence in the sport fishery, not absolute numbers.

**Northern California**

There has been no long-term monitoring program for eulachon in California, making the assessment of historical abundance and abundance trends difficult. Within California, large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Moyle et al. 1995) (Table A-1, Figure 2). In addition, Moyle et al. (1995) and Moyle (2002) stated that small numbers of eulachon have been reported from the Smith River

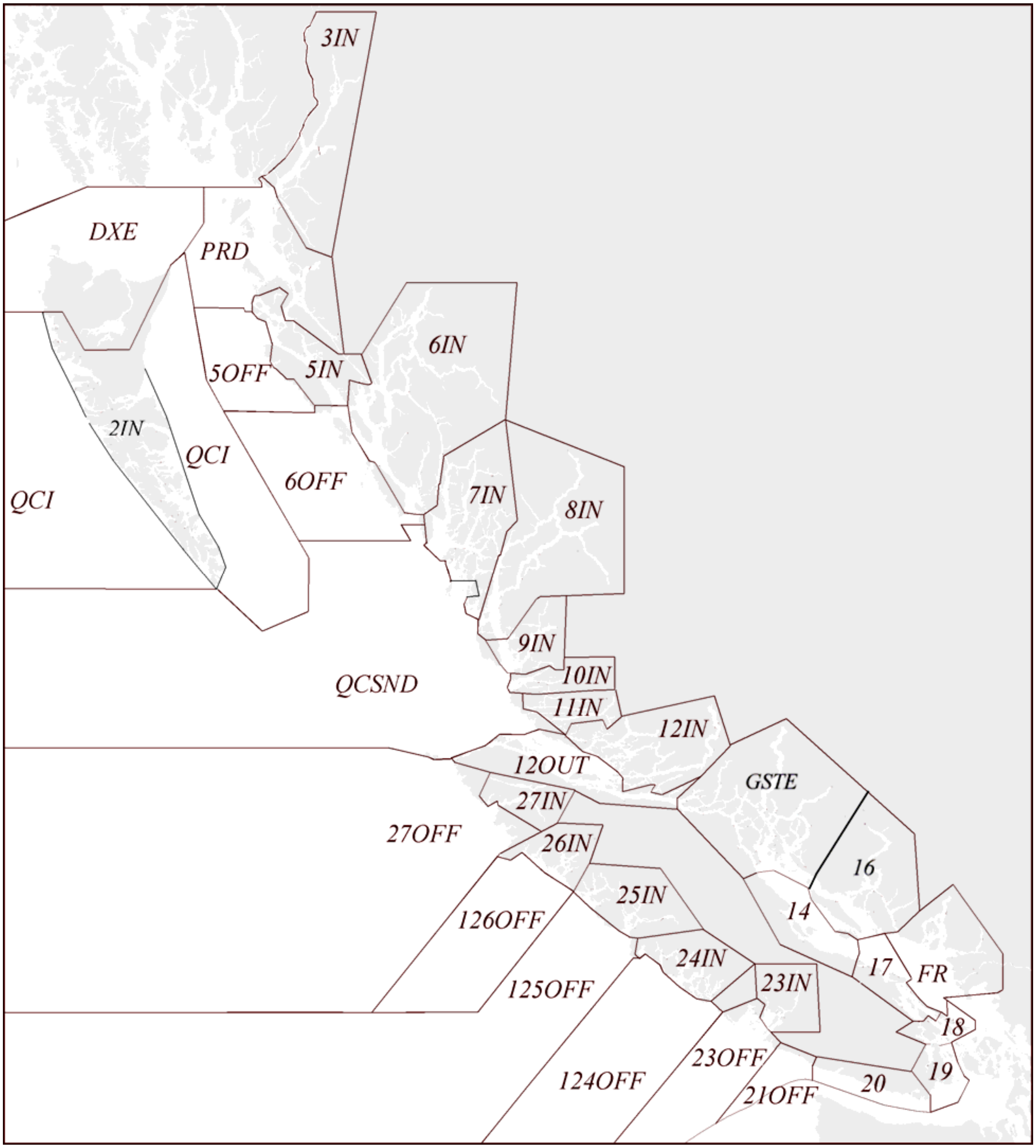



Figure 21. Map of major shrimp management areas on the coast of British Columbia. Map modified from DFO (2009c).

Table 6. Marine Recreational Finfish Statistical Survey (MRFSS) and Shore and Estuary Boat Survey (SEBS) eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

| | South Beach | | | Winchester Bay | | | Bandon | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. fish | No. fishers | CPUE | No. fish | No. fishers | CPUE | No. fish | No. fishers | CPUE |
| 1983 | | | | | | | | | |
| 1987 | | | | | | | | | |
| 1993 | 53 | 11 | 4.8 | 8 | 4 | 2.0 | | | |
| 1994 | | | | | | | | | |
| 1995 | | | | 18 | 1 | 18.0 | | | |
| 1999 | | | | | | | 66 | 6 | 11.0 |
| Total | 53 | 11 | 4.8 | 26 | 5 | 5.2 | 66 | 6 | 11.0 |

Table 6 continued horizontally. MRFSS and SEBS eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

| | Charleston | | | Brookings | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. fish | No. fishers | CPUE | No. fish | No. fishers | CPUE | No. fish | No. fishers | CPUE |
| 1983 | 1 | 2 | 0.5 | | | | 1 | 2 | 0.5 |
| 1987 | 2 | 3 | 0.7 | | | | 2 | 3 | 0.7 |
| 1993 | | | | | | | 61 | 15 | 4.1 |
| 1994 | | | | 4 | 2 | 2.0 | 4 | 2 | 2.0 |
| 1995 | | | | | | | 18 | 1 | 18.0 |
| 1999 | | | | | | | 66 | 6 | 11.0 |
| Total | 3 | 5 | 0.6 | 4 | 2 | 2.0 | 152 | 29 | 5.5 |

(Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) stated that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries.

Eulachon were of great cultural and subsistence importance to the Yurok Tribe on the lower Klamath River (Trihey and Associates 1996) and the Yurok people consider eulachon to be a Tribal Trust Species along with spring and fall Chinook salmon, coho salmon, steelhead, Pacific lamprey (*Lampetra tridentata*) , and green sturgeon (*Acipenser medirostris*) (Trihey and Associates 1996, Larson and Belchik 1998). Eulachon once supported popular recreational fisheries in northern California rivers, but were never commercially important in California. The only reported commercial catch of eulachon in northern California occurred in 1963 when a combined total of 56,000 lb (25 mt) was landed from the Klamath River, the Mad River, and Redwood Creek. According to Larson and Belchik (1998, p. 4):

> Literature regarding … [eulachon] specific to the Klamath River Basin is limited to accounts of mere presence and qualitative descriptions of the species. Though integral components of Yurok culture, eulachon … have not been of commercial importance in the Klamath and are … totally unstudied as to their run strengths.

Larson and Belchik (1998, p. 6) also reported that according to accounts of Yurok tribal elders:

> The last noticeable runs of eulachon were observed [in the Klamath River] in 1988 and 1989 by tribal fishers. Most fishers interviewed perceived a decline in the mid to late 1970s, while about a fifth thought it was in the 1980s. A minority of those interviewed noticed declines in the 1950s and 1960s.

Larson and Belchik (1998, p. 7) further stated that:

> In December 1988 and May 1989, a total of 44 eulachon were identified in outmigrant salmonid seining operations in and above the Klamath River estuary (CDFG unpublished seining data). Though only selected sites are seined and salmonids are the targeted species, no eulachon have been positively identified since at least 1991 (M. Wallace, CDFG, pers. commun.).

As detailed in Larson and Belchik (1998), the Yurok Tribal Fisheries Program spent more than 119 hours of staff time from February 5 to May 6, 1996, sampling for eulachon in the lower Klamath River at 5 different sites where eulachon had been noted in the past without encountering a single eulachon. However, one eulachon was captured by a Yurok tribal member near the mouth of the Klamath River in 1996 (Larson and Belchik 1998). Sweetnam et al. (2001, p. 478), in the CDFG Status Report on Living Marine Resources, stated that "In recent years, eulachon numbers seem to have declined drastically, so they are now rare or absent from the Mad River and Redwood Creek and scarce in the Klamath River." CDFG (Sweetnam et al. 2001, p. 478) also stated that "the eulachon and its fishery have been largely ignored in the past" in California, and perhaps the perceived lack of eulachon in the Klamath River, currently and in the recent past, represent a low point in a natural cycle. In January 2007 six eulachon were reportedly caught by tribal fishermen on the Klamath River.[12]

The BRT was concerned that there are almost no scientifically obtained abundance data available for eulachon in the Klamath River or any other basin in northern California. Ethnographic studies, pioneer diaries, interviews with local fishers, personal communications from managers, and newspaper accounts are therefore the best information available that provide documentation of eulachon occurrence in the Klamath River and other rivers on the northern California coast.

The BRT discussed several possible interpretations of the available information. In particular, the BRT discussed the possibility that historically runs of eulachon in the Klamath River were episodic and perhaps only occasionally large enough to be noticed. The BRT also considered the possibility that eulachon still occur in low but viable numbers in northern California rivers but are not frequently observed because of the absence of a formal monitoring program. The BRT also discussed the possibility that some eulachon may spawn in estuarine environments and are not observed in the riverine environment.

The BRT concluded, however, that explanations that posit the absence of sustained Klamath River eulachon runs historically are less consistent with the available information than the hypothesis that Klamath River eulachon runs used to be regular and large enough to be readily noticeable and now are at most small and sporadic. In particular, various accounts written by CDFG personnel (Fry 1979, Sweetnam et al. 2001, CDFG 2008), Yurok Tribal Fisheries Department personnel (Larson and Belchik 1998), the National Resource Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin (NRC 2004), or available academic literature (Moyle et al. 1995, Moyle 2002, Hamilton et al. 2005) universally describe accounts of the past occurrence of eulachon in the Klamath River and their subsequent decline. Based on the available information, the BRT was therefore unable to estimate the historical abundance of eulachon in northern California, but the BRT found no reason to discount the veracity of these anecdotal sources, which span a period of approximately 100 years and are nearly universal in their description of noticeable runs of eulachon having once ascended the Klamath River.

Likewise, although the BRT was concerned about the absence of a contemporary monitoring program for eulachon, the information available strongly indicated that noticeable runs of eulachon are not currently spawning in Klamath River or other northern California rivers. In particular, the BRT thought it likely that if eulachon were returning in any substantial numbers, it would be reported by residents or those engaged in recreation, research, or management on rivers in northern California. The BRT noted that large eulachon runs tend to attract the attention of fishermen, and the previous runs on the Klamath River were readily noticeable (e.g., "the fish moved up in huge swarms, followed by large flocks of feeding seabirds" [Moyle 2002, p. 240]). The BRT therefore concluded that the available information was most readily interpreted as indicating that noticeable, regularly returning runs of eulachon used to be present in the Klamath River, but have been rare or sporadic for a period of several decades.

[12] D. Hillemeier, Yurok Tribal Fisheries Department, Klamath, CA. Pers. commun., 23 June 2008.

Although the BRT was reasonably confident that eulachon have declined substantially in northern California, it is also clear that they have not been totally absent from this area in recent years.  In particular, recent reports from Yurok tribal fisheries biologists of a few eulachon being caught incidentally in other fisheries on the Klamath in 2007 indicates eulachon still on occasion enter the Klamath River in low numbers.

**Columbia River**

The Columbia River and its tributaries support the largest eulachon run in the world (Hay et al. 2002).  Despite its size and the importance of the fishery (Appendix B and Appendix D), estimates of adult spawning stock abundance are unavailable and the primary information sources on trends in Columbia River eulachon abundance are catch records.  In addition to regular returns to mainstem spawning locations in the Columbia River and on the Cowlitz River (most years), eulachon are known to spawn in the following lower Columbia River tributaries: Grays River (common use), Skamokawa Creek (infrequent use), Elochoman River (periodic use), Kalama River (common use), Lewis River (common use), and Sandy River (common use in large run years) (Table A-1, Figure 2) (WDFW and ODFW 2008).

Commercial fishery records begin in 1888 (Table 7 through Table 9, Figure 22) and local newspapers record catches in the Columbia River as early as 1867 (see Appendix B).  A large recreational dip net fishery for which catch records are unavailable has existed in concert with commercial fisheries, and the importance of the eulachon run to local Indian tribes was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001).  The Joint Columbia River Management Staff (JCRMS 2007) stated that "limited past creel census information suggest that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time."

The BRT did not have confidence in the fishery landings, particularly prior to 2001 in the Columbia River as an accurate index of the actual abundance of the species.  Landings are influenced by market conditions, fishing effort, weather, and many other factors other than actual fish abundance (WDFW and ODFW 2008).  After implementation in 2000 of the interim Joint State Eulachon Management Plan (WDFW and ODFW 2001), the commercial fishery landings have become a relatively accurate index of the trend in the run size of eulachon returning to the Columbia River.  For instance, eulachon returns increased during 2001–2003, dropped slightly in 2004, then dropped dramatically in 2005, which is reflected in both the commercial landings and CPUE data collected during 2001–2007.  This pattern was also essentially identical to that seen in offshore eulachon abundance indices (Figure 16 and Figure 17) and in abundance and catch records in several other rivers (e.g., Fraser and Klinaklini rivers) in the DPS.  JCRMS (2007) has concluded that recent commercial landings "do provide a useful measure of the relative annual run strength."  In particular, state fisheries managers of Columbia River eulachon use commercial landings to judge whether population trends are upward, neutral, or downward (JCRMS 2007).

Although not useful for estimating an accurate trend, the long-term landings data do indicate that commercial catch levels were consistently high (>500 mt and often >1,000 mt) for the three-quarters of a century period from about 1915 to 1992 (Table 9, Figure 22).  Catches

Table 7. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1888 | | | | | | | 150,000 | | 150,000 | Collins 1892 (p. 231) |
| 1889 | | | | | | | 60,000 | | 60,000 | Reed et al. 1891 (p. 39) |
| 1890 | | | | | | | | 1,000 | 1,000 | Crawford 1890 (p. 8) |
| 1891 | | | | | | | 150,000 | | 150,000 | Reed et al. 1892 (p. 9) |
| 1892 | | | | | | | 125,000 | 500,000 | 625,000 | Reed et al. 1892 (p. 42), Crawford 1892 (p. 9–10) |
| 1893 | | | | | | | | | Unknown[b] | |
| 1894 | | | | | | | | 300,000[c] | 300,000 | Crawford 1894 (p.5) |
| 1895 | 31,125 | | 20,625 | | 230,500 | | | | 282,250 | Wilcox 1898 (p. 604, 607, 629) |
| 1896 | | | | | | | 338,675 | 338,675 | 677,350 | McGuire 1896 (p. 77), Crawford 1896 (p. 9) |
| 1897 | | | | | | | 677,480 | 344,000 | 1,021,480 | McGuire 1898 (p. 35), Little 1898 (p. 88) |
| 1898 | | | | | | | 450,000 | 287,000 | 737,000 | McGuire 1898 (p. 118), Little 1898 (p. 15) |
| 1899 | | | | | | | 280,500 | 280,420 | 560,920 | Reed 1900 (p. 19), Little 1901 (p. 72) |
| 1900 | | | | | | | 260,200 | 227,400 | 487,600 | Reed 1900 (p. 69), Little 1901 (p. 82) |
| 1901 | | | | | | | 265,380 | | 265,380 | Van Dusen 1903 (p. 52) |
| 1902 | | | | | | | 122,454 | 450,000 | 572,454 | Van Dusen 1903 (p. 135), Kershaw 1902 (p. 82) |
| 1903 | | | | | | | 102,000 | 300,000 | 402,000 | Van Dusen 1904 (p. 69), Kershaw 1904 (p. 81) |
| 1904 | | | | | | | 15,138 | 425,322 | 440,460 | Wilcox 1907 (p. 33–34, p. 45) |
| 1905 | | | | | | | 143,015 | 340,000 | 483,015 | Van Dusen 1907 (p. 111), Riseland 1907 (p. 81) |
| 1906 | | | | | | | 163,000 | 340,000 | 503,000 | Van Dusen 1907 (p. 190), Riseland 1907 (p. 56) |
| 1907 | | | | | | | 169,804 | | 169,804 | Van Dusen and McCallister 1908 (p. 110) |
| 1908 | | | | | | | 262,022 | 340,000 | 602,022 | Van Dusen and McCallister 1906 (p. 150), Riseland 1909 (p. 25) |
| 1909 | | | | | | | 209,608 | 340,000 | 549,608 | Van Dusen and McCallister 1911 (p. 36), Riseland 1909 (p. 37) |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1910 | | | | | | | 272,478 | 350,000 | 622,478 | McCallister and Clanton 1911 (p. 44), Riseland 1911 (p. 46) |
| 1911 | | | | | | | 174,639 | 175,000 | 349,639 | Clanton 1913 (p. 112), Riseland 1911 (p. 58) |
| 1912 | | | | | | | 320,336 | 175,000 | 495,336 | Clanton 1913 (p. 112), Riseland 1911 (p. 48) |
| 1913 | | | | | | | | 200,000 | 200,000 | Riseland 1913 (p. 63) |
| 1914 | | | | | | | | | Unknown[b] | |
| 1915 | | | 1,609,500 | | | | | | 1,609,500 | Radcliffe 1920 (p. 64–65) |
| 1916 | | | | | | | | 641,595 | 641,595 | Darwin 1917 (p. 103) |
| 1917 | | | | | | | | 2,806,129 | 2,806,129 | Darwin 1917 (p. 173) |
| 1918 | | | | | | | | 1,633,700 | 1,633,700 | Darwin 1920 (p. 64) |
| 1919 | | | | | | | | 2,405,360 | 2,405,360 | Darwin 1920 (p. 121) |
| 1920 | | | | | | | | 977,084 | 977,084 | Darwin 1920 (p. 162) |
| 1921 | | | | | | | | 1,051,283 | 1,051,283 | Darwin 1921 (p. 236) |
| 1922 | | | | | | | 215,000 | 1,156,180 | 1,371,180 | Sette 1926 (p. 306), Brennan 1936 (p. 100) |
| 1923 | | | | | | | 277,195 | 752,223 | 1,029,418 | Sette 1926 (p. 346–347), Brennan 1936 (p. 100) |
| 1924 | | | | | | | 226,800 | 779,422 | 1,006,222 | Sette 1928 (p. 409), Pollock 1925 (p. 44) |
| 1925 | | | | | | | 308,676 | 1,092,028 | 1,400,704 | Sette 1928 (p. 445), Pollock 1925 (p. 97) |
| 1926 | | | | | | | 72,900 | 1,194,314 | 1,267,214 | Sette and Fiedler 1929 (p. 514), Pollock 1928 (p. 104) |
| 1927 | | | | | | | 411,732 | 881,314 | 1,293,046 | Fiedler 1930 (p. 570), Pollock 1928 (p. 168) |
| 1928 | | | | | | | 19,148 | 1,149,670 | 1,168,818 | Maybury 1930 (p. 33), Cleaver 1951 (p. 80) |
| 1929 | | | | | | | 50,061 | 1,158,419 | 1,208,480 | Maybury 1930 (p. 84), Cleaver 1951 (p. 80) |
| 1930 | | | | | | | 194,172 | 1,260,314 | 1,454,486 | Pollock 1932 (p. 14, 49), Cleaver 1951 (p. 80) |
| 1931 | | | | | | | 435,306 | 1,521,966 | 1,957,272 | Pollock 1932 (p. 14, 103), Cleaver 1951 (p. 80) |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1932 | | | | | | | 233,993 | 1,349,955 | 1,583,948 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1933 | | | | | | | 520,418 | 872,172 | 1,392,590 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1934 | | | | | | | 536,036 | 957,120 | 1,520,156 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1935 | | | | | | | 132,773 | 2,199,185 | 2,331,958 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1936 | 194,705 | 27,200 | 2,583,525 | 0 | 144,325 | 134,102 | | | 3,083,857 | Cleaver 1951 (p. 154) |
| 1937 | 432,063 | 7,350 | 1,999,030 | 0 | 0 | 0 | | | 2,438,443 | Cleaver 1951 (p. 154) |
| 1938 | 866,700 | 2,100 | 33,100 | 76,600 | 63,100 | 0 | | | 1,041,600 | WDFW and ODFW 2002 |
| 1939 | 721,600 | 35,700 | 996,400 | 0 | 1,342,700 | 0 | | | 3,096,400 | WDFW and ODFW 2002 |
| 1940 | 820,200 | 53,700 | 736,800 | 3,000 | 1,341,300 | 127,500 | | | 3,082,500 | WDFW and ODFW 2002 |
| 1941 | 193,200 | 0 | 1,793,000 | 0 | 377,000 | 168,600 | | | 2,531,800 | WDFW and ODFW 2002 |
| 1942 | 318,600 | 51,800 | 1,555,300 | 0 | 0 | 760,300 | | | 2,686,000 | WDFW and ODFW 2002 |
| 1943 | 643,000 | 3,700 | 2,972,500 | 0 | 273,200 | 84,900 | | | 3,977,300 | WDFW and ODFW 2002 |
| 1944 | 572,700 | 10,900 | 1,126,400 | 44,300 | 514,200 | 0 | | | 2,268,500 | WDFW and ODFW 2002 |
| 1945 | 633,300 | 59,200 | 2,048,400 | 32,500 | 1,552,800 | 1,393,100 | | | 5,719,300 | WDFW and ODFW 2002 |
| 1946 | 253,200 | 300 | 2,674,000 | 0 | 0 | 348,500 | | | 3,276,000 | WDFW and ODFW 2002 |
| 1947 | 352,300 | 0 | 1,192,600 | 0 | 0 | 0 | | | 1,544,900 | WDFW and ODFW 2002 |
| 1948 | 1,015,800 | 0 | 2,197,800 | 0 | 547,600 | 212,900 | | | 3,974,100 | WDFW and ODFW 2002 |
| 1949 | 919,100 | 300 | 800 | 0 | 1,940,900 | 472,500 | | | 3,333,600 | WDFW and ODFW 2002 |
| 1950 | 912,700 | 11,600 | 0 | 1,000 | 557,200 | 0 | | | 1,482,500 | WDFW and ODFW 2002 |
| 1951 | 1,337,600 | 0 | 0 | 0 | 0 | 179,300 | | | 1,516,900 | WDFW and ODFW 2002 |
| 1952 | 867,100 | 0 | 380,600 | 17,800 | 8,100 | 1,300 | | | 1,274,900 | WDFW and ODFW 2002 |
| 1953 | 439,300 | 15,600 | 795,400 | 2,800 | 0 | 457,900 | | | 1,711,000 | WDFW and ODFW 2002 |
| 1954 | 673,900 | 0 | 792,900 | 16,200 | 360,900 | 40,400 | | | 1,884,300 | WDFW and ODFW 2002 |
| 1955 | 887,500 | 0 | 1,349,600 | 0 | 0 | 0 | | | 2,237,100 | WDFW and ODFW 2002 |
| 1956 | 877,400 | 0 | 575,100 | 32,600 | 0 | 198,800 | | | 1,683,900 | WDFW and ODFW 2002 |
| 1957 | 377,500 | 2,200 | 987,800 | 0 | 0 | 211,500 | | | 1,579,000 | WDFW and ODFW 2002 |
| 1958 | 373,300 | 0 | 2,243,100 | 0 | 0 | 0 | | | 2,616,400 | WDFW and ODFW 2002 |
| 1959 | 760,000 | 0 | 62,300 | 44,100 | 889,700 | 0 | | | 1,756,100 | WDFW and ODFW 2002 |
| 1960 | 185,700 | 700 | 985,800 | 0 | 0 | 0 | | | 1,172,200 | WDFW and ODFW 2002 |
| 1961 | 466,400 | 0 | 585,900 | 0 | 0 | 0 | | | 1,052,300 | WDFW and ODFW 2002 |
| 1962 | 690,300 | 0 | 783,300 | 0 | 0 | 0 | | | 1,473,600 | WDFW and ODFW 2002 |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 222,300 | 21,300 | 833,500 | 0 | 0 | 0 | | | 1,077,100 | WDFW and ODFW 2002 |
| 1964 | 452,900 | 0 | 388,900 | 0 | 0 | 0 | | | 841,800 | WDFW and ODFW 2002 |
| 1965 | 828,700 | 0 | 0 | 0 | 82,000 | 0 | | | 910,700 | WDFW and ODFW 2002 |
| 1966 | 712,200 | 0 | 316,100 | 0 | 0 | 0 | | | 1,028,300 | WDFW and ODFW 2002 |
| 1967 | 357,100 | 23,200 | 620,500 | 0 | 0 | 0 | | | 1,000,800 | WDFW and ODFW 2002 |
| 1968 | 133,300 | 1,200 | 813,000 | 0 | 0 | 0 | | | 947,500 | WDFW and ODFW 2002 |
| 1969 | 113,700 | 52,800 | 917,200 | 0 | 0 | 0 | | | 1,083,700 | WDFW and ODFW 2002 |
| 1970 | 238,200 | 4,500 | 559,700 | 55,900 | 325,600 | 0 | | | 1,183,900 | WDFW and ODFW 2002 |
| 1971 | 364,500 | 0 | 509,400 | 0 | 902,800 | 0 | | | 1,776,700 | WDFW and ODFW 2002 |
| 1972 | 304,100 | 0 | 1,339,400 | 0 | 0 | 0 | | | 1,643,500 | WDFW and ODFW 2002 |
| 1973 | 132,000 | 0 | 2,302,400 | 0 | 0 | 0 | | | 2,434,400 | WDFW and ODFW 2002 |
| 1974 | 868,400 | 6,200 | 1,474,700 | 0 | 500 | 12,000 | | | 2,361,800 | WDFW and ODFW 2002 |
| 1975 | 28,300 | 0 | 2,049,300 | 0 | 0 | 0 | | | 2,077,600 | WDFW and ODFW 2002 |
| 1976 | 9,400 | 0 | 3,055,300 | 0 | 0 | 10,400 | | | 3,075,100 | WDFW and ODFW 2002 |
| 1977 | 662,700 | 0 | 0 | 326,200 | 0 | 764,100 | | | 1,753,000 | WDFW and ODFW 2002 |
| 1978 | 16,600 | 0 | 2,642,700 | 0 | 21,000 | 0 | | | 2,680,300 | WDFW and ODFW 2002 |
| 1979 | 313,600 | 0 | 18,200 | 0 | 233,300 | 591,600 | | | 1,156,700 | WDFW and ODFW 2002 |
| 1980 | 160,100 | 8,800 | 116,500 | 700 | 2,651,600 | 273,800 | | | 3,211,500 | WDFW and ODFW 2002 |
| 1981 | 158,200 | 0 | 932,500 | 0 | 567,100 | 14,500 | | | 1,672,300 | WDFW and ODFW 2002 |
| 1982 | 304,200 | 0 | 1,343,200 | 8,200 | 554,400 | 0 | | | 2,210,000 | WDFW and ODFW 2002 |
| 1983 | 58,700 | 0 | 1,307,300 | 0 | 1,364,400 | 0 | | | 2,730,400 | WDFW and ODFW 2002 |
| 1984 | 120,400 | 0 | 377,600 | 0 | 0 | 0 | | | 498,000 | WDFW and ODFW 2002 |
| 1985 | 537,800 | 34,900 | 1,160,800 | 0 | 0 | 304,500 | | | 2,038,000 | WDFW and ODFW 2002 |
| 1986 | 53,000 | 0 | 3,736,100 | 0 | 49,700 | 0 | | | 3,838,800 | WDFW and ODFW 2002 |
| 1987 | 73,600 | 0 | 1,321,000 | 700 | 500,400 | 0 | | | 1,895,700 | WDFW and ODFW 2002 |
| 1988 | 72,800 | 0 | 2,244,300 | 0 | 549,600 | 1,000 | | | 2,867,700 | WDFW and ODFW 2002 |
| 1989 | 65,200 | 0 | 3,001,600 | 0 | 0 | 0 | | | 3,066,800 | WDFW and ODFW 2002 |
| 1990 | 6,400 | 0 | 2,756,200 | 0 | 21,600 | 0 | | | 2,784,200 | JCRMS 2007 |
| 1991 | 5,800 | 0 | 2,944,600 | 0 | 0 | 0 | | | 2,950,400 | JCRMS 2007 |
| 1992 | 800 | 0 | 3,673,000 | 0 | 0 | 0 | | | 3,673,800 | JCRMS 2007 |
| 1993 | 33,200 | 0 | 413,900 | 66,800 | 0 | 0 | | | 513,900 | JCRMS 2007 |
| 1994 | 200 | 0 | 43,200 | 0 | 0 | 0 | | | 43,400 | JCRMS 2007 |
| 1995 | 7,700 | 0 | 431,400 | 900 | 0 | 0 | | | 440,000 | JCRMS 2007 |
| 1996 | 7,100 | 0 | 2,000 | 0 | 0 | 0 | | | 9,100 | JCRMS 2007 |
| 1997 | 37,100 | 0 | 21,500 | 0 | 0 | 0 | | | 58,600 | JCRMS 2007 |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 11,900 | 0 | 200 | 0 | 0 | 0 | | | 12,100 | JCRMS 2007 |
| 1999 | 20,900 | 0 | 0 | 0 | 0 | 0 | | | 20,900 | JCRMS 2007 |
| 2000 | 31,000 | 0 | 0 | 0 | 0 | 0 | | | 31,000 | JCRMS 2007 |
| 2001 | 158,800 | 0 | 154,300 | 0 | 0 | 0 | | | 313,100 | JCRMS 2007 |
| 2002 | 58,000 | 0 | 169,600 | 0 | 493,600 | 0 | | | 721,200 | JCRMS 2007 |
| 2003 | 66,900 | 0 | 464,400 | 0 | 529,100 | 23,000 | | | 1,083,400 | JCRMS 2007 |
| 2004 | 15,400 | 0 | 216,200 | 0 | 0 | 0 | | | 231,600 | JCRMS 2007 |
| 2005 | 100 | 0 | 100 | 0 | 0 | 0 | | | 200 | JCRMS 2007 |
| 2006 | 13,100 | 0 | 0 | 0 | 0 | 0 | | | 13,100 | JCRMS 2007 |
| 2007 | 7,100 | 0 | 1,200 | 0 | 0 | 0 | | | 8,300 | JCRMS 2007 |
| 2008 | 11,400 | 0 | 5,900 | 0 | 0 | 0 | | | 17,300 | JCRMS 2008 |
| 2009 | 5,551 | 0 | 12,093 | 0 | 0 | 0 | | | 17,644 | WDFW 2009 |

[a]Some Oregon commercial smelt catch values may be statewide smelt catch and may include an unknown number of noneulachon smelt caught in coastal streams.
[b]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[c]Crawford (1894, p. 5) reported landings that equated to a monetary value of $3,000. At an average of one cent per pound, this equates to approximately 300,000 pounds of eulachon.

Table 8. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1888 | 150,000 | 1,620,000 | 1,845,000 |
| 1889 | 60,000 | 648,000 | 738,000 |
| 1890 | 1,000 | 10,800 | 12,300 |
| 1891 | 150,000 | 1,620,000 | 1,845,000 |
| 1892 | 625,000 | 6,750,000 | 7,687,500 |
| 1893 | Unknown* | — | — |
| 1894 | 300,000 | 3,240,000 | 3,690,000 |
| 1895 | 313,375 | 3,384,450 | 3,854,513 |
| 1896 | 677,350 | 7,315,380 | 8,331,405 |
| 1897 | 1,021,480 | 11,031,984 | 12,564,204 |
| 1898 | 737,000 | 7,959,600 | 9,065,100 |
| 1899 | 560,920 | 6,057,936 | 6,899,316 |
| 1900 | 487,600 | 5,266,080 | 5,997,480 |
| 1901 | 265,380 | 2,866,104 | 3,264,174 |
| 1902 | 572,454 | 6,182,503 | 7,041,184 |
| 1903 | 402,000 | 4,341,600 | 4,944,600 |
| 1904 | 440,460 | 4,756,968 | 5,417,658 |
| 1905 | 483,015 | 5,216,562 | 5,941,085 |
| 1906 | 503,000 | 5,432,400 | 6,186,900 |
| 1907 | 169,804 | 1,833,883 | 2,088,589 |
| 1908 | 602,022 | 6,501,838 | 7,404,871 |
| 1909 | 549,608 | 5,935,766 | 6,760,178 |
| 1910 | 622,478 | 6,722,762 | 7,656,479 |
| 1911 | 349,639 | 3,776,101 | 4,300,560 |
| 1912 | 495,336 | 5,349,629 | 6,092,633 |
| 1913 | 200,000 | 2,160,000 | 2,460,000 |
| 1914 | Unknown* | — | — |
| 1915 | 1,609,500 | 17,382,600 | 19,796,850 |
| 1916 | 641,595 | 6,929,226 | 7,891,619 |
| 1917 | 2,806,129 | 30,306,193 | 34,515,387 |
| 1918 | 1,633,700 | 17,643,960 | 20,094,510 |
| 1919 | 2,405,360 | 25,977,888 | 29,585,928 |
| 1920 | 977,084 | 10,552,507 | 12,018,133 |
| 1921 | 1,051,283 | 11,353,856 | 12,930,781 |
| 1922 | 1,371,180 | 14,808,744 | 16,865,514 |
| 1923 | 1,029,418 | 11,117,714 | 12,661,841 |
| 1924 | 1,006,222 | 10,867,198 | 12,376,531 |
| 1925 | 1,400,704 | 15,127,603 | 17,228,659 |
| 1926 | 1,267,214 | 13,685,911 | 15,586,732 |
| 1927 | 1,293,046 | 13,964,897 | 15,904,466 |
| 1928 | 1,168,818 | 12,623,234 | 14,376,461 |
| 1929 | 1,208,480 | 13,051,584 | 14,864,304 |
| 1930 | 1,454,486 | 15,708,449 | 17,890,178 |

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1931 | 1,957,272 | 21,138,538 | 24,074,446 |
| 1932 | 1,583,948 | 17,106,638 | 19,482,560 |
| 1933 | 1,392,590 | 15,039,972 | 17,128,857 |
| 1934 | 1,520,156 | 16,417,685 | 18,697,919 |
| 1935 | 2,331,958 | 25,185,146 | 28,683,083 |
| 1936 | 3,083,857 | 33,305,656 | 37,931,441 |
| 1937 | 2,438,443 | 26,335,184 | 29,992,849 |
| 1938 | 1,041,600 | 11,249,280 | 12,811,680 |
| 1939 | 3,096,400 | 33,441,120 | 38,085,720 |
| 1940 | 3,082,500 | 33,291,000 | 37,914,750 |
| 1941 | 2,531,800 | 27,343,440 | 31,141,140 |
| 1942 | 2,686,000 | 29,008,800 | 33,037,800 |
| 1943 | 3,977,300 | 42,954,840 | 48,920,790 |
| 1944 | 2,268,500 | 24,499,800 | 27,902,550 |
| 1945 | 5,719,300 | 61,768,440 | 70,347,390 |
| 1946 | 3,276,000 | 35,380,800 | 40,294,800 |
| 1947 | 1,544,900 | 16,684,920 | 19,002,270 |
| 1948 | 3,974,100 | 42,920,280 | 48,881,430 |
| 1949 | 3,333,600 | 36,002,880 | 41,003,280 |
| 1950 | 1,482,500 | 16,011,000 | 18,234,750 |
| 1951 | 1,516,900 | 16,382,520 | 18,657,870 |
| 1952 | 1,274,900 | 13,768,920 | 15,681,270 |
| 1953 | 1,711,000 | 18,478,800 | 21,045,300 |
| 1954 | 1,884,300 | 20,350,440 | 23,176,890 |
| 1955 | 2,237,100 | 24,160,680 | 27,516,330 |
| 1956 | 1,683,900 | 18,186,120 | 20,711,970 |
| 1957 | 1,579,000 | 17,053,200 | 19,421,700 |
| 1958 | 2,616,400 | 28,257,120 | 32,181,720 |
| 1959 | 1,756,100 | 18,965,880 | 21,600,030 |
| 1960 | 1,172,200 | 12,659,760 | 14,418,060 |
| 1961 | 1,052,300 | 11,364,840 | 12,943,290 |
| 1962 | 1,473,600 | 15,914,880 | 18,125,280 |
| 1963 | 1,077,100 | 11,632,680 | 13,248,330 |
| 1964 | 841,800 | 9,091,440 | 10,354,140 |
| 1965 | 910,700 | 9,835,560 | 11,201,610 |
| 1966 | 1,028,300 | 11,105,640 | 12,648,090 |
| 1967 | 1,000,800 | 10,808,640 | 12,309,840 |
| 1968 | 947,500 | 10,233,000 | 11,654,250 |
| 1969 | 1,083,700 | 11,703,960 | 13,329,510 |
| 1970 | 1,183,900 | 12,786,120 | 14,561,970 |
| 1971 | 1,776,700 | 19,188,360 | 21,853,410 |
| 1972 | 1,643,500 | 17,749,800 | 20,215,050 |
| 1973 | 2,434,400 | 26,291,520 | 29,943,120 |

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1974 | 2,361,800 | 25,507,440 | 29,050,140 |
| 1975 | 2,077,600 | 22,438,080 | 25,554,480 |
| 1976 | 3,075,100 | 33,211,080 | 37,823,730 |
| 1977 | 1,753,000 | 18,932,400 | 21,561,900 |
| 1978 | 2,680,300 | 28,947,240 | 32,967,690 |
| 1979 | 1,156,700 | 12,492,360 | 14,227,410 |
| 1980 | 3,211,500 | 34,684,200 | 39,501,450 |
| 1981 | 1,672,300 | 18,060,840 | 20,569,290 |
| 1982 | 2,210,000 | 23,868,000 | 27,183,000 |
| 1983 | 2,730,400 | 29,488,320 | 33,583,920 |
| 1984 | 498,000 | 5,378,400 | 6,125,400 |
| 1985 | 2,038,000 | 22,010,400 | 25,067,400 |
| 1986 | 3,838,800 | 41,459,040 | 47,217,240 |
| 1987 | 1,895,700 | 20,473,560 | 23,317,110 |
| 1988 | 2,867,700 | 30,971,160 | 35,272,710 |
| 1989 | 3,066,800 | 33,121,440 | 37,721,640 |
| 1990 | 2,784,200 | 30,069,360 | 34,245,660 |
| 1991 | 2,950,400 | 31,864,320 | 36,289,920 |
| 1992 | 3,673,800 | 39,677,040 | 45,187,740 |
| 1993 | 513,900 | 5,550,120 | 6,320,970 |
| 1994 | 43,400 | 468,720 | 533,820 |
| 1995 | 440,000 | 4,752,000 | 5,412,000 |
| 1996 | 9,100 | 98,280 | 111,930 |
| 1997 | 58,600 | 632,880 | 720,780 |
| 1998 | 12,100 | 130,680 | 148,830 |
| 1999 | 20,900 | 225,720 | 257,070 |
| 2000 | 31,000 | 334,800 | 381,300 |
| 2001 | 313,100 | 3,381,480 | 3,851,130 |
| 2002 | 721,200 | 7,788,960 | 8,870,760 |
| 2003 | 1,083,400 | 11,700,720 | 13,325,820 |
| 2004 | 231,600 | 2,501,280 | 2,848,680 |
| 2005 | 200 | 2,160 | 2,460 |
| 2006 | 13,100 | 141,480 | 161,130 |
| 2007 | 8,310 | 89,748 | 102,213 |
| 2008 | 17,300 | 186,840 | 212,790 |
| 2009 | 17,644 | 190,555 | 217,021 |

*Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.

Table 9. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 1888 | 68.04 | | | | | |
| 1889 | 27.22 | | | | | |
| 1890 | 0.45 | | | | | |
| 1891 | 68.04 | | | | | |
| 1892 | 283.50 | | | | | |
| 1893 | Unknown[a] | | | | | |
| 1894 | 136.08 | | | | | |
| 1895 | 142.14 | | | | | |
| 1896 | 307.24 | | | | | |
| 1897 | 463.34 | | | | | |
| 1898 | 334.30 | | | | | |
| 1899 | 254.43 | | | | | |
| 1900 | 221.17 | 113.40 | | | | 27.2 |
| 1901 | 120.37 | 108.86 | | | | 27.2 |
| 1902 | 259.66 | 90.72 | | | | 22.7 |
| 1903 | 182.34 | 128.97 | | | | 22.7 |
| 1904 | 199.79 | 129.27 | | | | 18.1 |
| 1905 | 219.09 | 22.68 | | | | 4.5 |
| 1906 | 228.16 | 13.61 | | | | 5.4 |
| 1907 | 77.02 | 6.80 | | | | 4.5 |
| 1908 | 273.07 | 10.21 | | | | 4.1 |
| 1909 | 249.30 | 31.75 | | | | 4.5 |
| 1910 | 282.35 | 42.50 | | | | 136.1 |
| 1911 | 158.59 | 32.66 | | | | 113.4 |
| 1912 | 224.68 | 36.29 | | | | 90.7 |
| 1913 | 90.72 | 10.52 | | | | 68.0 |
| 1914 | Unknown[a] | 6.44 | | | | 54.4 |
| 1915 | 730.06 | 12.34 | | | | 45.4 |
| 1916 | 291.02 | 12.52 | | | | 45.4 |
| 1917 | 1,272.84 | 17.28 | | | | |
| 1918 | 741.03 | 15.20 | | | | |
| 1919 | 1,091.05 | 5.94 | | | | 1.9 |
| 1920 | 443.20 | 5.22 | | | | |
| 1921 | 476.85 | 8.53 | | | | |
| 1922 | 621.96 | 7.98 | | | | |
| 1923 | 466.94 | 19.87 | | | | |
| 1924 | 456.41 | 36.51 | | | | 15.4 |
| 1925 | 635.35 | 16.19 | | | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| **Year** | **Columbia River** | **Fraser River** | **Knight Inlet (Klinaklini River)** | **Bella Coola River** | **Kemano River** | **Skeena River** |
|---|---|---|---|---|---|---|
| 1926 | 574.80 | 17.24 | | | | 1.1 |
| 1927 | 586.52 | 12.97 | | | | 9.1 |
| 1928 | 530.17 | 18.73 | | | | |
| 1929 | 548.16 | 9.71 | | | | 6.6 |
| 1930 | 659.74 | 35.33 | | | | 5.4 |
| 1931 | 887.80 | 6.30 | | | | 2.7 |
| 1932 | 718.47 | 5.03 | | | | 3.3 |
| 1933 | 631.67 | 6.94 | | | | |
| 1934 | 689.53 | 10.25 | | | | |
| 1935 | 1,057.76 | 15.47 | | | | 0.9 |
| 1936 | 1,398.81 | 10.07 | | | | |
| 1937 | 1,106.06 | 4.08 | | | | |
| 1938 | 472.46 | 7.67 | | | | |
| 1939 | 1,404.50 | 20.59 | | | | |
| 1940 | 1,398.20 | 34.16 | | | | |
| 1941 | 1,148.41 | 50.1 | | | | 1.0 |
| 1942 | 1,218.35 | 152.7 | | | | |
| 1943 | 1,804.07 | 154.8 | | | | |
| 1944 | 1,028.97 | 65.7 | | Unknown[b] | | |
| 1945 | 2,594.23 | 73.87 | | 8.0 | | |
| 1946 | 1,485.97 | 115.7 | | 10.0 | | |
| 1947 | 700.75 | 231.1 | 135.0 | Unknown[b] | | |
| 1948 | 1,802.62 | 112.8 | | 20.0 | | |
| 1949 | 1,512.10 | 102.7 | 70.0 | 8.5 | | |
| 1950 | 672.45 | 36.2 | 100.0 | 44.0 | | |
| 1951 | 688.05 | 189.3 | 20.0 | 10.0 | | |
| 1952 | 578.28 | 421.0 | 27.5 | 12.3 | | |
| 1953 | 776.10 | 158.6 | | 41.7 | | |
| 1954 | 854.70 | 151.6 | | 69.4 | | |
| 1955 | 1,014.73 | 238.8 | | 7.6 | | |
| 1956 | 763.80 | 235.5 | | 6.2 | | |
| 1957 | 716.22 | 33.2 | | 5.6 | | |
| 1958 | 1,186.78 | 92.1 | | 8.4 | | |
| 1959 | 796.55 | 132.0 | 45.0 | 7.0 | | |
| 1960 | 531.70 | 84.0 | 60.0 | 0.3 | | |
| 1961 | 477.32 | 216.9 | | 2.0 | | |
| 1962 | 668.41 | 178.2 | 70.0 | 2.8 | | |
| 1963 | 488.56 | 159.3 | | 8.4 | | |
| 1964 | 381.83 | 105.5 | | 22.4 | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 1965 | 413.09 | 87.8 | 100.0 | 11.8 | | |
| 1966 | 466.43 | 101.9 | | 9.2 | | |
| 1967 | 453.96 | 86.8 | 100.0 | 11.5 | | |
| 1968 | 429.78 | 46.0 | 100.0 | 10.6 | | |
| 1969 | 491.56 | 29.8 | 80.0 | 7.8 | | |
| 1970 | 537.01 | 71.7 | 40.0 | 9.2 | | |
| 1971 | 805.90 | 34.5 | 20.0 | 16.8 | | |
| 1972 | 745.48 | 53.2 | 50.0 | 6.7 | | |
| 1973 | 1,104.23 | 53.1 | 40.0 | 12.3 | | |
| 1974 | 1,071.29 | 75.3 | | 10.6 | | |
| 1975 | 942.38 | 27.7 | | 12.0 | | |
| 1976 | 1,394.84 | 36.7 | | 50.0 | | |
| 1977 | 795.15 | 32.2 | 50.0 | 35.0 | | |
| 1978 | 1,215.76 | 38.6 | | 25.0 | | |
| 1979 | 524.67 | 22.3 | | 19.8 | | |
| 1980 | 1,456.71 | 24.4 | | 33.0 | | |
| 1981 | 758.54 | 21.2 | | 38.5 | | |
| 1982 | 1,002.44 | 13.7 | | 22.0 | | |
| 1983 | 1,238.49 | 10.8 | | 30.5 | | |
| 1984 | 225.89 | 11.8 | | 30.0 | | |
| 1985 | 924.42 | 29.2 | | Unknown[b] | | |
| 1986 | 1,741.25 | 49.6 | | Unknown[b] | | |
| 1987 | 859.88 | 19.3 | | Unknown[b] | | |
| 1988 | 1,300.77 | 39.5 | | Unknown[b] | 43.2 | |
| 1989 | 1,391.08 | 18.7 | | Unknown[b] | 50.2 | |
| 1990 | 1,262.89 | 19.9 | | Unknown[b] | 44.1 | |
| 1991 | 1,338.28 | 12.3 | | Unknown[b] | 57.2 | |
| 1992 | 1,666.41 | 19.6 | | Unknown[b] | 65.4 | |
| 1993 | 233.10 | 8.7 | | Unknown[b] | 93.0 | |
| 1994 | 19.69 | 6.1 | | 20.0 | 20.6 | |
| 1995 | 199.58 | 15.5 | | 22.0 | 69.2 | |
| 1996 | 4.13 | 63.2 | | Unknown[b] | 81.0 | |
| 1997 | 26.58 | Closed | | Unknown[b] | 41.9 | |
| 1998 | 5.49 | Closed | | Unknown[b] | 61.7 | |
| 1999 | 9.48 | Closed | | 0.0 | | |
| 2000 | 14.06 | Closed | | 0.0 | | |
| 2001 | 142.02 | Closed | | | | |
| 2002 | 327.13 | 5.8 | | | | |
| 2003 | 491.42 | Closed | | | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 2004 | 105.05 | 0.4 | | | | |
| 2005 | 0.09 | Closed | | | | |
| 2006 | 5.94 | Closed | | | | |
| 2007 | 3.77 | Closed | | | | |
| 2008 | 7.85 | Closed | | | | |
| 2009 | 8.00 | Closed | | | | |

[a]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[b]Landings of unknown size occurred but data were not recorded (Hay 2002).

declined greatly to 233 mt in 1993 and to an average of less than 40 mt between 1994 and 2000. From 2001 to 2004, the catches increased to an average of 266 mt, before falling to less than 5 mt from 2005 to 2008. Fishing restrictions were instituted in 1995, so the low catches after that time are in part due to these restrictions (Figure 23 and Figure 24). Nonetheless, the steep decline in 1993 and subsequent low abundance as indexed by the fishery is generally accepted by fishery managers as indicating a marked decline in the abundance of the stock (Bargmann et al. 2005). The WDFW and ODFW Joint Columbia River Management Staff (JCRMS 2007) concluded that "run sizes [of Columbia River eulachon], as indexed by commercial landings, remained relatively stable for several decades until landings dropped suddenly in 1993 and remained low for several years thereafter." Following this period of time, "Due to reduced seasons during 1995–2000, landings are not completely comparable with previous years; however, it is apparent that the abundance of smelt in the Columbia River Basin was much reduced during 1993–2000" (JCRMS 2005) (Table 7, Figure 22 through Figure 25).

A previous petition (Wright 1999) and NMFS finding on this petition (NMFS 1999) mentioned years where zero catches were reported for eulachon in the Columbia River. The present status review uncovered additional published Columbia River commercial fishery landings data in annual reports of state and federal fisheries agencies that fill in most of these gaps in the catch record (Table 7, Figure 22), with the exception of 1893 and 1914. In both cases, a survey of periodicals (Appendix D) and available online digital newspaper resources (see Appendix B) found articles describing the presence of eulachon in the Columbia River in those years.

The Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001 (with an interim plan in effect in 2000), which provides for three levels of fishing based on parental run strength, juvenile production, and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005). Effort in this fishery

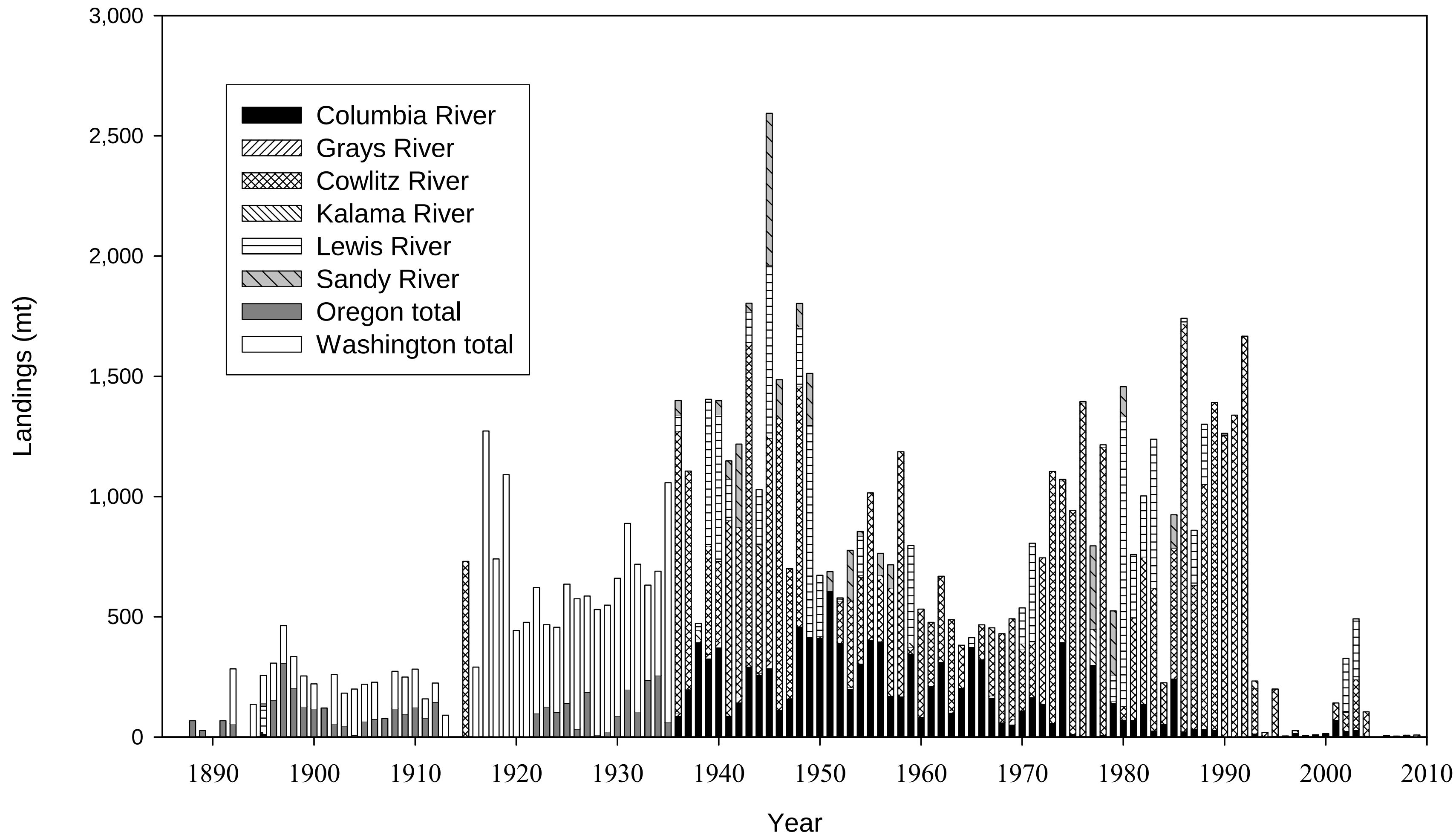



Figure 22. Commercial eulachon fishery landings in the Columbia River and tributaries from 1888 to 2009. Landings occurred in 1890 and in the Grays and Kalama rivers in many years; however, values are too small to be evident on the graph. Landings occurred in 1893 and 1914, based on newspaper and periodical sources (see Appendix B and Appendix D), but official records have not been located. Data sources listed in Table 7.

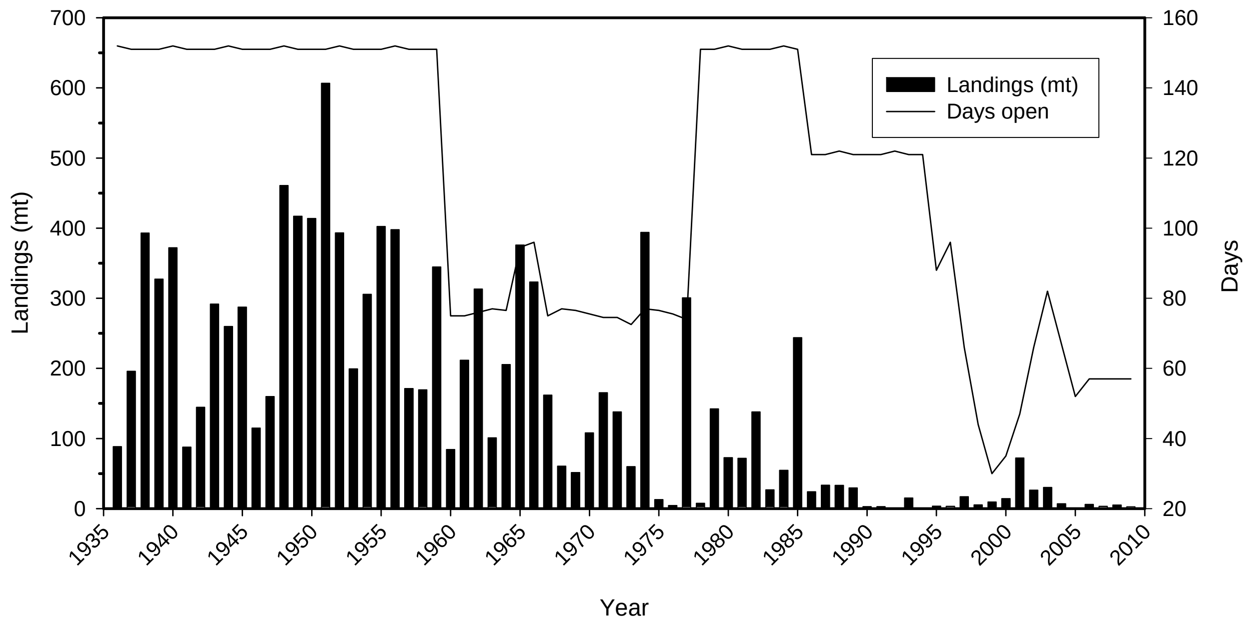



Figure 23. Commercial landings of eulachon and estimated total number of days the fishery was open in the Columbia River from 1935 to 2009.

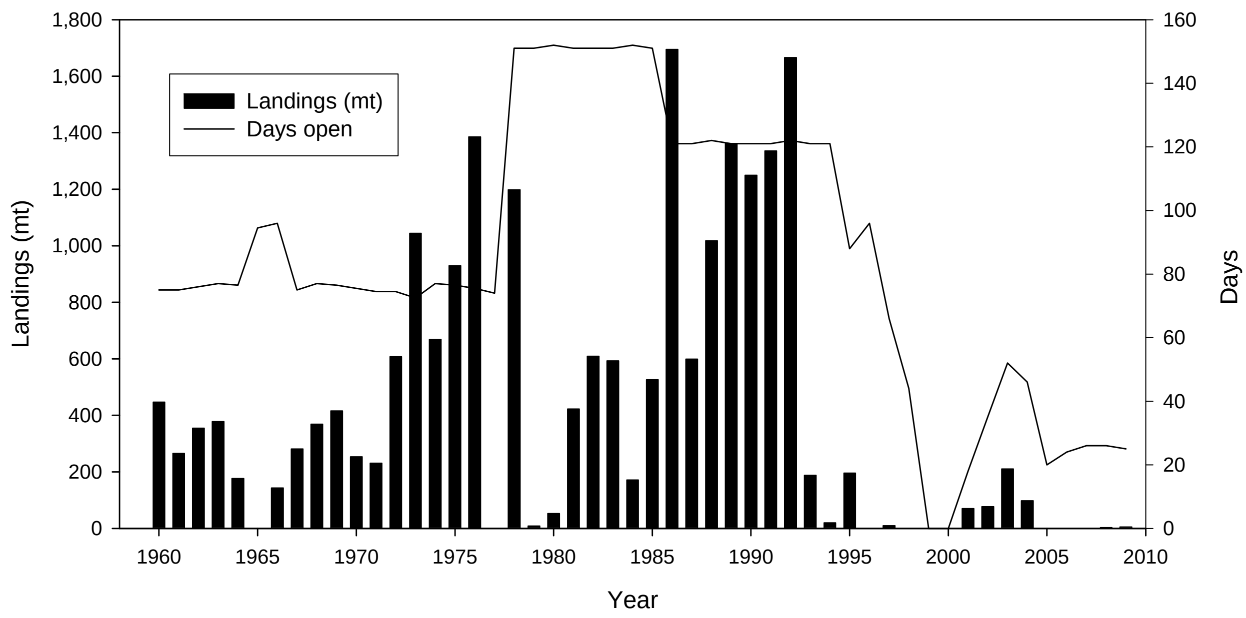



Figure 24. Commercial landings of eulachon and estimated total number of days the fishery was open in the Cowlitz River from 1960 to 2009.

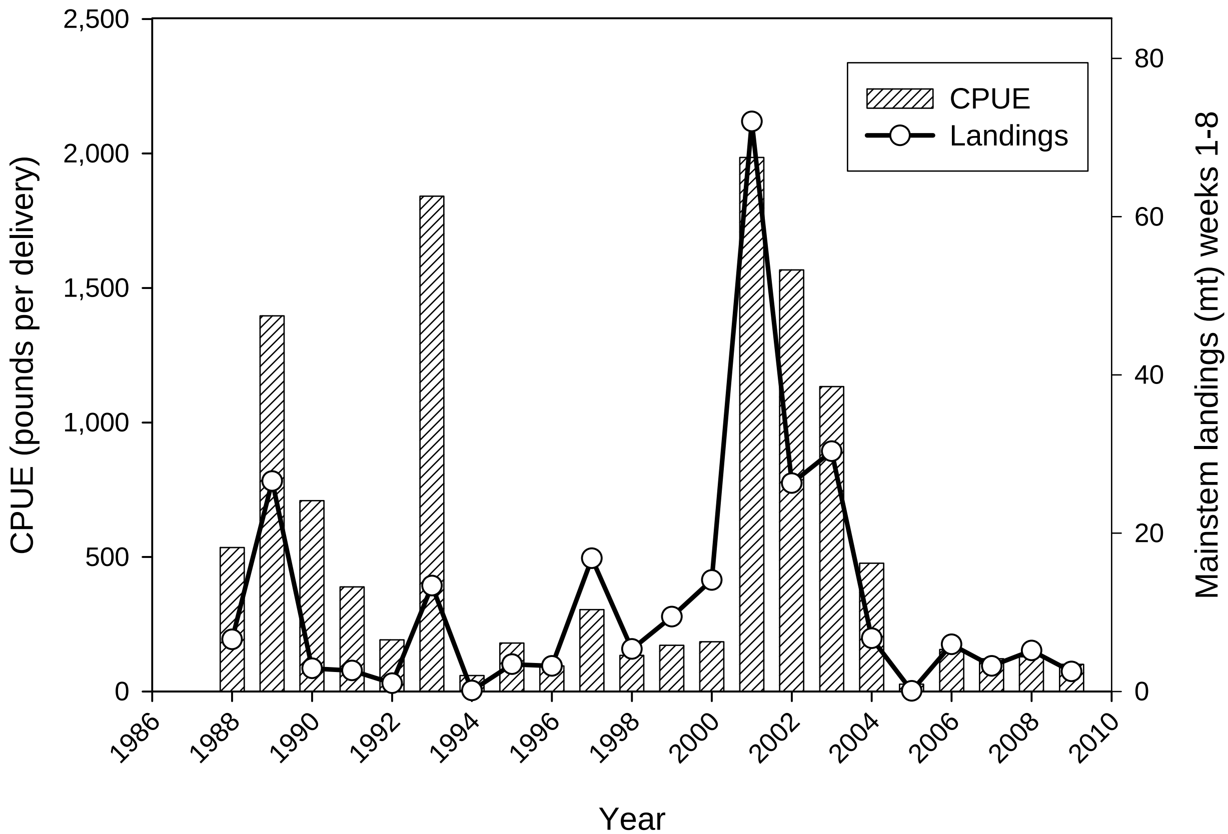



Figure 25. Columbia River commercial eulachon landings (season total may include landings during the previous December) and CPUE as pounds per delivery. Data from JCRMS (2009, their Table 17).

typically involves fewer than 10 vessels. WDFW and ODFW (2008) described these three levels of fishing: 1) Level One fisheries are the most conservative (commercial and recreational openings of 12–24 hours per week for Columbia and Cowlitz rivers) and are designed to act as a test fishery when there are indications of a poor return or great uncertainty in potential run strength, 2) Level Two fisheries (commercial and recreational openings of 2–3 days per week and potential of expansion to other tributaries) are indicated when fishery data suggest a moderate or strong run size, and 3) Level Three fisheries (commercial openings up to 4 days per week in all areas and all tributaries open to recreational fishing 4–7 days per week) may occur when abundance and productivity indicators are very strong.

The Columbia River eulachon fishery operated as a Level One test fishery in 2001; began as a Level Two fishery in 2002, switching to Level Three on February 1; operated at Level Three in 2003; started off as Level Three in 2004, with some later tributary commercial fishery restrictions; operated at Level Two in 2005 until February 23 when it was reduced to a Level One fishery; and has operated as a Level One test fishery in 2006 through 2009 (JCRMS 2005, 2006, 2007, 2008, 2009). The ability to adjust in-season fishery levels based on observed returns to the fishery, and its accurate tracking of past fluctuations in run strength, illustrates the utility of the Columbia River eulachon fishery statistics as an index of relative annual abundance (JCRMS 2007) (Figure 23 and Figure 24).

There is some information indicating that there have been periods of relatively low eulachon abundance in the past in the Columbia River. In particular, several anecdotal sources reported on a decline in the 1830s to 1860s (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963, Hinrichsen 1998, Martin 2008). Eulachon were once again seen in large numbers in the early to mid 1860s (Anderson 1872, 1877, Huntington 1963, Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008). Based on the available information, the BRT concluded that this information was probably accurate and likely indicated that a true and severe decline in eulachon returns and subsequent recovery occurred during that time period.

Subsequent to the decline in 1993, state and tribal fishery agencies have instituted additional monitoring efforts for Columbia River eulachon. For example, Figure 26 presents data from a larval sampling program that measures larval densities (averaged across stations and depths at selected index sites) that was initiated in 1994 for the Cowlitz River and expanded to include the Kalama River in 1995, the mainstem Columbia River in 1996, Elochoman and Lewis rivers in 1997, and Grays and Sandy rivers in 1998 (JCRMS 2005). Interannual comparison of larval densities prior to about 2003 is unreliable because "larval sampling techniques … did not include repeat sampling of the same area over the duration of the out migration period" (JCRMS 2007, p. 23), but since that time multiple surveys have been conducted each season at mainstem Columbia River sites that sample downstream of all the potential spawning locations, with the exception of Grays River. Notably, the larval densities show a peak in 2001–2002 that corresponds to a similar peak in catches (Figure 22) and offshore juvenile abundance (Figure 16 and Figure 17). Although spawning stock abundance has not been estimated using these larval surveys, the combination of data from the larval density survey and commercial and recreational landings "provides an indication of the relative run strength of eulachon in the Columbia River" (JCRMS 2007, p. 23).

The BRT had concerns about the absence of fishery-independent abundance data for Columbia River eulachon prior to the mid-1990s. The BRT agreed with state fishery managers, however, that the available catch and effort information indicate an abrupt decline in abundance in the early 1990s, and there is no evidence that the population has returned to its former level. The decline in the early 1990s appeared to coincide with a decline of eulachon in British Columbia, suggesting that a common cause, such as changing ocean conditions, was responsible for declines in both areas.

### Fraser River

Eulachon return on a regular basis to the Fraser River and on an irregular basis to the Squamish River in Howe Sound to the north (Table A-1, Figure 3) (Hay and McCarter 2000, Moody 2008). Eulachon usually begin to ascend the Fraser River at the end of March and spawning occurs in April until the middle of May. Eulachon are no longer seen spawning in some areas of the Fraser River where they used to occur. Historically, spawning occurred "primarily between Chilliwack and Mission in areas of coarse sand but also in localized areas of the North and South Arms as well as in the vicinity of the Pitt and Alouette rivers" (Higgins et al. 1987). Currently spawning is confined to areas downstream of Mission.

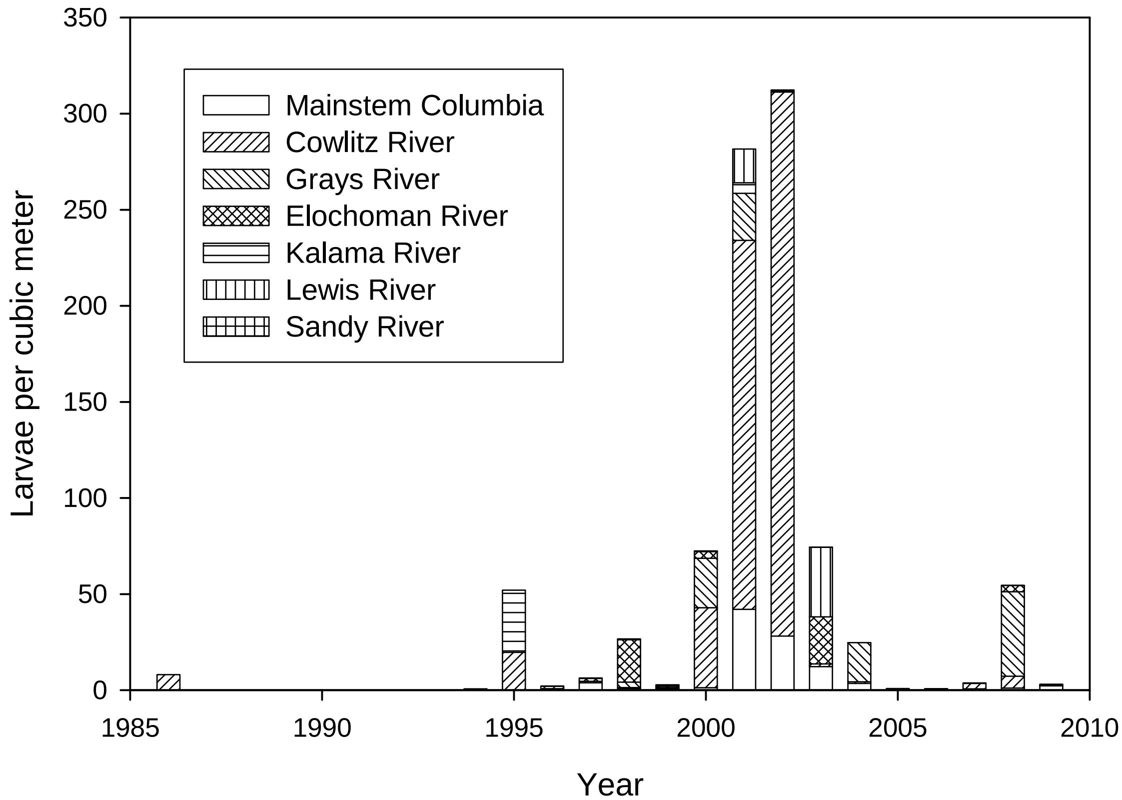



Figure 26. Columbia River larval eulachon sampling. Interannual comparisons are problematic due to inconsistent effort and methods from year to year. Larvae were encountered in the Sandy River in 1998–2000 and 2003; however, values are too small (0.1 per cubic meter) to be evident on the graph. Data from JCRMS (2008, 2009, its Table 18).

In the past, Fraser River eulachon runs supported First Nations subsistence fisheries and large commercial and recreational fisheries. Between 1941 and 1996, commercial landings averaged about 83 mt (Table 9, Table 10, and Figure 27). For much of this period, the commercial fishery landings are not a good indicator of relative abundance, since landings were largely driven by market demand (Moody 2008). In 1997 the commercial eulachon fishery was closed and commercial landings have occurred in only 2 of the last 10 years; 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a). Hay et al. (2003) estimated that First Nations and recreational fisheries historically landed about 10 mt annually. Estimates of recreational fishery landings were presented in graphical form in Moody (2008, her Figure 2.22) for a portion of the Fraser River (1956, 1963–1967, 1970–1980, closed since 2005).

Moody (2008) stated that the First Nation catch amounted to 2.57 mt in 2003. However, by 2005 all First Nation, commercial, and recreational fisheries were closed due to conservation concerns (DFO 2006a). A eulachon test fishery operated on the Fraser River near New Westminster from 1995 to 2005 (with the exception of 1999) (Figure 27); however, this fishery has not operated since 2005 (DFO 2008a). This test fishery was meant to be an in-season

Table 10. Estimated eulachon spawner biomass (mt) in the north arm and south arm of the Fraser River and total number of eulachon, assuming a range of 9.9 to 13.3 eulachon per pound, based on the mean reported weight of eulachon in the Fraser River of 34 to 46 g. Biomass data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

| Year | South arm | North arm | Total biomass (mt) | Total biomass (pounds) | Number of fish at 9.9 per pound | Number of fish at 13.3 per pound |
|---|---|---|---|---|---|---|
| 1995 | 258 | 44 | 302 | 665,796 | 6,591,381 | 8,855,087 |
| 1996 | 1,582 | 329 | 1,911 | 4,213,034 | 41,709,035 | 56,033,350 |
| 1997 | 57 | 17 | 74 | 163,142 | 1,615,107 | 2,169,790 |
| 1998 | 107 | 29 | 136 | 299,829 | 2,968,304 | 3,987,721 |
| 1999 | 392 | 26 | 418 | 921,532 | 9,123,169 | 12,256,379 |
| 2000 | 76 | 54 | 130 | 286,601 | 2,837,349 | 3,811,793 |
| 2001 | 422 | 187 | 609 | 1,342,615 | 13,291,890 | 17,856,782 |
| 2002 | 354 | 140 | 494 | 1,089,084 | 10,781,927 | 14,484,812 |
| 2003 | 200 | 66 | 266 | 586,430 | 5,805,653 | 7,799,514 |
| 2004 | 24 | 9 | 33 | 72,753 | 720,250 | 967,609 |
| 2005 | 14 | 2 | 16 | 35,274 | 349,212 | 469,144 |
| 2006 | 24 | 5 | 29 | 63,934 | 632,947 | 850,323 |
| 2007 | 34 | 7 | 41 | 90,390 | 894,856 | 1,202,181 |
| 2008 | 8 | 2 | 10 | 22,046 | 218,258 | 293,215 |
| 2009 | 12 | 2 | 14 | 30,865 | 305,561 | 410,501 |

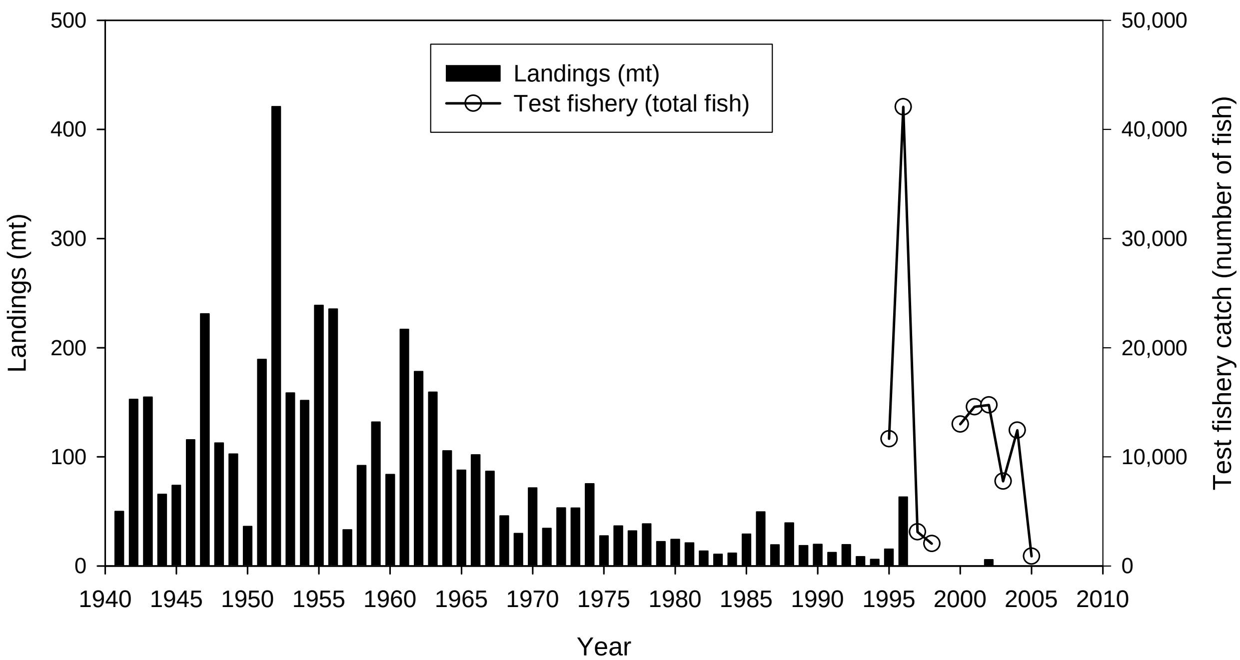



Figure 27. Eulachon landings in Fraser River commercial fishery (1940–2009) and total fish caught in Fraser River test fishery (1995–2005). Commercial fishery was closed in 1997–2001, 2003, and 2005–2009. Data from Hay (2002) and DFO (2008a).

measure of eulachon run strength and resulting data consisted of the total number of eulachon caught daily at the same site, with the same gear, over the same time period, and at similar tidal conditions (Therriault and McCarter 2005, DFO 2008a). When in operation, a catch of less than 5,000 in this test fishery was considered a conservation concern (DFO 2006a).

Table 10, Table 11, and Figure 28 present spawning stock biomass data (DFO 2008a, p. 11) that is derived from:

> an intensive sampling process [that] takes place in the Fraser River during the seven to eight weeks following spawning (April/May). This survey uses towed, small mesh nets to gather samples of eulachon eggs and larvae. The number of eggs and larvae gathered in each tow are hand counted at the Pacific Biological Station. The egg and larval count is then combined with data on the daily Fraser River discharge and historical data on eulachon fecundity (eggs produced per female) to generate an estimate of spawning stock biomass.

DFO (2008a, p. 11) stated that:

> A low spawning stock biomass for one year is cause for caution and a low spawning stock biomass for two consecutive years indicates a conservation concern. A low spawning stock biomass has been defined as less than 150 mt.

A recent population assessment of Fraser River eulachon by DFO (2007a, p. 3) stated that:

> Despite limited directed fisheries in recent years, the Fraser River eulachon stock remains at a precariously low level. This stock has failed to recover from its collapse. SSB [spawning stock biomass] estimated from the egg and larval survey conducted in 2006 was 29 tonnes. The framework documents suggest that a low SSB (<150 tonnes) for one year is cause for concern and a restriction on removals should be activated, while a low SSB for two (or more) consecutive years is more cause for alarm and should signal a halt to all removals (Hay et al. 2003, 2005). Since 2007 is the fourth consecutive year where Fraser River eulachon SSB has been below 150 tonnes, unprecedented in this short time series, no removals should be allowed in 2008.

Subsequent to this statement, spawner biomass for the 2008 and 2009 eulachon run in the Fraser River has been estimated at 10 and 14 mt, respectively (data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm). Figure 29 presents the Fraser River eulachon spawner abundance trend over the time period of the available data (1995–2009). A trend of 0.76 (95% CI, 0.67–0.88) for Fraser River eulachon was calculated from these data. Over the three-generation time of approximately 10 years, the overall biomass of the Fraser River eulachon population has undergone a 96.6% decline (1999, 418 mt; 2009, 14 mt). Under the International Union for the Conservation of Nature (IUCN) decline criteria (A1), a reduction in population size of this magnitude, "where the reduction or its causes may not have ceased or may not be understood or may not be reversible" (IUCN 2006), would place Fraser River eulachon in the IUCN critically endangered category (IUCN 2001, 2006).

The methodology on the Fraser River of utilizing mean egg and larval plankton density and river discharge rates (gathered throughout a seven-week outmigrant period at five locations) in combination with known relative fecundity (egg production per gram of female) and sex ratio

Table 11. Available estimated eulachon spawner biomass (mt) or estimated total number of spawners in British Columbia rivers in the DPS.

| Year | Fraser River (mt)[a] | Klinaklini River (mt)[b] | Kingcome River (mt)[b] | Wannock/Kilbella rivers (no. of fish)[c] | Bella Coola River (mt)[c] | Kitimat River (no. of fish)[d] | Skeena River (mt)[e] |
|---|---|---|---|---|---|---|---|
| 1993 | — | | | | | 514,000 | |
| 1994 | — | | | | | 527,000 | |
| 1995 | 302 | 40 | | | | | |
| 1996 | 1,911 | | | | | 440,000 | |
| 1997 | 74 | | 14.4 | | | | 3.0 |
| 1998 | 136 | | | | | | |
| 1999 | 418 | | | | | | |
| 2000 | 130 | | | | | | |
| 2001 | 609 | | | | 0.039 | | |
| 2002 | 494 | | | | ≈0.050 | | |
| 2003 | 266 | | | | 0.016 | | |
| 2004 | 33 | | | | 0.007 | | |
| 2005 | 16 | | | 2,700 | | | |
| 2006 | 29 | | | 23,000 | | <1,000 | |
| 2007 | 41 | | | | | | |
| 2008 | 10 | | | | | | |
| 2009 | 14 | | | | | | |

[a]Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.
[b]Berry and Jacob 1998 (as cited in Moody 2008).
[c]Moody 2008.
[d]Pederson et al. 1995 and Ecometrix 2006 (as cited in Moody 2008).
[e]Lewis 1997.

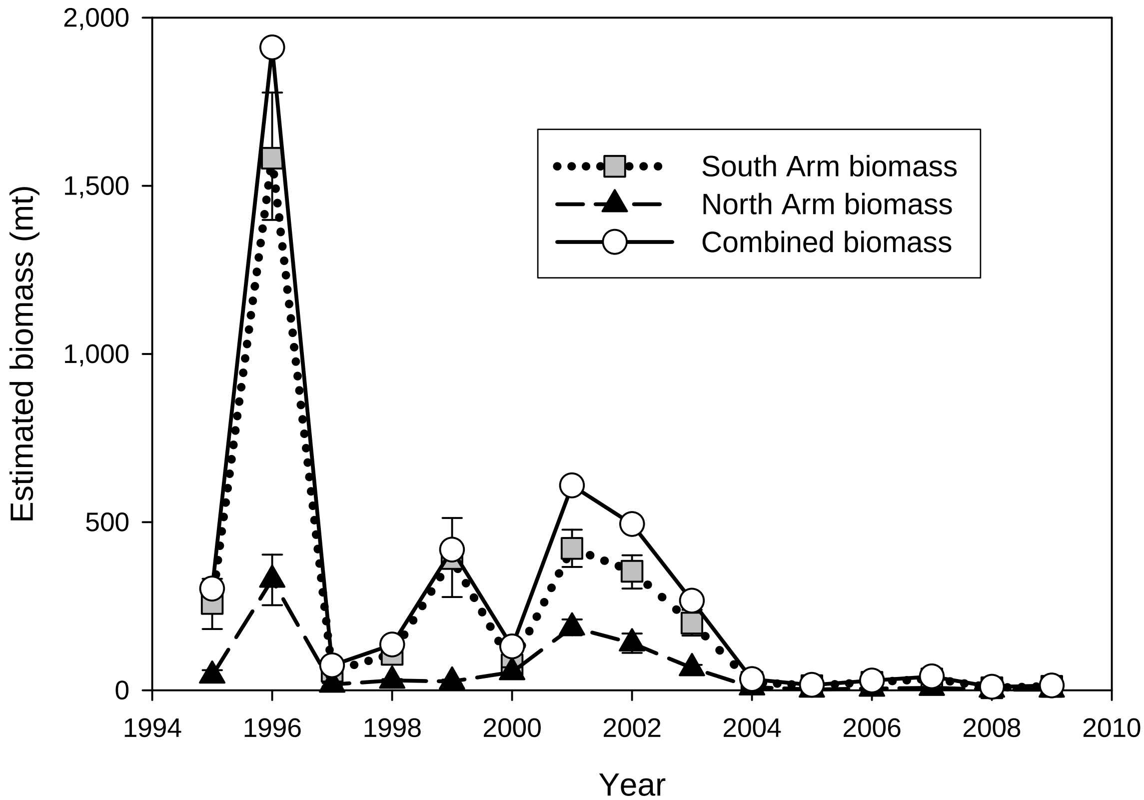



Figure 28. Fraser River eulachon spawning stock biomass from 1995 to 2009 (estimated from egg and larval surveys). Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

to estimate spawning stock biomass has passed rigorous scientific review in Canada (Hay et al. 2002, 2003, 2005, McCarter and Hay 2003, Therriault and McCarter 2005). This methodology is similar to methods used since the early 1970s by many fisheries agencies (WDFW, DFO, CDFG, and Alaska Department of Fish and Game) to calculate Pacific herring spawning stock abundance based on estimates of intertidal and subtidal egg deposition and relative fecundity. The BRT therefore was confident that observed trends in the Fraser River spawning stock abundance data represented a true picture of the status of Fraser River eulachon.

According to Therriault and McCarter (2005), the Fraser River test fishery data did not correspond well with the spawning stock estimates that were based on the egg and larval survey and this may have resulted from variation in the catchability of adults. Eulachon abundance can be inflated when they form dense schools, which can lead to an overestimate of abundance. On the other hand, eulachon may avoid the test fishery gear, leading to an underestimate of the run size. Due to these and other problems with the test fishery methodology (Therriault and McCarter 2005), the BRT did not put a lot of confidence in these data.

The BRT did not formally analyze commercial, recreational, or subsistence fishery landings between 1881 and the present in the Fraser River, as it is believed that for much of this period the commercial fishery landings were largely driven by market demand (Hay et al. 2002,

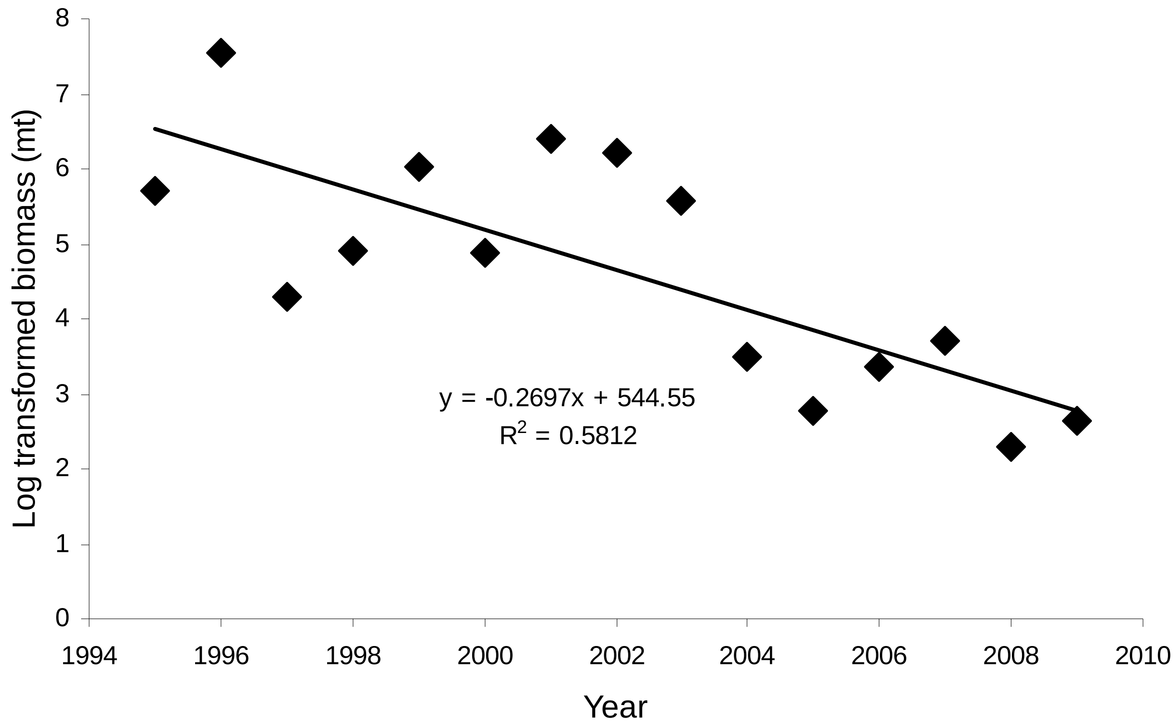



Figure 29. Trend of Fraser River eulachon spawner abundance (mt) from 1995 to 2009. Trend calculated from data in Figure 28.

Moody 2008). However, these data do indicate that eulachon were generally present at harvestable abundance levels in the Fraser River during this time period.

**Knight Inlet**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Klinaklini River at the head of Knight Inlet on the British Columbia coast (Table A-1, Figure 3). Irregular eulachon runs in the Johnstone Strait Region include the Kakweiken River, Homathko River (Bute Inlet), and Stafford and Apple rivers (Loughborough Inlet). Peak spawn timing in the area occurs about the middle of April (Hay and McCarter 2000, Hay 2002, Moody 2008).

There is only a single year's estimate of spawning stock biomass for the Klinaklini River (1995) (Table 11). Records of a commercial fishery are available for 1943–1945 and 1947. First Nations fisheries landings on the Klinaklini River are available for 1947, 1949–1950, 1952, 1959–1973, and 1977 (Table 9); however, after 1977 there is very limited documentation of run sizes of eulachon on the Klinaklini River and these are all anecdotal in nature. These anecdotal qualitative run size comments are listed in Table 12 and indicate an improvement in recent run size estimates.

Prior to 1943 when fisheries-dependent catch records begin, our information for run size of the Klinaklini River is either anecdotal or comes from ethnographic studies. Numerous ethnographic studies describe a large First Nations eulachon fishery on the Klinaklini River that

Table 12. Qualitative assessments of eulachon run strength for rivers north of the Fraser River, 1991–2007.

| Year | Klinaklini River | Kingcome River | Bella Coola River | Rivers Inlet | Kemano River | Kitimat River | Skeena River |
|---|---|---|---|---|---|---|---|
| 1991 | | | | | | Last strong run[a] | |
| 1992 | | | | | | | |
| 1993 | | | | | | | |
| 1994 | | | | | | | |
| 1995 | ≈15% of the historic run size[a] | | | | | | |
| 1996 | | | Last large run[a] | | | | |
| 1997 | | | | | | | |
| 1998 | | | Average run[a] | | | Nonexistent[b] | Very few[a] |
| 1999 | | | No run[a]<br>Small run[b] | No run[b]<br>Run failed[a] | Negligible[b] | Nonexistent[b] | Very few[a] |
| 2000 | None or poor[b]<br>Very low[c] | No run[b] | No run[c] | No run[b] | Kowesas–low[b]<br>Kemano–low[b]<br>Kitlope–low[b] | Very low in 2000[c] | Little activity observed[c] |
| 2001 | | Improved run[a] | | No catch[a] | Low catch[a] | | |
| 2002 | | Good run[a] | | No catch[a] | Low catch[a] | | |
| 2003 | | Poor run[a] | | No catch[a] | | Good[c] | |
| 2004 | Low returns[a] | Poor run[a] | Run virtually gone[c] | No catch[a] | Good spawning success[d] | | |
| 2005 | Low returns[a] | Average run[a] | | Run size of 2,700[a] | Almost no eulachon returned[e] | | Good run[a] |
| 2006 | | Run absent[a] | Run virtually gone[c] | Run size of 23,000[a] | No significant eulachon returns[f] | Lowest on record, <1,000 spawners[a] | Virtually no run[a] |
| 2007 | Very good run[a] | Small returns[a] | | | In estuary but did not ascend the river[a] | Small run of short duration[g] | |

[a]Moody 2008
[b]Hay and McCarter 2000
[c]Appendix C in Pickard and Marmorek 2007
[d]Alcan 2005
[e]Alcan 2006
[f]Alcan 2007
[g]Kitamaat Village Council 2007

attracted up to 2,000 Kwakiutl First Nation members in the late nineteenth century (Macnair 1971), some from as far as 250 miles away by canoe (Codere 1990).

There were commercial eulachon fisheries in Knight Inlet in the 1940s that primarily supplied food for the fur farm industry. Combined commercial and First Nations subsistence fisheries landed between 18 and 90 mt annually from 1943 and 1977 in Knight Inlet (Moody 2008), although landings reported by Hay and McCarter (2000) and reported in Table 9 were somewhat higher. At times, eulachon landings from Kingcome and Knight Inlet may have been reported as Knight Inlet landings, which may explain some of this discrepancy (Moody 2008). Berry and Jacob (1998, as cited in Moody 2008) "estimated spawning biomass at approximately 40 mt in the Klinaklini River in 1995" with a larval-based assessment (Hay and McCarter 2000). This value was "thought to be approximately 15% of the historic run size" (Berry and Jacob 1998, as cited in Moody 2008). Based on anecdotal information, Moody (2008) stated that eulachon returns to the Klinaklini River were said to be low "during the 2004 and 2005 seasons … but in 2007, the Klinaklini returns improved and, overall, it appeared to be a very good run" (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Knight Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the available information. However, the BRT concluded that available catch records, the extensive ethnographic literature, and anecdotal information indicates that Klinaklini River eulachon were probably present in larger annual runs in the past and that current run sizes of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (summaries in Macnair 1971, Codere 1990). However, anecdotal information indicates that recent returns of eulachon to the Klinaklini River have improved from a low point in 2004–2005, so the status of this population is not entirely clear.

**Kingcome Inlet**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kingcome River at the head of Kingcome Inlet on the British Columbia central coast (Table A-1, Figure 3). Peak spawn timing in the area occurs about the middle of April (Moody 2008). Berry and Jacob (1998, p. 4) reported that "there were at least four waves of spawning with peaks on April 2, April 15, April 21, and May 2, 1997, with the largest occurring around April 15" in the Kingcome River. Berry and Jacob (1998) also reported that there was a spawn in the Kingcome River prior to March 16 and again in early June as indicated by the presence of eggs in the water column.

There is only a single year's estimate of spawning stock biomass for the Kingcome River (1997) (Table 11). First Nations fisheries landings on the Kingcome River are available for 1950, 1957, 1960, 1961, 1963, and 1966 (Moody 2008, her Figure 2.20); however, after 1977 there is very limited documentation of run sizes of eulachon on the Kingcome River and these are all anecdotal in nature. These qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

When Kingcome Inlet First Nation fisheries landings have been reported separately from Knight Inlet, the estimates have averaged around an annual catch of 9 mt (Moody 2008). Moody (2008) reported that the eulachon run in the Kingcome River in 1971 was very small and light catches were reported in 1972. Berry and Jacob (1998) stated that a minimum estimated 14.35 mt of eulachon spawned in the Kingcome River from March 16 to June 3, 1997. Based on anecdotal information, Moody (2008) reported that "In 2001 the Kingcome run improved and was considered good in 2002, with approximately 330 gallons of grease produced." The eulachon run to the Kingcome River was considered to be poor in 2003 and 2004 and of average size in 2005 (Moody 2008). However, eulachon were reportedly absent from the Kingcome River in 2006 "and only small returns were seen in 2007" (Table 12) (Moody 2008).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Kingcome Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicates that Kingcome River eulachon were probably present in larger annual runs in the past.

**Rivers Inlet**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Wannock, Chuckwalla, and Kilbella rivers in Rivers Inlet on the central coast of British Columbia (Table A-1, Figure 3). The spawning stock biomass of eulachon in Rivers Inlet was estimated using scientific survey methods in 2005 and 2006. First Nations fisheries landings on the Wannock River are available for 1967, 1968, and 1971; however, after 1971 there is very limited documentation of run sizes of eulachon in Rivers Inlet and (with the exception of the information available for 2005 and 2006) these are anecdotal in nature. These anecdotal qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fishery landings data for the Wannock River were limited to the years 1967, 1968, and 1971 when catches were 1.81, 2.27, and 4.54 mt, respectively (Moody 2008). Moody (2008) stated that eulachon in "the Wannock River had been gradually declining since the 1970s" and that no eulachon have been caught in First Nations fisheries in the Rivers Inlet area since 1997, when about 150 kg of eulachon were landed from the Kilbella and Chuckwalla rivers (Berry and Jacob 1998). Berry and Jacob (1998, p. 3–4) further reported that "Virtually no eulachon eggs or larvae were found in any of the 376 samples from the Wannock River in 1997" and "this observation is consistent with in-field observations of eulachon entering the river mouth only to exit and possibly go to the nearby Chukwalla or Kilbella rivers to spawn." In 2005 an estimated 2,700 adults returned to the Wannock River, based on the capture of only 11 adults during spawner abundance surveys (Moody 2008) (Table 11). An additional three adult eulachon were taken on the Kilbella River in 2005 (Moody 2008). Moody (2008) stated that this adult spawner survey was repeated in 2006 and although "no adults [were] captured … an estimate of 23,000 adult spawners was calculated" (Table 11 and Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Rivers Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. The BRT was also concerned that the incomplete record of eulachon catch and spawn biomass in Rivers Inlet does not establish whether eulachon returned on an annual basis to this system in the past. However, the BRT believed that available recent estimates of spawning stock abundance, catch records, ethnographic literature (Hilton 1990), and anecdotal information indicates that Rivers Inlet eulachon were present in larger annual runs in the past. The BRT also believed that the recent spawning stock estimates of 2,700 to 23,000 individual spawners is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

**Dean Channel**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Bella Coola, Dean, and Kimsquit rivers in Dean Channel (Table A-1, Figure 3). Kennedy and Bouchard (1990, p. 325) summarized ethnographic studies on the Nuxalk (Bella Coola) First Nation and stated that "because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola." Moody (2008) indicated that historically, peak run timing of eulachon in the Bella Coola River occurred in late March or early April (Table A-9). Moody (2007) also reported that recent run timing of eulachon to the Bella Coola River occurs earlier in the season than it did historically.

Spawning stock biomass data for the Bella Coola River were available for 2001–2004 (Table 11). Records of the Nuxalk First Nation eulachon fishery on the Bella Coola River are available for 1945 and 1946, 1948–1989, 1995, and 1998 (Moody 2008, her Figure 3.13). Moody (2008) also provided estimated First Nations eulachon catch based on a model of eulachon grease production from 1980 to 1998. Anecdotal qualitative run-size comments are listed in Table 12.

Moody (2007) reports relative abundance estimates, based on egg and larval surveys similar to those used on the Fraser River, for the Bella Coola River in 2001 (0.039 mt), 2002 (0.045–0.050 mt), 2003 (0.016 mt), and 2004 (0.0072 mt) (Table 11). Nuxalk First Nation subsistence fishery landings of eulachon from the Bella Coola River show an average catch of 18 mt between 1948 and 1984 (Table 9, Figure 30), with a low of 0.3 mt in 1960 and a high of nearly 70 mt in 1954, based on data available in Hay (2002). These data suggest that recent (2001–2004) spawner biomass in the Bella Coola River is approximately two orders of magnitude less than the average First Nations eulachon landings were between 1948 and 1984. According to Moody (2007), it has been 9 years since the last First Nations fishery occurred on the Bella Coola River.

Anecdotal information indicated that only a very few eulachon are currently found in other rivers in Dean Channel such as the Kimsquit River and the Taleomy, Assek, and Noeick rivers in South Bentnick Arm off Dean Channel (Moody 2008). Moody (2007, 2008) also stated that "it appears that 1996 was the last large run of eulachon to the Bella Coola River" and noticeable runs have not returned to the Dean Channel/Bella Coola area since 1999 (Table 12).

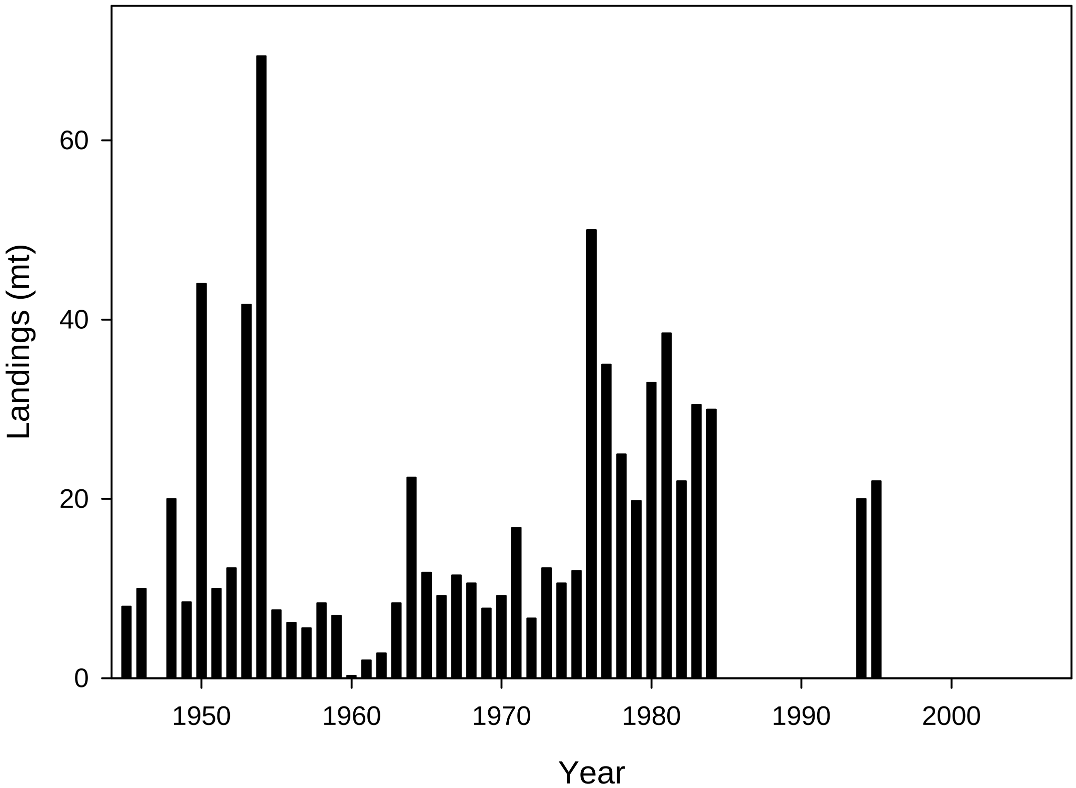



Figure 30. Estimated eulachon First Nations fishery landings on the Bella Coola River (data from Hay 2002). Landings of unknown size occurred from 1985 to 1993 and from 1996 to 1998 (Hay 2002). No fishery has occurred on the Bella Coola River since 1999.

The BRT believed that available spawning stock biomass data collected since 2001, catch records, extensive ethnographic literature, and anecdotal information indicate that Bella Coola River and Dean Channel eulachon in general were present in much larger annual runs in the past. The present run sizes of eulachon appear inconsistent with the historic level of grease production that is extensively documented in the ethnographic literature on the Nuxalk First Nations Peoples (Kennedy and Bouchard 1990, Moody 2008). The BRT was concerned that this information and available data indicate that eulachon in Dean Channel may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

**Gardner Canal**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kemano, Kowesas, and Kitlope rivers in Gardner Canal (Table A-1, Figure 3). Eulachon spawn in late March and early April on the Kemano River, which is unusual in that it is a clear, nonturbid system in a region that is dominated by glacially turbid rivers (Moody 2008).

First Nations fisheries landings on the Kemano River are available for 1969–1973 and 1988–2007. CPUE data in this fishery from 1988–2007 (reported as metric tons caught per set) were presented in graphical form in Moody (2008, her Figure 2.16). A summary of ethnographic studies of the Haisla First Nation indicates that “eulachon were especially important with runs in the … Kemano and Kitlope rivers … in such numbers that they were an important export” (Hamori-Torok 1990, p. 306). Anecdotal qualitative run-size comments on Kemano River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fisheries landings on the Kemano River ranged from 18.1 to 81.7 mt from 1969 to 1973 (average of 44.3 mt) (Moody 2008, her Figure 2.16). Rio Tinto Alcan Inc. operates a hydroelectric generation facility on the Kemano River and, as part of an environmental management plan, has funded monitoring of eulachon since 1988 (Lewis et al. 2002). From 1988 to 1998, landings ranged from 20.6 to 93.0 mt (average of 57 mt) (Lewis et al. 2002, Moody 2008) (Table 9). However, according to Moody (2008), no run occurred in 1999.

First Nations landings in the Kemano River were low from 2000 to 2002, but improved to between 60 and 80 mt in 2003 and 2004 (Alcan 2005, Moody 2008, her Figure 2.16); however, anecdotal information indicated that eulachon returns were not detected in the Kemano River in 2005 and 2006 (Table 12) (Alcan 2006, 2007, EcoMetrix 2006, as cited in Moody 2008). Based on anecdotal information, Moody (2008) reported that “eulachon were seen in the Kemano estuary in 2007. However, they did not ascend the river.” CPUE data showed similar trends to First Nation fishery landings, with a sharp drop from about 2.5 mt per set in 1998 to less than 0.5 mt per set from 1999 to 2002, a rebound to between 0.5 and 1 mt per set in 2003–2004, and no fish caught in 2005–2007 (Lewis et al. 2002, Moody 2008, her Figure 2.16).

It was the BRT’s best professional judgment that available CPUE data collected since 1988, First Nations catch records, extensive ethnographic literature, and anecdotal information indicate that Kemano River, and Gardner Canal eulachon in general, were present in larger annual runs in the past and that present run sizes of eulachon appear inconsistent with the historic level of grease production that is well documented for this region in the ethnographic literature (Hamori-Torok 1990).

In addition, the BRT believed that the inability to detect eulachon in the Kemano River since 2004 using the same monitoring methods that have been in place since 1988 (Lewis et al. 2002, Moody 2008, her Figure 2.16) and anecdotal information from Rio Tinto Alcan biological surveys that eulachon have failed to return to the Kemano River in 2005–2007 (Alcan 2005, 2006, 2007) is cause for concern, as this information indicates that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

### Douglas Channel

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kitimat and Kildala rivers in Douglas Channel (Table A-1, Figure 3). Spawning in the Kitimat River reportedly peaks in mid to late March (Moody 2008).

The spawning stock biomass of eulachon in the Kitimat River was estimated using scientific survey methods in 1993 (Table 11). First Nations fisheries landings on the Kitimat

River are available for 1969 to 1972. CPUE in this fishery, reported as number of fish caught in a 24-hour period, and estimated spawner abundance are available for 1994–1996 and 1998–2007. A summary of ethnographic studies of the Haisla First Nation indicates that “eulachon were especially important with runs in the Kitimat [and] Kildala … rivers in such numbers that they were an important export” (Hamori-Torok 1990, p. 308). Anecdotal qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Between 1969 and 1972, Kitimat River First Nations fisheries landings of eulachon ranged from 27.2 to 81.6 mt (Moody 2008, her Figure 2.14). The Kitimat River First Nations eulachon fishery reportedly came to an end in 1972 as pollution by industrial (pulp mill) and municipal effluent discharges made the eulachon unpalatable (Pederson et al. 1995, Moody 2008). Pederson et al. (1995) estimated a total spawning biomass in the Kitimat River of 22.6 mt or about 514,000 individual eulachon in 1993. According to Moody (2008, p. 34), CPUE of eulachon on the Kitimat River, as presented in EcoMetrix (2006), declined from 50–60 fish per 24-hour gill net set in 1994–1996 to less than 2 eulachon per gill net set since 1998. According to EcoMetrix (2006, as cited in Moody 2008), abundance of eulachon from 1994 to 1996 ranged between 527,000 and 440,000 individual spawners and from 1998 to 2005 ranged between 13,600 and less than 1,000 (Table 11). Based on anecdotal information, Moody (2008, p. 34) stated that “the last strong run returned to the Kitimat River in 1991 and runs from 1992 to 1996 were estimated at half the size of 1991” (Table 12).

The BRT believed that the available spawning stock biomass data available for 1993, CPUE data since 1994, First Nations landing records, extensive ethnographic literature, and anecdotal information indicate that Kitimat River and Douglas Channel eulachon in general were present in larger annual runs in the past and that present run-size estimates of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (Hamori-Torok 1990). The BRT believed that the decline in estimated spawning stock on the Kitimat River from an annual run size of more than 500,000 eulachon in the mid-1990s to levels of less than 1,000 individual eulachon in 2005 (EcoMetrix 2006, Moody 2008) is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

### Skeena River

Hay and McCarter (2000) and Moody (2008) reported that an annual run of eulachon return on a regular basis to the Skeena River and its tributaries (particularly the Ecstall and Khyex rivers) (Table A-1, Figure 3). The Skeena River run was reportedly small, of short duration, and difficult to harvest because of the large size of the mainstem Skeena River (Stoffels 2001, Moody 2008). Based on anecdotal information, eulachon historically returned to the Skeena River around the first week of March, but in the past decade returns have occasionally returned as early as mid-February (Moody 2008).

The spawning stock biomass of eulachon in the Skeena River was estimated using scientific survey methods in 1997 (Table 11). Combined commercial and First Nations fisheries landings on the Skeena River are available for 1900–1916, 1919, 1924, 1926, 1927, 1929–1932, 1935, and 1941 (Table 9). Qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Lewis (1997) estimated the total spawning stock abundance of the Skeena River eulachon at only 3.0 mt in 1997. A small commercial eulachon fishery operated between 1924 and 1946 (landings ranged from 15.4 mt in 1924 to 0.9 mt in 1935) (Moody 2008). However, total landings records were as high as 100 mt at one time and averaged 27.5 mt from 1900 to 1941 (Table 9). It is likely that local market demands have driven subsistence and past commercial fisheries statistics on the Skeena River and the BRT did not believe that these data were a good index of abundance. Moody (2008) reported anecdotal information indicating that very few Skeena River eulachon were observed between 1997 and 1999, a good run occurred in 2005, and virtually no eulachon were observed in 2006 (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in the Skeena River, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicate that Skeena River eulachon were present in larger annual runs in the past that at one time supported a large fishery. Although the current status of this subpopulation is unknown, the BRT believed that anecdotal information indicates declines in abundance have occurred.

## Assessment of Demographic Risk and the Risk Matrix Approach

In previous NMFS status reviews, BRTs have used a risk matrix as a method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used for more than 10 years in Pacific salmonid status reviews (e.g., Good et al. 2005, Hard et al. 2007), as well as in reviews of Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), and black abalone (*Haliotis cracherodi*) (VanBlaricom et al. 2009). In this risk matrix approach, the collective condition of individual populations is summarized at the DPS level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity (Table 13). These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk. The summary of demographic risks and other pertinent information obtained by this approach is then considered by the BRT in determining the species' overall level of extinction risk.

After reviewing all relevant biological information for the species, each BRT member assigns a risk score (see below) to each of the four demographic criteria. The scores are tallied (means, modes, and range of scores), reviewed, and the range of perspectives discussed by the BRT before making its overall risk determination (see Table 13 for a summary of demographic risk scores). Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. For example, a DPS with a single extant subpopulation

Table 13. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four viable salmonid population parameters (McElhany et al. 2000) plus a recent events category.

| **Risk category** | **Mean (± SD) and modal score** |
|---|---|
| Abundance[a]<br>Comments: | 4.3 (±0.48)<br>4 |
| Growth rate/productivity[a]<br>Comments: | 3.0 (±1.05)<br>2 |
| Spatial structure and connectivity[a]<br>Comments: | 3.7 (±0.67)<br>4 |
| Diversity[a]<br>Comments: | 2.6 (±0.52)<br>3 |
| Recent events[b] | |

[a]Rate overall risk to the DPS on 5-point scale (1–very low risk, 2–low risk, 3–moderate risk, 4–high risk, 5–very high risk).
[b]Rate recent events from double plus (++) strong benefit to double minus (– –) strong detriment.

might be at a high level of extinction risk because of high risk to spatial structure/connectivity, even if it exhibited low risk for the other demographic criteria. Another species might be at risk of extinction because of moderate risks to several demographic criteria.

For scoring population viability criteria, risks for each demographic criterion are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. *Very low risk*. Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.

2. *Low risk*. Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3. *Moderate risk*. This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

4. *High risk*. This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.

5. *Very high risk*. This factor by itself indicates danger of extinction in the near future.

Recent events: The recent events category considers events that have predictable consequences for DPS status in the foreseeable future but have occurred too recently to be reflected in the demographic data. Examples include a climatic regime shift or El Niño that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

| | |
|---|---|
| ++ | expect a strong improvement in status of the DPS, |
| + | expect some improvement in status, |
| 0 | neutral effect on status, |
| – | expect some decline in status, and |
| – – | expect strong decline in status. |

# Threats Analysis

According to Section 4 of the ESA, the Secretary of Commerce or the Interior shall determine whether a species is threatened or endangered as a result of any (or a combination) of the following factors: 1) destruction or modification of habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors. Collectively, these are often referred to as factors for decline. Herein we examine four of these five factors for their historical, current, or potential impact on eulachon. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species. Current and potential threats, along with current species distribution and abundance, help determine the species' present vulnerability to extinction. We include information regarding historic threats to assist in interpretation of population trends. The relationship between historic threats and population trends also provides insights that may help project future population changes in response to current and potential threats.

## Destruction or Modification of Habitat

### Dams and water diversions

Dams and water diversions can change downstream flow intensity and flow timing, reduce transport of fine sediments, and cut off the source of larger sediments like sand and gravel for downstream habitats. Reduced peak flows as a result of upstream dams can also lead to less scouring of the streambed, less erosion, and less deposition of sediments. The streambed downstream of dams may become progressively coarser and become dominated by cobbles and large gravels as smaller gravels and sand are transported downstream without being replaced by transport from upstream sources.

**Klamath River**—There are six hydroelectric dams on the Klamath River (Link River, Keno, J.C. Boyle, Copco 1, Copco 2, and Iron Gate) (NRC 2008). The impact of these dams, and others on the tributary Trinity River (Lewiston and Trinity dams), as well as associated irrigation withdrawals in the upper Klamath River basin, have shifted the spring peak flow of the lower Klamath River from its historical peak in April to its current peak in March, one full month earlier (NRC 2004).

**Columbia River**—Operation of 28 mainstem and about 300 tributary dams and water withdrawals for irrigation have significantly altered the natural hydrologic pattern of the Columbia River (Sherwood et al. 1990, Bottom et al. 2005). According to Bottom et al. (2005, p. xxix):

> the magnitude of maximum spring freshet flow [in the Columbia River] has decreased more than 40% from the predevelopment period (1859–1899) to the present. Flow regulation is responsible for approximately 75% of this loss, irrigation withdrawal for approximately 20%, and climate change for approximately 5% … The timing of maximum spring freshet flow also has changed, primarily because of hydropower and irrigation development upriver, resulting in an approximate two-week shift earlier in the year (mean predevelopment date of 12 June compared to modern mean date of 29 May).

Bottom et al. (2005, p. xx) also stated that:

> Riverine sediment transport to the estuary, an important process affecting the quantity and quality of estuarine habitat for salmon [and other fishes], is correlated with peak river flows … [It] is estimated that the … change in annual average sediment transport (at Vancouver, Washington) for 1945–1999 flows has been about 50–60% of the nineteenth century (1858–1899) virgin sediment transport. The reduction in sands and gravels is higher (>70% of predevelopment) than for silts and clays.

Bonneville Dam on the mainstem Columbia at RKM 235 also impedes migration of eulachon to historical spawning habitat above the dam in the Hood River and possibly the Klickitat River (Smith and Saalfeld 1955, WDFW and ODFW 2008). Eulachon reportedly are unable to ascend fish ladders designed for Pacific salmon (LCFRB 2004a).

**Columbia River tributaries**—In the mid 2000s, Sandy River Basin Partners (2005, p. 2-30) stated that:

> Natural discharge patterns in the Sandy River Basin are primarily altered by 1) storage and diversion of water on the Sandy River (Marmot Dam at RM 30 [RKM 48.3]) and Little Sandy River (Little Sandy Diversion Dam at RM 1.7 [RKM 2.7]), 2) storage and diversion of water from the Bull Run River since 1891 to supply the City of Portland's municipal water needs (the Headworks Dam at RM

> 6 [RKM 9.6]), and 3) diversion of water from the Sandy Hatchery weir on Cedar Creek at RM 0.05 (RKM 0.8), as well as withdrawal of water from Alder Creek to partially supply the City of Sandy's municipal requirements.

Subsequently, Marmot Dam was removed in 2007 and the Little Sandy Dam was taken down in 2008, which should restore much of the river's natural hydrology and result in significant sediment transport into the lower Sandy River where eulachon have spawned in the past.

There are two major dams on the mainstem Cowlitz River: Mayfield Dam at RKM 83.7 forms Mayfield Lake and Mossyrock Dam at RKM 104.6 forms Riffe Lake (Wade 2000b). These dams and other run-of-river dams in the hydropower system largely control flow in the mainstem Cowlitz River. Following the eruption of Mount St. Helens in 1980, the USACE constructed an SRS on the North Fork Toutle "to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns" (LCFRB 2004a, p. E-374). The SRS was constructed in 1989 about 49 km above the confluence of the Toutle and Cowlitz rivers, is approximately 50 m in height, and extends 600 m across the valley of the North Fork Toutle River. The SRS continues to be a source of fine sediment to the lower Cowlitz River (LCFRB 2004a). Anderson (2009, p. 5) stated that:

> The SRS [on the Toutle River], constructed by the USACE, has become ineffective at trapping sediments. Lower Cowlitz River eulachon spawning habitat is considered degraded while the Toutle River is assumed absent of spawning habitat due to this fine sediment inundation. … WDFW considers past and continued fine sediment deposition in the Toutle and Cowlitz rivers as a moderate to high risk for eulachon.

There are three major dams on the mainstem Lewis River, also known as the North Fork Lewis River: Merwin Dam (aka Ariel Dam) at RKM 31.4, built in 1931, forms Lake Merwin; Yale Dam at RKM 55, built in 1953, forms Yale Lake; and Swift Dam at RKM 77.1, built in 1958, forms Swift Creek Reservoir (Wade 2000a). The Lower Columbia Fish Recovery Board (LCFRB 2004a, p. G-35) stated that:

> Hydropower regulation has altered the hydrograph of the lower mainstem [of the Lewis River].… Predam data reveals peaks due to fall/winter rains, winter rain-on-snow, and spring snowmelt. Postdam data shows less overall flow variation, with a general increase in winter flows due to power needs. Postdam data shows a decrease in spring snowmelt flows due to reservoir filling in preparation for dry summer conditions.… The risk of extreme winter peaks has also been reduced, with the trade-off being the reduction of potentially beneficial large magnitude channel-forming flows. … The long-term effects on channel morphology and sediment supply have not been thoroughly investigated.

**British Columbia**—In the mid-1980s there were an estimated 802 licensed dams in the Fraser River basin, mostly for irrigation purposes in the dryer areas above Hope (Birtwell et al. 1988). The impact on eulachon of water withdrawals associated with reservoirs in the Fraser

River has not been studied. The other eulachon river in British Columbia where hydrology has been significantly altered by water diversions is the Kemano River. A hydroelectric plant began operating on the Kemano River in 1954 (Lewis et al. 2002, p. 1), that is powered by:

> water from the Nechako Reservoir [in the Fraser River basin] [that] passes through a 16-km-long diversion tunnel, past the turbines at the Kemano Powerhouse, and into the Kemano River, dropping a total of 850 m. ... The powerhouse outflow combines with the natural flow of the Kemano River and tributaries and flows 16 km to saltwater at Kemano Bay on Gardner Canal.

Lewis et al. (2002, p. 22) further stated that:

> Flow at the Kemano/Wahoo confluence is composed of Kemano Powerhouse discharge and the natural flow from the Kemano River and tributaries. On average, the Kemano powerhouse contributes 57% of the flow at the Kemano/Wahoo confluence. Within the period of eulachon spawning, when natural flows are near the seasonal minimum, discharge from the powerhouse accounts for 80% of the flow at the Kemano/Wahoo confluence. The relative contribution of powerhouse discharge declines to 64% during eulachon incubation and later, during larval migration, to 38% as natural discharges increase.

According to DFO and Transport Canada (2008):

> Kleana Power Corporation proposes to develop a run-of-river hydroelectric power project on the Klinaklini River. … The project consists of: head pond, diversion weir and intake, 18 km penstock/tunnel, powerhouse, tailrace, waste rock disposal, upgrading of the existing logging roads and new road extension where necessary, upgrade to the existing barge landing facility, construction camp, concrete batch plant, and a 180 km twinned aerial transmission line from the powerhouse to Campbell River.

**Sediment dredging**

Potential dredging impacts on eulachon consist of direct effects of entrainment of adults and eggs and potential for smothering of eggs with sediment (Howell and Uusitalo 2000, Howell et al. 2001). Indirect effects may consist of altering the freshwater spawning habitat and estuarine nursery habitat. Larson and Moehl (1990) documented direct entrainment of small amounts of eulachon by hopper dredge at the mouth of the Columbia River during May-October 1985–1988. Johnston (1981, p. 427) reviewed dredging activities in estuarine environments and listed “increased turbidity; altered tidal exchange, mixing, and circulation; reduced nutrient outflow from marshes and swamps; increased saltwater intrusion; and creation of an environment highly susceptible to recurrent low dissolved oxygen levels” as negative impacts. In addition, dredging can resuspend harmful contaminants contained in sediments where they may be more available to estuarine biota in the water column. Lasalle (1990, p. 1) also reviewed the potential physical effects of dredging and listed mobilization of sediment-associated chemical compounds and increased turbidity, as well as the potential “reduction in dissolved oxygen (resulting from the oxidation of anoxic sediment compounds)” as generally expected alterations.

Hay and McCarter (2000) indicated that dredging during the eulachon spawning season in the Fraser River continued until the late 1990s. Tutty and Morrison (1976) estimated about 0.9 mt of adult eulachon were directly entrained during hopper dredging activities between March 15 and June 4, 1976, on the lower Fraser River. Hay and McCarter (2000, p. 38) stated that "the direct loss of about 1 tonne of eulachons may have been small relative to potential deleterious impacts on survival of eulachons eggs—either from the direct effect of entrainment of spawned eggs, or the silt-induced smothering of eggs deposition [sic] in waters downstream of the dredging operations." Hay and McCarter (2000) suggested dredging should be confined to periods outside of the spawning season to minimize impacts on eulachon and that the effects of sediment removal on eulachon spawning habitats should be a topic of research.

FREMP (2007) estimated that from 0.76 to 3.22 million cubic meters of sediment were dredged annually from the lower Fraser River during the years 1997–2007 to prevent grounding of commercial shipping. Increases in vessel size have required deepening of the shipping channel in recent years (FREMP 2007). As mentioned in Pickard and Marmorek (2007), suction dredging is currently restricted to months when eulachon are not spawning in the Fraser and Kitimat rivers. According to FREMP (2006, p. 40), "hydraulic suction dredging and large-scale clamshell dredging undertaken in the Fraser River estuary is restricted so that there is no dredging conducted from March 1 to June 15 of any given year."

It has been suggested that eulachon spawning distribution in the Fraser River has changed in response to dredging and channelization and that dredging, even outside of the spawning period, affects eulachon by destabilization of substrates (Pickard and Marmorek 2007). Pickard and Marmorek (2007, p. 8) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "there is consensus that dredging is not the cause of the coastwide decline in eulachon, but there is disagreement about the importance of dredging impacts on eulachon resilience in rivers where it occurs."

The Cowlitz Indian Tribe (2007, p. 15–16) observed that:

> the Cowlitz River and in particular the Toutle River has been greatly impacted by the eruption of Mount St. Helens in 1980 and the resulting SRS built by the U.S. Army Corps of Engineers. Releases of fine sediment from behind the SRS during the spring, when normally the river is clear, have been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later (Lou Reebs, personal communication).

USACE (2007) stated that:

> as much as 414 million cubic yards (mcy) of material will erode from the Mount St. Helens sediment avalanche through year 2035. In addition, it was estimated that over the period from 2000 to 2035 as much as 27 mcy of this material would be deposited in the lower Cowlitz River and will need to be removed in order to maintain flood protection levels in Kelso, Longview, Castle Rock, and Lexington. … This trend is a result of increased sedimentation from the Toutle River watershed from sediments being passed through the SRS in greater amounts. The ability of the SRS to trap sand has decreased since 1998 when the sediment reservoir behind the dam filled in. All flow now passes through the spillway as

> designed, carrying sediment downstream. … Significant sand deposition … continues to occur at the mouth of the Cowlitz River, which has severely reduced the capacity of the river channel to transport sand. … Channel capacity and the authorized levels of flood protection for Kelso, Longview, Lexington, and Castle Rock have been reduced below authorized levels due to sediment deposition in the lower Cowlitz River. … In addition to the initial dredging effort, annual follow-on dredging from the transition area to Cowlitz RM 2.5 [RKM 4.0] to maintain the dredged channel depths and bottom widths will be needed to maintain flood protection levels for the next 5 years. The Corps is also investigating long-term dredging and nondredging alternatives that would maintain the authorized levels of flood protection for the communities on the lower Cowlitz River through the year 2035.

Furthermore, USACE's environmental assessment of interim dredging activities on the Cowlitz River (USACE 2007, p. 33) indicated that:

> The proposed … dredging action may affect spawning adults, outmigrating juveniles, and larvae [of eulachon] in the water column by entrainment. Eggs may be affected by removing substrate needed to allow egg adhesion for incubation and by covering of incubating eggs by increasing suspended sediment.

Sherwood et al. (1990) provided a detailed analysis of historical dredging activities in the Columbia River estuary through the 1980s. They estimated that about 300 million cubic meters of largely sand-sized material were removed from the estuary and river channels between 1909, when substantial dredging started, and 1982. Currently, USACE routinely dredges the mainstem Columbia River shipping channel. The Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001, p. 25) stated that this "Dredging should not be conducted in winter and early spring to avoid entrainment of eulachon adults or larvae." Romano et al. (2002) suggested that the dynamic nature of sand sediments in areas proposed for channel deepening in the Columbia River were unlikely to support eulachon egg incubation and that direct effects of dredging in these areas on eulachon would be minimal. However, "[eulachon] eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation" (Romano et al. 2002, p. 8).

In response to an earlier draft of the present status review document, Anderson (2009, p. 4–5) stated that:

> Risks dependent on timing, location, and life history stage in relation to dredging and in-water dredge material disposal pose a low to moderate threat for adult eulachon and a high risk for incubating eggs. … WDFW considers dredging effects on adult eulachon as a low risk in the mainstem Columbia River and a low to moderate risk in the tributaries. … The risk to larval eulachon from mainstem Columbia River dredging activities is low and in the tributaries is moderate. … Dredging activities can affect egg survival through direct entrainment and from suffocation through burial. The risk to eulachon eggs from dredging and in-water dredge material disposal in eulachon spawning habitat is high.

### Shoreline construction

**Columbia River**—Estuarine habitat in the Columbia River has been modified through "shoreline armoring and construction of structures over water, channel dredging and removal of large woody debris, channelization by pile dikes, and other structures" (Bottom et al. 2005, p. 18). Thomas (1983) estimated that estuarine acreage at the time of his study was only about 76% of the acreage of the estuary in 1870. This reduction was largely the result of dike and levee construction. Approximately 43% of tidal marshes and 77% of tidal swamps in the Columbia River estuary were estimated to have been lost since 1870 (Thomas 1983). Sherwood et al. (1990, p. 299) also reviewed historical changes in the Columbia River estuary and found that "large changes in the morphology of the estuary have been caused by navigational improvements (jetties, dredged channels, and pile dikes) and by the diking and filling of much of the wetland area." Sherwood et al. (1990) suggested that the greatest cause of change in the morphology of the Columbia River estuary was due to construction of permeable pile dikes and jetties, particularly jetties at the mouth of the river. LCFRB (2004a, p. A-157) reported that:

> Artificial channel confinement has altered river discharge and hydrology, as well as disconnected the [Columbia] river from much of its floodplain. … Additionally, channel manipulations for transportation or development have also had substantial influence on river discharge and hydrologic processes in the river.

Bottom et al. (2005, p. xxii) provided a chronology of changes in the Columbia River estuary and stated that:

> The productive capacity of the estuary has likely declined over the past century through the combined effects of diking and filling of shallow-water habitats…. Loss of approximately 65% of the tidal marshes and swamps that existed in the estuary prior to 1870, combined with the loss of 12% of deepwater area, has contributed to a 12–20% reduction in the estuary's tidal prism.

**Columbia River tributaries**—The LCFRB (2004a, p. E-89) observed that "the mainstem Cowlitz below Mayfield Dam has been heavily altered due to adjacent land uses including agriculture, rural residential development, transportation corridors, urbanization, and industry." The LCFRB (2004a, p. E-30) also reported that "the lower 20 miles of the Cowlitz has experienced severe loss of floodplain connectivity due to dikes, riprap, or deposited dredge spoils originating from the Mount St. Helens eruption" (see also Wade 2000b). Major population centers in the lower Cowlitz River basin with their associated industrial and residential development include the towns of Castle Rock, Longview, and Kelso (LCFRB 2004a).

The only urban area in the Kalama River basin is the City of Kalama, located near the river's mouth where dikes have been constructed in the historical floodplain to protect nearby roads and industrial developments (Wade 2000a, LCFRB 2004a). Future development is likely to be concentrated along the lower mainstem Kalama River, where increasing residential development has also occurred in recent years (LCFRB 2004a).

Much of the lower mainstem Lewis River is also "disconnected from its floodplain by dikes and levees" (LCFRB 2004a, p. G-55) and "the largest urban population center, the City of Woodland, lies near the mouth of the river" (Wade 2000a, p. 23). According to (LCFRB 2004a, p. G-87), "the mainstem Lewis below Merwin Dam has been heavily altered due to adjacent land uses including agriculture, residential development, transportation corridors, and industry."

**British Columbia**—Pickard and Marmorek (2007) reported that results of a DFO workshop to determine research priorities for eulachon indicated that shoreline construction in the form of roads, bridges, dikes, piers, wharfs, and so forth may have an impact on eulachon in the Skeena, Kitimat, Kemano, Fraser, and Columbia rivers. According to Pickard and Marmorek (2007, p. 14):

> There is evidence of change in the habitat in developed rivers such as the Fraser and Kitimat. These changes include the loss of side channels, loss of habitat complexity/diversity, and increase in velocity. These habitat changes are thought to affect eulachon, however the magnitude of the effect is not clear.

Pickard and Marmorek (2007) also suggested that an increase in river velocities likely would result in eggs and larvae being rapidly washed downstream, where they may encounter high salinities at an early age. The fate of eggs and larvae that may be prematurely washed out to sea is unknown.

The largest city in British Columbia, Vancouver, together with all of its associated industrial and urban development, abuts the Fraser River estuary (Birtwell et al. 1988). Moody (2008) indicated that an extensive system of dikes was constructed in the lower Fraser River following the 1948 flood. According to Plate (2009, p. 3 and p. iii), recent plans to construct "a new 10-lane Port Mann Bridge [over the Fraser River] represents a major addition to shoreline and in-river construction on the lower Fraser River" and is of concern because "eulachon spawn directly beneath the [current] Port Mann Bridge pillars and in the close upstream vicinity of the bridge, and as expected eulachon use all channels under the bridge for migration to upstream areas."

### Climate change impacts on freshwater habitat

Analyses of temperature trends for the U.S. Pacific Northwest (Mote et al. 1999); the maritime portions of Oregon, Washington, and British Columbia (Mote 2003a); and the Puget Sound–Georgia Basin region (Mote 2003b) have shown that air temperature increased 0.8°C, 0.9°C, and 1.5°C in these respective regions during the twentieth century. Warming in each of these areas was substantially greater than the global average of 0.76 ± 0.19°C (IPCC 2007). During the next century, warming in the Pacific Northwest is predicted to range from 0.1°C to 0.6°C per decade with a mean estimate of 0.3°C per decade, compared to an approximate 0.1°C per decade warming that occurred during the twentieth century (Mote et al. 2005b). Although fluctuations in climate related indices like the PDO and El Niño Southern Oscillation (ENSO) may explain about a third of this temperature rise, "the widespread and fairly monotonic increases in temperature exceed what can be explained by Pacific climate variability and are consistent with the global pattern of anthropogenic temperature increases" (Mote et al. 2005a, p. 47). Results from 10 different climate model simulations that assume two different greenhouse gas emission scenarios predict a 1ºC to 6ºC increase in air temperature for the Pacific Northwest by 2100 (ISAB 2007).

These higher temperatures have led to declines in snowpack, measured as springtime snow water equivalent, in much of the North American west, with the Oregon (Mote et al. 2005a) and Washington (Mote 2006) Cascade Mountains having the largest losses in snow water equivalent. Projected milder wintertime temperatures in much of the North American west suggest that "losses in snowpack observed to date will continue and even accelerate" (Mote et al. 2005a, p. 48). Additional hydrological changes that have occurred in the North American west over the past 50–70 years include more precipitation falling as rain rather than snow (Knowles et al. 2006) and an earlier onset of snowmelt (Groisman et al. 2004, Knowles et al. 2006), resulting in "increased fractions of annual flow occurring earlier in the water year by 1–4 weeks" relative to conditions during the 1950s to 1970s (Stewart et al. 2005, p. 1,136). Trends toward earlier flows "are strongest for midelevation gauges in the interior Northwest, western Canada, and coastal Alaska" (Stewart et al. 2005, p. 1,152).

It is expected that snowmelt dominated systems at low to moderate elevations (Regonda et al. 2005, Knowles et al. 2006) and near-coastal mountains in the Pacific Northwest and California (Hamlet et al. 2005, p. 4,560) will be particularly impacted by declines in the fraction of precipitation falling as snow and thus may experience the greatest changes in river hydrology. Some systems are expected to change from a pattern of steady snow accumulation to a pattern of repeated snow accumulation and loss during the winter season. The Independent Scientific Advisory Board (ISAB 2007, p. iii) summarized projected changes associated with climate change in the Columbia Basin and stated that "Warmer temperatures will result in more precipitation falling as rain rather than snow; snow pack will diminish, and stream flow timing will be altered; and peak river flows will likely increase."

Pickard and Marmorek (2007) summarized similar findings, reported by participants at a DFO workshop to determine research priorities for eulachon, relative to climate-driven changes in freshwater hydrology that are occurring in coastal British Columbia. This report presented evidence that "snowpack accumulations have been declining in many watersheds (e.g., Kitimat, Fraser)" (Pickard and Marmorek 2007, p. 20). Spring freshets throughout British Columbia are also reported to be occurring earlier in the year and more precipitation at lower elevations is reported to be coming as rain than in snow (Pickard and Marmorek 2007, p. 20). Glaciers in British Columbia are also reported to be melting at a faster rate, although "overall runoff from B.C. glaciers is declining due to their reduced size" (Pickard and Marmorek 2007, p. 20).

Foreman et al. (2001) and Morrison et al. (2002) examined historical temperatures and flows in the Fraser River over the past 100 years. Foreman et al. (2001) found that the date at which one-half of the Fraser River yearly discharge is reached occurred at a rate of 0.09 days earlier each year between 1913 and 2000, and that average summer temperatures at Hell's Gate on the Fraser River increased at a rate of 0.022°C per year (0.2°C per decade) from 1953 to 1998. Morrison et al. (2002) developed a flow model based on these trends and predicted that by 2070–2090 spring freshets in the Fraser River would occur on average 24 days earlier in the year and mean summer water temperatures would likely increase by 1.9°C. DFO (2008d) also predicted that peak flows will come earlier in the year and peak flows will be lower over the coming century in the Fraser River.

Meier et al. (2003) and Barry (2006) summarized data on the worldwide status of glaciers, which shows that pervasive glacial retreat has occurred over the past 100 years and suggests that glacial wastage has accelerated in the last several decades. Meier et al. (2003, p. 133) stated that "the retreats of the last century exceed any seen in the last several millennia and are out of the range of normal climate variability for this time period." ISAB (2007, p. 12), in reference to the Pacific Northwest stated that:

> Most glaciers in the region reached their recent maximum extent in the mid-1800s and since that time have been in rapid retreat. Recent studies indicate that the retreat of the past approximately 150 years has now brought many Northwest glaciers back to levels last seen approximately 6,000 years ago.

Since the majority of eulachon rivers are fed by extensive snowmelt or glacial runoff, elevated temperatures, changes in snow pack, and changes in the timing and intensity of stream flows will likely have impacts on eulachon. In most rivers, eulachon typically spawn well before the spring freshet, near the seasonal flow minimum, and this strategy typically results in egg hatch coinciding with peak spring river discharge. The expected alteration in stream flow timing may cause eulachon to spawn earlier or be flushed out of spawning rivers at an earlier date. Early emigration, together with the anticipated delay in the onset of coastal upwelling (see Climate Change Impacts on Ocean Conditions subsection below), may result in a mismatch between entry of larval eulachon into the ocean and coastal upwelling, which could have a negative impact on marine survival of eulachon during this critical transition period.

There are already indications, perhaps in response to warming conditions or altered stream flow timing, that adult eulachon are returning earlier in the season to several rivers within the southern DPS (Moody 2008). Based on accounts in Portland, Oregon, newspapers between 1867 and 1923, the mean date of initial appearance of eulachon in the Columbia River during that time was February 12 (Figure 6, Appendix B). Documented initial landings in the Columbia River commercial eulachon fishery for the years 1949 to 2008 were more than a month earlier, averaging around January 8, based on data supplied by WDFW.[13] Similarly, Lewis et al. (2002, p. 68) noticed a trend for the eulachon run in the Kemano River, British Columbia, to begin and end earlier over the 11-year period from 1988 to 1998. Pickard and Marmorek (2007, p. 20) also reported that "run timing has been getting earlier since 1988–2003 in [the] Kemano [River]."

### Climate change impacts on ocean conditions

Evidence has accumulated over the last decade to demonstrate that there are natural decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua et al. 1997, Zhang et al. 1997). One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index whose opposite regimes, characterized by a positive and negative PDO, typically last for 20–30 years (Mantua and Hare 2002) (Figure 15). Negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest, and positive values are associated

[13] B. James, Statewide Eulachon Landings database, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.

with warmer, less productive conditions. Warmer, less productive conditions off the Pacific Northwest are also associated with the ENSO, which is unrelated to the PDO and occurs on average every 2 to 7 years and may last from 6 to 18 months.

Changes in regional patterns of the PDO and ENSO have been associated with variation in the abundance of Pacific salmon, forage fish, and species such as Pacific hake in the ocean off the Pacific Northwest (McFarlane et al. 2000, ISAB 2007). ISAB (2007, p. 57–58) suggested that conditions that occur during a positive PDO or an El Niño period may represent possible analogs for future impacts of global warming in the North Pacific and Pacific Northwest. However, as the Intergovernmental Panel on Climate Change (IPCC) stated in its fourth assessment report (IPCC 2007, p. 399), "Long-term trends [in temperature] are rather difficult to discern in the upper Pacific Ocean because of the strong interannual and decadal variability (ENSO and the PDO) and the relatively short length of the observational records."

According to ISAB (2007, p. v):

> Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity … [and] the structure of marine communities.

**Warmer ocean temperatures**—Levitus et al. (2000, 2005) documented warming of the world's oceans that corresponds to a mean temperature increase of 0.037°C from 1955 to 1998 (Levitus et al. 2005, p. 1). Most of this warming has occurred in the upper 700 m of the ocean over the past 50 years (Levitus et al. 2005). Relatively smaller temperature increases in the world ocean over the past 50 years, compared to the mean worldwide terrestrial air temperature increase of 0.76 ± 0.19°C (IPCC 2007) over the past 100 years, illustrates the ocean's enormous heat capacity compared to the atmosphere (Levitus et al. 2005). According to the IPCC (2007, p. 387):

> The oceans are warming. Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m. … Relative to 1961 to 2003, the period 1993 to 2003 has high rates of warming but since 2003 there has been some cooling.

The ISAB (2007, p. 65) reported that "In the subarctic Northeast Pacific, sea surface temperatures show a warming trend and salinities a decreasing trend, over the last half century." Sea surface temperatures compiled from lighthouse records in the Canadian portion of the Strait of Georgia show an increase from 1915 to 2004 of 1.0°C (Beamish et al. 2008). However, long-term temperature increase in the ocean off the Pacific Northwest is not occurring in a linear fashion. Crawford et al. (2007, p. 176) reported that the long-term temperature records along Line P, which extends out more than 1,400 km from the North American west coast into the mid Gulf of Alaska, show an increase in temperature by 0.9°C from 1958 to 2005 between depths of 10 and 50 m. But Line P temperature records showed no significant increase prior to 1972 or after 1981 and most of the long-term temperature trend was likely driven by the PDO increase associated with the 1977 regime shift (Crawford et al. 2007, IPCC 2007). Water temperatures off British Columbia were reportedly warmer in 2004 and 2005 than the previous 50 years (DFO 2006b); however, in 2008 water temperatures "off the Pacific coast of Canada were the coldest in 50 years of observations, and the cooling extended far into the Pacific Ocean and south along the American coast" (DFO 2009e, p. 4).

**Changes in intensity and timing of upwelling**—Primary productivity in the northern California Current ecosystem is fueled by wind-driven upwelling of cold, nutrient-rich, deep waters to the surface. Along the coasts of British Columbia, Washington, and Oregon, ocean upwelling is dependent on strong coastal northerly or equator-ward winds which drive warm surface waters offshore and induce upwelling of the deep waters (Bakun 1990, Ware and Thomson 1991, ISAB 2007). Upwelling-favorable winds are more frequent in the spring and summer, but do not occur uniformly even at those times. Ocean upwelling off California is much more consistent, less seasonal, and stronger on average than in areas farther north.

Coastal, upwelling-favorable winds are generated by the "pressure gradient between a thermal low-pressure cell that develops over the heated land mass and the higher barometric pressure over the cooler ocean" (Bakun 1990, p. 198). Bakun (1990) hypothesized that climate warming will intensify these thermal land-sea differences, since land areas are predicted to warm twice as fast as the oceans, and should lead to more intense coastal upwelling in the California Current Province. These land-sea pressure gradients may be further enhanced, leading to even more intense upwelling, if warming leads to less terrestrial vegetation and thus even higher land-sea thermal differences (Diffenbaugh et al. 2004). More intense upwelling should lead to increased primary productivity in the California Current, but the peak upwelling season might occur up to one month later, and primarily from June to September in the northern portion of the California Current (Snyder et al. 2003, Barth et al. 2007, ISAB 2007). Barth et al. (2007, p. 3719) stated that "Delayed early season upwelling and stronger late season upwelling are consistent with predictions of the influence of global warming on coastal upwelling regions." In addition, warming conditions are likely to increase the density of surface waters, resulting in strong water column stratification, which may impede wind-driven upwelling and reduce the availability of nutrients at the ocean surface (ISAB 2007).

**Ocean acidification**—Global increases in atmospheric $CO_2$ have caused an increase in the amount of $CO_2$ absorbed by the oceans. According to the IPCC (2007, p. 387):

> Ocean biogeochemistry is changing. The total inorganic carbon content of the oceans has increased by 118 ± 19 GtC [gigatons carbon] between the end of the preindustrial period (about 1750) and 1994 and continues to increase. … The increase in total inorganic carbon caused a decrease in the depth at which calcium carbonate dissolves, and also caused a decrease in surface ocean pH by an average of 0.1 units since 1750. Direct observations of pH at available time series stations for the last 20 years also show trends of decreasing pH at a rate of 0.02 pH units per decade.

Decreased pH of ocean waters "decreases the availability of carbonate ions and lowers the saturation state of major shell-forming carbonates in marine animals" and is expected to severely impact the abundance and distribution of calcareous organisms such as corals, shelled mollusks, foraminifera, coccolithophores, and pelagic pteropods (ISAB 2007, p. 71). These changes will have unknown consequences for pelagic communities.

**Expected impact on eulachon**—The ISAB functions to provide independent scientific advice to NMFS, the Columbia River Indian Tribes, and the Northwest Power and Conservation Council. In its document Climate Change Impacts on Columbia River Basin Fish and Wildlife, the ISAB (2007, p. 72) stated that:

> Global climate change in the Pacific Northwest is predicted to result in changes in coastal ecosystems … that may be similar or potentially even more severe than those experienced during past periods of strong El Niño events and warm phases of the PDO, with warmer upper ocean temperatures, increased stratification and decreased productivity along the coast. However, a lack of certainty in future wind and weather patterns yields large uncertainties for future changes. …if upwelling winds remain unchanged from those of the past century, coastal upwelling may become less effective at pumping cold, nutrient-rich [water] to the upper ocean because of increased stability in the upper ocean caused by surface warming. Or, as some modeling studies and hypotheses suggest, upwelling winds may become more intense, and perhaps the timing for the upwelling season will change because of timing shifts in upwelling wind patterns. With warmer ocean temperatures we can expect shifts in the size and species composition of zooplankton to smaller lipid-replete zooplankton instead of large, lipid-rich, cool-water species. Because of food chain effects and warm ocean waters, forage fishes will decline and warm-water predators will increase.

All the above predicted changes will likely influence the growth, productivity, survival, and migration of eulachon. Pacific hake undergo seasonal migrations from their winter spawning grounds off southern California to their northern feeding grounds off the west coast of Vancouver Island in summer (Ware and McFarlane 1995, Benson et al. 2002). Large adult Pacific hake are known to prey on eulachon, and the dominant prey of both small Pacific hake and eulachon are euphuasiids (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Beamish et al. (2008, p. 34) stated that "The projected long-term increase in temperatures may result in more offshore hake moving into the Canadian zone, and in the spawning and rearing area off California moving north." Thus projected ocean warming is likely to result in an altered distribution of both predators on eulachon and competitors for food resources.

Initial eulachon survival during the critical transition period between larval and juvenile stages is likely linked to the intensity and timing of upwelling in the northern California Current Province. However, the potential shift of peak upwelling to one month later than normal may result in a temporal trophic match-mismatch between eulachon larval entry into the ocean and presence of preferred prey organisms whose productivity is dependent on the early initiation of upwelling conditions. These conditions would likely have significant negative impacts on marine survival rates of eulachon and recent recruitment failure of eulachon may be traced to mortality during this critical period. Larval and juvenile eulachon are planktivorous and are adapted to feed on a northern or boreal suite of copepods during the critical larval/juvenile transition.

There are two main suites or assemblages of copepod species over the continental shelf off the west coast of North America: a boreal shelf assemblage (e.g., *Calanus marshallae*, *Pseudocalanus mimus*, and *Acartia longiremis*) that normally occurs from central Oregon to the Bering Sea and a southern assemblage (e.g., *Paracalanus parvus*, *Mesocalanus tenuicornis*, *Clausocalanus* spp., and *Ctenocalanus vanus*) that is most abundant along the California coast (Mackas et al. 2001, 2007). Changes in the relative abundance and distribution of these copepod assemblages covary with oceanographic conditions (Roemmich and McGowan 1995, Mackas et al. 2001, 2007, Peterson and Keister 2003, Zamon and Welch 2005, Hooff and Peterson 2006). When warm conditions prevail, as during an El Niño year or when the PDO is positive, the distribution of zooplankton communities can shift to the north and the southern assemblage of copepods can become dominant off southern Vancouver Island (Mackas et al. 2007). For example, abundance of boreal shelf copepods was much lower than normal and southern species dominated off southern Vancouver Island during the warm years between 1992 and 1998 (Mackas et al. 2007). Thus warmer ocean conditions may be expected to contribute to a mismatch between eulachon life history and preferred prey species.

Ocean conditions off the Pacific Northwest in 2005 were similar to what may be expected if climate change predictions for the next 100 years are accurate. According to Barth et al. (2007, p. 3,719), there was a "1-month delay in the 2005 spring transition to upwelling-favorable wind stress in the northern California Current," and during May to July, upwelling-favorable winds were at their lowest levels in 20 years and "nearshore surface waters averaged 2°C warmer than normal." Eulachon returns to spawning rivers in the southern DPS were poor during this period of unfavorable ocean conditions from 2004 to 2008 (JCRMS 2008) and may portend how eulachon will respond to warming ocean conditions.

### Water quality

**General contaminants**—The high lipid content of eulachon suggests they are susceptible to absorption of lipophilic organic contaminants (Higgins et al. 1987, Pickard and Marmorek 2007). Contaminants considered of most concern include: 1) synthetic chlorinated organic chemicals, such as hexachlorobenzene, DDTs, and the polychlorinated biphenyls (PCBs); 2) polycyclic aromatic hydrocarbons (PAHs) from petroleum and creosoted pilings; 3) dioxins and a host of other organic compounds; 4) metals such as mercury, arsenic, and lead; and 5) endocrine-disrupting compounds and new toxics like PBDE (polybrominated diphenyl ether, flame retardants).

No rigorous toxicological studies of the effects of environmental contaminants on eulachon were found. In the Washington Department of Fisheries Annual Report for 1953, Schoettler (1953, p. 54) stated that:

> The effects of the industrial waste products discharged directly into the Columbia River near the mouth of the Cowlitz are under study by the Fisheries Department in cooperation with the State Pollution Commission. In 1951 shipments of artificially fertilized smelt eggs were taken to the Deception Pass Marine laboratory. After hatching, the fry were subjected to various intensities of waste sulfite liquor. Results indicate that the liquors were harmful to young smelt. … Of equal importance were preliminary pollution studies on adult smelt. Effluents

> from three industrial plants at Longview were used. The smelt were placed in a partitioned trough which held pure river water on one side and river water mixed with certain dilutions of effluent on the other. The number of fish emerging from either side of the trough were carefully enumerated. Under these circumstances smelt showed an aversion to the effluents in dilutions approximating 1 part to 800.

The Environmental Protection Agency (EPA 2002) examined contaminants in fish, including whole eulachon, from the Columbia River in 1996–1998. In general EPA (2002, p. 9-204) stated that whole body analysis revealed that:

> While eulachon … had a high lipid content, they had some of the lowest levels of organic chemicals of all the species tested. Aroclors [a mixture of PCBs] and chlordane were not detected in the eulachon. Eulachon had the highest average concentration of arsenic and lead.

Contamination levels in three combined whole body samples of eulachon in the Columbia River collected at RKM 63–66 ranged 860–930 μg/kg arsenic, 9–10 μg/kg cadmium, 920–990 μg/kg copper, 370–680 μg/kg lead, less than 35 μg/kg mercury, 270–300 μg/kg selenium, 10–11 μg/kg p,p'-DDE, less than 4 μg/kg p,p'-DDT, less than 37 μg/kg Aroclor 1254, less than 37 μg/kg Aroclor 1260, less than 0.00005–0.0001 μg/kg 2,3,7,8-TCDD [a chlorinated dioxin], and 0.00058–0.00078 μg/kg 2,3,7,8-TCDF [a chlorinated furan] (EPA 2002). In addition, EPA (2002, p. E-4) stated that:

> DDE [a metabolite of DDT], the most commonly found pesticide in fish tissue from our study … [was found at] 11 ppb [parts per billion] in whole body eulachon. … Aroclors [a PCB mixture] [were] … nondetectable in eulachon … [and] concentrations of arsenic … [were] 890 ppb in whole body eulachon. Mercury … [was at] nondetectable levels in … whole body eulachon.

Rogers et al. (1990, p. 713) examined tissues and whole eulachon from the Fraser River for organochlorine contaminants and found that:

> [eulachon] tissue samples contained chlorophenols from wood preservation operations and chloroguaiacols from pulp bleaching. Whole fish also contained DDE and DDD [metabolites of DDT], while PCBs were present in some fish gonads in 1986, but not in 1988. With the exception of whole body concentrations of 2,3,4,6-tetrachlorophenol (TeCP), concentrations of pentachlorophenol (PCP), 3,4,5- trichloroguaiacol (3,4,5-TCG), tetrachloroguaiacol (TtiCG), DDE, and DDD in whole bodies, livers and gonads revealed an increasing trend with distance of the eulachon capture site upstream from the Fraser River mouth.

Chan et al. (1996, p. 32) examined eulachon collected from the Nass, Kitimat, and Bella Coola rivers and from Kingcome and Knight inlets for levels of persistent organic pollutants including dichlorodiphenyltrichloroethane, hexachlorobenzene, hexachlorohexanes, dieldrin, chlordane, mirex, and PCBs and found that "levels of chlorinated pesticides and PCB increased from the north to the south, with the lowest from Nass River and highest from Knight Inlet." However, contaminant levels in eulachon "were at least an order of magnitude lower than the maximum residual limit established by Health Canada or the action level established by the U.S. Food and Drug Administration" (Chan et al. 1996, p. 40). Since eulachon do not feed during their freshwater spawning run, "the uptake of toxic chemicals must occur directly from the environment" (Rogers et al. 1990, p. 725).

There are innumerable publications analyzing chemical contaminants and their sources in the lower Columbia River basin and only a select number of large-scale reviews are mentioned herein. Rosetta and Borys (1996) estimated that approximately 48% of the volume of contaminant discharges to the lower Columbia River came from industrial sources (5% from chemical and allied products, 3% from primary metal, and 39% from paper and other product manufacturers) and 52% from sewage treatment plants. Fifty-seven facilities in the lower Columbia River were identified as having the potential to release chlorinated dioxins and furans and "55 environmental cleanup sites in the State of Oregon, and 13 sites in the State of Washington [were found to] contain PCB contamination in either groundwater, sediment, or soil which may have the potential to impact the lower Columbia River" (Rosetta and Borys 1996, p. E-7).

Further breakdown of contaminant sources for the lower Columbia River are presented in Tetra Tech (1996). Hinck et al. (2004, 2006) examined contaminant levels throughout the Columbia River Basin, primarily in three resident nonanadromous target species: common carp (*Cyprinus carpio*), bass (*Micropterus* sp.), and largescale sucker (*Catostomus macrocheilus*). Fish were exposed to a variety of chemical and elemental contaminants throughout the Columbia River (Hinck et al. 2004). Temporal trend analyses indicated that PCBs were decreasing in concentration in sites with historical data; however, concentrations of the organochlorine contaminants PCBs and total p,p′-DDE were higher in the lower and middle Columbia River than in the upper Columbia River (Hinck et al. 2004, 2006).

Hall (1976, p. 45) reviewed water quality and sources of pollution in the lower Fraser River and stated that:

> There appear to be two main water quality problems in the lower Fraser, both apparently attributable to the urban-industrial complex of metropolitan Vancouver, namely pathogens and trace metals. … Potential problems are apparent regarding toxic substances such as trace metals. Concentrations are not high enough to be acutely toxic to fish but the sporadic occurrence of higher concentrations of trace metals such as lead, mercury, and zinc in the lower reaches of the river and accumulations in sediments give some cause for concern, especially since these substances are not biodegradable and bioamplification through food chain concentration or direct absorption by the organism cannot be ignored in the sensitive estuarine areas of the lower Fraser.

Types and sources of contaminants in the lower Fraser River consist of insecticides and herbicides used in agricultural production; wood preservatives associated with the lumber industry (e.g., chromium, copper, arsenic, chlorinated phenols, dioxins, polynuclear aromatic hydrocarbons, phenolics, and creosote); leachates from landfills; a wide range of contaminants in stormwater discharge; industrial effluents associated with metal, cement, forest products, and food industries; and municipal effluents (Birtwell et al. 1988).

Although the central and north coast regions of British Columbia possess relatively pristine environments compared to areas to the south, even this area has marine environmental quality concerns. Haggerty et al. (2003) identified a number of contaminant sources in British Columbia's central coast, which extends from northern Vancouver Island to just south of the Queen Charlotte Islands, including: salmon aquaculture, oil pollution, wastewater, pollution from cruise ships, shipping and boating, forestry and forest products, mining, and atmospheric and oceanic transport of chemical contaminants.

Similarly, Johannessen et al. (2007a) identified the 10 main contaminant sources in the north coast regions of British Columbia, which includes eulachon spawning rivers from the Klinaklini to the Nass rivers, to be: vessel traffic, ports, forestry, pulp and paper mills, mining and smelting, aquaculture, Coast Guard and military sites, global pollutants, offshore oil and gas, and ocean dumping. In a larger context, incorporating both the central and north coasts of British Columbia (aka Pacific North Coast Integrated Management Area [PNCIMA]), Johannessen et al. (2007b) listed the main sources of chemical contaminants as: aquaculture, vessel traffic, ports/harbors/marinas, forestry, pulp and paper, mining and smelting, ocean dumping, Coast Guard and military sites, oil and gas, and global pollutants. Detailed analyses of these contaminant sources are found in the relevant publications (Haggerty et al. 2003, Johannessen et al. 2007a, 2007b) and only a selected few major contaminant sources are mentioned below.

Johannessen et al. (2007b) indicates that 78 finfish and 24 shellfish farms operate in the PNCIMA. Many of these are located in the Queen Charlotte Strait near Knight and Kingcome inlets and pose a source of organic waste materials and of "pesticides and other persistent pollutants in fish used in the production of feed" (Johannessen et al. 2007b, p. ix). An average of more than 400,000 vessels of all types transit the PNCIMA annually. About 56% of these vessels are passenger ferries and cruise ships that transport about 1.5 million passengers yearly through the PNCIMA (Johannessen et al. 2007b). According to Johannessen et al. (2007b, p. 12), "Contaminant issues associated with marine traffic include the discharge of sewage, grey water, oily bilge water, shipboard solid wastes, and release of antifouling compounds from ablative coatings."

Prince Rupert and Kitimat, the two main industrial ports in the PNCIMA, are expanding and increasing their capacity for large industrial shipping. The industrial port of Kitimat currently serves the Alcan aluminum smelter, the Eurocan paper mill, and the Methanex methanol plant (Johannessen et al. 2007b). A new Kitimat liquefied natural gas terminal is to begin construction in 2010, and there are plans for a new Kitimat Marine Terminal and pipeline to transport petroleum from near Edmonton, Alberta, to Kitimat and condensate from Kitimat to near Edmonton, together with numerous other industrial terminal projects (Port of Kitimat 2009). Johannessen et al. (2007b, p. ix) stated that:

> Four [pulp] mills exist in the area [PNCIMA], though two of them have operated intermittently. All Canadian pulp mills underwent significant effluent treatment upgrades in the 1990s such that discharge of solids, discharge of oxygen demand, and chlorinated compounds such as dioxins and furans are now significantly reduced.

Johannessen et al. (2007b, p. 25–26) indicated that within the PNCIMA, "12 [mine] sites are a risk to produce acid rock drainage and heavy metal leachate" and that the only active smelter in the PNCIMA is the aluminum smelter at Kitimat, where "several studies have detected elevated PAH concentrations in both marine biota and sediments in the Kitimat Arm area." Johnson et al. (2009) detected elevated concentrations of PAHs in sediments of Kitimat Arm, that are similar to PAHs originating from the Alcan smelter, and in salmon and flatfish collected in Kitimat arm. However, Johnson et al. (2009, p. xv) concluded that:

> The process changes introduced by Alcan appear to be effective at reducing inputs of PAHs into the environment and biota of Kitimat Arm, as PAH concentrations in sediments and fish and fish disease prevalences have remained stable or declined over the past 5 years of sampling.

Kime (1995, p. 67–68) reviewed the literature on the effects of contaminants on fish reproduction prior to fertilization, showed that these effects can occur throughout the reproductive system, and stated that:

> They may cause lesions, haemorrhage, or malformations in the gonads, pituitary, liver, and the brain. Production and secretion of hormones of the hypothalamus, pituitary, and gonads is usually inhibited and their metabolism by the liver can be altered. … Gametes have been shown to be particularly sensitive to pollutants, both in their development, particularly the production and growth of oocytes involving vitellogenin synthesis, and in their fertility. Sperm motility, in particular, has special potential as a rapid and sensitive indicator of pollutant activity.

Analyses of these reproductive biomarkers (quantifiable parameters of an organism's biological state) go beyond the traditional toxicological test of establishing the dose of a contaminant causing death in 50% of the test organisms ($LD_{50}$) and are an example of the problems researchers have in assessing the effects of chronic low-level exposure of contaminants or mixtures of contaminants on fish and fish populations (Eggen et al. 2004, Carvan et al. 2008). As pointed out by Carvan et al. (2008, p. 1,023), most of the problems facing modern ecotoxicology are much more subtle and require development of a suite of biomarkers and the use of controlled laboratory experiments on sentinel fish species, such as zebrafish (*Danio rerio*) (much as laboratory rats are used to assess risk of toxicant exposure to higher mammals), to assess risk to closely related fish species.

**Temperature**—Smith and Saalfeld (1955) reported that eulachon are present in the Columbia River when water temperatures are between 2°C and 10°C and delay migration into spawning tributaries until temperatures are above about 4.4°C (WDFW and ODFW 2001). When river temperatures vary above or below normal, eulachon may fail to spawn in normal areas, delay spawning, or migrate into other tributaries (Smith and Saalfeld 1955, WDFW and ODFW 2001).

Snyder (1970) reported on studies in 1968 and 1969 that examined the temperature tolerance of adult eulachon and eggs taken from the Columbia and Cowlitz rivers and found that eggs were more tolerant to temperature increases than were adults. Increases of 2.8°C and 5.6°C killed 50% and 100% of adult smelt, respectively, within 8 days. Even when exposed to temperatures elevated by 9°C for a single hour, 50% of adult eulachon were dead after 32 hours. When placed in water 3.9°C above river temperatures, females failed to deposit eggs (Snyder 1970). Slightly different results were reported by Blahm and McConnell (1971) on effects of increased temperature on eulachon collected from the Cowlitz River in 1968 and 1969. They reported that the incipient lethal temperature for eulachon acclimated to 5°C was 11°C. All eulachon exposed to 11°C were dead after 8 days exposure. When eulachon had been acclimated to 10°C, a sudden exposure to 18°C for one hour followed by return to 10°C resulted in at least 50% mortality within 50 hours (Blahm and McConnell 1971). All female fish exposed to elevated temperatures failed to deposit eggs within 50 hours, in contrast to female eulachon in control conditions that successfully deposited eggs (Snyder and Blahm 1971).

When evaluating temperature criteria for Washington's water quality standards, Hicks (2000, p. 99) stated that:

> The studies on smelt indicate they have a lower lethal temperature limit than do the salmonids and a lower optimum temperature preferendum. … Given that adult spawners and outgoing juveniles may be in fresh waters as late as March to mid-April, and their temperature requirements may be more strict than most salmonids, the protection of smelt is an important consideration in setting water quality standards. In waters supporting smelt, it is recommended that the 7-day average of the daily maximum temperatures not exceed 12–14°C prior to May 1, with no single daily maximum temperature greater than 16°C.

### Catastrophic events

Larson and Belchik (1998, p. 7) reported that "The eruption of Mount St. Helens severely impacted Cowlitz River spawning success in 1980 and the consequent return of adults in 1984."

Emmett et al. (1990) documented the effects of the dramatic increase in turbidity in the Columbia River on fishes in the estuary following the 18 May 1980 eruption of Mount St. Helens, which resulted in introduction of large quantities of volcanic ash and sediment into the Columbia River estuary. Although hampered by the absence of long-term pre-eruption data, Emmett et al. (1990) showed that densities of benthic invertebrates, particularly amphipods, were significantly reduced and feeding habits and distribution of estuarine fishes were altered following the eruption.

## Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

### Commercial harvest

Landing records of eulachon in commercial fisheries in the Fraser and Columbia rivers were discussed in the above Summary of Regional Demographic Data subsection. Eulachon have been commercially harvested in the Columbia River since the late 1860s and commercial landing records begin in 1888 (Table 7, Figure 22). Smith and Saalfeld (1955), the Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001), and Bargmann et al. (2005) describe gear types and fishery regulations pertaining to the modern era of the Columbia River commercial eulachon fishery. As described in the Summary of Regional Demographic Data subsection, the Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001, which provides for three levels of fishing intensity based on an in-season estimate of parental run strength and preseason estimates of juvenile production and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005).

More recently, JCRMS (2009, p. 26–27) stated that:

> For January 1–March 31, 2009, the mainstem Columbia River commercial fishery was open from 7 a.m. to 2 p.m. on Mondays and Thursdays. … The Cowlitz River was open from 6 a.m. to 10 p.m. on Saturdays. The Sandy River was open year-round, 7 days a week, 24 hours a day, per permanent regulations. ... Pounds landed in the mainstem Columbia River commercial fisheries [amounted to] 5,600 pounds. No commercial landings were made in Oregon tributaries (i.e., Sandy River) during 2009. Pounds landed in the Cowlitz River commercial fishery [amounted to] 12,100 pounds. … All other Washington tributaries were closed to commercial fishing during 2009.

DFO (2008c) provides a brief history of the Fraser River commercial eulachon fishery, which began in the 1870s and, besides the Nass River fishery which ended in the 1940s, has been the only commercial eulachon fishery operating in British Columbia. DFO (2008c) reported that:

> From 1903 to 1912, the Fraser River eulachon fishery was the fifth largest commercial fishery in BC. … Historically, anyone with a Category C licence or a limited entry vessel-based category of licence was eligible to fish eulachon. … Up to 1995, the fishery was passively managed with an open time from March 15 to May 31 for commercial drift gill nets with a one day per week closure. In 1995 … the fishery was restricted to three days per week in an attempt to provide a “spawning window” which would allow some fish to swim unimpeded by nets to their spawning areas. … The commercial eulachon fishery was closed in 1997 due to the inability to control effort and participation and to ensure conservation objectives were met. … The commercial eulachon fishery sells to the fresh fish market for food. Some of the catch is sold as bait for recreational sturgeon fishing. Based on fish slip records for the period 1980 to 1995, the number of active vessels ranged between 8 and 45.

The Fraser River commercial fishery for eulachon has essentially been closed since 1997, only opening briefly in 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a).

**Recreational harvest**

Fry (1979, p. 90) reported that in California, in the past, there were “relatively minor [eulachon] sport fisheries near river mouths, the Klamath fishery being the largest. Dip nets are used.” Numerous anecdotal digital newspaper sources were found that indicate substantial recreational fisheries existed in the Klamath River and in other northern California rivers, as well as in the Umpqua River during the 1960s to the 1980s (see Appendix B).

A large recreational dipnet fishery that occurs almost exclusively in Columbia River tributaries, and for which catch records are unavailable, has existed in concert with commercial fisheries (Bargmann et al. 2005). JCRMS (2008) stated that:

> Prior to 1997, the recreational fishery in Washington tributaries was open 7 days per week the entire year. ... Smelt dippers in Washington were allowed 20 pounds [9.1 kg] per person each day, but beginning in late 1998 the limit has sometimes been 10 pounds [4.5 kg] per person. In Oregon the daily limit remains 25 pounds [11.4 kg] per person with the season open throughout the year. The recreational dip net fishery is very popular, drawing thousands of participants. Smelt are used for human consumption and are also in great demand for sturgeon bait. Annual recreational catch estimates are not available; however, limited past creel census information suggests that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time.

USACE (1952, p. 2,873) reported that:

> During the smelt run literally thousands of people line the banks of the streams, utilizing all sorts of gear to make a catch of this delectable fish. Data are lacking to show the magnitude of this catch, but during the 1948 smelt run to the Sandy River, 32,422 noncommercial licenses were issued to persons engaged in dipping this fish.

In reference to the 2009 recreational fishery season, JCRMS (2009, p. 27) stated that:

> The mainstem Columbia River was open to both Washington and Oregon recreational fishers 7 days per week on a 24-hour basis, with a bag limit of 25 pounds per person under Level One restrictions. The Washington tributary season was restricted to the Cowlitz River from 6 a.m. to 10 p.m. on Saturdays with a bag limit of 10 pounds per person. All Oregon tributaries were open to recreational dipping 7 days per week the entire year as per permanent regulations. Recreational fishing was poor due to low abundance.

Currently, recreational fishing for eulachon with dip nets, gill nets, minnow nets, or cast nets is prohibited in all freshwater systems of British Columbia (DFO Web site at http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/opportunities-possibilites/fin-nageoire-eng.htm. In saltwater, recreational fishing for eulachon is prohibited due to conservation concerns in Areas 6 to 10 (central coast of British Columbia) and 28 and 29 (near the mouth of the Fraser River). In Areas 1 to 5 (north coast of British Columbia) and 11 to 27 (Queen Charlotte Strait, Strait of Georgia, and west coast Vancouver Island), a year round daily limit of 20 kg of eulachon can be recreationally harvested with dip net or gill net, although this harvest is likely minor since eulachon are only accessible to the recreational fishery when they return to spawn in the spring and are close enough to the surface and shore to be caught (DFO 2009f).

## Tribal and First Nations fisheries

The importance of the eulachon run to local Indian tribes in the lower Columbia River was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001). JCRMS (2009, p. 26) stated that currently:

> Tribal harvest is essentially nonexistent. … However, the Yakama Nation has taken a few pounds of smelt from the Cowlitz River annually, for ceremonial and subsistence purposes.

Available landing records of eulachon in First Nations subsistence fisheries in British Columbia south of the Nass River were discussed in the above Summary of Regional Demographic Data subsection. Rivers where some data were available included the Fraser, Klinaklini, Kingcome, Wannock, Bella Coola, Kemano, and Kitimat. DFO (2008c) stated that:

> Aboriginal communal licences specify the locations and method permitted for use by First Nations for food, social, and ceremonial harvests. Eulachons are harvested when they return to freshwater to spawn. … Fishing methods will vary by First Nations and river system, but may include beach seine, gill net, conical nets, and dip nets. … Limited information is available on the extent of First Nations' harvest of eulachons for food, social, and ceremonial purposes.

Pickard and Marmorek (2007, p. 40) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "it seems unlikely that overfishing is the cause of the recent sharp declines in eulachon abundance; however, it is important to understand how harvesting severely depressed populations may affect the recovery of populations."

# Predation and Disease

## Predation

WDFW and ODFW (2001, p. 5) stated that "impressive numbers of predators and scavengers accompany large runs of smelt from the time they first enter the Columbia through completion of spawning." Beach et al. (1981, 1985) and Jeffries (1984) observed that harbor seals, California sea lions, and Steller sea lions (*Eumetopias jubatus*) move into the Columbia River to feed on eulachon runs in the winter. Jeffries (1984, p. 20) observed that "harbor seals were frequently reported in the area where the Cowlitz River enters the Columbia" and "these population increases … were apparently due to the migration of eulachon into spawning tributaries." Many harbor seals migrate from Grays Harbor and Willapa Bay to the Columbia River in the winter (Beach et al. 1985). Between 1,000 and 1,500 harbor seals have been observed using haul out sites as far as 45 miles upriver on the Columbia River at this time of year and "are frequently seen as far upriver as Longview, Washington (RM 55 [RKM 88.5]), apparently following eulachon runs into this area" (Beach et al. 1981, p. 73). NMFS (1997, p. 29) stated that the highest counts of seals in the river coincide with the winter spawning of eulachon.

Based on the presence of otoliths in harbor seal scat collected from the Columbia River during 1981–1982, Jeffries (1984) reported that eulachon were eaten by 50%, 87%, 44%, and 12% of the harbor seals present in January, February, March, and April, respectively. Brown et al. (1989) determined that 98% of the prey eaten by harbor seals in the Columbia River during the winters of 1986 to 1988 were eulachon, and that 100% of harbor seal stomachs examined contained eulachon (Brown et al. 1989, NMFS 1997). Brown et al. (1989) also estimated that the more than 2,000 harbor seals present during mid winter 1987 in the Columbia River consumed from 2.5 to 10.2 million eulachon or from 105 to 428 mt (assuming an average weight of 42 g per eulachon), which is equal to 12% to 50% of the Columbia River commercial fishery landings of eulachon for that year.

Although accounting for only 0.4% of the diet, Olesiuk (1993) estimated that the 12,000–15,000 harbor seals present in the Strait of Georgia during 1988 consumed an average of approximately 40 mt of eulachon. Harbor seals were known to concentrate and feed on eulachon in the Klinaklini River estuary at the head of Knight Inlet during the eulachon spawning migration in March (Spalding 1964). Eulachon also congregate in the Skeena River off Point Lambert during the eulachon spawning migration in that river (Fisher 1947) and likely follow the eulachon up the tributary Ecstall River (Fisher 1952). Both Imler and Sarber (1947) and Pitcher (1980) indicate that eulachon were the dominant prey of harbor seals from late May to mid-July during eulachon spawning migrations on the Copper River Delta in Alaska. Based on stomach content analyses, harbor seals also prey on eulachon in Prince William Sound (Pitcher 1980, Lowry et al. 2001), lower Cook Inlet, and off Kodiak Island (Pitcher 1980). Nearly 5% of 269 harbor seal stomachs examined in all areas of the Gulf of Alaska by Pitcher (1980) contained eulachon remains.

Eulachon are also a primary prey species of California sea lions in the Columbia River in January to June (Beach et al. 1985, Brown et al. 1995, NMFS 1997), and California sea lions have been observed near Longview at the time of the eulachon run (Beach et al. 1981). Jeffries (1984, p. 17) observed that peak numbers of California sea lions (200–250) in the Columbia River occurred during the months of February and March and they were believed to "move upriver following and feeding on the annual eulachon smelt runs." Maximum numbers of Steller sea lions (80–100) in the Columbia River also occurred during this time of year when they "have been observed feeding upriver on eulachon" (Jeffries 1984, p. 19). Seals and sea lions have also been observed above New Westminster in the Fraser River during the eulachon spawning migration (Hay and McCarter 2000).

Bigg (1988) noted that about 60 individual Steller sea lions congregated each year between 1978 and 1982 near the mouth of the Fraser River at Sand Heads in mid-March to early May to feed on eulachon that spawn in the Fraser at that time. Steller sea lions were similarly reported by fishery officers to enter numerous inlets on the mainland coast of British Columbia to feed on returning eulachon during February to April (Bigg 1988). Although Pitcher (1981) reported that eulachon were not a part of the diet of Steller sea lions in the Gulf of Alaska, numerous other studies (Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009) have emphasized the seasonal importance of eulachon to Steller sea lions in Southeast Alaska. Steller sea lions are attracted in large numbers to spawning eulachon runs in April and May in various locations in northern Southeast Alaska, especially the Yakutat forelands and Lynn Canal (Sigler et al. 2004, Womble et al. 2005, 2009). Eulachon provide a predictable energy-rich prey item for Steller sea lions during the spring gestation and pupping season (Womble 2003, Sigler et al. 2004). Sigler et al. (2004) estimated that about 10% of the population of Southeast Alaska Steller sea lions were in Berners Bay on Lynn Canal during the 2002 eulachon run and that many other Steller sea lions were likely aggregated in the vicinity of one of the 32 other documented eulachon spawning runs in Southeast Alaska. Large aggregations of Steller sea lions have also been found in the vicinity of the mouth of the Alsek River and Taku, Lutak, and Taiya inlets during eulachon runs (Womble 2003).

Northern fur seals consume eulachon in the California Current (Antonelis and Fiscus 1980) and particularly offshore of Oregon and Washington (Antonelis and Perez 1984). Peak numbers of northern fur seals appear off Oregon and Washington in April (Antonelis and Perez 1984). Based on fur seal diet analyses, Antonelis and Perez (1984) calculated that fur seals consumed a yearly average of 600 mt of eulachon in this offshore region between 1958 and 1974. By comparison, the Columbia River commercial fishery landed an average yearly catch of 650 mt of eulachon over this same time period (Table 9). Spalding (1964) reported that about 100 yearling fur seals congregated at the head of Knight Inlet in March 1961 and that four of these fur seals had been feeding exclusively on eulachon in the Klinaklini River estuary, while another 60 fur seals in the middle of the inlet were feeding on squid. Clemens et al. (1936, p. 6) reported on an analysis of stomach contents of 593 northern fur seals sampled from late March to late June off the west coast of Vancouver Island and stated that:

> Eulachon proved to be the third most important organism in the food of the fur seals [after herring and salmon]. It was found to occur in some 20% of the full stomachs but as a rule in rather small quantities. It comprised about 3% of the total food.

Moore et al. (2000) reported that feeding behavior of beluga whales appears to coincide with the timing and pattern of eulachon runs in Cook Inlet, Alaska. Belugas congregate near the Susitna River Delta at the time of early summer eulachon runs and eulachon have been identified in beluga stomachs (Moore et al. 2000).

Marston et al. (2002) documented 34 separate bird species feeding on eulachon returning to spawn in rivers draining into Berners Bay, Alaska, amounting to more than 46,000 avian predators in 1996 and more than 36,500 in 1997. Thousands of gulls and some of the hundreds of eagles were observed feeding heavily on eulachon during the upriver migration, while shorebirds, waterfowl, corvids, and many eagles fed on spawned-out, dying fish (Marston et al. 2002). WDFW and ODFW (2001, p. 5) stated that "gull counts in the mid-1980s along the lower Cowlitz River during the peak of eulachon abundance exceeded 10,000 birds of 8 species" and that during the 1980s "peak counts of bald eagles in conjunction with eulachon upstream migration and spawning were as high as 50 in areas of the lower mainstem Columbia, along the Cowlitz, and along the Lewis" (Table A-10).

According to Fry (1979, p. 15) "Green sturgeon take advantage of spawning eulachon in the Klamath River, but (like eagles and gulls) probably do more scavenging than actual preying." Analysis of stomach contents revealed that eulachon eggs were a seasonally important prey item for juvenile white sturgeon in May and June 1988 in the Columbia River below Bonneville Dam at RKM 153 (2–12 % of the diet) and RKM 211 (25–50% of the diet) (McCabe et al. 1993).

Eulachon occurred in 100% of 229 spiny dogfish stomachs containing food taken in the Fraser River in May 1953, and in 23% and 92% of stomachs analyzed outside the river's mouth in May 1950 and 1953, respectively (Chatwin and Forrester 1953). According to Chatwin and Forrester (1953, p. 38), "The dogfish which support the fishery in the Fraser River in mid-May are clearly dependent upon the appearance of the eulachon." Analyses of more than 14,000 spiny dogfish stomachs in British Columbia waters over a 30-year period ending in 1977 revealed that eulachon represented approximately 5.5% of the annual dogfish diet, and represented a greater percentage of food types consumed for young (13.4%) and immature (10.2%) dogfish than for adults (1.6%) (Jones and Geen 1977).

Eulachon occurred at low frequency (<1%) in 416 Pacific cod stomachs examined in British Columbia (Hart 1949). Eulachon are also eaten by large Pacific hake, which become increasingly piscivirous as they age, with euphausiids being the dominant prey of small Pacific hake (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Livingston (1983, p. 630) determined that eulachon off Oregon in the spring of 1980 "comprised 22% by weight of the diet of 450–549 mm Pacific whiting [hake] and 79.6% by weight of the diet of 550+ mm fish." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents 61% of the offshore pelagic biomass in the California Current system (Ware and McFarlane 1995), and recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that the feeding migration of Pacific hake may be extending further north within the northern California Current system. Although only about 5% of Pacific hake stomachs examined by Outram and Haegele (1972) off the west coast of Vancouver Island in 1970 contained eulachon, the large biomass of Pacific hake in this region in summer may have a significant impact on eulachon biomass in the area (Hay and McCarter 2000).

Yang and Nelson (2000, p. 159–160) stated that "eulachon [in the Gulf of Alaska in 1990, 1993, and 1996] were consumed by the main piscivorous species (arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock) but … comprised no more than 5% of the stomach content weight of each of the predator species in every year." These predator species consumed eulachon whose mean standard length ranged from 100 to 150 mm (Yang and Nelson 2000). In 1990 and 2001, eulachon comprised about 5.5% and 2.5% by weight, respectively, of the total sablefish stomach contents examined in the Gulf of Alaska (Yang 1993, Yang et al. 2006). In the Gulf of Alaska, "sablefish less than 55 cm FL only consumed smaller eulachon (<100 mm SL), whereas larger sablefish (>55 cm FL) also consumed some larger eulachon (about 150 mm SL)" (Yang 1993, p. 97). Eulachon were prey items in about 4% of 753 arrowtooth flounder stomachs examined (70% of stomachs contained no food) off the west coast of Vancouver Island in 1968 and 1969 (Kabata and Forrester 1974). Similarly, eulachon were found in about 5% of 341 arrowtooth flounder stomachs examined (about 49% of stomachs were empty) in the summer of 1989 off the coast north of Cape Blanco, Oregon (Buckley et al. 1999).

Barraclough (1967) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 6–8 June 1966, when eulachon larvae

(4.5–16 mm FL) and postlarvae/juveniles (24–49 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (33–182 mm FL), surf smelt (70–133 mm FL), Pacific sand lance (35–73 mm FL), and Chinook (67–148 mm FL), sockeye (88–140 mm FL), and chum (37.5 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged from 3–14 for Pacific herring, 1–4 for surf smelt, 1–8 for Pacific sand lance, 9–137 for Chinook, 4–12 for sockeye, and 100 for chum salmon (Barraclough 1967). Similarly, Robinson et al. (1968b) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 5–9 June 1967, when large numbers of eulachon larvae (5–12 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (37–258 mm FL), surf smelt (75 mm FL), Pacific sand lance (44–106 mm FL), kelp greenling (63–67 mm FL), threespine stickleback (68 mm FL), steelhead (150 mm FL), and Chinook (100 mm FL), sockeye (98 mm FL), and chum (63–86 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged 1–300 for Pacific herring, 1 for surf smelt, 3–16 for Pacific sand lance, 1–19 for kelp greenling, 12 for threespine stickleback, 1 for steelhead, and 4 for Chinook, 3 for sockeye, and 2–60 for chum salmon (Robinson et al. 1968b).

Barraclough and Fulton (1967) reported on larval/postlarval eulachon (16–26 mm FL) in the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 4–8 July 1966. Species and the range of fork lengths of fish consuming eulachon larvae and postlarvae included coho (160 mm FL), sockeye (117 mm FL), chum (95–112 mm FL), and pink (88–135 mm FL) salmon. Numbers of eulachon larvae and postlarvae consumed by individual fish ranged 7 for coho, 13 for sockeye, 2–20 for chum, and 2–118 for pink salmon (Barraclough and Fulton 1967). Moffitt et al. (2002, p. 4) indicated that coho salmon parr and adult Dolly Varden feed on eulachon eggs and larvae in rivers in Southeast Alaska and "returning adult sockeye salmon in the Copper River delta have been found with adult eulachon in their stomachs." Similarly, adult spring-run Chinook salmon have been found with upwards of a dozen eulachon in their stomachs on the Cowlitz River during the spring spawning migration of the two species (Rich 1921). These instances of returning adult salmon feeding on eulachon are highly unusual as "it is well known that the habit of adult salmon, entering streams for the purpose of spawning, is to cease feeding at least as soon as the freshwater is entered" (Rich 1921, p. 7).

Ecosystem impacts of the recent and ongoing expansion of large numbers of jumbo (aka Humboldt) squid (*Dosidicus gigas*) into waters off Oregon, Washington, and British Columbia are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). An analysis of the contents of 503 jumbo squid stomachs collected in the northern California Current, including 40 collected off Oregon and Washington, failed to record the presence of eulachon or other osmerid smelts in the jumbo squid diet (Field et al. 2007). Jumbo squid, however, were shown to prey heavily on Pacific hake in the size range of 15–45 cm and adult Pacific hake are known predators on eulachon. The absence of eulachon in the diet of jumbo squid analyzed by Field et al. (2007) may be due to a combination of low eulachon abundance in the study area and a lack of significant overlap in the two species' depth range; eulachon are commonly found between 20 and 150 m deep (Hay and McCarter 2000) and are seldom encountered below 200 m and jumbo squid in the Field et al. (2007) study were mostly collected below this depth. Further diet studies of jumbo squid collected off Oregon in 2009 are ongoing; however, a further 400 squid stomachs examined since the publication of Field et al. (2007) has yet to yield eulachon or any osmerids in the diet of jumbo squid.[14] Rapid digestion of small pelagic fish may also limit the ability to detect eulachon in jumbo squid stomachs.

### Disease

Very little information was found relative to impacts of diseases on eulachon. Hedrick et al. (2003) isolated viral hemorrhagic septicemia virus (VHSV) for the first time from adult eulachon collected in March 2001 in Oregon's Sandy River. Six of 15 pooled samples, each consisting of 5 fish, tested positive for VHSV. The overall impact of this virus on eulachon is difficult to assess. This virus has been isolated from a wide range of marine fish hosts and given the right conditions may "cause significant disease associated with morbidity and mortality in populations of marine fish" (Hedrick et al. 2003, p. 212).

## Other Natural or Man-made Factors

### Competition

Euphausiids (principally *Thysanoessa spiniferia* and *Euphausia pacifica*) are a primary prey item of eulachon in the open ocean and are also eaten by many other competing species. Tanasichuk et al. (1991) showed that euphausiids were the most important prey for both spiny dogfish and Pacific hake off the lower west coast of Vancouver Island. Livingston (1983) determined that euphausiids constituted 72% and 90% of the diet by weight of Pacific hake examined off Oregon and Washington, respectively, in 1967, and 97% of the diet by weight of Pacific hake 350–449 mm long off Oregon in 1980. Similarly, Outram and Haegele (1972) indicated that euphausiids were the most numerous prey item of Pacific hake off the British Columbia coast in 1970, occurring in 94% of Pacific hake stomachs analyzed. Rexstad and Pikitch (1986, p. 955) stated that "euphausiids constitute the primary source of food for Pacific hake in the North Pacific." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents the largest component of the offshore pelagic fish biomass in the California Current system (Ware and McFarlane 1995). Recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that Pacific hake spawning may be shifting further north within the northern California Current system. This places more young of the year Pacific hake in that ecosystem (Phillips et al. 2007) in direct competition with eulachon for their preferred prey, euphausiids.

Several studies (Suchman and Brodeur 2005, Ruzicka et al. 2007, Brodeur et al. 2008, Suchman et al. 2008) have suggested that seasonal predation by large jellyfish can have a substantial impact on zooplankton populations in the California Current and these jellyfish may represent significant competitors with pelagic fishes for zooplankton resources. Brodeur et al. (2008, p. 649) examined spatial and dietary overlap of large jellyfish with a number of pelagic fishes in the California Current and stated that:

---

[14] J. Field, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 15 October 2009.

isotope and diet analyses suggest that jellyfish occupy a trophic level similar to that of small pelagic fishes such as herring, sardines, and northern anchovy. Thus jellyfish have the potential, given their substantial biomass, of competing with these species.

Although eulachon were not specifically examined in this study, a large percentage of the diets of the two large jellyfish examined (*Chrysaora fuscescens* and *Aurelia labiata*) consisted of copepods and various euphausiid life history forms from eggs to adults (Brodeur et al. 2008) that are also significant components of the eulachon diet.

**Euphausiid fisheries**

A commercial fishery for euphausiids (also known as krill) occurs in the British Columbia portion of the Strait of Georgia (DFO 2007b). According to DFO (2007b, p. 6), euphausiid biomass in British Columbia waters "is dominated by five [species]: *Euphausia pacifica*, *Thysanoessa spinifera*, *T. inspinata*, *T. longipes* and *T. raschii*," and *E. pacifica* accounts for 70–100% of the biomass in the Strait of Georgia. The Integrated Fisheries Management Plan for euphausiids limits annual total allowable catch (TAC) of euphausiids in the Strait of Georgia to 500 mt (DFO 2007b). DFO (2007b, p. 3 of its Appendix A) stated that this level of harvest is considered to "be conservative and sustainable" within the Strait of Georgia. Eulachon originating from rivers draining into the Strait of Georgia likely leave the strait for waters over the continental shelf prior to reaching a size where they would begin consuming euphausiids, and thus the impact of this euphausiid fishery on eulachon is expected to be minor.

Although no directed commercial fishery for euphausiids has occurred in U.S. waters off the West Coast, recognition of the importance of krill in the diet of many species influenced the Pacific Fisheries Management Council to propose a ban on commercial harvest of all species of krill (euphausiids) in the Exclusive Economic Zone off the U.S. West Coast, which includes California, Oregon, and Washington (PFMC and NMFS 2008). This krill harvest ban was formally implemented as Amendment 12 to the Coastal Pelagic Species Fishery Management Plan in July 2009 (NMFS 2009).

**Eulachon bycatch**

Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Hay et al. 1999a, 1999b, Olsen et al. 2000, NWFSC 2008, Hannah and Jones 2009). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur from the west coast of Vancouver Island to the U.S. West Coast off Cape Mendocino, California (Hannah and Jones 2003) (Figure 31). *Pandalus jordani* is known as the ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific ocean shrimp in California. Herein we use the common name ocean shrimp in reference to *P. jordani* as suggested by the American Fisheries Society (McLaughlin et al. 2005). Similar trawl fisheries operate in British Columbia, which mainly target ocean shrimp (aka smooth pink shrimp in Canada), northern pink shrimp (*P. borealis eous*), and sidestripe shrimp (*Pandalopsis dispar*) (Hay et al. 1999a, 1999b, Olsen et al. 2000, Hannah and Jones 2007, NWFSC 2008, DFO 2009c). Information on ocean shrimp fisheries can be found for Washington online at

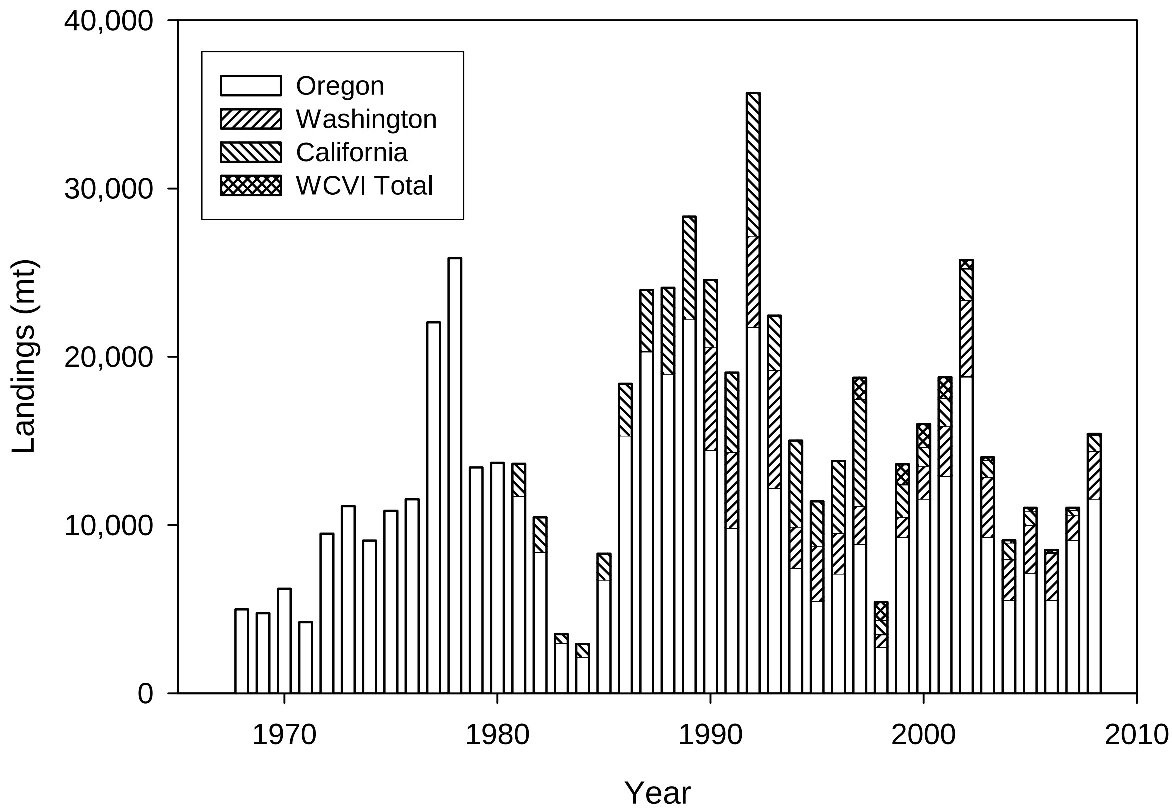



Figure 31. Commercial landings in ocean shrimp trawl fisheries off the U.S. West Coast and in British Columbia, Canada, off the west coast of Vancouver Island. Data for Washington from tables online at http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon from Rien[15] and Hannah and Jones (2009), for California from tables online at http://swr.nmfs.noaa.gov/fmd/bill/landings.htm, and for the west coast of Vancouver Island from DFO (2009a).

http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon online at http://www.dfw.state.or.us/MRP/shellfish/commercial/shrimp_landings.asp#about, for California in Frimodig et al. (2007), and for British Columbia online at http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/shrimp/Default_e.htm.

Prior to the mandated use of bycatch reduction devices (BRDs) in the ocean shrimp fishery, 32–61% of the total catch in the ocean shrimp fishery consisted of nonshrimp biomass, made up mostly of Pacific hake, various species of smelt, yellowtail rockfish, sablefish, and lingcod (*Ophiodon elongatus*) (Hannah and Jones 2007). Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 1996, 2003, Hannah and Jones 2007, 2009, Frimodig 2008) and great progress has been made in reducing bycatch, particularly of larger-bodied fishes. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007).

---

[15] T. Rein, ODFW, Clackamas, OR. Pers. commun., 24 June 2008.

Beginning in 2000 in British Columbia and 2003 in Washington, Oregon, and California, mandated use of of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008). The nearly 97% use of rigid-grate BRDs and increasing use of grates with bar spacing of one inch or less in the Oregon shrimp trawl fishery (Hannah and Jones 2009), and the required use of rigid-grate BRDs with a grid space no greater than 44.5 mm (1.75 inches) and the recommendation to use a 25 mm (1 inch) space between the grid bars when targeting pink shrimp in the British Columbia shrimp trawl fisheries (DFO 2009c) are likely to reduce bycatch rates of small-bodied fishes even further.

Following recognition that large numbers of eulachon were occurring as bycatch in Queen Charlotte Sound shrimp fisheries (Hay and McCarter 2000, Olsen et al. 2000) and of a concurrent decline in central coast British Columbia eulachon stocks, DFO closed the Queen Charlotte Sound shrimp trawl fishery in 1999, which has remained closed "because of concerns for central coast eulachon stocks" (DFO 2009c, p. 11). Concerns over eulachon bycatch in offshore west coast Vancouver Island shrimp trawl fisheries also led DFO to set eulachon bycatch action levels for west coast Vancouver Island (DFO 2009c, 2009d). This action level is set at 1% of the west coast Vancouver Island eulachon abundance index, which is based on biomass estimates of eulachon derived from the annual shrimp abundance survey (DFO 2009c, p. 11). If estimated eulachon bycatch exceeds this 1% level, additional "management actions could include: closure of the shrimp trawl fishery, closure of certain areas to shrimp trawling, or restricting trawling to beam trawlers which have been found to have a lower impact on eulachon than otter trawlers" (DFO 2009d, p. 15). Similar action levels are not in place off the U.S. West Coast.

Although ocean shrimp fisheries operate in Washington, Oregon, and northern California, NMFS's West Coast Groundfish Observer Program (WCGOP) only observes vessels in Oregon and California, since Washington State has not yet issued a ruling allowing federal observer coverage of its state-managed fisheries (NWFSC 2008, p. 1). The BRT has recently received revised data collected by NMFS's WCGOP that update previous estimates of bycatch ratios of eulachon in the Oregon ocean shrimp fishery. Eulachon bycatch in the Oregon ocean shrimp trawl fishery in the years 2004, 2005, and 2007 was estimated at 0.0005, 0.0007, and 0.0008, respectively (WCGOP[16]). Based on these bycatch ratios, the estimated biomass of eulachon taken as bycatch in the Oregon ocean shrimp fishery was calculated at about 2.9 mt in 2004, 5.0 mt in 2005, and 7.7 mt in 2007—assuming total ocean shrimp catches of 5,534 mt (12.2 million lb), 7,167 mt (15.8 million lb), and 9,117 mt (20.1 million lb) in 2004, 2005, and 2007, respectively (Figure 31). Similar eulachon bycatch ratio and total biomass data for California ocean shrimp fisheries were only available for 2004; the eulachon bycatch ratio for that year was 0.0002 (WCGOP[17]) and the biomass of eulachon bycatch was estimated at 0.20 mt—based on a total ocean shrimp catch of 992 mt (2.2 million lb). These data were calculated by applying the yearly observed bycatch ratio of eulachon (observed biomass of eulachon/observed ocean shrimp biomass) to the total yearly Oregon or California ocean shrimp fishery landings (Figure 31).

[16] J. Majewski, unpublished data, NWFSC West Coast Groundfish Observer Program. Pers. commun., 14 October 2009.
[17] See footnote 16.

Unfortunately, no data are available on the level of eulachon bycatch that may be occurring in the Washington State ocean shrimp trawl fishery. In addition, due to sampling conditions and time constraints, not all smelt were identified to the species level in the Oregon and California ocean shrimp trawl fishery observer database and thus a portion of the bycatch in these fisheries was recorded as unidentified smelt. Estimated average biomass of unidentified smelt occurring as bycatch in the Oregon ocean shrimp trawl fishery was reported as 5.6 mt across the 3 years with observer data: 2004, 2005, and 2007 (NWFSC 2008, its Table 3).

Based on the portion of the smelt bycatch biomass identified to species in the Oregon ocean shrimp fishery by the WCGOP (NWFSC 2008), the unidentified smelt biomass was likely about 60% eulachon. NWFSC (2008, p. 24) calculated a eulachon bycatch rate of 0.0004 (±0.0030 SE) in the 2007 ocean shrimp trawl fishery north of 40°10′N latitude. Bellman et al. (2008, p. 38) used the ratio from NWFSC (2008) and total fleet landings of pink shrimp (mt, based on fish tickets) to calculate a bycatch of 4.7 mt of eulachon in the pink shrimp fishery north of 40°10′N latitude in 2007 including northern California, Oregon, and Washington. The depressed abundance of the southern DPS of eulachon may also be contributing to the above estimated levels of eulachon bycatch.

Presumably, most eulachon caught as bycatch in offshore ocean shrimp trawl fisheries off Oregon and California originate in the Columbia River, as apparent abundance of populations spawning to the south of the Columbia River have suffered severe declines. However, eulachon off California, Oregon, and Washington represent only a portion of the Columbia River eulachon subpopulation. Triennial groundfish trawl surveys conducted off the U.S. West Coast in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002) indicate that 80 to 90% of all the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 4, and Figure 19), where eulachon are believed to be largely a mixture of Columbia River and Fraser River subpopulations (Beacham et al. 2005, DFO 2009d).

Genetic analyses of this stock mixture "indicated that there are continued stock proportions of approximately 60:40 Columbia:Fraser in these areas" (DFO 2009d, p. 14). The genetic composition of eulachon off northern California, Oregon, and Washington has not been studied, and it is not known whether eulachon ocean migratory patterns may be specific to certain genetically differentiated stocks, as has been shown for certain Chinook (Myers et al. 1998, Weitkamp 2010) and coho (Weitkamp and Neely 2002) salmon ESUs. Why some eulachon juveniles turn north and some turn south as they exit the Columbia River mouth is unknown, but if there is a genetic or stock specific component to this behavior, then threats to the smaller segment of the subpopulation that occurs south of the Columbia River would be of even greater concern.

As shown above, it is likely that the majority of eulachon originating in the Columbia River are subject to bycatch in the West Coast Vancouver Island shrimp trawl fishery. Offshore of west coast Vancouver Island, most eulachon occur in SMAs 23OFF, 21OFF, 124OFF, and 125OFF (Figure 21). According to DFO (2009c, p. 8) recent effort and shrimp catch are down, due to low demand for pink shrimp since "no machine peelers were operating in BC." Thus in SMAs 124OFF and 125OFF offshore of west coast Vancouver Island, where encounters with eulachon are high, "no shrimp trawl fishing occurred in … 2004 and very little effort has occurred in 2005, 2006, 2007, and 2008" (DFO 2009c, p. 11). The combination of reduced effort and required BRD use may be partly why the 1% eulachon action level has not been reached since the year 2000. The current 1% eulachon action level is 20 mt for SMAs 124OFF and 125OFF and 7.5 mt for the combination of SMAs 23OFF, 21OFF, and 23IN (DFO 2009a, p. 10) (Figure 21).

A recent workshop to determine research priorities for eulachon in Canada examined many hypotheses concerning threats to eulachon in British Columbia and concluded that eulachon bycatch in shrimp trawl fisheries was "potentially an important contributing factor in reducing recovery, along with temperature/food/hake, other harvest, but of uncertain or unknown magnitude" (Pickard and Marmorek 2007, p. 36). Hay and McCarter (2000) stated that "Although the shrimp trawl industry probably has not caused the recent decline in eulachons, we cannot rule out the possibility that it could be a factor in limiting the recovery of certain stocks."

**Collateral BRD mortality**

Although data on survivability of BRDs by small pelagic fishes such as eulachon are scarce, many studies on other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14). Results of several studies have shown a direct relationship between length and survival of fish escaping trawl nets, either with or without deflecting grids (Sangster et al. 1996, Suuronen et al. 1996, Ingólfsson et al. 2007), indicating that smaller fish with their poorer swimming ability and endurance may be more likely to suffer greater injury and stress during their escape from trawl gear than larger fish (Broadhurst et al. 2006, Ingólfsson et al. 2007). A recent workshop (Pickard and Marmorek 2007, p. 31–33) to determine research priorities for eulachon in Canada recommended the need to research the effectiveness of BRDs and the need to estimate mortality, not just bycatch. It is difficult to evaluate the true effectiveness of BRDs in a fishery without knowing the survival rate of fish that are deflected by the BRD and escape the trawl net (Broadhurst 2000, Suuronen 2005, Broadhurst et al. 2006).

**Nonindigenous species**

Potential impacts and risks of nonindigenous aquatic species to native fish species include increased predation, increased competition for habitats and food, alteration of food webs, and transmission of new diseases and parasites (ISAB 2008). The negative impact of nonindigenous species is recognized as one of the leading factors causing imperilment of native North American freshwater aquatic species (Lassuy 1995, ISAB 2008) and was listed as a factor leading to the extinction of 40 North America fish species and subspecies, representing a full 68% of those lost over the past 100 years (Miller et al. 1989). NRC (2004) reported that 17 nonindigenous fish species inhabit the lower Klamath River basin, but their impact on eulachon has not been studied. Schade and Bonar (2005) estimated that the percent of total fish species that are nonnative in streams in California, Oregon and Washington, were 39.6%, 24.5%, and 18.4%, respectively.

Systma et al. (2004, p. 50) surveyed the lower Columbia River for nonindigenous species at 134 stations between 2001 and 2004 and found that:

> Of the 269 species identified, 54 (21%) were introduced, 92 (34%) were native, and 123 (45%) were cryptogenic [origin unknown]. … Over the past 10 years, a new [nonindigenous] invertebrate species was discovered about every 5 months [in the lower Columbia River].

By contrast, the rate of discovery of nonindigenous fish species in the lower Columbia River peaked in the 1950s (Systma et al. 2004). The Systma et al. (2004) survey identified 33 nonindigenous fish species in the lower Columbia River. Similarly, Pickard and Marmorek (2007, p. 41) stated that "Invasive, nonnative fish (carp, largemouth bass, crappie, catfish) have been increasing in the lower Fraser River." ISAB (2008) and Sanderson et al. (2009) recently documented the risks posed by nonindigenous species to native salmonids in the Columbia River basin and the Pacific Northwest, respectively. There is evidence that nonnative striped bass (*Morone saxatilis*) ate substantial numbers of adult eulachon in the Umpqua River when eulachon were abundant in that river in the late 1960s to early 1980s (see Umpqua River newspaper articles in Appendix B).

Bottom et al. (2005, p. xxii) examined the potential impacts of three prominent nonindigenous species on the lower Columbia River and stated that:

> Significant changes in the modern estuarine community through species introductions have not been assessed. However, the Asian clam, *Corbicula fluminea*, has expanded far into the lower mainstem reservoirs and tributary basins since its introduction into the estuary in 1938. *Pseudodiaptomus inopinus,* a calanoid copepod also introduced from Asia, has appeared prominently in the estuary since 1980, and American shad (*Alosa sapidissima*) has grown to a substantial population in the Columbia River since its introduction in 1885–1886. Fifteen other nonindigenous fishes are now common in the estuary. The specific impacts on the estuarine ecosystem … from any of these populations are speculative. However, given the tremendous abundance of *C. fluminea* and American shad (peak Bonneville Dam passage counts of $3 \times 10^6$), it is not unreasonable to expect that their consumption rates may have significantly modified the estuarine food web.

Cordell et al. (2008) documented the presence of several additional Asian copepods in the lower Columbia River and found that the calanoid copepod *P. inopinus* has largely been replaced by other Asian species, particularly *P. forbesi*. How these ongoing invasions of nonindigenous zooplanketers, mediated by ballast water exchange of large ships, will affect the estuarine food web is unknown, although the lower Columbia River may eventually come to resemble the San Francisco estuary, which "now has an East Asian copepod fauna" (Cordell et al. 2008).

## Qualitative Threats Assessment

Although the question of how a DPS came to be at risk is important, a population or DPS that has been reduced to low abundance will continue to be at risk for demographic and genetic reasons until it reaches a larger size, regardless of the reasons for its initial decline. Furthermore, in some cases, a factor that was important in causing the original declines may no longer be an impediment to recovery. Unlike some ESA-listed species that face a single primary threat, eulachon face numerous potential threats throughout every stage of their life cycle. It is therefore relatively easy to simply list current and past potential threats to eulachon populations, but it is much more difficult to evaluate the relative importance of a wide range of interacting factors. The BRT also recognized that evaluating the degree to which factors for decline will continue to pose a threat generally requires consideration of issues that are more in the realm of social science than biological science—such as whether proposed changes will be funded, and, if funded, will be implemented effectively.

Nevertheless, the potential role that various threats have played in the decline of the southern DPS of eulachon was examined by the BRT in light of the question posed by the Northwest Region's Draft BRT Eulachon Instructions, articulated as follows:

> In [your] evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document your consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence.

The potential roles that 16 current threats may play in the decline of the southern DPS of eulachon were ranked according to severity in the Klamath, Columbia, and Fraser rivers and in that portion of the DPS along the mainland coast of British Columbia (Table 14 through Table 18). Also noted is the ESA factor for decline within which each threat falls (Table 14). The results of the BRT's analysis of the severity of threats to eulachon are presented in Table 15 through Table 18 in rank order from most severe to least severe for each geographical subset as determined by the mean BRT threat scores. Also presented in these tables are the standard deviation about the mean threat scores, the modal score, the range of scores, and the number of BRT members scoring the threat.

The BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon in all four subareas of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subareas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats. In most categories, some portion of the BRT felt that insufficient data were available to score the threat severity (thereby marking the threat severity as unknown) as indicated by the number of BRT members voting (column N) in Table 15 through Table 18.

Table 14. Example worksheet for analysis of the severity of current threats to the southern DPS of eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. Insufficient data to score the threat severity is indicated by “u” for unknown. Threats that are not applicable to the area are indicated by NA. Threats are grouped within the four statutory listing factors: 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; and 4) other natural or man-made factors affecting its continued existence.

| **River basin** | **Dams/water diversions** | **Dredging** | **Shoreline construction** | **Climate change impacts on ocean conditions** | **Climate change impacts on freshwater habitat** | **Water quality** | **Catastrophic events** | **Commercial harvest** | **Recreational harvest** | **Tribal/First Nations fisheries** | **Scientific monitoring** | **Disease** | **Predation** | **Competition** | **Eulachon bycatch** | **Nonindegenous species** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Klamath River | | NA | | | | | | NA | | | NA | | | | | |
| Columbia River | | | | | | | | | | | | | | | | |
| Fraser River | | | | | | | | | | | | | | | | |
| British Columbia coast | | | | | | | | NA | | | | | | | | |
| | Listing factor 1) The present or threatened destruction, modification, or curtailment of habitat or range | | | | | | | Listing factor 2) Over-utilization for commercial, recreational, scientific, or educational purposes | | | | Listing factor 3) Disease or predation | | Listing factor 4) Other natural or man-made factors | | |

Table 15. Results of qualitative ranking by the eulachon BRT of severity of threats for Klamath River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.2 | 0.6 | 4 | 3–5 | 10 |
| Dams/water diversions | 3.4 | 0.9 | 3 | 2–5 | 8 |
| Eulachon bycatch | 3.3 | 0.7 | 3 | 2–4 | 9 |
| Climate change impacts on freshwater habitat | 3.3 | 0.7 | 3 | 2–4 | 10 |
| Predation | 2.7 | 0.9 | 3 | 1–4 | 9 |
| Water quality | 2.5 | 1.1 | 3 | 1–4 | 10 |
| Catastrophic events | 2.3 | 1.8 | 1 | 1–5 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Shoreline construction | 1.9 | 1.1 | 1 | 1–4 | 9 |
| Tribal/First Nations fisheries | 1.7 | 0.8 | 1 | 1–3 | 10 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Recreational harvest | 1.4 | 0.9 | 1 | 1–3 | 9 |

Table 16. Results of qualitative ranking by the eulachon BRT of severity of threats for Columbia River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.3 | 0.7 | 4 | 3–5 | 10 |
| Eulachon bycatch | 3.8 | 0.7 | 4 | 3–5 | 9 |
| Climate change impacts on freshwater habitat | 3.4 | 0.5 | 3 | 3–4 | 10 |
| Dams/water diversions | 3.3 | 1.1 | 3 | 2–5 | 9 |
| Water quality | 3.0 | 0.7 | 3 | 2–4 | 10 |
| Dredging | 2.9 | 0.6 | 3 | 2–4 | 9 |
| Predation | 2.9 | 0.8 | 3 | 1–4 | 9 |
| Catastrophic events | 2.8 | 1.5 | 2 | 1–5 | 8 |
| Commercial harvest | 2.5 | 1.0 | 2 | 1–4 | 10 |
| Shoreline construction | 2.4 | 1.0 | 3 | 1–4 | 9 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Recreational harvest | 1.8 | 0.8 | 2 | 1–3 | 10 |
| Tribal/First Nations fisheries | 1.7 | 0.8 | 1 | 1–3 | 10 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 10 |

Table 17. Results of qualitative ranking by the eulachon BRT of severity of threats for Fraser River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.1 | 0.6 | 4 | 3–5 | 9 |
| Eulachon bycatch | 3.7 | 0.7 | 3 | 3–5 | 9 |
| Predation | 3.1 | 0.4 | 3 | 3–4 | 8 |
| Climate change impacts on freshwater habitat | 3.1 | 0.6 | 3 | 2–4 | 9 |
| Water quality | 2.7 | 0.7 | 3 | 2–4 | 9 |
| Commercial harvest | 2.7 | 0.9 | 2 | 2–4 | 9 |
| Dredging | 2.6 | 0.7 | 2 | 2–4 | 8 |
| Dams/water diversions | 2.5 | 1.6 | 1 | 1–5 | 6 |
| Shoreline construction | 2.3 | 1.0 | 3 | 1–4 | 9 |
| Catastrophic events | 2.3 | 1.8 | 1 | 1–5 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Tribal/First Nations fisheries | 1.8 | 0.8 | 1 | 1–3 | 9 |
| Recreational harvest | 1.7 | 0.9 | 1 | 1–3 | 9 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 9 |

Table 18. Results of qualitative ranking by the eulachon BRT of severity of threats for eulachon in mainland British Columbia Rivers south of the Nass River. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.1 | 0.6 | 4 | 3–5 | 9 |
| Eulachon bycatch | 3.6 | 0.9 | 4 | 2–5 | 9 |
| Predation | 3.1 | 0.4 | 3 | 3–4 | 8 |
| Climate change impacts on freshwater habitat | 2.9 | 1.2 | 3 | 1–4 | 9 |
| Catastrophic events | 2.4 | 1.7 | 2 | 1–5 | 8 |
| Shoreline construction | 2.3 | 0.9 | 2 | 1–4 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Water quality | 2.1 | 1.0 | 2 | 1–4 | 8 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Tribal First Nations fisheries | 1.9 | 0.8 | 2 | 1–3 | 9 |
| Dam/water diversions | 1.8 | 1.2 | 1 | 1–4 | 6 |
| Dredging | 1.7 | 1.0 | 1 | 1–4 | 9 |
| Nonindigenous species | 1.5 | 0.8 | 1 | 1–3 | 6 |
| Recreational harvest | 1.4 | 0.9 | 1 | 1–3 | 9 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 9 |

# Overall Risk Determination

The BRT's determination of overall risk to the species used these categories: at high risk of extinction, at moderate risk of extinction, or not at risk of extinction. Table 19 describes these qualitative reference levels of extinction risk. Quantitative and qualitative conservation assessments for other species have often used a 100-year time frame in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000), and the BRT adopted this time scale as the period over which it had confidence in evaluating risk. The overall extinction risk determination reflected informed professional judgment by each BRT member. This assessment was guided by the results of the risk matrix analysis, integrating information about demographic risks with expectations about likely interactions with threats and other factors.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the BRT adopted the likelihood point method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under the Northwest Forest Plan (FEMAT 1993). Table 20 is an example worksheet and results. In this approach, each BRT member distributes 10 likelihood points among the 3 species extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status. Thus if a member were certain that the species was in the not at risk category, he or she could assign all 10 points to that category. A reviewer with less certainty about the species' status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999, as well as in reviews of Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), and black abalone (VanBlaricom et al. 2009).

# Summary of Risk Conclusions for the Southern DPS of Eulachon

The BRT's scores for overall risk to the southern DPS of eulachon, throughout all of its range, were heavily weighted to moderate risk with this category receiving 60% of the likelihood points. High risk received 32% of the likelihood points and not at risk received 8% of the points. The BRT was concerned that, although eulachon are a relatively poorly monitored species, most of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. The BRT was particularly concerned that two large spawning populations—in the Columbia and Fraser rivers—have declined to what appear to be historically low levels in the Fraser River and nearly so in the Columbia River. Overall risk scores for abundance ranged from 4 to 5 (see Table 13).

The BRT was concerned that there is very little monitoring data available for northern California eulachon, but determined that the available information suggests that eulachon in northern California experienced an abrupt decline several decades ago. The BRT was also concerned that recent attempts to estimate actual spawner abundance in some rivers in British Columbia that are known to have supported significant First Nations fisheries in the past have resulted in very low estimates of spawning stock. The BRT was also concerned that the current sizes of central and north coast British Columbia eulachon populations appear inconsistent with

Table 19. Description of reference levels for the BRT's assessment of the species' or DPS extinction risk.

| | Qualitative reference levels of relative extinction risk |
|---|---|
| ↑ Continuum of decreasing relative risk of extinction | 1). Moderate risk: A species or DPS is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to be at a high level of extinction risk (see description of high risk below). A species/DPS may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or DPS is more likely than not to be at high risk depends on various case-specific and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or DPS (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. Please explain the time scale over which the BRT has confidence in evaluating moderate risk.<br><br>2. High risk: A species or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, or diversity that place its persistence in question. The demographics of a species/DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species/DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create such imminent demographic risks. |
| Extinct | A species or DPS is extinct when there is no longer a living representative. |

the ethnographic literature that describes an extensive grease trading network based on eulachon catch (discussed by Hay, 2002, p. 103).

In addition, the BRT was concerned that the current abundance of the many individual populations within the DPS may be sufficiently low to be an additional risk factor, even for populations (such as the Columbia and Fraser) where the absolute population size seems large compared to many other at-risk fish populations. Indeed, the BRT considered a central question in this status review to be whether a DPS or subpopulation may be at risk of extinction when there may be hundreds of thousands or perhaps millions of individuals remaining in the population. In evaluating this issue, the BRT concluded that eulachon (and other similar forage fishes) (see Dulvy et al. 2004) may be at significant risk at population sizes that are a fraction of their historical levels but are still large compared to what would be considered normal for other ESA listed species (see above discussion in the Absolute Numbers subsection).

Of relevance to this issue are recent reviews of extinction risk in marine fishes illustrating that forage fish are not immune to risk of extirpation at the population scale (Dulvy et al. 2003, Reynolds et al. 2005). Hutchings (2000, 2001a, 2001b) and others (Dulvy et al. 2003, Mace and

Table 20. Example worksheet and results of the evaluation of the overall level of extinction risk for the southern DPS of eulachon using the likelihood point method (FEMAT 1993).

| | **Overall extinction risk category**[a] | | |
|---|---|---|---|
| | **Not at risk** | **Moderate risk** | **High risk** |
| Number of likelihood points[b] | 8 | 60 | 32 |
| *Comments*: | | | |

[a]These evaluations do not consider protective efforts, and therefore are not recommendations regarding ESA listing status.
[b]Each BRT member distributes 10 likelihood points among the 3 overall extinction risk categories. Placement of all 10 points in a given risk category reflect 100% certainty that level of risk reflects the true level of extinction risk for the species. Distributing points between risk categories reflects uncertainty in whether a given category reflects the true species status.

Hudson 1999, Hutchings and Reynolds 2004) cite empirical analyses indicating that marine fishes likely have similar extinction probabilities to those of nonmarine taxa. A number of inshore populations of Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*) have either been extirpated or have not shown signs of recovery from depletions that are unprecedented in the historic record (Smedbol and Stevenson 2001). An example involves the disappearance of the Icelandic spring-spawning population of Atlantic herring (Beverton 1990), whose last known census population size in 1972 was 700,000 (Dulvy et al. 2004).

The BRT believes that high eulachon MVP sizes are necessary 1) to ensure that a critical threshold density of adult eulachon are available during breeding events for maintenance of normal reproductive processes, 2) to produce enough offspring to counteract high in-river egg and larval mortality and planktonic larval mortality in the ocean, and 3) to produce enough offspring to buffer against the action of local environmental conditions which may lead to random sweepstake recruitment events, where only a small minority of spawning individuals contribute to subsequent generations. In species with this life history pattern, the genetically effective population size can be several orders of magnitude lower than the census size (Hedgecock 1994, ICES 2004), and minimum viable census sizes may therefore be on the order of 50,000 to 500,000 (Dulvy et al. 2004). The BRT was concerned that in a number of subareas of the DPS (Klamath, Fraser, and Bella Coola rivers, Rivers Inlet, etc.), population sizes of eulachon are below what would be considered MVP sizes for highly fecund species.

The BRT noted that variable year-class strength in marine fishes with pelagic larvae is dependent on survival of larvae prior to recruitment and is driven by match-mismatch of larvae and their planktonic food supply (Hjort 1914, Lasker 1975, Sinclair and Tremblay 1984), oceanographic transport mechanisms (Parrish et al. 1981), variable environmental ocean conditions (Shepherd et al. 1984, McFarlane et al. 2000), and predation (Bailey and Houde 1989). The operation of these dynamic ocean conditions and their impacts on eulachon recruitment were amply illustrated in the Columbia River population where high larval densities were observed in 2000–2003, followed by lower than average adult returns in 2004, 2005, and 2006 (JCRMS 2007).

Failure to time spawning activity with river conditions conducive to successful fertilization and egg survival, and to the appearance of larval prey species in the oceanic environment, also contribute to high rates of environmentally driven egg and larval mortality. The BRT was concerned that there is evidence that climate change is leading to relatively rapid changes in both oceanic and freshwater environmental conditions that eulachon are unable to tolerate. Eulachon are basically a cold-water species adapted to feed on a northern suite of copepods in the ocean during the critical transition period from larvae to juvenile and much of their recent recruitment failure may be traced to mortality during this critical period. However, there have been recent shifts in the suite of copepod species available to eulachon that favor a more southerly species assemblage (Mackas et al. 2001, 2007, Hooff and Peterson 2006) and the BRT was concerned that climate change may be contributing to a mismatch between eulachon life history and prey species. It is also likely that pelagic fish with their shorter life cycles may be less resilient to long-term climatic changes than longer-lived demersal species.

However, the ability of the Columbia River eulachon stock to respond rapidly to the good ocean conditions of the late 1999–early 2002 period illustrates the species' resiliency, and the BRT viewed this resiliency as providing the species with a buffer against future environmental perturbations. The productivity potential or intrinsic rate of increase of eulachon (Musick et al. 2000) as indicated by life history characteristics such as low age-at-maturity, small body size, and planktonic larvae was recognized by the BRT as likely conferring eulachon with some resilience to extinction as they retain the ability to rapidly respond to favorable ocean conditions. However, the BRT was concerned that there is no empirical or theoretical grounds to conclude that high fecundity as a life history character confers resilience on a fish species in comparison to a species with lower fecundity (Sadovy 2001, Reynolds et al. 2005).

Overall, the BRT's risk scores for growth rate and productivity of the DPS ranged from 2 to 5 with a mean score of 3 (Table 13). Recent ocean conditions in the California Current Province in the fall of 2007 and spring-summer of 2008 were considered favorable for eulachon (PDO data online at http://jisao.washington.edu/pdo/ and http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/b-latest-updates.cfm), and the BRT postulated that this may indicate elevated eulachon returns may be expected starting with the 2011 run year. However, the BRT was concerned that these changes in the ocean, favorable to eulachon larval survival, may be of short-term duration, similar to the late 1998-early 2002 period.

In terms of threats related to diversity, the BRT was concerned that not only are eulachon semelparous (spawn once and die) but if recent estimates of age structure in eulachon are correct (Clarke et al. 2007), then spawning adults—particularly in southern areas such as the Columbia and Fraser rivers—may be limited to a single age class, which likely increases their vulnerability to perturbations and provides less of a buffer against year-class failure than species such as herring that spawn repeatedly and have variable ages at maturity.

The BRT was also concerned about the apparently very low abundance of the Klamath River subpopulation, which might be expected to have unique adaptations to conditions at the southernmost extent of the range, and about the potential loss of biocomplexity in Fraser River eulachon due to contraction of spawning locations, as documented by Higgins et al. (1987). The BRT noted some positive signs including observations that eulachon continue to display variation in spawn timing, age-at-maturity, and spawning locations and a high degree of biocomplexity (i.e., many spawning locations and spawn-timing variation) in Columbia River eulachon, which may buffer this stock from freshwater environmental perturbations. Overall, the BRT risk scores for diversity of the DPS ranged from 2 to 3 with a mean score of 2.6 (Table 13).

The BRT also had concerns about risks related to spatial structure and distribution. In particular, because the major spawning populations within the DPS appear to have declined substantially, the BRT was concerned that if some formerly significant populations, such as in the Klamath River, become extirpated, there will be less opportunity for successful recolonization. In addition, the apparent decline of populations in northern California may result in contraction of the southern portion of the DPS's range. The BRT also noted that several populations that used to support significant First Nations fisheries on the British Columbia coast have declined to very low levels (e.g., Bella Coola and Wannock rivers). Positive signs for spatial structure and connectivity noted by the BRT include considerations that eulachon appear to have the potential to recolonize given their apparent ability to stray from the natal spawning area, at least within rivers sharing the same estuary. In addition, the perceived historical spatial structure of the DPS, with the possible exception of the Klamath River, remains intact. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 (Table 13).

The BRT noted several recent events that appear likely to impact eulachon. Global patterns suggest the long-term trend is for a warmer, less-productive ocean regime in the California Current and the Transitional Pacific. The recent decline in abundance or relative abundance of eulachon in many systems coupled with the probable disruption of metapopulation structure may make it more difficult for eulachon to adapt to warming ocean conditions. In addition, warming conditions have allowed both Pacific hake (Phillips et al. 2007) and Pacific sardine (Emmett et al. 2005) to expand their distributions to the north, increasing predation on eulachon by Pacific hake and competition for food resources by both species. The recent and ongoing expansion of large numbers of jumbo squid into waters off Oregon, Washington, and British Columbia are also likely to have a significant impact on eulachon; however, ecosystem impacts of jumbo squid are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). Recent invasions of Asian copepods into the Columbia River estuary (Cordell et al. 2008) may have a negative influence on the Columbia River population. However, cold ocean conditions in spring 2008 suggest that this may have been a good year for eulachon recruitment. The effects of these recent positive and negative events are difficult to estimate; most members indicated that the net effect is likely to be negative.

## Significant Portion of Its Range Question

The BRT concluded that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range and in effect answered the question in the affirmative as to whether the southern DPS of eulachon is at risk throughout a significant portion of its range.

# Glossary

**adipose fin.** A fin without a bone or cartilage, located behind the dorsal fin.

**ADFG.** For *Alaska Department of Fish and Game*. Department that manages certain fisheries in the State of Alaska.

**AFSC.** For *Alaska Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**Allee effect.** The circumstance of reduced population growth occurring at low population size. This can result from the impact of low spawner density on fertilization success or some other vital reproductive function.

**allele.** An alternative form of a gene that can occur at the same location (locus) on homologous (paired) chromosomes. A population can have many alleles for a particular locus, but an individual can carry no more than two alleles at a diploid locus.

**anadromous.** Species that spend their adult lives in the ocean but move into freshwater streams to reproduce or spawn (e.g., salmon).

**anthropogenic.** Caused or produced by human action.

**ATU.** For *accumulated thermal unit*. An ATU is a measurement that describes the accumulation of heat over time. One ATU is equal to one degree Celsius for one day. In water of 10°C, an organism would accumulate 10 ATUs per day.

**BRD**. For *bycatch reduction device*.

**BRT.** For *Biological Review Team*. The team of scientists who evaluates scientific information considered in a National Marine Fisheries Service status review.

**bycatch.** Animals caught by fishing that were not the intended target of the fishing activity. Such unwanted catch is often wasted. Both discarded and retained species can be considered bycatch.

**CDFG.** For *California Department of Fish and Game*. Department that comanages certain fisheries in the State of California.

**comanagers.** Federal, state, and tribal agencies that cooperatively manage fish in the Pacific Northwest.

**CPUE.** For *catch per unit effort*. A measure of the density or population size of an animal that is targeted by fishing. Large CPUEs indicate large populations, since many individuals are caught for every unit of fishing effort.

**DFO.** For *Department of Fisheries and Oceans Canada*. Department that manages fisheries in Canada.

**DDT.** For *dichlorodiphenyltrichloroethane* and its metabolites, including *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD, *o,p'*-DDE, and *o,p'*-DDT. These are banned organochlorine pesticides that were used to control insects that harm crops, as well as malaria-carrying mosquitoes. DDTs are still used in some parts of the world to control mosquitoes.

**DPS.** For *distinct population segment*. A DPS is a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. The Endangered Species Act provides for listing species, subspecies, or distinct population segments of vertebrate species.

**DNA.** For *deoxyribonucleic acid***.** DNA is a complex molecule that carries an organism's heritable information. DNA consists of a polysugar-phosphate backbone from which the bases (nucleotides) project. DNA forms a double helix that is held together by hydrogen bonds between specific base pairs (thymine to adenine, guanine to cytosine). Each strand in the double helix is complementary to its partner strand in terms of its base sequence. The two types of DNA commonly used to examine genetic variation are *mitochondrial DNA* (mtDNA), a circular molecule that is maternally inherited, and microsatellite (nuclear) DNA, which is organized into a set of chromosomes. See also **allele, microsatellite DNA, mitochondrial DNA**.

**endangered species.** A species in danger of extinction throughout all or a significant portion of its range, with respect to the Endangered Species Act. See also **ESA, threatened species**.

**effective population size (Ne).** The number of reproducing individuals in an ideal population that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration. Typically, Ne is less than either a population's total number of sexually mature adults present or the total number of adults that reproduced. Effective population can be defined in terms of the amount of increase in homozygosity (inbreeding effective number) or the amount of allele frequency drift (variance effective number).

**ENSO.** For *El Niño-Southern Oscillation*. Pattern of climate variability most clearly defined by year-to-year variations in sea surface temperature in the tropical equatorial Pacific Ocean in the zone extending from the South American coast to slightly west of the international date line.

**ESA.** For U.S. *Endangered Species Act* of 1973. Passed by Congress, it provides a means whereby the ecosystem on which threatened and endangered species depend may be conserved.

**estuary.** A semienclosed body of water having connections to the ocean at the downstream end and freshwater streams at the upstream end. Water in estuaries thus tends to be at an intermediate and variable salinity and temperature.

**ESU.** For *evolutionarily significant unit*. An ESU represents a distinct population segment of Pacific salmon under the Endangered Species Act that 1) is substantially reproductively isolated from nonspecific populations, and 2) represents an important component of the evolutionary legacy of the species.

**fecundity.** The potential reproductive capacity of an organism or population, measured by the number of gametes (eggs).

**FEMAT**. For *Forest Ecosystem Management Assessment Team*.

**FL.** For *fork length*. Length in millimeters from the tip of the snout to the center of the fork in the tail or caudal fin. Compare **SL** and **TL.**

**genetic distance.** A quantitative measure of genetic difference between a pair of samples.

**haplotype.** The collective genotype of a number of closely linked loci; the constellation of alleles present at a particular region of genomic or mitochondrial DNA.

**INPFC.** For *International North Pacific Fisheries Commission*.

**ISAB**. For *Independent Scientific Advisory Board*.

**IUCN.** For *International Union for the Conservation of Nature*. The full, legal name of the organization is the International Union for Conservation of Nature and Natural Resources. Online at http://www.iucn.org.

**iteroparous.** Said of an organism that reproduces several or many times during a lifetime. Compare **semelparous**.

**JCRMS**. For *Joint Columbia River Management Staff*. A joint undertaking of the Washington Department of Fish and Wildlife and the Oregon Department of Fish and Wildlife.

**$LC_{50}$.** The lethal concentration of a chemical or substance that kills 50% of the test organisms in a given time period, normally 96 hours for aquatic organisms.

**LCFRB.** For *Lower Columbia Fish Recovery Board*.

**meristic trait.** A discretely varying and countable trait (e.g., number of fin rays or basibranchial teeth).

**metapopulation.** An assembly of closely related subpopulations (usually spatially fragmented) that were established by colonists, survive for a while, send out migrants, and eventually disappear. The persistence of a subpopulation depends on the rate of colonization successfully balancing the local extinction rate.

**microsatellite DNA.** A class of repetitive DNA. Microsatellites are simple sequence repeats one to eight nucleotides in length. For example, the repeat unit can be simply "CA" and might exist in a tandem array (CACACACACA) 50 or more repeat units in length. The number of repeats in an array can be highly polymorphic. See also **DNA**.

**mitochondrial DNA.** The DNA genome contained within mitochondria and encoding a small subset of mitochondrial functions; mtDNA is typically circular and 15–20 kilobases in size, containing little noncoding information between genes. See also **DNA**.

**morphometric trait.** A discretely varying trait related to the size and shape of landmarks from whole organs or organisms analyzed by appropriately invariant biometric methods in order to answer biological questions.

**MVP.** For *minimum viable population*.

**NMFS**. For *National Marine Fisheries Service*. Also known as NOAA Fisheries Service

**NWFSC.** For *Northwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**ODFW.** For *Oregon Department of Fish and Wildlife*. Department that comanages certain fisheries in the State of Oregon.

**otolith.** Crystalline calcium carbonate structure within the inner ear of fish. These structures have distinctive shapes, sizes, and internal and surface features that can be used for age determination and species identification.

**ppb.** For *parts per billion*. A unit of chemical concentration.

**ppm.** For *parts per million*. A unit of chemical concentration.

**ppt.** For *parts per thousand*. A unit of chemical concentration.

**PDO.** For *Pacific Interdecadal Oscillation*. A long-term pattern of North Pacific climate variability. PDO events persist for 20–30 years, while typical El Niño events persist for 6 to 18 months. The climatic indicators of the PDO are most visible in the North Pacific region.

**phenotypic.** Pertaining to the appearance (or other measurable characteristic) of an organism that results from interaction of the genotype and environment.

**PCB.** For *polychlorinated biphenyl*. Persistent contaminants of aquatic sediments and biota that are very widespread. Commercial formulations of PCBs are mixtures of individual chlorinated biphenyls (congeners) varying according to the numbers of chlorines and their ring positions on the biphenyl. Prior to the 1975 congressional ban on PCB manufacture, various mixtures of some 209 individual PCBs were used extensively in electrical transformers, capacitors, paints, waxes, inks, dust control agents, paper, and pesticides.

**PAH.** For *polycyclic aromatic hydrocarbon***.** PAHs are widely distributed throughout the marine environment and commonly occur in sediments in urban coastal and estuarine areas. Sources include crude oil, petroleum products, and residues from combustion of fossil fuels. They are composed of fused benzene rings, with or without alkyl substituents (e.g., methyl groups).

**population.** A group of individuals of a species living in a certain area that maintain some degree of reproductive isolation.

**Puget Sound.** A coastal fjord-like estuarine inlet of the Pacific Ocean located in northwest Washington State between the Cascade and Olympic mountains and covering an area of more than 9,000 $km^2$ including 3,700 km of coastline.

**semelparous.** Said of an organism that reproduces but once during its lifetime. Compare **iteroparous**.

**SL.** For *standard length***.** Length in millimeters from the tip of the snout to the base of the caudal peduncle. Compare **FL** and **TL**.

**SMA**. For *shrimp management area*.

**SWFSC.** For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**species.** Biological: A small group of organisms formally recognized by the scientific community as distinct from other groups. Legal: Refers to joint policy of the USFWS and NMFS that considers a species as defined by the ESA to include biological species, subspecies, and DPSs.

**SRS**. For *sediment retention structure*.

**Strait of Georgia.** A strait between Vancouver Island and the mainland Pacific coast of British Columbia. It is approximately 220 km long, averages 35 km wide, and has a surface area of approximately 6,900 $km^2$. Archipelagos and narrow channels mark each end of the Strait of Georgia, including the Gulf Islands and San Juan Islands in the south and the Discovery Islands in the north. The main channels to the south are Haro Strait and Rosario Strait, which connect the Strait of Georgia to the Strait of Juan de Fuca. In the north, Discovery Passage is the main channel connecting the Strait of Georgia to Johnstone Strait.

**SWFSC.** For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**threatened species.** A species not presently in danger of extinction but likely to become so in the foreseeable future, with respect to the Endangered Species Act. See also **endangered species, ESA**.

**TL.** For *total length*. Length in millimeters from the tip of the snout to the tip of the farthest lobe of the tail or caudal fin. Compare **FL** and **SL**.

**trophic.** Pertaining to nutrition. A trophic migration would be a movement of fish to a feeding area.

**USACE**. For *U.S. Army Corps of Engineers*.

**USFWS.** For *U.S. Fish and Wildlife Service*.

**viable salmonid population.** An independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a long time frame (McElhany et al. 2000).

**WDFW.** For *Washington Department of Fish and Wildlife***.** Department that comanages certain fisheries in Washington State. The agency was formed in the early 1990s by combining the Washington Department of Fisheries and Washington Department of Wildlife.

# References


Acuna, E., P. Goddard, and S. Kotwicki (compilers). 2003. 2002 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2003-01. Online at http://www.afsc.noaa .gov/Publications/ProcRpt/PR%202003-01.pdf [accessed 23 February 2010].

Acuna, E., and S. Kotwicki (compilers). 2004. 2003 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2004-02. Online at http://www.afsc.noaa.gov/ Publications/ProcRpt/PR%202004-02.pdf [accessed 23 February 2010].

Acuna, E., and S. Kotwicki (compilers). 2006. 2004 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2006-09. Online at http://www.afsc.noaa.gov/ Publications/ProcRpt/PR%202006-09.pdf [accessed 23 February 2010].

Acuna, E., and R. R. Lauth. 2008. Results of the 2007 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-181. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-181.pdf [accessed 23 February 2010].

ADFG (Alaska Dept. Fish and Game). 1972. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 13:53–54, 66–71 [as cited in Spangler et al. 2003].

ADFG (Alaska Dept. Fish and Game). 1973. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 14:53–54, 66–71 [as cited in Spangler et al. 2003].

ADFG (Alaska Dept. Fish and Game). 1974. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 15:161–162, 170–172 [as cited in Spangler et al. 2003].

Alcan. 2005. Alcan Primary Metal–British Columbia Environmental Annual Report 2004. Online at http://www.riotintoalcaninbc.com/environmental-reports/2004/index.html [accessed 23 February 2010].

Alcan. 2006. Alcan Primary Metal–British Columbia Environmental Annual Report 2005. Online at http://www.riotintoalcaninbc.com/media/reports/2005%20Alcan%20EAR.pdf [accessed 23 February 2010].

Alcan. 2007. Alcan Primary Metal–British Columbia Annual Environmental Report 2006. Online at http://www.riotintoalcaninbc.com/media/reports/2006%20AER%205.1.pdf [accessed 23 February 2010].

Alheit, J., and E. Hagen. 1997. Long-term climate forcing of European herring and sardine populations. Fish. Oceanogr. 6:130–139.

Allen, L. G., M. M. Yoklavich, G. M. Cailliet, and M. H. Horn. 2006. Bays and estuaries. *In* L. G. Allen, D. J. Pondella, and M. H. Horn (eds.), The ecology of marine fishes: California and adjacent waters, p. 119–148. University of California Press, Berkeley.

Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dept. Commer., NOAA Tech. Rep. NMFS 66.

Alton, M. S., and M. O. Nelson. 1970. Food of Pacific hake, *Merluccius productus*, in Washington and northern Oregon coastal waters. *In* Pacific hake, p. 35–42. U.S. Fish and Wildlife Service Circ. 332.

Anchor Environmental. 2003. Fish periodicity in WRIA 1. Anchor Environmental LLC, Seattle, WA. Online at http://whatcomsalmon.whatcomcounty.org/pdf/fishperiodicity_january2003.pdf [accessed 23 February 2010].

Anderson, A. C. 1872. The dominion at the west: A brief description of the province of British Columbia, its climate, and resources. The government prize essay, 1872. Richard Wolfenden, Government Printer, Victoria, BC.

Anderson, A. C. 1877. Report of the Inspector of Fisheries for British Columbia for the year of 1876. Appendix No. 21. *In* Report of the Commissioner of Fisheries for the year ending 31st December 1876, p. 339–347. MacLean, Roger & Co., Ottawa, ON.

Anderson, P. 2009. Letter from P. Anderson (Interim Director, Washington Dept. Fish and Wildlife) to G. Griffin (Protected Resources Division, NMFS Northwest Region) dated 12 May 2009. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Anthony, J. A., D. D. Roby, and K. R. Turco. 2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. J. Exp. Mar. Biol. Ecol. 248:53–78.

Antonelis Jr., G. A., and C. H. Fiscus. 1980. The pinnipeds of the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 21:68–78.

Antonelis Jr., G. A., and M. A. Perez. 1984. Estimated annual food consumption by northern fur seals in the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 25:135–145.

Arai, H. P. 1967. A preliminary report on a study of the parasites of marine fishes of Burke Channel, British Columbia. Fish. Res. Board Can. Manuscr. Rep. Ser. 925.

Arai, H. P. 1969. Preliminary report on the parasites of certain marine fishes of British Columbia. Bull. Fish. Res. Board Can. 26:2319–2337.

Armstrong, R. H., and M. Hermans. 2007. Eulachon (*Thaleichthys pacificus*). Coastal forests and mountains ecoregions of Southeastern Alaska and the Tongass National Forest: A conservation assessment and resource synthesis–Chapter 8.9. Online at conserveonline.org/workspaces/akcfm/pdfs/8.9_Eulachon.pdf [accessed 23 February 2010].

Atkinson, D. 1994. Temperature and organism size—A biological law for ectotherms? Adv. Ecol. Res. 25:1–58.

Auth, T. B., and R. D. Brodeur. 2006. Distribution and community structure of ichthyoplankton off the coast of Oregon, USA, in 2000 and 2002. Mar. Ecol. Prog. Ser. 319:199–213.

Avise, J. C., J. Arnold, R. M. Ball, E. Bermingham, T. Lamb, J. E. Neigel, C. A. Reeb, and N. C. Saunders. 1987. Intraspecific phylogeography: The mitochondrial DNA bridge between population genetics and systematics. Annu. Rev. Ecol. Syst. 18:489–522.

Babcock, J. P. 1927. The food value of some British Columbia fish. *In* Report of the Commissioner of Fisheries for the year ended December 31st, 1926, with appendices, p. E72–E75. Charles F, Banfield, Printer to the King's Most Excellent Majesty, Victoria, BC.

Bailey, B. E. 1952. Marine oils, with special reference to those of Canada. Bull. Fish. Res. Board Can. 89.

Bailey, K. M., and E. D. Houde. 1989. Predation on eggs and larvae of marine fishes and the recruitment problem. Adv. Mar. Bio. 25:1–83.

Bakun, A. 1990. Global climate change and intensification of coastal upwelling. Science 247:198–201.

Bargmann, G., J. DeVore, and B. Tweit. 2005. Risk-averse management of eulachon in the Columbia River system. Fisheries assessment and management in data-limited situations, p. 21–29. Rep. AK-SG-05-02. Alaska Sea Grant College Program, Fairbanks.

Barnhart, R. A., M. J. Boyd, and J. E. Pequegnat. 1992. The ecology of Humboldt Bay, California: An estuarine profile. U.S. Fish and Wildlife Service Biol. Rep. No. 1.

Barraclough, W. E. 1964. Contribution to the marine life history of the eulachon *Thaleichthys pacificus*. Bull. Fish. Res. Board Can. 21:1333–1337.

Barraclough, W. E. 1967. Data record. Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 6–8, 1966. Bull. Fish. Res. Board Can. Manuscr. Rep. Ser. 928.

Barraclough, W. E., and J. D. Fulton. 1967. Data record. Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, July 4–8, 1966. Bull. Fish. Res. Board Can. Manuscr. Rep. Ser. 940.

Barrett, B. M., F. M. Thompson, and S. N. Wick. 1984. Adult anadromous investigations: May-October 1983. Alaska Dept. Fish and Game, Susitna Hydro Aquatic Studies., Rep. No. 1, Alaska Power Authority document 1450 [excerpts published in Willson et al. 2006, p. 63–66].

Barry, R. G. 2006. The status of research on glaciers and global glacier recession: A review. Prog. Phys. Geog. 30:285–306.

Barth, J. A., B. A. Menge, J. Lubchenco, F. Chan, J. M. Bane, A. R. Kirincich, M. A. McManus, K. J. Nielsen, S. D. Pierce, and L. Washburn. 2007. Delayed upwelling alters nearshore coastal ocean ecosystems in the northern California Current. Proc. Natl. Acad. Sci. USA 194:3719–3724.

Bath, G. E., S. R. Thorrold, C. M. Jones, S. E. Campana, J. W. McLaren, and J. H. W. Lam. 2000. Strontium and barium uptake in aragonitic otoliths of marine fish. Geochim. Cosmochim. Acta 64:1705–1714.

Baumgartner, T. R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. Calif. Coop. Ocean. Fish. Investig. Rep. 33:24-40.

BC Ministry of Sustainable Resource Management. 2002. British Columbia marine ecological classification: Marine ecosections and ecounits, Version 2.0. Province of British Columbia, Resources Information Standards Committee. Online at http://ilmbwww.gov.bc.ca/risc/pubs/coastal/marine/version%202/bcmec_version_2.pdf [accessed 23 February 2010].

Beach, R. J., A. C. Geiger, S. J. Jeffries, and S. D. Treacy. 1981. Marine mammal-fishery interactions on the Columbia River and adjacent waters, 1981. NWAFC Processed Rep. 82-04. NWAFC, Seattle, WA.

Beach, R. J., A. C. Geiger, S. J. Jeffries, S. D. Treacy, and B. L. Troutman. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980–82. NWAFC Processed Rep. 85-04. Seattle, WA

Beacham, T. D., D. E. Hay, and K. D. Le. 2005. Population structure and stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt, in the Pacific Northwest. Mar. Biotechnol. 7:363–372.

Beacham, T. D., J. F. Schweigert, C. MacConnachie, K. D. Le, K. Labaree, and K. M. Miller. 2002. Population structure of herring (*Clupea pallassi*) in British Columbia determined by microsatellites, with comparisons to Southeast Alaska and California. Dept. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat. Research Document 2002/109. Online at http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/2002/2002_109_e.htm [accessed 23 February 2010].

Beamish, R. J., J. R. King, and G. A. McFarlane. 2008. Country reports, Canada. *In* R. J. Beamish, (ed.), Impacts of climate and climate change on the key species in the fisheries in the North Pacific, p. 15–51. PICES Working Group on Climate Change Shifts in Fish Production and Fisheries Management. PICES Scientific Report No. 35. Online at http://www.pices.int/publications/scientific_reports/Report35/Rep_35_default.aspx [accessed 23 February 2010].

Beamish, R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112:735–743.

Begg, G. A., J. A. Hare, and D. D. Sheehan. 1999. The role of life history parameters as indicators of stock structure. Fish. Res. 43:141–163.

Bellman, M., E. Heery, and J. Hastie. 2008. Estimated discard and total catch of selected groundfish species in the 2007 U. S. West Coast fisheries. Pacific States Marine Fisheries Commission and Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division, Seattle, WA. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/totalmortality2007.pdf [accessed 23 February 2010].

Benson, A. J., G. A. McFarlane, S. E. Allen, and J. F. Dower. 2002. Changes in Pacific hake (*Merluccius productus*) migration patterns and juvenile growth related to the 1989 regime shift. Can. J. Fish. Aquat. Sci. 59:1969–1979.

Berry, M. D., and W. Jacob. 1998. 1997 eulachon research on the Kingcome and Wannock rivers–Final rep. Final rep. to Science Council of British Columbia (SCBC #96/97-715). Online at http://www.for.gov.bc.ca/hfd/library/FRBC1997/FRBC1997MR206.PDF [accessed 23 February 2010].

Betts, M. F. 1994. The subsistence hooligan fishery of the Chilkat and Chilkoot rivers. Tech. Paper No. 213. Alaska Dept. Fish and Game, Division of Subsistence, Juneau.

Beverton, R. J. H. 1990. Small pelagic fish and the threat of fishing; are they endangered? J. Fish Biol. 37(Suppl. A):5–16.

Bigg, M. A. 1988. Status of the Steller sea lion, *Eumetopias jubatus*, in Canada. Can. Field Nat. 102:315–336.

Birtwell, I. K., C. D. Levings, J. S. Macdonald, and I. H. Rogers. 1988. A review of fish habitat issues in the Fraser River system. Water Pollut. Res. J. Can. 23:1–30.

Blahm, T. H., and McConnell, R. J. 1971. Mortality of adult eulachon (*Thaleichthys pacificus*) subjected to sudden increases in water temperature. Northwest Sci. 45:178–82.

Blaylock, R. B., L. Margolis, and J. C. Holmes. 1998. Zoogeography of the parasites of Pacific halibut (*Hippoglossus stenolepis*) in the northeast Pacific. Can. J. Zool. 76:2262–2273.

Bond, G., W. Broecker, S. Johnson, J. McManus, L. Labeyrie, J. Jouzel, and G. Bonani. 1993. Correlation between climate records from North Atlantic sediments and Greenland ice. Nature 365: 143-147.

Borgerson, L. A., N. E. Stewart, K. K. Jones, and S. R. Mamoyac. 1991. Yaquina River Basin Management Plan. Oregon Dept. Fish and Wildlife, Salem.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-68.

Bowlby, C. E. 1981. Feeding behavior of pinnipeds in the Klamath River, northern California. Master's thesis. Humboldt State Univ., Arcata, CA.

Boyd, R. T., and Y. P. Hajda. 1987. Seasonal population movement along the lower Columbia River: The social and ecological context. Am. Ethnol. 14:309–326.

Brennan, B. M. 1936. Forty-second to forty-fifth annual reports of the State Department of Fisheries for the period from April 1, 1931 to March 31, 1935, fiscal years of 1931 to 1934, inclusive. Washington Dept. Fisheries, Olympia.

Briggs, J. C. 1974. Marine zoogeography. McGraw-Hill, New York.

British Columbia Conservation Data Centre. 2008. BC species and ecosystems explorer. BC Ministry of Environment, Victoria. Online at http://a100.gov.bc.ca/pub/eswp/ [accessed 23 February 2010].

Broadhurst, M. K. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. Revs. Fish Biol. Fish. 10:27–60.

Broadhurst, M. K., P. Suuronen, and A. Hulme. 2006. Estimating collateral mortality from towed fishing gear. Fish Fish. 7:180–218.

Brocklesby, H. N. 1941. The chemistry and technology of marine animal oils with particular reference to those of Canada. Bull. Fish. Res. Board Can. 59.

Brocklesby, H. N., and O. F. Denstedt. 1933. The industrial chemistry of fish oils with special reference to those of British Columbia. Bull. Fish. Res. Board Can. 37.

Brodeur, R. D., C. L. Suchman, D. C. Reese, T. W. Miller, and E. A. Daly. 2008. Spatial overlap and trophic interactions between pelagic fish and large jellyfish in the northern California Current. Mar. Biol. 154:649–659.

Brown, R. F., S. J. Jeffries, and J. T. Harvey. 1989. Seasonal abundance and winter feeding ecology of harbor seals in the Columbia River. *In* Abstracts 8th biennial conference on the biology of marine mammals, Pacific Grove, CA, 7–11 December 1989, p. 9, Society for Marine Mammalogy. The society's Web site is http://marinemammalscience.org/ [accessed 10 May 2010].

Brown, R. F., S. D. Riemer, and S. J. Jeffries. 1995. Food of pinnipeds collected during the Columbia River area salmon gillnet observation program, 1991–1994. Wildlife Diversity Program Tech. Rep. 95-6-01. Oregon Dept. Fish and Wildlife, Salem.

BRT (Biological Review Team). 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. December 15 draft. NMFS Northwest Fisheries Science Center, Seattle, WA. Online at http://www.nwr.noaa.gov/Other-Marine-Species/upload/Eulachon-Review.pdf [accessed 18 March 2009].

Buchheister, A., and M. T. Wilson. 2005. Shrinkage correction and length conversion equations for *Theragra chalcogramma*, *Mallotus villosus,* and *Thaleichthys pacificus*. J. Fish Biol. 67:541–548.

Buckley, T. W., and P. A. Livingston. 1997. Geographic variation in the diet of Pacific hake, with a note on cannibalism. Calif. Coop. Ocean. Fish. Investig. Rep. 38:53–62.

Buckley, T. W., G. E. Tyler, D. M. Smith, and P. A. Livingston. 1999. Food habits of some commercially important groundfish off the coasts of California, Oregon, Washington, and British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-102. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-102.pdf [accessed 23 February 2010].

Builder Ramsey, T., T. A. Turk, E. L. Fruh, J. R. Wallace, B. H. Horness, A. J. Cook, K. L. Bosley, D. J. Kamikawa, L. C. Hufnagle Jr., and K. Piner. 2002. The 1999 Northwest Fisheries Science Center Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-55. Online at http://www.nwfsc.noaa.gov/assets/25/4277_06162004_130254_tm55.pdf [accessed 23 February 2010].

Burroughs, R. D. 1961. The natural history of the Lewis and Clark expedition. Michigan State University Press, Lansing.

Byram, S., and D. G. Lewis. 2001. Ourigan: Wealth of the Northwest Coast. Ore. Hist. Quart. 102:127–157.

Cambria Gordon Ltd. 2006. Eulachon of the Pacific Northwest: A life history. Living Landscapes Program, Royal BC Museum. Online at http://www.livinglandscapes.bc.ca/northwest/eulachon/resources/lifehisreport.pdf [accessed 23 February 2010].

Canadian Bureau of Statistics. 1941. Fisheries Statistics of Canada, 1917–1941. Canada Dept. Trade and Commerce, Dominion Bureau of Statistics, Fisheries Statistics Branch. Printer to the King's Most Excellent Majesty, Ottawa, ON.

Carls, M. G., S. W. Johnson, M. R. Lindeberg, A. D. Neff, P. M. Harris, and R. Waples. 2008. Status review of Lynn Canal herring (*Clupea pallasii*). Online at http://www.fakr.noaa.gov/protectedresources/herring/statusrev0308.pdf [accessed 22 February 2010].

Carvan III, M. J., J. P. Incardona, and M. L. Rise. 2008. Meeting the challenges of aquatic vertebrate ecotoxicology. Bioscience 58:1015–1025.

Caughley, G. 1994. Directions in conservation biology. J. Anim. Ecol. 63:215–244.

Caughley, G., and A. Gunn. 1996. Conservation biology in theory and practice. Blackwell Science, Cambridge, MA.

CDFG (California Dept. Fish and Game). 2008. Letter dated 13 June 2008 to Peter B. Adams, Southwest Fisheries Science Center, from Steve Cannata, California Dept. Fish and Game. Subject: Eulachon data search. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Chan, H. M., M. El Khoury, M. Sedgemore, S. Sedgemore, and H. V. Kuhnlein. 1996. Organochlorine pesticides and polychlorinated biphenyl congeners in ooligan grease: A traditional food fat of British Columbia First Nations. J. Food Compos. Anal. 9:32–42.

Chatwin, B. M., and C. R. Forrester. 1953. Feeding habits of dogfish (*Squalus suckleyi* (Girard)). Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 95:35–38.

Chen, L. 1971. Systematics, variation, distribution, and biology of rockfishes of the subgenus *Sebastomus* (Pisces, Scorpaenidae, Sebastes). Bull. Scripps Inst. Oceanogr. Univ. Calif. 18:1–107.

Clanton, R. E. 1913. Biennial report of the Department of Fisheries of the State of Oregon to the Twenty-seventh Legislative Assembly, regular session, 1913. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Clark, E. D., and R. W. Clough. 1926. Chemical composition of fish and shellfish. Bureau of Fisheries document No. 1000. *In* H. R. Beard (ed.), Nutritive value of fish and shellfish, p. 502–526. Report of the U. S. Commissioner of Fisheries for the fiscal year 1925, Appendix X.

Clarke, A. D., A. Lewis, and K. H. Telmer. 2007. Life history and age at maturity of an anadromous smelt, the eulachon *Thaleichthys pacificus* (Richardson). J. Fish Biol. 71:1479–1493.

Cleaver, F. C. 1951. Fisheries statistics of Oregon. Oregon Fish Commission contribution No. 16. Oregon Fish Commission, Portland.

Clemens, W. A., J. L. Hart, and G. V. Wilby. 1936. Analysis of stomach contents of fur seals taken off the west coast of Vancouver Island in April and May, 1935. Stud. Sta. Biol. Bd. Can. 160. DFO, Ottawa, ON.

Clemens, W. A., and G. V. Wilby. 1946. Fishes of the Pacific Coast of Canada. Bull. Fish. Res. Board Can. 68.

Clemens, W. A., and G. V. Wilby. 1967. Fishes of the Pacific coast of Canada. Bull. Fish. Res. Board Can. 68 (2nd printing of 2nd edition).

Codere, H. 1990. Kwakiutl: Traditional culture. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 359–377. Smithsonian Institution, Washington, DC.

Coleman, B. A. 1986. The 1980 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length, and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-100. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc100.pdf [accessed 23 February 2010].

Coleman, B. A. 1988. The 1986 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-152. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc152.pdf [accessed 23 February 2010].

Collins, J. W. 1892. Report on the fisheries of the Pacific coast of the United States. Rep. U.S. Comm. Fish and Fisheries XVI, Appendix 1:3–269. U.S. Government Printing Office, Washington, DC.

Collison, H. A. 1941. The oolichan fishery. B.C. Hist. Q. 5(1):25–31.

Cooke, K. D., J. Holmes, G. W. Fleischer, R. E. Thomas, and P. H. Ressler. 2006. Distributional changes observed in the geographic range of Pacific hake (*Merluccius productus*) in association with ocean conditions off the Pacific coast of Canada and the United States. ICES 2005 Annual Science Conference Products. Online at http://www.ices.dk/asc2006/Abstracts/Blist.pdf [accessed 23 February 2010].

Cooper, A. B., and M. S. Mangel. 1999. The dangers of undetected metapopulation structure for the conservation of salmonids. Fish. Bull. 97:213–226.

Cordell, J. R., S. M. Bollens, R. Draheim, and M. Sytsma. 2008. Asian copepods on the move: Recent invasions in the Columbia-Snake River system, USA. ICES J. Mar. Sci. 65:753–758.

Cowlitz Indian Tribe. 2007. Petition to list the southern eulachon (*Thaleichthys pacificus*) distinct population segment as threatened or endangered under the federal Endangered Species Act, 9 November 2007. Cowlitz Indian Tribe, Longview, WA. Online at http://www.nwr.noaa .gov/Other-Marine-Species/upload/Smelt_Petition_11_07.pdf [accessed 23 February 2010].

Craig, J. A. 1947. Letter dated 11 August 1947 from Joe A. Craig, acting director, Washington Dept. Fisheries, to Gordon M. Quarnstrom, editor, Longview Daily News, Longview, WA. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Craig, J. A., and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bull. U.S. Bur. Fish. 49:132–216.

Craig, J. A., and A. J. Suomela. 1940. A survey of the Sandy River and its tributaries, 1940, with reference to fish management. Special Scientific Rep. No. 14. U.S. Fish and Wildlife Service, Washington, DC.

Crawford, J. 1890. First report of the State Fish Commissioner, State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1892. Third annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1894. Fifth annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1896. Seventh annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, P. W. 1878 (unpubl. manuscr.). Narrative of the overland journey to Oregon. Microfilm A92, Univ. Washington, Suzzalo Library, Seattle (original in Bancroft Library, Univ. California Berkeley).

Crawford, W., J. Galbraith, and J. N. Bolingbroke. 2007. Line P ocean temperature and salinity, 1956–2005. Progr. Oceanogr.75:161–178.

Cummings, E., and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Coastal Rivers Investigation Information Rep. 70-11. Fish Commission of Oregon, Research Division, Corvallis.

Curtis, E. S. 1915. The North American Indian, Vol. 10. Johnson Reprint Corp., New York. Online at http://curtis.library.northwestern.edu/ [accessed 24 February 2010].

Dammers, W. 1988. Columbia River smelt commercial harvest, age, and larval sampling. Memo from Wolf Dammers to Don McIsaac ,Washington Dept. Fisheries, 28 January 1988. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd, Suite 1100, Portland, OR 97232.)

Darwin, L. H. 1917. Twenty-sixth and twenty-seventh annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1915, to 31 March 1917. Washington Dept. Fish and Game, Olympia.

Darwin, L. H. 1920. Twenty-eighth and twenty-ninth annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1917, to 31 March 1919. Washington Dept. Fish and Game, Olympia.

Darwin, L. H. 1921. Thirtieth and thirty-first annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1919, to 31 March 1921. Washington Dept. Fish and Game, Olympia.

DeLacy, A. C., and B. S. Batts. 1963. Possible population heterogeneity in the Columbia River smelt. Fisheries Research Institute Circular No. 198. Univ. Washington, College of Fisheries, Seattle.

DeLacy, A. C., B. S. Miller, and S. F. Borton. 1972. Checklist of Puget Sound Fishes. WSG 72-3. Univ. Washington, Washington Sea Grant, Division of Marine Resources, Seattle.

Deschamps, G., S. G. Wright, and R. E. Watson. 1970. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964–1966, p. 1–55. Tech. Rep. No.7. Washington Dept. Fisheries, Olympia.

DFO (Dept. Fisheries and Oceans Canada). 2006a. Fraser River eulachon (*Thaleichthys pacificus*): 2006 population assessment and harvest recommendations for 2007. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/039. Online at http://www.dfo-mpo.gc.ca/csas/Csas/status/2006/SAR-AS2006_039_E.pdf [accessed 10 May 2010].

DFO (Dept. Fisheries and Oceans Canada). 2006b. State of the Pacific Ocean 2005. Ocean Status Rep. 2006/001. DFO Canada, Pacific Region. Online at http://www.pac.dfo-mpo.gc.ca/science/psarc-ceesp/osrs/StateofOceans2005fnl.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2007a. Fraser River eulachon (*Thaleichthys pacificus*): 2007 population assessment and harvest recommendations for 2008. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/048. Online at http://www.dfo-mpo.gc.ca/csas/Csas/status/2007/SAR-AS2007_048_e.pdf [accessed 10 May 2010].

DFO (Dept. Fisheries and Oceans Canada). 2007b. Integrated fisheries management plan euphausiids, 1 January 2007 to 31 December 2012. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans07/Krill07-12.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008a. Eulachon integrated fisheries management plan, 1 April 2008 to 31 March 2009. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans08/2008_IFMP-Eulachon.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008b. Shrimp survey bulletin 08-02, July 2008. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008c. Overview of the eulachon fishery. Pelagics & Minor Finfish-Pacific Region. Online at http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/pelagic-pelagique/eulachon-eulakane/overview-apercu-eng.htm [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008d. Predicting the temperature of the Fraser River, climate change conditions. Online at http://www-sci.pac.dfo-mpo.gc.ca/osap/projects/fraser/climate_e.htm [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009a. Shrimp survey bulletin 09-01, July 2009. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009b. Shrimp survey bulletin 09-02, July 2009. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009c. Integrated fisheries management plan shrimp trawl, 1 April 2009 to 31 March 2010. DFO Canada, Pacific Region. Online at http://www.dfo-mpo.gc .ca/Library/336240.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009d. Eulachon integrated fisheries management plan, 1 April 2009 to 31 March 2010. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans09/IFMP_Eulachon_2009.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009e. State of the Pacific Ocean 2008. Canadian Science Advisory Secretariat Science Advisory Rep. 2009/030. DFO Canada, Pacific Region. Online at http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2009/2009_030_e.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009f. 2009-2011 British Columbia tidal waters sport fishing guide. Online at http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/SFG-GPS/SFGtidal-GPSmaree-eng.pdf [accessed 23 February 2010].

DFO and Transport Canada. 2008. Comprehensive study scoping document pursuant to Section 21(1) of the Canadian Environmental Assessment Act for the Klinaklini River Hydroelectric Project proposed by Kleana Power Corporation in south-central coast of British Columbia. CEA Registry Reference No.: 07-03-36321. Online at http://a100.gov.bc.ca/appsdata/epic/documents/p289/1210953739414_8e248a8d30d90ddfeb0b46a94c6ea47bd9c755f2db90.pdf [accessed 23 February 2010].

Diffenbaugh, N. S., M. A. Snyder, and L. C. Sloan. 2004. Could $CO_2$-induced land-cover feedbacks alter near-shore upwelling regimes? Proc. Natl. Acad. Sc. USA 101:27–32.

Dodimead, A. J., F. Favorite, and T. Hirano. 1963. Salmon of the North Pacific Ocean–Part II. Review of oceanography of the subarctic Pacific region. Int. North Pac. Fish. Comm. Bull. 13.

Doyle, M. J., K. L. Mier, M. S. Busby, and R. D. Brodeur. 2002. Regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean. Prog. Oceanogr. 53:247–281.

Duff, W. 1952. The upper Stalo Indians: An introductory ethnography. Master's thesis. Univ. Washington, Seattle.

Dulvy, N. K., J. R. Ellis, N. B. Goodwin, A. Grant, J. D. Reynolds, and S. Jennings. 2004. Methods of assessing extinction risk in marine fishes. Fish Fish. 5:255–276.

Dulvy, N. K., Y. Sadovy, and J. D. Reynolds. 2003. Extinction vulnerability in marine populations. Fish Fish. 4:25–64.

EcoMetrix (EcoMetrix Inc.). 2006. Summary of 2006 eulachon study results and 2007 study design. Report prepared for Eurocan Pulp and Paper Co., Kitimat, BC. EcoMetrix Inc., Brampton, ON.

Eggen, R. I., R. Behra, P. Burkhardt-Holm, B. I. Escher, and N. Schweigert. 2004. Challenges in ecotoxicology. Environ. Sci. Technol. 38:58A–64A.

Ekman, S. 1953. Zoogeography of the sea. Sidgwick and Jackson Ltd., London.

Eldridge, M. B., and C. F. Bryan. 1972. Larval fish survey of Humboldt Bay, California. U.S. Dept. Commer., NOAA Tech. Rep. NMFS-SSRF-665.

Eller, A., and N. Hillgruber. 2005. Eulachon larvae *(Thaleichthys pacificus)* retention in the surface waters of Berners Bay, Alaska [abstract]. American Fisheries Society, 135th Annual Meeting, Anchorage, AK, Sept. 2005. American Fisheries Society, Bethesda, MD.

Emmett, R. L., P. J. Bentley, and G. K. Krutzikowsky. 2001. Ecology of marine predatory and prey fishes off the Columbia River, 1998 and 1999. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-51. Online at http://www.nwfsc.noaa.gov/assets/25/4015_06162004_141153_tm51.pdf [accessed 23 February 2010].

Emmett R. L., R. D. Brodeur, T. W. Miller, S. S. Pool, G. K. Krutzikowsky, P. J. Bentley, and J. McCrae. 2005. Pacific sardine (*Sardinops sagax*) abundance, distribution, and ecological relationships in the Pacific Northwest. Calif. Coop. Ocean. Fish. Investig. Rep. 46:122–143.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, Vol. II: Species life history summaries. ELMR Rep. 8. U.S. Dept. of Commer., NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Emmett, R. L., G. T. McCabe Jr., and W. D. Muir. 1990. Effects of the 1980 Mount St. Helens eruption on Columbia River estuarine fishes: Implications for dredging in Northwest estuaries. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes, p. 74–91. Workshop proceedings, Sept. 8–9, 1988. Univ. Washington, Sea Grant Program, Seattle.

Environment Canada. 2008. A national ecological framework for Canada. Online at http://sis.agr.gc.ca/cansis/nsdb/ecostrat/intro.html [accessed 23 February 2010].

EPA (U.S. Environmental Protection Agency). 2002. Columbia River basin fish contaminant survey 1996–1998. EPA 910-R-02-006. EPA, Region 10, Seattle, WA. Online at http://yosemite.epa.gov/r10/oea.nsf/0703bc6b0c5525b088256bdc0076fc44/c3a9164ed269353788256c09005d36b7/$FILE/Fish%20Study.PDF [accessed 23 February 2010].

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Forest Service, BLM, USFWS, NOAA, EPA, and National Park Service, Portland, OR.

Fiedler, R. H. 1930. Fishery industries of the United States, 1928. Bureau of Fisheries document No. 1067. Appendix IX (p. 401–625) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1929 with appendixes. U.S. Government Printing Office, Washington, DC.

Fiedler, R. H. 1939. Fishery industries of the United States, 1936. Administrative Rep. No. 27. Appendix I (p. 1–276) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1937 with appendixes. U.S. Government Printing Office, Washington, DC.

Fiedler, R. H. 1941. Fishery industries of the United States, 1938. Administrative Rep. No. 37. Appendix III (p. 169–554) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1939 with appendixes. U.S. Government Printing Office, Washington, DC.

Field, J. C., K. Baltz, A. J. Phillips, and W. A. Walker. 2007. Range expansion and trophic interactions of the jumbo squid, *Dosidicus gigas*, in the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 48:131–146.

Fisher, H. D. 1947. The harbour seals (*Phoca vitulina richardii*) on the Skeena River, B.C. Fish. Res. Board Can. Progress Reports of the Pacific Coast Stations 72:36–40.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bull. Fish. Res. Board Can. 93.

Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, L. C. Hufnagle, A. R. Kronlund, J. A. Holmes, and C. D. Wilson. 2005. The 2003 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-65. Online at http://www.nwfsc.noaa .gov/assets/25/6233_06272005_114457_haketm65final.pdf [accessed 23 February 2010].

Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, and L. C. Hufnagle. 2008. The 2005 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-94. Online at http://www.nwfsc.noaa.gov/assets/25/6835_11062008_165201 _Hake2005SurveyTM94Final.pdf [accessed 23 February 2010].

Flory, E. 2008a. Biological assessment/biological evaluation threatened, endangered, and Forest Service sensitive listed wildlife species. Cascade Point, Berners Bay Barge Ramp Permit Application, Supplemental Information, Attachment 8. Aquatic Science Inc., Juneau, AK. Online at http:// www.juneau.org/plancomm/documents/Attachment8.PDF [accessed 22 February 2010].

Flory, E. 2008b. Eulachon distribution in the Taku River, Juneau, Alaska, 2008. Aquatic Science Inc., Juneau. Online at http://dnr.alaska.gov/mlw/mining/largemine/tulsequah/pdf2/eulachon2tuls.pdf [accessed 22 February 2010].

Foley, P. 1997. Extinction models for local populations. *In*: I. Hanski and M. E. Gilpin (eds.), Metapopulation biology, p. 215–246. Academic Press, New York.

Foreman, M. G. G., D. K. Lee, J. Morrison, S. Macdonald, D. Barnes, and I. V. Williams. 2001. Simulations and retrospective analyses of Fraser watershed flows and temperatures. Atmos. Ocean 39:89–105.

Franchère, G. 1967. Adventure at Astoria, 1810–1814 [edited and translated by H. C. Franchère]. University of Oklahoma Press, Norman.

Franchère, G. 1968. A voyage to the northwest coast of America, M. M. Quaife (ed.). The Citadel Press, New York.

Franchère, G. 1969. The Journal of Gabriel Franchère, 1811–1814. The Champlain Society, Toronto, ON.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fish. Oceanogr. 7:1–21.

Franzel, J., and K. A. Nelson. 1981. Stikine River eulachon (*Thaleichthys pacificus*). U.S. Forest Service, Petersburg Ranger District, Petersburg, AK. Abstract reprinted in Willson et al. 2006, AFSC Processed Report 2006-12, p. 100–101.

FREMP (Fraser River Estuary Management Program). 2006. Environmental management strategy for dredging in the Fraser River estuary. Burrard Inlet Environmental Action Program and Fraser River Estuary Management Program. Online at http://bieapfremp.org/fremp/pdf_files/Environmental%20Management%20Strategy%20for%20Dredging%20FINAL%20FINAL.pdf [accessed 22 February 2010].

FREMP (Fraser River Estuary Management Program). 2007. Sediment budget and dredging activities annual report for the fiscal year 1 April 2006 to 31 March 2007. Fraser River Estuary Management Program. Online at http://bieapfremp.org/fremp/pdf_files/Dredging%20AR%202006-2007%20FINAL%20Jan%2008.pdf [accessed 19 February 2010].

Frimodig, A. 2008. Informational report: Bycatch reduction devices used in the pink shrimp trawl fishery. Rep. to California Fish and Game Commission. California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project. Online at http://www.dfg.ca.gov/marine/pdfs/brd_report.pdf [accessed 23 February 2010].

Frimodig, A., M. Horeczko, T. Mason, B. Owens, M. Prall, and S. Wertz. 2007. Information concerning the pink shrimp trawl fishery off northern California. Rep. to California Fish and Game Commission, California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project. Online at http://www.dfg.ca.gov/marine/pdfs/pinkshrimp.pdf [accessed 23 February 2010].

Fry Jr., D. H. 1979. Anadromous fishes of California, California Dept. Fish and Game, Sacramento. Online at http://cdm15024.contentdm.oclc.org/cdm4/item_viewer.php?CISOROOT=/p178601ccp2&CISOPTR=103 [accessed 19 February 2010].

Gabriel, W. L., and A. V. Tyler. 1980. Preliminary analysis of Pacific coast demersal fish assemblages. Mar. Fish. Rev. 42(3–4):83–88.

Gallant, A. L., E. F. Binnian, J. W. Omernik, and M. B. Shasby. 1995. Ecoregions of Alaska. U.S. Geological Survey Prof. Pap. 1567. U.S. Government Printing Office, Washington, DC

Garrison, K. J., and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. FRI-UW-8216. Univ. Washington, Fisheries Research Institute, Seattle.

Gass, P. 1807. A journal of the voyages and travels of a Corps of Discovery, under the command of Capt. Lewis and Capt. Clark of the Army of the United States, from the mouth of the River Missouri through the interior parts of North America to the Pacific Ocean, during the years 1804, 1805, and 1806. D. McKeehan, Pittsburgh. Reprinted in 1996 as The definitive journals of Lewis and Clark, Patrick Gass. G. E. Moulton (ed.), Vol. 9 of the Nebraska edition. University of Nebraska Press, Lincoln, and in 1997 as The journals of Patrick Gass: Member of the Lewis and Clark Expedition, edited and annotated by Carol Lynn MacGregor. Mountain Press, Missoula, MT.]

Gaumer, T., D. Demory, and L. Osis. 1973. 1971 Coquille River estuary resource use study. Fish Commission of Oregon, Division of Management and Research. (Available from Oregon Dept. Fish and Wildlife, Fish Division, 3406 Cherry Ave. NE, Salem 97303.)

Gestring, K. B. 1991. Stomach contents of striped bass × white bass hybrids in the Tenmile Lake system. Oregon Dept. Fish and Wildlife Fish Division information report No. 91-1.

Gibson, D. I. 1996. Guide to the parasites of fishes of Canada, Part IV, Trematoda. Can. Spec. Publ. Fish. Aquat. Sci. No. 124.

Gilpin, M. E., and M. E. Soule. 1986. Minimum viable populations: Process of species extinctions. *In* M. E. Soule (ed.), Conservation biology: The science of scarcity and diversity, p. 19–34. Sinauer, Sunderland, MA.

Girard, G. 1858. General report upon the zoology of the several Pacific Railroad routes. Fishes. *In* Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, Pacific Railroad Rep. 10 (Pt. IV), p. 1–400.

Good, T. P., R. S. Waples, and P. Adams (eds.). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66. Online at http://www.nwfsc.noaa.gov/assets/25/6226_08302005_132955_brttechmemo66final2.pdf [accessed 23 February 2010].

Gotshall, D. W., G. H. Allen, and R. A. Barnhart. 1980. An annotated checklist of fishes from Humboldt Bay, California. Calif. Fish Game 66:220–232.

Gough, B. M. (ed.). 1992. The journal of Alexander Henry the Younger 1799–1814. Vol. II, The Saskatchewan and Columbia rivers. The Champlain Society, Toronto, ON.

Green, A. 1891. The economic fishes of British Columbia. Papers and communications read before the Natural History Society of British Columbia 1(1):20–33.

Groisman, P. Y., R. W. Knight, T. R. Karl, D. R. Easterling, B. Sun, and J. H. Lawrimore. 2004. Contemporary changes of the hydrological cycle over the contiguous United States: Trends derived from in situ observations. J. Hydrometerol. 5:64–85.

Gustafson, R. G., J. Drake, M. J. Ford, J. M. Myers, E. E. Holmes, and R. S. Waples. 2006. Status review of Cherry Point Pacific herring *(Clupea pallasii)* and updated status review of the Georgia Basin Pacific herring distinct population segment under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-76. Online at http://www.nwfsc.noaa.gov/assets/25/6539_08072006_141228_HerringTM76Final.pdf [accessed 23 February 2010].

Gustafson R. G., W. H. Lenarz, B. B. McCain, C. C. Schmitt, W. S. Grant, T. L. Builder, and R. D. Methot. 2000. Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-44. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm44/tm44.htm [accessed 23 February 2010].

Guttormsen, M. A., and P. T. Yasenak. 2007. Results of the 2003 and 2005 echo integration-trawl surveys in the Gulf of Alaska during summer, cruises MF2003-09 and OD2005-01. AFSC

Processed Rep. 2007-04. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR2007-04.pdf [accessed 23 February 2010].

Haggerty, D. R., B. McCorquodale, D. I. Johannessen, C. D. Levings, and P. S. Ross. 2003. Marine environmental quality in the central coast of British Columbia, Canada: A review of contaminant sources, types and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2507. DFO, Sidney, BC.

Hall, K. J. 1976. The quality of water in the lower Fraser River and sources of pollution. *In* A. H. J. Dorcey (ed.), The uncertain future of the lower Fraser, p. 21–46. Westwater Research Centre, University of British Columbia Press, Vancouver.

Halpin, M. M., and M. Seguin. 1990. Tsimshian, peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitskan. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 267–284. Smithsonian Institution, Washington, DC.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams—A synthesis of the historical evidence. Fisheries 30(4):10–20.

Hamlet, A. F., P. W. Mote, M. P. Clark, and D. P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. J. Climate 18:4545–4561.

Hamori-Torok, C. 1990. Haisla. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 306–311. Smithsonian Institution, Washington, DC.

Hannah, R. W., and S. A. Jones. 2003. Measuring the height of the fishing line and its effect on shrimp catch and bycatch in an ocean shrimp (*Pandalus jordani*) trawl. Fish. Res. 60:427–438.

Hannah, R. W., and S. A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (*Pandalus jordani*) trawl fishery. Fish. Res. 85:217–225.

Hannah, R., and S. Jones. 2009. 20th annual pink shrimp review. Oregon Dept. Fish Wildlife, Marine Resources Program, Newport. Online at http://www.dfw.state.or.us/MRP/publications/shrimp_newsletter2009.pdf [accessed 22 February 2010].

Hannah, R. W., S. A. Jones, and V. Hoover. 1996. Evaluation of fish excluder technology to reduce finfish bycatch in the ocean shrimp trawl fishery. ODFW Information Rep. 96-4. Oregon Dept. Fish and Wildlife, Marine Region, Newport.

Hannah, R. W., S. A. Jones, and K. M. Matteson. 2003. Observations of fish and shrimp behavior in ocean shrimp (*Pandalus jordani*) trawls. ODFW Information Rep. 2003-03. Oregon Dept. fish and Wildlife, Marine Resources Program, Newport.

Hanski, I. A., and M. E. Gilpin (eds.). 1997. Metapopulation biology. Academic Press, San Diego, CA.

Hard, J. J., J. M. Myers, M. J. Ford, R. G. Cope, G. R. Pess, R. S. Waples, G. A. Winans, B. A. Berejikian, F. W. Waknitz, P. B. Adams. P. A. Bisson, D. E. Campton, and R. R. Reisenbichler. 2007. Status review of Puget Sound steelhead *(Oncorhynchus mykiss)*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81. Online at http://www.nwfsc.noaa.gov/assets/25/6649_07312007_160715_SRSteelheadTM81Final.pdf [accessed 23 February 2010].

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaskan and west coast salmon. Fisheries 24:6–14.

Hart, J. L. 1943. Comparison of eulachon catch statistics for three years. J. Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 56:6.

Hart, J. L. 1949. Food of fish of the cod family. J. Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 79: 35–36.

Hart, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. 180.

Hart, J. L., and J. L. McHugh. 1944. The smelts (Osmeridae) of British Columbia. J. Fish. Res. Board Can. 64.

Hauser, L., and G. R. Carvalho. 2008. Paradigm shifts in marine fisheries genetics: Ugly hypotheses slain by beautiful facts. Fish Fish. 9:333–362.

Hawthorn, H. B., Belshaw, C. S., and S. M. Jamieson. 1960. The Indians of British Columbia. A study of contemporary social adjustment. University of Toronto Press, ON.

Hay, D. E. 1996. Coastal pelagics—Herring and eulachon. *In* Can. Tech. Rep. Fish. Aquat. Sci. 2108, Proceedings, Marine Ecosystem Monitoring Network—1995 March, p. 33–36. DFO, Nanaimo, BC.

Hay, D. 2002. The eulachon in Northern British Columbia. *In* T. Pitcher, M. Vasconcellos, S. Heymans, C. Brignall, and N. Haggan (eds.), Information supporting past and present ecosystem models of Northern British Columbia and the Newfoundland Shelf, p. 98–107. Fisheries Centre Research Reports, Vol. 10 No. 1. Univ. British Columbia, Fisheries Centre, Vancouver.

Hay, D. 2007. Eulachons-biological review. Presentation at the Feb. 2007 Workshop to Determine Research Priorities for Eulachon. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/2007eulawkshp_ch.pdf [accessed 23 February 2010].

Hay, D. E., and T. D. Beacham. 2005. Stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt in the eastern Pacific. Paper presented at ICES 2005 Annual Science Conference, Aberdeen, Scotland, UK. Online at http://www.ices.dk/products/CMdocs/2005/K/K1405.pdf [accessed 23 February 2010].

Hay, D. E., R. Harbo, J. Boutillier, E. Wylie, L. Convey, and P. B. McCarter. 1999a. Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Canadian Stock Assessment Secretariat research document 1999/179. DFO, Ottawa, ON.

Hay, D. E., R. Harbo, K. Southey, J. E. Clarke, G. Parker, and P. B. McCarter. 1999b. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch, with emphasis on eulachons. Canadian Stock Assessment Secretariat research document 99/26. DFO, Ottawa, ON.

Hay, D. E., and McCarter, P. B. 1997. Larval distribution, abundance, and stock structure of British Columbia herring. J. Fish Biol. 51(suppl. A):155–175.

Hay, D. E., and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Canadian Stock Assessment Secretariat research document 2000-145. DFO, Ottawa, ON. Online at http://www.dfo-mpo.gc.ca/csas/csas/DocREC/2000/PDF/2000_145e.pdf [accessed 23 February 2010].

Hay, D. E., P. B. McCarter, R. Joy, M. Thompson, and K. West. 2002. Fraser River eulachon biomass assessments and spawning distribution: 1995–2002. Canadian Science Advisory Secretariat research document 2002/117. DFO, Nanaimo, BC.

Hay, D. E., K. C. West, and A. D. Anderson. 2003. Indicators and "response" points for management of Fraser River eulachon: A comparison and discussion with recommendations. Canadian Science Advisory Secretariat research document 2003/051. DFO, Nanaimo, BC. Online at http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2003/RES2003_051_E.pdf [accessed 23 February 2010].

Hay, D. E., K. West, A. D. Anderson, and D. Rutherford. 2005. Indicators and "response" points for management of Fraser River eulachon: Protocols for managing a data-limited fishery. Fisheries Assessment and Management in Data-Limited Situations. Rep. AK-SG-05-02. Alaska Sea Grant College Program, Fairbanks.

Hedgecock, D. 1994. Does variance in reproductive success limit effective population sizes of marine organisms? *In* A. R. Beaumont (ed.), Genetics and evolution of aquatic organisms, p. 122–134. Chapman & Hall, London.

Hedgpeth, J. W. 1957. Marine biogeography. *In* J. W. Hedgpeth (ed.), Treatise on marine ecology and paleoecology, p. 359–382. Geological Society of America, Boulder, CO.

Hedrick, R. P., W. N. Batts, S. Yun, G. S. Traxler, J. Kaufman, and J. R. Winton. 2003. Host and geographic range extensions of the North American strain of viral hemorrhagic septicemia virus. Dis. Aquat. Organ. 55:211–220.

Hicks, M. 2000. Evaluating standards for protecting aquatic life in Washington's surface water quality standards: Temperature criteria (preliminary review draft discussion paper). Washington Dept. Ecology, Water Quality Program, Watershed Management Section, Olympia.

Higgins, P. S., I. K. Birtwell, B. T. Atagi, D. Chilton, M. Gang, G. M. Kruzynski, H. Mahood, G. E. Piercey, B. A. Raymond, I. H. Rogers, and S. Spohn. 1987. Some characteristics of the eulachon (*Thaleichthys pacificus*) captured in the Fraser River estuary, B.C., April 1986. Can. Manuscr. Rep. Fish. Aquat. Sci. 1913.

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proc. Natl. Acad. Sci. USA 100:6564–6568.

Hilton, S. F. 1990. Haihais, Bella Bella, and Oowekeeno. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 312–322. Smithsonian Institution, Washington, DC.

Hinck, J. E., C. J. Schmitt, T. M. Bartish, N. D. Denslow, V. S. Blazer, P. A. Anderson, J. J. Coyle, G. M. Dethloff, and D. E. Tillitt. 2004. Biomonitoring of environmental status and trends (BEST) program: Environmental contaminants and their effects on fish in the Columbia River basin. U.S. Geological Survey scientific investigations Rep. 2004-5154. USGS, Columbia, MO. Online at http://www.cerc.usgs.gov/pubs/center/pdfDocs/BEST-Columbia_River.pdf [accessed 23 February 2010].

Hinck, J. E., C. J. Schmitt, V. S. Blazer, N. D. Denslow, T. M. Bartish, P. J. Anderson, J. J. Coyle, G. M. Dethloff, and D. E. Tillitt. 2006. Environmental contaminants and biomarker responses in fish from the Columbia River and its tributaries: Spatial and temporal trends. Sci. Total Environ. 366:549–578.

Hinrichsen, R. A. 1998. The ghost run of the Cowlitz. Cowlitz Hist. Q. 40(2):5–21.

Hirch, M. 2003. Trading across time and space: Culture along the North American “grease trails” from a European perspective. Canadian Studies International Interdisciplinary Conference: Across time & space visions of Canada from abroad, Univ. College of the Cariboo, Kamloops, BC, 12–14 September 2003. Online at http://www.cwis.org/fwdp/pdf/Oolichan%20Paper%20(Mirjam).pdf [accessed 23 February 2010].

Hjort, J. 1914. Fluctuations in the great fisheries of Northern Europe. Cons. Perm. Int. Explor. Mer Rapp. P.-V. Reun. 20:1–228.

Hochachka, P. W., and G. N. Somero. 2002. Biochemical adaptation: Mechanism and process in physiological evolution. Oxford University Press, New York.

Holmes, J., K. Cooke, and G. Kronkite. 2008. Interactions between jumbo squid (*Dosidicus gigas*) and Pacific hake (*Merluccius productus*) in the northern California Current in 2007. Calif. Coop. Ocean. Fish. Investig. Rep. 49:129–141.

Hooff, R. C., and W. T. Peterson. 2006. Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California Current ecosystem. Limnol. Oceanogr. 51:2607–2620.

Hoskins, G. E., G. R. Bell, and T. P. T. Evelyn. 1976. The occurrence, distribution, and significance of infectious diseases and of neoplasms observed in fish in the Pacific Region up to the end of 1974. Fisheries and Marine Service, Tech. Rep. 609. Environment Canada, Ottawa, ON.

Hostick, G. A. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Coastal Rivers Investigation Information Rep. 74-11. Fish Commission of Oregon, Division of Management and Research, Salem.

Howell, M. D. 2001. Characterization of development in Columbia River prolarval eulachon, *Thaleichthys pacificus*, using selected morphometric characters. Washington Dept. Fish and Wildlife, Vancouver. Online at http://wdfw.wa.gov/fish/creel/smelt/USACE-20larval-20development.pdf [accessed 23 February 2010].

Howell, M. D., M. D. Romano, and T. A. Rien. 2001. Outmigration timing and distribution of larval eulachon, *Thaleichthys pacificus*, in the lower Columbia River, spring 2001. Washington Dept. Fish and Wildlife, Vancouver, and Oregon Dept. Fish and Wildlife, Clackamas.

Howell, M. D., and N. Uusitalo. 2000. Eulachon (*Thaleichthys pacificus*) studies related to lower Columbia River channel deepening operations. Washington Dept. Fish and Wildlife, Vancouver, and Oregon Dept. Fish and Wildlife, Clackamas.

Hubbs, C. L. 1925. A revision of the osmerid fishes of the North Pacific. Proc. Biol. Soc. Wash. 38:49–56.

Huntington, E. 1963. Reminiscences of Cowlitz County. Cowlitz County Hist. Q. 5(3):1–9.

Hutchings, J. A. 2000. Collapse and recovery of marine fishes. Nature 406:882–885.

Hutchings, J. A. 2001a. Conservation biology of marine fishes: Perceptions and caveats regarding assignment of extinction risk. Can. J. Fish. Aquat. Sci. 58:108–121.

Hutchings, J. A. 2001b. Influence of population decline, fishing, and spawner variability on the recovery of marine fishes. J. Fish Biol. 59(Suppl. A):306–322.

Hutchings, J. A., and J. D. Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. Bioscience 54:297–309.

Hutchinson, J. M. 1979. Seasonal distribution of fishes in Siuslaw Bay. Oregon Dept. Fish and Wildlife, Corvallis (as cited in Monaco et al. 1990).

ICES (International Council for the Exploration of the Seas). 2004. Report of the working group on the application of genetics in fisheries and mariculture. ICES CM No. 2004/F:04. ICES, Copenhagen, Denmark.

Imbrie, J., J. D. Hays, D. G. Martinson, A. McIntyre, A. C. Mix, J. J. Morley, N. G. Pisias, W. L. Prell, and N. J. Shackleton. 1984. The orbital theory of Pleistocene climate: Support from a revised chronology of the marine $\delta^{18}O$ record. *In* A. L. Berger, (ed.), Milankovitch and climate, Part 1, p. 269–305. D. Reidel, Norwell, MA.

Imler, R. H., and H. R. Sarber. 1947. Harbor seals and sea lions in Alaska. Spe. Sci. Rep. No. 28. U.S. Fish and Wildlife Service, Washington, DC.

Ingólfsson, O. A., A. V. Soldal, I. Huse, and M. Breen. 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. ICES J. Mar. Sci. 64:1836–1844.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment rep. of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York. Online at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm [accessed 23 February 2010].

Irving, W. 1868. Astoria, or, anecdotes of an enterprise beyond the Rocky Mountains. G. P. Putnam and Sons, New York.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, National Marine Fisheries Service, Portland, OR. Online at http://www.nwcouncil.org/library/isab/ISAB%202007-2%20Climate%20Change.pdf [accessed 23 February 2010].

ISAB (Independent Scientific Advisory Board). 2008. Nonnative species impacts on native salmonids in the Columbia River Basin, including recommendations for evaluating the use of non-native fish species in resident fish substitution projects. ISAB nonnative species rep., ISAB 2008-4. Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, NMFS, Portland, OR. Online at http://www.nwcouncil.org/library/isab/isab2008-4.htm [accessed 23 February 2010].

IUCN (International Union for the Conservation of Nature). 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, UK. Online at http://www.iucnredlist.org/technical-documents/categories-and-criteria [accessed 23 February 2010].

IUCN (International Union for the Conservation of Nature). 2006. Guidelines for using the IUCN Red List categories and criteria. Version 6.2. Prepared by Standards and Petitions Working Group of the IUCN SSC Biodiversity Assessments Subcommittee in December 2006. Online at http://intranet.iucn.org/webfiles/doc/SSC/RedList/RedListGuidelines.pdf [accessed 23 February 2010].

Iverson, S. J., K. J. Frost, and S. L. C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: Factors contributing to, among, and within species variability. Mar. Ecol. Prog. Ser. 241:161–181.

JCRMS (Joint Columbia River Management Staff). 2005. Joint staff report concerning commercial seasons for sturgeon and smelt in 2006. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/dec0605jointstaff.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2006. 2007 joint staff report: Stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/sturgeon_smelt07.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2007. 2008 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/crc2008_sturgeon_smelt_js_rpt.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2008. 2009 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/crc2009_sturgeon_smelt_js_rpt.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2009. 2010 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/2010_sturgeon_smelt.pdf [accessed 23 February 2010].

Jeffries, S. J. 1984. Marine mammals of the Columbia River Estuary. Final rep. on the Marine Mammals Work Unit of the Columbia River Estuary Data Development Program, Washington Department of Game, Olympia. Online at http://www.lcrep.org/pdfs/17%20MARINE %20MAMMALS%20OF%20THE%20COLUMBIA%20RIVER%20ESTUARY.pdf [accessed 23 February 2010].

Jennings, M. R. 1996. Past occurrence of eulachon, *Thaleichthys pacificus*, in streams tributary to Humboldt Bay, California. Calif. Fish Game 82(6):147–148.

Johannessen, D. I., J. S. Macdonald, K. A. Harris, and P. S. Ross. 2007a. Marine environmental quality in the Pacific North Coast Integrated Management Area (PNCIMA), British Columbia: A summary of contaminant sources, types and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2716.

Johannessen, D. I., K. A. Harris, J. S. Macdonald, and P. S. Ross. 2007b. Marine environmental quality in the north coast and Queen Charlotte Islands, British Columbia, Canada: A review of contaminant sources, types, and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2717.

Johnson, J. A., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua estuary, April 1977 through January 1986. Information Rep. 86-6. Oregon Dept. Fish and Wildlife, Corvallis.

Johnson, L. L., G. M. Ylitalo, M. S. Myers, B. F. Anulacion, J. Buzitis, W. L. Reichert, and T. K. Collier. 2009. Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98.

Online at http://www.nwfsc.noaa.gov/assets/25/6917_05122009_141859_PAHsKitimat TM98WebFinal.pdf [accessed 23 February 2010].

Johnston Jr., S. A. 1981. Estuarine dredge and fill activities: A review of impacts. Environ. Manag. 5:427–440.

Jones, B. C., and G. H. Geen. 1977. Food and feeding of spiny dogfish (*Squalus acanthias*) in British Columbia waters. J. Fish. Res. Board Can. 34:2067–2078.

Jordan, D. S., and C. H. Gilbert. 1899. The fishes of Bering Sea. *In* D. S. Jordan (ed.), The fur seals and fur-seal islands of the North Pacific Ocean, Part 3, p. 433–492. U.S. Government Printing Office, Washington, DC.

Jordan, D. S., and E. C. Starks. 1895. The fishes of Puget Sound. Contributions to biology from the Hopkins Laboratory of Biology No. 3. Proc. Calif. Acad. Sci. Ser. 2 5:785–855.

Joyce, T. L., M. B. Lambert, and S. Moffitt. 2004. Eulachon subsistence harvest opportunities. Final Rep. No. FIS02-075-1. USFWS Office of Subsistence Management, Fisheries Resource Monitoring Program, Anchorage, AK.

Kabata, Z. 1988. Copepoda and Branchiura. *In* L. Margolis and Z. Kabata (eds.). Guide to the parasites of fishes of Canada, Part II–Crustacea, p. 3–127. Can. Spec. Publ. Fish. Aquat. Sci. 101.

Kabata, Z., and C. R. Forrester. 1974. *Atheresthes stomias* (Jordan and Gilbert 1880) (Pisces: Pleuronectiformes) and its eye parasite *Phrixocephalus cincinnatus* Wilson 1908 (Copepoda: Lernaeoceridae) in Canadian Pacific waters. J. Fish. Res. Board Can. 31:1589–1595.

Kajimura, H., C. H. Fiscus, and R. K. Stroud. 1980. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington: With appendices on size and food of Dall's porpoise from Alaskan waters. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/NWC 2.

Kaukinen, K. H., K. J. Supernault, and K. M. Miller. 2004. Development of microsatellite loci in eulachon fish (*Thaleichthys pacificus*). Mol. Ecol. Notes 4:632–634.

Keller, A. A., T. L. Wick, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, and B. H. Horness. 2005. The 2000 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-70. Online at http://www.nwfsc.noaa.gov/assets/25/6459_03102006_131701_Slope2000FinalV2SA.pdf [accessed 23 February 2010].

Keller, A. A., E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, B. H. Horness, V. H. Simon, and V. J. Tuttle. 2006a. The 2001 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-72. Online at http://www.nwfsc.noaa.gov/assets/25/6460_03202007_121309_ Slope2001TechMemo.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, V. J. Tuttle, J. R. Wallace, V. H. Simon, E. L. Fruh, K. L. Bosley, and D. J. Kamikawa. 2006b. The 2002 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-

75. Online at http://www.nwfsc.noaa.gov/assets/25/6493_04062006_150352_ Slope2002TM75Final.pdf [accessed 23 February 2010].

Keller, A. A., V. H. Simon, B. H. Horness, J. R. Wallace, V. J. Tuttle, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007a. The 2003 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-86. Online at http://www.nwfsc.noaa.gov/assets/25/6719_01082008_151554_ GroundfishSurvey2003TM86FinalSA.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, V. H. Simon, V. J. Tuttle, J. R. Wallace, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007b. The 2004 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-87. Online at http://www.nwfsc.noaa.gov/assets/25/6656_01152008_153323_ GroundfishSurvey2004TM87FinalSA.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, E. L. Fruh, V. H. Simon, V. J. Tuttle, K. L. Bosley, J. C. Buchanan, D. J. Kamikawa, and J. R. Wallace. 2008. The 2005 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-93. Online at http://www.nwfsc.noaa.gov/assets/25/6802_08122008_165005_ GroundfishSurveyTM93Final.pdf [accessed 23 February 2010].

Kelson, J. 1996. Kitamaat River 1995 oolichan (*Thaleicthys pacificus*) study. Report prepared by Kitamaat Village Council for British Columbia Ministry of Forests (as cited in Moody 2008).

Kelson, J. 1997. Kitamaat River 1997 oolichan (*Thaleicthys paclficus*) study progress report (May-July, 1997). Final report to Science Council of British Columbia (SCBC No. 96/97-025). Online at http://www.for.gov.bc.ca/hfd/library/frbc1997/frbc1997mr215.pdf [accessed 23 February 2010].

Kennedy, D. I. D., and R. T. Bouchard. 1990. Bella Coola. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 323–339. Smithsonian Institution, Washington, DC.

Kershaw, T. R. 1902. Thirteenth annual report of the State Fish Commissioner to the Governor of the State of Washington. Metropolitan Press, Seattle.

Kershaw, T. R. 1904. 14th and 15th annual reports of the State Fish Commissioner to the Governor of the State of Washington. Metropolitan Press, Seattle.

Kime, D. E. 1995. The effects of pollution on reproduction in fish. Rev. Fish Biol. Fish. 5:52–96.

Kitamaat Village Council. 2007. Haisla Dootilh. Haisla Community Newsletter, Vol. 1, Issue 1. Kitamaat Village Council, Kitamaat Village, BC. Online at http://www.haisla.ca/files/ May%202007.pdf [accessed 23 February 2010].

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. J. Climate 19:4545–4559.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, B. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein, R. S. Waples. 2004. 2004 Status Review of Southern Resident Killer Whales (Orcinus orca) under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-62.

Krause, A. 1885. Die Tlinkit-Indianer. Ergebnisse einer Reise nach der Nordwestküste von Amerika und der Beringstrasse. H. Costenoble, Jena. Published in 1956 [Translated by E. Gunther] as The Tlingit Indians: Results of a trip to the northwest coast of America and the Bering Straits. University of Washington Press, Seattle.

Kreag, R. A. 1979. Natural resources of Coquille Estuary. Estuary Inventory Rep. Vol. 2, No. 7. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Kubik, S. W., and R. Wadman. 1977. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and Cook Inlet drainages. Federal Aid in Sport Fish Restoration, Annual Performance Rep. 1976–1977, Project F-9-9(18)G-I-H. Alaska Dept. Fish and Game, Sport Fish Division, Juneau.

Kubik, S. W., and R. Wadman. 1978. Inventory and cataloging of sport fish and sport fish waters of western Prince William Sound, lower Susitna and central Cook Inlet drainages. Federal Aid in Fish Restoration, Annual Performance Rept. 1977–1978, Project F-9-10(19)G-I-H. Alaska Dept. Fish and Game, Sport Fish Division, Juneau.

Kuhnlein, H. V., A. C. Chan, J. N. Thompson, and S. Nakai. 1982. Ooligan grease: A nutritious fat used by native people of coastal British Columbia. J. Ethnobiol. 2:154–161.

Kuhnlein, H. V., F. Yeboah, M. Sedgemore, S. Sedgemore, and H. M. Chan. 1996. Nutritional qualities of ooligan grease: A traditional food fat of British Columbia First Nations. J. Food Compos. Anal. 9:18–31.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochasticity and random catastrophes. Am. Nat. 142:911–927.

Langer, O. E., B. G. Shepherd, and P. R. Vroom. 1977. Biology of the Nass River eulachon (*Thaleichthys pacificus*). Canadian Fisheries and Marine Service Tech. Rep. 77-10.

Larson, K. W., and C. E. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes, workshop proceedings, 8–9 September 1988, p. 102–112. Univ. Washington, Sea Grant Program, Seattle.

Larson, Z. S., and M. R. Belchik. 1998. A preliminary status review of eulachon and Pacific lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program, Klamath, CA.

Lasalle, M. W. 1990. Physical and chemical alterations associated with dredging: An overview. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast fishes. Workshop proceedings, 8–9 September 1988, p. 1–12. Univ. Washington, Sea Grant Program, Seattle.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: The relation between inshore chlorophyll maximum layers and successful first feeding. Fish. Bull. 73:453–462.

Lassuy, D. 1995. Introduced species as a factor in extinction and endangerment of native fish species. Am. Fish. Soc. Symp. 15:391–396.

Lauth, R. R. 1997a. The 1995 Pacific West Coast upper continental slope trawl survey of groundfish resources off southern Oregon and northern California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-80. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-80.pdf [accessed 23 February 2010].

Lauth, R. R. 1997b. The 1996 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington and Oregon: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-81. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-81.pdf [accessed 23 February 2010].

Lauth, R. R. 1999. The 1997 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-98. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-98/Text%20from %20NOAA-TM-AFSC-98.pdf [accessed 23 February 2010].

Lauth , R. R. 2000. The 1999 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington , Oregon and California: Estimates of distribution , abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-115. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-115/Text%20from %20NOAA-TM-AFSC-115%20.pdf [accessed 23 February 2010].

Lauth, R, and E. Acuna (compilers). 2007a. 2005 bottom trawl survey of the eastern Bering Sea continental shelf. AFSC Processed Rep. 2007-1. Online at http://www.afsc.noaa.gov/ Publications/ProcRpt/PR2007-01.pdf [accessed 23 February 2010].

Lauth, R. R., and E. Acuna. 2007b. Results of the 2006 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-176. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-176.pdf [accessed 23 February 2010].

Lauth, R. R., M. E. Wilkins, and P. A. Raymore Jr. 1997. Results of trawl surveys of groundfish resources of the West Coast upper continental slope from 1989 to 1993. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-79.

Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6–10.

LCFRB (Lower Columbia Fish Recovery Board). 2004a. Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. Online at http://www.nwcouncil.org/fw/subbasinplanning/ lowerColumbia/plan/ [accessed 23 February 2010].

LCFRB (Lower Columbia Fish Recovery Board). 2004b. Eulachon. Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan, Appendix B, Ch. 15. Online at http://www.nwcouncil.org/ fw/subbasinplanning/lowerColumbia/plan/AppendixB_OtherSpecies.pdf [accessed 10 May 2010].

Levitus, S., J. I. Antonov, and T. P. Boyer. 2005. Warming of the world ocean, 1955–2003. Geophys. Res. Lett. 32: L02604. Online at http://dx.doi.org/ [DOI name 10.1029/2004GL021592, accessed 23 February 2010].

Levitus, S., J. Antonov, T. P. Boyer, and C. Stephens. 2000. Warming of the world ocean. Science 287:2225–2229.

Lewis, A. F. J. 1997. Skeena eulachon study 1997. Report prepared by Triton Environmental Consultants Ltd., Terrace, BC, and the Tsimshian Tribal Council, Prince Rupert, BC, for Forest Renewal BC. Final rep. to Science Council of British Columbia (SCBC #96/97-123). Online at http://www.for.gov.bc.ca/hfd/library/FRBC1997/FRBC1997MR216.PDF [accessed 23 February 2010].

Lewis, A. F. J., M. D. McGurk, and M. G. Galesloot. 2002. Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988–1998. Consultant's report prepared by Ecofish Research Ltd. for Alcan Primary Metal Ltd., Kitimat, BC.

Lindsey, C. C. 1966. Body sizes of poikilotherm vertebrates at different latitudes. Evolution 20:456–465.

Little, A. C. 1898. Ninth annual report of the state fish commissioner to the governor of the State of Washington. Gwin Hicks, state printer, Olympia.

Little, A. C. 1901. Tenth and eleventh annual reports of the state fish commissioner to the governor of the State of Washington, 1899–1900. Gwin Hicks, state printer, Olympia.

Livingston, P. 1983. Food habits of Pacific whiting, *Merluccius productus*, off the west coast of North America, 1967 and 1980. Fish. Bull. 81:629–636.

Longhurst, A. R. 2006. Ecological geography of the sea, 2nd edition. Elsevier Academic Press, Amsterdam.

Lord, J. K. 1866. The naturalist in Vancouver Island and British Columbia, Vol. 1. Richard Bentley, London. Republished by Elibron Classics, New York.

Lowry, L. F., K. J. Frost, J. M. Ver Hoef, and R. A. DeLong. 2001. Movements of satellite tagged subadult and adult harbor seals in Prince William Sound, Alaska. Mar. Mam. Sci. 17:835–861.

Mace, G. M., and E. J. Hudson. 1999. Attitudes toward sustainability and extinction. Conserv. Biol. 13:242–246.

MacFie, M. 1865. Vancouver Island and British Columbia: Their history, resources, and prospects. Longman, Green, Longman, Roberts & Green, London.

Mackas, D. L., S. Batten, and M. Trudel. 2007. Effects on zooplankton of a warmer ocean: Recent evidence from the Northeast Pacific. Prog. Oceanogr. 75:223–252.

Mackas, D. L., R. E. Thomson, and M. Galbraith. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985–1999, and their covariation with oceanographic conditions. Can. J. Fish. Aquat. Sci. 58:685–702.

Mackie, R. S. 1997. Trading beyond the mountains: The British fur trade on the Pacific, 1793–1843. University of British Columbia Press, Vancouver.

MacLachlan, M. (ed.). 1998. The Fort Langley Journals, 1827–1830. University of British Columbia Press, Vancouver.

Macnair, P. L. 1971. Descriptive notes on the Kwakiutl manufacture of eulachon oil. Syesis 4:169–177.

Maggiulli, N., Reeves, G. H., and R. A. Schmitz. 2006 eulachon spawning migration dynamics and associated avian feeding aggregation characteristics on the Copper River delta, Alaska [abstract]. *In* 2006 Annual Meeting of the Oregon Chapter of The Wildlife Society, p. 26. 14–17 February 2006, Agate Beach, OR. Oregon Chapter of the Wildlife Society, Corvallis, OR.

Mantua, N. J., and S. R. Hare. 2002. The Pacific decadal oscillation. J. Oceanogr. 58:35–44.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteorol. Soc. 78:1069–1079.

Margolis, L., and J. R. Arthur. 1979. Synopsis of the parasites of fishes of Canada. Bull. Fish. Res. Board Can. 199.

Marston, B. H., M. F. Willson, and S. M. Gende. 2002. Predator aggregations during eulachon *Thaleichthys pacificus* spawning runs. Mar. Ecol. Prog. Ser. 231:229–236.

Martin, I. 2008. Notes on historical smelt migrations in the Columbia and Cowlitz rivers, Exhibit AA. Attachment to letter to Chief NMFS, Protected Resources Division, from T. V. Dulcich; Schwabe, Williamson & Wyatt, Attorneys at Law, re. Code No. RIN0648-XF87-Comment on request for information regarding proposed listing of Pacific eulachon as an endangered or threatened species under the Endangered Species Act, 12 May 2008. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.) Online at http://www.regulations.gov/search/Regs/contentStreamer?objectId=090000648098f309 &disposition=attachment&contentType=pdf [accessed 24 February 2010].

Martin, I. 2009. Letter from Irene Martin (Skamokawa, WA) to Chief, NMFS, Protected Resources Division, dated 11 May 2009. Eulachon Status Review Response, May 2009, by Irene Martin, 11 p. + 5 attachments. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Martin, M. H., and D. M. Clausen. 1995. Data Report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-59. Online at http://www.afsc.noaa.gov/ Publications/AFSC-TM/NOAA-TM-AFSC-59.pdf [accessed 23 February 2010].

Martindale, A. R. C. 2003. A hunter-gatherer paramount chiefdom: Tsimshian developments through the contact period. *In* R. G. Matson, G. Coupland, and Q. Mackie (eds.), Emerging from the mist: Studies in Northwest Coast culture history, p. 12–49. University of British Columbia Press, Vancouver.

Maybury, C. R. 1930. Thirty-eighth and thirty-ninth annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1927, to March 31, 1929, fiscal years of 1927 and 1928. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

McAllister, D. E. 1963. A revision of the smelt family, Osmeridae. Nat. Mus. Can., Biol. Ser. 71, Bull. 191:1–53.

McCabe Jr., G. T., R. L. Emmett, and S. A. Hinton. 1993. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Sci. 67:170–180.

McCallister, H. C., and R. E. Clanton. 1911. Biennial report of the Department of Fisheries of the State of Oregon to the twenty-sixth legislative assembly 1911. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

McCarter, P. B., and D. E. Hay. 1999. Distribution of spawning eulachon stocks in the central coast of British Columbia as indicated by larval surveys. Canadian Stock Assessment Secretariat research document 99/177. DFO, Ottawa, ON.

McCarter, P. B., and D. Hay. 2003. Eulachon embryonic egg and larval outdrift sampling manual for ocean and river surveys. Can. Tech. Rep. Fish. Aquat. Sci. 2451.

McDonald, T. E., and L. Margolis. 1995. Synopsis of the parasites of fishes of Canada: Supplement (1978–1993). Can. Spec. Publ. Fish. Aquat. Sci. No. 122.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42. Online at http://www.nwfsc.noaa.gov/assets/25/5561_06162004_143739_tm42.pdf [accessed 23 February 2010].

McFarlane, G. A., and R. J. Beamish. 1985. Biology and fishery of Pacific whiting, *Merluccius productus*, in the Strait of Georgia. Mar. Fish. Rev. 47:23–34.

McFarlane, G. A., J. R. King, and R. J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progr. Oceanogr. 47:147–169.

McGuire, H. D. 1896. Third and fourth annual reports of the Fish and Game Protector of the State of Oregon, 1895–1896. W. H. Leeds, state printer, Salem.

McGuire, H. D. 1898. Fifth and sixth annual reports of the Fish and Game Protector of the State of Oregon, 1897–1898. W. H. Leeds, state printer, Salem.

McHugh, J. L. 1939. The eulachon. Progress report of the Pacific Biological Station, Nanaimo, B.C., and Pacific Fisheries Experimental Station, Prince Rupert, BC 40:17–22.

McHugh, J. L. 1940. Where does the eulachon spawn? Progress Rep. of the Pacific Biological Station, Nanaimo, BC, and Pacific Fisheries Experimental Station, Prince Rupert, BC 44:18–19.

McHugh, J. L. 1954. Geographic variation in the Pacific herring. Copeia 1954:139–154.

McLaughlin, P. A., D. K. Camp, M. V. Angel, E. L. Bousfield, P. Brunel, R. C. Brusca, D. Cadien, A. C. Cohen, K. Conlan, L. G. Eldredge, D. L. Felder, J. W. Goy, T. Haney, B. Hann, R. W. Heard, E. A. Hendrycks, H. H. Hobbs III, J. R. Holsinger, B. Kensley, D. R. Laubitz, S. E. LeCroy, R. Lemaitre, R. F. Maddocks, J. W. Martin, P. Mikkelsen, E. Nelson, W. A. Newman, R. M. Overstreet, W. J. Poly, W. W. Price, J. W. Reid, A. Robertson, D. C. Rogers, A. Ross, M. Schotte, F. R. Schram, C. T. Shih, L. Watling, G. D. F. Wilson, and D. D. Turgeon. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: Crustaceans. American Fisheries Society, Bethesda, MD.

McLean, J. E. 1999. Marine population structure in an anadromous fish: Life history influences patterns of neutral molecular variation in the eulachon, *Thaleichthys pacificus*. Master's thesis. Univ. British Columbia, Vancouver.

McLean, J. E., D. E. Hay, and E. B. Taylor. 1999. Marine population structure in an anadromous fish: Life history influences patterns of mitochondrial DNA variation in the eulachon, *Thaleichthys pacificus*. Mol. Ecol. 8:S143–S158.

McLean, J. E., and Taylor, E. B. 2001. Resolution of population structure in a species with high gene flow: Microsatellite variation in the eulachon (Osmeridae: *Thaleichthys pacificus*). Mar. Biol. 139:411–420.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Bull. Fish. Res. Board Can. 173.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, MD.

Meffe, G., and R. Carroll. 1994. Principles of conservation biology. Sinauer Associates Inc., Sunderland, MA.

Meier, M. F., M. B. Dyurgerov, and G. J. McCabe. 2003. The health of glaciers: Recent changes in glacier regime. Clim. Change 59:123–135.

Middleton, D. A. J., and R. M. Nisbet. 1997. Population persistence time: Estimates, models, mechanisms. Ecol. Appl. 7:107–117.

Miller, B. S., and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. Vol. 1. Family Petromysontidae (lampreys) through family Syngnathidae (Pipefishes). Univ. Washington, Fisheries Research Institute, Seattle.

Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game Fish Bull. 157.

Miller, D. J., and R. N. Lea. 1976. Guide to the coastal marine fishes of California, addendum added 1976. Calif. Dept. Fish Game Fish Bull. 157. 2nd edition.

Miller, J. A., and A. L. Shanks. 2005. Abundance and distribution of larval and juvenile fish in Coos Bay, Oregon: Time-series analysis based on light-trap collections. Mar. Ecol. Prog. Ser. 305:177–191.

Miller R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22–38.

Mills, D. D. 1982. Historical and contemporary fishing for salmon and eulachon at Klukwan: An interim report. ADFG Tech. Paper 69. Alaska Dept. Fish and Game, Division of Subsistence, Juneau.

Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationship to intracontinental tectonism. *In* C. H. Hocutt and E. O. Wiley (eds.), The zoogeography of North American freshwater fishes, p. 519–613. John Wiley and Sons, New York.

Mitchell, D. H. 1983. Seasonal settlements, village aggregations, and political autonomy on the central Northwest Coast. *In* E. Tooker (ed.), The development of political organization in native North America, p. 97–107. American Ethnological Society, Washington, DC.

Moffitt, S., B. Marston, and M. Miller. 2002. Summary of eulachon research in the Copper River Delta, 1998–2002. Regional information rep. 2A02-34. Alaska Dept. Fish and Game, Anchorage.

Monaco, M. E., R. L. Emmett, S. A. Hinton, and D. M. Nelson. 1990. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Vol. I: Data summaries. ELMR Rep. 4. U.S. Dept. Commerce, NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Moody, M. 2007. The Bella Coola eulachon fishery, its importance and its past and current status. Presentation at the February 2007 workshop to determine research priorities for eulachon. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/2007eulawkshp_ch.pdf [accessed 23 February 2010].

Moody, M. F. 2008. Eulachon past and present. Master's thesis. Univ. British Columbia, Vancouver. Online at https://circle.ubc.ca/bitstream/2429/676/1/ubc_2008_spring_moody_megan.pdf [accessed 23 February 2010].

Moore, S. E., K. E. W. Shelden, L. K. Litzky, B. A. Mahoney, and D. J. Rugh. 2000. Beluga, *Delphinapterus leucas*, habitat associations in Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):60–80.

Moring, J. R. 1996. Fish discoveries by the Lewis and Clark and Red River expeditions. Fisheries 21(7):6–12.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy, Washington, DC.

Morrison, J., M. Quick, and M. G. G. Foreman. 2002. Climate change in the Fraser River watershed: Flow and temperature predictions. J. Hydrol. 263:230–244.

Morstad, S. 1998. Eulachon—1998 season summary. Alaska Dept. Fish and Game, Anchorage (as cited in Spangler et al. 2003).

Morton, A. 2000. Occurrence, photo-identification and prey of white-sided dolphins *(Lagenorhyncus obliquidens)* in the Broughton Archipelago, Canada, 1984–1998. Mar. Mam. Sci. 16: 80–93.

Mote, P. W. 2003a. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. Northwest Sci. 77:271–282.

Mote, P. W. 2003b. Twentieth-century fluctuations and trends in temperature, precipitation, and mountain snowpack in the Georgia Basin-Puget Sound region. Can. Water Res. J. 28:567–586.

Mote, P. W. 2006. Climate-driven variability and trends in mountain snowpack in western North America. J. Climate 19:6209–6220.

Mote, P. W., D. J. Canning, D. L. Fluharty, R. C. Francis, J. F. Franklin, A. F. Hamlet, M. Hershman, M. Holmberg, K. N. Ideker, W. S. Keeton, D. P. Lettenmaier, L. R. Leung, N. J. Mantua, E. L. Miles, B. Noble, H. Parandvash, D. W. Peterson, A. K. Snover, and S. R. Willard. 1999. Impacts of climate variability and change in the Pacific Northwest. NOAA, Office of Global Programs, and JISAO/SMA Climate Impacts Group, Seattle, WA. Online at http://cses.washington.edu/db/pdf/moteetalgreenbook96.pdf [accessed 23 February 2010].

Mote, P. W., A. F. Hamlet, M. Clark, and D. P. Lettenmaier. 2005a. Declining mountain snowpack in western North America. Bull. Am. Meteorol. Soc. 86:39–49.

Mote, P.M., E. Salathé, and C. Peacock. 2005b. Scenarios of future climate for the Pacific Northwest. Univ. Washington Climate Impacts Group, Tech. Rep., October 2005. Online at http://cses.washington.edu/db/pdf/kc05scenarios462.pdf [accessed 23 February 2010].

Moulton, G. E. (ed.). 1990. The definitive journals of Lewis and Clark, Down the Columbia to Fort Clatsop. Vol. 6 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1991. The definitive journals of Lewis and Clark, From the Pacific to the Rockies. Vol. 7 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1995. The definitive journals of Lewis and Clark, John Ordway and Charles Floyd. Vol. 9 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1997. The definitive journals of Lewis and Clark, Joseph Whitehouse. Vol. 11 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moyle, P. B. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley and Los Angeles.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Eulachon. *In* Fish species of special concern in California, 2nd edition, p. 123–127. California Dept. Fish and Game, Inland Fisheries Division, Rancho Cordova.

Mueter, F. J., and B. L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fish. Bull. 100:559–581.

Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Information Rep. 77-3. Oregon Dept. Fish and Wildlife, Research Section, Salem.

Musick, J. A. 1999. Criteria to define extinction risk in marine fishes. Fisheries 24:6–14.

Musick, J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, G. R. Sedberry, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, H. Weeks, and S. G. Wright. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25(11): 6–30.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35. Online at http://www.nwfsc.noaa.gov/assets/25/4234_06172004_115524_chinook.pdf [accessed 23 February 2010].

Nebenzahl, D. (compiler). 2001. 2001 bottom trawl survey of the eastern Bering Sea continental shelf. AFSC Processed Rep. 2001-08. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202001-08.pdf [accessed 23 February 2010].

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, sixth edition. American Fisheries Society, Bethesda, MD.

Niblack, A. P. 1890. The coast Indians of southern Alaska and northern British Columbia. Based on the collections in the U.S. National Museum, and on the personal observation of the writer [a U.S. Navy Ensign] in connection with the survey of Alaska in the seasons of 1885, 1886, and 1887. *In* Report of the U.S. National Museum, 1888, p. 225–386. Smithsonian Institution, Washington, DC.

NMFS (National Marine Fisheries Service). 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-28.

NMFS (National Marine Fisheries Service). 1999. Endangered and threatened wildlife and plants; 90-day finding for a petition to list Columbia River eulachon (*Thaleichthys pacificus*) as endangered or threatened. Federal Register (Docket No. 991116306-9306-01; 29 November 1999) 64(228):66601–66603.

NMFS (National Marine Fisheries Service). 2000. Endangered and threatened species: Puget Sound populations of Pacific hake, Pacific cod, and walleye pollock. Federal Register (Docket No. 001103310-0310-01; 24 November 2000) 65(227):70514–70521.

NMFS (National Marine Fisheries Service). 2001. Endangered and threatened species: Puget Sound populations of copper rockfish, quillback rockfish, brown rockfish, and Pacific herring. Federal Register (Docket No. 010312061-1061-01; 3 April 2001) 66(64):17659–17668.

NMFS (National Marine Fisheries Service). 2002. Endangered and threatened wildlife and plants; 12-month finding on a petition to list bocaccio as threatened. Federal Register (50 CFR Parts 223 and 224; 19 November 2002) 67(223):69704–69708.

NMFS (National Marine Fisheries Service). 2003. Endangered and threatened species; Final endangered status for a distinct population segment of smalltooth sawfish (*Pristis pectinata*) in the United States. Federal Register (Docket No. 000303059-3034-03; 1 April 2003) 68(62):15674–15680.

NMFS (National Marine Fisheries Service). 2005. Listing endangered and threatened species and designating critical habitat: 12-month finding on petition to list the Cherry Point stock of Pacific herring as an endangered or threatened species. Federal Register (Docket No. 040511147-5142-02; I.D. 042804B; 7 June 2005) 70(108):33116–33122.

NMFS (National Marine Fisheries Service). 2008a. Listing endangered and threatened species: Notification of finding on a petition to list Pacific eulachon as an endangered or threatened species under the Endangered Species Act. Federal Register (Docket No. 080229343-8368-01; 21 March 2008) 73(49):13185–13189.

NMFS (National Marine Fisheries Service). 2008b. Endangered and threatened species; Notice of finding on a petition to list the Lynn Canal population of Pacific herring as a threatened or endangered species. Federal Register (Docket No. 070727423-8495-02; 11 April 2008) 73(71):19824–19825.

NMFS (National Marine Fisheries Service). 2009. Fisheries off West Coast states; Coastal pelagic species fishery; Amendment 12 to the Coastal Pelagic Species Fishery Management Plan, final rule. Federal Register (Docket No. 071106669-81372-03; 31 July 2009) 74(132):33372–33373.

NRC (National Research Council). 2004. Endangered and threatened fishes in the Klamath River basin: Causes of decline and strategies for recovery. Committee on Endangered and Threatened Fishes in the Klamath River Basin, National Research Council. The National Academies Press, Washington, DC.

NRC (National Research Council). 2008. Hydrology, ecology, and fishes of the Klamath River basin. Committee on Hydrology, Ecology, and Fishes of the Klamath River, National Research Council. The National Academies Press, Washington, DC.

NWFSC (Northwest Fisheries Science Center). 2008. Data report and summary analyses of the California and Oregon pink shrimp fisheries, December 2008. NWFSC, Fishery Resource Analysis and Monitoring Division, West Coast Groundfish Observer Program, Seattle, WA. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/pink_shrimp_report_final.pdf [accessed 23 February 2010].

NWIFC (Northwest Indian Fisheries Commission). 1998. Quinaults welcome rare visit by candlefish. Northwest Indian Fish. Comm. News 18(1):11.

Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50:305–307.

ODFW (Oregon Dept. Fish and Wildlife). 1991. Tenmile Basin Fish Management Plan. Oregon Dept. Fish and Wildlife, Citizen Advisory Committee, and Public Agency Cooperators. (Available from National Marine Fisheries Service, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

ODFW (Oregon Dept. Fish and Wildlife). 2006. The Oregon nearshore strategy. Online at http://www.dfw.state.or.us/MRP/nearshore/strategy/Strategy.pdf [accessed 23 February 2010].

ODFW and WDF (Oregon Dept. Fish and Wildlife and Washington Dept. Fisheries). 1987. Status report: Columbia River fish runs and fisheries 1960–1986. Oregon Dept. Fish and Wildlife, Portland, and Washington Dept. Fisheries, Olympia.

OFC (Oregon Fish Commission). 1953. Columbia River Progress Report 1953. Fish Commission of Oregon, Portland.

OFC (Oregon Fish Commission). 1970. Pelagic fisheries and coastal rivers investigation. Progress Report-Coastal Rivers Section, July 1, 1966–June 30, 1967. Fish Commission of Oregon, Research Division, Portland.

Olesiuk, P. F. 1993. Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fish. Bull. 91:491–515.

Olsen, N., J. A. Boutillier, and L. Convey. 2000. Estimated bycatch in the British Columbia shrimp trawl fishery. Canadian Stock Assessment Secretariat research document 2000/168. Online at http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2000/PDF/2000_168e.pdf [accessed 23 February 2010].

Olson, R. L. 1936. The Quinault Indians. Univ. Wash. Publ. Anthropol. 6(1).

Olson, W. M., and L. T. Hubbard Jr. 1984. Fishing: The key to Tlingit culture. *In* B. Gunda (ed.), The fishing culture of the world: Studies in ethnology, cultural ecology, and folklore, Vol. 2, p. 917–938. Akademiai Kiado, Hungary.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geogr. 77:118–125.

Omernik, J. M., and A. L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency Rep. EA/600/3-86/033.

Ormseth, O. A., L. Conners, M. Guttormsen, and J. Vollenweider. 2008. Appendix 2: Forage fishes in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 657–702. North Pacific Fishery Management Council, Anchorage. Online at http://www.afsc.noaa.gov/refm/docs/2008/GOAforage.pdf [accessed 23 February 2010].

Ormseth, O. A., and J. Vollenweider. 2007. Appendix 2: Forage fishes in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 1021–1023. North Pacific Fishery Management Council, Anchorage. Online at http://www.afsc.noaa.gov/REFM/docs/2007/GOAforage.pdf [accessed 23 February 2010].

Outram, D. N., and C. Haegele. 1972. Food of Pacific hake (*Merluccius productus*) on an offshore bank southwest of Vancouver Island, British Columbia. J. Fish. Res. Board Can. 29:1792–1795.

Parente, W. D., and G. R. Snyder. 1970. A pictorial record of the hatching and early development of the eulachon (*Thaleichthys pacificus*). Northwest Sci. 44:50–57.

Parks, N. B., F. R. Shaw, and R. L Henry. 1993. Results of a 1988 trawl survey of groundfish resources of the upper continental slope off Oregon. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-23. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-23.pdf [accessed 23 February 2010].

Parliament of Canada. 1900–1916. Annual report on the fisheries of British Columbia (1900–1916). *In* Sessional papers of the Dominion of Canada, Canadian Department of Marine Fisheries, Annual reports of the Inspector of Fisheries for British Columbia, 1900–1916.

Parnell, M. M., R. L. Emmett, and R. D. Brodeur. 2008. Ichthyoplankton community in the Columbia River plume off Oregon: Effects of fluctuating oceanographic conditions. Fish Bull. 106:161–173.

Parrish, R. H., C. S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceanogr. 1(2):175–203.

Payne, S. A., B. A. Johnson, and R. S. Otto. 1997. Proximate composition of some northeastern Pacific forage species. *In* Forage fishes in marine ecosystems, p. 721–724. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Rep. 97-01. Univ. Alaska Fairbanks.

Payne, S. A., B. A. Johnson, and R. S. Otto. 1999. Proximate composition of some northeastern Pacific forage fish species. Fish. Oceanogr. 8:159–177.

Pearsall, C. E. 1928. Autobiography of Clarence E. Pearsall. *In* C. E. Pearsall (ed.), History and genealogy of the Pearsall family in England and America, p. 1483–1757. H. S. Crocker Co., San Francisco.

Peden, A. E., and D. E. Wilson. 1976. Distribution of intertidal and subtidal fishes of northern British Columbia and southeastern Alaska. Syesis 9:221–248.

Pederson, R. V. K., U. N. Orr, and D. E. Hay. 1995. Distribution and preliminary stock assessment (1993) of the eulachon *Thaleichthys pacificus* in the lower Kitimat River, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2330. Online at http://dsp-psd.pwgsc.gc.ca/collection_2007/dfo-mpo/Fs97-4-2330E.pdf [accessed 23 February 2010].

Penttila, D. 2007. Marine forage fishes in Puget Sound. Puget Sound Nearshore Partnership Rep. 2007-03. Published by Army Corps of Engineers, Seattle District, Seattle, WA. Online at http://www.pugetsoundnearshore.org/technical_papers/marine_fish.pdf [accessed 23 February 2010].

Perez, M. A. 1994. Calorimetry measurements of energy value of some Alaskan fishes and squid. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-32.

Petersen, R. S. 2006. The role of traditional ecological knowledge in understanding a species and river system at risk: Pacific lamprey in the lower Klamath Basin. Master's thesis. Oregon State Univ., Corvallis.

Peterson, W. T., and J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: A multivariate approach. Deep-Sea Res. Pt. II Top. Stud. Oceanogr. 50:2499–2517.

PFMC (Pacific Fishery Management Council). 2008. Status of the Pacific Coast coastal pelagic species fishery and recommended acceptable biological catches. Stock assessment and fishery evaluation—2008. Online at http://www.pcouncil.org/bb/2008/0608/G1a_ATT1_0608.pdf [accessed 23 February 2010].

PFMC (Pacific Fishery Management Council) and NMFS (National Marine Fisheries Service). 2008. Management of krill as an essential component of the California Current ecosystem, Amendment 12 to the Coastal Pelagic Species Fishery Management Plan. Prepared by NMFS Southwest Region and Pacific Fishery Management Council. Online at http://www.pcouncil.org/wp-content/uploads/CPS_Am12_Krill_DraftEA.pdf [accessed 23 February 2010].

Phillips, A. J., S. Ralston, R. D. Brodeur, T. D. Auth, R. L. Emmett, C. Johnson, and V. G. Wespestad. 2007. Recent pre-recruit Pacific hake (M*erluccius productus*) occurrences in the northern California Current suggest a northward expansion of their spawning area. Calif. Coop. Ocean. Fish. Investig. Rep. 48:215–229.

Pickard, D., and D. R. Marmorek. 2007. A workshop to determine research priorities for eulachon, workshop report. Prepared by ESSA Technologies Ltd., Vancouver, BC, for Dept. Fisheries and Oceans Canada. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/2007eulawkshp.pdf [accessed 23 February 2010].

Pilling, A. R. 1978. Yurok. *In* R. F. Heizer (ed.), Handbook of North American Indians, Vol. 8, California, p. 137–154. Smithsonian Institution, Washington, DC.

Pitcher, K. W. 1980. Food of the harbor seal, *Phoca vitulina* Richards, in the Gulf of Alaska. Fish. Bull. 78: 544–549.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fish. Bull.. 79: 467–472.

Plate, E. M. 2009. Fraser River, Port Mann Bridge-Douglas Island eulachon study, 2009. LGL Limited, Environmental Research Associates, Sidney, BC, and Terra Remote Sensing Inc., Sidney, BC. Online at http://www.watershed-watch.org/publications/files/FraserEulachonReport-July15_2009.pdf [accessed 23 February 2010].

Pollock, C. R. 1925. Thirty-fourth and thirty-fifth annual reports of the state supervisor of fisheries for the period from April 1, 1923, to March 31, 1925. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Pollock, C. R. 1928. Thirty-sixth and thirty-seventh annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1925, to March 31, 1927. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Pollock, C. R. 1932. Fortieth and forty-first annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1929, to March 31, 1931. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Port of Kitimat. 2009. Investment summary, 2005–2015, from the Office of the Mayor: Joanne Monaghan. Online at http://www.kitimat.ca/assets/Business/PDFs/port-of-kitimat-investment-summary.pdf [accessed 23 February 2010].

Radcliffe, L. 1920. Fishery industries of the United States. Report of the Division of Statistics and Methods of the fisheries for 1918. Appendix X in Report of the U.S. Commissioner of Fisheries for the fiscal year 1918, with appendixes.

Ratti, F. 1979a. Natural resources of Umpqua estuary. Estuary inventory report, Vol. 2, No. 5. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Ratti, F. 1979b. Natural resources of Rogue estuary. Estuary inventory report, Vol. 2, No. 8. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Ray, C. 1960. The application of Bergmann's and Allen's rules to the poikilotherms. J. Morphol. 106:85–108.

Raymore Jr., P. A., and K. L. Weinberg. 1990. 1984 spring and autumn surveys of Pacific West Coast upper continental slope groundfish resources. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-179.

Reed, F. C. 1900. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-first regular session, 1901. Oregon Dept. Fisheries, W. H. Leeds, state printer, Salem.

Reed, F. C., E. P. Thompson, and R. C. Campbell. 1891. Third and fourth annual reports of the State Board of Fish Commissioners to the Governor of Oregon, sixteenth regular session legislative assembly, 1889–1890. F. C. Baker, state printer, Salem.

Reed, F. C., E. P. Thompson, and G. T. Myers. 1892. Fifth and sixth annual reports of the State Board of Fish Commissioners to the Governor of Oregon, 1891–1892. F. C. Baker, state printer, Salem.

Regonda, S. K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal cycle shifts in hydroclimatology over the western United States. J. Clim. 18:373–384.

Reimers, P. E., and K. J. Baxter. 1976. Fishes of Sixes River, Oregon. Information Rep. 76-4. Oregon Dept. Fish and Wildlife, Research Section, Salem.

Rexstad, E. A., and E. K. Pikitch. 1986. Stomach contents and food consumption estimates of Pacific hake, *Merluccius productus*. Fish. Bull. 84:947–956.

Reynolds, J. D., N. K. Dulvy, N. B. Goodwin, and J. A. Hutchings. 2005. Biology of extinction risk in marine fishes. Proc. R. Soc. Lond. Ser. B Biol. Sci. 272:2337–2344.

Rich, W. H. 1921. An instance of adult, sea-run Chinook salmon found feeding in freshwater. Calif. Fish Game 7:7–8.

Richardson, J. 1836. *Salmo* (*Mallotus*?) *pacificus* (Richardson) North-west Capelin. *In* Fauna Boreali-Americana; or the zoology of the northern parts of British America. Part third, the fish, p. 226–228. R. Bentley, London. (Reprint published 1974–1978 by Arno Press, New York).

Richardson, S. L., and W. G. Pearcy 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fish. Bull. 75:125–145.

Ricker, W. E., D. F. Manzer, and E. A. Neave. 1954. The Fraser River eulachon fishery, 1941–1953. Fish. Res. Board Can. Manuscr. Rep. 583.

Ridenhour, R. L., and T. D. Hofstra. 1994. Fishery resources of the Redwood Creek basin (California). Online at http://coastalwatersheds.ca.gov/Watersheds/NorthCoast/RedwoodCreek/RedwoodCreekBasin/RedwoodCreekAssessmentComponents/AnadromousSalmonidFisheryResources/tabid/193/Default.aspx [accessed 9 February 2010].

Riseland, J. L. 1907. Sixteenth and seventeenth annual reports of the state fish commissioner and game warden to the governor of the State of Washington. C. W. Corham, public printer, Olympia.

Riseland, J. L. 1909. Eighteenth and nineteenth annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington, 1907–1908. E. L. Boardman, public printer, Olympia.

Riseland, J. L. 1911. Twentieth and twenty-first annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington 1909–1910. E. L. Boardman, public printer, Olympia.

Riseland, J. L. 1913. Twenty-second and twenty-third annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington. Dept. Fisheries and Game, Frank Lamborn, public printer, Olympia.

Robinson, D. G., W. E. Barraclough, and J. D. Fulton. 1968a. Data record. Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, May 1–4, 1967. Fish. Res. Board Can. Manuscr. Rep. Ser. 964.

Robinson, D. G., W. E. Barraclough, and J. D. Fulton. 1968b. Data record. Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 5–9, 1967. Fish. Res. Board Can. Manuscr. Rep. Ser. 972.

Roemmich, D., and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324–1326.

Roffe, T., and B. Mate. 1984. Abundance and feeding habits of pinnipeds in the Rogue River, OR. J. Wildl. Manag. 48:1262–1274.

Rogers, B. J., M. E. Wangerin, K. J. Garrison, and D. E. Rogers. 1980. Epipelagic meroplankton, juvenile fish, and forage fish: Distribution and relative abundance in coastal waters near Yakutat. Interim report to Outer Continental Shelf Environmental Assessment Program. Univ. Washington, College of Fisheries, Fisheries Research Institute, Seattle.

Rogers, I. H., I. K. Birtwell, and G. M. Kruzynski. 1990. The Pacific eulachon (*Thaleichthys pacificus*) as a pollution indicator organism in the Fraser River estuary, Vancouver, British Columbia. Sci. Total Environ. 97(98):713–727.

Rohner, R. P. 1967. The people of the Gilford: A contemporary Kwakiutl village. Natl. Mus. Canada Bull. 225, Anthropol. Ser. 83.

Rollins, P. A. (ed.). 1995. The discovery of the Oregon Trail: Robert Stuart's narratives of his overland trip eastward from Astoria in 1812–13. University of Nebraska Press, Lincoln. (Originally published in 1935 by Edward Eberstadt & Sons, New York).

Romano, M. D., M. D. Howell, and T. A. Rien. 2002. Use of an artificial substrate to capture eulachon eggs in the lower Columbia River. *In* Report C: Eulachon studies related to lower Columbia River channel deepening operations. Contract no. W66QKZ13237198. Final rep. by Oregon Dept. Fish and Wildlife to the U. S. Army Corps of Engineers, Portland.

Rosetta, T., and D. Borys. 1996. Identification of sources of pollutants to the lower Columbia River basin. Oregon Dept. Environmental Quality, prepared for the Lower Columbia River Bi-state Program. Online at http://www.lcrep.org/pdfs/58.%2002750.pdf [accessed 23 February 2010].

Ross, A. 1849. Adventures of the first settlers on the Oregon or Columbia River &c. Alexander Ross, London. Reprinted in 1986 as Adventures of the first settlers on the Oregon or Columbia River, 1810–1813. University of Nebraska Press, Lincoln.

Roye, C. 1979. Natural resources of Coos Bay estuary. Estuary inventory rep., Vol. 2, No. 6. Oregon Dept. Fish and Wildlife, Corvallis.

Rugh, D. J., K. E. W. Shelden, and B. A. Mahoney. 2000. Distribution of belugas in Cook Inlet during June, July 1993–2000. Mar. Fish. Rev. 62(3):6.

Ruzicka, J. J., R. D. Brodeur, and T. J. Wainwright. 2007. Seasonal food web models for the Oregon inner-shelf ecosystem: Investigating the role of large jellyfish. Calif. Coop. Ocean. Fish. Investig. Rep. 48:106–128.

Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. J. Fish Biol. 59(Suppl. A):90–108.

Samis, S. C. 1977. Sampling eulachon eggs in the Fraser River using a submersible pump. Tech. Rep. PAC/T-77-18. Department of Fisheries and the Environment, Pacific Region, Water Quality Division Habitat Protection Directorate, Vancouver, BC.

Sanderson, B. L., K. A. Barnas, and A. M. W. Rub. 2009. Nonindigenous species of the Pacific Northwest: An overlooked risk to endangered salmon? Bioscience 59:245–256.

Sandy River Basin Partners. 2005. Sandy River basin characterization report. Online at http://www.sandyriverpartners.org/pdfs/SRBCR7-20-05.pdf (accessed 23 February 2010].

Sangster, G. I., K. M. Lehmann, and M. Breen. 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh codends. Fish. Res. 25:323–345.

Schade, C. B., and S. A. Bonar. 2005. Distribution and abundance of nonnative fishes in streams of the western United States. N. Am. J. Fish. Manag. 25:1386–1394.

Schlosser, I. J., and P. L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: Conceptual models, empirical evidence, and implications for conservation. *In* J. L. Nielsen (ed.), Evolution and the aquatic ecosystem: Defining unique units in population conservation, p. 392–401. Am. Fish. Soc. Symp. 17, Bethesda, MD.

Schoettler, R. J. 1953. Washington Department of Fisheries 62nd annual report. Washington Dept. Fisheries, Olympia.

Schultz, L. P., and A. C. DeLacy. 1935. Fishes of the American Northwest. J. Pan-Pacific Res. Inst. 10:365–380.

Schweigert, J., B. McCarter, T. Therriault, L. Flostrand, C. Hrabok, P. Winchell, and D. Johannessen. 2007. Ecosystem overview: Pacific North Coast Integrated Management Area (PNCIMA), Appendix H: Pelagic fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2667. Online at http://www.dfo-mpo.gc.ca/library/328842%20Appendix%20H.pdf [accessed 24 February 2010].

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184.

Sette, O. E. 1926. Fishery industries of the United States. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1925, and appendixes, p. 209–408. Bureau of Fisheries document 997. Appendix VII.

Sette, O. E. 1928. Fishery industries of the United States, 1926. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1927, with appendixes, p. 337–483. Bureau of Fisheries document 1025.

Sette, O. E., and R. H. Fiedler. 1929. Fishery industries of the United States, 1927. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1928, with appendixes, p. 401–547. Bureau of Fisheries document 1050.

Shaffer, J. A., D. Penttila, M. McHenry, and D. Vilella. 2007. Observations of eulachon, *Thaleichthys pacificus*, in the Elwha River, Olympic Peninsula, Washington. Northwest Sci. 81:76–81.

Shaw, F. R., M. E. Wilkins, K. L. Weinberg, M. Zimmermann, and R. R. Lauth. 2000. The 1998 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/NOAA-TM-AFSC-114.pdf [accessed 24 February 2010].

Shepherd, J. G., J. G. Pope, and R. D. Cousens. 1984. Variations in fish stocks and hypotheses concerning their links with climate. Cons. Perm. Int. Explor. Mer Rapp. P.-V. Reun. 185:255–267.

Sherwood, C. R., D. A. Jay, R. B. Harvey, P. Hamilton, and C. A. Simenstad. 1990. Historical changes in the Columbia River estuary. Prog. Oceanogr. 25:299–352.

Sidwell, V. D. 1981. Chemical and nutritional composition of finfishes, whales, crustaceans, mollusks, and their products. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/SEC-11.

Sigler, M. F., J. N. Womble, and J. J. Vollenweider. 2004. Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: A prespawning aggregation of eulachon (*Thaleichthys pacificus*). Can. J. Fish. Aquat. Sci. 61:1475–1484.

Simenstad, C. A., A. J. Wick, J. R. Cordell, R. M. Thom, and G. D. Williams. 2001. Decadal development of a created slough in the Chehalis River estuary: Year 2000 results. Report to U.S. Army Corps of Engineers, Seattle District, SAFS-UW-0110. Univ. Washington, School of Aquatic and Fishery Sciences, Seattle.

Sinclair, M., and M. J. Tremblay. 1984. Timing of spawning of Atlantic herring (*Clupea harengus harengus*) populations and the match-mismatch theory. Can. J. Fish. Aquat. Sci. 41:1055–1065.

Small, M., J. Loxterman, A. Frye, J. Von Bargen, C. Bowman, and S. Young. 2005. Temporal and spatial genetic structure among some Pacific herring population in Puget Sound and the southern Strait of Georgia. Trans. Am. Fish. Soc. 134:1329–1341.

Smedbol, R., and R. Stephenson. 2001. The importance of managing within-species diversity in cod and herring fisheries of the northwestern Atlantic. J. Fish Biol. 59(Suppl. A):109–128.

Smith, R. T. 1941 (unpubl. manuscr.). Notes on 1941 Nemah River (Washington) smelt run. Typewritten manuscript. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.

Smith, W. E., and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Dept. Fisheries, Olympia. Fish. Res. Pap. 1(3):3–26.

Smith, W. E., R. W. Saalfeld, E. H. LeMier, J. M. Smith, E. L. Preston, and C. O. Junge. 1953. 1953 smelt investigations, January through April. *In* Columbia River progress report, January through April 1953, p. 3–15. Washington Dept. Fisheries, Olympia.

Snyder, G. R. 1970. Thermal pollution of Columbia River might threaten smelt. Commer. Fish. Rev. 32(12):58–64.

Snyder, G. R., and T. H. Blahm. 1971. Effects of increased temperature on cold-water organisms. J. Water Poll. Control Fed. 43:890–899.

Snyder, M. A., L. C. Sloan, N. S. Diffenbaugh, and J. L. Bell. 2003. Future climate change and upwelling in the California Current. Geophys. Res. Lett. 30 (15):1823. Online at http://dx.doi.org/ [DOI name 10.1029/2003GL017647, accessed 24 February 2010].

Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Bull. Fish. Res. Board Can. 146.

Spangler, E. A. K. 2002. The ecology of eulachon (*Thaleichthys pacificus*) in Twentymile River, Alaska. Master's thesis. Univ. Alaska Fairbanks.

Spangler, E., R. Spangler, and B. Norcross. 2003. Eulachon subsistence use and ecology investigations of Cook Inlet, 2000–2002. Fisheries Resource Monitoring Program, Final Rep. 00-041. U.S. Fish and Wildlife Service, Office of Subsistence Management, Anchorage, AK.

Speckman, S. G., and J. F. Piatt. 2000. Historic and current use of Lower Cook Inlet, Alaska, by belugas, *Delphinapterus leucas*. Mar. Fish. Rev. 62(3):22–26.

Stables, T. B., C. J. Perrin, and M. L. Rosenau. 2005. Acoustic and trawl surveys to locate eulachon aggregations in the lower Fraser River, British Columbia. N. Am. J. Fish. Manag. 25:675–688.

Stacey, D. A. 1995. Eulachon: An historical overview. Common resources fishery research, report prepared for Department of Fisheries and Oceans Canada.

Stansby, M. E. 1976. Chemical characteristics of fish caught in the northeast Pacific Ocean. Mar. Fish. Rev. 38(9):1–11.

Stark, J. W., and D. M. Clausen. 1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-49. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-49.pdf [accessed 24 February 2010].

Starlund. G. C. 1960. 1960 annual report. Washington Dept. Fisheries, Olympia.

Stewart, F. L. 1975. The seasonal availability of fish species used by the coast Tsimshians of northern British Columbia. Syesis 8:375–388.

Stewart, H. 1977. Indian fishing: Early methods on the Northwest Coast. University of Washington Press, Seattle.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes towards earlier streamflow timing across western North America. J. Clim. 18:1136–1155.

Stockley. C. 1981. Smelt deadline in Cowlitz River. Memorandum. Washington Dept. Fisheries, Vancouver.

Stockley, C. E., and I. E. Ellis. 1970. Otter trawl trials for Columbia River smelt with associated notes and recommendations. Columbia River investigations supplemental progress report. Washington Dept. Fisheries, Management and Research Division, Olympia.

Stoffels, D. 2001. Background report: Eulachon in the north coast. Royal British Columbia Museum, Living Landscapes Outreach Program, Victoria, BC. Online at http://www.livinglandscapes.bc.ca/northwest/eulachon/resources/NCeulachon.pdf [accessed 24 February 2010].

Stout, H. A., R. G. Gustafson, W. H. Lenarz, B. B. McCain, D. M. Van Doornik, T. L. Builder, and R. D. Methot. 2001a. Status review of Pacific herring in Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-45. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm45/tm45.htm [accessed 24 February 2010].

Stout, H. A., B. B. McCain, R. D. Vetter, T. L. Builder, W. H. Lenarz, L. L. Johnson, and R. D. Methot. 2001b. Status review of copper rockfish, quillback rockfish, and brown rockfish in Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-46. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm46/tm46.htm [accessed 24 February 2010].

Stroud, R. K., C. H. Fiscus, and H. Kajimura. 1981. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington. Fish. Bull. 78:951–959.

Suchman, C. L., and R. D. Brodeur. 2005. Abundance and distribution of large medusae in surface waters of the northern California Current. Deep-Sea Res. Pt. II Top. Stud. Oceanogr. 52:51–72.

Suchman, C. L., E. A. Daly, J. E. Keister, W. T. Peterson, and R. D. Brodeur. 2008. Feeding patterns and predation potential of scyphomedusae in a highly productive upwelling region. Mar. Ecol. Progr. Ser. 358:161–172.

Suckley, G. 1860. Report on the fishes collected on the survey. Chapter I. Report upon the Salmonidae. *In* Reports of explorations and surveys: To ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, p. 307–368. Pacific Railroad Rep. 12 (Pt. III), No. 5.

Suckley, G., and J. G. Cooper. 1860. The natural history of Washington Territory and Oregon with much relating to Minnesota, Nebraska, Kansas, Utah, and California, between the thirty-sixth and forty-ninth parallels of latitude, being those parts of the final reports on the survey of the Northern Pacific Railroad route, relating to the natural history of the regions explored, with full catalogues and descriptions of the plants and animals collected from 1853 to 1860. Baillière Brothers, New York.

Summers, C. G. 1982. About Kelso, an historical gem, Cowlitz County, Washington. Speedy Litho Press, Longview.

Sutherland, R. 2001. Oolichan fishery of northern British Columbia. B. C. Hist. News 34:8–13.

Suuronen, P. 2005. Mortality of fish escaping trawl gears. FAO Fish. Tech. Pap. 478. FAO Rome.

Suuronen, P., J. A. Perez-Comas, E. Lehtonen,, and V. Tschernij. 1996. Size-related mortality of herring (*Clupea harengus* L.) escaping through a rigid sorting grid and trawl codend meshes. ICES J. Mar. Sci. 53:691–700.

Swain, D. P. 1999. Changes in the distribution of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence–Effects of environmental change or change in environmental preferences? Fish. Oceanogr. 8:1–17.

Swan, J. G. 1881. The eulachon or candle-fish of the Northwest Coast. Proc. U.S. Nat. Mus. (1880) 3:257–264.

Sweetnam, D. A., R. D. Baxter, and P. B. Moyle. 2001. True smelts. *In* W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson (eds.), California's living marine resources: A status report, p. 472–479. California. Dept. Fish and Game, Sacramento.

Sytsma, M. D., J. R. Cordell, J. W. Chapman, and R. C. Draheim. 2004. Lower Columbia River aquatic nonindigenous species survey 2001–2004. Final Tech. Rep. October + appendices. Prepared for the U.S. Coast Guard and the U.S. Fish and Wildlife Service. Online at http://www.clr.pdx.edu/docs/LCRANSFinalReport.pdf [accessed 24 February 2010].

Tanasichuk, R. W., D. M. Ware, W. Shaw, and G. A. McFarlane. 1991. Variations in diet, daily ration, and feeding periodicity of Pacific hake (*Merluccius productus*) and spiny dogfish (*Squalus acanthias*) off the lower west coast of Vancouver Island. Can. J. Fish. Aquat. Sci. 48:2118–2128.

Tetra Tech. 1996. Lower Columbia River bi-state program: The health of the river 1990–1996. Tetra Tech integrated Tech. Rep. 0253-01. Redmond, WA. Online at http://www.lcrep.org/pdfs/59.%2002939.pdf [accessed 24 February 2010].

Therriault, T. W., and P. B. McCarter. 2005. Using an eulachon indicator framework to provide advice on Fraser River harvest opportunities for 2006. Canadian Science Advisory Secretariat research document 2005/077.

Thomas, D. W. 1983. Changes in Columbia River estuary habitat types over the past century. Columbia River Estuary Data Development Program (CREDDP), Columbia River Estuary Study Taskforce, Astoria, OR.

Thompson, G. G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-198. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm198/index.html [accessed 24 February 2010].

Thomson, R. E. 1981. Oceanography of the British Columbia coast. Can. Spec. Publ. Fish Aquat. Sci. 56.

Tilman, D., and C. L. Lehman. 1997. Habitat destruction and species extinctions. *In* D. Tilman and P. Kareiva (eds.), Spatial ecology: The role of space in population dynamics and interspecific interactions, p. 233–249. Princeton University Press, NJ.

Trihey and Associates. 1996. Instream flow requirements for tribal trust species in the Klamath River. Prepared for the Yurok Tribe, Eureka, CA, by Trihey and Associates Inc., Concord, CA.

Tutty, B. D., and J. A. Morrison. 1976. Dredge monitoring capture data and entrainment estimates during the 1976 juvenile salmonid migration in the lower Fraser River. Tech. Rep. Ser. No. PAC/T-76-21. Environment Canada, Fisheries and Marine Service, Pacific Region, Habitat Protection Directorate.

Urrutia, V. 1998. They came to six rivers: The story of Cowlitz County. Cowlitz County Historical Society, Kelso, WA.

USACE (U.S. Army Corps of Engineers). 1952. Columbia River and tributaries, northwestern United States: Letter from the secretary of the army transmitting a letter from the chief of engineers, United States Army, dated June 28, 1949, submitting a report, together with accompanying papers and illustrations, on a review of reports on, and preliminary examinations and surveys of, the Columbia River and tributaries, northwestern United States, made pursuant to several congressional authorizations listed in the report. In eight volumes, Volume VII. House Document No. 531, 81st Congress, 2nd session. U.S. Govt. Printing Office, Wash., DC.

USACE (U.S. Army Corps of Engineers). 2007. Mount St. Helens project lower Cowlitz River interim dredging environmental assessment. Draft 13 June 2007. U.S. Army Corps of Engineers, Portland District, OR.

USFWS-NMFS (U.S. Fish and Wildlife Service and National Marine Fisheries Service). 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register, 7 February 1996, 61(26):4722–4725.

Valentine, J. W. 1966. Numerical analysis of marine molluscan ranges on the extratropical northeastern Pacific shelf. Limnol. Oceanogr. 11:198–211.

VanBlaricom, G., M. Neuman, J. Butler, A. DeVogelaere, R. Gustafson, C. Mobley, D. Richards, S. Rumsey, and B. Taylor. 2009. Status review report for black abalone (*Haliotis cracherodii* Leach, 1814). Online at http://swr.nmfs.noaa.gov/bfrp/BASR_Report_Final_8_Jan_2009-ver4.pdf [accessed February 2009].

Van Dusen, H. G. 1903. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-second regular session, 1903. Oregon Dept. Fisheries, W. H. Leeds, state printer, Salem.

Van Dusen, H. G. 1904. Annual reports of the Department of Fisheries of the State of Oregon for the years 1903 and 1904 to the twenty-third Legislative Assembly (regular session), 1905. Oregon Dept. Fisheries, J. R. Whitney, state printer, Salem.

Van Dusen, H. G. 1907. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-fourth regular session, 1909. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Van Dusen, H. G., and H. C. McCallister. 1908. Annual reports of the Department of Fisheries of the State of Oregon for the years 1907–1908 to the twenty-fifth Legislative Assembly, regular session, 1909. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Vincent-Lang, D. S., and I. Queral. 1984. *In* C. C. Estes and D. Vincent-Lang (eds.), Eulachon spawning habitat in the lower Susitna River. Susitna Hydro Aquatic Studies Report No. 3, Chapter 5, Aquatic habitat and instream flow investigations, May-October 1983. Alaska Power Authority Doc. No. 1934.

Vincik, R. F., and R. G. Titus. 2007. Occurrence of a eulachon, *Thaleichthys pacificus*, in the Lower Sacramento River, California. Calif. Fish Game 93:161–165.

von Szalay, P. G., M. E. Wilkins, and M. M. Martin. 2008. Data report: 2007 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-189. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-189.pdf [accessed 24 February 2010].

Wade, G. 2000a. Salmon and steelhead habitat limiting factors: Water Resource Inventory Area 27. WRIA 27 final report. Washington State Conservation Commission, Olympia.

Wade, G. 2000b. Salmon and steelhead habitat limiting factors: Water Resource Inventory Area 26. WRIA 26 final report. Washington State Conservation Commission, Olympia.

Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, J. A. Hurtado, W. G. Mullarkey, P. E. Reimers, N. T. Richmond, and T. J. Rumreich. 1990. Coos River basin fish management plan. Online at https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/6771/coos+river+basin.pdf;jsessionid=72F413C7D0DCF1D47062D792892BF9C8?sequence=1 [accessed 18 March 2010].

Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, W. G. Mullarkey, N. T. Richmond, and T. J. Rumreich. 1988. Coos Bay Fish Management Plan. Draft No.3. Oregon Dept. Fish and Wildlife, Corvallis (as cited in Monaco et al. 1990).

Wainwright, T. C., and R. G. Kope. 1999. Short communication: Methods of extinction risk assessment developed for U.S. West Coast salmon. ICES J. Mar. Sci. 56:444–448.

Waldman, J. R. 2005. Meristics. *In* S. X. Cadrin, K. D. Friedland, and J. R. Waldman (eds.), Stock identification methods applications in fishery science, p. 197–207. Elsevier Academic Press, Amsterdam.

Waldron, K. D. 1972. Fish larvae collected from the northeastern Pacific Ocean and Puget Sound during April and May 1967. U.S. Dept. Commer., NOAA Tech. Rep. NMFS-SSRF-663.

Ward, D., R. Robison, G. Nye, and D. Reed. 1971. 1970 fisheries statistical report. Washington Dept. Fisheries, Olympia.

Ware, D. M., and G. A. McFarlane. 1989. Fisheries production domains in the northeast Pacific Ocean. *In* R. J. Beamish, and G. A. McFarlane (eds.), Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108:359–379.

Ware, D. M., and G. A. McFarlane. 1995. Climate-induced changes in Pacific hake (*Merluccius productus*) abundance and pelagic community interactions in the Vancouver Island upwelling system. Can. Spec. Publ. Fish. Aquat. Sci. 121:509–521.

Ware, D. M., and R. E. Thomson. 1991. Link between long-term variability in upwelling and fish production in the northeast Pacific Ocean. Can. J. Fish. Aquat. Sci. 48:2296–2306.

WDFHMD (Washington Dept. Fisheries Habitat Management Division). 1992. Salmon, marine fish and shellfish resources, and associated fisheries in Washington's coastal and inland marine waters. Tech. Rep. 79. Washington Dept. Fisheries, Olympia.

WDFW (Washington Dept. Fish and Wildlife). 2009. Final season smelt update, Tuesday–March 31, 2009. Online at http://wdfw.wa.gov/fish/creel/smelt/2009/mar3109.pdf [accessed 24 February 2010].

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2001. Washington and Oregon Eulachon Management Plan. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem. Online at http://wdfw.wa.gov/fish/creel/smelt/wa-ore_eulachonmgmt.pdf [accessed 24 February 2010].

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2002. Status report Columbia River fish runs and fisheries 1938–2000. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem.

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2008. Summary of questions and requested information. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem.

Weinberg, K. L., M. E. Wilkins, and T. A. Dark. 1984. The 1983 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-70.

Weinberg, K. L., M. E. Wilkins, R. R. Lauth, and P. A. Raymore Jr. 1994a. The 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-33.pdf [accessed 24 February 2010].

Weinberg, K. L., M. Zimmermann and R. R. Lauth. 1994b. Appendices to the 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33.

Weinberg, K. L., M. E. Wilkins, F. R. Shaw, and M. Zimmermann. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-128.pdf [accessed 24 February 2010].

Weitkamp, L. 2010. Marine distributions of Chinook salmon from the West Coast of North America determined by coded wire tag recoveries. Trans. Am. Fish. Soc. 139:147–170.

Weitkamp, L., and K. Neely. 2002. Coho salmon (*Oncorhynchus kisutch*) ocean migration patterns: Insight from marine coded-wire tag recoveries. Can. J. Fish. Aquat. Sci. 59:1100–1115.

Wendler, H. O., and G. Nye. 1962. Columbia River investigations progress report, January through December, 1959. Washington Dept. Fisheries, Research Division, Olympia.

Wilcox, W. A. 1898. Notes on the fisheries of the Pacific coast in 1895. Report of the U.S. Commissioner of Fish and Fisheries for the year ending June 30, 1896, XXII:575–659. U.S. Government Printing Office, Washington, DC.

Wilcox, W. A. 1907. The commercial fisheries of the Pacific coast states in 1904. Bureau of Fisheries document 612. *In* Report of the Commissioner of Fisheries for the fiscal year 1905 and special papers. U.S. Government Printing Office, Washington, DC.

Wilkins, M. E. 1998. Appendices to the 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/ Publications/AFSC-TM/NOAA-TM-AFSC-89a.pdf [accessed 24 February 2010].

Wilkins, M. E., and F. R. Shaw. 2000. Appendices to the 1998 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at http://www.afsc.noaa

.gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/Appendices%20to%20NOAA-TM-AFSC-114.pdf [accessed 24 February 2010].

Wilkins, M. E., and K. L. Weinberg. 2002. Appendices to the 2001 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http://www.afsc.noaa.gov/race/media/publications/archives/pubs2002/techmemo128_append.pdf [accessed 24 February 2010].

Wilkins, M. E., M. Zimmermann, and K. L. Weinberg. 1998. The 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-89.pdf [accessed 24 February 2010].

Williams, S. 2009. Letter from S. Williams (Assistant Fish Division Administrator, Oregon Dept. Fish and Wildlife) to G. Griffin (Protected Resources Division, NMFS Northwest Region) 12 May 2009, re: Comments on federal proposed rule to list Pacific eulachon as threatened. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Willoughby, C. 1889. Indians of the Quinaielt [sic] Agency, Washington Territory. *In* Annual report of the Smithsonian Institution, year ending June 30, 1886, Part 1, p. 267–282. Smithsonian Institution, Washington, DC.

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K Koski. 2006. Eulachon: A review of biology and an annotated bibliography. Alaska Fisheries Science Center Processed Rep. 2006-12. U.S. Dept. Commer., AFSC, Auke Bay Laboratory, Juneau. Online at http://www.afsc.noaa.gov/publications/ProcRpt/PR%202006-12.pdf [accessed 24 February 2010].

Willson, M. F., and B. F. Marston. 2002. Fishing success of gulls at a Southeast Alaskan smelt run. J. Field Ornithol. 73:91–96.

Witteveen, B. H., R. J. Foy, and K. M. Wynne. 2004. The effect of predation (current and historical) by humpback whales (*Megaptera novaeangliae*) on fish abundance near Kodiak Island, Alaska. Fish. Bull. 104:10–20.

Womble, J. N. 2003. Seasonal distribution of Steller sea lions (*Eumetopias jubatus*) in relation to high-quality ephemeral prey species in southeastern Alaska. Master's thesis. Univ. Alaska Fairbanks.

Womble, J. N., and M. F. Sigler. 2006. Seasonal availability of abundant, energy-rich prey influences the abundance and diet of a marine predator, the Steller sea lion *Eumetopias juhatus*. Mar. Ecol. Progr. Ser. 325:281–293.

Womble, J. N., M. F. Sigler, and M. F. Willson. 2009. Linking seasonal distribution patterns with prey availability in a central-place forager, the Steller sea lion. J. Biogeogr. 36:439–451.

Womble, J. N., M. F. Willson, M. F. Sigler, B. P. Kelly, and G. R. VanBlaricom. 2005. Distribution of Steller sea lions *Eumetopias jubatus* in relation to spring-spawning fish in Southeast Alaska. Mar. Ecol. Progr. Ser. 294:271–282.

Wood, C. C., J. W. Bickham, J. Nelson, C. J. Foote, and J. C. Patton. 2008. Recurrent evolution of life history ecotypes in sockeye salmon: Implications for conservation and future evolution. Evol. Appl. 1:207–221.

Workman, L. J. 1997. Land of trees: Scannings from Quinault Country, the Grays Harbor Region, and beyond 1774–1997. Quinault Indian Nation, Taholah, WA.

Wright, S. 1999. Petition to list eulachon *Thaleichthys pacificus* as threatened or endangered under the Endangered Species Act. Online at http://www.nwr.noaa.gov/Other-Marine-Species/upload/Smelt_Petition_7_99.pdf [accessed 24 February 2010].

Wydoski, R. S., and R. R. Whitney. 2003. Inland fishes of Washington, second edition, revised and expanded. University of Washington Press, Seattle.

Yang, M. S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-22. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-22.pdf [accessed 24 February 2010].

Yang, M. S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-164. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-164.pdf [accessed 24 February 2010.

Yang, M. S., and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-112. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-112.pdf [accessed 24 February 2010].

Young, J. S. 1984. Identification of larval smelt (Osteichthyes: Salmoniformes: Osmeridae) from northern California. Master's thesis. Humboldt State Univ., Arcata, CA.

Zamon, J. E., and D. W. Welch. 2005. Rapid shift in zooplankton community composition on the northeast Pacific shelf during the 1998–1999 El Niño-La Niña event. Can. J. Fish. Aquat. Sci. 62:133–144.

Zeidberg, L. D., and B. H. Robison. 2007. Invasive range expansion by the Humboldt squid, *Dosidicus gigas,* in the eastern North Pacific. Proc. Natl. Acad. Sci. USA 104:12948–12950.

Zhang, Y., J. M. Wallace, and D. S. Battisti. 1997. ENSO-like interdecadal variability. J. Clim. 10:1004–1020.

Zimmermann, M. 1994. Appendices to the 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

Zimmermann, M., M. E. Wilkins, R. R. Lauth, and K. L. Weinberg. 1994. The 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

# Appendix A: Life History Tables

This appendix contains the following tables:

Table A-1. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **California** | | | |
| Sacramento River | Single fish | | Vincik and Titus 2007 |
| Gualala River | Anecdotal | | Fry 1979 |
| Jacoby and Jolly Giant creeks | Rare | Humboldt Bay | Jennings 1996 |
| Mad River | Irregular | | Moyle et al. 1995, Moyle 2002 |
| Redwood Creek | Irregular | | Moyle et al. 1995, Moyle 2002 |
| Klamath River | Regular | | Moyle et al. 1995, Moyle 2002 |
| Smith River | Rare | | Moyle et al. 1995, Moyle 2002 |
| **Oregon** | | | |
| Winchuk River | Unknown | | Willson et al. 2006 |
| Chetco River | | Chetco Estuary | WDFW and ODFW 2008 |
| Pistol River | Unknown | | Willson et al. 2006 |
| Hunter Creek | Unknown | | Willson et al. 2006 |
| Rogue River | Unknown | | Roffe and Mate 1984 |
| Euchre Creek | Unknown | | Willson et al. 2006 |
| Elk River | Unknown | | Willson et al. 2006 |
| Sixes River | Unknown | Sixes Estuary | Reimers and Baxter 1976 |
| Coquille River | Unknown | | Gaumer et al. 1973, Kreag 1979 |
| Coos Bay/ River | Unknown | Coos Bay | Cummings and Schwartz 1971 |
| Umpqua River | Unknown | Umpqua Estuary | OFC 1970, Johnson et al. 1986 |
| Tenmile Creek (drains lake system) | Unknown | | Willson et al. 2006 |
| Siuslaw River | Unknown | | Willson et al. 2006 |
| Tenmile Creek | Irregular | | WDFW and ODFW 2008 |
| Yaquina River | Unknown | | Borgerson et al. 1991, Willson et al. 2006 |
| Clatskanie River | One-time | Columbia River | Williams 2009 |
| Sandy River | Irregular | Columbia River | WDFW and ODFW 2008 |
| Tanner Creek | One-time | Columbia River | WDFW and ODFW 2008 |
| Hood River | Anecdotal | Columbia River | Smith and Saalfeld 1955 |
| **Washington** | | | |
| Columbia River mainstem | Regular | Columbia River | Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008 |
| Grays River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Skamokawa Creek | Irregular | Columbia River | WDFW and ODFW 2001, 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **Washington, continued** | | | |
| Elochoman River | Irregular | Columbia River | WDFW and ODFW 2001, 2008 |
| Cowlitz River | Regular | Columbia River | Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008 |
| Toutle River | Occasional | Columbia River | WDFW and ODFW 2008 |
| Kalama River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Lewis River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Washougal River | Unknown | Columbia River | WDFW and ODFW 2008 |
| Klickitat River | Anecdotal | Columbia River | Smith and Saalfeld 1955 |
| Bear River | Occasional | Willapa Bay | WDFW and ODFW 2001, 2008 |
| Naselle River | Occasional | Willapa Bay | WDFW and ODFW 2001, 2008 |
| Nemah River | Unknown | Willapa Bay | Smith 1941, WDFW and ODFW 2001, 2008 |
| Wynoochie River | Unknown | | WDFW and ODFW 2001, 2008 |
| Quinault River | Occasional | | WDFW and ODFW 2001, 2008 |
| Queets River | Occasional | | WDFW and ODFW 2001, 2008 |
| Quillayute River | Unknown | | WDFW and ODFW 2008 |
| Elwha River | Occasional | | Shaffer et al. 2007 |
| Puyallup River | Unknown | | Miller and Borton 1980 |
| **British Columbia** | | | |
| Fraser River | Regular | Fraser Estuary | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Squamish River | Irregular | Howe Sound | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Homathko River | Irregular | Bute Inlet-Johnstone Strait | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Stafford/Apple rivers | Unknown | Loughborough Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Port Neville | Unknown | Johnstone Strait | Hay and McCarter 2000, Hay 2002 |
| Franklin River | Unknown | Knight Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Klinaklini River | Regular | Knight Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kakweiken River | Unknown | Thompson Sound-Johnstone Strait | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kingcome River | Regular | Kingcome Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Nekite River | Unknown | Smith Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Hardy Inlet | Unknown | Rivers Inlet | Hay and McCarter 2000, Hay 2002 |
| Clyak River | Unknown | Moses Inlet-Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Wannock River | Regular | Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **British Columbia, continued** | | | |
| Chuckwalla/Kilbella rivers | Regular | Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kwatna River | Unknown | Burke Channel-Kwatna Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Quatlena River | Unknown | Burke Channel-Kwatna Inlet | Moody 2008 |
| Cascade Inlet | Unknown | Dean Channel | Hay and McCarter 2000, Hay 2002 |
| Skowquiltz River | Unknown | Dean Channel | Hay and McCarter 2000, Hay 2002 |
| Taleomy River | Unknown | Dean Channel-South Bentinck Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Noeick River | Unknown | Dean Channel-South Bentinck Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Aseek River | Unknown | Dean Channel-South Bentinck Arm | Moody 2008 |
| Kimsquit River | Regular | Dean Channel | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Dean River | Regular | Dean Channel | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Necleetsconay River/Paisla Creek | Regular | Dean Channel-North Bentick Arm | Moody 2008 |
| Bella Coola River | Regular | Dean Channel-North Bentick Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kainet or Lard Creek | Unknown | Kynoch Inlet-Mathieson Channel | Hay and McCarter 2000, Hay 2002 |
| Aaltanhash River | Unknown | Princess Royal Channel-Aaltanhash Inlet | Hay and McCarter 2000, Hay 2002 |
| Khutze River | Unknown | Princess Royal Channel-Khutze Inlet | Hay and McCarter 2000, Hay 2002 |
| Kemano/Wahoo rivers | Regular | Gardner Canal-Kemano Bay | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kowesas River | Regular | Gardner Canal-Chief Matthew's Bay | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kitlope River | Regular | Gardner Canal | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Foch Lagoon | Irregular | Douglas Channel | Hay and McCarter 2000, Hay 2002 |
| Giltoyees Inlet | Irregular | Douglas Channel | Hay and McCarter 2000, Hay 2002 |
| Kildala River | Regular | Douglas Channel-Kitimat Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **British Columbia, continued** | | | |
| Kitimat River | Regular | Douglas Channel-Kitimat Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Skeena River | Regular | Chatham Sound | Hay and McCarter 2000, Stoffels 2001,Hay 2002 |
| Ecstall River | Unknown | | Stoffels 2001, Moody 2008 |
| Khyex River | Unknown | | Stoffels 2001, Moody 2008 |
| Scotia Creek | Unknown | | Stoffels 2001 |
| Khtada Creek | Unknown | | Stoffels 2001 |
| Kasiks River | Unknown | | Stoffels 2001 |
| Gitnadoix River | Unknown | | Stoffels 2001 |
| Nass River | Regular | Portland Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| **Southeast Alaska** | | | |
| Wilson / Blossom rivers | | Smeaton Bay | Willson et al. 2006 |
| Chickamin River | | | Willson et al. 2006 |
| Unuk/Klahini/Eulachon rivers | Regular | Burroughs Bay | Willson et al. 2006 |
| Stikine River | | | Womble 2003,Willson et al. 2006 |
| Hulakon River, Grant Creek | | Bradfield Canal | Willson et al. 2006 |
| Bradfield River | | | Willson et al. 2006 |
| Speel/Whiting rivers | | Port Snettisham | Womble 2003,Willson et al. 2006 |
| Taku River | | | Womble 2003,Willson et al. 2006,Flory 2008b |
| Mendenhall River | | | Willson et al. 2006 |
| Eagle River | | | Willson et al. 2006 |
| Berners/Lace/Antler rivers | Regular | Berners Bay | Womble 2003, Willson et al. 2006 |
| Katzehin River | | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Skagway River | | Chilkoot Inlet | Willson et al. 2006 |
| Taiya River | | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Chilkoot/Ferebee rivers | Regular | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Chilkat River | Regular | Chilkat Inlet | Womble 2003, Willson et al. 2006 |
| Endicott River | | | Womble 2003, Willson et al. 2006 |
| Excursion River | | | Womble 2003, Willson et al. 2006 |
| Adams Inlet | | Glacier Bay | Womble 2003, Willson et al. 2006 |
| **Yakutat area, Alaska** | | | |
| Dixon River | | | Womble 2003, Willson et al. 2006 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **Yakutat area, Alaska, continued** | | | |
| Fairweather Slough | | | Willson et al. 2006 |
| Sea Otter Cr. | | | Willson et al. 2006 |
| Doame R. | | | Willson et al. 2006 |
| Alsek R., Clear Cr. | | Dry Bay | Womble 2003, Willson et al. 2006 |
| Dangerous/Italio/Akwe rivers | | | Willson et al. 2006 |
| Situk/Ahrnklin rivers/Tawah Cr. | | | Willson et al. 2006 |
| Lost R. | | | Willson et al. 2006 |
| **Southcentral Alaska** | | | |
| Pillar Cr., Kalsin R. (Kodiak Island) | | | Willson et al. 2006 |
| Martin R., Alaganik Slough, Ibeck Slough, Eyak R., Scott R., Copper R. (Copper River Delta) | | | Willson et al. 2006 |
| Resurrection R. | | Resurrection Bay | Willson et al. 2006 |
| Twentymile R., Portage Cr., Placer R., Chickaloon R., Virgin Cr. | | Turnagain Arm | Willson et al. 2006 |
| Susitna R., Yentna R., Beluga R., Kenai R. | | Cook Inlet | Willson et al. 2006 |
| **Western Alaska** | | | |
| Kametolook R. | Unknown | Gulf of Alaska | Willson et al. 2006 |
| Three Star R. | Unknown | Gulf of Alaska | Willson et al. 2006 |
| King Salmon R. | Unknown | Bristol Bay | Willson et al. 2006 |
| Meshik R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Sandy R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Bear R./Milky R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Unnamed river on Unimak Island | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| King Salmon R. | Unknown | Bristol Bay | Willson et al. 2006 |
| Nushagak R. | Unknown | Bristol Bay | Willson et al. 2006 |

Table A-2. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| **Estuary** | **Reference no. and occurrence** | **Personal communication** | **Reference source** |
|---|---|---|---|
| Skagit Bay | 260 rare | D. Penttila, Washington Dept. Fisheries, Seattle | 260. Miller, B. S., and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. 3 Volumes. Washington Sea Grant Program and Washington State Dept. Ecology, Seattle. |
| Hood Canal | 260 not found | D. Penttila, Washington Dept. Fisheries, Seattle | 260. Miller and Borton 1980 (Complete listing above.) |
| Puget Sound | 260, 452 rare | | 260. Miller and Borton 1980 (Complete listing above)<br>452. Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington, University of Washington Press, Seattle. |
| Grays Harbor | 96 | R. Brix, Washington Dept. Fisheries, Montesano | 96. Deschamps, G., S. G. Wright, and R. E. Watson. 1971. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964-1966, p. 1–55. Tech. Rep. No. 7. Washington Dept. Fisheries, Olympia. |
| Willapa Bay | | R. Brix, Washington Dept. Fisheries, Montesano | |
| Columbia River | 118, 269 | R. McConnell, NMFS, Hammond, OR | 118. EPA (U.S. Environmental Protection Agency). 1971. Columbia River thermal effects study. Vol. 1: Biological effects studies. EPA, U.S. Atomic Energy Commission, and National Marine Fisheries Service.<br>269. Misitano, D. A. 1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary, 1973. Fish. Bull. 75(1):218–222. |
| Nehalem Bay | Not found | G. Cailliet, Moss Landing Marine Laboratories, Moss Landing, CA | |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Tillamook Bay | 39, 131 not found | | 39. Bottom, D. L., and B. Forsberg. 1978. The fishes of Tillamook Bay. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis.<br>131. Forsberg, B. O., J. A. Johnson, and S. M. Klug. 1977. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis. |
| Netarts Bay | 399 not found | A. Chung, Oregon State Univ., Corvallis | 399. Stout, H. (ed.). 1976. The natural resources and human utilization of Netarts Bay, Oregon. Oregon State Univ., Corvallis. |
| Siletz River | 384 not found | G. Stewart, Oregon Dept. Fish and Wildlife, Newport | 384. Starr, R. 1979. Natural resources of Siletz estuary. Oregon Dept. Fish and Wildlife, Corvallis. |
| Yaquina Bay | Not found | J. Butler, Oregon Dept. Fish and Wildlife, Newport<br>W. DeBen, U.S. EPA, Newport, OR<br>G, Stewart, Oregon Dept. Fish and Wildlife, Newport | |
| Alsea River | Not found | J. Butler, Oregon Dept. Fish and Wildlife, Newport<br>G. Stewart, Oregon Dept. Fish and Wildlife, Newport | |
| Siuslaw River | 197 rare | J. McCleod, Oregon Dept. Fish and Wildlife, Florence | 197. Hutchinson, J. M. 1979. Seasonal distribution of fishes in Siuslaw Bay. Oregon Dept. Fish and Wildlife, Corvallis. |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Umpqua River | 200, 277, 323 | J. Johnson, Oregon Dept. Fish and Wildlife, Reedsport | 200. Johnson, J., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua estuary April 1977 through January 1986. Information Rep. 86-6. Oregon Dept. Fish and Wildlife, Corvallis.<br>277. Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Information Rep. 77-3. Oregon Dept. Fish and Wildlife, Corvallis.<br>323. Ratti, F. 1979b. Natural resources of Umpqua estuary. Estuary Inventory Rep. 2(5). Oregon Dept. Fish and Wildlife, Corvallis. |
| Coos Bay | 91, 193, 337, 429 rare | W. Mullarkey, Oregon Dept. Fish and Wildlife, Charleston | 91. Cummings, E, and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Information Rep. 70-11. Fish Commission of Oregon, Portland.<br>193. Hostick, G. A. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Information Rep. 74-11, Fish Commission of Oregon, Portland.<br>337. Roye, C. 1979. Natural resources of Coos Bay estuary. Oregon Dept. Fish and Wildlife, Corvallis.<br>429. Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, W. G. Mullarkey, N. T. Richmond, and T. J. Rumreich. 1988. Coos Bay fish management plan. Draft No. 3, Oregon Dept. Fish and Wildlife, Corvallis. |
| Rogue River | 322 rare | A. Riikula, Oregon Dept. Fish and Wildlife, Gold Beach | 322. Ratti, F. 1979a. Natural resources of Rogue Estuary. Estuary Inventory Rep. 2(8). Oregon Dept. Fish and Wildlife, Corvallis. |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
| --- | --- | --- | --- |
| Klamath River | 138 | T. Kisanuki, U.S. Fish and Wildlife Service, Arcata, CA<br>M. Orcutt, Hoopa Valley Tribe, Hoopa, CA.<br>M. Pisano, California Dept. Fish and Game, Arcata<br>R. Warner, California Dept. Fish and Game, Eureka | 138. Fry Jr., D. H. 1979. Anadromous fishes of California. Calif. Dept. Fish and Game, Sacramento. |
| Humboldt Bay | 165, 454 rare | R. Barnhart, U. S. Fish and Wildlife Service, Coop. Fish. Research Unit, Arcata, CA<br>C. Toole, Univ. California Cooperative Extension, Eureka<br>R. Warner, California Dept. Fish and Game, Eureka | 165. Gotshall, D. W., G. H. Allen, and R. A. Barnhart. 1980. An annotated checklist of fishes from Humboldt Bay, California. Calif. Fish Game 66(4):220–232.<br>454. Young, J. S. 1984. Identification of larval smelt (Osteichthes: Salmoniformes: Osmeridae) from northern California. Master's thesis. Humboldt State Univ., Arcata, CA. |
| Eel River | 270, 313 not found | | 270. Monroe, G. W., F. Reynolds, B. M. Browning, and J. W. Speth. 1974. Natural resources of the Eel River delta. Coastal Wetland Series No. 9, California Dept. Fish and Game, Sacramento.<br>313. Puckett, L. K. 1977. The Eel River estuary observations on morphometry, fishes, water quality, and invertebrates. Memo. Rep. California Dept. Fish and Game, Sacramento. |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Tomales Bay | 22, 264, 292 not found | | 22. Bane, G. W., and A. W. Bane. 1971. Bay fishes of northern California with emphasis on the Bodega Tomales Bay area. Mariscos Publications, Hampton Bays, NY.<br>264. Miller, D. J.,and R. N. Lea. 1972. Guide to the coastal marine fishes of California. California Dept. Fish Game. Fish Bull. 157.<br>292. Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50(4):305–307. |
| Central San Francisco/ Suisun/San Pablo bays | 264, 292 not found | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| South San Francisco Bay | Not found, 292, 294 | | 292. Odemar 1964<br>(Complete listing above.)<br>294. Oregon Dept. Fish and Wildlife and Washington Dept. Fisheries. 1987. Status report: Columbia River fish runs and fisheries 1960–1986. ODFW, Portland, and WDF, Olympia. |
| Elkhorn Slough | Not found, 264, 292 | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| Morro Bay | Not found, 264, 292 | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| Santa Monica Bay | Not found, 264 | | 264. Miller and Lea 1972<br>(Complete listing above.) |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| San Pedro Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Alamitos Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Anaheim Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Newport Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Mission Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| San Diego Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Tijuana Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |

Table A-3. Documented occurrence of eulachon in northern California rivers (see Appendix B for transcription of cited newspaper articles).

| Run year | Month | Klamath River | Redwood Creek | Mad River | Humboldt Bay tributaries | Source |
|---|---|---|---|---|---|---|
| 1908 | April-May | | X | | | San Francisco Call, San Francisco, CA |
| 1916 | February | X | | | | Calif. Academy of Sciences ichthyology collection |
| 1919 | February | X | | | | San Jose Mercury Herald, San Jose, CA |
| 1947 | March | X | | | | Calif. Academy of Sciences ichthyology collection |
| 1952 | February | X | | | | Humboldt Standard, Eureka, CA |
| 1955 | February | | X | | | Calif. Academy of Sciences ichthyology collection |
| 1963 | March | X | | | | Calif. Academy of Sciences ichthyology collection |
| | April | X | X | X | | Humboldt Standard, Eureka, CA; Odemar 1964 |
| 1965 | April | X | | | | Humboldt Standard, Eureka, CA |
| 1967 | April | | X | | | The Times-Standard, 14 March 1968, Eureka, CA |
| 1968 | March | X | | | | The Times-Standard, Eureka, CA |
| 1969 | April | X | | | | The Times-Standard, Eureka, CA |
| 1971 | March | X | | | | Humboldt Standard, Eureka, CA |
| 1972 | — | X | | | | Humboldt Standard, Eureka, CA |
| 1976 | April | X | X | X | | Humboldt Standard, Eureka, CA |
| 1977 | May | | | | X | Jennings 1996 |
| 1978 | April | X | X | | | Young 1984 |
| 1979 | March | X | | | | Young 1984 |
| | April | X | | | | |
| 1980 | March | X | | | | Young 1984 |
| | April | X | | | | |
| 1988 | December | X | | | | Larson and Belchik 1998 |
| 1989 | May | X | | | | Larson and Belchik 1998 |

Table A-4. Latitudinal and depth distribution of eulachon in fishery-independent upper continental slope and continental shelf bottom trawl surveys of groundfish on the U.S. West Coast.

| Year | Total no. of hauls | No. hauls with eulachon | Eulachon frequency in hauls | Survey depth range (m) | Survey latitudinal range (dd.mm) | Depth (m) | | | Latitudinal range (dd) | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Min | Max | South | North | |
| **Upper continental slope** | | | | | | | | | | | |
| 1989–1993 | 401 | 25 | 0.06 | 183–1,280 | 38.20–48.10 | 330 | 194 | 589 | 40.40 | 47.51 | Lauth et al. 1997 |
| 1995 | 106 | None | — | 183–1,280 | 40.30–43.00 | — | — | — | — | — | Lauth 1997a |
| 1996 | 203 | 2 | 0.01 | 183–1,280 | 43.00–48.10 | 377 | 366 | 387 | 44.56 | 46.17 | Lauth 1997b |
| 1997 | 182 | 2 | 0.01 | 183–1,280 | 34.30–48.10 | 319 | 259 | 379 | 46.17 | 47.11 | Lauth 1999 |
| 1999 | 199 | 2 | 0.01 | 183–1,280 | 34.30–48.10 | 291 | 242 | 339 | 42.07 | 46.17 | Lauth 2000 |
| 2000 | 330 | 10 | 0.03 | 183–1,280 | 35.00–48.10 | 291 | 186 | 608 | 41.82 | 45.81 | Keller et al. 2005 |
| 2001 | 334 | 1 | <0.01 | 183–1,280 | 34.15–48.10 | 214 | 214 | 214 | 45.03 | 45.03 | Keller et al. 2006a |
| 2002 | 427 | 9 | 0.02 | 183–1,280 | 32.30–48.10 | 250 | 189 | 390 | 44.69 | 46.28 | Keller et al. 2006b |
| **Continental shelf triennial survey** | | | | | | | | | | | |
| 1989 | 539 | 222 | 0.41 | 55–366 | 34.30–49.40 | 141 | 60 | 333 | 34.36 | 49.35 | Weinberg et al. 1994a |
| 1992 | 501 | 196 | 0.39 | 55–366 | 34.30–49.40 | 139 | 59 | 348 | 40.44 | 49.25 | Zimmerman et al. 1994 |
| 1995 | 522 | 88 | 0.17 | 55–500 | 34.30–49.40 | 137 | 66 | 328 | 41.24 | 49.34 | Wilkins et al. 1998 |
| 1998 | 527 | 45 | 0.08 | 55–500 | 34.30–49.40 | 147 | 79 | 322 | 42.24 | 49.14 | Shaw et al. 2000 |
| 2001 | 506 | 130 | 0.26 | 55–500 | 34.30–49.40 | 147 | 62 | 466 | 42.25 | 49.05 | Weinberg et al. 2002 |
| **Continental slope and shelf** | | | | | | | | | | | |
| 2003 | 574 | 29 | 0.05 | 55–1,280 | 32.30–48.10 | 126 | 51 | 237 | 33.97 | 48.40 | Keller et al. 2007a |
| 2004 | 508 | 40 | 0.08 | 55–1,280 | 32.30–48.10 | 119 | 55 | 220 | 34.51 | 48.23 | Keller et al. 2007b |
| 2005 | 675 | 19 | 0.03 | 55–1,280 | 32.30–48.10 | 130 | 96 | 169 | 42.00 | 47.90 | Keller et al. 2008 |

Table A-5. Latitudinal, longitudinal, and depth distribution of eulachon in AFSC fishery-independent bottom trawl surveys of groundfish in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. Data available online at http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm.

| Year | No. hauls with eulachon | Depth (m) | | | Latitudinal range (dd.mm) | | Longitudinal range (dd.mm) | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Min. | Max. | South | North | East | West |
| **Gulf of Alaska** | | | | | | | | |
| 1984 | 178 | 188 | 27 | 393 | 54.40 | 60.28 | 134.23 | 162.40 |
| 1987 | 226 | 170 | 26 | 402 | 54.42 | 60.25 | 132.94 | 162.65 |
| 1990 | 284 | 184 | 20 | 432 | 54.49 | 60.27 | 133.07 | 162.96 |
| 1993 | 294 | 181 | 20 | 351 | 54.35 | 60.32 | 133.33 | 162.60 |
| 1996 | 272 | 165 | 28 | 474 | 53.80 | 60.19 | 132.90 | 166.39 |
| 1999 | 277 | 172 | 16 | 409 | 53.54 | 60.20 | 132.82 | 166.63 |
| 2001 | 117 | 174 | 62 | 297 | 52.64 | 59.87 | 146.97 | 165.43 |
| 2003 | 230 | 173 | 31 | 566 | 52.77 | 60.30 | 132.89 | 169.00 |
| 2005 | 259 | 169 | 23 | 548 | 53.66 | 60.21 | 132.88 | 164.78 |
| 2007 | 237 | 165 | 32 | 516 | 54.24 | 60.30 | 132.83 | 162.10 |
| **Eastern Bering Sea** | | | | | | | | |
| 1982 | 29 | 103 | 40 | 159 | 55.00 | 56.68 | 159.76 | 168.20 |
| 1983 | 43 | 91 | 29 | 159 | 55.00 | 59.65 | 158.42 | 176.56 |
| 1984 | 30 | 108 | 49 | 163 | 54.98 | 57.34 | 159.67 | 170.07 |
| 1985 | 19 | 126 | 101 | 157 | 55.00 | 56.83 | 166.31 | 170.49 |
| 1986 | 38 | 106 | 49 | 155 | 54.99 | 57.01 | 160.37 | 170.07 |
| 1987 | 27 | 114 | 33 | 155 | 55.00 | 57.98 | 159.76 | 168.20 |
| 1988 | 17 | 95 | 31 | 155 | 55.01 | 58.09 | 158.42 | 167.04 |
| 1989 | 21 | 114 | 49 | 159 | 54.82 | 58.00 | 162.79 | 172.20 |
| 1990 | 25 | 102 | 18 | 159 | 55.01 | 60.32 | 158.32 | 170.07 |
| 1991 | 23 | 119 | 49 | 155 | 55.00 | 57.69 | 162.82 | 167.64 |
| 1992 | 27 | 109 | 27 | 155 | 55.00 | 60.36 | 161.00 | 170.07 |
| 1993 | 20 | 95 | 22 | 148 | 55.32 | 59.68 | 159.06 | 171.52 |
| 1994 | 40 | 92 | 16 | 154 | 54.99 | 60.00 | 159.09 | 171.53 |
| 1995 | 38 | 97 | 29 | 143 | 54.99 | 57.01 | 159.08 | 172.66 |
| 1996 | 38 | 104 | 35 | 155 | 54.99 | 57.98 | 158.32 | 172.63 |
| 1997 | 38 | 100 | 39 | 157 | 55.01 | 57.68 | 159.76 | 168.87 |
| 1998 | 56 | 94 | 34 | 154 | 54.99 | 57.99 | 158.97 | 170.49 |
| 1999 | 39 | 106 | 53 | 155 | 55.01 | 57.01 | 162.80 | 168.26 |
| 2000 | 46 | 98 | 37 | 153 | 55.00 | 60.34 | 159.07 | 171.41 |
| 2001 | 62 | 90 | 46 | 153 | 54.99 | 58.00 | 159.02 | 168.90 |
| 2002 | 44 | 91 | 32 | 153 | 55.00 | 58.67 | 158.40 | 168.30 |
| 2003 | 36 | 103 | 32 | 156 | 55.00 | 60.00 | 158.42 | 175.27 |
| 2004 | 39 | 102 | 25 | 156 | 54.99 | 59.32 | 158.35 | 174.46 |
| 2005 | 36 | 101 | 24 | 154 | 55.00 | 61.00 | 159.12 | 176.24 |
| 2006 | 37 | 98 | 36 | 146 | 55.33 | 58.02 | 158.97 | 170.70 |
| 2007 | 48 | 96 | 21 | 155 | 55.00 | 59.00 | 160.36 | 172.86 |
| 2008 | 37 | 100 | 44 | 156 | 54.99 | 61.32 | 160.37 | 174.89 |
| **Aleutian Islands** | | | | | | | | |
| 1986-1997 | 13 | 170 | 62 | 404 | 51.90 | 53.76 | 166.96 | 176.46 |
| 2000-2006 | 12 | 164 | 89 | 197 | 53.58 | 53.78 | 166.77 | 167.37 |

Table A-6. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

| Year | Sex | N | Proportion of fish in each age class 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Columbia River** | | | | | | | | | | | |
| 1984 | NR | 104 | | | <0.11 | **0.50** | 0.27 | 0.08 | <0.05 | | Dammers 1988 |
| 1985 | NR | 100 | | | 0.02 | 0.25 | **0.48** | 0.20 | 0.03 | 0.02 | Dammers 1988 |
| 1986 | NR | 144 | | 0.04 | **0.35** | **0.35** | 0.15 | 0.10 | 0.01 | <0.01 | Dammers 1988 |
| 1992 | NR | NR | | | 0.26 | **0.49** | 0.25 | | | | WDFW and ODFW 2001 |
| 1993 | NR | NR | | | **0.39** | **0.39** | 0.22 | | | | WDFW and ODFW 2001 |
| 1994 | NR | NR | | | **0.66** | 0.28 | 0.006 | | | | WDFW and ODFW 2001 |
| 1995 | NR | NR | | | 0.41 | **0.46** | 0.13 | | | | WDFW and ODFW 2001 |
| 1996 | NR | NR | | | **0.56** | 0.39 | 0.05 | | | | WDFW and ODFW 2001 |
| 1997 | NR | NR | | | **0.60** | 0.33 | 0.07 | | | | WDFW and ODFW 2001 |
| 1998 | NR | NR | | | **0.56** | 0.37 | 0.07 | | | | |
| **Frazier River** | | | | | | | | | | | |
| 1986 | NR | 20 | | | | 0.40 | **0.45** | 0.10 | 0.05 | | Higgins et al. 1987 |
| **Kemano River** | | | | | | | | | | | |
| 1988 | M | 76 | | | 0.24 | **0.45** | 0.29 | 0.03 | | | Lewis et al. 2002 |
| 1989 | M | 101 | | 0.01 | 0.15 | 0.29 | **0.43** | 0.13 | | | Lewis et al. 2002 |
| 1990 | M | 143 | | | 0.15 | **0.48** | 0.33 | 0.03 | | | Lewis et al. 2002 |
| 1992 | M | 158 | | | 0.28 | **0.37** | 0.33 | 0.02 | | | Lewis et al. 2002 |
| 1993 | M | 213 | | | 0.31 | **0.37** | 0.31 | 0.01 | | | Lewis et al. 2002 |
| 1994 | M | 152 | | | **0.41** | 0.40 | 0.19 | | | | Lewis et al. 2002 |
| 1995 | M | 124 | | | 0.13 | **0.39** | 0.32 | 0.15 | 0.01 | | Lewis et al. 2002 |
| 1996 | M | 135 | | | 0.21 | **0.45** | 0.23 | 0.10 | | | Lewis et al. 2002 |
| 1997 | M | 171 | | 0.05 | **0.55** | 0.28 | 0.11 | 0.01 | | | Lewis et al. 2002 |
| 1998 | M | 86 | | | 0.26 | 0.31 | **0.43** | | | | Lewis et al. 2002 |
| 1988 | F | 120 | | | 0.16 | **0.42** | 0.39 | 0.03 | | | Lewis et al. 2002 |
| 1989 | F | 111 | | 0.09 | 0.26 | **0.32** | 0.28 | 0.05 | | | Lewis et al. 2002 |
| 1990 | F | 144 | | | 0.17 | **0.41** | 0.34 | 0.08 | | | Lewis et al. 2002 |
| 1992 | F | 96 | | | **0.47** | 0.39 | 0.14 | 0.01 | | | Lewis et al. 2002 |
| 1993 | F | 192 | | | **0.45** | 0.38 | 0.18 | | | | Lewis et al. 2002 |
| 1994 | F | 175 | | | **0.51** | 0.36 | 0.13 | | | | Lewis et al. 2002 |

Table A-6 continued. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

| | | | Proportion of fish in each age class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Sex** | **N** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Reference** |
| 1995 | F | 118 | | | 0.14 | **0.37** | 0.36 | 0.12 | | | Lewis et al. 2002 |
| 1996 | F | 140 | | | 0.17 | **0.52** | 0.24 | 0.06 | | | Lewis et al. 2002 |
| 1998 | F | 91 | | 0.01 | 0.19 | **0.54** | 0.26 | | | | Lewis et al. 2002 |
| **Kitimat River** | | | | | | | | | | | |
| 1993 | F | 59 | | | **0.75** | 0.20 | 0.02 | 0.03 | | | Pederson et al. 1995 |
| **Nass River** | | | | | | | | | | | |
| 1969 | NR | 53 | | | 0.15 | **0.83** | 0.02 | | | | Langer et al. 1997 |
| 1970 | NR | 256 | | | 0.38 | **0.56** | 0.06 | | | | Langer et al. 1997 |
| 1971 | NR | 378 | | 0.04 | **0.68** | 0.24 | 0.04 | | | | Langer et al. 1997 |
| **Copper River delta** | | | | | | | | | | | |
| Eyak River | | | | | | | | | | | |
| 2002 | NR | 445 | | | 0.01 | **0.97** | 0.02 | | | | Moffit et al. 2002 |
| Alaganik Slough | | | | | | | | | | | |
| 1998 | NR | 460 | | | 0.01 | 0.08 | **0.91** | | | | Moffit et al. 2002 |
| 2000 | NR | 99 | | | **0.73** | 0.27 | | | | | Moffit et al. 2002 |
| Ibeck Creek | | | | | | | | | | | |
| 2001 | NR | 1,215 | | | 0.04 | **0.96** | <0.01 | <0.01 | | | Moffit et al. 2002 |
| **Copper River** | | | | | | | | | | | |
| Flag Point Channel | | | | | | | | | | | |
| 1998 | NR | 2,591 | | | <0.01 | 0.09 | **0.90** | <0.01 | | | Moffit et al. 2002 |
| 2000 | NR | 1,338 | | <0.01 | **0.48** | **0.48** | 0.40 | <0.01 | | | Moffit et al. 2002 |
| 2001 | NR | 1,699 | | <0.01 | **0.56** | 0.43 | 0.01 | | | | Moffit et al. 2002 |
| 2002 | NR | 1,290 | | | 0.01 | **0.98** | 0.01 | | | | Moffit et al. 2002 |
| 60-km Bridge | | | | | | | | | | | |
| 2002 | NR | 812 | | | 0.01 | **0.98** | 0.01 | | | | Moffit et al. 2002 |
| **Twentymile River** | | | | | | | | | | | |
| 2000 | M | 235 | | 0.09 | **0.51** | 0.36 | 0.04 | | | | Spangler et al. 2003 |
| 2001 | M | 585 | | 0.06 | **0.83** | 0.01 | | | | | Spangler et al. 2003 |
| 2000 | F | 49 | 0.02 | 0.23 | **0.57** | 0.14 | 0.04 | | | | Spangler et al. 2003 |
| 2001 | F | 425 | | 0.08 | **0.88** | 0.04 | | | | | Spangler et al. 2003 |

Table A-7. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NR = not recorded, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| **Alaska** | | | | | | | | | | | | | |
| Susitna River | 1982[a] | — | NR, NS | 213.0 | — | — | — | — | — | — | — | — | — |
| | 1983[a] | — | NR, NS | 206.0 | — | — | — | — | — | — | — | — | — |
| Twentymile River | 1976[b] | — | NR | 228.0 | — | — | 209–249 | 22 | 224 | — | — | 210–246 | 40 |
| | 1977[c] | — | NR | 228.0 | — | — | 162–270 | — | 223 | — | — | 202–255 | 408 |
| | | | | | | | | | | | | | Total |
| | 2000[d] | — | FL | 215.0 | — | 0.9 | 166–242 | 222 | 202 | — | 3.0 | 143–234 | 49 |
| | 2001[d] | — | FL | 209.0 | — | 0.5 | 100–241 | 585 | 203 | — | 0.6 | 99–253 | 425 |
| Copper River delta | | | | | | | | | | | | | |
| Eyak River | 2002[e] | 3 | SL | 180.0 | — | 4 | — | 4 | — | — | — | — | — |
| | | 4 | SL | 187.0 | — | 0 | — | 430 | 187 | — | 12 | — | 2 |
| | | 5 | SL | 192.0 | — | 3 | — | 9 | — | — | — | — | — |
| Ibeck Creek | 2001[e] | 3 | SL | 180.0 | — | 2 | — | 40 | 164 | — | 4 | — | 2 |
| | | 4 | SL | 177.0 | — | 0 | — | 1,089 | 171 | — | 1 | — | 75 |
| | | 5 | SL | 186.0 | — | 3 | — | 5 | — | — | — | — | — |
| | | 6 | SL | 182.0 | — | 3 | — | 4 | — | — | — | — | — |
| | 2003[f] | — | SL | 179.0 | — | 10 | 138–207 | 1,249 | 173 | — | 9 | 154–206 | 101 |
| Alaganik Slough | 1998[e] | 3 | SL | 179.0 | — | 3 | — | 6 | — | — | — | — | — |
| | | 4 | SL | 175.0 | — | 2 | — | 35 | 172 | — | 2 | — | 2 |
| | | 5 | SL | 179.0 | — | 0 | — | 377 | 175 | — | 2 | — | 40 |
| | 2000[e] | 3 | SL | 160.0 | — | 1 | — | 47 | 160 | — | 2 | — | 25 |
| | | 4 | SL | 174.0 | — | 3 | — | 21 | 173 | — | 9 | — | 6 |
| Copper River | | | | | | | | | | | | | |
| Flag Point Channel | 1998[e] | 3 | SL | 179.0 | — | 3 | — | 7 | 181 | — | 1 | — | 2 |
| | | 4 | SL | 182.0 | — | 1 | — | 151 | 175 | — | 1 | — | 96 |
| | | 5 | SL | 183.0 | — | 0 | — | 1,848 | 177 | — | 0 | — | 478 |
| | | 6 | SL | 176.0 | — | 2 | — | 7 | 186 | — | 10 | — | 2 |
| | 2000[e] | 2 | SL | 182.0 | — | NA | — | 1 | — | — | — | — | — |
| | | 3 | SL | 174.0 | — | 0 | — | 534 | 168 | — | 1 | — | 109 |
| | | 4 | SL | 176.0 | — | 0 | — | 547 | 172 | — | 1 | — | 99 |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Flag Point Channel | | 5 | SL | 183.0 | — | 2 | — | 43 | 164 | — | 5 | — | 5 |
| (continued) | | 6 | SL | 192.0 | — | NA | — | 1 | — | — | — | — | — |
| | 2001[e] | 2 | SL | — | — | — | — | — | 154 | — | NA | — | 1 |
| | | 3 | SL | 174.0 | — | 0 | — | 643 | 167 | — | 1 | — | 306 |
| | | 4 | SL | 180.0 | — | 0 | — | 571 | 172 | — | 1 | — | 155 |
| | | 5 | SL | 179.0 | — | 2 | — | 21 | 166 | — | 3 | — | 2 |
| | 2002[e] | 3 | SL | 178.0 | — | 3 | — | 16 | 185 | — | 6 | — | 2 |
| | | 4 | SL | 183.0 | — | 0 | — | 1,081 | 178 | — | 1 | — | 175 |
| | | 5 | SL | 188.0 | — | 3 | — | 15 | 190 | — | NA | — | 1 |
| 60-km Bridge | 2002[e] | 3 | SL | 181.0 | — | 8 | — | 3 | 176 | — | 4 | — | 7 |
| | | 4 | SL | 186.0 | — | 0 | — | 575 | 181 | — | 1 | — | 218 |
| | | 5 | SL | 191.0 | — | 3 | — | 9 | — | — | — | — | — |
| Southeast Alaska | | | | | | | | | | | | | |
| Stikine River[g] | 1979 | 2 | FL | 180.0 | — | — | 141–197 | — | — | — | — | — | — |
| | | 3 | FL | 190.0 | — | — | 165–210 | — | — | — | — | — | — |
| | | 4 | FL | 194.0 | — | — | 173–211 | — | — | — | — | — | — |
| | 1980 | 2 | FL | 172.0 | — | — | 155–179 | — | — | — | — | — | — |
| | | 3 | FL | 186.0 | — | — | 162–208 | — | — | — | — | — | — |
| | | 4 | FL | 201.0 | — | — | 195–208 | — | — | — | — | — | — |
| **British Columbia** | | | | | | | | | | | | | |
| Nass River[h] | 1970 | 3 | SL | 173.0 | 11.3 | — | — | 87 | 171 | 16.2 | — | — | 11 |
| | | 4 | SL | 179.0 | 11.2 | — | — | 123 | 181 | 11.8 | — | — | 19 |
| | | 5 | SL | 188.0 | 6.1 | — | — | 12 | 192 | 3.5 | — | — | 4 |
| | 1971 | 2 | SL | 155.0 | 10.9 | — | — | 5 | 144 | 6.9 | — | — | 9 |
| | | 3 | SL | 167.0 | 52.3 | — | — | 74 | 157 | 16.2 | — | — | 183 |
| | | 4 | SL | 174.0 | 10.2 | — | — | 33 | 171 | 10.3 | — | — | 60 |
| | | 5 | SL | 188.0 | 19.8 | — | — | 7 | 183 | 11.3 | — | — | 7 |
| Skeena River | 2003[i] | — | FL, NS | 189.0 | — | 2 | — | 52 | | | | | |
| Kitimat River | 1993[j] | 3 | SL | — | — | — | — | — | 169 | — | 1.5 | 149–187 | 44 |
| | | 4 | SL | — | — | — | — | — | 175 | — | 1.5 | 165–181 | 12 |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kitimat River (cont.) | | 5 | SL | — | — | — | — | — | 184 | — | NA | NA | 1 |
| | | 6 | SL | — | — | — | — | — | 170 | — | 9.5 | 160–189 | 2 |
| | 1997[k] | 2 | SL | 173.0 | 9.9 | — | — | 2 | 162 | 0.0 | — | — | 1 |
| | | 3 | SL | 176.0 | 14.4 | — | — | 28 | 180 | 9.9 | — | — | 25 |
| | | 4 | SL | 175.0 | 12.9 | — | — | 16 | 174 | 11.6 | — | — | 37 |
| | | 5 | SL | 184.0 | 15.6 | — | — | 13 | 183 | 12.7 | — | — | 10 |
| | | 6 | SL | 182.0 | 0.0 | — | — | 1 | 178 | 17.7 | — | — | 2 |
| Kemano River | 1988[l] | 3 | FL | 168.0 | — | — | — | — | 165 | — | — | — | — |
| | | 4 | FL | 175.0 | — | — | — | — | 174 | — | — | — | — |
| | | 5 | FL | 187.0 | — | — | — | — | 186 | — | — | — | — |
| | | 6 | FL | 195.0 | — | — | — | — | 196 | — | — | — | — |
| | 1989[l] | 2 | FL | 190.0 | — | — | — | — | 181 | — | — | — | — |
| | | 3 | FL | 188.0 | — | — | — | — | 181 | — | — | — | — |
| | | 4 | FL | 189.0 | — | — | — | — | 184 | — | — | — | — |
| | | 5 | FL | 189.0 | — | — | — | — | 181 | — | — | — | — |
| | | 6 | FL | 183.0 | — | — | — | — | 176 | — | — | — | — |
| | 1990[l] | 3 | FL | 177.0 | — | — | — | — | 182 | — | — | — | — |
| | | 4 | FL | 188.0 | — | — | — | — | 187 | — | — | — | — |
| | | 5 | FL | 196.0 | — | — | — | — | 194 | — | — | — | — |
| | | 6 | FL | 206.0 | — | — | — | — | 194 | — | — | — | — |
| | 1992[l] | 3 | FL | 177.0 | — | — | — | — | 173 | — | — | — | — |
| | | 4 | FL | 187.0 | — | — | — | — | 182 | — | — | — | — |
| | | 5 | FL | 196.0 | — | — | — | — | 198 | — | — | — | — |
| | | 6 | FL | 207.0 | — | — | — | — | 214 | — | — | — | — |
| | 1993[l] | 3 | FL | 176.0 | — | — | — | — | 170 | — | — | — | — |
| | | 4 | FL | 187.0 | — | — | — | — | 186 | — | — | — | — |
| | | 5 | FL | 198.0 | — | — | — | — | 195 | — | — | — | — |
| | | 6 | FL | 207.0 | — | — | — | — | — | — | — | — | — |
| | 1994[l] | 3 | FL | 169.0 | — | — | — | — | 166 | — | — | — | — |
| | | 4 | FL | 182.0 | — | — | — | — | 181 | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kemano River (cont.) | | 5 | FL | 186.0 | — | — | — | — | 186 | — | — | — | — |
| | 1995[l] | 3 | FL | 171.0 | — | — | — | — | 174 | — | — | — | — |
| | | 4 | FL | 181.0 | — | — | — | — | 182 | — | — | — | — |
| | | 5 | FL | 183.0 | — | — | — | — | 181 | — | — | — | — |
| | | 6 | FL | 190.0 | — | — | — | — | 195 | — | — | — | — |
| | | 7 | FL | 201.0 | — | — | — | — | — | — | — | — | — |
| | 1996[l] | 3 | FL | 188.0 | — | — | — | — | 185 | — | — | — | — |
| | | 4 | FL | 192.0 | — | — | — | — | 185 | — | — | — | — |
| | | 5 | FL | 195.0 | — | — | — | — | 186 | — | — | — | — |
| | | 6 | FL | 193.0 | — | — | — | — | 195 | — | — | — | — |
| | 1998[l] | 2 | FL | — | — | — | — | — | 175 | — | — | — | — |
| | | 3 | FL | 177.0 | — | — | — | — | 172 | — | — | — | — |
| | | 4 | FL | 174.0 | — | — | — | — | 172 | — | — | — | — |
| | | 5 | FL | 181.0 | — | — | — | — | 174 | — | — | — | — |
| | 2003[i] | — | FL, NS | 196.0 | — | 3 | — | 36 | — | — | — | — | — |
| Fraser River | 1986[m] | — | FL | 182.0 | 13.3 | — | 129–212 | 325 | 164 | 21.6 | — | 124–200 | 95 |
| | 1995[n] | — | SL | 158.0 | 11.0 | — | — | 311 | 158 | 10.4 | — | — | 352 |
| | 1996[n] | — | SL | 156.0 | 10.4 | — | — | 241 | 155 | 10.7 | — | — | 218 |
| | 1997[n] | — | SL | 161.0 | 12.0 | — | — | 254 | 158 | 10.4 | — | — | 259 |
| | 1998[n] | — | SL | 158.0 | 12.6 | — | — | 260 | 158 | 15.6 | — | — | 156 |
| | 2000[n] | — | SL | 162.0 | 10.4 | — | — | 108 | 163 | 9.3 | — | — | 93 |
| | 2001[n] | — | SL | 160.0 | 6.4 | — | — | 50 | 156 | 5.3 | — | — | 50 |
| | 4/25/2001[o] | — | FL, NS | 171.0 | 7.2 | — | 117–186 | 138 | — | — | — | — | — |
| | 5/2/2001[o] | — | FL, NS | 171.0 | 7.4 | — | 154–195 | 47 | — | — | — | — | — |
| | 5/3/2002[o] | — | FL, NS | 181.0 | 22.0 | — | 116–206 | 20 | — | — | — | — | — |
| | 2003[i] | — | FL, NS | 183.0 | — | 3 | — | 45 | — | — | — | — | — |
| | 2009[p] | — | — | 192.0 | — | — | — | 77 | 180 | — | — | — | 171 |
| **Washington** | | | | | | | | | | | | | |
| Columbia River | 3/2/1962[q] | — | FL | 155.0 | — | — | 132–180 | 99 | | | | | |
| | 1968 | — | FL | 153.0 | — | — | — | — | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, NA = not applicable.

| Location (river basin) | Date | Age | Method | Male length (mm) Mean | SD | SE | Range | No. | Female length (mm) Mean | SD | SE | Range | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Columbia River (cont.) | 1969 | — | FL, NS | 161.0 | — | — | — | — | — | — | — | — | — |
| | 1978[r] | — | FL | 183.0 | 13.1 | — | 142–250 | 674 | 178 | 12.9 | — | 153–205 | 59 |
| | 1984[s] | 3 | FL, NS | | | | 134–158 | 11 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 125–167 | 52 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 115–185 | 28 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 156–189 | 8 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 148–191 | 5 | — | — | — | — | — |
| | 1985[s] | 3 | FL, NS | — | — | — | 148–150 | 2 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 153–183 | 25 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 156–196 | 48 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 170–204 | 20 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 178–188 | 3 | — | — | — | — | — |
| | | 8 | FL, NS | — | — | — | 192–203 | 2 | — | — | — | — | — |
| | 1986[s] | 2 | FL, NS | — | — | — | 134–145 | 5 | — | — | — | — | — |
| | | 3 | FL, NS | — | — | — | 133–198 | 50 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 125–201 | 50 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 165–211 | 22 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 182–220 | 14 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 201–209 | 2 | — | — | — | — | — |
| | | 8 | FL, NS | 217.0 | — | — | NA | 1 | — | — | — | — | — |
| | 1992[t] | 3 | FL, NS | 169.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 189.3 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 190.8 | — | — | — | — | — | — | — | — | — |
| | 1993[t] | 3 | FL, NS | 164.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 159.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 149.0 | — | — | — | — | — | — | — | — | — |
| | 1994[t] | 3 | FL, NS | 178.7 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 177.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 164.8 | — | — | — | — | — | — | — | — | — |
| | 1994[r] | 2 | FL | 181.0 | 16.8 | — | 151–201 | 12 | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, TL = total length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Columbia River (cont.) | | 3 | FL | 181.0 | 11.6 | — | 163–205 | 25 | 179 | 13.2 | — | 163–193 | 7 |
| | | 4 | FL | 179.0 | 15.8 | — | 156–209 | 16 | 168 | 10.6 | — | 160–175 | 2 |
| | | 5 | FL | 168.0 | 7.5 | — | 160–178 | 5 | 150 | NA | — | NA | 1 |
| | 1995[t] | 3 | FL, NS | 171.3 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 181.0 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 197.5 | — | — | — | — | — | — | — | — | — |
| | 1996[t] | 3 | FL, NS | 168.5 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 179.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 170.2 | — | — | — | — | — | — | — | — | — |
| | 1997[t] | 3 | FL, NS | 165.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 170.5 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 162.8 | — | — | — | — | — | — | — | — | — |
| | 1998[t] | 3 | FL, NS | 173.5 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 181.5 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 175.9 | — | — | — | — | — | — | — | — | — |
| | 2003[i] | — | FL, NS | 175.0 | — | 3 | — | 25 | — | — | — | — | — |
| Cowlitz River | 2/21/1962[q] | — | FL | 162.0 | — | — | 138–195 | 100 | — | — | — | — | — |
| | 3/17/1962[q] | — | FL | 157.0 | — | — | 133–191 | 100 | — | — | — | — | — |
| | 3/19/1962[q] | — | FL | 159.0 | — | — | 143–185 | 50 | 163 | — | — | 121–198 | 98 |
| | 3/31/1962[q] | — | FL | 164.0 | — | — | 134–196 | 99 | 160 | — | — | 121–197 | 98 |
| | 4/5/1962[q] | — | FL | 153.0 | — | — | 128–180 | 100 | 150 | — | — | 118–185 | 95 |
| | 4/7/1962[q] | — | FL | 161.0 | — | — | 134–193 | 97 | — | — | — | — | — |
| Elochoman River | 3/28/1962[q] | — | FL | 153.0 | — | — | 126–190 | 96 | 159 | — | — | 136–194 | 95 |
| Elwha River[u] | 2005 | — | TL | 180.0 | 10.1 | — | 171–195 | 7 | 166 | 28.5 | — | 125–250 | 18 |
| **Oregon** | | | | | | | | | | | | | |
| Tenmile Creek[v] | 1992 | — | FL, NS | 189.0 | — | — | — | 24 | — | — | — | — | — |
| | 1993 | — | FL, NS | 170.0 | — | — | — | 6 | — | — | — | — | — |
| | 1994 | — | FL, NS | 155.0 | — | — | — | 1 | — | — | — | — | — |
| | 2001 | — | FL, NS | 177.0 | — | — | — | 23 | — | — | — | — | — |
| | 2003 | — | FL, NS | 208.0 | — | — | — | 3 | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Tenmile Creek (cont.) | 2005 | — | FL, NS | 165.0 | — | — | — | 7 | — | — | — | — | — |
| | 2007 | — | FL, NS | 170.0 | — | — | — | 1 | — | — | — | — | — |
| | 2008 | — | FL, NS | 182.0 | — | — | — | 1 | — | — | — | — | — |

[a]Barrett et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubik and Wadman 1977
[c]Kubik and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Langer et al. 1977
[i]Clarke et al. 2007
[j]Pedersen et al. 1995
[k]Kelson 1997
[l]Lewis et al. 2002
[m]Higgins et al. 1987
[n]Hay et al. 2002 (their Table 3)
[o]Stables et al. 2005
[p]Plate 2009
[q]DeLacy and Batts 1963
[r]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[s]Dammers 1988
[t]WDFW and ODFW 2001
[u]Shaffer et al. 2007
[v]WDFW and ODFW 2008

Table A-8. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

| Location | | | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Year | Age | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| **Alaska** | | | | | | | | | | | | |
| Susitna River | 1982[a] Not sexed | — | 72.0 | — | — | — | — | — | — | — | — | — |
| | 1983[a] Not sexed | — | 64.0 | — | — | — | — | — | — | — | — | — |
| Twentymile River | 1976[b] | — | 66.0 | — | — | 41–91 | 200 | 68.0 | — | — | 45–95 | 40 |
| | 1977[c] | — | 90.7 | — | — | 45.4–127 | — | 86.2 | — | — | 54.4–127 | 408 |
| | 2000[d] | — | 69.9 | — | 1.0 | 26.5–104 | 222 | 60.0 | — | 2.8 | 29–101 | 49 |
| | 2001[d] | — | 65.8 | — | 0.5 | 6-106 | 585 | 60.1 | — | 0.5 | 28–122 | 425 |
| Copper River delta | | | | | | | | | | | | |
| Eyak River | 2002[e] | 3 | 43.0 | — | 2.0 | — | 4 | — | — | — | — | — |
| | | 4 | 55.0 | — | 0.0 | — | 430 | 50.0 | — | 10.0 | — | 2 |
| | | 5 | 58.0 | — | 2.0 | — | 9 | — | — | — | — | — |
| Ibeck Creek | 2001[e] | 3 | 53.0 | — | 2.0 | — | 40 | 38.0 | — | 2.0 | — | 3 |
| | | 4 | 50.0 | — | 0.0 | — | 1,089 | 46.0 | — | 1.0 | — | 75 |
| | | 5 | 60.0 | — | 5.0 | — | 5 | — | — | — | — | — |
| | | 6 | 52.0 | — | 4.0 | — | 4 | — | — | — | — | — |
| | 2003[f] | — | 56.0 | | 10.0 | 23–89 | 1,249 | 47.0 | — | 9.0 | 31–82 | 101 |
| Alaganik Slough | 1998[e] | 3 | 53.0 | — | 4.0 | — | 6 | — | — | — | — | — |
| | | 4 | 44.0 | — | 1.0 | — | 35 | 34.5 | — | 1.0 | — | 2 |
| | | 5 | 48.0 | — | 0.0 | — | 377 | 39.9 | — | 1.0 | — | 40 |
| | 2000[e] | 3 | 37.0 | — | 1.0 | — | 47 | 35.0 | — | 2.0 | — | 25 |
| | | 4 | 48.0 | — | 3.0 | — | 21 | 43.0 | — | 6.0 | — | 6 |
| Copper River | | | | | | | | | | | | |
| Flag Point channel | 1998[e] | 3 | 52.0 | — | 2.0 | — | 7 | 56.0 | — | 8.0 | — | 2 |
| | | 4 | 57.0 | — | 1.0 | — | 151 | 49.6 | — | 1.0 | — | 96 |
| | | 5 | 55.0 | — | 0.0 | — | 1,848 | 51.1 | — | 0.0 | — | 478 |
| | | 6 | 52.0 | — | 3.0 | — | 7 | 67.0 | — | 14.0 | — | 2 |
| | 2000[f] | 2 | 55.0 | — | NA | — | 1 | — | — | — | — | — |
| | | 3 | 47.0 | — | 0.0 | — | 534 | 43.0 | — | 1.0 | — | 109 |
| | | 4 | 47.0 | — | 0.0 | — | 547 | 47.0 | — | 1.0 | — | 99 |

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

| Location | | | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Year | Age | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Flag Point Channel | | 5 | 53 | — | 2.0 | — | 43 | 39.0 | — | 3.0 | — | 5 |
| (cont.) | | 6 | 60 | — | NA | — | 1 | — | — | — | — | — |
| | 2001[f] | 2 | — | — | — | — | — | 37.0 | — | NA | — | 1 |
| | | 3 | 48 | — | 0.0 | — | 643 | 45.0 | — | 1.0 | — | 306 |
| | | 4 | 52 | — | 0.0 | — | 571 | 48.0 | — | 1.0 | — | 155 |
| | | 5 | 52 | — | 2.0 | — | 21 | 47.0 | — | 3.0 | — | 2 |
| | 2002[f] | 3 | 53 | — | 3.0 | — | 16 | 47.0 | — | 2.0 | — | 2 |
| | | 4 | 57 | — | 0.0 | — | 1,081 | 52.0 | — | 1.0 | — | 175 |
| | | 5 | 62 | — | 3.0 | — | 15 | 66.0 | — | NA | — | 1 |
| 60-km Bridge | 2002[f] | 3 | 57 | — | 7.0 | — | 3 | 51.0 | — | 3.0 | — | 7 |
| | | 4 | 62 | — | 0.0 | — | 575 | 58.0 | — | 1.0 | — | 218 |
| | | 5 | 68 | — | 3.0 | — | 9 | — | — | — | — | — |
| Southeast Alaska | | | | | | | | | | | | |
| Stikine River[g] | 1979 | 2 | 38 | — | — | 18–50 | — | — | — | — | — | — |
| | | 3 | 46 | — | — | 28–60 | — | — | — | — | — | — |
| | | 4 | 52 | — | — | 34–58 | — | — | — | — | — | — |
| | 1980 | 2 | 35 | — | — | 30–42 | — | — | — | — | — | — |
| | | 3 | 46 | — | — | 32–60 | — | — | — | — | — | — |
| | | 4 | 58 | — | — | 52–64 | — | — | — | — | — | — |
| **British Columbia** | | | | | | | | | | — | — | — |
| Skeena River | 2003[h] Not sexed | — | 48.7 | — | 1.7 | — | 52 | — | — | — | — | — |
| Kitimat River | 1993[i] | 3 | — | — | — | — | — | 43.0 | — | 1.5 | 27–71 | 44 |
| | | 4 | — | — | — | — | — | 50.5 | — | 2.0 | 40–60 | 12 |
| | | 5 | — | — | — | — | — | 52.0 | — | NA | NA | 1 |
| | | 6 | — | — | — | — | — | 40.2 | — | 7.8 | 48–80 | 2 |
| | 1997[j] | 2 | 42.4 | 5.9 | — | — | 2 | 33.8 | NA | — | — | 1 |
| | | 3 | 46.2 | 11.3 | — | — | 28 | 44.9 | 10.5 | — | — | 25 |
| | | 4 | 45.6 | 11.0 | — | — | 16 | 41.9 | 9.1 | — | — | 37 |
| | | 5 | 55.0 | 16.6 | — | — | 13 | 48.6 | 12.6 | — | — | 10 |
| | | 6 | 50.4 | N/A | — | — | 1 | 47.2 | 19.7 | — | — | 2 |

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured.

| Location (river basin) | Year | Age | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kemano River | 1988–1998[k] | — | 47.5 | 10.9 | — | — | 1,110 | 44.2 | 10.7 | — | — | 1,433 |
| | 2003[h] | — | 57.5 | — | 2.3 | — | 36 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| Fraser River | 1986[l] | — | 46.3 | 10.7 | — | 13.8–81 | 325 | 34.7 | 14.5 | — | 12.9–63.7 | 95 |
| | 1995[m] | — | 42.8 | 10.9 | — | — | 311 | 44.3 | 9.6 | — | — | 352 |
| | 1996[m] | — | 40.8 | 9.5 | — | — | 241 | 42.8 | 9.9 | — | — | 218 |
| | 1997[m] | — | 38.1 | 9.1 | — | — | 254 | 38.0 | 7.1 | — | — | 259 |
| | 1998[m] | — | 36.7 | 8.6 | — | — | 260 | 37.0 | 9.9 | — | — | 156 |
| | 2000[m] | — | 43.2 | 9.0 | — | — | 108 | 46.2 | 8.4 | — | — | 93 |
| | 2001[m] | — | 36.7 | 5.0 | — | — | 50 | 37.4 | 3.5 | — | — | 50 |
| | 2003[h] | — | 47.2 | — | 1.6 | — | 45 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| | 2009[n] | — | 59.0 | — | — | — | 77 | 51.0 | — | — | — | 171 |
| **Washington** | | | | | | | | | | | | |
| Columbia River | 1978[o] | — | 42.0 | 9.9 | — | 20–76.1 | 674 | 39.6 | 10.6 | — | 20.5–64.3 | 59 |
| | 2003[h] | — | 37.3 | — | 1.8 | — | 25 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| Elwha River[p] | 2005 | — | 40.3 | 5.8 | — | 36–49 | 7 | 28.9 | 12.2 | — | 11–58 | 18 |

[a]Barret et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubic and Wadman 1977
[c]Kubic and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Clarke et al. 2007
[i]Pederson et al. 1995
[j]Kelson 1997
[k]Lewis et al. 2002
[l]Higgins et al. 1987
[m]Hay et al. 2002, their Table 3
[n]Plate 2009
[o]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[p]Shaffer et al. 2007

Table A-9.  Range (gray) and peak (black) timing of documented river entry or spawn timing for eulachon.

[a]References in Table A-3.
[b]WDFW and ODFW 2008
[c]WDFW and ODFW 2001
[d]Shaffer et al. 2007
[e]Ricker et al. 1954, Hart 1943, Hart and McHugh 1944
[f]Mills 1982
[g]Lewis et al. 2002
[h]Moody 2008
[i]Pedersen et al. 1995, Kelson 1996 (cited in Moody 2008).
[j]Lewis 1997
[k]Langer et al. 1977
[l]Franzel and Nelson 1981
[m]Flory 2008b, Berry and Jacob 1998
[n]Marston et al. 2002, Eller and Hillgruber 2005
[o]Betts 1994
[p]Joyce et al. 2004
[q]Moffitt et al. 2002
[r]Kubik and Wadman 1977, 1978, Spangler et al. 2003
[s]Barrett et al. 1984 (cited in Spangler et al. 2003).

Table A-10. Documented avian predators on spawning runs of eulachon.

| Avian predator | River system: Twentymile River[a] | Copper River delta[b] | Berner's Bay[c, d] | Columbia River[e] |
|---|---|---|---|---|
| Gulls (*Larus* spp.) | X | | | |
| Herring gull (*Larus argentatus*) | | X | X | X |
| Thayer's gull (*L. thayeri)* | | | X | X |
| Glaucous-winged gull (*L. glaucescens*) | | X | X | X |
| Glaucus gull (*L. hyperboreus* ) | | | | X |
| Mew gull (*L. canus*) | | X | X | |
| Western gull (*L. occidentalis*) | | | | X |
| California gull (*L. californicus*) | | | | X |
| Bonaparte's gull (*L. philadelphia*) | | X | X | X |
| Ring-billed gull (*L. delawarensis*) | | | | X |
| Terns (*Sterna* spp.) | | | X | |
| Bald eagle (*Haliaeetus leucocephalus*) | X | X | X | X |
| Marbled murrelet (*Branchyrhamphus marmoratus*) | | | X | |
| Cormorants (*Phalacrocorax* spp.) | | | | X |
| Mergansers (*Mergus* spp.) | | | X | X |
| Grebes (*Podiceps* spp.) | | | X | |
| Scoters (*Melanitta* spp.) | | | X | |
| Loons (*Gavia* spp.) | | | X | |
| Corvids | | | X | |
| Common raven (*Corvus corax*) | | X | | |
| Northwestern crow (*C. caurinus*) | | X | | |
| Black-billed magpie (*Pica hudsonia*) | | X | | |

[a]Spangler 2002
[b]Maggiulli et al. 2006
[c]Willson and Marston 2002
[d]Marston et al. 2002
[e]WDFW and ODFW 2001

Table A-11. Temperatures at the time of river entry and spawning for eulachon in different river systems.

| Location | Temperature | Incubation time | Reference |
|---|---|---|---|
| Columbia River | 6.5°–9.0°C | ≈ 21 days | Parente and Snyder 1970 |
| Cowlitz River | 4.5°–7.0°C | 30–49 days | Smith and Saalfeld 1955 |
| Fraser River | 4.0°–5.0°C | ≈ 28 days | Hay and McCarter 2000 |
| Fraser River | 4.4°–7.2°C | 30–40 days | Hart 1973 |
| Kemano River | 1.1°–6.5°C | 50 days | Lewis et al. 2002 |
| Kitimat River | 4.0°–7.0°C | ≈ 42 days | Willson et al. 2006, their Table 4 |
| Nass River | 0.0°–2.0°C | Unknown | Langer et al. 1977 |

# Appendix B: Selected Accounts of Eulachon in Local Newspapers

[*Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting obvious typographical errors without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncracies of spelling and phrasing in the older works are generally preserved. Some of the excerpts are market ads.*]

Table B-1. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| Oregon Spectator | Oregon City, Oregon Territory | Smelt, eulachon | 2-5-1846 | 3-1855 | Oregon Spectator Index, 1846–1855, Vol. 1 and 2 |
| Oregonian | Portland, Oregon Territory | Smelt, eulachon | 12-4-1850 | 1-28-1850 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Morning Oregonian | Portland, OR | Smelt, eulachon | 8-19-1861 | 4-23-1890 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Weekly Oregonian | Portland, OR | Smelt, eulachon | 2-4-1854 | 11-15-1862 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Daily Oregonian | Portland, OR | Smelt, eulachon | 7-19-1869<br>8-11-1869<br>8-19-1869<br>8-23-1869<br>10-2-1875 | | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Oregonian | Portland, OR | Smelt, eulachon | 2-4-1861 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Democratic Standard | Portland, Oregon Territory | Smelt, eulachon | 8-30-1854 | 2-16-1859 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Eugene Register-Guard | Eugene, OR | Umpqua smelt | 1912 | 2007 | Online at news.google.com |
| Vancouver Register | Vancouver, Wash. Territory | Visual search for smelt | 10-7-1865<br><br>2-15-1868<br>6-6-1868 | 9-14-1867<br><br>3-7-1868<br>0-9-1869 | Historic Newspapers in Washington. http://www.secstate.wa.gov/ history/newspapers.aspx |
| Olympia Record | Olympia, WA | Smelt, eulachon | 5-13-1902 | 1-3-1923 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Morning Olympian | Olympia, WA | Smelt, eulachon | 3-15-1891 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Tacoma Daily News | Tacoma, WA | Smelt, eulachon | 8-25-1890 | 12-31-1898 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Bellingham Herald | Bellingham, WA | Smelt, eulachon, hooligan, candlefish | 10-2-1903 | 12-30-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Centralia Chronicle | Centralia, WA | Smelt, eulachon | 8-1-1889<br><br>2-7-1902 | 6-26-1890<br><br>6-13-1902 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| Centralia Daily Chronicle | Centralia, WA | Smelt, eulachon | 5-1-1908 | 1-11-1913 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 9-2-1918 | 2-28-1920 | |
| | | | 7-14-1928 | 12-31-1937 | |
| Centralia Daily Chronicle-Examiner | Centralia, WA | Smelt, eulachon | 1-13-1913 | 12-31-1913 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 7-1-1914 | 12-31-1915 | |
| Centralia News-Examiner | Centralia, WA | Smelt, eulachon | 9-23-1904 | 2-23-1910 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 12-28-1911 | | |
| | | | 10-3-1912 | | |
| | | | 10-21-1912 | | |
| | | | 12-29-1912 | | |
| | | | 12-11-1913 | | |
| | | | 4-11-1916 | 05-18-1916 | |
| Centralia Weekly Chronicle | Centralia, WA | Smelt, eulachon | 11-9-1910 | 10-2-1912 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Chehalis Bee-Nugget | Chehalis, WA | Smelt, eulachon | 10-28-1921 | 5-24-1938 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Chehalis Bee | Chehalis, WA | Smelt, eulachon | 5-21-1897 | | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 7-16-1897 | | |
| | | | 7-23-1897 | | |
| Kalama Beacon | Kalama, Wash. Territory | Visual search | 5-19-1871 | 2-10-1874 | Univ. Washington Library, Microfilm A-48 |
| Eureka Humboldt Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 1-1-1958 | 05-31-1967 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Humboldt Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 1-1-1952 | 12-31-1957 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Times-Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 6-1-1967 | 12-31-1977 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| San Francisco Call | San Francisco, CA | Smelt, candlefish, candle fish, eulachon | 1895 | 1910 | California Digital Newspaper Collection. http://cbsr.tabbec.com/ |
| San Francisco Bulletin | San Francisco, CA | Smelt, candlefish, candle fish, eulachon | 10-8-1855 | 12-31-1891 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| San Jose Mercury News | San Jose, CA | Smelt, candlefish, candle fish, eulachon | 11-5-1861 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |

# Oregon (Columbia River)

**Morning Oregonian (Portland), Saturday, 6 April 1867, p. 4, col. 2**

> Smelt—Holman & Co. of the Union Fish Market have just received a fine lot of smelt, halibut, etc. They keep on hand the best and freshest fish of the season. Call on them on Washington Street near Second.

**Morning Oregonian (Portland), Thursday, 9 April 1868, p. 4, col. 6**

Fish! Fish!
At the Franklin Fish Market!
134 First St., Portland
Just Received Fresh from the Fisheries, Smelt by the Million

**Morning Oregonian (Portland), Friday, 15 January 1869, p. 2, col. 4**

New To-Day, Oak Point Smelt!
At the Franklin Fish Market, 134 First Street.
Just Received by the Str. Ranger—large supply.

**Morning Oregonian (Portland), Thursday, 21 January 1869, p. 2, col. 4**

Fresh Oak Point Smelt at the Franklin Fish Market by the Steamer "Okanagan"

**Morning Oregonian (Portland), Tuesday, 25 January 1870, p. 2, col. 4**

New Today, Fresh Smelt, Three Pounds for 25 Cents
Arrived last night at the "Union Fish Market," Washington Street between First and Second
Hotels and Restaurants Supplied Cheap—J. Quinn.

**Daily Oregonian (Portland), Saturday, 28 January 1871, p. 2, col. 3**

New To-Day, Fresh Smelt
A Fresh Lot Arrived Last Night for Sale at Quinn's Union Fish Market on Waddington Street.
Hotels and Restaurants Supplied at Low Rates.

**Daily Oregonian (Portland), Wednesday, 1 February 1871, p. 4, col. 1**

Local Brevities

> Six tons of smelt arrived from down the river on Monday night, and the market may be said to be full and terms in favor of the buyer.

**Daily Oregonian (Portland), Saturday, 20 January 1872, p. 3, col. 2**

Local Brevities

> The first smelt of the season appeared in the market last evening.
>
> The First Smelt at Quinn's—Quinn, of the Union Market, Washington Street, is, as usual, the first on hand with the delicacies of the season. This time he has the first catch of smelt. Call early, if you would make sure of a mess.

**Daily Oregonian (Portland), Friday, 16 February 1872, p. 3, col. 3**

> Smelt—Quinn, of the Union Fish Market, has sufficient quantity of smelt now to supply all demands. The prices are so low that everybody can eat 'em. … Don't go home without a mess of smelt.

**Daily Oregonian (Portland), Tuesday, 8 December 1874, p. 2, col. 2**

First Smelt!
The First Lot of Smelt of the Season!
At Quinn's, 3 lbs for 25 Cents

**Daily Oregonian (Portland), Wednesday, 17 March 1875, p. 3, col. 3**

> Smelt—the first of the season—from the Columbia River in large quantities at Malarkey's, Second Street, between Stark and Washington. Get a mess.

**Daily Oregonian (Portland), Tuesday, 22 February 1876, p. 2, col. 5**

Columbia River Smelt!
First of the Season of 1876
At C. A. Malarkey's New York Market, S.E. Cor. Stark and Second streets

**Daily Oregonian (Portland), Friday, 25 February 1876, p. 3, col. 3**

1,000 Pounds Fresh Columbia River Smelt, for Sale Wholesale and Retail by C. A. Malarkey, S.E. Corner Stark and Second streets.

**Daily Oregonian (Portland), Wednesday, 1 March 1876, p. 2, col. 4**

Fresh Columbia River Smelt. I received last night the largest lot that has come to market this season. 3 lbs for 25 cts. C. A. Malarkey New York Market, S. E. Cor. Stark and Second streets.

**Daily Oregonian (Portland), Saturday, 4 March 1876, p. 2, col. 3**

Caution.

> Fresh Columbia River Smelt. The public are cautioned against buying Puget Sound Smelt for Columbia River Smelt. Come to headquarters for the latter.

Large lot received again last night. C. A. Malarkey, New York Market, S. E. Cor. Stark and Second.

**Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3**

Columbia River Smelt!
First of the Season of 1878!
Wholesale and Retail at Chas. A. Malarkey's New York Market
S.E. Cor. Stark and Second sts., Portland

**Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3**

Hurra! Hurra!
First Columbia River Smelt of the Season
Smelt! Smelt! Smelt!
At 5 Cents per Pound
Wholesale and Retail at Dougherty & Browne's Washington Market
Corner Fourth and Washington streets

**Daily Oregonian (Portland), Thursday, 22 January 1880, p. 2, col. 3**

Smelt, Smelt, Columbia River Smelt
First of the season 1880
At C. A. Malarkey's New York Market, Stark Street between First and Second

**Morning Oregonian (Portland), Thursday, 5 February 1880, p. 1, col. 4**

Smelt fishermen are making good wages on the river now. Some make $40 a night with dip nets. Hapgood Cannery at Waterford has put up 8,000 pounds. There is a big run.

**Daily Oregonian (Portland), Thursday, 12 February 1880, p. 3, col. 1**

Dead Smelt—A gentlemen who came up the river from Astoria yesterday, informs us that millions of smelt are dying from some unknown cause in the Columbia and floating ashore. In the vicinity of Pillar Rock the bank is lined with these little fish for some distance, and hundreds of voracious sea gulls are constantly devouring them.

**Morning Oregonian (Portland), Saturday, 8 January 1881, p. 2, col. 3**

Smelt, Columbia River Smelt, Season 1881
A Fine Lot just Received by C. A. Malarkey, New York Market
N.E. Corner Oak and Second Street
Country Orders Promptly Filled

**Morning Oregonian (Portland), Wednesday, 27 February 1882, p. 3, col. 1**

C. A. Malarkey, Second and Oak, Will Receive this Morning a Choice Lot of Columbia River Smelt.

**Morning Oregonian (Portland), Tuesday, 6 March 1883, p. 2, col. 4**

New To-Day, Smelt, First of the Season
At Williams & Sons General Market

**Morning Oregonian (Portland), Tuesday, 13 March 1883, p. 3, col. 7**

Smelt! Smelt! Columbia River Smelt!
These Most Delicious Fish Are Now Being Received by C. A. Malarkey Daily
Orders from the Country Will Be Filled Promptly.
C. A. Malarkey, New York Market, N.E. Corner Oak and Second St.

**Morning Oregonian (Portland), Monday, 25 February 1884, p. 1, col. 8**

Smelt, Smelt, Columbia River Smelt!
First of the season of 1884 have now arrived
Send your orders to Chas. A. Malarkey, N.W. Corner Fourth and Morrison streets

**Morning Oregonian (Portland), Tuesday, 4 March 1884, p. 2, col. 4**

Smelt, Smelt, Columbia River Smelt!
The Most Delicious of All Fish are Now Coming to Market
Country Customers Will Find It to their Advantage to Order from C. A. Malarkey, Fourth and Morrison sts

**Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 1**

Columbia River Smelt

> These delicious little fish have made their appearance at Astoria, and C. A. Malarkey corner of Fourth and Morrison has made arrangements to receive a full supply during the season. He expects the first lot to-day. Call early and leave your order.

**Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 3**

Local and General

> The Little Fish Coming—Polish up your frying pan, for Malarkey says he is going to have Columbia River smelt to-day. These little fish have become of considerable importance to fishermen and several boats have been kept on the lookout for their advent for the past two weeks. The advance guard of the immigration came up the river a little way some days since, but smelling the snow

in eastern Oregon, took a wheel back. The ones behind are shoving on the ones before, and countless millions of smelt are crossing in over the bar, anxious to reach the Cowlitz or the Sandy.

**Oregonian (Portland), Wednesday, 25 February 1885, p. 3, col. 1**

Brief Mention

Considerable anxiety has been expressed about the Columbia River smelt fleet now overdue here and anxiously awaited by all good citizens. It is now stated that the smelt are hovering off the bar waiting for a pilot.

**Oregonian (Portland), Friday, 27 February 1885, p. 3, col. 2**

Fish In Supply. … The first box of Columbia River smelt, so long looked for, was received by J. W. and V. Cook last evening. It contained about 20 pounds—the result of a night's fishing by five men. There will be plenty in a few days, sure.

**Daily Oregonian (Portland), Friday, 13 March 1885, p. 3, col. 2**

Local and General

No Hope For Smelts—Fishermen generally have about given up hope of a smelt harvest this year. In speaking of the matter yesterday, a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years. It would be interesting to know why the smelt deserted the river and in what ocean wilderness they wandered all these 40 years. If they have gone again to stay 40 years, most of us may as well say good-bye to them for we'll eat no more Columbia River smelt unless the doctrine of transmogrification is true, in which case if a fellow is changed into a seal or a sturgeon he may have a chance at them once more.

**Morning Oregonian (Portland), Sunday, 31 January 1886, p. 5, col. 1**

There is a great rivalry just now among the fish dealers. The first smelt are now in the market. Malarkey went down the river yesterday, met the steamer as she was coming up and secured all the smelt, which were piled up last night triumphantly on his tables.

**Morning Oregonian (Portland), Tuesday, 2 February 1886, p. 3, col. 1**

Wm. McGuire & Co., corner Third and Morrison streets, corralled all of the smelt that came to town yesterday, consequently they have the only fresh smelt in the city. They received 25 large boxes—over 4,000 pounds—and are prepared to furnish everybody at reasonable prices. They are prepared to fill all orders from the country at lowest rates and guarantee perfect satisfaction. Send in your orders. Telephone 371.

**Morning Oregonian (Portland), Sunday, 7 February 1886, p. 5, col. 6**

Columbia River Smelt

Wm. McGuire & Co., Third and Morrison, have made arrangements to receive large supplies of fresh smelt daily and are prepared to fill all orders from the country at lowest rates. Send in your orders early.

**Morning Oregonian (Portland), Tuesday, 10 February 1886, p. 2, col. 4**

Smelt And Salmon

Columbia River smelt and genuine Chinook salmon received daily and for sale in any quantity from one pound to one ton by C. A. Malarkey, corner of Fourth and Morrison streets.

**Morning Oregonian (Portland), Saturday, 11 December 1886, p. 5, col. 1**

The first Columbia River smelt of the season came up yesterday to George Ginstin, of the Baltimore Market, No. 290 First.

**Morning Oregonian (Portland), Wednesday, 19 January 1887, p. 3, col. 2**

Local and General

A Few Good Fish— … Vin Cook says they had a mess of Columbia River smelt down at Clifton the other day, but have not been able to catch any since. It will not be long till these delicious little fish are here.

**Oregonian (Portland), Friday, 28 January 1887, p. 3, col. 2**

Local and General

Fish In Demand— … while [another fisherman] proudly exhibited a sample of genuine Columbia River smelt. Vin Cook has a party on the lookout for the arrival of these anxiously awaited little fish, and they yesterday sent him up several pounds. The advance of the main school of smelt may be expected any day now. It was about this time last year that the first shipment came up.

**Oregonian (Portland), Thursday, 24 February 1887, p. 5, col. 2**

Local and General

> Fishing For Smelt—No doubt many people once in a while give a thought to the Columbia River smelt, which would have been in market before now but for the cool spell, but probably very few have any idea of the number who are keeping a sharp lookout along the Columbia for the advent of these little fish. Although the Columbia from the mouth of the Willamette for a long way up has been frozen for some time and there has been snow all along down the river, not a day has passed for the last three weeks but what seines have been put out and dip nets plied at various points in vain search for the smelt. At Oak Point two men in the employ of a fish dealer here have been going out twice every day for the past three weeks and probing the Columbia with dip nets, but nary a smelt have they caught. As the ice is now going out the fish may be expected any day.

**Morning Oregonian (Portland), Monday, 1 March 1887, p. 3, col. 4**

> Fish dealers were all on hand when the [steamer ship] Telephone arrived yesterday, expecting to see a shipment of Columbia River smelt. They were disappointed, but the little fish will be here soon or not at all.

**Morning Oregonian (Portland), Saturday, 5 March 1887, p. 3, col. 3**

Brief Mention

> The prospect is that we are to have no Columbia River smelt this season.

**Oregonian (Portland), Wednesday, 9 March 1887, p. 3, col. 3**

Local and General

> Coming Up on the Rise—People had about given up all idea of seeing any Columbia River smelt this season, but it appears that they have not deserted us but were only lying off the mouth of the river waiting for the water to become decently warm in order to swarm to their spawning place in the Cowlitz and Sandy. Deep sea fishermen at Astoria report that the cod and groupers caught by them of late have been literally filled with smelt and they predict a large run. The late heavy warm rains have put the schools a motion and in a few days it will perhaps be possible to walk across the Sandy on the backs of the smelt. …
>
> Smelt at Last—Late last night McGuire & Co., fish dealers, corner o' Third and Morrison streets, received a telegram from down the river stating that several boxes of Columbia River smelt would arrive on the [steamer ship] Telephone today for them. These will be the first smelt of the season and as the steamer will arrive about 2:30 everybody can have smelt for dinner by leaving orders early today.

**Morning Oregonian (Portland), Thursday, 10 March 1887, p. 5, col. 3**

Local and General

The Smelt Here—The first lot of smelt of the season arrived on the [steamer ship] Telephone yesterday, and very fine they were, being much larger and plumper than the first to arrive usually are. A number of them were evidently caught by Indians in the old-fashioned way by sweeping a stick armed with sharp pointed nails through the water and impaling the smelts thereon.

**Morning Oregonian (Portland), Friday, 11 March 1887, p. 3, col. 3**

And now the smelt come in earnest. C. A. Malarkey came up the river last evening having secured the entire catch of these delicious fish along the Columbia for the day some two tons in all. He is prepared to furnish all both great and small, and as he has the only smelt in the city orders should be left early this forenoon.

**Sunday Oregonian (Portland), 26 February 1888, p. 5, col. 3**

Fish and Fishing

… The smelt season is about over apparently. They have not come above the Cowlitz as yet, and are not likely to visit the Sandy this season. They have gone so far up the Cowlitz now that there is trouble to get them and boxes of them which a few days ago could be bought for 50 cents have jumped to $3.

**Sunday Oregonian (Portland), 11 March 1888, p. 5, col. 2**

In and About Portland

Large quantities of smelt still continue to be sent up from the Cowlitz. Nothing has been heard of them reaching the Sandy yet.

**Morning Oregonian (Portland), Thursday, 13 December 1888, p. 8, col. 1**

Picked Up About the Town

The First, Lone Smelt—Mr. Calper, who has a salmon fishery on Lewis River, a day or two since caught a fine large Columbia River smelt, which in some manner became entangled in his net. This is the first smelt of the season, and it comes to hand unusually early, as they generally put in an appearance some time in February. It is also a little strange that the first smelt heard from should be taken in Lewis River, as for the three past seasons the shoals of these fish have not come any farther up than the Cowlitz. It will hardly be worth while for our epicures to make up their mouths for smelt yet awhile. One swallow does not make it summer, nor does one smelt make it spring, and in all probability we shall have a cold snap before we shall see smelt in the market.

**Morning Oregonian (Portland), Thursday, 27 December 1888, p. 5, col. 2**

Portland and Vicinity

Smelt for Christmas Dinner—Last evening a gentleman marched into the reporter's room of The Oregonian office and left a parcel with the compliments of Vin Cook. On opening the package it was found to be a cigar box filled with genuine Columbia River smelt, which glistened in the lamplight like silver. A short time since a notice was published in The Oregonian of a single smelt having been caught by Mr. Calper in his salmon seine in Lewis River. Mr. Cook, who is at Clifton, seeing this, sent out a boat to drift for smelt and enough was caught to make a course for the Christmas dinner for all hands at Clifton and some left to send to The Oregonian. It is hardly probable that any one in this region ever had Columbia River smelt for dinner on Christmas before. The smelt usually arrive in February and what they mean by coming so much earlier than usual this year it is impossible to say. They have some queer ways, as only a few years since they forgot to come up entirely. It may be that they have had some premonition that there would be no winter this time and if so the chances are ten to one that they will find themselves fooled. If the weather should "come off" warm with rain it is not unlikely that there will be smelt in the market very soon.

**Morning Oregonian (Portland), Saturday, 12 January 1889; p. 8, col. 1**

Gathered by Reporters
First Shipment for the Season of Columbia River
Smelt Quickly Disposed Of

Nothing Too Rich For Us—The first shipment of Columbia River smelt of this season arrived here yesterday. There were only 35 pounds of them, and they were all disposed of by McGuire & Co. before they arrived for 50 cents per pound, that being the price fixed by the fishermen, who have been out drifting for several nights in hopes of making a haul. The price made no difference, and many more could have been sold. Wealthy people at the East think nothing of paying a dollar a pound or more for the first salmon or trout of the season, and our wealthy people are not going to be left on the first Columbia River smelt, no matter what the price is.

**Morning Oregonian (Portland), Thursday, 21 February 1889, p. 5, col. 1**

Columbia River Smelt—Columbia River smelt are coming in plentiful and Malarkey & Co., corner of Fourth and Morrison streets, have enough to supply everybody at cheaper prices than ever before. The run will not last long and if you want a mess of these delicious little fish now is the time to get them. This firm makes a specialty of shipping these fish and orders from the country for any quantity will be promptly filled.

**Morning Oregonian (Portland), Friday, 22 February 1889, p. 4, col. 3**

Smelt, Smelt

> Columbia River Smelt are now growing plentiful and cheap. Parties wishing to procure smelt for salting down can buy them by the box at a low price. Remember that the run lasts but a short time. Malarkey & Co., Fourth and Morrison streets.

**Morning Oregonian (Portland), Wednesday, 18 December 1889, p. 6, col. 7**

The Very First of the Season
A Small Lot of Smelt Have Put in an Appearance in the City

> A small lot of genuine Columbia River smelt were displayed at C. A. Malarkey & Co.'s market yesterday. They were, it is needless to say, the first of the season, and as the fisherman who sent them up wrote, "they are the earliest smelt that ever went into Portland market." J. B. Johnson captured them near Quinn's Landing, and the 25 pounds represent three night's work out in the cold. He has got ahead of Vin Cook this year, and broken the record, for no living man has ever seen Columbia River smelt here so early before. They generally arrive about the 1st of January, and when they come it is considered that winter is over. Many who saw the smelt yesterday, said "well winter is over," but it is more probable that the smelt have made a mistake. Many things have been mentioned as tending to indicate that we are to have a hard winter, but the arrival of these smelt is the first thing which seems to indicate that winter is over, and we might as well cling to the hope till it is dispelled.

**Morning Oregonian (Portland), Monday, 23 December 1889, p. 5, col. 1**

> Something about Early Smelt—Mr. James Quinn, formerly a well-known resident of this city, but for years a resident at Quinn's Landing on the lower Columbia, demurs to the statement published in these columns a few days since, to the effect that some Columbia River smelt received here on that day were, as the man who caught them claimed, the earliest smelt ever seen in the Portland market. Mr. Quinn says he had fresh Columbia River smelt in his market on Washington Street, on the 8th of December, 1869. From this it appears that Mr. Johnson in 1889 was 10 days behind Mr. Quinn in 1869 in getting smelt to this market. It is the belief of many fishermen that smelt and Chinook salmon both are in the river all winter, and could be taken if fished for, but the game would hardly be worth the candle.

**Morning Oregonian (Portland), Friday, 22 January 1892, p. 5, col. 2**

> The Smelt as a Weather Prophet—The shoals of smelt which have been in the Columbia River for the past month or six weeks have struck into the Cowlitz. Over a ton of these fish were sent up from the Cowlitz Wednesday evening, and it was supposed that they would continue to be plentiful, but the next day only a

small lot arrived, and it is feared that the shoals will soon go up the river out of reach, and the smelt season will be over. The fact that the smelt have started up for their spawning grounds is considered by many to indicate that winter is over. It is scarcely probable that there will be any ice or snow this winter.

**Morning Oregonian (Portland), Monday, 28 November 1892, p. 6, col. 2**

Columbia Smelt. An Unusually Early Catch of the Dainty Little Fish

A lot of Columbia River smelt were received in this city Saturday, and very fine ones they were. This is the earliest time of year that smelt have ever been caught. They were taken by J. B. Johnson, near Eagle Cliff, and the first sales were made at 75 cents per pound, which is the highest price ever paid for the delicious little pan fish.

The Columbia River smelt did not put in an appearance formerly, as a general thing, till about the 1st of February, and if there happened to be a cold winter and ice in the Columbia, they did not materialize until after the ice had gone out, when they arrived in the Cowlitz in immense shoals, and shortly after in the Sandy in like numbers. For several years past fishermen have been using dip nets in the Columbia, searching for smelt, and last year and the year before at Christmastime they caught small lots right along. The first man who got a shipment into market received a high price, as every market man was anxious to have the first lot, which he had no trouble in disposing of at 50 cents per pound. The price would soon drop to 25 cents, then to a bit, and when the shoals of fish got into the Cowlitz they would sell for 5 cents. Soon they would be shipped all over the country, and then there would be many more smelt than could be got rid of at any price.

The fact that the smelt were to be found in the river in December led some to imagine that they were there all winter, staying in deep water. If such is the case, Mr. Johnson, who made this early catch and broke the record, has probably found one of their haunts. Some people think that the freshet in the Columbia—if a rise of five feet at Vancouver can be called a freshet—has brought the fish up the river. There is no probability, however, of their going up the Cowlitz to their spawning grounds till the snow is gone out of the mountains at the headwaters of that stream.

The Columbia River smelt is what is called farther north the oolihan, or candlefish, and is esteemed as one of the most delicious little fish caught. Salmon and trout have no superiors in their season, but the smelt comes at a season when other fish are scarce, and so is most esteemed. If it is going to come at this season and mix itself up with Sound smelt and all the other fish in the market, its good qualities will have to submit to the test of comparison.

**Morning Oregonian (Portland), Monday, 1 January 1893, p. 5, col. 1**

Smelt Have Returned—The Columbia River smelt, which arrived earlier this season than ever before so far as known, and were well along on their way up the

Cowlitz River to their spawning grounds when the snow storm came on and drove them back, have re-entered the Cowlitz and will for a time be plentiful in the local market. They re-entered the Cowlitz last Friday, and a man who happened to be loafing along the bank of the river saw them pouring up the stream in a solid column about two feet in width. He hastily secured a dip net, worked with a will for two hours, caught the boat coming to this city and sold his catch for $25. He was much elated with his success, and expressed his intention of devoting the remainder of his life to fishing.

**Morning Oregonian (Portland), Wednesday, 2 January 1895, p. 9, col. 1–2**

Great Quantities of Smelt

The Columbia River smelt, the most delicious of panfish, during the past year commenced coming to market in October, more than a month earlier than ever known before. Small quantities have been received almost daily ever since, but within the past week the shoals have entered the Cowlitz River, on their way to their spawning grounds, and they have been taken in large quantities. The change in the weather has been so slight as hardly to check them, although ice or snow might send them back into the deep waters of the Columbia. With the first rains, the immense shoals of these fish will swarm the Cowlitz and tons of them will be coming to market, and they will be shipped to all parts of the country. No method has yet been discovered of preserving the delicate flavor of these fish, which are so fat as to be known to the Indians as the candle fish. Large quantities might be put up yearly if any process could be discovered which would preserve their good qualities.

**Morning Oregonian (Portland), Thursday, 28 March 1895, p. 8, col. 3–4**

The Big Run of Smelt

The enormous run of smelt in the Sandy River is attracting wide attention. If all the statements of those who have been out there are true, and they seem to be verified by the wagonloads of smelt taken, the run is the biggest that has been seen in the Sandy for the past 15 years. When the O. R. & N. railroad was in course of construction, and there was a large encampment on the river, the water suddenly came alive with the fish, and the railroad employees feasted on smelt for several days. Great wagonloads were taken. The next run occurred six years ago, it is claimed by those who know, but the run was comparatively small, and was soon over. There are now hundreds of people catching smelt by the tons. A wagon may be filled in half an hour. The wagon is driven into the shallow water, and the fish are scooped into the wagon by means of a small scoop net. It is stated some of the farmers are catching the fish in wagonloads and distributing them over their farms for fertilizing purposes, where some are smoking them, and many are being packed in salt. The fish move along close to the shore. The females come with the first run, and the males afterward. One can put his hands in the water and feel the fish bumping against them. Mr. Joseph Paquet was down the river several days ago and saw indications that the fish were going up the river. They were followed by droves of seagulls, watching, apparently, to catch the fish which happen to come near the surface. They were on the way to spawning-ground. The habits of the smelt are rather peculiar. They have usually appeared in the Cowlitz River, and not in the Lewis River, but this year they have entered the Lewis and very few in the Cowlitz. The run went on past the Willamette and entered the turbid and always discolored waters of the Sandy River. W. F. Allen, who was on the Sandy in all the smelt runs for the past 30 years, will go out today and see how the present run sizes up with what he saw in the long ago.

**Morning Oregonian (Portland), Monday, 1 April 1895, p. 5, col. 4–5**

All Fished for Smelt
Large Number of Portlanders Visit the Sandy to Enjoy the Sport

The banks of the Sandy River for many miles were the scene of great activity all day yesterday, made so by the presence of hundreds of pleasure seekers, bent upon catching smelt or watching others catch them. A gentleman who has made a careful estimate, from personal observation, states that the catch during the week has fully averaged 100 tons per day. It is thought that this run is the greatest that has occurred for over 30 years, and of the longest duration. The runs do not usually last over five or six days, but the fish were still running very thick yesterday, the eighth day. It is thought the run will now dwindle down, as all fish now going up are males. The females go up to the spawning grounds first and they are followed by the males. It is inferred that the run is almost over, as the males have already been running since the middle of the week. As far as could be ascertained yesterday no females were caught, all being males, very firm and plump. A few of the fish gave evidence of some hard knocks during their trip up the river. If the gentleman who estimated the catch at 100 tons a day is right the entire catch during the run will foot up a 1,000 tons.

All yesterday vehicles of every sort, loaded with families, well supplied with boxes and sacks and dip nets, prepared to catch smelt, poured to the banks of the Sandy. The favorite place was at the county bridge. The river has here cut a deep channel through the slightly wooded uplands, and winds its sinuous ways like a thread of silver to blend with the majestic Columbia, a few miles below. Where the bridge spans the river there is a sort of open space, and to the southeast the river makes a gentle curve, sweeping around a gravel and sandbar of about five acres in extent. A full view of the bridge and surroundings may be had from the county road to the westward, just before it plunges down a winding grade to the bridge. The gravel was covered with fishermen and women, both great and small. With long poles, on which were suspended dip nets made of most anything that will allow the water to run off, they were constantly dipping out the sluggish smelt. Toward the point of the gravel bank, which the water sweeps around swiftly, a dozen or more of wagons had been backed into the stream up to the hub, and these were being filled by means of nets of larger size. It was an interesting sight to see these wagons fill up and others take the place. The men swung the nets with monotonous regularity, and rarely ever failed to bring up from a dozen to half a dozen wriggling fish. The smelt seemed to run around this point in more condensed bunches than below, along the margin of the gravel bank. The experienced fisherman was provided with a sort of metal funnel, well perforated with holes, on the end of a light pole, about eight feet long. But it was comparatively an easy matter to catch in a few minutes all anyone would care to take of them.

From a sportsman's point of view the taking of fish in this manner cannot be regarded as very exhilarating exercise, still it is a sort of change. One good thing about it is that no one went home without a fine string, or rather sack of fish. The smelt caught in the Sandy were very plump and firm. At this time of year the river is very clear and cold. Evidence of prodigality and waste was apparent from the piles of half-dried fish near the bridge. And yet, with all the millions which were taken from the river, millions went on to the spawning ground. On their return trip they keep well in the center of the river and move faster than when on the way up.

A large number of people went out from the city in carriages and on bicycles merely to see the fishing. It was a day that will not soon be forgotten in the interior of the county, and if there is a family within 10 miles of the Sandy that has not had a feast of fish last week, it has not been because they could not be had in unlimited quantities.

**Morning Oregonian (Portland), Wednesday, 4 December 1895, p. 12, col. 3**

First Smelt Arrive
But They're Mighty Dear—Wait, and They'll Soon Be Cheaper.

Among the various species of fish which form the great harvest of the mighty Columbia, none is more eagerly looked for or more highly appreciated than the smelt, the Columbia River smelt, or "candle-fish," being considered by many people of this section the prince of all pan fish. Ten or a dozen years ago, they did not appear in this market as a general thing till after the cold weather was past, in February or March, or as soon as the main school began crowding up the Cowlitz and other tributaries of the Columbia to their breeding grounds. Of late years fishermen have taken to fishing for them with seines in the Columbia, and it has been found that they are in the river nearly all winter, and year after year they have been coming earlier and earlier to market, the fishermen who gets in the first lot reaping a rich reward for his trouble. The first lots have sold for 50 cents per pound, and, as they become more plentiful, the price goes down to 25 cents, then to 15 cents, and finally to 5 cents, when they come in by scores of bushels at a time, till finally they are so plentiful that there is no sale for them.

Last year the smelt arrived just before Christmas, and the run lasted a long time, the quantity of little fish disposed of here being probably much greater than in any previous year and yielding a handsome return to the fishermen. This was the earliest the smelt ever came to market; but the record has been beaten this season, as a small lot, just a few pounds, were received here yesterday. This is positively the earliest arrival of smelt known, and unless freezing weather comes on and drives them back, or to the bottom, it may be expected that the fish will soon arrive in quantities. They were held at 75 cents per pound, as they were looked upon more as a curiosity than as an article of merchandise.

The sturgeon, which, until within the past year or two, thronged the Columbia and devoured enormous quantities of smelt, are now very scarce, and this will probably result in an increase in the shoals of smelt, which, however, have always been immense.

**Morning Oregonian (Portland), Tuesday, 29 December 1896, p. 9, col. 4**

The Story of Smelt
How It Is Mentioned by an Early Visitor to Oregon

A gentleman of this city, who has a copy of "Francheve's Narrative," which is the diary of Gilbert Francheve [Franchère], of Montreal, who was a clerk in the trading company of John Jacob Astor, and who visited the Columbia in 1811, is of the opinion that Francheve makes the first mention of the Columbia River smelt. He says:

"February brings a small fish about the size of a sardine. It has an exquisite flavor, and is taken in immense quantities by means of a scoop net, which the Indians, seated in canoes, plunge into the schools, but the season is short, not even lasting two weeks."

The season for smelt has grown much longer within the past few years, since fishermen have made it a business of going out hunting for the advance guards of the schools. Some years since, they were seldom seen in market until February, when the great schools began pushing their way up the Cowlitz and Sandy to their spawning grounds, and in a short time the run was over, or the fish had become soft and not fit for food. Last year the first smelt caught in the Columbia in drift nets came to market in December, and the season lasted nearly three months, the fish being good all the time till after they were well on their way to the spawning grounds.

It is probable that mention has been made of the vast schools of smelt entering the Columbia before Francheve [Franchère] wrote his diary, as the smelt were always here, and the earliest residents along the river have described how the Indians caught them by means of a long rod, through which nails had been driven, forming a sort of comb, or rake, which they moved swiftly through the schools of smelt, bringing up many impaled upon these nails. Smelt fishing now brings in considerable money to the fishermen, owing to the greater length of the season. Late in the season the price gets very low, but then the only limit to the catch is the amount that can be disposed of. Many are salted by farmers along the river, and some are smoked, but the fish is best in a fresh state, and for the pan has no superior on the coast.

**Morning Oregonian (Portland), Saturday, 7 December 1907, p. 12, col. 1–2**

Good Things in Portland Markets, by Lilian Tingle

Columbia River smelt cost 50 cents [per pound].

**Morning Oregonian (Portland), Saturday, 14 December 1907, p. 12, col. 1–2**

Good Things in Portland Markets, by Lilian Tingle

Columbia River smelt … are 20 to 25 cents per pound.

**Morning Oregonian (Portland), Saturday, 29 February 1908, p. 5, col. 1–2**

Good Things in Markets, by Lilian Tingle

I saw even more varieties of fish in the market than there were last week. Columbia River smelt were 12½ cents a pound, and scarce at that, when I inquired about it, but more may be in today.

**Morning Oregonian (Portland), Saturday, 7 March 1908, p. 12, col. 1–2**

Good Things in Markets, by Lilian Tingle

Columbia River smelt was selling at two pounds for 25 cents ….

**Morning Oregonian (Portland), Saturday, 19 December 1908, p. 10, col. 2**

What the Markets Offer, by Lilian Tingle

Columbia River smelt are more plentiful and are to be had at a reasonable price.

**Morning Oregonian (Portland), Saturday, 24 December 1908, p. 15, col. 2**

What the Markets Offer, by Lilian Tingle

The cold weather has kept the price of Columbia River smelt up to 30 and 35 cents a pound.

**Morning Oregonian (Portland), Saturday, 9 January 1909, p. 8, col. 2**

Good Things in Markets

Columbia River smelt was about 10 cents a pound yesterday, but the supply is of course affected by the weather.

**Morning Oregonian (Portland), Tuesday, 2 February 1909, p. 9, col. 2**

The Run Is On—Fresh Columbia River smelt, 5 cents a pound. Maces Market, 151 Fourth Street.

**Morning Oregonian (Portland), Saturday, 13 February 1909, p. 12, col. 4**

Good Things in Markets

Columbia River smelt was selling at 4 and 5 cents a pound earlier in the week, but cost 7 to 10 cents when I inquired; and no man would risk a statement as to whether it was likely to be down again today or up higher.

**Morning Oregonian (Portland), Friday, 24 December 1909, p. 10, col. 2**

Good Things in Markets

The fish market is exceedingly well supplied with the sea dainties for which Portland is famous … Columbia River smelt, 40 to 50 cents [per pound].

**Morning Oregonian (Portland), Saturday, 12 February 1910, p. 12, col. 2**

Good Things in Portland Markets, by Lilian Tingle

Columbia River smelt may be considered the most interesting feature of the market this week, of interest alike to epicure and economist. At 5 cents a pound, or six pounds for a quarter, this dainty fish is within the reach of everyone. Many thrifty housekeepers take advantage of the season of plenty, and buying smelt by the box at about 3 cents a pound. Proceed to secure inexpensive future breakfast or luncheon dishes by salting, smoking, pickling or canning this "violet of the waters."

**Sunday Oregonian (Portland), 13 February 1910, p. 9, col. 4–5**

Smelt Cannery Offered
Kelso Owners Seek Someone to Operate Plant
Heavy Catches Are Accompanied by No Diminution of Supply—Cowlitz Yields Well

Owners of an idle canning plant in Kelso are seeking someone who will engage in the packing of Columbia River smelt in that city.

F. L. Stewart, a banker of Kelso, who is in Portland, expresses the conviction that the opportunities are good for using the plant for smelt canning in winter and fruit and vegetable canning in the spring and summer. The cannery was started as a cooperative venture, but has been idle about two years.

Although the smelt, now so generously in the Portland markets, bear the name "Columbia River," the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately

15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

In spite of the heavy catches there is apparently no diminution in the yearly runs of fish and at the height of the season they get down to a low figure.

At the beginning of the present season fishermen got $3 a box for the first run, but the price, as the run increased, dropped rapidly until now the fishermen realize about 25 cents a box. Last year the price went as low as 15 cents. The largest catch reported this season was 45 boxes, taken between 7 and 11 a.m., by two men in one boat.

Some of the residents of Kelso smoke the fish as they would herring and find that smoked smelt are a delicacy. The cannery plan, however, would be to put them up in form similar to sardines.

**Morning Oregonian (Portland), Thursday, 17 February 1910, p. 8, col. 4**

Cowlitz Full of Smelt
Big Run May Presage Prosperous Salmon Season Later On

Astoria, Ore., Feb. 16—The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fisherman.

This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon.

**Sunday Oregonian (Portland), 27 February 1910, Section 5, p. 8**

Smelt Fishing on the Cowlitz
How an Army of Men Catch the Biggest Run Known in the Last 20 Years
By R. G. Callvert

A hobo the other day wandered along the fringe of the riverbank that lies between the floating docks and the railroad track at Kelso, picking up discarded smelt for an easy meal.

"Here, drop those rotten fish and come down and get some fresh ones," shouted a fisherman from a float where smelt were being packed into boxes for shipment.

Discarded fish may look good to a tramp in most countries, but in Kelso during the smelt run only a stranger with a most aggravated antipathy to exertion need go without the freshest product of the Cowlitz River.

Had the tramp known it and been inclined toward the effort, an old can tied at the end of a stick plunged into the water from a nearby log boom would have brought him up in one sweep all the smelt he could eat in a day. Or by lying on the log boom he could have pulled out enough fish with his bare hands for a square meal.

There is not much romance connected with the taking of the smelt that are so plentiful in the markets of Portland and the Northwest during four or five months of each winter. There is no battling with waves and storms such as are encountered by the hardy herring fishermen of the Atlantic. For the sportsman, smelt fishing would be just about as exciting as clam digging and the amount of skill required about the same. Smelt fishing furnishes tales, however, that are novelties among fish stories in that while almost unbelievable they are nevertheless true.

During the smelt runs fish are so plentiful that even the voracious seagull becomes almost sated. When the gulls are at all hungry the fishermen sometimes find amusement tossing smelt into the air, which the birds catch before they reach the water. A seagull on the wing will seize a fish perhaps by the tail and reverse it with a toss in the air and gulp it head first in the twinkling of an eye.

So plentifully do the smelt run that frequently children bail them out of the water with tin cans securing half fish and half water. When the water is shallow enough the smelt can be taken with the bare hands, for the skin of the fish is not slimy when in the water.

While the Cowlitz River is the only known spawning ground for smelt where the fish may be taken year by year, they have been known to run up the Lewis River and also up the Sandy. At the time the smelt ran up the Lewis River, 14 years ago, there was only a small run of male smelt in the Cowlitz and the fishermen transferred their operations to the Lewis. When smelt run in numbers up the river it is apparently independently of the Cowlitz run and it is said to occur in the Sandy about once in eight years. It is truthfully related that at the time of the last run up the Sandy a party of Portland young men went out with dip nets on a fishing expedition. One man lost his dip net, but luckily found an old, rusty, discarded birdcage. This he attached to the end of a pole and successfully kept pace with his more fortunate companions. This is the only record in fishing annals of successful fishing with a birdcage, although if the novelty of the experiment invites one it can undoubtedly be successfully duplicated in the Cowlitz River any day between now and April 1.

During the last big smelt run in the Sandy farmers drove their wagons to stream, filled them with dip nets and used the fish for fertilizing fruit trees. An unusually large quantity of pork with a fishy taste sold in the markets some months afterwards revealed the fact that some of the farmers had utilized the fish surplus in feeding their hogs.

This season the Cowlitz River is the spawning ground of the greatest run of smelt ever known by fishermen who have been engaged in the business for 20 years. It is now estimated that by the close of the season the river will have yielded 300,000 boxes of smelt, each box weighing 50 pounds. This will represent an output of 10,000,000 pounds or 5,000 tons and a smelt average about eight fish to the pound means the marketing of 80,000,000 fish.

The smelt has peculiarities of his own, as pronounced as those of the salmon. What is known commercially as the "Columbia River smelt" is caught in paying quantities regularly year by year only in Cowlitz River, which is a tributary of the Columbia River rising in the State of Washington.

The main fishing grounds of the river extend over an area during the season of not more than eight or 10 miles as a rule. Like those of the salmon the smelt runs come in from the sea through the mouth of the Columbia River. In the earliest catches, when smelt bring from $3.50 to $3 per box, the fish are taken in limited numbers in the Columbia.

In the Columbia some fish are caught in the early season by gillnetters, but when the season is well along the gillnetter cannot compete with the regular smelt fisherman, for the former has to pick the fish out one by one from the meshes of his net. The latter uses a dip net attached to a long pole, and after locating a school of fish simply bails them out of the river and into his boat, sometimes getting as many fish as he can lift out of the water.

The smelt lie in schools close to the bottom of the river and are therefore found at varying depths. The fisherman prospects for the schools with the reverse end of his pole, and if the end of the pole is plunged into an accumulated number of fish, the wriggles of the small bodies that results is communicated to the hands of the fisherman.

Most of the fishing is done at night, for the light of day seems to scatter the fish, yet even in daylight hours the fishermen are able to pursue their occupation with good results.

Before Kelso accumulated a variety of industries along its waterfront, one of the best fishing points was opposite the Northern Pacific depot, from where one can toss a stone into the water. The driving of piles, however, seems to have driven the fish farther up the stream, and this season they have been found most plentifully about one and one-half miles above the town. Between the small floating docks and the fishing grounds boats are continually plying, going upstream empty and returning ladened with fish. Fully 500 boats are utilized in the industry and of these about 75 are powerboats.

As a rule there are two men to each boat and the crafts are filled in almost an incredibly short space of time. Last Tuesday night J. A. Sprague, one of the principal shippers of Kelso, and one companion loaded his launch to its capacity in 45 minutes. This represents a catch of 45 boxes, or one 50-pound box a minute. Last year a catch of 125 boxes for two men held the record for a night's fishing. This year there have been frequent occasions when two men brought in 200 boxes to represent a day's work.

To the ordinary fisherman who has no regular market to supply, a catch of 200 boxes of smelt in the height of the season is worth about $50. On the Cowlitz River; however, there are a number of men who ship direct to retail markets, maintain boats of their own and buy from other fishermen. Portland wholesalers have buyers at Kelso and probably the greater portion of the retail trade is supplied through Portland. At Kelso, however, smelt have been shipped direct as far East as Wisconsin.

The output of the river, say the fishermen, could be greatly increased if the market demands were sufficient to justify more men engaging in the industry. Kelso has no facilities for shipping fish in cold storage. A cold storage plant is one of the enterprises the town wants, for it is believed that the market can be broadened and a demand created in the Far Eastern states. Canning in the form of sardines is also suggested, and in Kelso there is a cannery that was utilized as a cooperative plant by fruit and vegetable growers until last year, that will be turned over to any experienced man who will engage in the business.

Kelso has a group of enterprising citizens who have done much to build up the town to its present population of 2,800. Practically the same group of businessmen established the electric light plant and city waterworks, built a $15,000 opera house, erected a drawbridge across the Cowlitz River, which they afterwards sold to the county, established a newspaper office, invested in the cooperative cannery mentioned and have aided and encouraged several other enterprises.

They are now seeking to put the smelt fishing on a basis where it will pay better returns to the fishermen and increase the number of men engaged in the industry. This effort is apparently justified, for though the output of smelt is slowly growing year by year, the increasing inroads upon the schools of fish do not seem to diminish their number.

Cowlitz River fishermen are now advocating the licensing of persons engaged in commercial smelt fishing. Frequently, during the season, schoolboys will go out, load up a few boats with fish and become easy marks for the buyers. The result is a demoralizing market, the boys being content with enough money to buy candy or a few toys. Often too, groups of Greeks or Italians will come up the Cowlitz in boats, remain at the fishing grounds for a few days and sell their catches for whatever they can get, again upsetting the prices paid the regular fishermen. The men who are regularly engaged in the industry want the protection of a reasonable license, which, they believe, will cut out the itinerant fisherman.

It is a saying among fishermen that a big run of smelt presages a big run of salmon. If this is true, the salmon fisheries of the Columbia should have a prosperous season this year, for the smelt run is unprecedented in volume.

**Morning Oregonian (Portland), Thursday, 8 December 1910, p. 21, col. 6**

Smelt in the River
Good Hauls Looked For in about 10 Days

Astoria, Ore., Dec. 7— … Two days ago a few smelt were seen at the mouth of Grays River, showing that they are beginning to come in, and good hauls of this class of fish may be looked for in about 10 days or two weeks.

**Morning Oregonian (Portland), Thursday, 5 January 1911, p. 21, col. 1**

Run of Smelt is Small

Astoria, Ore., Jan 4.—(Special)—Quite a few smelt have been caught during the last few days in the vicinity of Clifton, but none has been taken as yet in the Grays River. It is said the water in that stream is too low and a freshet must come before the smelt will be attracted that way.

**Morning Oregonian (Portland), Saturday, 7 January 1911, p. 12, col. 4**

Good Things in Markets

Columbia River smelt, though less costly than on its first appearance, sold yesterday at 25 cents a pound, but will probably soon reach the lower prices we are accustomed to.

**Morning Oregonian (Portland), Saturday, 11 February 1911, p. 8, col. 4**

Good Things in Markets

The day of very cheap Columbia River smelt is not yet, though any market man will tell you it may be expected at any time now. Smelt were selling yesterday at 10 to 12½ cents a pound, and were quite scarce at that, though earlier in the week they were to be had at three pounds for 25 cents.

**Morning Oregonian (Portland), Friday, 18 February 1911, p. 10, col. 3**

Good Things in the Market

The smelt are here! The run is sufficiently strong to reduce the price to 5 cents a pound, and at every dealer's the fish are on hand in boxfuls.

**Morning Oregonian (Portland), Wednesday, 22 February 1911, p. 18, col. 2**

Marine Notes

First of the season's catch of smelt in the Cowlitz River, amounting to 35 tons was brought to Portland on the steamer Lurline. Another consignment was transported by the steamer Joseph Kellogg.

**Morning Oregonian (Portland), Saturday, 25 February 1911, p. 12, col. 2**

Good Things in Markets, by Lilian Tingle

The heavy run of Columbia River smelt has come in earnest this week. The delicious little fish are selling at three pounds for a dime, 10 pounds for a quarter, or one dollar a box, and there is enough for every one.

**Morning Oregonian (Portland), Saturday, 2 December 1911, p. 11, col. 2**

First Columbia River Smelt of the Season at Mace's Market

**Morning Oregonian (Portland), Saturday, 27 January 1912, p. 4, col. 3**

Good Things in Markets

> Columbia River smelt is not really plentiful, but is to be had at 6 to 8 cents a pound.

**Morning Oregonian (Portland), Saturday, 10 February 1912, p. 12, col. 4**

Good Things in Markets, by Lilian Tingle

> Columbia River smelt are still the leading feature in the fish markets, and are selling at about 8 cents a pound.

**Morning Oregonian (Portland), Tuesday, 2 April 1912, p. 7, col. 3**

Smelt Run Now On
Millions of Small Fish Enter the Sandy River
Sunday Crowds Active

> Troutdale, Ore., April 1—(Special)—This thriving little city should have been named Smeltdale, as there isn't a trout anywhere near it. But the dainty little smelt is just now the attraction that has made the town the Mecca of thousands who are all returning home laden down with all the fish they care to take away with them.
>
> The great run of smelt from the Columbia River began on Thursday last and was at its greatest yesterday. An ideal day and the prospect of unlimited catches, together with the exciting sport of taking them, brought people from every direction. The banks were lined with teams from all over the county and automobiles from the city, and the entire day was spent in a vain effort to deplete the Sandy River of its finny denizens.
>
> Millions Will Die [subhead]
>
> Thousands were caught but millions got away, only to swim against the strong current for a few days longer and then float back dead, dying or exhausted, when the greatest run known will all be over.
>
> Nine years ago there was a similar run of smelt in the Sandy. This is the only river, excepting the Cowlitz that is ever entered by them from the Columbia. No one can ever predict when they are coming. It is only when the water is seen to be fairly alive with them that the word goes out and for a few days all other business is suspended while the people from far and near lay in a big supply.
>
> Birdcages Used as Nets [subhead]

Yesterday's sport was exciting enough. It was attended with many involuntary baths and much mirth. The fishing appliances consisted of nets tied to long poles and every scoop into the water brought up fish.

In place of the regulation net there were to be seen improvised scoops made of wire gauze, coal oil cans and even birdcages. A motion picture outfit made films and every sort of a water craft did a rushing business all day long.

The great run will cease as suddenly as it began.

**Morning Oregonian (Portland), Saturday, 23 November 1912, p. 16, col. 4**

Smelt Are Running Early
Fish Caught Close to Ocean Bring Fancy Prices

ASTORIA, Ore., Nov. 22—(Special)—Smelt are entering the river earlier this year than ever before. Last night one man who was fishing for herring in the lower river not far from Sand Island caught a pound and a half of smelt in his net, and as a result he is going out with a regular smelt net.

Columbia River smelt are considered the most toothsome fish found on the coast, and when caught close to the ocean are exceptionally fine, those taken early in the season often selling as high as a dollar a pound.

**Sunday Oregonian (Portland), 15 December 1912, p. 14, col. 4**

Good Things in Markets

Columbia River smelt is the "newest thing" in the fish market and is available, in small quantities only, at 25 cents a pound.

**Sunday Oregonian (Portland), 2 February 1913, p. 16, col. 5**

Good Things in Markets

Columbia River smelt again is in the market, in generous supply, and can now be had at six pounds for 25 cents.

**San Jose Evening News (San Jose, CA), Monday, 14 April 1913, p. 5, col. 4–5**

Unusual Run of Smelt near Portland—Farmers Carry Fish by Wagonloads for Fertilizer

Portland, Ore., April 14—A run of smelt which promises to break all records has come into the Sandy River, a tributary of the Columbia, 12 miles from Portland.

An army of farmers and people from the city are busy scooping out the little fish in water buckets, dip nets, inverted birdcages and with pitchforks. The supply is so far beyond the demands of the markets that farmers are hauling them off by the wagonload and distributing them over their plowed lands as fertilizer.

One cent a pound is the market price for smelt along the Sandy, with but scant demand, since people there and in Portland have become surfeited with them.

Heavy runs of smelt in the Sandy appear at intervals of several years, but this one is denominated a freak. The run is both ahead of time and unusually heavy.

**Morning Oregonian (Portland), Saturday, 29 November 1913, p. 12, col. 1**

Good Things in Portland Markets

The first Columbia River smelt of the season is on the market this week at $1 a pound.

**Morning Oregonian (Portland), Friday, 5 December 1913, p. 14, col. 4**

Columbia Smelt on Sale
Weather Makes Fish Scarce and Retail Price is 25 Cents a Pound

Columbia River smelt have appeared in the market. The run, so far, has been a small one, and as long as the present kind of weather continues, the fish will not be plentiful, but warm rains and higher water in the river will bring them in abundance.

The big run, which is due later, will be in the Cowlitz River. Smelt are retailing in the markets at 25 cents a pound.

**Morning Oregonian (Portland), Wednesday, 14 January 1914, p. 14, col. 2**

Marine Notes

First of the smelt caught this season in the Cowlitz River arrived yesterday on the steamer Joseph Kellogg, the shipment consisting of 60 boxes. Owing to high water in that stream the catch is regarded as light.

**Sunday Oregonian (Portland), 18 January 1914, p. 6, col. 6**

Columbia River smelt are so plentiful as to confound the price jugglers.

**Morning Oregonian (Portland), Thursday, 5 February 1914, p. 16, col. 6**

Marine Notes

It was estimated that the deliveries of smelt from the Cowlitz River and lower Columbia district yesterday were between 1,200 and 1,500 boxes. The launch Frolic brought 425 cases from the Cowlitz.

**Morning Oregonian (Portland), Friday, 27 February 1914, p. 14, col. 3–4**

Good Things in Markets

> Columbia River smelt is still at flood tide and is expected to be abundant [in the fish market] until possibly the middle of March.

**Morning Oregonian (Portland), Tuesday, 31 March 1914, p. 10, col. 6**

Smelt Are Destroyed
Prosecutions May Follow Use of Fish as Fertilizer
Mr. Finley Says Law against Wanton Waste of Food Will Be Enforced against Sandy River People

> The smelt running in the Sandy River are attracting many people to that locality. Inasmuch as the fish are extremely plentiful, it is no trouble at all to catch them in nets or makeshift scoops. The fact that the fish are so abundant has led many persons to catch them without limit.
>
> "The State Board of Fish and Game Commissioners desire to give public notice that the law passed as the last session of the Legislature concerning the wanton waste of fish will be strictly enforced," said William L. Finley. "The Columbia River smelt is one of our most valuable commercial fish. The fact that it comes in great numbers into Cowlitz, the Sandy and certain other streams at about this time of the year, leads some people to believe that the supply is inexhaustible.
>
> "These fish come in from the sea and go into the rivers to spawn. We have to depend upon our future supply from the natural spawning of these fish. At the present time many people living in the vicinity of Troutdale are catching far greater numbers of these fish than they have any use for; in fact, they are loaded into gunny sacks and into wagons and not used in any way except as a fertilizer.
>
> "It is an economic waste and an outrage that such a fine pan fish as the smelt should be wantonly destroyed and wasted. There is nothing governing the amount of these fish that can be caught or the method of catching them, yet there is a strict law against the wanton waste of food of this kind. If it is not observed, complaints will be sworn out and arrests will follow."

**Morning Oregonian (Portland), Saturday, 2 January 1915, p. 5, col. 4**

Kelso Prepares for Smelt Run

> Kelso, Wash., Jan. 1—(Special)—The Columbia River Smelt Company is erecting a new dock near the depot at Kelso to facilitate the work of handling and shipping the smelt catch during the approaching season. It is now almost time for the arrival of the fish and old fishermen expect the run to start as soon as the river rises. The fish never start their run until the river is muddied by rains. Plans are

being made to open an Eastern market on a more extensive scale than last year when shipments in refrigerator cars were made for the first time.

**Morning Oregonian (Portland), Saturday, 9 January 1915, p. 8, col. 6–7**

Good Things in Markets

In the fish market: Variety is considerable this week still and the ripple on the surface is caused by a run of smelt up the Columbia River. They are in the Cowlitz strong and here in Portland are selling at two pounds for 25 cents, with every prospect of rapid descent in price.

**Morning Oregonian (Portland), Monday, 15 February 1915, p. 9, col. 6–7**

Cowlitz Has No Smelt

Vancouver, Wash., Feb. 14—(Special)—That some person desiring to keep the smelt from running up the Cowlitz River at Kelso dumped several barrels of lime in the mouth of the river, just as the smelt were beginning to run, is a story told at Kelso.

It is known that for two or three days the smelt passed the Cowlitz River and went into the Kalama River, the first time since 1847. There is not a great deal of current at the mouth of the river where it is said the lime was dumped into the river. Many persons say, however, that it was just a whim of the smelt themselves to select the Kalama River. It is reported that another big run of smelt has started in at the mouth of the Columbia River.

**Morning Oregonian (Portland), Wednesday, 8 March 1915, p. 11, col. 1**

New Run Fresh Columbia River Smelt, 75c for 50-lb Box, Order Shipped Promptly
Sanitary Fish Co., First and Washington

**Morning Oregonian (Portland), Tuesday, 9 March 1915, p. 5, col. 4–5**

Smelt in Lewis on Wane
Gulls Prey on Third Run that is Wakened by Swift Current

Vancouver, Wash., March 8—(Special)—The third run of smelt in the Lewis River at Woodland is beginning to wane and the price has dropped. The smelt, which are said not to eat after they leave salt water, are dying by thousands, and may be seen floating downstream. Many are weak and cannot swim against the current.

Seagulls by the thousands hover over the Columbia River and follow the smelt from the time the smelt enter the mouth of the Columbia River. They refuse to eat the dead smelt. So thick are the smelt in the Lewis River that they are dipped out in bunches from 50 to 75 pounds. One man made a dip yesterday that weighed 68 pounds.

**Morning Oregonian (Portland), Friday, 31 December 1915, p. 9, col. 4**

Smelt Are Becoming Plentiful

Kelso, Wash., Dec. 20—(Special)—Columbia River smelt are being taken in increasing numbers in the mouth of the Cowlitz and along the Columbia by the gillnetters, and fishermen are expecting a large enough supply of the fish so as to permit of dip net fishing at almost any time. Many boxes of smelt are leaving the Kelso depot daily, and the fishermen are securing good prices for their catches.

**Morning Oregonian (Portland), Friday, 31 December 1915, p. 12, col. 3–4**

Good Things in the Market

The fish market is enlivened by the intelligence that a considerable run of Columbia River smelt appeared in the Cowlitz on Wednesday, and consequently the price has dropped to 15 cents a pound.

**Morning Oregonian (Portland), Friday, 28 January 1916, p. 11, col. 1–2**

Good Things in the Market

The influx of Columbia River smelt has been completely checked by the cold, but frozen stock sells at 12½ cents a pound.

**Morning Oregonian (Portland), Tuesday, 7 March 1916, p. 16, col. 6**

Marine Notes.

Smelt shipments delivered here yesterday aboard the launch Beaver, which came from the Cowlitz River, numbered 212 boxes.

**Morning Oregonian (Portland), Saturday, 21 December 1918, p. 18, col. 7**

Columbia River Smelt 15c per lb. Single frozen, properly packed to arrive in good condition in 5-pound to 15-pound lots, within 150 miles of Portland. Write for quotations on larger quantities. Northwest Fish Products Co., 205 Yamhill St., Portland, Ore. Phone Main 4760.

**Morning Oregonian (Portland), Wednesday, 5 February 1919, p. 13, col. 6**

Run of Smelt Begins
Farmers Join Fishermen in Cowlitz River Catches

The annual run of smelt in the Cowlitz River has started, according to reports received in Portland yesterday. Farmers and people living in the vicinity of the river have joined with the smelt fishermen in catching the fish, which are said to be running in large schools.

As a result of the commencement of the run, prices of Columbia River smelt dropped to 4 and 5 cents per pound in Portland. It will be several months before the smelt can be expected in the Sandy River, although the fish do not ply through this stream every year. However, for the past two years Portland people have made large smelt catches in the Sandy.

**Morning Oregonian (Portland), Monday, 17 February 1919, p. 8, col. 6**

Disappearance of Smelt Feared
Pioneer Cowlitz Fishermen Deplores Lack of Protective Laws

KALAMA, Wash., Feb. 13—(To the Editor.)—I have been fishing smelt since 1879 and for over 25 years after that date never saw the Cowlitz River without a big run of smelt. Some winters they would come as early as January and sometimes as late as March. Then they would come so thick that a fish boat could be loaded with a small dip net in a few hours.

For the last eight years I have noticed the large runs have disappeared; for three years, or three winters, the most smelt have been caught in the Kalama, Lewis and Sandy rivers, and it looks like the smelt were done for in the Cowlitz forever.

This winter we got a surprise. A big run of smelt entered the Cowlitz after the markets had been well supplied from the smelt caught by gill nets in the lower Columbia. As soon as the smelt entered the Cowlitz several hundred launches loaded up. My boy caught a ton and one-half in five or six hours and expected to make a stake out of it. He went over to Rainier, but the smelt buyers were blocked, and also in Kelso. At least 150 fish boatloads at two tons each have been dumped overboard inside of three days and a big troller loaded and bound for a lower river port with seven tons of smelt got foul of a bootlegger just after being loaded and bound out of the Cowlitz, and struck the sandbar in the mouth of the Cowlitz. He kept driving ahead and drove her high and dry. The river falling about his launch, he was compelled to jettison his cargo overboard, as nobody wanted his smelt for nothing.

The whole thing is a disgrace. Every fisherman and cannery man knows that the smelt is the natural food for the Chinook salmon. The young salmon, after leaving the spawning ground and hatcheries, feed on the young smelt, and the large salmon fatten on the grown smelt. This run of smelt, most likely the last big run ever to come into the Cowlitz, will be followed up by launches to the very spawning grounds. My boy was offered a contract by one of our big smelt merchants at $8 per boatload of 2⅓ tons, a trifle over ⅛ of a cent per pound.

There is no law against dumping a few hundred tons of these fine fish overboard, but we should have a law to protect the smelt, as well as the salmon. Our lawmakers in Salem and Olympia are not all to blame, but the fish law agitators in both houses, who fight all kinds of battles between themselves on how to protect the salmon, let the salmon starve and don't think of feeding this royal fish. I am sure that in less than 15 years from now smelt will be as scarce as the elk in the mountains. These plentiful launches with the big scoop nets will soon finish the smelt business. I am able to see it. It is my trade and business. The smelt-buying merchants about Kelso and Kalama consist of about a dozen, and get discharged sailors and soldiers to dip the smelt at from $3 to $5 a ton. They get fat on the destruction of the smelt. Whatever can be dumped fresh on the market at 75 cents to $1 a box goes. Several hundred tons may go into cold storage and be retailed later from 10 to 12½ cents per pound. It would be wise and easy to draft a law that would be of benefit to the salmon, the fishermen and the children. —Charles Wood

**Morning Oregonian (Portland), Tuesday, 1 April 1919, p. 10, col. 5**

Those Who Come and Go

Run of smelt in the Sandy River attracted scores of guests from the hotels yesterday. To the easterners and people from California the sight was wonderful. "About everyone in the hotels has gone out to the Sandy River," said Clerk J. J. O'Brien, at the Hotel Portland. "Those who went yesterday came back so excited and talked so much about the fish that they caused others to go out today. One easterner declared there was more fish than water in the river."

**Morning Oregonian (Portland), Saturday, 1 January 1920, p. 1, col. 2**

Smelt on Market Here
First Shipments of Cowlitz River Run Are Received

Portland markets yesterday were selling the first of the new run of Columbia River smelt, the fish having been shipped from Cowlitz River, where the run is said to be quite heavy. The fish are what is known as the "widow" run, being the forerunners of the main run, which starts generally in February. About 20 boxes of the fish were received yesterday from the Cowlitz by the Portland Fish Company, which reports that they will continue to receive consignments daily until the run ceases. Heavy catches generally reduce the "widow" run within a short time, it is stated, and smelt are off the market until the main run starts.

The wholesale price for the smelt yesterday was 13 cents a pound, and the retail price at most of the markets was 20 cents. When the main run begins the fish are caught in such quantities that the price generally drops much lower.

**Morning Oregonian (Portland), Tuesday, 27 April 1920, p. 10, col. 6**

Those Who Come and Go

When A. N. Ward gets back to the Hot Stove Club at Malden, Mass., [he] will have a fish story to tell that his fellow townsmen will probably not believe and will stamp it as a traveler's tale. When Mr. Ward recounts that he saw a river so filled with fish that the stream was virtually one solid mass of fish for miles, and contained millions of smelt, the Maldenites will sniff with suspicion. When he says that in five minutes he, or anyone, could gather enough fish from the Sandy River with his coat, or auto robe, or any old thing, to fill a car to overflowing, they'll be certain that he is drawing the long bow. And yet, those were the things which Mr. Ward saw when he toured the Columbia River highway yesterday. He saw the great smelt run and saw miles upon miles of parked cars, while their drivers were filling gunny sacks, cans, buckets, tubs, boxes and any container they could secure, with smelt. At home Mr. Ward is an undertaker, and with his wife he is at the Multnomah, returning from the profiteer belt of California.

**Morning Oregonian (Portland), Wednesday, 28 April 1920, p. 15, col. 4–5**

Smelt Run Biggest Ever
Prow of Boat Turns Up Hundreds All Night Long

"My observation is that this is the biggest smelt run that has ever come up the Columbia River," was the statement made yesterday by State Game Warden Carl D. Shoemaker after he spent Monday night on the river in a motorboat. "We found early this morning that the seagulls are following the smelt all the way from Vancouver Bridge to the mouth of Sandy and that a solid wave of smelt is coming upstream between these points, or a distance of about 10 miles. The prow of our boat turned up hundreds of them all night long."

Mr. Shoemaker says there are no indications of the run slacking and that tons of fish are being shipped to Oregon and Washington points and many are going into local cold-storage plants. It is found that female smelt predominate over males in the present run, indicative of another heavy one next year.

**Morning Oregonian (Portland), Monday, 3 May 1920, p. 4, col. 2**

Smelt Run Nears End
School in Sandy Keeps over Spawning Beds
Within Next Few Days Dipnetters Will Be Hard Put to Get a Meal from Waters

The record run of smelt, so far as the Sandy River is concerned, is all but over. Within the next few days the gulls and the dipnetters will be hard put to find a meal in the deeps and shallows that aforetime held smelt by the billion. But few fish were obtained yesterday and the disappointments were in keeping—for not more than 50 fishermen were congregated at the Troutdale Bridge at any one time during the day.

Most of the dipnetters, however, managed to get a sack or so, by watching for the stray fringes of the now depleted and rapidly vanishing school. The main body of the run held well to the center of the stream, over the spawning beds, and only the commercial fishermen, with improvised piers and rowboats, were able to reach the profitable coigns of vantage.

The Sandy River smelt run, more than a month overdue by comparison with previous seasons, began 10 days ago and within half a week had attained unheard of proportions. Launches in the Columbia River outside, near the mouth of the

Sandy, ploughed through pools of smelt so dense that the curving wave at the bow was a cascade of shining fish. The smelt even drove far past the Sandy and as far up the river as Bonneville.

**Morning Oregonian (Portland), Wednesday, 5 May 1920, p. 10, col. 2**

Like the Sands of the Sea

Take all the hyperbolic similes expressive of vastitude of numbers, stir them well together, segregate the triple-extracted essence and confine it in a humdinger of extravagant comparison, and one will but have paid tribute to the fringes of the Columbia River smelt run. Naught save deity could give it census, for the count would worst mortal mathematics as that science is ordinarily employed. These observations are by way of preface to the statement that a Portland resident has been arrested on the count of wasting food fish, because he sought to fertilize his fruit trees with passé smelt.

There are those who will charge the game department with mulish conformance to law, asserting that the statute invoked was never intended to deal with billions upon billions of silver “hooligans,” swimming up the Columbia just as they did on the morning Captain Gray’s visit, ever and ever so long ago. To chirk up a cherry tree or two with half a peck from that seemingly inexhaustible measure, the sea, would to many commend itself not only as a trifling tithe on nature’s largess but as a most sensible procedure.

When the grandfathers of the present were the boys of yesterday, back in Ohio, Michigan, Minnesota, Wisconsin, and New York, along the entire Atlantic coast and well into the middle-west, the flight of passenger pigeons was an annual event comparable to the smelt run of the Columbia. On sunny days, with the spring mornings all golden and green, when those epochal pilgrimages were on the wing, it is recorded that the face of the sky was darkened as by a heavy cloud—a living veil of plumage that swept on and on, and endured till dusk. And thus for many days. They narrate, those same grandsires, that one might feed a bullet to the muzzle-loading squirrel rifle and fire at random upward, through the hurtling avalanche of pigeons. Not one but several birds would fall to that hazard, it is recounted. Yet the passenger pigeon is gone, and wealth would reward the man who could prove the existence of a single flock, a single bird. The species is with the great auk and the dodo, and while it may have perished in some stormy passage between the northern and southern continents, there is abundant evidence against the market hunter and the game assassin.

Natural history is replete with tragedies in which man plays the role of villain. Ethically and economically—and merely, for an additional reason, because all waste is wicked—the game department is fortified in its enforcement of the law with respect to the smelt run.

**Morning Oregonian (Portland), Friday, 7 May 1920, p. 10, col. 7**

Habits of Smelt Little Known
Study Made of Fish which Authorities Know under Several Names

Portland, May 6—(To the Editor)—Please publish the following information, and any other interesting facts, about the smelt. How long until they hatch, and how long do they stay in fresh water after hatching? How long before they come back to spawn? Do all that come up the river die, and what becomes of them when dead? What is their correct name? Are there such fish other places than the Columbia River? —A Subscriber

The scientific name of the Columbia River smelt is Thaleichthys pacificus. It is described in encyclopedias and dictionaries under "candlefish." The Indians called it "oolachan," sometimes spelled "eulachon," which has been corrupted by whites into "hooligan." It is common in Alaska and British Columbia streams, as well as in the Columbia.

R. E. Clanton, master fish warden, is authority for the statement that the longevity and habits of the Columbia River smelt have never been made the subject of exhaustive study, and that this season is the first in which trained observation has been directed.

The present attempt includes a study of the reproductive organs of the female smelt, to discover whether nature has provided for a second spawning. It is not known at present whether smelt return to the ocean or perish in the rivers—as does the salmon after visiting the spawning beds.

If the billions of smelt in an ordinary run were to die in freshwater, it is contended, the evidence of such demise would be prevalent, even to the point of pollution, of so mighty a stream as the Columbia. On the other hand, the return of the smelt run to salt water, if it does return, never has been observed. Fish commission officials, including Master Warden Clanton and Secretary Carl Shoemaker, of the fish commission, expect to make tests this week toward solving the riddle.

The journey of the smelt fry to the ocean is another phase of the life cycle that is darkness. None has seen, so far as the records show, the migration of the infant fish from the birthplace river to salt water. Their numbers must be uncounted myriads, and even if the fry were even an inch in length the passage of the infant smelt would be plainly discernible. It is conjectured that the fry run to sea when extremely small.

But all this is guesswork. An attempt is now launched to learn more of the actual life history of the Columbia River smelt. Specimens now held at Bonneville hatchery will be kept under observation to determine whether they are subject to demise after spawning, while an attempt will also be made, with nets, to discover whether any portion of the recent heavy run has retraced its course to the Pacific.

**Morning Oregonian (Portland), Thursday, 20 January 1921, p. 4, col. 2**

Smelt Enter Cowlitz River

Kelso, Wash., Jan. 19—(Special)—For the first time this season smelt were dipped in the Cowlitz River today. A few smelt had been gillnetted in the Cowlitz earlier this winter before the freshet, and for the last two weeks the Columbia River gillnetters have been getting smelt on the lower Columbia. It is thought that the present run is what is known as the early winter run and that the main run of the little fish will not be here for several weeks more.

**Morning Oregonian (Portland), Friday, 18 February 1921, p. 11, col. 1**

Lewis River Rises

Woodland, Wash., Feb. 17—(Special)—Warm winds and melting snow in the mountains have caused a decided rise in the Lewis River. The water has already reached within a foot of the high-water record. Muddy water is driving the run of smelt out of the river into the Columbia.

**Morning Oregonian (Portland), Saturday, 19 February 1921, p. 13, col. 1–2**

Many Fruits in Season

Columbia River smelt retailed at two pounds for 15 cents yesterday.

**Morning Oregonian (Portland), Saturday, 19 March 1921, p. 13, col. 2**

Fish for Lent Plenty

Prices will cover all the stages between 5 cents a pound for Columbia River smelt to 50 cents a pound for lobster shipped from the Atlantic seaboard.

**Morning Oregonian (Portland), Saturday, 24 December 1921, p. 12, col. 1**

Smelt Put in Appearance

Columbia River smelt have appeared for the holiday season in large quantities. They are being dipped up with nets and selling retail here at 15 cents a pound, in comparison with 25 cents a pound, which was the price until yesterday.

**Morning Oregonian (Portland), Saturday, 14 January 1922, p. 10, col. 2–3**

Did the Smelt Neglect their Tryst?

If nature forgot us for a single season, in all her bounties, we should be like so many children squalling in the dark. Quite helpless, very hungry and probably petulant. Occasionally the good dame does forget, neglecting some customary gift, and men puzzle themselves to discover the reason. They do not always find an answer. Why was it, as was recorded 25 years ago, that there had been noted long periods during which the smelt run deserted the Columbia River? For 20 years, so these observers asserted, the pleasing little eulachon was—to put it tritely—conspicuous by his absence.

The drying racks of the Indians were not laden, and the residents along the great river and its tributaries scanned the streams vainly for the return of their favorite fish, who was wont to be as punctual as April. There is no record of the year in which the run reappeared, nor is there more than the testimony of a few individuals, as preserved in news reports, to substantiate the disappearance. Undoubtedly it was the ancient and continuous custom of the smelt to frequent the Columbia as spawning time. Captain Robert Gray, whose good ship lent its name to the river, found them plentiful in 1792, and did not neglect to pay his compliments. It is to be regretted that the record of their truancy is not more specific, better verified, for instances in which anadromous fish fail to keep their natural appointments are more than rare.

Regarded across a third of a century, the claim is doubtful, and one cannot but incline to an opinion that the smelt were punctual, but unobserved. It might have been that the run, lengthy as it is, passed the specific points of observation at periods of high and murky water, to spawn far upstream. The weakness of this theory, which is otherwise entirely tenable, is that such conditions would scarcely be repeated annually over a long period of years. An instance that proves how easy it is to overlook the presence of the run is that of the appearance of the smelt in the Sandy River last spring. Unusually high water prevailed at the time the run was expected, and all observers were confident that the hordes of smelt had not entered the stream. Later they revised their opinion, for schools of infant smelt were noticed in early summer, and it became apparent that the fish had arrived and fulfilled their destiny without a single person glimpsing the millions of adult fish in the muddy current. Yet, as has been said, it is a bit far-fetched to fancy that such conditions could be indefinitely repeated.

The habits of anadromous fish are definite and precise. They return from the sea at well established seasons to the waters of their own birth to deposit their eggs. In this impulse the smelt are one with the salmon, whose cousins they are, and the confirmed belief is that such runs do not fail until the run itself is obliterated. With salmon this has repeatedly been proved. It is logical to assume that the multitudinous smelt conform to the same law, and that those early observers confused loose report and limited observation with fact until they had for themselves established a tradition. This may not be true, but if it is not true one of ocean's mysteries remains unsolved, and it is to be regretted that the record is so imperfectly preserved.

**Morning Oregonian (Portland), Monday, 6 February 1922, p. 6, col. 2**

Smelt Run in Cowlitz Small

Kelso, Wash., Feb. 5—(Special)—A small run of Columbia River smelt is in the Cowlitz River and the fishermen are making small catches of the little fish, which are a great table delicacy throughout the northwest. Boats can get but three or four boxes a night. It may be several weeks before a heavier run arrives, say those familiar with smelt fishing operations, as few fish have been caught by the Columbia River gillnetters.

**Morning Oregonian (Portland), Saturday, 11 February 1922, p. 12, col. 1**

A large supply of Columbia River smelt is available at 15 cents a pound, and in some places at two pounds for 25 cents.

**Morning Oregonian (Portland), Tuesday, 21 February 1922, p. 7, col. 6**

Smelt Run Again Enters Cowlitz

Kelso, Wash., Feb. 20—(Special)—What is thought to be the main run of Columbia River smelt entered the Cowlitz River last night and large catches of smelt were made by the fishermen. Later, however, the run decreased, and there is some doubt whether or not this is the main run. The fish have been late in coming up the river this year, although there have been small runs in the Cowlitz several times during the winter.

**Morning Oregonian (Portland), Saturday, 25 February 1922, p. 12, col. 1**

Columbia Smelt Price Is Reduced, Fresh Seafood Sells Three Pounds for 25 Cents
Large Supply on Hand, Smelt Prices Cut

The price of a popular seafood that is recognized in Portland as a real delicacy was cut almost in two when dealers reduced prices of Columbia River smelt. These tasty, silvery fish are now available at three pounds for 25 cents. The price a week ago was 15 cents a pound. Dealers report a good supply on hand to supply a brisk popular demand. The smelt are fresh from the Columbia River.

**Morning Oregonian (Portland), Saturday, 4 March 1922, p. 15, col. 1**

Smelt Also Take Fall

Another popular product that has dropped in price is Columbia River smelt. These tasty little fish may be had at two pounds for 15 cents or four pounds for a quarter. In some stores the price is three pounds for 15 cents. These prices are the lowest of the season so far and caused a heavy demand.

**Morning Oregonian (Portland), Wednesday, 12 April 1922, p. 13, col. 3**

Smelt Reported Running in Sandy
Fish Keeping to Middle of Stream, It Is Said
Licenses Not Needed

Nets, sieves, baskets and dippers of various kinds will be at a premium for a few days, and many thousand gallons will be consumed along the Columbia River highway route between Portland and the Sandy River, for the smelt are running again.

A silvery phalanx 15 feet wide and six inches deep is flowing upstream in the Sandy for the first time in two years, the dainty little fish completely ignoring the stream last year. By the millions, the tiny smelt are seeking the headwaters, a phenomenon which will attract thousands to the river banks and flood Portland homes with the toothsome little delicacy for many days.

For the true fisherman there is no sport in catching smelt during a run, for it requires no more effort than the dipping of a net into the water and removing it filled to the brim with flopping, silver fish, but the run has a great attraction for the fireside fisherman who desires great results from a minimum of effort.

Length of Run Uncertain [subhead]

How long will the run last? This is a question which cannot be answered with any degree of certainty. Runs have been known to last from two days to 24 days. A good deal depends on the weather. Should conditions moderate and a heavy, warm rain develop, high water in the Sandy will prove too great an obstacle for the small fish to negotiate. They have traveled a long distance by the time they arrive in the Sandy and are tired.

On the other hand, should the weather continue cool, with little rain, a long run can be anticipated. Indications are that there still will be a considerable run next Sunday to accommodate the holiday flow of autoists.

Though the smelt have been known to ignore the Sandy for as high as eight consecutive years, of late the runs have been quite constant, the failure of the fish to appear last year being quite out of the ordinary. A late spring usually presages a heavy smelt run, according to Lou Karlow, deputy county clerk, whose home is on the banks of the river and whose wife telephoned to Portland the first news of the run yesterday morning.

Run Appears Big [subhead]

The run looks like a big one, similar to that of two years ago, according to Carl Shoemaker, master fish warden, although he said yesterday the fish were keeping to the middle of the stream. However, he expected the run would reach such proportions, probably by today, that the merest tyro fisherman can stand on the bank of the stream and dip up all he wants.

No fishing license will be required, said Mr. Shoemaker, for persons who desire only to take smelt for their own use. Those who operate commercially, however, and sell their catch, must provide themselves with a dip net or dragnet license. No waste will be tolerated, said Mr. Shoemaker.

**Morning Oregonian (Portland), Thursday, 13 April 1922, p. 8, col. 2**

Smelt Thick in Sandy
Autoists Congest Highway in Rush for Fish
Calls for Assistance Cause Sheriff to Dispatch Entire Motorcycle Squad to District

Smelt scouts up the Sandy River evidently reported favorably concerning that stream as a spawning ground, for millions of the silvery little fish reached from bank to bank yesterday by the time autoists in any number began to gather in the vicinity of Troutdale.

More than 2,000 automobiles congested the Columbia River highway near the Sandy before noon and calls for assistance caused Sheriff Hurlburt to dispatch his entire motorcycle squad of six men and machines to the district to direct traffic and break the jam which had ensued.

Birdcages, lace curtains and many other substitutes for fish nets made their appearance and only a few minutes in the stream sufficed to supply any family with enough smelt for a reunion. All indications are that the run will last for a week or more and it is expected that the traffic will attain proportions by next Sunday which may make it necessary to employ traffic officers in addition to the sheriff's complement.

It is not necessary to have a fishing license if the smelt are dipped out of the river for the use of oneself and family.

**Morning Oregonian (Portland), Thursday, 13 April 1922, p. 10, col. 7**

Those Who Come and Go
Tales of Folks at the Hotels

Smelt in the Sandy River, out near Troutdale, are as interesting to tourists at the hotels as they are to the householders of Portland. News of the annual run of smelt in the Sandy was received at the hotels yesterday and many persons chartered automobiles to go out and see this famous run. To the easterner who is not familiar with a run of fish and particularly to people who live in the interior, the smelt are a wonderful attraction. The march of millions of these silver fish swarming up the confines of the glacial waters of the Sandy River toward their spawning grounds never fails to evoke exclamations of astonishment. Hotel clerks have learned that they can recommend a real attraction to visitors by sending them out the highway to see the run of smelt. Tourists yesterday were so notified and they were also advised to equip themselves with nets or buckets or something with which to scoop up the fish, for no one can stand on the bank of the stream and see the myriad of fish passing them without a wild desire to go fishing on the spot. The trouble with catching smelt is that the fisher gets more than he needs or can use, so he brings back a gunnysack or two with the fish and inflicts them on everyone who can be induced to accept them. Smelt are as fine eating fish as can be found when scooped from the Sandy waters, but a person cannot eat more than several dozen.

**Sunday Oregonian (Portland), 16 April 1922, p. 3, col. 2**

Smelt Season Ends at Kelso

Kelso, Wash., April 15—(Special)—Final shipment of smelt was made by Kelso fishermen this week, and they will be busy the rest of this month getting their salmon fishing equipment ready for the spring season and moving their outfits to drifts along the Columbia River. This has been a very good smelt season, the prolonged cold weather being a benefit to the industry.

**Morning Oregonian (Portland), Tuesday, 18 April 1922, p. 1, col. 2**

Locks Block Smelt Run
Millions of Tiny Fish Caught at Cascades of Columbia

Hood River, Ore., April 17—(Special)—The run of smelt has reached the Cascades of the Columbia, where they are blocked. Millions of the fish are trying to get to the headwaters by way of the government locks. Deputy Sheriff Meyers today telephoned to Sheriff Johnson that residents of Cascade Locks, utilizing as various an assortment of improvised nets as one sees at the Sandy, are taking fish by the boxfuls at the lower end of the locks.

Schools of smelt appeared at Eagle Creek Saturday.

**Morning Oregonian (Portland), Monday, 1 May 1922, p. 4, col. 2**

Pantries Stocked with Smelt

Hood River, Ore., April 30—(Special)—Residents of Cascade Locks and Stevenson, Wash., made the most of the recent smelt run up the Columbia to the foot of the rapids below the Cascades, and many pantries have been stocked with dried and salted fish. A. J. Pratt, a Stevenson, Wash. man, who captured 1,600 pounds of smelt, salted and smoked them. His shrinkage, he reports was 66 percent, as he now has left 575 pounds of kippered smelt.

**Morning Oregonian (Portland), Monday, 1 May 1922, p. 8, col. 3**

Marvel of the Smelt

The Eugene Register has printed what we think is a timely warning concerning smelt. It predicts that unless there is some curb on the taking of this variety of fish, smelt will go the way of the passenger pigeon and the buffalo.

Probably the fact made impressive by these early tragedies that wild life cannot long maintain itself against man’s unrestrained rapacity, will cause us to take heed before the smelt have disappeared. But why not for once depart from the usual custom of delaying regulation until scarcity is upon us?

Smelt fishing in the Sandy River is an asset to Portland whose importance is hardly realized. The incidents of the spring run have no counterpart anywhere. The Sandy is not the only stream in which smelt appear in vast numbers, but it is the one stream in which they swarm that is readily accessible from a populous community.

Sandy River is a stream worth visiting for its scenic beauty alone. The point where the Columbia highway crosses it is within less than an hour's automobile ride from Portland over a paved road. It happens that the reaches of the stream directly above and below the highway bridge are the smelt fishing grounds.

There, in beautiful surroundings and without license, hindrance, or limit, the Portland citizen, one hour's journey from home, may with the crudest of home-made appliance dip out and take away as many delectable food fishes as the novelty of the occasion impels him to take. It is as the Eugene paper remarks—the rule is to take more than one can possibly use or give away. Smelt taking in the Sandy, in which thousands of persons—rich and poor—participate annually, is one of the spectacles, one of the marvels, of the northwest and of the Columbia highway.

The habits of the smelt, or candlefish as it is properly called, are little understood. Presumably they return to the stream in which they were spawned. If that be true, whatever protection given them elsewhere will not restock Sandy River if it is once fished out. As an important contribution to the food supply and as an advertisement for this community, smelt runs are worthy of scientific study and of protection, if need be, from greed and waste.

**Morning Oregonian (Portland), Tuesday, 9 May 1922, p. 10, col. 8**

How Indians Once Took Smelt
Nails in Canoe Paddles Impaled Fish, Recalls Captain Gray

Pasco, Wash., May 7—(To the Editor)—The Oregonian's editorial "Marvel of the Smelt" reminds me of the first runs of smelt in the Cowlitz River. The Indians drove sharp pointed nails through thin paddles, and as they forced their canoes upstream through the school, or rather stream of smelt, would soon fill their canoes by shaking the smelt from the nails in their paddles.

I have not been on the Cowlitz for many years, but understand that the smelt runs on that river do not compare with the runs of the '60s, when steamboats did not run above Monticello or Freeport—they now run to Kelso. Did steamboats on the Columbia or log booms at its mouth check its smelt run? If so your Sandy River runs are safe, as steamboats cannot disturb them.

We used to know when the smelt were in the Columbia by the number of seagulls that followed the schools.

Another thought: Is there not a danger of "overpopulation" of smelt if their taking is restricted? Hundreds of millions of eggs are deposited every year. Will the few thousands of fish captured relieve a congestion that would drive the smelt to some other stream? You are in error in saying the smelt is properly called a candle fish. The candle fish is only taken in salt waters like Puget Sound, and takes its name from the fact that when it is dried its mouth opens wide and makes a base to support the greasy bones that stand upright. A lighted match touched to the tail of the dried fish makes a perfect candle. The flesh of the candle fish is far inferior to the smelt.

The Columbia seems to be the only river that has the two distinct varieties of the best of fish, salmon and smelt.

The Yukon River salmon is larger and compares in flavor with our Columbia River variety, but there are no smelt to compare with the genuine Columbia River variety, which seek the Cowlitz, Kalama, Sandy and other small streams every spring to spawn. —W. P. Gray

**Morning Oregonian (Portland), Friday, 29 December 1922, p. 12, col. 5**

New Today in the Markets

A few smelt made their appearance on the Portland market yesterday, bringing the price, which was formerly about 35 cents, down to 30 cents. Marketmen state that fishermen have discovered a school of the fish making their way up the Columbia River.

# Oregon (Umpqua River)

**Eugene Register-Guard, Friday, 21 February 1969, p. C1**

Streams Back in Shape, Fishing Slow, by Pete Cornacchia

Smelt dippers at Scottsburg Park, downstream from the highway bridge across the Umpqua, hadn't netted much since early in the week, reported Hugh Smith at the Tackle Box in Reedsport. But, judging from past years, the migration up to spawning grounds somewhere above Elkton is expected to continue at least another two weeks and a new batch of smelt could show at any time.

Lots of 25-pound limits were collected among the mob of dippers at the park last weekend, he said. Nearly all of the silvery fish were males, which usually are the first to show. Dipping was best along the bank and at night on the ebb tide. [Online at http://news.google.com/newspapers?id=SGkRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=3321,4455711&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 28 February 1969, p. 5B**

Long-handle Nets Ambush Smelt Migrating Close to Banks of Umpqua River [lead-in head], Action Slow on Steelhead, Smelt Run, by Pete Cornacchia

> The lower Umpqua has produced a few sturgeon recently in the Gardiner area but has been offering only a trickle of smelt to dippers up at Scottsburg Park. Regardless of reports in the Portland papers, Umpqua smelt dippers aren't getting their 25-pound limits.
>
> Smelt traffic has been light ever since the opening surge two weeks ago and hopes of another buildup in the run are dwindling. Oldtimers point out that swarms of gulls always follow the smelt up the river but there is no great number of birds on the river now. [Online at http://news.google.com/newspapers?id=T2kRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=5316,6039358&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 22 March 1970, p. 2C**

It's Striper Time, by Pete Cornacchia

> … About a month ago several Mapleton fishermen started catching big stripers which apparently had followed a previously unheard-of smelt run into upper tidewater on the Siuslaw. [Online at http://news.google.com/newspapers?id=IcIUAAAAIBAJ&sjid=8eADAAAAIBAJ&pg=5240,5619960&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 5 February 1971, p. 3C**

Umpqua Yielding Variety: Steelhead, Smelt, Sturgeon, by Pete Cornacchia

> And if you've had enough steelhead and/or hang-ups for one winter, Umpqua tidewater offers a good but sporadic run of smelt for dippers in the Scottsburg vicinity and increasing white sturgeon activity down in the bay. …
>
> The Umpqua appears to have a good smelt run, though they're coming through in spurts. Success for dippers on the banks at the state park below Scottsburg has varied from day to day. [Online at http://news.google.com/newspapers?id=9gwRAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=3712,778489&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 26 February 1971, p. 2B**

Outlook Poor for Anglers, Good for Dippers, Diggers, by Pete Cornacchia

> Get that dip net out again, for those sneaky smelt are back again. Bigger than ever.
>
> But if you're less than thrilled with the chase and taste of the eulachon … tides are good … for dredging bay clams. …

After most of the smelting fraternity on the lower Umpqua had put their nets away for the year, these unpredictable fish suddenly showed again last weekend. Dippers at Scottsburg State Park have done quite well every night this week, reported Jim DiBala at Echo Resort. More smelt than before and they're larger than usual. [Online at http://news.google.com/newspapers?id=Cw0RAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=4477,5470935&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 8 February 1972, p. 3B**

On the Outside [column head], Passing the Word, by Pete Cornacchia

When the smelt come up the Umpqua to spawn, usually about this time of year, I forget the steelhead and head for tidewater. Not to dip for smelt with all the others at Scottsburg State Park below the Highway 38 bridge, but to prey on the great white sturgeon and the striped bass which prey on the smelt as they move up the river.

Sure enough, smelt are beginning to show in the lower Umpqua. Just a trickle as yet, however. Several persons have told recently of seeing stripers feeding on smelt at the surface, but dippers at the park haven't been collecting much in their long-handled nets.

"Commercial netters have been getting a few from time to time," said Jim DiBala at Echo Resort. "But dipping has hardly been worth the effort. I fished about an hour yesterday and got three smelt, which is about how it's been.

"They should be here any time now, though. Could be on the next tide."

As in other streams, the smelt run in the Umpqua is a very unpredictable thing which has been quite strong in some years and very weak in others. Sometimes the fish go through when the river is too high and muddy to get at them.

Water conditions have been good for the past week, but the Umpqua was rising again Monday and probably will continue to climb if the thaw continues in the upper reaches. [Online at http://news.google.com/newspapers?id=Q8kTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=3531,1895262&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 25 February 1972, p. 1B**

Smelt Run Picking Up in Umpqua, by Pete Cornacchia

The smelt run in the Umpqua, which for several weeks had been a slow walk rather than a run, came on strong Wednesday afternoon to spur hopes of both dippers and striped bass fishermen.

"Dipnetters took several limits last night and were still taking smelt this morning," Mrs. Jim DiBala reported Thursday from Echo Resort. She was referring to the dippers at the state park below the Highway 38 bridge at Scottsburg. For personal use, daily limit on smelt is 25 pounds.

How long the run would remain strong was anybody's guess. [Online at http://news.google.com/newspapers?id=UskTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=3871,6403187&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 27 February 1972, p. 3D**

Smelt Run Draws Many to Umpqua, by Pete Cornacchia

It had started raining again and the cold wind which had been whipping up whitecaps on the flats along the lower Umpqua had an awfully mean bite for a southwester.

But the men, women, kids and dogs strung along the silty beach above and below the boat ramp at Scottsburg State Park didn't seem to mind. In shiny wet rain gear or soggy wool jackets, some huddled by the spitting and sputtering fires while others knee-deep at the edge of the high and muddy river swung long-handle nets out into the chocolate flow.

When they lifted the nets from the water after a long sweep downstream, usually a handful of silvery fish flashed in the bottom of the cords. The fish were dumped into a bucket or plastic container, then the dipper waded back into the water to make another sweep.

The smelt were running strong at last and some of the dippers were getting their 25-pound limits, as had others the previous afternoon and night. The run had been light up to this last week of February, as it had been on other streams in Oregon and Washington.

But now lots of the little fish were moving upstream to spawn and the dippers were there to get their share, no matter how raw the weather or how muddy the river. The strong run might continue for several more days, or it could be back to a sporadic trickle by tomorrow.

Like the swarms of gulls which follow the smelt up the river and tell of their presence, the dippers can't count on tomorrows.

For a host of anglers, the arrival of smelt raises hope not so much for a tasty meal as for the oncoming of voracious striped bass which also prey on the little fish as they travel upstream. [Online at http://news.google.com/newspapers?id=VMkTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=4273,6843290&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 3 March 1972, p. 5B**

High, Muddy Streams Ruin Angling Hopes.

Lower Umpqua: … Smelt still in river; few limits. [Online at http://news.google.com/newspapers?id=4mkRAAAAIBAJ&sjid=DuEDAAAAIBAJ&pg=6514,720966&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 21 April 1972, p. 3B**

Fish Prospects Better as Streams Improve, by Pete Cornacchia

> … Discovery of the very late smelt run brought the dipnetters back to Scottsburg Park, where several quick 25-pound limits were collected early in the week. [Online at http://news.google.com/newspapers?id=6cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6493,5070734&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 25 April 1972, p. 3B**

On the Outside [column head], High Lakes, by Pete Cornacchia

> … weather was great but catches fell off sharply.
>
> So did smelt dipping on the Umpqua. …
>
> The Chinook in the Umpqua apparently haven't done much reading and aren't aware that salmon don't eat much after moving into freshwater on their spawning runs, [the Game Commission's Dave Anderson] noted. Many of the fish which he has checked recently were packed with smelt, just like the stripers.
>
> Dipnetters weren't doing quite that well on smelt, though Dave did check a 25-pound limit for one patient and persistent soul near Scottsburg Park. The man got his quota with about one smelt on each dip. At a few ounces per fish, that took a few dips. [Online at http://news.google.com/newspapers?id=7cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6535,6170162&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 4 February 1973, p. B1**

Arrival of Smelt Draws Gulls, Stripers, Sturgeon, Anglers to Lower Umpqua [lead-in head], Smelt: Tiny, Tasty, Unpredictable, by Pete Cornacchia

> "They were getting quite a few smelt here last weekend," remarked a man standing beside a fire. "Some came close to getting their 25 pounds, too.
>
> "Not much since then, though. We had a big crowd here last night, but nobody did much."
>
> But the unpredictable smelt might suddenly start showing again any time, he said.
>
> "Last year, the run faded out for several weeks and we figured that was it," he went on. "Then a lot of smelt came through in the middle of April. Wife and I caught two Chinook and a 30-pound striper that were stuffed with them. …"
>
> For many anglers, the arrival of smelt in the Umpqua raises hope not so much for a tasty meal of them as for the oncoming of sturgeon and striped bass. Like the gulls and the dippers, sturgeon and stripers also come running when the smelt

are running. [Online at http://news.google.com/newspapers?id=o2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4621,691873&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 9 February 1973, p. 3D**

Lower Umpqua Promising; Angling Slow on Steelhead, by Pete Cornacchia

Smelt keep coming up Umpqua tidewater in spurts ….

The Umpqua has lost its winter tan and in turning green has cleared enough that most of the smelt are traveling well out in the middle of the river. At Scottsburg State Park, dippers in boats have been doing better than those on the banks. [Online at http://news.google.com/newspapers?id=qGoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4830,2011247&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 16 February 1973, p. 3D**

From Smelt to Sturgeon, Prospects Best on Umpqua, by Pete Cornacchia

Smelt are still running in the lower Umpqua but they're staying well out in the middle of the relatively clear flow and dipnetters on the bank at Scottsburg State Park haven't been doing much. [Online at http://news.google.com/newspapers?id=r2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4286,3686790&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 20 February 1973, p. 3B**

On the Outside [column head], Wary Bass, by Pete Cornacchia

In checking angling pressure and catch on the lower Umpqua from February into fall last year, Game Commission biologist Dave Anderson also did a lot of stomach content analysis on stripers.

… In the spring, from the middle of March through the middle of May, 46.7 percent of the stomachs examined in the river above Reedsport had nothing in them.

In that stretch and during that period, smelt were found in 50.7 percent of the stomachs and made up 91 percent of the springtime diet. …

In mid-April, when anglers in the Scottsburg area were catching both spring Chinook and stripers, a late and large run of smelt suddenly showed up. Salmon or striper, most of the fish caught in the next couple weeks were stuffed with smelt. [Online at http://news.google.com/newspapers?id=smoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=5421,4513119&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 31 January 1974, p. 3B**

Outlook for Outside [lead-in head], Rivers Rising; Smelt Arrive, by Pete Cornacchia

> Arrival of smelt in the lower Umpqua has made dippers happy, but there's little good news to precede the bad for steelhead anglers.
>
> Swarming gulls pointed to the first waves of the Umpqua's smelt run the latter part of last week and dipnetters have been taking fish each day since then, according to Dave Anderson, State Wildlife Commission fisheries biologist at Reedsport.
>
> He said dippers along the banks at Scottsburg State Park below the highway 38 bridge have had varying success from day to day, with some 25-pound limits for the harder workers. The Umpqua like most coast streams remains muddy and rather high. [Online at http://news.google.com/newspapers?id=jLoUAAAAIBAJ&sjid=P-ADAAAAIBAJ&pg=6688,6779760&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 February 1974, p. 3B**

Outlook for Outside [lead-in head], Hopes Better for Anglers, by Pete Cornacchia

> Dipnetters are still taking smelt from the Umpqua below Scottsburg, with success varying from day to day. Best hauls have come at low tide. [Online at http://news.google.com/newspapers?id=tQUTAAAAIBAJ&sjid=A9gDAAAAIBAJ&pg=6348,1409295&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 17 February 1974, p. 5B**

Monsters lurk in Umpqua, by Pete Cornacchia

> … we had seen no sign of the big white sturgeon which usually follow close behind the smelt at this time of year. The smelt had been running for nearly three weeks and the dippers were still taking a few up at Scottsburg. [Online at http://news.google.com/newspapers?id=vgUTAAAAIBAJ&sjid=A9gDAAAAIBAJ&pg=4770,3459056&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 26 March 1974, p. B1**

On the Outside [column head], Sun Out, Fish In, by Pete Cornacchia

> The poor water conditions and long spell of foul weather didn't keep dipnetters from converging on a strong smelt run at Scottsburg. [Online at http://news.google.com/newspapers?id=ABMRAAAAIBAJ&sjid=NOADAAAAIBAJ&pg=6255,5535261&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 29 January 1976, p. 2D**

On the Outside [column head], Sturgeon Following Smelt into Umpqua Fishing Holes, by Pete Cornacchia

> [White sturgeon are] gathering in the murky depths near Gardiner and above Reedsport to feed on spawned-out smelt. …
>
> As for the smelt, the run has shriveled to a trickle and dipnetters at Scottsburg have had to work hard for the few fish they've panned this week. [Online at http://news.google.com/newspapers?id=knkRAAAAIBAJ&sjid=PeADAAAAIBAJ&pg=6627,7406766&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 8 February 1976, p. 3B**

Like the Gulls, the Great White Sturgeon Comes Running when Smelt Are Running [lead-in head], Waiting for the Big Ones, by Pete Cornacchia

> Like the gulls that were cruising back and forth, the several people who were standing knee-deep near the bank weren't finding much in the green waters of the lower Umpqua.
>
> Like the white and grey birds winging along or resting in the eddies, they had gathered where the river rolls past Scottsburg State Park in hopes of scooping up smelt. But not since the arrival of a good run three weeks ago had there been much sign of the silvery little fish.
>
> Time after time, the men dipped their long-handled nets into the water, lifted, and dipped again. Neither was there much reward for the efforts of the two men who were dipping from a boat anchored in the middle of the river.
>
> Still, the dippers knew, the smelt could suddenly show again at any time.
>
> For many anglers, however, the arrival of smelt in the Umpqua raises hope not so much for a tasty fried meal as the oncoming of the great white sturgeon. Like the gulls and the people, these huge fish come running when the smelt are running. [Online at http://news.google.com/newspapers?id=CxMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=2919,1791554&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 26 February 1976, p. 2B**

On the Outside [column head], Conditions Remain Lousy for Anglers, by Pete Cornacchia

> Smelt are running again in the lower Umpqua. …
>
> Smelt were back in the Umpqua at Scottsburg early in the week but they were running deep and in the middle of the river. Dippers in boats took some 25-pound limits on the evening low tides. [Online at http://news.google.com/newspapers

?id=HRMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=6253,6671366&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 25 January 1977, p. B1**

Steelies in Mind, Smelt in Net, by Pete Cornacchia

> And that's where we finally came upon a gathering of fish [on the Siuslaw River].
>
> Scattered over the sand and gravel along the shallow edges, like purplish noodles, were rafts of smelt.
>
> O'Neal grabbed the big landing net and went splashing and slashing through the shallows like an Alaskan brown bear ankle-deep in sockeyes. But the mesh, of course, was too wide for dipping fish six to seven inches long. So he folded the cords over in a wad and tied them so that the net looked more like King Kong's fly swatter.
>
> Then he stood in one spot while I circled around and drove the scurrying groups of smelt past him, where he flipped them onto the bank in quick scoops. Before the little devils finally tired of all this nonsense and departed, we managed to gather enough for a meal or two. …
>
> For either steelhead or smelt, however, the much larger Umpqua should offer better prospects than the Siuslaw in the next month. While the unpredictable smelt usually are beginning to arrive in both streams about this time, the Umpqua normally draws a much greater run over a longer period. [Online at http://news.google.com/newspapers?id=KYoQAAAAIBAJ&sjid=KuADAAAAIBAJ&pg=3816,6033795&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 3 February 1977, p. 2B**

Outlook for Outside [lead-in head], Prospects Remain Poor for Anglers, by Pete Cornacchia

> No smelt are evident yet in the Scottsburg vicinity on the Umpqua, reports Ben Carlson at Greenacres. [Online at http://news.google.com/newspapers?id=UXwRAAAAIBAJ&sjid=mtkDAAAAIBAJ&pg=4244,542469&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 24 March 1977, p. 3B**

Outlook for Outside [lead-in head], Chinook Caught in Lower Rivers, by Pete Cornacchia

> Still no sign of smelt in the Scottsburg area. …
>
> At midweek, state police reported that the heavy smelt run in the Sandy [River] was on the decline but dippers were still doing fairly well at Troutdale. The fish have been staying in the deepest water during the day and running close to the banks only at night. [Online at http://news.google.com/newspapers?id

=2XkRAAAAIBAJ&sjid=JOADAAAAIBAJ&pg=4351,5873279&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 2 February 1978, p. 2B**

Outlook for Outside [lead-in head], Lower Umpqua Good for Smelt, Sturgeon, by Pete Cornacchia

> Smelt dippers are still doing well around Scottsburg State Park, according to Ben Carlson in Ben's Bait and Tackle Shop at Green Acres. He reported that 25-pound limits have been rare but dippers have been taking fish consistently at night and at low tide. Daytime dipping has been better from boats in midstream than from the bank. [Online at http://news.google.com/newspapers?id =cHARAAAAIBAJ&sjid=7uEDAAAAIBAJ&pg=6680,369906&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 February 1978, p. 6B**

Outlook for Outside [lead-in head], Bay Catches Better, But Streams Stingy, by Pete Cornacchia

> … The Umpqua … has been slow … for smelt at Scottsburg. [Online at http://news.google.com/newspapers?id=hXARAAAAIBAJ&sjid =7uEDAAAAIBAJ&pg=6645,6113567&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Thursday, Feb 15, 1979, p. 2C**

Outlook for Outside [lead-in head], Smelt Make their Move, But Not the Steelhead, by Pete Cornacchia

> The slowly receding waters have brought a new batch of smelt to the lower Umpqua but no great upswing in catches for steelhead anglers on most other streams.
>
> The Umpqua was high and muddy Wednesday after rising five feet from the previous day, but smelt dippers on the bank and in boats were doing well at Scottsburg Park, reported John Johnson, state fisheries biologist at Reedsport. [Online at http://news.google.com/newspapers?id=724RAAAAIBAJ&sjid =_uEDAAAAIBAJ&pg=6561,4446377&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 February 1980, p. 2D**

On the Outside [lead-in head], Siuslaw Good Steelhead Bet, by Pete Cornacchia

> … Increasing sturgeon activity at Gardiner on the lower Umpqua points to the arrival of smelt, though dippers have not found much sign of the latter up at Scottsburg. …

Lower Umpqua and Smith rivers: … Some smelt are showing. The run is not large enough to dip. [Online at http://news.google.com/newspapers?id =uBoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=6685,1874436&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 28 February 1980, p. 4B**

On the Outside [lead-in head], Streams Are High, Fish Are Dark, by Pete Cornacchia

The lower Umpqua remains slow … and smelt dippers at Scottsburg no longer have much hope of getting a run this winter. [Online at http://news.google.com/ newspapers?id=xRoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=4258,7969800 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 19 February 1981, p. 2B**

Brood Rainbows Planted in Ponds, by Pete Cornacchia

… smelt could be pleasing dippers near the head of tidewater at Scottsburg before long. A big rise often will bring a rush of these unpredictable fish, which may arrive any time from January into spring and sometimes never show. Dippers on the bank usually will do better when the river is up and colored, rather than low and clear, for the smelt frequently will be running along the edge of the water instead of deep in midstream. [Online at http://news.google.com/ newspapers?id=EHERAAAAIBAJ&sjid=S-IDAAAAIBAJ&pg=6662,5105936 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 5 March 1981, p. 7B**

Cold Water Hasn't Helped Fishing Prospects, by Pete Cornacchia

Lower Umpqua: … No smelt showing. [Online at http://news.google.com/ newspapers?id=_EkVAAAAIBAJ&sjid=SuIDAAAAIBAJ&pg=6624,1285997 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 11 February 1982, p. 2C**

Outlook for Outside [lead-in head], It Depends on the Weather, by Pete Cornacchia

… Smelt dippers are still waiting for another batch to show near the head of tidewater at Scottsburg [on the Umpqua River], where a small run faded soon after appearing about two weeks ago. [Online at http://news.google.com/ newspapers?id=wnERAAAAIBAJ&sjid=XOIDAAAAIBAJ&pg=3596,2269070 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 17 February 1983, p. 2C**

Outlook for Outside [lead-in head], Steelhead There, But Fishing Isn't, by Pete Cornacchia

> … Little sign of smelt has been reported in the Scottsburg area. [Online at http://news.google.com/newspapers?id=k3ERAAAAIBAJ&sjid=WeIDAAAAIBAJ&pg=6567,3925333&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 15 March 1983, p. D1**

Spring Fever, by Pete Cornacchia

> The only smelt seen in the Umpqua this winter have come from the market, which may be the chief reason for the generally poor response from sturgeon. [Online at http://news.google.com/newspapers?id=0soTAAAAIBAJ&sjid=QOIDAAAAIBAJ&pg=6221,3529041&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 February 1984, p. 6C**

Outlook for Outside [lead-in head], Lake Creek Fishing Good, by Pete Cornacchia

> The high water has brought no sign of smelt in the lower Umpqua or in the Sandy on the Columbia. [Online at http://news.google.com/newspapers?id=uGoVAAAAIBAJ&sjid=juEDAAAAIBAJ&pg=6505,5503108&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 14 February 1985, p. 2C**

The Coastal Streams Too Full to Fish, by Pete Cornacchia

> Very little sign of smelt in the Columbia, Sandy and Umpqua. [Online at http://news.google.com/newspapers?id=McUUAAAAIBAJ&sjid=i-EDAAAAIBAJ&pg=6681,3015823&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 March 1985, p. 2B**

Outlook for Outside [lead-in head], State's Angling Action is Better on the Coast, by Pete Cornacchia

> Despite a lack of smelt as attractive forage, the lower Umpqua has been yielding a fair number of sturgeon … . [Online at http://news.google.com/newspapers?id=j2oVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6658,1567378&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 14 March 1985, p. 2B**

Outlook for Outside [lead-in head], Trout Plants Spice Action, by Pete Cornacchia

> Apparently this will be another year in which smelt dippers will not be taking very many fish from the Sandy or Umpqua. Smelt entered the Sandy last week but have remained below the Interstate 84 bridge, where state police report dipping has not been worth the effort. [Online at http://news.google.com/newspapers?id=lWoVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6742,3370082&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 30 January 1986, p. 3C**

Outlook for Outside [lead-in head], Steelheading Good on Upper Siuslaw, by Pete Cornacchia

> … No smelt have been reported [on the Umpqua River]. [Online at http://news.google.com/newspapers?id=12AVAAAAIBAJ&sjid=BeEDAAAAIBAJ&pg=4531,6382367&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 27 February 1986, p. 2B**

Outlook for Outside, Fishing

> Lower Umpqua: … No smelt reported. [Online at http://news.google.com/newspapers?id=JsUUAAAAIBAJ&sjid=kOEDAAAAIBAJ&pg=3330,6304140&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 19 February 1987, p. 2B**

Outlook for Outside [lead-in head], Coast Rivers Improve But Not Fishing, by Pete Cornacchia

> Lower Umpqua: … No smelt have shown so far. [Online at http://news.google.com/newspapers?id=Z2kVAAAAIBAJ&sjid=fOEDAAAAIBAJ&pg=5540,4244267&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 21 January 1988, p. 2D**

Outlook for Outside [lead-in head], Conditions Improve for Steelhead Anglers, by Pete Cornacchia

> Lower Umpqua [under subhead Angling]: … No smelt have shown. [Online at http://news.google.com/newspapers?id=5msVAAAAIBAJ&sjid=n-EDAAAAIBAJ&pg=2617,4250273&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday 11 February 1988, p. 1D-2D**

Cowlitz Smelt a Quick Catch for Dipnetters, by Pete Cornacchia

> Smelt also used to make frequent January-April appearances in Oregon's Umpqua but have forsaken this river in recent years. [Online at http://news.google.com/newspapers?id=FmwVAAAAIBAJ&sjid=p-EDAAAAIBAJ&pg=5029,2166079&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 2 March 1989, p. 2D**

Outlook for Outside, Angling

> Lower Umpqua: … No smelt have shown yet. [Online at http://news.google.com/newspapers?id=0W0VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=4949,391197&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 March 1989, p. 2D**

Outlook for Outside, Angling

> Lower Umpqua: … no harvestable numbers of smelt. [Online at http://news.google.com/newspapers?id=420VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=2299,6102792&dq=site:news.google.com+umpqua+smelt&hl=en]

# Washington

**Vancouver Register (Washington Territory), Wednesday, 6 April 1867, p. 3, col. 1**

> Smelt—This delicate fish, which has never before been known to come up higher than Lewis River, has made its appearance off this city in large numbers. They can be caught by hand—evening, just after dark is the best time.

**Kalama Beacon (Washington Territory), Friday, 1 March 1872, p. 1, col. 1**

> A Piscatorial Exploit—A few days ago, at Camp Enterprise on the Cowlitz, Johnny McGrath, who "runs" things there, performed a feat at smelt catching that places him in the van of fishers. With a little dip net of only 16 inches diameter across the open end, he stood on the river bank and caught by scooping two barrels of fish within half an hour! In the lower Columbia River tributaries this species of herring are now running in schools of myriads, and literally fill the Cowlitz in shoals that occupy the entire space of the stream; and what is singular, although apparently moving forward up the river, there is at present no diminution of their volume.

**Kalama Beacon, (Washington Territory), Friday, 22 March 1872, p. 1, col. 1**

The Smelts—These piscatory phenomenon seemed to pass the rear of their column up the Cowlitz and tributaries last week. There seems to be no return of any portion of them downstream; and whither they are tending, and where can such myriads find room at the head of the Cowlitz, is something that would not be an inappropriate study for an Agassiz, or some other piscatorial student.

**Kalama Beacon, (Washington Territory), Saturday, 8 February 1873, p. 1, col. 2**

A Piscatory Advent—The annual return to the Cowlitz River of that delicious little fish called the smelt commenced a couple of weeks ago, and the river is literally alive with them. With a scoop net of about 15 to 20 inches in diameter, it is practicable to stand anywhere on the bank and scoop a barrel full in 10 or 15 minutes. The run will last about a month longer, but toward the latter end of the season they are pronounced inferior and the catch is abandoned. A few days ago, the steamer Rescue transported seven tons of these fish at once to fill orders from Portland.

**Kalama Beacon, (Washington Territory), Tuesday, 10 February 1874, p. 1, col. 1**

The Smelt Run—That delicious little fish is playing truant this season, so far. According to the period of their annual visits heretofore, they have been due in the Cowlitz for two or three weeks past; but they have not yet put in an appearance, and may fail altogether, as they do sometimes in streams frequented by them.

**Daily Olympian, Monday, 16 March 1896, p. 3, col. 4**

Fresh Supply of Fish

The Columbia Market today received a fresh supply of … Columbia River smelt … All fresh and nice. Columbia foot of Sixth.

**Daily Olympian, Wednesday, 2 February 1898, p. 3, col. 1**

Brevities of the Day

M. Giles of the Main Street Market has just received an invoice of fine Columbia River smelt.

**Centralia Daily Chronicle, Wednesday, 3 February 1909, p. 3, col. 1**

Fresh Columbia River Smelts, 5 c per Pound at Kent's Fish Market, Tower Avenue Phone 613 and Your Order Will Be Promptly Delivered

**Centralia Daily Chronicle, Tuesday, 16 March 1909, p. 3, col. 2**

The Last Run of Fresh Smelts Is On and Will Last Only a Few Days Longer
A Good Supply at Kent's Fish Market on Tower Avenue, 5 Cents per Pound, Phone 613

**Centralia Daily Chronicle, Tuesday, 8 February 1910, p. 3, col. 2**

The Columbia River Smelt Are Now In. Get Them at the Main Street Fish Market

**Centralia Daily Chronicle, Thursday, 23 February 1911, p. 3, col. 1**

Columbia River Smelt Can Be Had at the Main St. Fish Market and the Centralia Fish Market on North Tower Ave, 5 Cents per Pound

**Centralia Daily Chronicle, Thursday, 1 February 1912, p. 3, col. 5**

Centralia Fish Market
Columbia River Smelts, Per lb 5c

**Centralia Daily Chronicle-Examiner, Thursday, 16 January 1913, p. 6, col. 6**

Columbia River Smelts, 5c per Pound, City Fish Market, Carsten Building

**Centralia Daily Chronicle-Examiner, Friday, 17 January 1913, p. 6, col. 2**

Smelt Run Is On in Earnest

> Kelso, Jan. 17—Columbia River smelt, or Cowlitz River smelt, as they should be called, have come into the Cowlitz in ever increasing numbers since the fag end of last week, and fishermen now report that the run is a satisfactory one, although not extremely large. Monday saw the first large catch, more than one thousand boxes of 50 pounds each, or 50,000 pounds, being caught and shipped from Kelso. The gill nets have been discarded for the nets of the dip variety, and a force of a score or more of boats has been busy in midstream.

**Centralia Daily Chronicle, Friday, 31 January 1913, p. 3, col. 6**

We are Now Well Supplied with Choice Columbia River Smelt, Shipments Daily, 5 Cents a Pound, City Fish Market, Carstens Building

**Centralia Daily Chronicle-Examiner, Monday, 10 February 1913, p. 6, col. 6**

> 1,200,000 smelt were caught in the Cowlitz River last Sunday.

**Olympia Daily Recorder, Wednesday, 14 January 1914, p. 2, col. 7**

Run of Smelt Largest Ever in the Columbia

> Portland, Ore., Jan. 14—The greatest run of smelt ever in the Columbia River is now being harvested. Fresh offerings of Columbia River smelt were quoted at 5 cents a pound today by the wholesale fish trade and there were indications that even this low price would be cut. The market is glutted.
>
> Such heavy catches by gillnetters of the lower Columbia River were never before seen in this market. As a rule the gillnetters catch only limited supplies before the fish enter the Cowlitz, when they are caught in abundance with dip nets.

**Centralia Daily Chronicle-Examiner, Tuesday, 23 February 1915, p. 3, col. 3**

Heavy Smelt Run in Lewis

> Kelso, Feb. 23—That the heavy run of smelt have passed up the Cowlitz River for this season seems certain from the enormous numbers of the tiny fish which have poured up the Lewis River during the past few days. Not satisfied with the Kalama River, which they first entered, the main run of the fish went into the Lewis River, and at the present time that stream looks like the Cowlitz at this season of other years. Smelt everywhere in the waters, filling it from bank to bank and all the way from the mouth far above Woodland.

**Centralia Daily Chronicle, Wednesday, 17 March 1915, p. 3, col. 4**

Big Smelt Run

> Woodland, Wash., March 17—The great run of smelt in the Lewis River during the past month and which seemed to be decreasing last week has been increased by another run which started yesterday, and the fish coming now are of as good quality as have ever been caught here, but the price has ruled so low that there are not many fishermen taking them. Seagulls and other fish-eating birds are doing their best to clean them up. The gulls are on the river by the hundreds of thousands, their flight being almost solid at times, and the sand bars when covered by them look like a snow bank. Immense numbers of the little fish are lying dead in the river and a good rain, with a rise in the river, would be a great help, as it would wash the dead fish out. This is the first season in seven years the fish have come in here.

**Centralia Daily Chronicle-Examiner, Wednesday, 31 March 1915, p. 1, col. 3**

Smelt Come Too Late

> Kelso, March 31—Too late to do the fishermen of the Cowlitz River any good, because the market is already loaded up and the price down, large numbers

of smelt came into the river some time last week. For some unknown reason the smelt this year wandered everywhere except into the Cowlitz, which in seasons past has been their regular abode. This is the first run of smelt of any size in the Cowlitz this year.

**Centralia Daily Chronicle-Examiner, Friday, 17 December 1915, p. 2, col. 2**

Smelt Coming In

Kelso, Dec. 17—Smelt are coming into the Cowlitz River in increasing numbers, as shown by growing catches of the gillnetters. Gillnetting for smelt at this season of the year is profitable, as the fish bring 20 cents a pound. Later on the fishermen will be lucky to get that much a box.

**Centralia Daily Chronicle-Examiner, Friday, 31 December 1915, p. 7, col. 5**

Many Smelt Caught

Kelso, Dec. 31—Since the drop in the Cowlitz River smelt have been plentiful in the stream and gillnetting for them has been going on merrily. Many boxes of fish are being caught daily in this manner and the fishermen are getting good prices for them.

**Centralia Daily Chronicle, Wednesday, 12 February 1920, p. 8, col. 4**

Wait for Smelt

Kelso, Feb. 12—A few smelt have been caught in the Cowlitz River the past two years and fishermen are hopeful that a heavy run of the fish will soon appear in the stream. Smelt in large numbers were reported to be nearing the mouth of the Cowlitz just before the recent cold weather and fishermen think that they may soon be in the stream now that the ice is gone. Last year was the only one in the last three years that the smelt came into the Cowlitz, the main run going up the Lewis River in 1927 and 1928.

**Centralia Daily Chronicle, Friday, 25 January 1929, p. 2, col. 5-6**

Smelt Running

Longview, Jan. 25—The annual horde of smelt is coming up the Columbia River. The run is at present in the vicinity of Cathlamet, about 40 miles west of here, according to local fishermen. There is considerable conjecture here as to whether the shining silvery millions of little fish will journey up the Cowlitz or the Lewis rivers. The Cowlitz was the usual habitat until two years ago when they selected the Lewis, 30 miles further up stream. It was thought to be an "off year," which occurred once in about seven years previous. But last season the smelt passed by the Cowlitz and went up the Lewis again. Fishermen are scratching their heads and wondering which stream will be selected this year.

**Centralia Daily Chronicle, Saturday, 23 February 1929, p. 4, col. 4**

Smelt Overdue

Kelso, Feb. 23—The main run of Columbia River smelt into the Cowlitz or Lewis rivers is considerably past due and fishermen are waiting for the run to enter one of the streams. The run has gone up the Lewis River for the past two years. The fish have been caught by gillnetters in large quantities in the Columbia River near Rainier, Ore., recently. It is believed the cold spell and the low stage of water in the streams has held up the migration.

**Centralia Daily Chronicle, Tuesday, 5 March 1929, p. 8, col. 5**

Smelt Shipped

Kelso, March 5—Shipments of Columbia River smelt from Kelso have averaged 150 boxes a day during the past week, according to express company representatives. The fish are taken by gillnetters operating in the Columbia River, the run not having entered either the Cowlitz or Lewis rivers to date this year. Ordinarily the run enters one of the streams late in January or early in February and it has never been known to be as late as it has been this year.

**Centralia Daily Chronicle, Saturday, 8 March 1930, p. 4, col. 1**

Smelt Are Running—Stories of "smelt catches" are running rampant about town this week. The silvery fish entered the Cowlitz several days ago and are now reported to be working their way upstream between Ostrander and Castle Rock. A net on the end of a long pole, a little deftness in its use and one's smelt order is soon filled.

**Chehalis Bee Nugget, Friday, 21 March 1930, p. 5, col. 2**

Smelt at Toledo

For the past week the Cowlitz River bank has been crowded with people who are busy dipping smelt from the river.

**Centralia Daily Chronicle, Wednesday, 31 December 1930, p. 8, col. 3**

Smelt Are Running

Kelso, Dec. 31—A few Columbia River smelt, are being dipped from the Cowlitz River each night, but the run of fish this winter is lighter than the usual small midwinter run and the fish will be gone within a few days. The main run of smelt does not come into the Cowlitz until late in February ordinarily. Smelt are now selling at about 15 cents a pound.

**Centralia Daily Chronicle, Thursday, 29 January 1931, p. 4, col. 4**

Smelt Run Begins

Longview, Jan. 29—(AP)—The smelt run is on! Innumerable thousands of the little fish are wriggling their way up the Cowlitz River today after meandering for several weeks in the Columbia below here. Several score boxes were packed from last night's dipping by eager commercial fishermen and heavy shipments to outside points have begun. The fish sell locally at four pounds for 25 cents.

**Centralia Daily Chronicle, Saturday, 21 February 1931, p. 5, col. 3**

Smelt Still Run

Kelso, Feb. 21—Heavy rains the past few days, which brought the Cowlitz River up several feet, have not interfered with the run of smelt that came into the river early this month, and heavy catches of fish were made the past two days. A new run of fish came into the Cowlitz this week. The demand for the fish is holding firm and heavy shipments are going out by rail, truck and boat daily.

**Centralia Daily Chronicle, Thursday, 12 March 1931, p. 2, col. 2**

Smelt Still Run

Kelso, Mar. 12—Another heavy run of smelt came in the Cowlitz River Sunday. They are of fine quality and fishermen are catching great quantities of them. The markets are holding up well this year and heavy shipments continue by rail, mail and truck. Distribution of smelt by truck has been developing on a large scale, and trucks now carry the smelt to points as far distant as Idaho and northern California.

**Centralia Daily Chronicle, Tuesday, 22 December 1931, p. 3, col. 5**

First Smelt of Season Show Up

Kelso, Dec. 22—(AP)—Mother Nature presented Cowlitz County a Christmas present today when the first smelt of the season appeared in the Cowlitz River. Johnny Wannassay, veteran Indian smelt fisherman, dipped the first catch. It ran about 200 pounds. For several years Wannassay has beaten other fishermen to this honor.

This first run [of] smelt is small. In fishing parlance it is called the scout run and precedes a major or larger run. The smelt come into the Cowlitz in large schools between December and May. When smelt fishing is at its height approximately 200 men find employment in dipping, packing and processing the fish, which are shipped to all parts of the world in one form or another.

**Centralia Daily Chronicle, Wednesday, 6 January 1932, p. 8, col. 6**

Quality of Smelt Unusually Good

Portland, Jan. 6—(AP)—"The smelt are running." This was the call today from many Columbia River and Cowlitz River points as hordes of the small fish piled up stream in silvery waves. Reports from the two streams said the run is one of the earliest large invasions on record, and it was taken by many to presage an early spring.

Dealers here report the quality of the fish this year is unusually good. The present showing is regarded as rather spectacular and wholly unexpected. Many unemployed persons are working with dip nets on the two rivers. Fancy smelt are selling in Portland markets as low as three pounds for 25 cents.

**Centralia Daily Chronicle, Monday, 1 February 1932, p. 2, col. 8**

May Plant Smelt

Kelso, Feb. 1—Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama River and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful. The smelt are believed to have a four-year cycle, returning to their native stream after four years, to spawn.

**Centralia Daily Chronicle, Monday, 4 April 1932, p. 4, col. 7**

Smelt Run Ends

Kelso, April 4—(AP)—The annual smelt run in the Cowlitz River appears to be over and from other points comes word that catches in the Lewis River and in the Sandy River near Portland are also practically nil. Shipments from Kelso last Friday, when catches made before the closed period beginning Friday morning were sent to market, were very light and yesterday several fishing boats that went as far upstream as the regulations permit, found no smelt worth dipping in the Cowlitz River.

**Centralia Daily Chronicle, Wednesday, 4 January 1933, p. 6, col. 5**

Smelt Running

Longview, Jan. 4—(AP)—The annual winter run of smelt, forerunner of a spring run to come a month or two later, is hovering in the mouth of the Cowlitz River this week. The run has been proceeding slowly up the Columbia River for the past several weeks. Gillnetters in the Columbia are making most of the catches while a few commercial fishermen with dip nets are operating in the Cowlitz.

**Centralia Daily Chronicle, Monday, 7 April 1933, p. 3, col. 2**

Fish Notes—Smelt fishing in the Cowlitz River ended several days ago, but the seagulls remained to do their own fishing. Now, according to fishermen returning from the river, each day sees fewer gulls hovering over the water. This is taken as a sure indication that the smelt run is just about over.

**Centralia Daily Chronicle, Wednesday, 28 February 1934, p. 6, col. 2**

Smelt Season—Smelt are in the Cowlitz River but in "straggly" quantities, according to fishermen who have been after them with nets. Welfare people here received smelt yesterday that were collected at Castle Rock by fish inspectors, who took them from persons having in their possession more than the legal limit of 20 pounds. The Cowlitz is closed from 8 a. m. Friday to 8 p. m. Saturday to both individual and commercial fishermen.

**Centralia Daily Chronicle, Friday, 1 February 1935, p. 8, col. 2**

Shipping Smelt

Kelso, Feb. 1—The largest shipments of Columbia River smelt of the year have been made from here the past few days. Approximately 400 boxes, or more than 10 tons of the fish have been shipped daily by express to the more distant points and by truck to Portland and Puget Sound.

The heaviest shippers are the Columbia River Smelt Company and the Central Smelt Company. The latter is an organization of gill-net operators.

**Centralia Daily Chronicle, Thursday, 5 December 1935, p. 14, col. 3**

Smelt Running

Longview, Dec. 5—(AP)—The first smelt run of the 1935–36 season was reported off Clatskanie, in the lower Columbia River, today. A small shipment was made from that point to Portland markets yesterday, and two boxes were shipped from Kelso.

Smelt takes so far are males, indicating them to be the advance, or scout run. The female schools are due later.

# California

**Daily Evening Bulletin (San Francisco), Friday, 5 December 1879, p. 1, col. 1**

> Candle Fish of the Klamath—A very odd fish is found in large numbers in the Klamath, near its mouth. They are called candle fish. When grown, they are only six or eight inches long. They are very full of oil, which seems to be distributed all through their bodies. Dry them thoroughly and light either end and they will burn with as bright a light as a candle, and for about as long a time. Hence their name. They can be caught abundantly with seines. In their dry state they are quite pleasant to eat, the oil in them not having an odor or disagreeable flavor.

**San Francisco Call, Saturday, 2 May 1908, p. 12, col. 5**

> Redwood City, May 1—The local Izaak Waltons, who have been pressed for time, have been enjoying good fishing within the city limits. Redwood Creek, especially, near the works of the Alaska Codfish Company, is teeming with smelt, some of those recently caught running over a foot in length.

**San Jose Mercury Herald, Saturday, 15 February 1919, p. 5, col. 4**

Candle Fish Run Opens in the North

> Eureka, Cal., Feb. 14—The yearly run of candle fish has begun in the Klamath River and fishermen state that it exceeds in volume anything heretofore recorded. It is said that if any means could be found of canning this fish a new product of high food value could find its way to the market. The candle fish is particularly rich in valuable oils.

**Humboldt Standard (Eureka), Thursday, 21 February 1952, p. 9, col. 7–8**

Around Our Town, by Scoop Bean

> Scattered Notes—Candle fish are running in the Klamath River—they are caught at night with dip nets—the fish are said to have received their present name from early white settlers who sometimes inserted a wick in the smoked fish for a source of candlelight.

**Humboldt Standard (Eureka), Friday, 1 April 1955, p. 10, col. 3–5**

How're They Biting? by Chet Schwarzkopf

> … Jack Morris, maestro at Blue Creek Lodge on the Klamath, … says … "I guess you know we also have a big run of candlefish each spring that affords the people here lots of fun as well as good eating."

**Humboldt Standard (Eureka), Wednesday, 10 April 1963, p. 10, col. 3**

Heavy Candlefish Run in Klamath

> Klamath—Meat market sales showed a sharp decline around Klamath over the weekend and Monday. Almost everyone was eating crisp-fried candlefish. Awaited by the old-timers, as a heavy run of candlefish seems to herald a good salmon and steelhead fishing season to come, word spread fast, when the "run" started, a little late this year. Most popular "dipping" area was near the public boat ramp in the Klamath Glen area, perhaps due to easy accessibility.
>
> Owners of the large nets needed to dip for these small fish reported a "turn-over" practically every hour, as each one borrowing it returned the net within a very short time. A few dips netted each one their limit in pounds, and more than enough to feed their families.

**Humboldt Standard (Eureka), Monday, 15 April 1963, p. 13**

Thousands of Candlefish in Heavy Redwood Creek Run

> [Photo caption 1:] Joe January of Sacramento dips up a net load of candlefish at the mouth of Redwood Creek near Orick. Thousands of the silvery fish, called Columbia River smelt in most waters, are running in the creek and the Klamath River, heading upstream to spawn. According to local Fish and Game authorities, this is the first time candlefish have run up Redwood Creek in large numbers. Normally the fish are found only in the Klamath River and a few other northern rivers.
>
> [Photo caption 2:] Commercial fishermen net candlefish in the ocean at the mouth of Redwood Creek. Left to right are Fred Shipman, Stanley Dombek and Lawrence Lazio. Commercial catches must be made in salt water.
>
> [Photo caption 3:] A herd of sea lions enjoys a feast of candlefish as the silvery smelt run by the thousands at Redwood Creek. Fish derive their local name from the fact Indians dried them and used them for candles.
>
> [Photo caption 4:] Silvery candlefish measure five to six inches in length, with a few up to nine inches. Thousands of the small smelt are running up Redwood Creek and the Klamath River to spawn.
>
> [Photo caption 5:] Lawrence Lazio of Eureka demonstrates the density of the current candlefish runs by catching them with his hands. Many people lacking nets did just that and caught enough fish for a large fish fry.
>
> [Photo caption 6:] Fred Shipman, left, and Stanley Dombeck deliver a large commercial catch of candlefish to a local fish company. The smelt will be sent to the Bay Area and Los Angeles.

**Humboldt Standard (Eureka), Tuesday, 16 April 1963, p. 7**

Candlefish Running in Mad River

> [Photo captions:] Local fishermen use nets for an unusual run of silvery candlefish in the Mad River. In top photo, two unidentified men watch as Bill Damgaard, left, and Bob Hoffman, both of McKinleyville, wade into the water to net the fish. Mrs. Sarah Gillman, below, of McKinleyville, empties her net laden with candlefish into a bucket. Heavy runs of the fish, also known as Columbia River smelt, also are reported in Redwood Creek and the Klamath River.

**Humboldt Standard (Eureka), Tuesday, 23 April 1963, p. 20**

Surf Netters Catch Candlefish near Redwood Creek

> [Photo caption:] Countless candlefish are still running at Redwood Creek, this time in the Pacific surf. Scores of fishermen took advantage of Sunday's spring weather to enjoy the sport and prepare for a fish fry. The silvery fish, commonly called Columbia River smelt, derived their local name from the fact Indians used them as candles. The fish normally run only in the Klamath River and other northern streams but recently heavy runs have been reported in Redwood Creek and Mad River and now in the surf.

**Humboldt Standard (Eureka), Friday, 9April 1965, p. 13, col. 1**

Sideline Slants[column head], Candlefish Run Top Weekend Prospect, by Don Terbush

> The annual spawning run of candlefish is on in the Klamath River and the oily rascals are said to be numerous. Big runs are usually followed by large runs of salmon, according to veteran anglers along the river.
>
> Don't forget—a valid fishing license is required.

**Times-Standard (Eureka), Thursday, 14 March 1968, p. 19, col. 1**

Anglin' Around, by Ray Peart

> Candlefish at Klamath—It has started. The small fish called candlefish or eulachon are making their spawning run up the Klamath and should be found in Redwood Creek and Mad River soon.
>
> Eulachon normally die after spawning, but Marine Resources biologists tell me they have recovered a few spawned-out fish in the ocean while conducting shrimp sampling cruises.
>
> The eulachon (Thaleichthys pacificus) was first recorded from British Columbia waters in 1866 by A. Gunther on the basis of four specimens eight to nine inches in length, collected near Vancouver Island by C. B. Wood, surgeon on HMS Plumper, and presented to the British Museum. The fish is common along the whole coast of British Columbia, and enters large rivers during March, April

and May to spawn. It matures at two to three years of age and usually dies after spawning. The average female spawns 25,000 eggs which hatch in two to three weeks. The young are then carried by the current to the sea where they mature.

In the old days, eulachon were used extensively by Indians for food and production of oil for cooking. Previous to the advent of manufactured candles and other lighting devices, these fish were dried, fitted with wicks and used as candles, hence the frequently used name, candlefish.

Most people now smoke the fish, and some of the oil is worked out this way. They are very rich. Others pickle them. A gourmet treat is the roe from females mixed with salami and eggs, made into patties and fried.

Last year there was a huge run of candlefish in Redwood Creek. For eight days, these small dry-feeling fish swam up past Orick in a continuous school from bank to bank. That was around the first week in April.

It's fun to net these fish. Take the family for a day at the beach. The limit is 25 pounds and you do need a license. Check the 1968 Sport Fishing Regulations for new rules concerning netting candlefish in Redwood Creek and Mad River.

**Times-Standard (Eureka), Wednesday, 16 April 1969, p. 21, col. 5**

Candlefish Run Again in Klamath

Klamath—Large catches of candlefish have been taken from the Klamath River this past week, and were still running heavily Sunday evening.

Quite a number of fish are brought up each dip of the large nets used. The heavy run is late this year, as usually the month of March is the time of most of the run. A number of the local people smoke large quantities of the fish, as well as those who enjoy them just fried very crisp.

Candlefish are similar to the Columbia River smelt. A heavy concentration of seagulls and large groups of sea lions accompany the run. Several days last week, the sand spit at the mouth of the river was covered with the sea lions, as they sunned themselves, after dining on the fish, no doubt.

**Times-Standard (Eureka), Friday, 19 March 1971, p. 11, col. 1**

Sideline Slants [column head], Candlefish Running, by Steve Terbush

"Candlefish are running at the mouth of the Klamath River," was Bill Dimmick's comment from Orick. "I've seen a lot of nets heading that way."

**Times-Standard (Eureka), Friday, 5 May 1972, p. 19, col. 1**

Sideline Slants, by Steve Terbush

Mrs. Paul observes from Klamath that "this has been a wonderful candlefish year and that usually means a good salmon year on the Klamath River."

**Times-Standard (Eureka), Friday, 16 April 1976, p. 13, col. 1**

Sideline Slants, by Steve Terbush

> Humboldt County Fish hatchery chief Steve Sanders … noted that "they are still picking up candlefish at Redwood Creek. The catches are light although some limits are being taken."

**Times-Standard (Eureka), Friday, 23 April 1976, p. 9, col. 1**

Sideline Slants, by Steve Terbush

> Candlefish in the Klamath, Redwood Creek and Mad River … are the major items of interest to North coast sports anglers this weekend.
>
> "There are lots of candlefish in the Mad River," reports hatchery superintendent Bob Will. "Last weekend it was hot. They are higher up than I've ever seen them—clear up to Blue Lake which is unusual. Of course, the fishing area is only open to the railroad bridge at Essex.
>
> "About every third year there are always a few," Bob added. "This year it seems there is an extraordinary amount."
>
> "They are still picking up candlefish in Redwood Creek, said Humboldt County Fish Hatchery chief Steve Sanders. "And I would recommend Stone Lagoon for fishing. There's not much pressure and I'm sure there are fish in there. If they (anglers) have a boat all the better."

# Appendix C: Selected Accounts of Eulachon in Early Historical References

*[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling and phrasing in these older works are generally preserved.]*

# Klamath River

**Autobiography of Clarence E. Pearsall (Pearsall 1928, p. 1614)**

Early 1890s

> At other times, with a single haul of their dip nets they [the Yurok fishers] caught fifteen or twenty pounds of quah-rah [candlefish], a small fish that when thoroughly dried burns like a candle.

# Columbia River

**Journal of Patrick Gass [Sergeant on the Lewis and Clark Expedition] (Gass 1807, p. 194–197 in Moulton's 1996 reprint edition)**

25 February 1806 (Fort Clatsop)

> Tuesday 25. The rain continued and the weather was stormy. About 10 o'clock the Natives went away, though it continued to rain very fast. They brought us yesterday a number of small fish [eulachon], of a very excellent kind, resembling a herring, and about half the size.

26 February 1806 (Fort Clatsop)

> Wednesday 26. We had a fair morning; some of the hunters went out, as our store of provisions was getting small, and three men went in search of these small fish, which we had found very good eating.

2 March 1806 (Fort Clatsop)

> Sunday 2. This day was also wet. The fishing party returned at night, and brought with them some thousands of the same kind of small fish, we got from the Natives a few days ago, and also some sturgeons.

6 March 1806 (Fort Clatsop)

> Thursday 6. Our stock of provisions being nearly exhausted, six men were sent out in different directions to hunt, and three more were sent to endeavor to procure some fish, as the Natives take a great number of the small fish about 20 miles distant from the fort by water.

9 March 1806 (Fort Clatsop)

> In the afternoon some of the Natives came to visit us, and brought some of the small fish, which they call ulken.

11 March 1806 (Fort Clatsop)

At noon our fishermen returned with some ulken and sturgeon.

**The Definitive Journals of Lewis and Clark, Down the Columbia to Fort Clatsop (Moulton 1990)**

24 February 1806 (p. 342–344)

> This evening we were visited by Comowooll the Clatsop Chief and 12 men women & children of his nation. … The chief and his party had brought for sail … a species of small fish which now begin to run, and are taken in great quantities in the Columbia R. about 40 miles above us by means of skiming or scooping nets. On this page I have drawn the likeness of them as large as life; it is as perfect as I can make it with my pen and will serve to give a general idea of the fish. The rays of the fins are boney but not sharp tho' somewhat pointed. The small fin on the back next to the tail has no rays of bone being a thin membranous pellicle. The fins next to the gills have eleven rays each. Those of the abdomen have eight each, those of the pinna-ani [anal fin] are 20 and 2 half formed in front. That of the back has eleven rays. All the fins are of a white colour. The back is of a bluish duskey colour and that of the lower part of the sides and belley is of a silvery white. No spots on any part. The first bone of the gills next behind the eye is of a bluis cast, and the second of a light goald colour nearly white. The puple of the eye is black and the iris of a silver white. The underjaw exceeds the upper; and the mouth opens to great extent, folding like that of the herring. It has no teeth. The abdomen is obtuse and smooth; in this differing from the herring, shad anchovey &c of the Malacopterygious Order & Class Clupea, to which however I think it more nearly allyed than to any other, altho' it has not their accute and serrate abdomen and the underjaw exceeding the upper. The scales of this little fish are so small and thin that without minute inspection you would suppose they had none. They are filled with roes of a pure white colour and have scarcely any perceptable alimentary duct. I find them best when cooked in Indian stile, which is by roasting a number of them together on a wooden spit without any previous preparation whatever. They are so fat they require no additional sauce, and I think them superior to any fish I ever tasted, even more delicate and lussious than the white fish of the lakes which have heretofore formed my standart of excellence among the fishes. I have heard the fresh anchovey much extolled but I hope I shall be pardoned for believing this quite as good. The bones are so soft and fine that they form no obstruction in eating this fish. We purchased all the articles which these people brought us …. The sturgeon which they brought us was also good of it's kind. We determine to send a party up the river to procure some of those fish.

2 March 1806 (p. 368)

> … late this evening Drewyer arrived with a most acceptable supply of fat sturgeon, fresh anchovies [eulachon] and a bag containing about a bushel of wappetoe. We feasted on anchovies and wappetoe.

4 March 1806 (p. 378)

> The anchovey [eulachon] is so delicate that they soon become tainted unless pickled or smoked. The Natives run a small stick through their gills and hang them in the smoke of their lodges, or kindle a small fire under them for the purpose of drying them. They need no previous preparation of guting &c and will cure in 24 hours.

**The Definitive Journals of Lewis and Clark, From the Pacific to the Rockies (Moulton 1991)**

16 [March 1806] (p. 44)

> The anchovey [eulachon] had ceased to run; the white salmon trout [steelhead] have succeeded them.

25 March 1806 (p. 12)

> ... at noon we halted and dined. Here some Clatsops came to us in a canoe loaded with dryed anchovies [eulachon], which they call olthen [Chinookan ú-lxan, meaning dried eulachon], wappetoe and sturgeon.

29 March 1806 (Sauvies Island) (p. 27)

> They had large quantities of dryed anchovies [eulachon] strung on small sticks by the gills and others which had been first dryed in this manner were now arranged in large sheets with strings of bark and hung suspended by poles in the roofs of their houses.

**The Journals of John Ordway [Member of the Lewis and Clark Expedition] May 14, 1804–September 23, 1906, (Moulton 1995, p. 275–278)**

2 March 1806 (Fort Clatsop)

> … in the evening the three men returned from the village with a considerable quantity of the little fish [eulachon] resembling herren [sic] only a size smaller—and some sturgeon and a few wapatoes, which they purchased from them. The Natives catch a vast quantity of fish.

9 March 1806 (Fort Clatsop)

> Several of the Clatsop Indians came to the fort with some small fish [eulachon] … to trade to us.

11 March 1806 (Fort Clatsop)

> Sergt. Pryor returned with a considerable quantity of small fish and sturgeon.

21 March 1806 (Fort Clatsop)

> … a number of Natives visited us with some dryed small fish to trade which they call in their language oll-can [dried eulachon].

**The Journals of Joseph Whitehouse [Sergeant on the Lewis and Clark Expedition], May 14, 1804–April 2, 1806 (Moulton 1997, p. 423–430)**

26 February 1806 (Fort Clatsop)

> … 2 of our men went in a canoe in order to go to the Clatsop & Cathlameht Village in order to purchase some fish from the Natives. We found the fish that we had purchased from them 2 days past, to be well tasted & fat, especially the small fish [eulachon], which had the resemblance of a herring but much better tasted.

2 March 1806 (Fort Clatsop)

> In the evening, three of our men returned who had been trading at the Clatsop Village. They brought with them a considerable quantity of those small kind of fish, which we purchased from the Natives some days past; these fish were a size smaller than the herring. … The Natives gave them some fish without any recompence being made to them. These Indians catch great quantities of different kinds of fish in a creek lying a small distance above their village.

5 March 1806 (Fort Clatsop)

> … a number of the Natives came in canoes to the fort. They brought with them some sturgeon & some small fish [eulachon] to trade with us. Our officers purchased the whole of them.

17 March 1806 (Fort Clatsop)

> … purchased from the Natives … a few small fish [eulachon], the small fish not unlike a herring getting scarce among the Natives.

21 March 1806 (Fort Clatsop)

> The Natives came to the fort & brought some dried fish, which the Indians called all-can [dried eulachon], we purchased some of these fish from them.

**The Discovery of the Oregon Trail: Robert Stuart's Narratives of his Overland Trip Eastward from Astoria in 1812–13 (Rollins 1995)**

1812 (p. 8)

> … the dreary months of January and February, after which sturgeon and uth-le-chan [eulachon] may be taken in great numbers, the former sometimes by the spear, but more generally by the hook and line; and the latter by the scoop net. The uthlechan is about six inches long and somewhat similar to our smelt, is a very delicious little fish, and so fat as to burn like a candle, and are often used for that purpose by the Natives.

1 July 1812 (p. 30)

> Here are the best and almost only fisheries of uthulhuns [eulachon] and sturgeon—the former they take in immense numbers by the operation of the scoop net from the middle of March till the middle of April, and the latter [principally] by the hook and line during the spring and fall seasons—the uthulhuns are a kind of smelt, and when dried for preservation, are much similar to smoked herrings.

**Wilson Price Hunt's Diary of his Overland Trip Westward to Astoria in 1811–12 (Rollins 1995, p. 308)**

15 February 1812

> On the 15th, we passed several large islands. The land on the left bank was covered with oaks and ash trees, but all was inundated. I stopped at some Indian huts where I found four of our fellow countrymen who were bartering for sturgeon and were fishing for excellent small fish, which were about six inches long. The Indians call them othlecan [eulachon], and catch many of them in the springtime.

**A Voyage to the Northwest Coast of America (Franchère 1968, p. 180)**

> February brings a small fish about the size of a sardine. It has an exquisite flavor and is taken in immense quantities by means of a scoop net which the Indians, seated in canoes, plunge into the schools: but the season is short, not even lasting two weeks.

**Adventure at Astoria, 1810–1814 (Franchère 1967, p. 108)**

> February brings a little fish, somewhat longer and broader than the sardine, that we took at first to be a smelt [eulachon]. It has a delicate flavor and is abundant, but the season for catching it lasts only a short time.

**The Journal of Gabriel Franchère, 1811–1814 (Franchère 1969, p. 110–111)**

> At the beginning of February [1812] the Indians brought us large quantities of a small fish [eulachon] six or seven inches long, which we found excellent. …
>
> The Natives continued to supply us with small fish until the 20th, when the season was over. This fish, which is very abundant, is caught by means of a scoop or rake, which is simply a long pole to one end of which they have fastened sharply pointed pegs; by pulling it back and forth through the water they catch the fish on the pegs and soon have a canoe full. The women dry these fish, which furnish their principal food supply during the months of April, May, and June, threading them when dry in a double row on cords which are six feet long. They even trade in them with the Natives of the upper river, for these fish are not caught further up than the territory of the Chreluits [Chinook Indians], about 15 leagues from the mouth of the Columbia.

**The Journal of Alexander Henry the Younger 1799–1814 (Gough 1992)**

6 January 1814 (p. 635)

> This evening a canoe arrived from above which brought us four large sturgeon and a few smelt [eulachon]. These are the first of these small fish we have seen here this season. They generally make their appearance here in February, but the gentlemen who arrived today from above tell us the Indians take them at present in great abundance about the entrance of the Willamette River.

7 January 1814 (p. 637)

> The great smoke which now rises from the three Chinook villages denotes the return of these people to their winter quarters, which is usually at this period. They will contrive to augment in numbers daily, as the smelt [eulachon] fishing is approaching fast and then the sturgeon fishing follows, and, as the spring draws near, the salmon fishing approaches, the Natives from the northward will also bend their course here also.

11 January 1814 (p. 642)

> Passed Mount Coffin on the north side. … We saw … many of the Natives fishing smelt [eulachon] with a scoop net along the shores.

27 January 1814 (p. 665)

> The insides of these Indians houses are crowded with smelt [eulachon] drying, suspended by the heads to poles, the roofs are lined everywhere excepting the fire place is full, all hanging tail downwards. Several canoes were also full laying off at anchor. ... We passed several fishing parties, tented on the beach, who had … canoes loaded with smelt. …. At 9 o'clock we passed Mount Coffin, and at 11 o'clock we passed Oak Point. We saw several sea lions. … The number of gulls

and other birds that feed on fish are surprisingly numerous here at present, much more so than last fall. The cause I presume is they are attracted by the numerous shoals of smelt which are going up the river at this season of the year. Seals are very numerous also.

8 February 1814 (between Mount Coffin and Oak Point on the Columbia River, p. 676)

We observed on the beach and floating on the surface of the water great numbers of smelt [eulachon] dead and dying, the same fate which attends the salmon, and seems to attack the small fish in the river. They all die apparently for want of food, there being not the least particle of any substance in their gut, which consists of only one very small green filament. Gulls, shell drakes, and other waterfowl that feed on fish are uncommonly numerous, also eagles both baldhead and grey. Herons are very common along the shore and perched on the trees.

26 February 1814 (Fort George, aka FortAstoria, p. 683)

Two Indian canoes came over, on their way up to catch sturgeon and smelt [eulachon]. I saw a kind of pole about 10 feet long and 2 inches broad, one side was fixed a range of small bones, about a ¼ of an inch asunder, and about one inch in length, and very sharp; the range of teeth extending about six feet up the blade, this I understand is used in the smelt fisheries.

6 March 1814 (Fort George, aka Fort Astoria, p. 695)

Several canoes deeply loaded with smelt [eulachon] and sturgeon arrived from above and proceeded to the Calpoh's Village, having sold some of the smelt to us and passed on.

19 March 1814 (Fort George, aka Fort Astoria, p. 701)

The sturgeon continue to be plenty, and the smelt [eulachon] few; they do not all die as soon as I had imagined when I was last above in the beginning of February, as Mr McKay tells me they are now in the same state as they were then, a few found dead along the beach, and others dead and dying in the water.

3 April 1814 (p. 708)

We now have sufficient of their dried smelt [eulachon] which has been purchased mostly from the Chinooks and Clatsop, who buy the fish above themselves, and before it is brought down and strung up to dry it is spoiled. The dried smelt from above is much better by being dried on the spot. I now desired them to be traded at 1 fathom of small blue Canton beads for 5 fathoms of smelt. Yesterday we had traded at 4 fathoms.

**Adventures of the First Settlers on the Oregon or Columbia River &c (Ross 1849, p. 94–95)**

> There is a small fish resembling the smelt or herring, known by the name of ulichan, which enters the [Columbia] river in immense shoals, in the spring of the year. The ulichans are generally an article of trade with the distant tribes, as they are caught only at the entrance of large rivers. To prepare them for a distant market, they are laid side to side, head and tail alternately, and then a thread run through both extremities links them together, in which state they are dried, smoked, and sold by the fathom, hence they have obtained the name of fathom-fish.

**Trading Beyond the Mountains: The British Fur Trade on the Pacific, 1793–1843 (Mackie 1997, p. 30)**

> In April 1821, James Keith of Fort George [at Astoria, Oregon] wrote to his supplier, Perkins and Company, about the difficulties of obtaining a provision supply in this extremely remote region. Keith was dependent on the Chinook people of the lower Columbia for salmon, sturgeon, and wildfowl. "The winter has been unusually severe both as to the degree of cold & quality & duration of the snow," he wrote. "The fishery of the smelt [eulachon] being lately over, the Natives begin to bring us a chance sturgeon & wild fowl, which when more abundant will be gratifying to people from a long sea voyage…."

***Salmo* (*Mallotus*?) *pacificus* (Richardson) North-west Capelin (Richardson 1836, p. 226–227)**

> The Indian name of this fish is oulachan. It comes annually in immense shoals into the Columbia about the 23rd of February, but ascends no higher than the Katpootl [Lewis River], a tributary which joins it about 60 miles from its mouth. It keeps close to the bottom of the stream in the day, and is caught only in the night. The instrument used in its capture by the Natives is a long stick armed with sharp points, which is plunged into the midst of the shoal, and several are generally transfixed by each stroke. It is the favourite food of the sturgeon, which enters the river at the same time, and never has a better flavour than when it preys on this fish. The oulachan spawns in the different small streams which fall into the lower part of the Columbia. It is much prized as an article of food by the Natives and arrives opportunely in the interval between the expenditure of their winter stock of dry salmon and the first appearance of the quinnat [Chinook salmon] in May.

**Report on the Fishes Collected on the Survey (Suckley 1860, p. 348–349)**

> They [eulachon] formerly entered the Columbia River in great numbers, and were equally abundant in Puget Sound. At present, although sparingly found in the waters named, they cannot be considered as occurring in large numbers south or east of the southern end of Vancouver's Island. In the latter locality they are very abundant in certain seasons, but nearly always a season of abundance is followed

by three or four years of scarcity. Further northward they are constantly abundant. The Haida, Stickene, and Chumtseyan Indians, living along the coasts of British and Russian America, bring vast quantities of these fish with them when visiting the white settlements on Puget Sound. The fish thus brought are for the consumption of the strangers during their stay, and have been simply dried, without salt, and for convenience in drying or transportation have been strung on sharp, pliable sticks which are passed through the heads.

In July 1856, Dr. William Fraser Tolmie, chief factor of the Hon. Hudson Bay Company, a gentleman well known to naturalists for his interest in science, presented me with a bunch of dried eulachon, which he had obtained from some of the "Northern" Indians. Dr. Tolmie also gave me the following memoranda: "These fish were caught at the mouth of Nass River, which empties into salt water near latitude 54°40′ north. The Indian name of the species is almost unspellable. Formerly they were quite abundant between the 46th and 49th parallels of north latitude. They are now but seldom caught south of latitude 50° north in any great number. North of that point they are still taken by the savages in vast quantities, and are smoked and dried for trade and home consumption. When eaten after being thus prepared they should be either steamed or broiled."

**The Naturalist in Vancouver Island and British Columbia, Vol. 1 (Lord 1866, p. 96)**

Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together. From the same causes the eulachon has also disappeared from Puget's Sound, and is now seldom caught south of latitude 50°N.

**The Dominion at the West: A Brief Description of the Province of British Columbia, its Climate and Resources (Anderson 1872, p. 30–32)**

A very valuable fish entering Fraser River to spawn in early spring, is the *Thaleichthys* (or preferably *Osmerus*) *Richardsonii*—locally known as the oolâ-han.* It appears in immense shoals, and is caught either with the scoop net, or, like the herring on the seaboard, with the rake. This simple device is merely a long light pole, flattened in one direction so as to pass readily through the water, and with the edge set towards the lower extremity with a row of sharply pointed teeth. The fisherman, entering the shoal, passes the implement repeatedly through the water, with a rapid stroke, each time transfixing several fish. Thus a copious supply is soon secured. The oolâhan is, in the estimation of most people, one of the most delicious products of the sea. Smaller than the herring, it is of a far more delicate flavor; and so rich that, when dried, it is inflammable.† This fish is not confined to Fraser River, but frequents likewise the Nass, a large stream issuing on the frontier between British Columbia and Alaska; another stream debouching into Gardner's Canal; and probably other rivers along the coast. Those caught at the mouth of the Nass are of a qua1ity even richer than those of Fraser River. The Natives, who assemble there in great numbers in spring to prosecute the fishery, besides drying them in large quantities, extract from the surplus a fine oil, which is highly prized by them as a luxury, and forms a staple article of barter with the interior tribes.

* I was long under the impression that this fish was a variety of Pilchard (*Clupanodon thrissa*) peculiar to the Pacific; and am indebted to Dr. Robert Brown, of Edinburgh, formerly in command of the Vancouver Island Exploring Expedition, for the correction adopted above.

† So much so, indeed, that, in Alaska, where it is likewise found, it is I believe called the "candle-fish." It is mentioned by Franchère, in his account of the Columbia River, under the name of outhelekane, from which its present designation is modified; and, from the circumstance of its being strung on cords by the Natives to dry, was called by the voyageurs poisson à la brasse, or fathom-fish. They were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

**Reminiscences of Cowlitz County (Huntington 1963, p. 5)**

Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. The Indians and white people at times caught a few with a stick with a sharp nail in it. After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife), having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

**Narrative of the Overland Journey to Oregon (Crawford 1878, unpublished manuscript, p. 369)**

Events of 1865
Appearance of Smelts on Cowlitz

In Feby and March 1865, there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. They always go along in close trains from one foot wide to two or three feet wide, falling in close concert. The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

**Report of the Inspector of Fisheries for British Columbia for the Year of 1876 (Anderson 1877, p. 345)**

> The oolá-han, called also in Alaska, the candle-fish, (*Thale-chthys* or *Osmerus Richardson*) although it may occur low down in the list of marine and anadromous fishes which I undertake at present only partially to furnish, is not therefore to be regarded as in my estimation the least important. I again venture to refer to certain notes which I have already made public; and I now repeat my increased conviction that the value of this fish for diverse economical purposes has not yet been fully understood. Formerly resorting in enormous shoals to the estuary of the Columbia River, it disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore. In Fraser River these fish are found, and resort thither regularly in heavy shoals; but little advantage is taken of their advent, beyond what are caught and consumed as a luxurious adjunct to the table while fresh, and a few casks hastily salted for sale and consumption at home, chiefly in fulfilment of private orders. At the Squawmish River, discharging at the head of Howe Sound, I found, on enquiry, that these fish enter the river, as elsewhere, early in the spring, and ascend as high as the head or the Island of Stââ-mis, forming the delta; thence, after spawning, returning to the sea. Several other rivers along the coast are known to be frequented by these fish; and there are doubtless others of which we are not, so far, cognizant. The Nass River, however, discharging into Observatory Inlet, close to the Alaskan boundary, stands preeminent as an oolá-han fishery, as well for the enormous supply it yields, as for the superior quality of its fish.

**Astoria, or, Anecdotes of an Enterprise beyond the Rocky Mountains (Irving 1868, p. 404)**

> About the beginning of February, a small kind of fish, about six inches long, called by the Natives the uthlecan, and resembling the smelt, made its appearance at the mouth of the river. It is said to be of delicious flavor, and so fat as to burn like a candle, for which it is often used by the Natives. It enters the river in immense shoals, like solid columns, often extending to the depth of five or more feet, and is scooped up by the Natives with small nets at the end of poles. In this way they will soon fill a canoe, or form a great heap upon the riverbanks. These fish constitute a principal article of their food; the women drying them and stringing them on cords. As the uthlecan is only found in the lower part of the river, the arrival of it soon brought back the Natives to the coast; who again resorted to the factory to trade, and from that time furnished plentiful supplies of fish.

**The Eulachon or Candle-fish of the Northwest Coast (Swan 1881, p. 258)**

> The eulachon are found in limited numbers at certain seasons in the Columbia River, Shoalwater Bay [Willapa Bay], Gray's Harbor, and at the mouth of the various small streams of the coast, and also in the waters of Puget Sound, where they are taken in seines and nets with smelt and other varieties of small fish, but

they are thin and poor, and not to be compared to the same varieties further north. Even those taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized. The few secured on Puget Sound are sold by the fishermen as smelts. The best kinds are caught further north, and great quantities are salted by the Hudson's Bay Company, at their trading post at Fort Simpson, British Columbia, and either sold in the Victoria market or shipped direct to London in tierces, barrels, and kits.

As an article of food and for the grease or fat contained in them, the eulachon are highly prized by the Indians of northern British Columbia and southern Alaska, where they abound; particularly at the Nass River, British Columbia, where they are annually taken in enormous quantities, and where they seem to attain their very finest condition.

# Fraser River, British Columbia

### The Fort Langley [a Hudson's Bay Company post on the lower Fraser] Journals, 1827–1830 (MacLachlan 1998)

28 April 1828 (p. 60)

> The little fishes which the Chinooks call ullachun [eulachon] begin to make their appearance here, and are joyfully hailed by the Indians of the river.

29 April 1828 (p. 60)

> We made a trial to take some of the little fish Chinook fashion [with the rake], and proved very successful as enough were taken to give a prog [?] to all hands.

14 April 1829 (p. 109)

> The small fish in the Columbia called ulluchans [eulachons] is also within the river, but not yet this high.

4 May 1830 (p. 147)

> The small fish called ulachans [eulachons] are arrived.

# Other British Columbia Waters

### The Economic Fishes of British Columbia (Green 1891, p. 30)

> The oolachan (*Thaleichthys pacificus*), an anadromous fish of about 9 inches in length, makes its appearance in the tidal waters of the Fraser about the middle of April, and in the Nass about the 23rd of March. When fresh is a delicious little fish, but it deteriorates with carriage, and is never seen to perfection in the

Victoria market. Numbers of oolachans are put up in pickle in small kits, and some are cured and smoked like bloaters.

Oolachan grease is an article much used and appreciated by the Indians. A large trade is done in this commodity between the Indians of the Nass River and those of the interior, in exchange for furs. In appearance and consistency it resembles lard, and is used on dried salmon or halibut, much in the same manner as we use butter on bread. A short account of its manufacture on the northern rivers may be of interest to you. As I before stated the oolachans arrive in March when the ice is still on the river. All the Indians who have any right to fish in the river, and this priviledge is jealously guarded, come from far and near to the fishery, and erect temporary dwellings along the banks or on the ice. The firewood for drying out the oil has to be brought from a distance, all that in the immediate vicinity of the fishery having been used long ago. The fish are taken under the ice with purse nets, and are left in heaps until they are, to say the least of it, high; partial decomposition assisting the extraction of the oil. They are then boiled in troughs which are about 5 feet long by 2 feet wide, and the fat is skimmed off, and put into square cedar boxes about the size and shape of a coal oil tin. Originally the grease was extracted by filling a wooden trough with water, and heating it with red-hot stones; this mode is now obsolete, the troughs having a sheet iron bottom built over a long and narrow furnace.

The oolachan has more than its fair share of enemies; sturgeon, salmon and porpoises follow it into the rivers, while bears and the settler's pigs gorge themselves with the exhausted shotten [sic] fish. At Port Hammond I once saw two pigs standing up to their backs in the water, and diving for oolachans; they seldom failed to bring one up.

**Vancouver Island and British Columbia: Their History, Resources, and Prospects (MacFie 1865, p. 163–165)**

Hoolakans ascend the streams in April in dense shoals. Their approach is indicated by the presence of seagulls swooping down to devour them, and causing the banks of the river to echo with their screeching. This species are about the size of a small herring, and are so fat as to baffle ordinary methods of cooking to prepare them for the table. Oil is pressed from them by the Indians on the coast, and disposed of to tribes in the interior. …

When dried, the hoolakan is often used by the Natives as a torch, and, when lighted, it emits a brilliant light. The Indians catch this species of fish by impaling them on rows of nails at the end of a stick, about four feet long, and so thickly do they swarm, that every time this rude implement is waved in the water, two or three of them adhere to it.

**The Coast Indians of Southern Alaska and Northern British Columbia (Niblack 1890, p. 276 and p. 299)**

Eulachon (*Thaleichthys pacificus*), the so-called "candle-fish," a kind of smelt, run in March and April at the mouth of the Skeena, Nass, and Stikeen rivers.

These have the greatest proportion of fatty matter known in any fish. In frying they melt almost completely into oil, and need only the insertion of some kind of a wick to serve as a candle. …

Eulachon or “candle-fish” run only in the mouths of rivers, particularly the Skeena, Nass, and Stikine in this region. They are considered great delicacies, and are dried and traded up and down the coast by the Indians who are fortunate enough to control the season’s catch.

# Appendix D: Selected Accounts of Eulachon in an Early Periodical

*[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling are generally preserved.]*

**Pacific Fisherman, March 1905, vol. 3(3), p. 19**

Big Catch of Smelt

C. R. Gatchet, a Portland fish dealer, reports that 150 tons of smelt were taken from the Cowlitz River between February 1 and 7. All were caught between Kelso and the mouth of the river. Mr. Gatchet kept a close account of the output. Allowing five smelt to the pound, the catch represents 1,500,000 fish. At the market price of five cents a pound they are worth $15,000.

**Pacific Fisherman, April 1905, vol. 3(4), p. 11**

Kelso Smelt Industry

Kelso, in Cowlitz County, Washington, with 1,200 population, is the center of the smelt industry. No other point visited by the myriad schools of fish can rival it. The season lasts several months, that just closed having commenced November 19, and ended March 15. During this period Kelso records show that 400 tons of smelt were sent from there to the world. This tonnage represents 16,000 boxes of smelt, each box weighing 50 pounds.

The fact that you can dip smelt from the Cowlitz River with a pitch fork, drive a wagon into the stream and load the bed in a short time, or annually ship to the hungry world 400 tons of this diminutive fish is a matter of pride at Kelso, for this community takes first honors in the smelt industry.

Catching smelt on the Cowlitz is an interesting process. The fleet of small boats stand out in the stream, one man to each craft, armed with dip net having a 15-foot handle. The ring at the end of the pole has a spread of 18 inches, while the net behind it is of sufficient capacity to carry many pounds of fish. The schools of fish, which surge up the river, are soon located, when the fishermen commence dipping down stream. Each stroke is richly rewarded, for, after a school is located, there are few water hauls. Lee Galloway, one of the best fishermen of the stream, has last season's record, catching 96 boxes in one night, each box weighing 50 pounds. This record means that with one of these poles he lifted from the stream 4,800 pounds of fish, or about two and a half tons.
—Charles R. Gatchet

**Pacific Fisherman, April 1906, vol. 4(4), p. 16**

Smelt Cease Running—The run of smelt on the Cowlitz River has ceased after a very successful season. The season's catch was the largest ever taken from the Cowlitz River. Over 700 tons were shipped, the amount being double that handled last year.

**Pacific Fisherman, April 1907, vol. 5(4), p. 8**

Kelso's Important Smelt Fishing Industry, by G. E. Kellogg

There are places, hundreds of them, which are noted for the production of some staple or marketable article, and of all the thus noted towns in Western Washington, Kelso has the distinction of being the best known on account of the smelt industry.

The little fish which tickles the palates of thousands of people each winter are the mainstay of the fishing people of this vicinity and not only put thousands of dollars in their pockets each year, but they add a great deal to the prosperity of Kelso and vicinity.

The smelt are a peculiar fish. Hatched in the headwaters of the Cowlitz or Sandy they return to the open sea in the spring. Returning in the fall and winter they unfailingly enter the Cowlitz, seeking the old spawning grounds beyond the reach of fishermen's nets. They travel in schools, or rather strings, the first run arriving at or near Kelso about the Holidays. The run of fish is most uncertain. Sometimes they last until the middle of March and sometimes they stop short in January.

So far this season there have been upwards of 3,000 boxes shipped from Kelso, a total of 37,350 pounds, going by express in the month of January alone. Carload shipments have been made in years when smelt were plentiful and cheap, but lately the demand has kept up so steadily that the fish are shipped almost as fast as they can be taken from the water.

Smelt have always been so plentiful that they never needed protection by law other than licensing fishermen, and there has never been any thought or fear of their extinction entertained by anyone who knew their habits.

Thus we have an industry which might be called perpetual, as there is no doubt of its continuance for many years to come.

We are enabled to produce the accompanying engravings showing smelt fishing scenes in the vicinity of Kelso by the courtesy of the Kelso Journal.

**Pacific Fisherman, April 1907, vol. 5(4)**

Smelt in the upper Columbia River—For the first time in many years smelt are running up the Columbia River above Kalama. Large schools have been passing Vancouver, Wash., and fishermen have reaped a rich harvest. The few smelt which have hitherto gone further up the river have been of poor quality, but these have been of the best. Just what turned the smelt aside from their favorite haunts up past Kelso has not yet been determined.

**Pacific Fisherman, January 1910, vol. 8(1), p. 19**

Columbia River

> … Smelt have arrived in the river for the first time this winter and are being caught in the vicinity of Kathlamet. They are a luxury on the breakfast table as the fishermen are wholesaling them at 25 cents per pound, but at the same time their flesh is so firm and high flavored that they are well worth the price for an epicure.

**Pacific Fisherman, March 1910, vol. 8(3), p. 14**

Columbia River

> The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fishermen. This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon. The increased run found the trade unprepared to handle it successfully and this accounts for the breaking of values to 10c and even lower. … Although the smelt, now so generously in the Portland markets, bear the name "Columbia River," the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately 15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

**Pacific Fisherman, April 1913, vol. 11(4)**

Donate Carload of Smelt to Sufferers

> The citizens of Kelso, Wash., donated a carload of Columbia River or Cowlitz River smelt, 20,000 pounds in all, to the Ohio flood sufferers. The Kelso fishermen donated 400 boxes of fish, the businessmen paid for the boxes and labor and an express company and the railroad furnished the transportation free.

**Pacific Fisherman, February 1914, vol. 12(2), p. 20**

Heavy Run of Smelts in Columbia River Valley

> An unusually heavy run of smelts appeared in the Columbia River in January and large catches are now being made in that river and its numerous tributaries, more particularly in the Cowlitz River, where the annual run of this delicious species forms the basis of a considerable commercial industry. This year, in addition to being shipped fresh on ice, large numbers are being dried at the Kelso plant of the Northwestern DeAquating Company, thus making it possible to almost indefinitely extend the market for Cowlitz smelts.

**Pacific Fisherman, February 1915, vol. 13(2), p. 29**

Smelt in the Kalama River

Early in February smelt entered the Kalama River in large numbers and the fishermen reaped a harvest for a time. It is a rare thing for the smelt to enter this river in any numbers. In the Cowlitz River, where the smelt usually run in immense numbers, few have been seen this season. Considerable catches have been made in the Columbia River proper.

**Pacific Fisherman, March 1918, vol. 16(3), p. 51**

Eulachon Run Late

Great preparations were made this year for handling large shipments of eulachon from the Columbia River, as the fish has become well established in several Eastern markets and interest has been greatly stimulated by the Bureau of Fisheries exploitation work. The run, however, has so far been very disappointing. Up to the first of March the usual run in the Cowlitz River has not appeared, and a fair run that started in the Kalama River was of short duration.

During the second week of March the eulachon appeared in large numbers in the Lewis River, and large catches have been made, with the fish in unusually good condition. The handling of the catch is somewhat more difficult than if the fish had run in the usual direction, but a heavy shipping movement to the East has been started, and it is expected that the shipments in that direction will reach important figures before the run is over. There was a fairly large movement last year, and the fish were well liked wherever they appeared, a large quantity having been placed on the New York market at a time of acute food shortage.

**Pacific Fisherman, May 1920, vol. 18(5), p. 48**

Oregon Smelt Running

The annual run of smelt in the Sandy River, an Oregon tributary of the Columbia, started April 24.

**Pacific Fisherman, March 1924, vol. 23(3), p. 35**

Shipping Smelt

For several weeks during February, shipments of smelt from Kelso, Wash., amounted to about 2,000 fifty-pound boxes daily, according to W. A. Mabie, manager of the Columbia River Smelt Company. Most of the shipments went to Portland, Ore., for distribution to consuming markets.

**Pacific Fisherman, February 1926, vol. 24(3), p. 30**

Columbia River Activities

Up to the last of January, the run of smelt in the Columbia River, which usually starts about January 15, had not appeared. About the middle of the month there was a small run, but few went up as high as the Cowlitz River or any of the other small streams which empty into the Columbia, except for about one day Grays River on the Washington side opposite Astoria fishermen secured considerable poundage. The run is still looked for by experienced men.

**Pacific Fisherman, March 1926, vol. 24(4), p. 44**

Good Oulachan Pack

The Candle Fish Company, Kelso, Wash., engaged in dry salting oulachans, or Cowlitz River smelts, for the Chinese market, reports that owing to the unusually good run this year little difficulty is anticipated in filling their contracts. More than 80 tons of salted oulachans were in the company's vats on the Kelso dock Feb. 15. Profiting by this year's experience the company is planning on improvements that will more than double their production next year.

Most of the catches during February were made at Sandy Bend between Kelso and Castle Rock. Fishermen and individual shippers of fresh smelts have been reaping a harvest from their catches, the Columbia River Smelt Company shipping on an average of 500 boxes daily.

**Pacific Fisherman, Annual Statistical Volume, January 1930, vol. 28(2), p. 189**

The run of Columbia River smelt appeared in the Cowlitz River again in 1929 in volume reported to exceed that of any previous season. The two preceding years had been complete failures and had given rise to the fear that pollution had destroyed the Cowlitz smelt, a supposition adequately disproved by the experience in 1929.

**Pacific Fisherman, Annual Statistical Volume, January 1933, vol. 31(2), p. 167**

Cowlitz Smelt

At the opening of the year production of fresh fish in the Pacific Northwest centered to a large degree on the Columbia River, where the winter salmon season yielded in a normal way, while the smelt run supplied another item of fresh fish. Before the smelt entered the Cowlitz the fishermen were able to hold the price to them at 2c per lb or above by the simple expedient of suspending their operations whenever the price went below that figure.

When the smelt run struck the Cowlitz the price dropped off sharply, as has been mentioned. The Washington smelt catch was one of the largest on record, being 1,476,939 lbs, surpassed in the previous seven years only by 1931.

# Appendix E: Substantive Scientific Comments from Peer Review

We received comments from five peer reviewers of the summary of the eulachon (*Thaleichthys pacificus*) status review completed in December 2008 (BRT 2008) and respond to them here. Reviewers were asked to assess the scientific validity of the status review, including any assumptions, methods, results, and conclusions. Reviewers were asked to focus on the quality of the data collected or used for the assessment, appropriateness of the analyses, validity of the results and conclusions, and appropriateness of the scope of the assessment (e.g., whether all relevant data and information were considered). We have summarized and organized the reviewers' comments into categories relevant to issues raised by the Eulachon Biological Review Team (BRT), composed of 10 federal scientists from 3 agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, and U.S. Forest Service. The peer reviewers are identified by number in order to preserve their anonymity.

In general, four of the five reviewers supported the conclusions of the Eulachon BRT. One reviewer did not agree with the delineation of the southern DPS of eulachon and argued that genetic and demographic evidence supports a much finer distinct population segment (DPS) structure for eulachon in this region. This same reviewer also pointed out a lack of information on eulachon marine distributions off the U.S. West Coast.

## Delineation of a Distinct Population Segment

### Review

Reviewer 1 stated that the discreteness and significance decisions were "well considered and defensible" and agreed that "the proposed DPS is discrete and significant and that its northern boundary is most defensibly delineated by Nass River, British Columbia." Reviewer 2 commented extensively on the proposed DPS scenario, and a summary of this reviewer's comments and our responses are presented below. Reviewer 3 stated that "the possibility exists that the Klamath River population (and associated populations to the south) is or was distinct." Reviewer 4 stated that the "conclusion that multiple discrete populations of eulachon exist appears well supported by the available evidence" and that "designation of a DPS encompassing all areas south of the Nass River/Dixon Entrance … appears to be the most strongly supported by the weight of available evidence, although other configurations of DPS(s) cannot be ruled out." Reviewer 5 did not address the appropriateness of the proposed southern DPS of eulachon, but requested clarification on one item, which we respond to below.

## Response

No response is required to comments by reviewers 1 and 4. With regard to the comment of Reviewer 3, the BRT was also cognizant of the possibility that the eulachon population in the Klamath River and in other steams of California may represent fish that have unique characteristics; however, the best available information is insufficient at present to identify what these characteristics are or were and whether they may have risen to the level of identifying eulachon in California as being “markedly separated” from populations to the north.

## Reviewer 2, Item 1

Reviewer 2 felt that it was not clear “why there were only six [DPS] scenarios when many more might have been proposed” and found “it puzzling that the BRT did not consider the option that the Columbia River was a DPS.” Furthermore, Reviewer 2 suggested that “the scenario that each river system represents a DPS … would have an approximate conceptual model of a river-based or stream-based salmon (*Oncorhynchus* spp.) stock structure as a precedent.”

## Response

As described in the “Evaluation of Discreteness and Significance for Eulachon” subsection of the BRT report, “other possible geographic configurations [of a DPS] that incorporated the petitioned unit were contemplated, but were not seriously considered by the BRT” (BRT 2008, p. 26) The BRT did discuss during its deliberations whether the Columbia River was a DPS, and after examining the available data and applying the discreteness and significance criteria for delineation of a DPS, no member of the BRT advocated for including this scenario in the final list that was voted on. The inclusion of scenario 6 (Multiple DPSs of eulachon in Washington, Oregon, and California) in the final voting process allowed BRT members to place some “likelihood points” in this scenario, which was representative of a scenario where every river is a DPS (including the Columbia River). Only 4% of all members’ likelihood points were cast for scenario 6.

We agree that, conceptually, it is reasonable to view stock structure of eulachon in a similar manner to Pacific salmon, and believe we have applied the DPS policies with regard to eulachon in a manner consistent with how previous BRTs have applied this policy to Pacific salmon. With regard to most Pacific salmon that have been examined under the U.S. Endangered Species Act, DPSs (which in the case of Chinook [*O. tshawytscha*], coho [*O. kisutch*], sockeye [*O. nerka*], chum [*O. keta*], and pink salmon [*O. gorbuscha*] are statutorily defined as Evolutionarily Significant Units [ESUs]) of these species consist of numerous demographically independent populations occupying a large number of individual drainages spread over large geographic areas. In only a few instances (e.g., some sockeye salmon ESUs) have Pacific salmon ESUs been designated on the basis of a single river basin. Pacific salmon DPS structure is thus conceptually consistent with the structure of the proposed southern DPS of eulachon, which may be composed of multiple subpopulations or stocks.

## Reviewer 2, Item 2

Reviewer 2 stated that "it is difficult to reconcile the conclusion of the BRT that there is one major DPS with the assertion that the BRT also acknowledges that finer population structure may exist." Reviewer 2 felt that spawn timing and genetic differences represent compelling evidence "that finer structure does exist between the Fraser and Columbia rivers."

## Response

The ESA requires the best available scientific and commercial information be used in determining the listing status of a species. However, the best available scientific information for eulachon is at present inadequate to define a particular DPS with 100% certainty, as reflected in the percentage distribution of likelihood points among four of six proposed DPS scenarios (see Table 1). Thus the BRT acknowledges that additional scientific research might result in evidence supporting either subdivision or expansion of the current DPS boundaries.

It is also important to acknowledge that the discreteness and significance criteria (USFWS-NMFS 1996) define a DPS, which is likely to be composed of many stocks or subpopulations. Previously designated DPSs of several marine fish include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history, genetic, and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008). Similarly, application of NMFS's ESU policy to Pacific salmon in the contiguous United States has resulted in designation of 52 ESUs, each of which is commonly composed of numerous populations that are often genetically and demographically differentiated one from another. In practical terms, if all genetically differentiated populations were to receive ESU status, there could conceivably be thousands of Pacific salmon ESUs.

The BRT did not believe that the available genetic or demographic data provide evidence that eulachon in the Fraser and Columbia rivers were "markedly separated" populations, as required by the DPS policy. With regard to the genetic microsatellite DNA study of Beacham et al. (2005), the BRT was concerned that this study compared samples between the Fraser and Columbia rivers taken in a single year, and thus the temporal stability of the genetic variation observed between these two rivers could not be adequately assessed. The BRT concerns with regard to temporal stability derive from the realization that reported year-to-year genetic variation within three British Columbia coastal river systems (Nass, Kemano, and Bella Coola rivers) in that study was as great as the variation among the rivers (Beacham et al. 2005). This temporal genetic variation indicates that additional research is needed to identify appropriate sampling and data collection strategies to fully characterize genetic relationships among eulachon populations.

## Reviewer 2, Item 3

Reviewer 2 invoked "significant genetic differences" between the Columbia and Fraser rivers described in Beacham et al. (2005) as evidence supporting a finer DPS structure, but at the same time described the statistically "significant differences in genetic composition between a sample taken in the Cowlitz River and one taken in the main stem of the Columbia" as "puzzling" in light of the assumption that the "basis for a [eulachon] population would be an estuary, perhaps formed by the confluence of a number of rivers." Reviewer 2 felt that "clearly some additional genetic analyses focusing on examination of potential differences within the Columbia River system would be very revealing."

### Response

Genetic samples described in Beacham et al. (2005) were taken in the Cowlitz and Columbia rivers in different years, which may partly explain the statistical differences in genetic composition between these two samples from the Columbia River drainage. Comparison of multiple year samples in the Kemano, Bella Coola (2 years of sampling each), and Nass (3 years of samples) rivers also showed statistically significant differences among samples from the same river across years. Beacham et al. (2005, p. 367) stated that "differentiation among sampling years within populations was similar to the level of differentiation among populations for these three putative populations." Thus it is uncertain whether some of the observed genetic differences described in Beacham et al. (2005) are temporally stable. We agree with the reviewer that further genetic studies of eulachon within the Columbia River and elsewhere are necessary to resolve these questions.

### Reviewer 5, Item 1

In reference to the third item in our list of evidence supportive of DPS scenario 4 (one DPS from Fraser River to California), Reviewer 5 stated that:

> … you argue that the pattern [of increasing length and weight with an increase in latitude] is found in many other vertebrate poikilotherms, so you tended to discount this evidence. However, in other places in the document, you seem to use parallels found in other fishes to support your findings. I found this somewhat contradictory, so perhaps a little more explanation would be useful.

### Response

Many quantifiable marine fish life history characters—such as body size-at-age, maximum age, and fecundity—increase with increasing latitude and the associated decline in rearing temperatures. Although some of these traits may have a broad genetic basis and may reflect local adaptations of evolutionary importance, they are usually strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and they can sometimes be used to infer the degree of independence among populations. However, differences in phenotypic and life history traits among populations do not provide definitive information on reproductive isolation between populations, because the genetic basis of many phenotypic and life history traits is weak or unknown.

At decreasing rearing temperatures, which can be expected in the northern portion of a species range in the northern hemisphere, a near universal relationship ensues among poikilotherms (i.e., cold-blooded organisms) where rates of growth are slower and size at a given age is larger (Ray 1960, Atkinson 1994). As most vertebrate poikilotherms exhibit similar latitudinal clines in these life history characters, their presence in eulachon offers at best weak evidence that eulachon in the southern and northern portion of their range are “markedly separated” from one another.

In both DPS scenario 4 (one DPS from Fraser River and south) and DPS scenario 1 (no DPS structure), where latitudinal differences in quantifiable life history characters or lack of differences other than those associated with latitude were mentioned as a supportive factor, parallel patterns with other fish species were pointed out to illustrate the apparent weakness of this evidence. We considered these geographic patterns in life history characters similarly in considering both DPS scenarios. Latitudinal variation in life history characters offered little support for either scenario (although other evidence may be more supportive), a fact which is reflected in the BRT’s assignment of likelihood points to these two DPS scenarios (about 27% to scenario 4 and about 12% to scenario 1).

## Appropriateness of the Scope of the Assessment

### Review

Reviewer 1 stated that “it is my opinion that the best available data on eulachon spawning from California north to Alaska have been detailed and analyzed as part of the review” and the BRT “has made appropriate and exhaustive use of the best available scientific data that bear upon the questions at hand.” Reviewer 2 commented that “the thoroughness of the literature review is impressive and … all facets of life history, historical use, habitat, commercial fisheries and traditional uses are described.” However, Reviewer 2 questioned whether the BRT examined all available databases relevant to marine distribution of eulachon in offshore waters of Washington, Oregon, and California. Reviewer 3 commented that the “Summary of the Scientific Conclusions” was an “excellent review of the literature.” Reviewer 4 stated that the “status review is very thorough” and “it appears that the BRT has based its conclusions on the best available information.” Reviewer 4 also stated that inclusion “of historical anecdotal records (e.g., old newspaper reports) and aboriginal traditional knowledge … were important in filling out the gaps in scientific data, and were influential in developing a qualitative ‘weight of evidence’ of eulachon status.” Reviewer 5 stated that “it seems to me you have been very thorough.”

### Response

No response is required to comments by reviewers 1, 3, 4, and 5. Although known marine distribution and abundance of eulachon was thoroughly discussed during the BRT’s deliberations, we agree that the summary of the status review (BRT 2008) failed to present or summarize all available information on marine distribution of eulachon off the U.S. West Coast and we attempt to rectify that oversight in this technical memorandum (see the Marine Distribution subsection in the Historical and Current Distribution subsection).

# Status of the Southern DPS of Eulachon

### Reviewers 2 and 4

Reviewer 2 did not address the appropriateness of the status assessment of the southern DPS of eulachon. Reviewer 4 stated that the BRT's conclusion that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range "appears to be strongly supported by the available information, which indicates severe declines in abundance and historically low population levels throughout most of the species range." Comments of the other reviewers are addressed below.

### Reviewer 1

Reviewer 1 stated that the "BRT has appropriately weighed the various degrees to which age and size at maturity and fecundity can influence rate of population recovery." Furthermore Reviewer 1 felt that the BRT "note[d] correctly (in my opinion) the high probability that eulachon require comparatively high minimum viable population sizes to persist throughout the DPS." Reviewer 1 also believed that the BRT's application of the risk matrix approach "is not unreasonable when assessing extinction risk." However, in light of the demographic risks outlined by the BRT, Reviewer 1 "was somewhat surprised by the conclusion that the DPS is at moderate, rather than high, risk of extinction" and "might have expected a greater percentage of the available points to have been in the high risk category." In addition, although Reviewer 1 acknowledged that "the BRT has concluded that the DPS is at moderate risk of extinction throughout all of its range," the reviewer felt that "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range would be useful."

### Response

The BRT also noted and discussed the apparent discrepancy between its high concern for individual demographic risks (abundance, productivity, spatial connectivity, and diversity) and the placement of the majority of likelihood points in the "moderate" rather than "high risk" category. It was apparent that some BRT members placed substantial emphasis on the innate productivity and demonstrated resilience of eulachon to ameliorate concerns they may have had in the categories of abundance, spatial connectivity, and diversity, and that factor weighed heavily on their overall consideration of the DPS's relative risk of extinction. This divergence of opinion on the productivity category is also reflected in the risk matrix scores for that demographic criterion compared to abundance, spatial connectivity, and diversity. For instance, BRT scores for abundance of the DPS ranged from 4 ("high risk") to 5 ("very high risk") with a modal score of 4, whereas BRT scores for growth rate and productivity of the DPS ranged from 2 ("low risk") to 5 ("very high risk") with a modal score of 2. This divergence of opinion on the ability of the species' innate productivity potential to buffer its extinction risk is also likely reflected in the final risk vote; although all BRT members put the preponderance of their points in the moderate or high risk category, only 3 of 10 members put the majority of their points in the high risk category.

In the memo from the NMFS Northwest Region Office to the Northwest Fisheries Science Center requesting the formation of a BRT to review the status of eulachon, the BRT was instructed as follows:

> If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range. In determining whether a portion of the species' or DPS' range is "significant," please follow the guidance articulated in Waples et al. 2007 (Waples, R. S., P. B. Adams, J. Bohnsack, and B. Taylor. 2007. A biological framework for evaluating whether a species is threatened or endangered in a significant portion of its range. Conserv. Biol. 21(4):964–974).

Once the BRT had concluded that the southern DPS of eulachon was at "moderate risk" of extinction throughout all of its range, the BRT did begin to discuss the implications of whether the DPS may be at "high risk" of extinction in a significant portion of its range, but determined that its instructions from the region did not require a formal analysis of this question. Thus the BRT believes that providing "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range" involves legal and policy issues that are currently beyond the scope of its mandate. The BRT was also cognizant of the fact that previous BRTs involved in ESA status reviews, which had resulted in equivalent conclusions of moderate risk ("likely to become at risk of extinction") throughout a species' range, had not felt compelled to formally pursue the question of whether the species was then at high risk ("at risk of extinction") in a significant portion of its range (Good et al. 2005, Hard et al. 2007).

**Reviewer 3**

Reviewer 3 agreed with the BRT's "conclusion that the southern DPS of eulachon, as defined in the report, is at moderate risk of extinction throughout its range." However, Reviewer 3 stated the evidence also "suggests that eulachon … are on the verge of extinction" in California.

**Response**

The BRT had similar concerns about eulachon in northern California. As presented in the summary of the status review (BRT 2008, p. 63), with the exception of abundance, the BRT had most concerns about demographic risks related to spatial structure and connectivity of the southern DPS of eulachon (see Table 13); and the BRT was particularly concerned about the potential for extirpation of the northern California subpopulation. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 and a modal score of 4, indicating that risks to the spatial structure of the southern DPS of eulachon were rated as high risk by the BRT (see Table 13).

**Reviewer 5**

In reference to Table 9 through Table 13 in the summary of the status review (BRT 2008, Table 15 through Table 19 in the present document), which summarized the results of the BRT's attempt to qualitatively rank the severity of threats to eulachon, Reviewer 5 was “troubled by the statement that an opinion of not applicable for a particular threat criterion was rated the same as unknown (i.e., equivalent to not voting on that criterion)” and the reviewer stated that, “If a factor is not applicable to a given river system, then it seems to me that this would mean a rating of 1; (low threat)—or even better a zero (if that were possible). I have to wonder if this would change the rankings of factors in these lists.”

**Response**

In practical terms, 2 members of the BRT voted a total of 5 times that a threat was “not applicable” out a total of 600 individual votes on the various threat categories and subareas of the DPS. Nearly all members voted “unknown” at least once, for a total of 100 times. If these 5 “not applicable” votes are scored as 1 or very low threat, the rankings of threats in the Klamath and Columbia River subpopulations are unaffected. “Dams/water diversions” in the Fraser River subpopulation drops from 8th place to 11th place and “dams/water diversions” in the mainland British Columbia subpopulation drops from 11th place to 12th place, based on rankings of the mean scores. Modal scores are unaffected. These readjustments would have no impact on the BRT’s identification of the severity of the top four identified threats in each subarea of the DPS.

## Use of Political Boundaries for Defining a DPS

**Review**

Reviewer 2 commented extensively on the petitioner’s argument (see Cowlitz Indian Tribe 2007) that, under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively “discrete” from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. After providing comments on differences in management of eulachon between the U.S. and Canada, Reviewer 2 stated that “the delineation of DPSs on the basis of political boundaries is probably mistaken, both on biological and operational grounds.”

**Response**

We agree. Although the joint USFWS-NMFS policy (USFWS-NMFS 1996) states that international boundaries within the geographical range of the species may be used to delimit a DPS in the United States, in past assessments of DPSs of marine fish and ESUs of Pacific salmon, NMFS has placed the emphasis on biological information in defining DPSs and ESUs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological and ecological information in identifying whether DPSs of eulachon could be delineated.

# Recent NOAA Technical Memorandums

**published by the**

## Northwest Fisheries Science Center

**NOAA Technical Memorandum NMFS-NWFSC-**

**104** **Horne, P.J., I.C. Kaplan, K.N. Marshall, P.S. Levin, C.J. Harvey, A.J. Hermann, and E.A. Fulton. 2010.** Design and parameterization of a spatially explicit ecosystem model of the central California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-104, 140 p. NTIS number pending.

**103** **Dufault, A.M., K. Marshall, and I.C. Kaplan. 2009.** A synthesis of diets and trophic overlap of marine species in the California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-103, 81 p. NTIS number pending.

**102** **Reppond, K.D. 2009.** Biochemistry of red king crab (*Paralithodes camtschaticus*) from different locations in Alaskan waters. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-102, 16 p. NTIS number pending.

**101** **Sands, N.J., K. Rawson, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Determination of independent populations and viability criteria for the Hood Canal summer chum salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-101, 58 p. NTIS number pending.

**100** **Linbo, T.L. 2009.** Zebrafish *(Danio rerio)* husbandry and colony maintenance at the Northwest Fisheries Science Center. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-100, 62 p. NTIS number PB2009-113299.

**99** **Rawson, K., N.J. Sands, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Viability criteria for the Lake Ozette sockeye salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-99, 38 p. NTIS number PB2009-113298.

**98** **Johnson, L.L., G.M. Ylitalo, M.S. Myers, B.F. Anulacion, J. Buzitis, W.L. Reichert, and T.K. Collier. 2009.** Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98, 123 p. NTIS number PB2009-110295.

**97** **Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2009.** Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-97, 63 p. NTIS number PB2009-113671.

**Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov).**

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

**Refer to NMFS No:**
**2011/03866**

December 30, 2011

Kevin Moynahan
Chief, Regulatory Branch
Portland District, Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Endangered Species Act Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Ocean Terminals Dock Construction, Sheet Pile, and Placement of Fill, Coos Bay (Coos Bay 6$^{th}$ field HUC 171003040303), Coos County, Oregon (Corps No.: NWP-1995-501/3)

Dear Mr. Moynahan:

The enclosed document contains a biological opinion (opinion) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of a proposal by the Portland District of the U.S. Army Corps of Engineers (Corps) to authorize construction of the above-mentioned dock, sheet pile, and placement of fill under the authorities of section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act.

In this opinion, NMFS concludes that the proposed action is not likely to adversely affect Steller sea lions (*Eumotopias jubatus*), blue whales (*Balaenoptere musculus*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), Southern Resident killer whales (*Orcinus orca*), Sei whales (*Balaenoptera borealis*), sperm whales (*Physeter macrocephalus*), green sea turtles (*Chelonia mydas*), leatherback sea turtles (*Dermochelys coriacea*), loggerhead sea turtles (*Caretta caretta*), and olive ridley sea turtles (*Lepidochelys olivacea*).

The NMFS also concluded that the proposed action is not likely to jeopardize the continued existence of Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), southern distinct population segment (southern)of Pacific eulachon (*Thaleichthys pacificus*), southern distinct population segment (southern) North American green sturgeon (*Acipenser medirostris*) or result in the destruction or adverse modification of their designated critical habitats.

As required by section 7 of the ESA, NMFS is providing an incidental take statement with the opinion. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The take statement sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal action agency must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of listed species.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes five conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. Two of these conservation recommendations are a subset of the ESA take statement's terms and conditions. Section 305(b) (4) (B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations.

If the response is inconsistent with the EFH conservation recommendations, the Federal action agency must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations. In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Please direct questions regarding this opinion to Jim Muck, fisheries biologist in the Oregon Coast Habitat Branch of the Oregon State Habitat Office, at 541.957.3394.

Sincerely,

William W. Stelle, Jr.
Regional Administrator

cc: John Craig, Consultant
Garret Dorsey, Corps
Jim Lyons, OTC

# Endangered Species Act Biological Opinion
# and
# Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response
# for the

Ocean Terminals Dock Construction, Sheet Pile, and Placement of Fill
Coos Bay (Coos Bay 6th field HUC 171003040303)
Coos County, Oregon
(Corps No.: NWP-1995-501/3)

NMFS Consultation Number: 2011/03866

Federal Action Agency: U.S. Army Corps of Engineers

Affected Species and Determinations:

| ESA-Listed Species | ESA Status | Is the action likely to adversely affect this species or its critical habitat? | Is the Action likely to jeopardize this species? | Is the action likely to destroy or adversely modify critical habitat for this species? |
|---|---|---|---|---|
| Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) | Threatened | Yes | No | No |
| Southern distinct population segment green sturgeon (*Acipenser medirostris*) | Threatened | Yes | No | No |
| Southern distinct population segment Pacific eulachon (*Thaleichthys pacificus*) | Threatened | Yes | No | No |
| Eastern distinct population segment Steller sea lion (*Eumetopias jubatus*) | Threatened | No | No | No |
| Blue whale (*Balaenoptera musculus*) | Endangered | No | No | No |
| Fin whale (*Balaenoptera physalus*) | Endangered | No | No | No |
| Humpback whale (*Megaptera novaeangliae*) | Endangered | No | No | No |
| Southern resident killer whale (*Orcinus orca*) | Endangered | No | No | No |
| Sei whale (*Balaenoptera borealis*) | Endangered | No | No | No |
| Sperm whale (*Physeter macrocephalus*) | Endangered | No | No | No |
| Green turtle (*Chelonia mydas*) | Endangered | No | No | No |
| Leatherback turtle (*Dermochelys coriacea*) | Endangered | No | No | No |
| Loggerhead turtle (*Caretta caretta*) | Threatened | No | No | No |
| Olive ridley turtle (*Lepidochelys olivacea*) | Endangered | No | No | No |

| Fishery Management Plan that Describes EFH in the Action Area | Would the action adversely affect EFH? | Are EFH conservation recommendations provided? |
|---|---|---|
| Pacific Coast Salmon | Yes | Yes, five recommendations |
| Coastal Pelagic Species | Yes | Yes, five recommendations |
| Pacific Coast Groundfish | Yes | Yes, five recommendations |

| | |
|---|---|
| Consultation Conducted By: | National Marine Fisheries Service<br>Northwest Region |
| Issued by: | for William W. Stelle, Jr.<br>Regional Administrator |
| Date: | December 30, 2011 |

**TABLE OF CONTENTS**

## GLOSSARY

For purposes of this consultation –

Action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by a Federal action agency.

Action area means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action.

Applicant means any person who requires formal approval, authorization, or funding from a Federal action agency as a prerequisite to conducting the action.

Conserve, conserving, and conservation mean to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to the Federal Endangered Species Act are no longer necessary.

Conservation recommendation means a suggestion by NMFS regarding a discretionary measure to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information.

Critical habitat means any geographical area designated as critical habitat in CFR part 226.

Cumulative effects are those effects of future state or private activities, not involving Federal action, that are reasonably certain to occur within the action area of the Federal action subject to consultation.

Effects of the action are the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action that will be added to the environmental baseline.

Endangered species are in danger of extinction throughout all or a significant portion of its range.

Environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process.

Fishery biologist means a person that has an ecological education, thorough knowledge of aquatic biology and fish management, and is professionally engaged in fish research or management activities; a supervisory fishery biologist is professionally responsible for the supervision of biologists and technical staff engaged in fish research or management.

Harm means significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

Hazardous material means any chemical or substance which, if released into an aquatic habitat, could harm fish, including, but not limited to, petroleum products, radioactive material, chemical agents, and pesticides.

Incidental take means takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal action agency or applicant.

Indirect effects are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Interdependent actions have no independent utility apart from the action under consideration.

Interrelated actions are part of a larger action and depend on the larger action for their justification.

In-water work includes any part of an action that occurs below ordinary high or within the wetted channel, *e.g.*, excavation of streambed materials, fish capture and removal, flow diversion, streambank protection, and work area isolation.

Jeopardize the continued existence of means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Listed species are any species of fish, wildlife, or plant which has been determined to be endangered or threatened under section 4 of the Federal Endangered Species Act.

Ordinary high water (OHW) elevation means the elevation to which the high water ordinarily rises annually in season, excluding exceptionally high water levels caused by large flood events. The ordinary high water elevation is typically below the bankfull elevation. The ordinary high water elevation is considered equivalent to the bankfull elevation if the ordinary high water lines are indeterminate.

Primary constituent elements (PCE) are the biological and physical features of critical habitat that are essential to the conservation of listed species.

Reasonable and prudent measures (RPM) are actions the NMFS believes necessary or appropriate to minimize the amount or extent of incidental take.

Recovery means an improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Federal Endangered Species Act.

Scope of the action means the range of actions and impacts to be considered in the analysis of effects.

Sound exposure level (SEL) means a measure of sound energy dose that is defined as the constant sound level acting for one second that has the same acoustic energy as the original sound (Hastings and Popper 2005). SEL is calculated by summing the cumulative pressure squared over time as decibels re 1 micropascal$^2$-second.
Stream-floodplain corridor means the main stream channel and its functional floodplain.

Take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

Threatened species are likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Working adequately means erosion controls that do not allow ambient stream turbidity to increase by more than 10% above background 100 feet below the discharge, when measured relative to a control point immediately upstream of the turbidity-causing activity.

## LIST OF ABBREVIATIONS

| | |
|---|---|
| CFR | Code of Federal Regulations |
| CHART | Critical Habitat Analytical Review Team |
| dB | decibel (dB) |
| EFH | Essential Fish Habitat |
| ESA | Endangered Species Act |
| FR | Federal Register |
| HUC | Hydraulic Unit Code |
| LAA | Like to adversely affect |
| MSA | Magnuson Stevens Act |
| NLAA | Not likely to adversely affect |
| NMFS | National Marine Fisheries Service |
| NDPS | Northern distinct population segment |
| OC | Oregon Coast |
| ODFW | Oregon Department of Fish and Wildlife |
| OHW | Ordinary High Water |
| OTC | Ocean Terminals Company |
| PCE | Primary constituent element |
| RPM | Reasonable and prudent measure |
| SEL | Sound exposure level |
| TRT | Technical Review Team |
| VSP | Viable Salmonid Population |

# 1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into sections 2 and 3 below.

## 1.1 Background

The biological opinion (opinion) and incidental take statement portions of this document were prepared by the National Marine Fisheries Service (NMFS) in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, *et seq*.), and implementing regulations at 50 CFR 402.

The NMFS also completed an essential fish habitat (EFH) consultation. It was prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600.

The opinion and EFH conservation recommendations are both in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-5444) ("Data Quality Act") and underwent pre-dissemination review. The administrative record for this consultation is on file at the Oregon Coast Habitat Branch in Roseburg, Oregon.

## 1.2 Consultation History

The NMFS based this opinion on information provided in the consultation request letter dated August 23, 2011, from the Portland District of the U.S. Army Corps of Engineers (Corps) and the enclosed project description. The Corps determined that the proposed action is likely to adversely affect (LAA) Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), southern distinct population segment (southern) of North American green sturgeon (*Acipenser medirostris*), southern distinct population segment (southern)of Pacific eulachon (*Thaleichthys pacificus*), the eastern distinct population segment of Steller sea lions (*Eumetopias jubatus)*(referred to as Steller sea lion) , and designated critical habitat for OC coho salmon and southern green sturgeon. Although the Corps determined that the proposed action is LAA the Steller sea lion as in their request for formal consultation, NMFS concluded in this opinion that the proposed action is NLAA Steller sea lions.

The NMFS sent an additional information request letter to the Corps on September 23, 2011. The Corps and the consultant for Ocean Terminals Company (OTC) worked with NMFS to provide the necessary information. The information requested was received on October 21, 2011, and formal consultation was initiated by NMFS.

Previously, the Corps issued Clean Water Act section 404 and Rivers and Harbors Act section 10 permits to OTC on July 16, 1997, but these permits expired on April 30, 2000. The Corps and NMFS consulted on a proposed  dock expansion and improvements for the OTC project in 2001, which resulted in a biological opinion written by NMFS (NWP 1995-00501; refer to NMFS No.: 2001/00519). This action was never completed and now is modified from the original proposed action.

In the original permit application, OTC proposed as mitigation for adverse effects of the proposed activities to restore a 24.7-acre site to a functional intertidal wetland. This site is located 9 miles from the project area and 6 miles upstream in Isthmus Slough. Although the dock expansion was never completed, OTC did complete the associated mitigation. The physical actions necessary for this restoration were completed by OTC in October 1997.

The dredging necessary to maintain the OTC docks is covered in a previous biological opinion 'Unified Maintenance Dredging Program for Oregon Coastal Projects' (refer to NMFS No: 2009/01756). Since the effects of dredging were addressed by this consultation, no further discussion of the effects of the maintenance dredging is warranted in this opinion.

Jim Muck (NMFS staff biologist) toured the project site with John Craig (consultant) on September 16, 2011. Mr. Muck also toured the OTC dock site again and the mitigation site with Ken Phippen (NMFS), John Craig (consultant), and Jim Lyons (OTC) on October 20, 2011.

**1.3 Proposed Action**

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

The Corps, with regulatory authority found in section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act, proposes to issue a permit to OTC for dock improvements, construction of sheet pile, placement of fill, and placement of riprap along the Coos Bay estuary located in Section 10, Township 25 South, Range 13 West, North Bend, Oregon (Coos Bay $6^{th}$ field HUC 171003040303).

The proposed project is the construction of a new dock measuring 400 feet long by 50 feet wide. The new dock will be located to the north of the existing dock (see Figure 1). The new dock and improvement to the existing dock will require installation of 194 concrete piles and concrete decking. The pilings measure 24 inches in diameter and OTC will install the pilings using a vibratory hammer. The OTC will not proof the piles with strikes from an impact hammer. Additionally, OTC is planning to remove 256 treated pilings unneeded treated wood piles during the existing dock improvements. Only piles that are used for structural integrity of the existing dock will remain. The OTC estimates that over 90% of the existing piles are to be removed.

OTC is proposing to construct a sheet pile bulkhead located inside the new and existing 800-foot docks (Figure 2). At the north end, the sheet pile bulkhead will incorporate a 45 degree wing directly to the shore. At the southern end, OTC is planning a smaller length of wing-wall angled toward the shore. Backfill will consist of clean sand from the North Spit of Coos Bay. The additional fill will allow for employee parking, log storage, and direct access for the front loaders to load ships at the dock.


**Figure 1.** Ocean Terminals Company site view showing log yard and existing dock.

To the south of the existing dock, the applicant is proposing a 400 linear-foot section of shoreline to be filled with clean, compacted sand and a rock face consisting of 12- inch minus riprap and 36-inch riprap used for the toe (Figure 2). The total amount of rock proposed is 3,000 yards. The toe of the riprap is figured near the 12-foot depth contour.

Placement of fill will impact 3.9 acres behind the sheet pile and riprap. The applicant will build the project in three phases. Phase 1 will consist of the construction of the 800 feet of sheet pile and associated backfill. Erosion control measures will be implemented during construction as appropriate. Phase 2 will consist of fill placement and riprap to the south of the existing dock. During Phase 3, 400 linear feet of new dock will be constructed to the north of the existing dock.

No dredging is proposed with this action. The facility is one of the sites included in the unified dredging permit held and managed by the Port of Coos Bay. The ODFW-preferred in-water work period for Coos Bay estuary including the project site is October 1 through February 15.

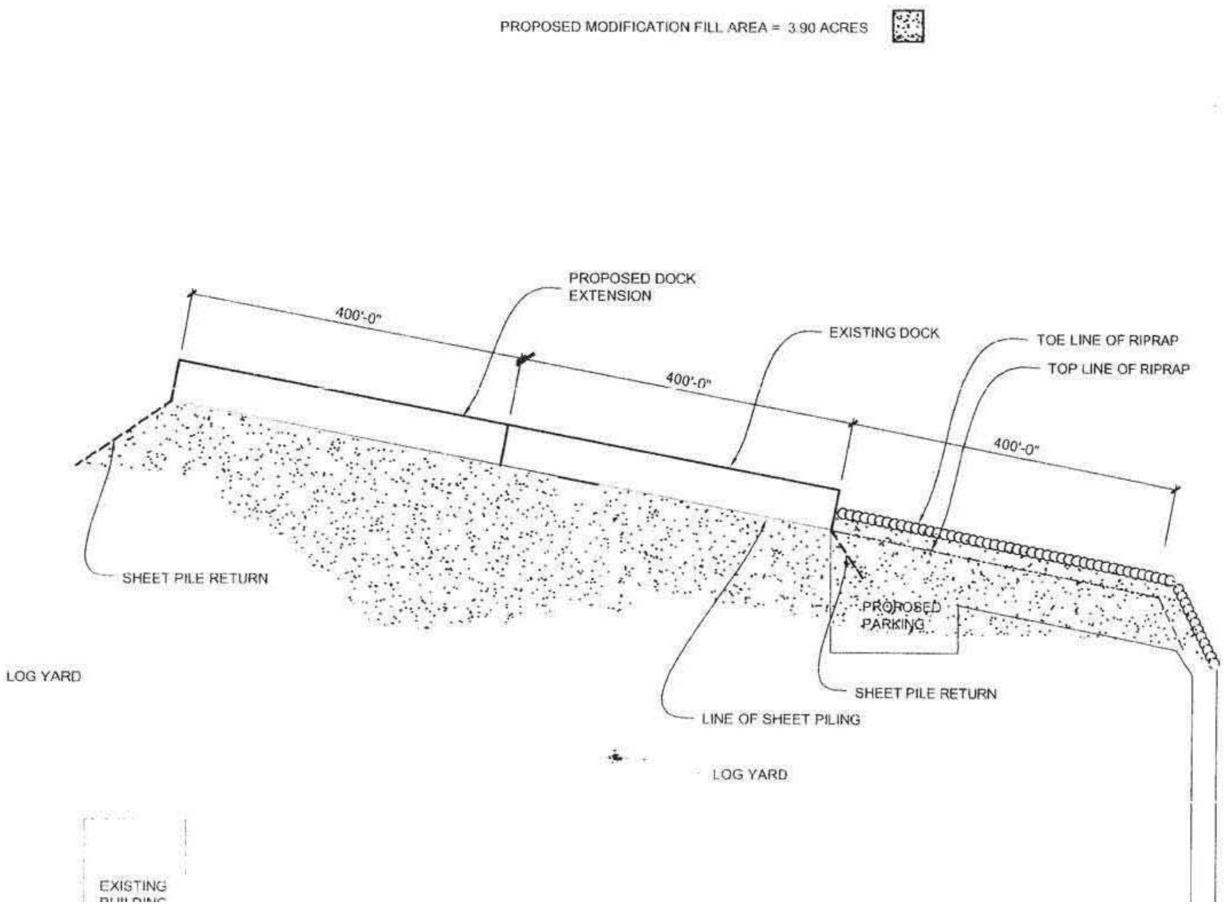



**Figure 2**. Ocean Terminals Company proposed action including 400- by 50-foot northern dock, 3.9 acres of fill, sheet pile location, and riprap located to the south.

The construction fill will create 3.9 additional impervious acres. The southern area of the construction fill will be used for employee parking; the rest of the OTC site is used for log storage and dock loading. The OTC will route all water from the dock back into the stromwater facilities (Figure 3). The OTC will treat stormwater by constructing oil/water separators in the ten catch basins and by the filtration that occurs through two ditch lines located on the western property lines. The OTC will inspect catch basins monthly, clean catch basins at a minimum twice yearly, and clean drains as needed. Stormwater will enter the estuary through three culvert outflows and one drainage ditch.

In OTC's original consultation with NMFS in 1997, OTC proposed to restore a 24.7-acre site, 9 miles from the project area and 6 miles upstream, on Isthmus Slough to a functional intertidal wetland as mitigation for adverse effects of the proposed activities. The physical actions necessary for this restoration were completed by OTC in October of 1997.

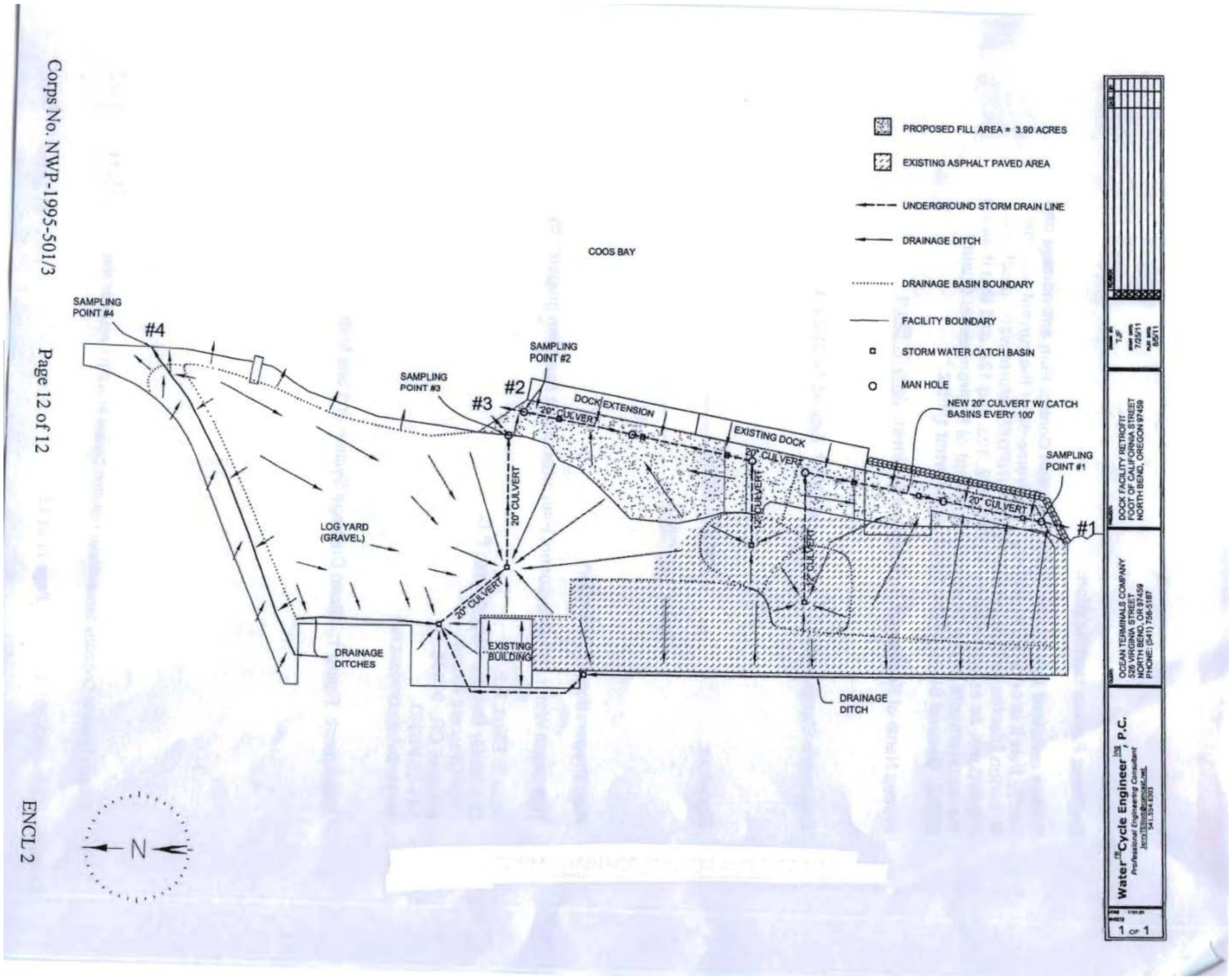


**Figure 3.** Location and flow diagram for stormwater at Ocean Terminals Company facility at North Bend, Oregon.

The Corps determined that the OTC mitigation requirements for the new dock, improvements to the existing dock, and fill did not require all of the 24.7 credit acres accrued at the Lyons mitigation site on Isthmus Slough and therefore OTC has sold the additional credits to other interests. After the site was restored to natural tidal function, the site now contains 32 credit acres. All credits from the site have been sold.

The OTC completed the mitigation for the proposed action in 1997. The OTC mitigation requirements from the Corps included 1.4 acres in restoration credits (1 to 1 ratio) and 10.65 acres enhancement credits (3 to 1 ratio). The initial fill impact from the 1997 OTC application was 4.95 acres. The Corps mitigation requirements for the 4.95 acre fill in 1997 required a 1 to 1 ratio of 1.4 acres dike removal, and required 3 to 1 enhancement ratio mitigation totaled 10.65 acres. The total acre of mitigation equates to 12.05 acres. The proposed action in 2011 calls for 3.9 acres fill, however, OTC is not modifying the original mitigation such that enhancement credits now exceed a ratio over 4 to 1.

In 1997, the OTC removed the 1.4 acres of dike, filled in the agriculture ditches, removed the existing tidegate, and allowed the 24.7 acres of pastureland to flood with water. No vegetation planting was required in the original mitigation plan. Wetland mitigation monitoring reports have been submitted to the Corps. Later, mapping showed that actually 32.0 acres were flooded.

## 1.4 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). For this consultation, the action area is within the Coos Bay Frontal 5$^{th}$ field HUC 1710030403 (Coos Bay 6$^{th}$ field HUC 171003040303). The action area for this consultation includes all riverine and estuarine habitats accessible to OC coho salmon, southern green sturgeon, and eulachon (Table 1) in Coos Bay estuary within the project area located at approximately river mile 10. The action area includes areas where stormwater effects extends downstream, approximately 10 miles to the confluence with the Pacific ocean, and extends approximately 40 miles upstream to the head of tide. Effects due to stormwater include contribution of dissolved copper, which has a fate and transport showing it stays in the system until it finally dilutes in the ocean. The head of tide is Coos River and is located at the confluence of East and West forks of the Millicoma Rivers, and at the Dellwood area for the South Coos River. The piling installation impact and fill zone extends 100 feet upstream and downstream from the project fill activities.

The action area also includes the shipping lanes from the OTC terminal including outside the breakwaters of Coos Bay Jetty until the ships reach their port in China, specifically for ESA marine mammals and turtles (Table 1). These species are discussed in the not likely to adversely affect (NLAA) Section 2.11 of this opinion.

Adult OC coho salmon use the action area as a migratory corridor and staging area as they move upstream to spawning habitat in Coos River tributaries. Adult OC coho salmon begin to arrive in Coos Bay in the fall and peak in abundance in November through early December. Juvenile OC coho salmon begin their outmigration from their natal streams to the ocean in late February and use the Coos Bay estuary for rearing, refuge and the physiological transition to saltwater. They are likely present in the action area from March through June, with a peak from mid-April to mid-May. Juvenile OC coho salmon are not expected in the action area during construction.

The NMFS defined two distinct population segments of green sturgeon: a northern distinct population segment with spawning populations in the Klamath and Rogue rivers and a southern that spawns in the Sacramento River. The southern green sturgeon was listed as threatened in 2006 (71 FR 17757), and includes all spawning populations south of the Eel River in California. Critical habitat for southern green sturgeon within the Coos Bay terminates at head of tide (74 FR 52300). Subadult and adult southern green sturgeon use the action area as habitat for growth and development to adulthood and for adult and subadult feeding. Southern green sturgeon are known to congregate in coastal waters and estuaries, including non-natal estuaries such as Coos Bay. Beamis and Kynard (1997) suggest that southern green sturgeon move into estuaries of non-natal rivers to feed. Data from Washington studies indicate that southern green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007). The NMFS does not expect adult or juvenile southern green sturgeon to be present in the action area during the construction period of October 1 to February 15.

Eulachon range from the Mad River in northern California to the Skeena River in British Columbia, Canada. They inhabit several riverine and estuarine systems along the west coast and population sizes vary between these systems. Eulachon are rarely observed in Coos Bay.. The NMFS listed Pacific eulachon as threatened under the ESA, protective regulations were issued on March 18, 2010 (75 FR 13012). The NMFS did not designate critical habitat for Pacific eulachon in the Coos Bay watershed. Eulachon adults return to freshwater from January to March and evidence suggests that adult eulachon may return as early as December to spawn (WDFW and ODFW 2001). Adult eulachon are unlikely to be present in the estuary during October through December, but may become present in January through February. Although eulachon are not known to spawn in Coos Bay tributaries, typical spawning for eulachon occurs from January through July, with the peak in mid-April to mid-June, though there is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuarine and near-shore marine areas. When eggs hatch in 20 to 40 days, eulachon larvae immediately wash downstream to estuarine and ocean areas where they feed on phytoplankton and zooplankton.

Steller sea lions in Oregon are from the eastern distinct population segment, listed by NMFS as threatened on November 26, 1990 (55 FR 49204) (Table 1). Steller sea lions can occur in Oregon waters throughout the year. Breeding rookeries for eastern Steller sea lions are located at Long Brown and Seal Rocks at Orford Reef, and Pyramid Rock at Rogue Reef. These locations are designated critical habitat for Steller sea lions. However, the area of critical habitat closest to the action area is more than 50 miles away and therefore the proposed action will have no effect on critical habitat for Steller sea lions.

The NMFS listed the following marine mammals and turtle under the ESA: (1) Southern Resident (SR) killer whales as endangered under the ESA on November 18, 2005 (70 FR 69903) and designated critical habitat on November 29, 2006 (71 FR 69054); (2) blue, humpback, fin, and sei whales as endangered on December 2, 1970 (35 FR 18319); and (3) leatherback sea turtles as endangered on June 2, 1970 (Table 1).

Individuals of these species are migratory along the Oregon Coast and their presence in the ocean portion of the action area is likely only transitory, with the exception of leatherback sea turtles. Leatherback sea turtles likely use the action area for feeding, too. The action area is not designated critical habitat for SR killer whales and the closest area of critical habitat is 480 miles away in the Puget Sound of Washington State. Additionally, Chinook salmon affected by the proposed action do not occur in SR killer whale critical habitat (based on knowledge of their marine distribution from coded-wire tag recoveries (Weitkamp 2010). Therefore, no effects to SR killer whale critical habitat are anticipated, and no further mention of it will occur in this document. The action area is proposed critical habitat for leatherback sea turtles, but there is no mechanism for the proposed action to affect either of the two identified physical or biological features essential to their conservation (vessel traffic is not considered a threat to turtle passage; 75 FR 319). Therefore, no effects to proposed leatherback turtle critical habitat are anticipated, and no further mention of it will occur in this document.

**Table 1.** Federal Register notices for final rules that list threatened and endangered species, designate critical habitats, or apply protective regulations to listed species considered in this consultation. Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered; "P" means proposed.

| Species | Listing Status | Critical Habitat | Protective Regulations |
|---|---|---|---|
| **Anadromous Fish** | | | |
| **Coho salmon (***O. kisutch***)** | | | |
| Oregon Coast | T 6/20/11; 76 FR 35755 | 2/11/08; 73 FR 7816 | 2/11/08; 73 FR 7816 |
| **Green sturgeon** *(Acipenser medirostris)* | | | |
| Southern | T 4/07/06; 71 FR 17757 | 10/09/09; 74 FR 52300 | 6/02/10; 75 FR 30714 |
| **Eulachon** (*Thaleichthys pacificus*) | | | |
| Eulachon | T 3/18/10; 75 FR 13012 | 10/20/2011, 76 FR 65324 | |
| **Marine Mammals** | | | |
| **Steller sea lion (***Eumetopias jubatus***)** | | | |
| Eastern | T 5/5/1997; 63 FR 24345 | 8/ 27/93; 58 FR 45269 | 11/26/90; 55 FR 49204 |
| **Blue whale** (*Balaenoptera musculus*) | | | |
| | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Fin whale** (*Balaenoptera physalus*) | | | |
| | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Humpback whale** (*Megaptera novaeangliae*) | | | |
| | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Killer whale** (*Orcinus orca*) | | | |
| Southern Resident | E 11/18/05; 70 FR 69903 | 11/26/06; 71 FR 69054 | ESA section 9 applies |
| **Sei whale** (*Balaenoptera borealis*) | | | |
| | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Sperm whale** (*Physeter macrocephalus*) | | | |
| | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Marine Turtles** | | | |
| **Green sea turtle** (*Chelonia mydas*) | | | |
| Excludes Pacific Coast of Mexico and Florida | ET 7/28/78; 43 FR 32800 | 9/02/98; 63 FR 46693 | ESA section 9 applies |
| **Leatherback sea turtle** (*Dermochelys coriacea*) | | | |
| | E 6/02/70 ; 39 FR 19320 | 3/23/79; 44 FR 17710<br>P 1/5/2010; 75 FR 319 | ESA section 9 applies |
| **Loggerhead sea turtle** (*Caretta caretta*) | | | |
| | T 7/28/78; 43 FR 32800 | Not applicable | 7/28/78; 43 FR 32800 |
| **Olive ridley sea turtle** (*Lepidochelys olivacea*) | | | |
| | ET 7/28/78; 43 FR 32800 | Not applicable | ESA section 9 applies |

## 2. ENDANGERED SPECIES ACT BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA established a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat on which they depend. Section 7(a)(2) of the ESA requires Federal agencies to consult with the U.S. Fish and Wildlife Service, NMFS, or both, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Section 7(b)(3) requires that at the conclusion of consultation, the Service provide an opinion stating how the agencies' actions will affect listed species or their critical habitat. If incidental take is expected, Section 7(b)(4) requires the provision of an incidental take statement (ITS) specifying the impact of any incidental taking, and including reasonable and prudent measures to minimize such impacts.

### 2.1 Introduction to the Biological Opinion

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The jeopardy analysis considers both survival and recovery of the species. The adverse modification analysis considers the impacts to the conservation value of the designated critical habitat.

"To jeopardize the continued existence of a listed species" means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02).

This opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat.[1]

We will use the following approach to determine whether the proposed action described in section 1.3 is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- *Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action*. This section describes the current status of each listed species and its critical habitat relative to the conditions needed for recovery. For listed salmon and steelhead, NMFS has developed specific guidance for analyzing the status of the listed species' component populations in a "viable salmonid populations" paper (VSP; McElhany *et al.* 2000). The VSP approach considers the abundance, productivity, spatial structure, and diversity of each population as part of the overall review of a species' status. For listed salmon and steelhead, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, we rely on viability assessments and criteria in

[1] Memorandum from William T. Hogarth to Regional Administrators, Office of Protected Resources, NMFS (Application of the "Destruction or Adverse Modification" Standard Under Section 7(a)(2) of the Endangered Species Act) (November 7, 2005).

technical recovery team documents and recovery plans, where available, that describe how VSP criteria are applied to specific populations, major population groups, and species. We determine the rangewide status of critical habitat by examining the condition of its physical or biological features (also called "primary constituent elements" or PCEs in some designations) – which were identified when the critical habitat was designated. Species and critical habitat status are discussed in section 2.2.

- *Describe the environmental baseline for the proposed action*. The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities in the action area. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in section 2.3 of this opinion.
- *Analyze the effects of the proposed actions*. In this step, NMFS considers how the proposed action would affect the species' reproduction, numbers, and distribution or, in the case of salmon and steelhead, their VSP characteristics. The NMFS also evaluates the proposed action's effects on critical habitat features. The effects of the action are described in section 2.4 of this opinion.
- *Describe any cumulative effects.* Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in section 2.5 of this opinion.
- *Integrate and synthesize the above factors to assess the risk that the proposed action poses to species and critical habitat.* In this step, NMFS adds the effects of the action (section 2.4) to the environmental baseline (section 2.3) and the cumulative effects (section 2.5) to assess whether the action could reasonably be expected to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (section 2.2). Integration and synthesis occurs in section 2.6 of this opinion.
- *Reach jeopardy and adverse modification conclusions*. Conclusions regarding jeopardy and the destruction or adverse modification of critical habitat are presented in section 2.7. These conclusions flow from the logic and rationale presented in the Integration and Synthesis section (2.6).
- *If necessary, define a reasonable and prudent alternative to the proposed action.* If, in completing the last step in the analysis, NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify a reasonable and prudent alternative (RPA) to the action. The RPA must not be likely to jeopardize the continued existence of ESA-listed species nor adversely modify their designated critical habitat and it must meet other regulatory requirements.

In this opinion, NMFS concludes that the proposed action is NLAA Steller sea lions, blue whales, fin whales, humpback whales, Southern Resident killer whales, Sei whales, sperm whales, green sea turtles, leatherback sea turtles, loggerhead sea turtles, olive ridley sea turtles. The applicable standard to find that a proposed action is NLAA ESA-listed species is that all of the effects of the action are expected to be discountable, insignificant or completely beneficial. Discountable effects cannot be reasonably expected to occur. Insignificant effects are so mild that the effect cannot be meaningfully measured, detected or evaluated. Beneficial effects are contemporaneous positive effects without any adverse effect on the listed species or critical habitat, even if the long-term effects are beneficial. These species are discussed in Section 2.11 of the opinion under NLAA species.

## 2.2 Rangewide Status of the Species and Critical Habitat

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, can be found in the listing regulations and critical habitat designations published in the Federal Register (Table 1).

Climate change is likely to play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. Areas with elevations high enough to maintain temperatures well below freezing for most of the winter and early spring will be less affected. Low-elevation areas are likely to be more affected.

During the last century, average regional air temperatures increased by 1.5°F, and increased up to 4°F in some areas (USGCRP 2009). Warming is likely to continue during the next century as average temperatures increase another 3°F to 10°F (USGCRP 2009). Overall, about one-third of the current cold-water fish habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (USGCRP 2009).

Precipitation trends during the next century are less certain than for temperature but more precipitation is likely to occur during October through March and less during summer months, and more of the winter precipitation is likely to fall as rain rather than snow (ISAB 2007, USGCRP 2009). Where snow occurs, a warmer climate will cause earlier runoff so stream flows in late spring, summer, and fall will be lower and water temperatures will be warmer (ISAB 2007, USGCRP 2009).

Higher winter stream flows increase the risk that winter floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (USGCRP 2009). Earlier peak stream flows will also flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and the risk of predation (USGCRP 2009). Lower stream flows and warmer water temperatures during summer will degrade summer rearing conditions, in part by increasing the prevalence and virulence of fish diseases and parasites (USGCRP 2009). Other adverse effects are likely to include altered migration patterns, accelerated embryo development, premature emergence of fry, variation in quality and quantity of tributary rearing habitat, and increased competition and predation risk from warm-water, non-native species (ISAB 2007).

The earth's oceans are also warming, with considerable interannual and inter-decadal variability superimposed on the longer-term trend (Bindoff *et al*. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005, Zabel *et al*. 2006, USGCRP 2009). Ocean conditions adverse to salmon and steelhead may be more likely under a warming climate (Zabel *et al*. 2006).

### 2.2.1 Status of the Species

Climate change, as described in section 2.2, is likely to adversely affect the size and distribution of populations of ESA-listed anadromous fish in the Pacific Northwest. The size and distribution of the populations considered in this opinion generally have declined over the past few decades due to natural phenomena and human activity, including the operation of hydropower systems, over-harvest, hatcheries, and habitat degradation. Enlarged populations of terns, seals, sea lions, and other aquatic predators in the Pacific Northwest have been identified as factors that may be limiting the productivity of some Pacific salmon and steelhead populations (Ford *et al*. 2010).

***OC Coho Salmon.*** This species includes populations of OC coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco. The Cow Creek hatchery stock (South Umpqua population) is managed as an integrated program and is included as part of the ESU because the original brood stock was founded from the local natural origin population and natural origin coho salmon have been incorporated into the brood stock on a regular basis. OC coho salmon were first listed in February 2008. As part of a legal settlement agreement in 2008, NMFS completed a new status review for the evolutionary significant unit (ESU). In 2011, NMFS issued a final rule re-promulgating the threatened listing for OC coho salmon (USDC 2011b).

The OC-Technical Review Team (TRT) identified 56 populations: 21 independent and 35 dependent. The dependent populations were dependent on strays from other populations to maintain them over long time periods. The TRT grouped the 21 independent populations into five biogeographic strata (Table 2) (Lawson *et al.* 2007).

**Table 2.** OC coho salmon populations. Dependent populations (D) are populations that historically would not have had a high likelihood of persisting in isolation for 100 years. These populations relied upon periodic immigration from other populations to maintain their abundance. Independent populations are populations that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years and are rated as functionally independent (FI) and potentially independent (PI) (McElhany *et al.* 2000, Lawson *et al.* 2007).

| Stratum | Population | Type | Stratum | Population | Type |
|---|---|---|---|---|---|
| North Coast | Necanicum | PI | Mid-Coast (cont.) | Alsea | FI |
| | Ecola | D | | Big (Alsea) | D |
| | Arch Cape | D | | Vingie | D |
| | Short Sands | D | | Yachats | D |
| | Nehalem | FI | | Cummins | D |
| | Spring | D | | Bob | D |
| | Watseco | D | | Tenmile | D |
| | Tillamook | FI | | Rock | D |
| | Netarts | D | | Big (Siuslaw) | D |
| | Rover | D | | China | D |
| | Sand | D | | Cape | D |
| | Nestucca | FI | | Berry | D |
| | Neskowin | D | | Sutton | D |
| Mid-Coast | Salmon | PI | Lakes | Siuslaw | FI |
| | Devils | D | | Siltcoos | PI |
| | Siletz | FI | | Tahkenitch | PI |
| | Schoolhouse | D | | Tenmile | PI |
| | Fogarty | D | Umpqua | Lower Umpqua | FI |
| | Depoe | D | | Middle Umpqua | FI |
| | Rocky | D | | North Umpqua | FI |
| | Spencer | D | | South Umpqua | FI |
| | Wade | D | Mid-South Coast | Threemile | D |
| | Coal | D | | Coos | FI |
| | Moolack | D | | Coquille | FI |
| | Big (Yaquina) | D | | Johnson | D |
| | Yaquina | FI | | Twomile | D |
| | Theil | D | | Floras | PI |
| | Beaver | PI | | Sixes | PI |

Wainwright *et al.* (2008) determined that the weakest strata of OC coho salmon were in the North Coast and Mid-Coast of Oregon, which had only “low” certainty of being persistent. The strongest strata were the Lakes and Mid-South Coast, which had “high” certainty of being persistent. To increase certainty that the ESU as a whole is persistent, they recommended that restoration work should focus on those populations with low persistence, particularly those in the North Coast, Mid-Coast, and Umpqua strata.

A 2010 Biological Recovery Team (BRT) (Stout *et al.* 2011) noted significant improvements in hatchery and harvest practices have been made. It has not been demonstrated that productivity during periods of poor marine survival is now adequate to sustain the ESU. Recent increases in adult escapement do not provide strong evidence that the century-long downward trend has changed. The ability of the OC coho salmon ESU to survive another prolonged period of poor marine survival remains in question.

Current concerns for spatial structure focus on the Umpqua River. Of the four populations in the Umpqua stratum, two, the North Umpqua and South Umpqua, were of particular concern. The North Umpqua is controlled by Winchester Dam and has historically been dominated by hatchery fish. Hatchery influence has recently been reduced, but the natural productivity of this population remains to be demonstrated. The South Umpqua is a large, warm system with degraded habitat. Spawner distribution appears to be seriously restricted in this population, and it is probably the most vulnerable of any population in this ESU to increased temperatures.

Current status of diversity shows improvement through the waning effects of hatchery fish on populations of OC coho salmon. In addition, recent efforts in several coastal estuaries to restore lost wetlands should be beneficial. However, diversity is lower than it was historically because of the loss of both freshwater and tidal habitat loss coupled with the restriction of diversity from very low returns over the past 20 years.

The BRT concluded that there is a moderate certainty of ESU persistence over the next 100 years and a low-to-moderate certainty that the ESU is sustainable for the foreseeable future, assuming no future trends in factors affecting the ESU. The NMFS issued a final determination to retain the ESA-listing status, effective June 20, 2011. Thus, the February 2008 critical habitat designation and 4(d) regulations remain in effect (USDC 2011b).

Limiting factors and threats to the OC coho salmon ESU include (Stout *et al.* 2011, NOAA Fisheries 2011):

- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, stream flow, and water quality have been degraded as a result of cumulative impacts of agriculture, forestry, instream mining, dams, road crossings, dikes, levees, *etc*.
- Fish passage barriers that limit access to spawning and rearing habitats.
- Adverse climate, altered past ocean/marine productivity, and current ocean ecosystem conditions have favored competitors and predators and reduced salmon survival rates in freshwater rivers and lakes, estuaries, and marine environments.

<u>Coos River population.</u> OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population. An independent population is one that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years (Lawson *et al.* 2007). The Coos River population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU (Lawson *et al.* 2007).

Annual spawning surveys document the Coos River population's annual abundance varies considerably from year to year (Table 3).[2] The recent trend in this population's abundance is consistent with ESU level abundance trends. (Table 3). The Coos River population has been relatively stable except for the 2007 run year as the abundance fell to just 1,329 fish. The condition of freshwater habitat continues to limit the Coos River population production, especially the loss of winter habitat and stream complexity. This type of habitat is important to juvenile coho salmon looking for refuge during large flood events.

**Table 3.** Annual estimates of OC coho salmon natural spawner abundance in the Coos River system based on monitoring data collected by ODFW (includes Big Creek for 1990-2004).

| Year | Coos River Basin |
|---|---|
| 1990 | 2,273 |
| 1991 | 3,813 |
| 1992 | 16,545 |
| 1993 | 15,284 |
| 1994 | 14,685 |
| 1995 | 10,351 |
| 1996 | 12,128 |
| 1997 | 1,127 |
| 1998 | 3,167 |
| 1999 | 4,945 |
| 2000 | 5,386 |
| 2001 | 43,301 |
| 2002 | 35,429 |
| 2003 | 29,559 |
| 2004 | 24,116 |
| 2005 | 17,048 |
| 2006 | 11,266 |
| 2007 | 1,329 |
| 2008 | 14,881 |
| 2009 | 26,979 |
| 2010 | 27,658 |
| **1990-2010 Avg.** | **15,298** |

***Southern Green Sturgeon.*** Two distinct population segments (DPS) have been defined for southern green sturgeon, a northern DPS (spawning populations in the Klamath and Rogue rivers) and a southern DPS (spawners in the Sacramento River). Southern green sturgeon includes all naturally-spawned populations of southern green sturgeon that occur south of the Eel River in Humboldt County, California. When not spawning, this anadromous species is broadly distributed in nearshore marine areas from Mexico to the Bering Sea. Although it is commonly observed in bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America, the distribution and timing of estuarine use are poorly understood.

[2] http://oregonstate.edu/dept/ODFW/spawn/pdf%20files/coho/AnnualEstESU1996-2010.pdf

In addition to the Puget Sound recovery domain, southern green sturgeon occur in the Willamette and Lower Columbia, Oregon Coast, and Southern Oregon/Northern California Coasts recovery domains. However, southern green sturgeon habitat in the Puget Sound recovery area was not designated as critical habitat.

The principal factor for the decline of southern green sturgeon is the reduction of its spawning area to a single known population limited to a small portion of the Sacramento River. It is currently at risk of extinction primarily because of human-induced ‘‘takes’’ involving elimination of freshwater spawning habitat, degradation of freshwater and estuarine habitat quality, water diversions, fishing, and other causes (USDC 2010). Adequate water flow and temperature are issues of concern. Water diversions pose an unknown but potentially serious threat within the Sacramento and Feather rivers and the Sacramento River Delta. Poaching also poses an unknown but potentially serious threat because of high demand for sturgeon caviar. The effects of contaminants and nonnative species are also unknown but potentially serious threats. As mentioned above, retention of green sturgeon in both recreational and commercial fisheries is now prohibited within the western states, but the effect of capture/release in these fisheries is unknown. There is evidence of fish being retained illegally, although the magnitude of this activity likely is small (NOAA Fisheries 2011).

Southern green sturgeon are known to occupy Coos Bay during the summer months. Southern green sturgeon only spawn in the Sacramento River basin in California, therefore juvenile southern green sturgeon are not present in Coos Bay. However, adult and subadult southern green sturgeon use estuarine areas for foraging and growth and development outside of the natal river system (Moser and Lindley 2007). Data from Washington studies indicate that southern green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007). While in Coos Bay, they likely seek out the deepest habitats to rest during low tides and feed on invertebrates in shallow water during high tides.

***Eulachon.*** The southern distinct population segment of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Core populations for this species include the Fraser River, Columbia River, and (historically) the Klamath River. Eulachon leave saltwater to spawn in their natal streams late winter through early summer, and typically spawn at night in the lower reaches of larger rivers fed by snowmelt. After hatching, larvae are carried downstream and widely dispersed by estuarine and ocean currents. Eulachon movements in the ocean are poorly known although the amount of eulachon bycatch in the pink shrimp fishery seems to indicate that the distribution of these organisms overlap in the ocean.

The viability of this species is under assessment although abrupt and continuing declines in abundance throughout its range and the added vulnerability that a small population size presents for this type of highly fecund, broadcast spawning species are of particular concern. Of the four components of species viability criteria, abundance of the eulachon has declined to historical low levels, productivity is of concern due to climate change, diversity is limited to a single age class, and spatial structure is declining as runs sizes dwindle throughout their range (Drake *et al.* 2008).

In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River with no evidence of returning to their former population levels since then (Drake *et al.* 2008). Persistent low returns and landings of eulachon in the Columbia River from 1993 to 2000 prompted the states of Oregon and Washington to adopt a Joint State Eulachon Management Plan in 2001 that provides for restricted harvest management when parental run strength, juvenile production, and ocean productivity forecast a poor return (WDFW and ODFW 2001). Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings have again declined to the very low levels observed in the mid-1990s (JCRMS 2010), and since 2005, the fishery has operated at the most conservative level allowed in the management plan (JCRMS 2010). Large commercial and recreational fisheries have occurred in the Sandy River in the past. The most recent commercial harvest in the Sandy River was in 2003. No commercial harvest has been recorded for the Grays River from 1990 to the present, but larval sampling has confirmed successful spawning in recent years (USDC 2011a).

There is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuary. In the *Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries* (Monaco *et al*. 1990) it describes eulachon as “rare” in the Coos Bay estuary.

The primary factors responsible for the decline of the southern DPS of eulachon are changes in ocean conditions due to climate change (Gustafson *et al.* 2010, Gustafson *et al*. 2011), particularly in the southern portion of its range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success. Additional factors include climate-induced change to freshwater habitats, dams and water diversions (particularly in the Columbia and Klamath rivers where hydropower generation and flood control are major activities), and bycatch of eulachon in commercial fisheries (NOAA Fisheries 2011).

Other limiting factors include (Gustafson *et al.* 2010, Gustafson *et al*. 2011):

- adverse effects related to dams and water diversions
- artificial fish passage barriers
- increased water temperatures, insufficient streamflow
- altered sediment balances
- water pollution
- over-harvest
- predation

### 2.2.2 Status of the Critical Habitat

Climate change, as described in Section 2.2, is likely to adversely affect the conservation value of designated critical habitats in the Pacific Northwest. The conservation value of critical habitats considered in the opinion generally declined during the era of European settlement due to depletion of cold water habitat and other variations in quality and quantity of spawning, rearing, and migration habitats associated with development of riverine and estuarine areas (Ford *et al*. 2010).

The NMFS reviews the status of designated critical habitat affected by the proposed action by examining the condition and trends of PCEs throughout the designated area. These PCEs vary slightly for some species, due to biological and administrative reasons, but all consist of site types and site attributes associated with life history events.

**Oregon Coast Recovery Domain.** In this recovery domain, critical habitat has been designated for OC coho salmon, eulachon, and southern green sturgeon. Many large and small rivers supporting significant populations of OC coho salmon flow through this domain, including the Nehalem, Nestucca, Siletz, Yaquina, Alsea, Siuslaw, Umpqua, Coos, and Coquille.

The historical disturbance regime in the central Oregon Coast Range was dominated by a mixture of high and low-severity fires, with a natural rotation of approximately 271 years. Old-growth forest coverage in the Oregon Coast Range varied from 25 to 75% during the past 3,000 years, with a mean of 47%, and never fell below 5% (Wimberly *et al.* 2000). Currently, the Coast Range has approximately 5% old-growth, almost all of it on Federal lands. The dominant disturbance now is logging on a cycle of approximately 30 to 100 years, with fires suppressed.

***OC Coho Salmon.*** The state of Oregon (2005) completed an assessment of habitat conditions in the range of OC coho salmon in 2005. Oregon's assessment mapped how streams with high intrinsic potential for OC coho salmon rearing are distributed by land ownership categories. Agricultural lands and private industrial forests have by far the highest percentage of land ownership in high intrinsic potential areas and along all OC coho salmon stream miles. Federal lands have only about 20% of OC coho salmon stream miles and 10% of high intrinsic potential stream reaches. Because of this distribution, activities in lowland agricultural areas are particularly important to the conservation of OC coho salmon.

The OC coho salmon assessment concluded that at the scale of the entire domain, pools are generally abundant, although slow-water and off-channel habitat (which are important refugia for OC coho salmon during high winter flows) are limited in the majority of streams when compared to reference streams in minimally-disturbed areas. Amounts of large wood in streams are low in all four ODFW monitoring areas and land-use types relative to reference conditions. Amounts of fine sediment are high in three of the four monitoring areas, and were comparable to reference conditions only on public lands. Approximately 62 to 91% of tidal wetland acres (depending on estimation procedures) have been lost for functionally and potentially independent populations of OC coho salmon.

As part of the coastal OC coho salmon assessment, the Oregon Department of Environmental Quality analyzed the status and trends of water quality in the range of OC coho salmon using the Oregon water quality index, which is based on a combination of temperature, dissolved oxygen, biological oxygen demand, pH, total solids, nitrogen, total phosphates, and bacteria. Using the index at the species scale, 42% of monitored sites had excellent to good water quality and 29% show poor to very poor water quality. Within the four monitoring areas, the North Coast had the best overall conditions (six sites in excellent or good condition out of nine sites), and the Mid-South coast had the poorest conditions (no excellent condition sites and two out of eight sites in good condition). For the 10-year period monitored between 1992 and 2002, no sites showed a declining trend in water quality. The area with the most improving trends was the North Coast, where 66% of the sites (six out of nine) had a significant improvement in index scores. The Umpqua River basin, with one out of nine sites (11%) showing an improving trend, had the lowest number of improving sites.

The specific unit of OC coho salmon critical habitat that will be affected by the proposed action is the Coos Bay Frontal $5^{th}$ field HUC (1710030403). The action area comprises only a portion of the $5^{th}$ field HUC. This portion only contains PCEs necessary for rearing and migration (Table 4). The NMFS Critical Habitat Analytical Review Team (CHART) identified agriculture, forestry, grazing, road building/maintenance, and urbanization as key management activities affecting the PCEs within this watershed. More specifically, the landscape changes are largely from: a loss of large woody debris and forested land cover, dredging and urbanization of lower estuary, and diking and draining of wetlands (mostly for urban development, agriculture and grazing). The CHART considered this watershed and the associated Coos River mainstem as having high conservation value.

**Table 4.** PCEs of critical habitats designated for ESA-listed OC coho salmon and corresponding species life history events.

| Primary Constituent Elements | | Species Life History Event |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Freshwater spawning | Substrate<br>Water quality<br>Water quantity | Adult spawning<br>Embryo incubation<br>Alevin growth and development |
| Freshwater rearing | Floodplain connectivity<br>Forage<br>Natural cover<br>Water quality<br>Water quantity | Fry emergence from gravel<br>Fry/paar/smolt growth and development |
| Freshwater migration | Free of artificial obstruction<br>Natural cover<br>Water quality<br>Water quantity | Adult sexual maturation<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |
| Estuarine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Salinity<br>Water quality<br>Water quantity | Adult sexual maturation and "reverse smoltification"<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |
| Nearshore marine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Water quantity<br>Water quality | Adult growth and sexual maturation<br>Adult spawning migration<br>Nearshore juvenile rearing |
| Offshore marine areas | Forage<br>Water quality | Adult growth and sexual maturation<br>Adult spawning migration<br>Subadult rearing |

***Southern Green Sturgeon.*** For freshwater rivers north of and including the Eel River, the areas upstream of the head of the tide were not considered part of the geographical area occupied by the southern DPS. However, the critical habitat designation recognizes not only the importance of natal habitats, but of habitats throughout their range. Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) and freshwater (USDC 2009). Table 5 delineates PCEs for southern DPS green sturgeon.

The CHART identified several activities that may threaten the PCEs in coastal bays and estuaries and may necessitate the need for special management considerations or protection.

The application of pesticides may adversely affect prey resources and water quality within the bays and estuaries, as well as the growth and reproductive health of southern DPS green sturgeon through bioaccumulation. Other activities of concern include those that may disturb bottom substrates, adversely affect prey resources, or degrade water quality through re-suspension of contaminated sediments. Of particular concern are activities that affect prey resources. Prey resources can be affected by: commercial shipping and activities generating point source pollution and non-point source pollution that can discharge contaminants and result in bioaccumulation of contaminants in southern green sturgeon; disposal of dredged materials that can bury prey resources; and bottom trawl fisheries that can disturb the bottom (but may result in beneficial or adverse effects on prey resources for southern green sturgeon). In addition, petroleum spills from commercial shipping activities and proposed alternative energy hydrokinetic projects may affect water quality or hinder the migration of southern green sturgeon along the coast (USDC 2009).

The southern green sturgeon considered in this opinion migrate through the action area and use it for rearing. Thus, the affected PCEs for estuarine area are adult/subadult rearing and migration.

**Table 5.** PCEs of critical habitat proposed for southern green sturgeon and corresponding species life history events.

| **Primary Constituent Elements** | | **Species Life History Event** |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Freshwater riverine system | Food resources<br>Migratory corridor<br>Sediment quality<br>Substrate type or size<br>Water depth<br>Water flow<br>Water quality | Adult spawning<br>Embryo incubation, growth and development<br>Larval emergence, growth and development<br>Juvenile metamorphosis, growth and development |
| Estuarine areas | Food resources<br>Migratory corridor<br>Sediment quality<br>Water flow<br>Water depth<br>Water quality | Juvenile growth, development, seaward migration<br>Subadult growth, development, seasonal holding, and movement between estuarine and marine areas<br>Adult growth, development, seasonal holding, movements between estuarine and marine areas, upstream spawning movement, and seaward post-spawning movement |
| Coastal marine areas | Food resources<br>Migratory corridor<br>Water quality | Subadult growth and development, movement between estuarine and marine areas, and migration between marine areas<br>Adult sexual maturation, growth and development, movements between estuarine and marine areas, migration between marine areas, and spawning migration |

***Eulachon.*** The NMFS designated critical habitat for eulachon in October of 2011. Coos Bay was not designated as critical habitat for eulachon and therefore is not analyzed in this opinion.

## 2.3 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

The action area is located within the Coos Bay estuary, the second largest estuary in Oregon, and includes Isthmus Slough, a bifurcation of the estuary. Coos Bay is approximately 13,300 acres, averaging nearly 0.62 mile wide by 15 miles long (Cortright *et al*. 1987). The bay has nearly 30 tributaries, the major tributary being the Coos River. Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary, reducing an estimated 90% of Coos Bay marshes (Proctor *et al.* 1980). Intense development in and around the estuary has impacted the shoreline and intertidal zone by removing vegetation and habitats.

The Coos Bay estuary is classified as a drowned river mouth-type estuary, where winter flows discharge high volumes of sediment through the estuary. In summer, when discharge is lower, seawater inflow dominates the estuary. Isthmus Slough is listed on the Oregon Department of Environmental Quality 303(d) list for water quality limited streams for temperature, ammonia, chlorophyll, dissolved oxygen, fecal coliform, manganese, and pH (ODEQ 2008).

Tributaries to Coos Bay exhibit evidence of bed degradation and are disconnected with their floodplains. Bank erosion is common throughout their lengths, and bedrock is the predominant substrate. Urban, rural residential, and agriculture uses are impacting Coos Bay and its tributaries. Riparian vegetation is mostly limited to a narrow strip alongside the rivers. Bank erosion has elevated turbidity to levels that injure OC coho salmon and impair their feeding and sheltering. Limiting factors to the OC coho salmon population within the action area include degraded water quality and limited quantity of productive shallow-water habitat such as saltwater marsh and eelgrass beds.

The action area is located in North Bend upstream of the Highway101 bridge. The land use around the project site is primarily commercial and industrial.. The bay is maintained as a deepwater port by the Corps. The shoreline from OTC upstream is industrial property with deep docks and associated shipping traffic. The shoreline remains deep (20 feet or greater) for approximately 3 miles before reaching the confluence of Isthmus Slough. Shallow-water habitat (less than 10 feet) is not available on the western shoreline upstream from the OTC project until after the confluence of Isthmus Slough. The shoreline characteristics include riprap banks, docks located on treated piles, and historic fill. The east bank of the estuary of the action area has several historic dredging disposal spoil islands, contains large, shallow-water mudflats, and is actively farmed for oysters.

The shoreline in the action area contains mudflats with depths ranging from 1 to 7 feet in the fill location behind the sheet pile, and 7 to 36 feet in the location of the existing and proposed docks. The riprap toe for fill placement is estimated at 12 feet deep. The slope shoreline at the proposed sheet pile fill is very flat where as the shoreline at the proposed riprap fill is very steep. The existing banks contain concrete and rock placed for erosion protection. Historic treated piles are located through the shoreline, inside of the existing docks. No vegetation is present in the mud flats throughout the action area, or in the riparian area. Logs are stacked in the riparian area of the mudflats. The area's aquatic habitat is degraded and in poor condition.

## 2.4 Effects of the Action

"Effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

### 2.4.1 Effects on the Environment

The proposed action will affect the ESA-listed fish species by causing physical and biological changes to the environmental baseline, and through direct and indirect effects to these species. The proposed action includes offsite compensatory mitigation to reduce net adverse impacts by improving habitat conditions and survival for aquatic species. The NMFS will evaluate the net combined effects of the proposed action and the offsite compensatory mitigation measures as interrelated actions.

#### Water Quality Degradation

**Total Suspended Solids and Sedimentation.** In-water construction activities such as fill, pile driving, treated pile removal, and ground disturbance are likely to temporarily increase erosion and concentrations of total suspended solids and sedimentation. The OTC is placing a sediment curtain surrounding the placement of fill to minimize some of these impacts.

The largest negative effects to substrate will occur from driving of sheet pile, pile removal, and placement of associated construction fill. Short-term pulses of sediment are likely to occur after removal of the piles and the areas where material was disturbed during construction, driving piles, and during placement of fill behind the sheet pile. Decreasingly small pulses of sediment (re-suspension lasting a few hours to a day) may continue to occur for the next three months until all disturbed materials in the construction area settle into place. This sediment is not likely to move more than 100 feet downstream and upstream from the construction fill, pile driving, and pile removal activities. Some sedimentation of substrates, primarily used by OC coho salmon and southern green sturgeon for migration and rearing, will occur in the bay. Fine, redeposited sediments have the potential to reduce primary and secondary productivity (Spence *et al.* 1996) for juvenile OC coho salmon.

**Chemical Contaminants.** The OTC is also planning to remove 256 treated piles during dock improvements. The existing treated wood piles have been leaching contaminants into the water and the sediment for decades. Long-term beneficial effects include the reduction of predator ambush areas and removal of chemical contaminants. Short-term effects include the potential chemical contamination from broken piles or redistribution of chemicals during pile removal, especially without implementation of best management practices.

Any time machinery is operated in close proximity to a stream; there is some chance a large fuel spill or hydraulic line rupture will occur. The NMFS believes the probability of this occurring is very low, but not discountable. If a spill of this nature were to occur, its volume could likely be as little as a few ounces or as much as 50 gallons. If there is a leak, it is typically small resulting in only a few ounces being released. A small amount of fuel likely could be released from the construction area, where it would be noticeable as much as 100 feet downstream or upstream depending on the tidal cycle before being diluted to immeasurable concentrations, prior to reaching the lower limits of the action area. In the immediate area it could have short-term effects on water quality.

Increased impervious surface and resulting stormwater management will result in discharged stormwater into Coos Bay. The proposed project will add 0.46 acre of dock and adjacent 3.9 acres of fill to the impervious area. The outfall contribution areas are shown in Table 6.

Stormwater runoff delivers a wide variety of pollutants to aquatic ecosystems, such as nutrients, metals, petroleum-related compounds, and sediment washed off the road surface (Driscoll *et al*. 1990, Buckler and Granato 1999, Colman *et al.* 2001, Kayhanian *et al.* 2003). These ubiquitous pollutants are a source of potent adverse effects to ESA-listed OC coho salmon, green sturgeon, and eulachon and, even at ambient levels (Loge *et al*. 2006, Hecht *et al*. 2007, Johnson *et al*. 2007, Sandahl *et al*. 2007, Spromberg and Meador 2006). Aquatic contaminants often travel long distances in solution or attached to suspended sediments, or gather in sediments until they are mobilized and transported by next high flow (Anderson *et al*. 1996, Alpers *et al*. 2000a, 2000b). These contaminants also accumulate in the prey and tissues of juvenile salmon where, depending on the level of exposure, they cause a variety of lethal and sublethal effects on salmon including disrupted behavior, reduced olfactory function, immune suppression, reduced growth, disrupted smoltification, hormone disruption, disrupted reproduction, cellular damage, and physical and developmental abnormalities (Fresh *et al*. 2005, Hecht *et al*. 2007, LCREP 2007).

**Table 6.** Outfall Contribution Areas

| **Outfall Designation** | **Description** | **Area (Acres)** | **Impervious Area** | |
|---|---|---|---|---|
| | | | **Acres** | **Percent** |
| 1 | S. Outlet | 10.48 | 10.48 | 100% |
| 2 | N. Outlet | 3.31 | 3.31 | 100% |
| 3 | Center Outlet | 13.85 | 13.85 | 100% |
| 4 | N. Drain | 1.38 | .07 | 5% |
| Beach | Non-point | 0.75 | .04 | 5% |
| Facility Total | | 29.77 | 27.75 | |

Baldwin *et al*. (2003) exposed juvenile coho salmon to various concentrations of copper to evaluate sublethal effects on sensory physiology, specifically olfaction. These researchers demonstrated that short pulses of dissolved copper at concentrations as low as 2 µg/L over experimental background concentrations of 3 µg/L reduced olfactory sensory responsiveness within 20 minutes such that the response evoked by odorants was reduced by approximately 10%. At 10 µg/L over background, responsiveness was reduced by 67% within 30 minutes. They calculated neurotoxic thresholds sufficient to cause olfactory inhibition at 2.3 to 3.0 µg/L over background. They also referenced three studies that reported copper exposures over four hours cause cell death of olfactory receptor neurons within rainbow trout, Atlantic salmon, and Chinook. The concentrations tested are lower than common concentrations in stormwater outfalls, and thus indicate toxicity even after stormwater has been moderately diluted. The measured exposure times are likewise shorter than typical stormwater outfall discharge times. Inhibiting olfaction is detrimental to salmon because olfaction plays a significant role in the recognition and avoidance of predators and migration back to natal streams to spawn (Baldwin *et al*. 2003). More recent research indicates that the effect of 2 µg/L concentrations over experimental background concentrations of 3 µg/L reduces the survival of individuals (Hecht *et al.* 2007).

A review of zinc toxicity studies reveals effects including reduced growth, behavioral alteration (avoidance), reproduction impairment, increased respiration, decreased swimming ability, increased jaw and bronchial abnormalities, hyperactivity, and hyperglycemia. Juvenile fish are more sensitive. Both avoidance in juveniles and growth in adults exposed to zinc have been documented at 5.6 µg/L and 1,120µg/L, respectively. When making general comparisons between lethal and sublethal endpoints tested on juvenile rainbow trout, the sublethal effects occur at concentrations approximately 75% less (5.6 µg/L) than lethal effects (24 µg/L) (EPA 1980; Hansen *et al*. 2002). Even relatively low concentrations (5.6 µg/L, established for juvenile rainbow trout) resulted in avoidance of the plume. NMFS is certain that similar results for salmon will occur.

Stormwater is a complex mixture of many contaminants originating on roads, landscaping, and other surfaces. Most published literature addresses acute toxicity of single pollutants, although pollutants from stormwater exist in mixtures in waterbodies and interact with each other (*e.g.*, Niyogi *et al*. 2004). Rand and Petrocelli (1985) state that in "assessing chemically induced effects (responses), it is important to consider that in the natural aquatic environment organisms may be exposed not to a single chemical but rather to a myriad or mixture of different substances at the same or nearly at the same time. Exposures to mixtures may result in toxicological interactions." A toxicological interaction is one in which exposure to two or more pollutants results in a biological response quantitatively or qualitatively different from that expected from the action of each chemical alone. Exposure to two or more pollutants simultaneously may produce a response that is simply additive of the individual responses or one that is greater (synergistic) or less (antagonistic) than expected from the addition of their individual responses (Denton *et al*. 2002). For example, mixtures of zinc and copper have greater than additive toxicity to a wide variety of aquatic organisms including freshwater fish (Eisler 1993). Although the large number of pollutants and much larger number of toxicological interactions in urban stormwater make specific mechanisms of toxicological effects difficult to predict, there is ample evidence that the mixture of toxins in urban stormwater can degrade habitat enough to substantially reduce its ability to support spawning, feeding, and growth to maturity.

Sediment contamination from stormwater has also been identified in work by the Puget Sound Ambient Monitoring Program on changes and trends in Puget Sound sediments (Dutch *et al*.

2005). These authors noted an increase in PAHs in sediment since the 1980s, attributable to stormwater conveyance from increasing urbanization and vehicle traffic (Lefkovitz *et al*. 1997, Van Metre *et al*. 2000, both as cited in Dutch *et al*. 2005). Therefore, the accumulation of PAHs and other contaminants in the sediment will affect ESA-listed fish over the long term.

The OTC will achieve some stormwater treatment through construction of oil/water separators in the ten catch basins and filtration through ditch lines located on the western property lines of the OTC facility. However, oil/water separators do not remove heavy metals and not all the water flows through the ditchlines. Therefore, adequate removal of stormwater contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Water quality monitoring at this site has demonstrated inadequate treatment. Stormwater testing for sample site #3 on January 17, 2011, found copper at 26 μg/L and Zinc at 83.7 μg/L.[3] The proposed action will likely result in a small increase in discharge of heavy metals because: (1) It does not treat heavy metals any better than they were treated in 2011; (2) it is increasing the amount of impervious surfaces; and (3) the amount of vehicular use and parking is likely to marginally increase due to the increased capacity of shipping.

The improvements to the dock facility at the OTC terminal will allow 12 additional ships annually. These vessels will intake ballast water for stability of the ship. Ballast water has the opportunity to carry invasive species. The United States Coast Guard now requires these ships to empty their ballast water off-shore at least 200 nautical miles. For fish and invertebrates in the action area, the movement and operation of the vessels while in Port is not likely to create a detectable adverse affect on water quality or individuals because open ocean ballast exchange would have occurred outside of 200 nautical miles minimizing the likelihood of non-native species being introduced into Coos Bay.

**Loss of Shallow-Water Habitats and Forage.** The OTC is planning to use clean sand from the North Spit to fill behind the sheet pile and the riprap toe. The adverse effects include loss of shallow-water habitats, short-term negative water quality effects from sediment pulses (discussed above), reduction of benthic forage, and loss of shallow habitat for aquatic vegetation to recover.

The sheet pile and upstream riprap that provides fill containment can also affect water currents and depositional areas that provide food resources for ESA-listed species. The changing of the substrate on the slope from soft benthic substrate to rock riprap will change characteristics of the shoreline to harder surfaces, with interspatial hiding areas for fish.

Overwater structures and associated activities can impact ecological functions of habitat by altering those controlling factors that support key ecological functions such as rearing, and refugia (Nightingale and Simenstad 2001). It is hypothesized that overwater structures can cause long-term impacts to the biological community and the environment by altering predator/prey relationships, fish behavior, and habitat function.

[3] Email from John Craig, OTC consultant, to Jim Muck, NMFS, December 28, 2011 (Transmitting water quality testing results).

Shading, or the loss of ambient light to underwater environments, can reduce the abundance of phytoplankton, benthic macroalgae, and vascular plants such as eelgrass (Nightingale and Simenstad 2001). These primary producers are an important part of the food webs supporting juvenile salmon and other fish in estuarine and nearshore marine environments. However, with the sheet pile extended to 7 feet, much of the rearing area for plant growth is already impacted. Overwater structures can also impact fish migratory behavior by creating sharp underwater light contrasts through the casting of shade under ambient daylight conditions and artificial night lighting changes (Nightingale and Simenstad 2001).

The OTC completed compensatory mitigation in 1997 by breaching a diked pastureland and removing the existing tidegate. Fill from the dike was used to fill existing drainage ditches and construct a dike on the southern property line to prevent flooding of the adjacent land. The compensatory mitigation included 1.4 acres of restoration (1 to 1 credit ratio), and 10.20 acres of enhancement (3 to 1 credit ratio). The goal of the mitigation was the reestablishment of tidal flow to the protected pasture, restoring fish and wildlife functions and to allow low marsh and aquatic communities to reestablish. These mitigation goals are intended to compensate for the loss in shallow-water habitats and forage from the proposed project.

A monitoring report for the site was completed in May 2003 by Wetland Environmental Technologies (Craig 2003). The site is demonstrating anoxic soil conditions and formation of tidal channels. Pasture grasses and other aquatic plants have died as they do not tolerate brackish water. The salinity in the mitigation area was 25 parts per thousand (PPT) during monitoring. Clam holes are present through the mitigation area. The area continues to restore itself to a natural estuarine habitat meeting the goals of the compensatory mitigation plan.

**Hydro Acoustics.** Generally, vibratory hammers are much quieter than impact hammers. The degree to which an individual fish exposed to underwater sound will be affected (from a startle response to immediate mortality) is dependent on the number of variables such as species of fish, size of the fish, presence of a swimbladder, sound pressure intensity and frequency, shape of the sound wave (rise time), depth of the water around the pile and the bottom substrate composition and texture. The OTC proposes to use a vibratory hammer without any proofing for pile installation. Vibratory hammers produce a rounded sound pressure wave with a slower rise time. In contrast, impact hammers produce sharp sound pressure waves with rapid rise times, the equivalent of a punch versus a push in comparison to vibratory hammers. The sharp sound pressure waves associated with impact hammers represent a rapid change in water pressure level. In general, underwater noise affects rapid pressure changes, especially on gas-filled spaces in the body causing the injury and mortality effects to fish. Because the more rounded sound pressure wave produced by vibratory hammers produces a slower increase in pressure, the potential for injury and mortality is reduced. However, sound waves may cause migrating fish to move across the channel to avoid the noise and construction activities.

**Entrainment.** The proposed action will increase shipping in Coos Bay by one vessel per month, or 12 ships annually. NMFS determines the increase in shipping an interrelated effect from the proposed action. Large ships use intakes called a seachest to pull water for cooling and ballast water. Information is limited on intake seachest for ballast water and engine cooling systems for ships entering Coos Bay that are destined for loading at the OTC terminal. The OTC sent an e-mail with typical drawings for OTC ships.[4] The seachests are located at 14.1 feet depth when empty, and 26.9 feet depth when the vessel is full. The orifice area is 1.25 feet by 18.8 feet with 16 bars that are 0.4 inches wide along the longest length. The intake flow is 2.35 cubic feet/second. NMFS fish passage engineering staff reviewed these figures and determined that the screen and required intake flow meet NMFS screening measures, if the ship only used cooling intakes and not combined with ballast water intake.[5] The OTC ships do not require ballast water intake during log loading operations at the OTC terminal.

### 2.4.2 Effects on Listed Species

The in-water timing construction is planned for October 1 to February 15. The habitat in the action area is degraded, composed of concrete blocks, excess bark from log storage, and lacking aquatic or riparian vegetation. NMFS is reasonable certain that juvenile eulachon or OC coho salmon will not use the action area during the in-water work season (Table 7). Adult OC coho salmon migrate through the action area from September through December, with peak migration in October. Juvenile OC coho salmon are not present during construction because they are rearing in upper tributaries (Miller and Sadro 2003, Koski 2009). Adult eulachon are very rare in the Coos Bay estuary (Monaco *et al.* 1990), but may occur in the months of late December through May. Southern green sturgeon are not present during the in-water work period in the Coos Bay estuary (Moser and Lindley 2007).

The proposed action is reasonably likely to have the following direct and indirect effects on OC coho salmon, southern green sturgeon, and eulachon. The duration of the effects will vary from ephemeral (instantaneous to hours) or short-term (days to months), and indirect effects are long-term (years to decades, or the life of the project).

**Table 7.** Life cycle migration and rearing patterns of Eulachon, OC coho salmon, and green sturgeon located in the action area of the Coos Bay estuary. Darker colors represent peak occurrence. Construction window is located at the bottom row.

| Species | Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult OC coho salmon | | | | | | | | | | | | |
| Juveniles OC coho | | | | | | | | | | | | |
| Adult Eulachon | | | | | | | | | | | | |
| Juvenile Eulachon | | | | | | | | | | | | |
| Adult/subadult green sturgeon | | | | | | | | | | | | |
| Construction Window | | | | | | | | | | | | |

[4] E-mail from Lori Nelson (for Jim Lyons), OTC, to Jim Muck NOAA Fisheries, (November 10, 2011) (delivering Seachest drawings and flow for typical OTC vessels).

[5] E-mail from Aaron Beavers, NOAA Fisheries, to Jim Muck, NOAA Fisheries, (November 10, 2011) (reviewing screening and intake for vessels at the OTC terminal.)

### Water Quality Degradation

**Total Suspended Solids and Sedimentation.** The proposed action will re-suspend sediments during construction fill and pile driving. Consolidated substrate will be loosened and re-suspended either immediately because the activity will occur subtidally, or at a later time once the disturbed area is inundated on the next tide. The turbidity plume will likely persist for a few hours (1 to 3 hours) given that the sediment size is larger grain sand. Short-term pulses are likely to occur from pile driving and removal activities, and may redistribute sediment for several weeks after pile driving and removal activity. Although no estimates were provided for number of piles driven or removed per day, NMFS estimated that to drive and remove 194 piles and drive sheet pile, the project will take at least 2 months of in-water work. That will provide an exposure of at least 2 to possibly 3 months of sediment to ESA-listed species in the action area during construction.

Adult OC coho salmon will likely have exposure to very low levels (if any at all) of turbid water associated with the construction since the pile driving and removal will only disturb a small amount of sediment. Adult OC coho salmon and eulachon are expected to move away from areas where construction is occurring. Sedimentation is not likely to reduce food resources of juvenile OC coho salmon or southern green sturgeon due to the small amount of sediment disturbed, it remaining within 100 feet of the activity, and it matching the existing substrate in the action area. The NMFS is reasonably certain the effects of suspended sediment and sedimentation are insignificant and will not cause a reduction of survival or harm OC coho salmon, southern green sturgeon or eulachon.

**Chemical Contaminants.** Accidental release of fuel, oil, and other contaminants can injure or kill aquatic organisms. Petroleum based contaminants, such as fuel, oil, and some hydraulic fluids, contain polycyclic aromatic hydrocarbons, which can kill salmon at high levels of exposure and can also cause sub-lethal adverse effects at lower concentrations (Neff 1985).

Any spills outside of the contained work area may affect any OC coho salmon or eulachon that are in the immediately area or upstream or downstream from the spill depending on tide cycle. However, few individuals should be in the action area, and there is a very low risk of a spill. Therefore, this should have very little effect on the species. Any spills within the construction area should be cleaned up prior to removal of spill barriers.

OTC will remove approximately 256 treated piles as part of this project. The existing treated wood piles have been leaching contaminants into the water and the sediment for decades. The applicant did not propose conservation measures to reduce contaminants from leaching during pile removal. During removal there is potential for contaminants to be re-suspended in the water column without conservation measures to further minimize leaching of treated wood chemicals. Due to an incoming and outgoing tide, this suspension of contaminants will move up and down in the estuary with tidal flow and eventually resettle into the mud. Although this effect is considered short-term (2 to 3 months), these exposed contaminants have the potential to kill or cause sub-lethal adverse effects to OC coho salmon, green sturgeon, and eulachon. Additionally, future maintenance dredging can further redistribute these chemicals.

After pile removal, long-term water quality should improve with the replacement of concrete and steel piles. In the long-term, removal of treated piles is a benefit to ESA-listed species in the estuary.

Increased impervious surface and resulting stormwater management will result in discharged stormwater into Coos Bay. The proposed project will add 0.46 acre of dock and adjacent 3.9 acres of fill to the impervious area. Despite some stormwater treatment, complete removal of contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Coos Bay estuary maintains high salinity even during high winter rains. This demonstrates the estuary has slow flushing, even with high flows that occur during the winter. Stormwater entering at the OTC site will concentrate near the stormwater outlets at the estuary, but will linger in the estuary with the ongoing tide cycles until eventually flushed downstream. Concentrations of copper and zinc will exceed thresholds causing injury and death of ESA-listed species, as demonstrated by the January 2011 sampling. Given the concentration of contaminants, the volume of the bay, and tidal flushing, NMFS is reasonably certain these thresholds will be exceeded throughout areas within 200 feet of each outfall, with highest concentrations within 100 feet of each outfall.

Quantifying the number of ESA species that death and injury will occur is difficult to estimate, but NMFS is reasonable certain the number of individuals is small. This is due to the exposure of these species being limited because: 1) The habitat is degraded at the OTC site and is not preferable for any life stage of any ESA species; 2) OC coho salmon and eulachon will migrate through the affected area of contamination, but are unlikely to hold or rear, thus minimizing exposure time; and 3) southern green sturgeon are only present in the bay during the summer months when stormwater exposure is at its lowest.

**Loss of Shallow-Water Habitats and Forage.** The construction fill will modify 3.9 acre of subtidal and intertidal habitat estuary habitat will result with direct and indirect effects to OC coho salmon, eulachon, and southern green sturgeon. The direct physical effect of placing fill will be covering of the estuary floor, thus increasing the amount of deep subtidal habitat next to shore, making the loss of shallow-water habitat permanent, and steepening the slope of the nearshore areas.

Direct effects will include the potential for adult eulachon to be killed (smothering) during construction fill, although eulachon are at very rare numbers in Coos Bay (Monaco *et al.* 1990). The applicant is not proposing work area isolation. The NMFS is reasonable certain that adult OC coho salmon will swim away from the action area during construction fill *(Sediment and Turbidity are addressed above).* Southern green sturgeon are not expected in the action area during in-water work.

Indirect effects include a loss of intertidal habitat for estuarine invertebrates, less shallow-water habitat for juvenile fish, and a loss of refugia from predators. This can affect the smaller ESA-listed species such as eulachon and juvenile OC coho salmon as they lose the ability to avoid predators. The substrate of the area to be filled includes sand and sandy mud. It provides habitat for a variety of clams, amphipods, and ghost shrimp. The changing of the substrate on the slope from soft benthic substrate to rock riprap will change the species present at the site from mud-colonizing infaunal and epifaunal invertebrates to likely larger, mobile invertebrates and fish. Loss of these prey species will result in a reduction of food available to rearing adult and subadult southern green sturgeon and juvenile OC coho salmon.

As noted above, filling 3.9 acres will cause reduction in the prey base for threatened species, and reduce the shallow-water habitat needed for smaller fish to escape predators. However, compensatory mitigation will provide beneficial effects to off-set some of these losses. The OTC completed compensatory mitigation in 1997, by breaching a diked pastureland and removing the existing tidegate The goal of the mitigation was to reestablish tidal flow to the protected pasture, restore fish and wildlife functions such shallow-water habitats, and allow low marsh and aquatic communities to reestablish.

A monitoring report for the off-site mitigation was completed in May 2003 by Wetland Environmental Technologies (Craig 2003). The site is demonstrating anoxic soil conditions and formation of tidal channels. Pasture grasses and other aquatic plants have died as they do not tolerate brackish water. The salinity in the mitigation area was 25 PPT during monitoring. Clam holes are present through the OTC mitigation area. The area continues to restore itself to a natural estuarine habitat meeting the goals of the compensatory mitigation plan.

The mitigation has been providing benefits to southern green sturgeon, eulachon, and OC coho salmon for 14 years. These benefits are realized prior to the construction and habitat loss due to this project. The beneficial effect for ESA-listed species are as follows:

- The mitigation credits for OTC total 11.60 acres. The removal of the dike and existing tidegate converted 32 acres of upland pastureland to shallow, open water habitat. This area than became an undeclared mitigation bank for other applicants to purchase remaining credits. Under the Corps regulatory programs, OTC was required to use credits on the 11.60 acres (enhancement and restoration combined).
- The OTC Terminal Expansion Project is filling 3.9 acres of intertidal wetlands. The regulatory conversion exceeds the required 3 to 1 enhancement ratio.
- The OTC mitigation credits are adjacent to the Isthmus Slough Channel and provide shallow-water areas for juvenile rearing and escapement from potential predators. The intertidal areas provide “mud flats” that have sand and sediment deposition that provide habitat for clams, amphipods, and ghost shrimp. Ghost shrimp and clams are a major prey item for southern green sturgeon. A NMFS tour of the site showed visible clam holes in large numbers along the shoreline to Isthmus Slough Channel.
- The OTC filled all ditches from the agriculture operations previous occurring at the mitigation site. A major tide channel remained where the existing tidegate was located that runs throughout the length (west to east) of the 32 acre mitigation site. The site is naturally creating additional small channels created by tidal flushing. These areas provide additional rearing for young of the year OC coho salmon, eulachon, and other marine fishes. These channels are watered throughout the tide cycle.

Isthmus Slough is located approximately 2.75 miles upstream from OTC terminal, a tidal slough from the mainstem Coos River estuary. The mitigation site is located 8 miles upstream from the

OTC terminal on Isthmus Slough. The majority of the Coos Bay population of OC coho salmon originates from the mainstem Coos River. Tributaries of Isthmus Slough include Davis Creek and Noble Creek, both of which have OC coho salmon, but in low abundance. OC coho salmon originating from the mainstem of the Coos River may not realize the benefits of the Isthmus Slough mitigation as the distance upstream will more than likely prevent mainstem originating juvenile coho salmon the opportunity to use the shallow water for predatory refuge or benefit from the increase food production. The baseline habitat conditions for the action area are poor with no vegetation such as eel grass. The riparian area also has no vegetation and consists of concrete and stored logs on the shoreline, and the water column has many old treated wood pilings present. Although the location of the mitigation sight is not ideal for OC coho salmon, it does provide some habitat for juvenile rearing.

The mitigation site at Isthmus Slough is providing habitat for southern green sturgeon, and is recovering quite well from historic log rafting and diking that occurred along the shoreline of the slough. NMFS has determined the mitigation site provides some benefit to southern green sturgeon, especially in light of the baseline poor habitat in the action area.

OTC proposes to construct a new 400- by 60-foot dock. The dock is located on piles located about 10 to 15 feet above the water surface and will allow light to enter. The water depth under the dock range from 7 feet to 32 feet, and has a very steep slope. Presently there is no aquatic vegetation in the action area, nor is it predicted after project completion. Juvenile salmonids use the upper layer of the deep water within harbors (Heiser and Finn 1970, Cardwell *et al*. 1980, Pentec 2003). The shoreline upstream of the action area (several miles) is also deep draft docks, with very limited shallow-water habitat. Migrating fish in Coos Bay will either cross the channel to the eastern bank where shallow-water habitat is abundant, or move through surface waters along piers. No evidence has been reported that harbor facilities in marine environments in the action area contain concentrations of predators that might prey on juvenile salmonids.

**Hydro Acoustics.** The OTC is using a vibratory hammer without any proofing for sheet and pile installation. Vibratory hammers produce a rounded sound pressure wave with a slower rise time. In contrast, impact hammers produce sharp sound pressure waves with rapid rise times, the equivalent of a punch versus a push in comparison to vibratory hammers. The sharp sound pressure waves associated with impact hammers represent a rapid change in water pressure level. In general, underwater noise affects rapid pressure changes, especially on gas-filled spaces in the body causing the injury and mortality effects to fish. Because the more rounded sound pressure wave produced by vibratory hammers produces a slower increase in pressure, the potential for injury and mortality is reduced. However, sound waves may cause migrating fish to move across the channel to avoid the noise and construction activities. Sound waves from vibratory hammers will not significantly disrupt their normal behavioral patterns of OC coho salmon and eulachon, and therefore the action has an insignificant response effect. Southern green sturgeon are not present in the action area during the in-water work period and will not be affected by pile driving.

**<u>Entrainment</u>.**

The NMFS is reasonably certain the effects from the intake of engine cooling water are immeasurable to eulachon and OC coho salmon because: (1) The flow rate to cool the engines will allow juvenile OC coho salmon and adult eulachon to swim away from the finger weirs meeting NMFS screening criteria for fish of that size; (2) the intakes are located at least 14.1 feet deep where adult and juvenile eulachon and juvenile OC coho salmon are not present; (3) the habitat surrounding the docking facilities does not attract OC coho salmon or eulachon; (4) the engine noise should move fish away from the seachest intakes; and (5) ballast water intake is not required for ships at the OTC terminal while loading timber, reducing the amount of flow next to the intake seachest. The NMFS has determined the effects to southern green sturgeon are discountable and insignificant because they rear close to the bottom away from the seachest intakes and are large enough to avoid any entrainment risk if in the vicinity.

For fish and invertebrates in the action area, the movement and operation of the vessels while in Port is not likely to create a detectable adverse affect on water quality or individuals because: (1) Open ocean ballast exchange would have occurred outside of 200 nautical miles minimizing the likelihood of non-native species being introduced into Coos Bay; (2) construction of the OTC docks will increase the number of vessels that will be able to be loaded by one ship a month, or 12 ships annually. Substantial boating activity already occurs within Coos Bay thus the expected increase in boat traffic is not anticipated to result in measurable adverse impacts to ESA-listed species in the estuary.

### 2.4.3 Effects on Critical Habitat in the Action Area

The action area is in the Coos Bay Frontal 5th field HUC (1710030403), which is designated as critical habitat for OC coho salmon and southern green sturgeon. OC coho salmon adults and juveniles use the action area for rearing and migration. Additionally, southern green sturgeon adults and subadults use the action area for rearing and migration. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile OC coho salmon for rearing and migration and for adult and subadult green sturgeon rearing and migration. These PCEs include free passage, water quality, water quantity, natural cover, and forage. The likely effects of the action on these physical and biological features are listed below. The duration of effects will vary from ephemeral (instantaneous to hours) or short-term (days to months), and indirect effects are long-term (years to decades).

<u>OC coho salmon and southern green sturgeon estuary rearing and migration.</u>
*Water quality* – The OTC will achieve some stormwater treatment through construction of oil/water separators in the ten catch basins and filtration through ditch lines located on the western property lines of the OTC facility. However, oil/water separators do not remove heavy metals and not all the water flows through the ditchlines. Therefore, adequate removal of stormwater contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Water quality monitoring at this site has demonstrated inadequate treatment. Stormwater testing for sample site #3 on January 17, 2011, found copper at 26 μg/L and Zinc at 83.7 μg/L.[6] The proposed action will likely result in a small increase in discharge of heavy metals because: (1) It does not treat heavy metals any better than they were treated in 2011; (2) it is increasing the amount of impervious surfaces; and (3) the amount of vehicular use and parking is likely to marginally increase due to the increased capacity of shipping. The tested copper levels are six times greater than threshold levels injuring coho salmon. These chemicals will continue exposure as ongoing maintenance dredging near the facility will re-suspend the heavy metals in the water column. The effects of stormwater are reasonably likely to cause an adverse affect to water quality in Coos Bay.

Suspended sediment levels will be increased due to fine sediment mobilized by construction activities. In the short-term, the proposed action is likely to slightly degrade water quality as disturbed soil from pile removal, pile installation, and the construction fill are exposed to the estuary. However, suspended sediment is expected to decrease over the long-term as disturbed areas settle or are flushed out of the system. Accidental release of fuel, oil, or other contaminants is unlikely, but would degrade water quality from the spill location up to 100 feet downstream and 100 feet upstream. The project is lacking conservation measures to minimize chemical contaminates leaching from wood piles during extraction. These chemicals can cause an adverse short-term effect to any adult OC coho salmon near the action area, and may cause long-term effects by settling into downstream sediments. These sediments then may be re-suspended by dredging or other in-water activity and could potentially directly or indirectly affect OC coho salmon and southern green sturgeon. All other construction activities except pile removal impacts are short-term or discountable, such that the quality and function of this PCE will be maintained within the Coos Bay 5$^{th}$ field HUC.

*Natural cover and Forage* **–** Previous activities have eliminated the majority of the natural cover in the project area, except existing treated piles. Simply stated, the existing site is poor quality habitat. The sheet pile will extend out to a depth of seven feet, reducing the amount of shallow-water habitat by 3.9 acres. Shallow-water habitat is used by juvenile OC coho salmon to avoid predators.

Habitat suitability for macroinvertebrates, clams, and ghost shrimp will be eliminated during the construction fill of 3.9 acres. While the impact on habitat is great enough to result in some OC coho salmon and southern green sturgeon being affected, the scale of this impact is small.

The OTC has performed mitigation for these losses in natural cover and forage by providing 1.4 acres of restoration and 10.2 acres of enhancement. The mitigation was completed in 1997 and benefits are already realized.

*Free passage* – The dock structure that occupies the 1.1 acre of the OTC terminal will present obstacles to the movement and migration of both juvenile and adult OC coho salmon and perhaps a few adult southern green sturgeon. Vessels moving to and from slips well cause ESA-listed species to move out of the way. Thus, southern green sturgeon and OC coho salmon

---

[6] Email from John Craig, OTC consultant, to Jim Muck, NMFS, December 28, 2011 (Transmitting water quality testing results).

movement in the estuary will be affected by human activities and ship traffic. In contrast, the presence of people can have a positive effect in that few avian predators can be found lurking in harbors. The NMFS is reasonably certain the overall effect to passage is immeasurable for the follow reasons: (1) The shoreline is already a deep dock draft, (2) the dock is located high above the water surface on piles allowing light penetration to occur, and (3) fish can swim in deeper water or cross the channel to a more suitable habitat.

Information presented in the status and baseline sections of this opinion demonstrate that the Coos Bay Frontal 5th field watershed and estuary has been altered, but conditions still support successful rearing and migration. Three PCEs will be affected, but will not be functionally changed because effects will be small-scale, short-term, or unlikely. The adverse effects to water quality from sediment and re-suspension of contaminants from the treated pile removal can create a short-term adverse effect to OC coho salmon and southern green sturgeon. This adverse effect is at the site and reach scale, and short-term, but could be avoided with adequate conservation measures. The natural cover and forage will be adversely affected at the site but already off-set with pre-implementation mitigation. Stormwater will be treated to a level higher than pre-project conditions.

### 2.5 Cumulative Effects

"Cumulative effects" are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

The population of Coos County will grow by approximately 3% over the next 30 years (ODAS 2004). Most of this growth will occur in the county's more populated cities of Coos Bay, North Bend, Bandon, and Coquille. The increase in population growth is likely to cause greater use of the Coos River estuary by recreational and commercial boats. The physical, auditory, and chemical effects of increased non-project boat traffic in the next few decades is likely to reduce the conservation value of the habitat within the action area. Population growth in Coos County associated road and residential development, as well as maintenance and upgrading of the existing infrastructure, are also likely in the foreseeable future for this watershed.

### 2.6 Integration and Synthesis

The Integration and Synthesis section is the final step of NMFS' assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (section 2.4) to the environmental baseline (section 2.3) and the cumulative effects (section 2.5) to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2).

### 2.6.1 Species

**OC Coho Salmon.** The effects of the proposed action, when added to the status of OC coho salmon, the environmental baseline, and cumulative effects, will not appreciably reduce the likelihood of both the survival and recovery of OC coho salmon in the wild by reducing its numbers, reproduction, or distribution. In our analysis above, NMFS determined that the construction related effects from 3.9 acres of fill, the chemical contaminants from lack of best management practices during pile removal, and stormwater contaminants will directly and indirectly injure or kill a small number OC coho salmon. However, the number of individuals injured or killed is far too small to reduce the abundance or productivity of the Coos River population of OC coho salmon. This independent population has average returns of over 15,000 adults over the last 20 years and the effect of losing a small number of juvenile fish would be immeasurable. The proposed action will have no impact on population spatial structure or diversity. Because there would be no measurable effects to the viability of the Coos River population (the only population affected), the proposed action would not reduce the ability of the species as a whole to survive and recover.

**Southern Green Sturgeon.** The effects of the pile removal and associated chemical contaminates when added to the status of southern green sturgeon, the environmental baseline, and cumulative effects, will not appreciably reduce the likelihood of both the survival and recovery of southern green sturgeon by reducing its abundance, reproduction, or distribution. Pile removal will cause indirect and direct effects to southern green sturgeon from chemical leaching that is distributed into the sediment, and redistributed again during dredging or other in-water work activities. Stormwater may add additional copper and metals that may reach adverse effects to green sturgeon, especially during dredging activities that re-suspend the contaminants when sturgeon are rearing in the bay.

The indirect effect from the construction fill of 3.9 acres will reduce shallow-water habitat for prey species such as clams and ghost shrimp. However, this area is much degraded and productivity is low. The compensatory mitigation at the Isthmus Slough site will enhance 1.4 acres from dike removal and the associated removal of the tidegate, and enhancement of 10.2 acres of shallow, intertidal area. Benefits from the site are already realized as clam holes, shrimp, and anaerobic conditions exist in the intertidal wetlands. The construction fill will have no impact on population spatial structure or diversity of green sturgeon.

**Eulachon**. Adult eulachon may be injured during pile removal or during construction fill. Indirect effects may occur during increased contaminates from additional impervious area and the inadequate filtration to remove metals. OTC is planning to remove an estimated 256 treated piles, which without conservation measures, would release chemical contaminants into the estuary. The exposure levels of chemicals may reach high enough levels to kill adults, but will reach levels that can cause sub-lethal adverse effects. Additionally, the construction fill has a probability of killing through smothering eulachon during the in-water work period, especially from January 1 through February 15, although numbers are difficult to quantify. Given the amount of fill and chemical contaminants during pile removal and stormwater contribution, and knowing that eulachon are rare in Coos Bay, NMFS is reasonably certain the number of eulachon injured or killed is extremely small. The effects of the pile removal and associated chemical contaminates, additional stormwater, and smothering from placement of fill when added to the status of eulachon, the environmental baseline, and cumulative effects, are reasonably unlikely to appreciably reduce the likelihood of both the survival and recovery of eulachon by reducing its abundance, reproduction, or distribution.

### 2.6.2 Critical Habitat

Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary, reducing an estimated 90% of Coos Bay marshes (Proctor *et al.* 1980). The construction fill will eliminate an additional 3.9 acres of shallow, intertidal habitat. The 3.9 acres currently is much degraded with concrete, treated piles, bark from the existing log storage facility, and no riparian vegetation.

The compensatory mitigation at the Isthmus Slough site will enhance 1.4 acres from dike removal and the associated removal of the tidegate, and enhancement of 10.2 acres of shallow, intertidal area. Benefits from the site are already realized as clam holes, shrimp, and anaerobic conditions exist in the intertidal wetlands. Isthmus Slough is improving from historical conditions of log rafting and poor water quality. Isthmus Slough has very poor turn-over due to degraded water quality since only Noble and Davis creeks contribute flow, other than tidal infusion into the Bay.

The OTC is proposing to remove an estimated 256 treated piles and replacing the piles with concrete piles and decking. This will improve the long-term water quality in the Coos Bay estuary. However, short-term impacts from treated pile removal may cause adverse conditions for both eulachon and OC coho salmon, and contribute to further chemical contamination of the bay. The additional impervious area and lack of complete treatment of metals such as copper will increase chemical pollutants directly into the Coos Bay estuary creating an adverse effect to water quality. This area extends out 200 feet from the four stormwater outlets.

The effects of the proposed action, when added to the status of range-wide designation of OC coho salmon critical habitat, the environmental baseline, and cumulative effects, will not appreciably reduce the conservation value of designated critical habitat for the survival and recovery of the of OC coho salmon. Adverse effects resulting in degradation to PCEs will occur, but only at the action area scale. The proposed action will not reduce the conservation value of the Lower Coos Bay Frontal fifth-field watershed. Nor will it reduce the conservation value of the range-wide designation of critical habitat for OC coho salmon.

## 2.7 Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of OC coho salmon, southern green sturgeon, or eulachon or to destroy or adversely modify critical habitat designated for those species.

## 2.8. Incidental Take Statement

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For purposes of this consultation, we interpret "harass" to mean an intentional or negligent action that has the potential to injure an animal or disrupt its normal behaviors to a point where such behaviors are abandoned or significantly altered.[7] Section 7(b)(4) and Section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA, if that action is performed in compliance with the terms and conditions of this incidental take statement.

### 2.8.1 Amount or Extent of Take

**OC Coho Salmon.** The effects of the proposed action will occur in areas where adult and juvenile OC coho salmon are likely to be present. The action area is defined as juvenile and adult migration habitat and juvenile rearing habitat in degraded condition, but is essential to these life stages. The project will result in death and injury of adult and juvenile OC coho salmon from increasing chemical contaminants with treated pile removal and lack of adequate stormwater treatment. It will result in death and injury of some juvenile OC coho salmon due to loss of forage opportunity and predation effects from reduced shallow water habitat. This take will occur throughout the area of pile removal and within 200 feet of each outfall. Incidental take within that area meeting the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

The NMFS cannot precisely predict the number of fish reasonably certain to be harmed or killed due to treated pile removal, inadequate stormwater treatment, or loss of shallow water forage. The distribution and abundance of fish occurring within the action area are a function of habitat quality, competition, predation, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, while NMFS is reasonably certain a low number of individuals to be injured or killed, it cannot precisely predict a number of fish.

---

[7] The NMFS has not adopted a regulatory definition of harassment under the ESA. The World English Dictionary defines harass as "to trouble, torment, or confuse by continual persistent attacks, questions, etc." The U.S. Fish and Wildlife Service defines "harass" in its regulations as "an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering," 50 CFR 17.3. The interpretation we adopt in this consultation is consistent with our understanding of the dictionary definition of harass and is consistent with the U.S. Fish and Wildlife interpretation of the term.

The best available indicator for the extent of take is the number of days required to remove treated wood pilings. In addition, the number of days required to remove pilings is the most practical and feasible indicator to measure. In discussions with the consultant and other piling removal operations, NMFS estimates 10 piles can be removed per day. Thus, piling removal will occur on a maximum of 26 days. Exceeding 26 days of piling removal is a trigger for reinitiating consultation.

**Southern Green Sturgeon.** The effects of the proposed action will occur in areas where adult and subadult southern green sturgeon are likely to be present. The action area is defined as subadult and adult migration habitat and forage habitat in degraded condition, but is essential to these life stages. The project will result in death and injury of adult and subadult southern green sturgeon from chemical contaminants of treated pile removal and lack of adequate stormwater treatment. Incidental take within that area meeting the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

The NMFS cannot precisely predict the number of fish reasonably certain to be harmed or killed due to treated pile removal or inadequate stormwater treatment. The distribution and abundance of fish occurring within the action area are a function of habitat quality, competition, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, while NMFS is reasonably certain a low number of individuals to be injured or killed, it cannot precisely predict a number of fish.

The best available indicator for the extent of take is the number of days required to remove treated wood pilings. In addition, the number of days required to remove pilings is the most practical and feasible indicator to measure. In discussions with the consultant and other piling removal operations, NMFS estimates 10 piles can be removed per day. Thus, piling removal will occur on a maximum of 26 days. Exceeding 26 days of piling removal is a trigger for reinitiating consultation.

**Eulachon.** Eulachon were listed on March 18, 2010 (75 FR 13012) but protective regulations under 4(d) have yet to be promulgated; therefore, no prohibition under section 9 apply. Without the 4(d) regulations, take is not prohibited.

### 2.8.2 Effect of the Take

In the accompanying opinion, NMFS determined that this level of incidental take is not likely to result in jeopardy of the ESA-listed species.

### 2.8.3 Reasonable and Prudent Measures and Terms and Conditions

"Reasonable and prudent measures" are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). "Terms and conditions" implement the reasonable and prudent measures (50 CFR 402.14). These must be carried out for the exemption in section 7(o)(2) to apply.

The following measures are necessary and appropriate to minimize the impact of incidental take of listed species due to the proposed action:

The Corps shall:

1. Minimize incidental take resulting from removal of 256 treated piles by applying measures to avoid or minimize adverse effects to eulachon, OC coho salmon, or their critical habitats.
2. Minimize the incidental take resulting from construction fill by applying measures to avoid or minimize adverse effects to eulachon.
3. Minimize incidental take from stormwater runoff by applying permit conditions that minimize release of chemical contaminants in stormwater.
4. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this ITS are effective in minimizing the impact of incidental take.

The measures described below are non-discretionary, and must be undertaken by the Corps or, if an applicant is involved, must become binding conditions of any permit or grant issued to the applicant, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this ITS. If the Corps (1) fails to assume and implement the terms and conditions or (2) fails to require an applicant to adhere to the terms and conditions of the ITS through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, the Corps or applicant must report the progress of the action and its impact on the species to NMFS as specified in the ITS.

1. To implement reasonable and prudent measure #1 (pile removal measures to minimize chemical contaminants), the Corps shall require the OTC to:

    a. Install a floating surface boom to capture floating surface debris.
    b. Keep all equipment (*e.g.*, bucket, steel cable, vibratory hammer) out of the water, grip piles above waterline, and complete all work during low water and low current conditions.
    c. Dislodge the piling with a vibratory hammer, when possible; never intentionally break a pile by twisting or bending.
    d. Slowly lift the pile from the sediment and through the water column.
    e. Place the pile in a containment basin of a barge deck, pier, or shoreline without attempting to clean or remove any adhering sediment – a containment basin for removed piles and any adhering sediment may be constructed of durable plastic sheeting with sidewalls supported by hale bales or another support structure to contain all sediment and return flow which may otherwise be directed back into the waterway.
    f. Fill the holes left by each piling with clean native sediments immediately upon removal.

g. Dispose of all removed piles, floating surface debris, any sediment spilled on work surfaces, and all containment supplies at a permitted upland disposal site.
h. Make every attempt short of excavation to remove piling, if a pile is intractable, breaks above the surface, or breaks below the surface, cut the pile off at least 3 feet below the surface of the sediment.
i. If the pile is intractable or breaks above the surface, cut the pile at the sediment line.

2. To implement reasonable and prudent measure #2 (minimize incidental take from construction fill), the Corps shall require the OTC to:

   a. Place the construction fill from the upstream area behind the sheet pile first and then work downstream.
   b. Place the fill during the ebbing tide.
   c. Maintain the floating sediment curtain throughout the in-water construction fill, but keep a space at the bottom of the curtain at least one foot for fish to escape.

3. To implement reasonable and prudent measure #3 (stormwater), the Corps shall require OTC to maintain and manage stormwater facilities to ensure that the discharge copper concentration does not exceed 5.0 μg/L at all discharge points.

   a. This can be achieved either with cartridge installation or routing stormwater through swales.
   b. To maximize treatment efficiency prior to discharge to surface or subsurface waters. Implement and maintain one or both of the following specific treatment practices to increase efficacy. (See the Portland 2008 Stormwater Manual for examples).[8]
   c. Submit a maintenance and operations plan within one month following completion of construction:
      i. Provide the inspection timing in the maintenance and operations plan, at a minimum, cartridges need to be checked quarterly and after large rainfall events (greater than 1 inch in 24 hours) during the first year. In subsequent years:
         (1) During erosion events or active construction.
         (2) After the first storm after September 1 with measurable precipitation resulting in stormwater discharge.
         (3) When the flow rate through the cartridges or swales is noticeably diminished.
   d. For swales, use vegetation and soil amended swales designed for infiltration.
      i. Plant species within the swales which will uptake copper and/or zinc metals, *e.g.*, rushes or clover. See *e.g.,* Contaminant Removal in Runoff, Research Report WA-RD 404.1. Online at: www.wsdot.wa.gov/research/reports/fullreports/404.1.pdf

---

[8] Operations and Maintenance chapter available online at www.portlandonline.com/bes/index.cfm?c=47954&a=202884

ii. Monitor and replace vegetation within swales in accordance with a maintenance and operations plan, to be submitted within 1 month following construction.

iii. Remove and replace amended soil based on the maintenance and operations plan.

iv. For any vegetation treatments, monitor plantings yearly for 5 years to ensure a minimum of 80% cumulative survival. Dead plants shall be replaced, as necessary, to bring the site into conformance. If plantings fail to meet this standard, the applicant shall plant additional vegetation.

e. For cartridges, apply the following requirements:

i. Minimize the risk of larger concentrations by maintaining the Bayfilter system to design levels with frequent cartridge replacement and vault cleaning.

ii. Reduce the lot debris treated by swales and cartridges by monthly maintenance of oil/water vaults during the dry season.

iii. Stabilize, as necessary, all erodible elements of any conveyance system to minimize erosion.

iv. Sediment and liquid from any catch basin cleaning may only be disposed of in an approved facility.

4. To implement reasonable and prudent measure #4 (monitoring), the Corps shall ensure that OTC shall provide a report to NMFS with the results of the following:

a. Conduct stormwater discharge sampling.

i. The applicant will obtain samples for three (3) years following completion of construction from each outfall pipe or ditch.

ii. Sampling will be timed to capture the “first flush” of material from impervious surfaces, typically occurring during the “first fall storm event,” meaning the first storm after September 1 of each year that precipitation occurs and results in a stormwater discharge from the facility.

(1) Collect three discrete samples during within the first 12 hours of the first fall storm event and analyze each sample individually (*e.g.*, do not composite).

b. Record days with no precipitation preceding storm, rainfall duration, and the average storm intensity (rainfall inches per hour).

c. Prepare a Project Completion Report. Prepare and submit a project completion report to NMFS describing the OTC’s success in meeting the terms and conditions contained in this opinion. The content of the project completion report will include:

i. Project identification.

(1) Project name.

(2) Type of activity.

(3) Project location by 6th field USGS HUC and by latitude and longitude as determined from the appropriate 7-minute USGS quadrangle map.

(4) OTC contact person(s).
(5) Starting and ending dates for work completed.

ii. Swale plantings. Number, type, and source of plantings.

iii. Photo documentation. Photos of habitat conditions at the project site before, during and after project completion.[9]

(1) Include general views and close-ups showing details of the project and project area, including pre- and post-construction.
(2) Label each photo with date, time, project name, photographer's name, and the subject.

iv. Stormwater management. For swales, structural stormwater facilities, and conveyance systems, provide a maintenance and operations plan the timing of inspections and maintenance activities according to a regular schedule. Provide the plan within 30 days after construction is completed, for NMFS approval. Include a sample log, to be available for inspection on request by the COE or NMFS (see www.portlandonline.com/bes/index.cfm?c=34980&a=54730).

v. Other data. Include the following specific project data in the project completion report:

(1) A summary of pollution and erosion control inspection results, including a description of any erosion control failure, contaminant release, and efforts to correct such incidences.
(2) Any incidence of observed injury or mortality.

d. Provide Notice of any Variance or Exception From Stormwater Management Requirements. The applicant will notify NMFS in the event that it or its assignee, designee, or other successor in interest, if any, grants a variance or exception from any conservation, monitoring or other environmental measure pertaining to storm water management that otherwise would have been required under the applicant's permit.

e. Site Restoration.

i. Finished sheet pile, riprap, and final shoreline configuration.
ii. Final tidal current description.

f. Monitoring for extent of take. Complete treated pile removal within a maximum of 26 days. Report the number of days spent removing piles and total piles removed.

g. Reporting. Prepare and submit a summary of the turbidity monitoring, including a photograph of the baseline and compliance sites; a copy of turbidity measurements or observations with the date and time that each was taken; other relevant sampling conditions; and description of any sediment control failure, sediment release, and correction efforts.

h. Submit Reports. To submit the project completion monitoring report, or to reinitiate consultation, contact:

[9] Relevant habitat conditions may include characteristics of stream channels, eroding and stable streambanks in the project area, riparian vegetation, water quality, flows at base, bankfull and over-bankfull stages, and other visually-discernable environmental conditions at the project area, and upstream and downstream from the project.

Oregon State Habitat Office
National Marine Fisheries Service
Attn: 2011/03866
1201 NE Lloyd Blvd., Ste. 1100
Portland, Oregon 97232-1274

i. NOTICE. If a sick, injured or dead specimen of a threatened or endangered species is found in the project area, the finder must notify NMFS through the contact person identified in the transmittal letter for this opinion, or through NMFS Office of Law Enforcement at 1-800-853-1964, and follow any instructions. If the proposed action may worsen the fish's condition before NMFS can be contacted, the finder should attempt to move the fish to a suitable location near the capture site while keeping the fish in the water and reducing its stress as much as possible. Do not disturb the fish after it has been moved. If the fish is dead, or dies while being captured or moved, report the following information: (1) The NMFS consultation number (found on the top left of the transmittal letter for this Opinion), (2) the date, time, and location of discovery, (3) a brief description of circumstances and any information that may show the cause of death, and (4) photographs of the fish and where it was found. The NMFS also suggests that the finder coordinate with local biologists to recover any tags or other relevant research information. If the specimen is not needed by local biologists for tag recovery or by NMFS for analysis, the specimen should be returned to the water in which it was found, or otherwise discarded.

## 2.9. Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following conservation recommendation is a discretionary measure that NMFS believes is consistent with this obligation and therefore should be carried out by the Federal action agency:

1. The Corps should evaluate the success of the Isthmus Slough Mitigation Bank and review the possibility to provide additional enhancement to the site by adding eel grass plantings to the mitigation requirements from all bank users.
2. The Corps should look at opportunities to enhance, restore, and expand estuarine areas.

Please notify NMFS if the Federal action agency carries out any of these recommendations so that we will be kept informed of actions that are intended to improve the conservation of listed species or their designated critical habitats.

## 2.10 Reinitiation of Consultation

As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal action agency involvement or control over the action has been retained, or is authorized by law, and if: (1) The amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action on listed species or designated critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

To reinitiate consultation, contact the Oregon State Habitat Office of NMFS, and refer to the NMFS Number 2011/03866.

## 2.11 "Not Likely to Adversely Affect" Determinations

### Marine Mammal and Sea Turtles

The NMFS' concurrence or finding of the determination, "may affect, not likely to adversely affect" must be based on NMFS finding that the effects are all expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur. Based on best judgment, a person would not: (1) Be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effects to occur. Refer to the biological opinion for a description of the proposed action and action area.

### Species Determinations

**Steller Sea Lions**. Steller sea lions of the eastern DPS can occur in Oregon waters throughout the year, with two breeding rookeries at Rogue Reef and Orford Reef, and haul out locations used along the coast. Steller sea lions infrequently occur in Coos Bay, and there are no consistently used haulouts within 5 miles of Coos Bay (the most proximate haulout is Cape Arago on the outer coast). Given the short-term nature of construction and the infrequent nature of Steller sea lion occurrence in the project vicinity, NMFS concludes that potential effects from the proposed action are discountable. It is extremely unlikely that a Steller sea lion would be present during or exposed to the proposed construction activities in Coos Bay. Therefore, NMFS finds that the proposed action may affect, but is NLAA Steller sea lions.

**Other Marine Mammals and Sea Turtles** (Southern Resident killer whales, humpback whales, fin whales, blue whales, Sei whales, sperm whales, green sea turtles, leatherback sea turtles, loggerhead sea turtles, and olive ridley sea turtles).

The above identified marine mammal and sea turtle species are either not expected or extremely unlikely to occur in the Coos Bay channel or the Bay proper, and therefore the NMFS does not anticipate that adverse effects will result from removal of existing structures, pile installation, dock construction and improvements, and associated fill are discountable.

These species may occur along the Oregon Coast between the Coos Bay breakwater, in the shipping lanes to and from the port, or on a roundtrip between Coos Bay estuary the extent of the U.S. EEZ enroute to China where OTC ships are proposed to travel. Therefore, OTC ship movements to and from the OTC docks in Coos Bay through the marine transit area may affect marine mammal and sea turtle species. Effects are likely to be discountable or insignificant for the reasons described below.

The OTC ship movements through the marine transit area are anticipated to result in a minimal increase in current levels of ship traffic in the area (12 additional ships per year). The NMFS is not able to quantify existing traffic conditions in the marine transit area to provide context for the addition of up to 12 ship trips annually. However, NMFS does not anticipate that the additional 12 trips annually through the marine transit area would result in anything other than insignificant effects. Vessel strikes of marine mammals or sea turtles by OTC ships in the marine transit area are extremely unlikely, as described in more detail below.

ESA-listed marine mammal occurrence in the marine transit area would be infrequent, transitory and if present, at low density, and marine mammals would therefore be unlikely to encounter an OTC ship associated with the proposed project (NMFS 2008 a, b, c, d, e). Sea turtle occurrence through the marine transit area is rare (*i.e*., NMFS and USFWS 2007 a, b, c, d). Because the potential for an encounter between marine mammal or sea turtle species with these 12 additional ships per year is extremely unlikely, NMFS anticipates that the potential for a ship strike or other adverse interaction is discountable.

The proposed action is not likely to adversely affect the quality of marine mammal prey; however, it may affect the quantity of prey available, by take of OC coho salmon and southern green sturgeon. NMFS anticipates that the effects to Chinook salmon are similar to OC coho salmon. Any take of OC coho salmon, Chinook salmon, eulachon, or southern green sturgeon associated with the proposed actions (as described in the incidental take statement) would result in an insignificant reduction in adult equivalent prey resources for marine mammals that may intercept these and other prey species within their range (*i.e*., Southern Resident killer whales and Steller sea lions).

The NMFS finds all effects of the action are expected to be discountable or insignificant, and therefore provides a determination of “may affect, not likely to adversely affect” for Southern Resident killer whales, humpback whales, fin whales, blue whales, Sei whales, sperm whales, green turtles, leatherback turtles, loggerhead turtles, and olive ridley turtles.

## 3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Adverse effects include the direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the Corps and descriptions of EFH contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce for EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999).

### 3.1 Essential Fish Habitat Affected by the Project

The PFMC described and identified EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of groundfish, coastal pelagics, and Pacific salmon (Appendix A).

### 3.2 Adverse Effects on Essential Fish Habitat

Based on information provided by the action agency and the analysis of effects presented in the ESA portion of this document, NMFS concludes that the proposed action will have the following adverse effects on EFH designated for 49 species of Pacific Coast groundfish, five coastal pelagic species, and OC coho and Chinook salmon:

- Water quality degradation from:
  - Increase in suspended sediment (short-term);
    - construction fill in the intertidal and subtidal
    - jetting, vibrating, and removing treated piles
    - vibrating sheet piles and 194 concrete dock piles

Increased suspended sediment will cause an adverse affect on EFH from these activities. The increase will be short-term but likely high intensity, particularly during the removal of piles and fill during construction activities.

  - Chemical contamination caused by;
    - accidental spills during construction (short-term)

- removal of treated piles
- inadequate stormwater treatment

Removal of treated piles and accidental spills during construction and inadequate stormwater treatment are likely to adversely affect EFH.

- Changes to physical, chemical, and biological habitat including (long-term) from fill of 3.9 acres of estuary:
  - benthic productivity
  - loss of shallow-water habitats
  - predation (increase of and refuge from)
  - disruption of migratory pathways

Of the aforementioned pathways of effect, changes to benthic productivity from the construction fill and placement of riprap will adversely affect EFH.

- Vessel cooling intake seachest:
  - potential for entrainment
  - potential introduction of invasive species

Pelagic and groundfish EFH species are more likely to be entrained on the seachest due to the behavior of the species, and will create an adverse affect.

- Mitigation (long-term):
  - water column
  - intertidal habitat

The mitigation, completed in 1997, is a beneficial effect for EFH species. However, the spatial distance from the mid-estuary located at the action area to the mitigation site at Isthmus Slough may not provide benefit to all the various EFH species. Examples include reduction of salinity at the Isthmus Slough site and distance needed for migration. The Isthmus Slough mitigation does provide off-setting primary and secondary production which are prey species for most EFH species.

**3.3 Essential Fish Habitat Conservation Recommendations**

The NMFS expects that full implementation of these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in section 3.2 above, approximately 3.9 acres of designated EFH for groundfish, coastal pelagics, and Pacific salmon.

The following five conservation measures are necessary to avoid, mitigate, or offset the impact of the proposed action on EFH. These conservation recommendations include the ESA terms and conditions.

1. Juvenile Chinook salmon, young rockfish and flatfish are likely to be in the action area during ground disturbing activities, especially early in the in-water work period. These

life history stages are more susceptible to increased levels of turbidity. Thus, NMFS recommends that the Corps implement a turbidity monitoring plan with sufficient sampling stations to ensure that the turbidity plume is not extending more than 100 feet from the disturbance activity. An upriver and downriver compliance point is likely insufficient given the complex currents, tidal action, and wind-driven surface currents in coastal estuaries. Thus, several compliance points may be necessary to encompass a perimeter around the activity. Background turbidity, location, date, and time must be recorded before pile driving or excavation, and construction fill occurs. Sampling should occur every three hours. If turbidity is exceeding 10% above background for two consecutive sampling periods, NMFS recommends the applicant implement best management practices to minimize the extent of the plume.

2. The NMFS recommends the Corps implement Terms and Conditions #1, #2 and #3 in the ESA portion of this document to offset adverse effects to EFH from fill and pile removal activities.

3. The NMFS recommends that the Corps coordinate with the Coast Guard to develop rules to reduce the entrainment of fish during cooling and ballast water intake.

4. The Corps should evaluate the success of the Isthmus Slough Mitigation Bank and review the possibility to provide additional enhancement to the site by adding eel grass plantings to the mitigation requirements from all bank users.

5. The Corps should look at opportunities to enhance, restore, and expand estuarine areas.

**3.4 Statutory Response Requirement**

As required by section 305(b)(4)(B) of the MSA, the Federal action agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation from NMFS. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations, unless NMFS and the Federal action agency have agreed to use alternative time frames for the Federal action agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS Conservation Recommendations, the Federal action agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects, 50 CFR 600.920(k)(1).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

## 3.5 Supplemental Consultation

The Corps must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations, 50 CFR 600.920(l).

# 4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

**4.1 Utility:** Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users are the Corps.

An individual copy was provided to the Corps. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

**4.2 Integrity:** This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

**4.3 Objectivity:**

*Information Product Category*: Natural Resource Plan.

*Standards*: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq*., and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

*Best Available Information*: This consultation and supporting documents use the best available information, as referenced in the Literature Cited section. The analyses in this opinion/EFH consultation contain more background on information sources and quality.

*Referencing*: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

*Review Process*: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

# 5. LITERATURE CITED


Alpers, C.N., H. E. Taylor, and J.L. Domagalski (editors). 2000a. Metals Transport in the Sacramento River, California, 1996–1997 - Volume 1: Methods and Data. U.S. Geological Survey, Water-Resources Investigations Report 99-4286. Sacramento, California.

Alpers, C.N., R. C. Antweiler, H. E. Taylor, P. D. Dileanis, and J.L. Domagalski. 2000b. Metals Transport in the Sacramento River, California, 1996–1997 – Volume 2: Interpretation of Metal Loads. U.S. Geological Survey, Water-Resources Investigations Report 00-4002. Sacramento, California.

Anderson, C.W., F.A. Rinella and S.A. Rounds. 1996. Occurrence of Selected Trace Elements and Organic Compounds and Their Relation to Land Use in The Willamette River Basin, Oregon, 1992–94. U.S. Geological Survey, Water-Resources Investigations Report 96–4234, Portland, Oregon.

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22: 2266–2274.

Beamis, W.E., and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. *Environmental Biology of Fishes* 48:167-183.

Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan. 2007. Observations: Oceanic Climate Change and Sea Level. P. 385-432 in: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Buckler, D.R., and G.E. Granato. 1999. Assessing biological effects from highway-runoff constituents: U.S. Geological Survey Open File Report 99-240, Northborough, Massachusetts. 45 p.

Cardwell, R.D., M.I. Carr, and E.W. Sanborn. 1980. Water Quality and Flushing of Five Puget Sound Marinas. Washington Department of Fisheries, Technical Report 56, Olympia.

Colman, J.A., K.C. Rice, and T.C. Willoughby. 2001. Methodology and significance of studies of atmospheric deposition in highway runoff: U.S. Geological Survey Open-File Report 01-259, Northborough, Massachusetts, 63 p.

Cortright, R., J. Weber, and R. Bailey. 1987. The Oregon estuary plan book. Department of Land Conservation and Development. Salem, Ore.

Craig, J. 2003. Wetland Mitigation Monitoring Report. Prepared by Wetland Environmental Technologies, Inc. for Jim Lyons, Ocean Terminal Company.

Denton, D.L., C.E. Wheelock, S.A. Murray, L.A. Deanovic, B.D. Hammock, and D.E. Hinton. 2002. Joint acute toxicity of esfenvalerate and diazinon to larval fathead minnows (*Pimephales promelas*). Environmental Toxicology and Chemistry 22:336-341.

Drake, J., R. Emmett, K. Fresh, R. Gustafson, M. Rowse, D. Teel, M. Wilson, P. Adams, E.A.K. Spangler, and R. Spangler. 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon and California. Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington.

Driscoll, E.D., P.E. Shelley, and E.W. Strecher. 1990. Pollutant loadings and impacts from highway runoff, Volume III: Analytical investigation and research report. FHWD-RD-88-0088. Federal Highway Administration, Office of Engineering and Highway Operations Research and Devlepment, McLean, Virginia.

Dutch, M., V. Partridge, S. Aasen, and K. Welch. 2005. Changes and Trends in Puget Sound Sediments: Results of the Puget Sound Ambient Monitoring Program, 1989-2000. Publication No. 05-03-024. http://www.ecy.wa.gov/pubs/0503024.pdf. August 2005.

Eisler, R. 1993. Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Department of the Interior, Fish and Wildlife Service. Biological Report 10. 106 pp.

Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for copper. U.S. Environmental Protection Agency, Publication 440/5-80-036. 162 pp. EPA. 1983. Results of the Nationwide Urban Runoff Program. NTIS No. PB84-185545.

Ford, M.J. (ed.), T. Cooney, P. McElhany, N. Sands, L. Weitkamp, J. Hard, M. McClure, R. Kope, J. Myers, A. Albaugh, K. Barnas, D. Teel, P. Moran, and J. Cowen. 2010. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. Draft U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-XXX.

Fresh, K. L., E. Casillas, L. L. Johnson, D. L. Bottom. 2005. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-69, 105 p.

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105, 360 p.

Gustafson, R.G., M.J. Ford, P.B. Adams, J.S. Drake, R.L. Emmett, K.L. Fresh, M. Rowse, E.A.K. Spangler, R.E. Spangler, D.J. Teel, and M.T. Wilson. 2011. Conservation status of eulachon in the California Current. Fish and Fisheries. DOI: 10.1111/j.1467-2979.2011.00418.x.

Hansen, J.A., P.G. Welsh, J. Lipton, and P.G. Welsh. 2002. Relative Sensitivity of Bull Trout (*Salvelinus confluentus*) and Rainbow Trout (*Oncorhynchus mykiss*) to Acute Exposures of Cadmium and Zinc. Environmental Toxicology and Chemistry 21(1): 67-75.

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sub-lethal neurobehavioral toxicity. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-83, 39 p.

Heiser, D.W., and E.L. Finn, Jr. 1970. Observations of Juvenile Chum and Pink Salmon in Marina and Bulkhead Areas. Supplemental Progress Report, Puget Sound Studies, Washington Department of Fisheries, Management and Research Division, Olympia.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. ISAB Climate Change Report, ISAB 2007-2, Northwest Power and Conservation Council, Portland, Oregon.

JCRMS (Joint Columbia River Management Staff). 2010 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife.

Johnson, L.L., G.M. Ylitalo, M.R. Arkoosh, A.N. Kagley, C.L. Stafford, J.L. Bolton, J. Buzitis, B.F. Anulacion, and T.K. Collier. 2007. Contaminant exposure in outmigrant juvenile salmon from Pacific Northwest estuaries. Environmental Monitoring and Assessment. 124:167-194.

Kayhanian, M., A. Singh, C. Suverkropp, and S. Borroum. 2003. Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations. Journal of Environmental Engineering. 129: 975–990.

Koski, K.V. 2009. The fate of Coho Salmon Nomads: The Story of an Estuarine-Rearing Strategy Promoting Resilience. Ecology and Society 14(1):4. http://www.ecologyandsociety.org/vol14/iss1/art4/

Lawson, P.W., E.P. Bjorkstedt, M.W. Chilcote, C.W. Huntington, J.S. Mills, K.M.S. Moore, T.E. Nickelson, G.H. Reeves, H.A. Stout, T.C. Wainwright, and L.A. Weitkamp. 2007. Identification of historical populations of Coho salmon (*Oncorhynchus kisutch*) in the Oregon coast evolutionarily significant unit. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-79, 129 p.

LCREP (Lower Columbia River Estuary Partnership). 2007. Lower Columbia River and estuary ecosystem monitoring: Water quality and salmon sampling report. Lower Columbia River Estuary Partnership. Portland, Oregon.

Loge, F., M.R. Arkoosh, T.R. Ginn, L.L. Johnson, and T.K. Collier. 2006. Impact of Environmental Stressors on the Dynamics of Disease Transmission. Environmental Science & Technology. 39(18):7329-7336.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, Seattle, Washington, 156 p.

Miller, B. A., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. *Transactions of the American Fisheries Society* 132:546-559.

Monaco, M.E., R.L. Emmett, S.A. Hinton, and D.M. Nelson. 1990. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Vol. I: Data summaries. ELMR Rep. 4. U.S. Dept. Commerce, NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Moser, M., and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/sl0641-006-9028-1.

Neff, J.M. 1985. Polycyclic aromatic hydrocarbons. *In*: Fundamentals of aquatic toxicology, G.M. Rand, and S.R. Petrocelli (eds.), p. 416-454. Hemisphere Publishing, Washington, D.C.

Nightingale, B., and C. Simenstad. 2001. White Paper, Overwater Structures: Marine Issues. University of Washington, Wetland Ecosystem Team, Seattle.

Niyogi, S., P. Couture, G. Pyle, D.G. McDonald, and C.M. Wood. 2004. Acute cadmium biotic ligand model characteristics of laboratory-reared and wild yellow perch (*Perca flavescens*) relative to rainbow trout (*Oncorhynchus mykiss*). Can. J. Fish. Aquat. Sci. 61: 942–953.

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007a. Green Sea Turtle (*Chelonia mydas*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/greenturtle_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007b. Loggerhead Sea Turtle (*Caretta caretta*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/loggerhead_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007c. Leatherback Sea Turtle (*Chelonia mydas*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/greenturtle_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007d. Olive Ridley Sea Turtle (*Lepidochelys olivacea*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/oliveridley_5yearreview.pdf

NMFS (National Marine Fisheries Service). 2008a. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Blue Whale (*Balaenoptera musculus*): Eastern North Pacific Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whbl-en.pdf

NMFS (National Marine Fisheries Service). 2008b. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Fin Whale (*Balaenoptera physalus*): California/Oregon/Washington Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whfi-cow.pdf

NMFS (National Marine Fisheries Service). 2008c. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Humpback Whale (*Megaptera novaeangliae*): California/Oregon/Washington Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whhb-cow.pdf

NMFS (National Marine Fisheries Service). 2008d. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). Prepared by National Marine Fisheries Service, Northwest Regional Office. January 17, 2008. 251 pp.

NMFS (National Marine Fisheries Service). 2008e. Recovery Plan for the Steller sea lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD, 325 pgs.

NOAA (National Oceanic and Atmospheric Administration) Fisheries. 2011. Biennial report to Congress on the recovery program for threatened and endangered species October 1, 2008 – September 30, 2010. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

ODAS (Oregon Department of Administrative Services). 2004. Long-term population estimates. Salem, Oregon. http://www.oregon.gov/DAS/OEA/demographic.shtml (Accessed November 2011).

ODEQ (Oregon Department of Environmental Quality). 2008. Oregon's 2004/2006 Integrated 303(d) Report. URL: http://www.deq.state.or.us/wq/assessment/rpt0406.htm.

Pentec (Pentec Environmental). 2003. Movement of Juvenile Salmon through Modified Nearshore Habitats in the Lower Snohomish Estuary. Prepared for Port of Everett, Everett, Washington, by Pentec, Edmonds, Washington.

PFMC (Pacific Fishery Management Council). 1998. The Coastal Pelagic Species Fishery Management Plan: Amendment 8. Pacific Fishery Management Council, Portland, Oregon. December.

PFMC (Pacific Fishery Management Council). 1999. Amendment 14 to the Pacific Coast Salmon Plan. Appendix A: Description and identification of essential fish habitat, adverse impacts and recommended conservation measures for salmon. Pacific Fishery Management Council, Portland, Oregon. March.

PFMC (Pacific Fishery Management Council). 2005. Amendment 19 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon. November.

Proctor, C.M., C. Garcia, D.V. Galvin, G.B. Lewis, and L.C. Loehr. 1980. An ecological characterization of the Pacific Northwest coastal region. U.S. Fish and Wildlife Service. FWS/OBS-79/15.

Rand, G.M. and S.R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology: Methods and Applications. Editors. Hemisphere Publishing Corporation, Washington, D.C.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science & Technology. 41(8):2998-3004.

Scheuerell, M.D., and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 14:448-457.

Spence, B.C, G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon. *http://www.nwr.noaa.gov/1habcon/habweb/habguide/ManTech/front.htm*

Spromberg, J.A., and J.P. Meador. 2006. Relating chronic toxicity responses to population-level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Ecological Modeling 199(2006):240-252.

State of Oregon. 2005. Coho assessment part 1: Synthesis final report. Salem, Oregon.

Stout, H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G. Pess, G. Reeves, M. Scheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams, and T. Williams. 2011. Scientific conclusions of the status review for Oregon Coast coho salmon (*Oncorhynchus kisutch*). Draft revised report of the Oregon Coast Coho Salmon Biological Review Team. NOAA/NMFS/NWFSC, Seattle, Washington.

USDC (U.S. Department of Commerce). 2009. Endangered and threatened wildlife and plants: Final rulemaking to designate critical habitat for the threatened southern distinct population segment of North American green sturgeon. National Marine Fisheries Service. Federal Register 74(195):52300-52351.

USDC (U.S. Department of Commerce). 2010. Endangered and threatened wildlife and plants: Final rulemaking to establish take prohibitions for the threatened southern distinct population segment of North American green sturgeon. National Marine Fisheries Service. Federal Register 75(105):30714-30728.

USDC (U.S. Department of Commerce). 2011a. Endangered and threatened species, designation of critical habitat for southern distinct population segment of eulachon. Proposed rule; request for comment. National Marine Fisheries Service. Federal Register 76(3):515-536.

USDC (U.S. Department of Commerce). 2011b. Listing Endangered and Threatened Species: Threatened status for the Oregon Coast coho salmon evolutionarily significant unit. National Marine Fisheries Service. Federal Register 76(118):35755-35771.

USGCRP (U.S. Global Change Research Program). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, New York.

Wainwright, T.C., M.W. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout, and L.A. Weitkamp. 2008. Biological recovery criteria for the Oregon Coast coho salmon evolutionarily significant unit. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-91, 199 p.

WDFW and ODFW (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife). 2001. Joint state eulachon management plan.

Weitkamp, L. A. (2010): Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries, Transactions of the American Fisheries Society, 139:1, 147-170

Wimberly, M.C., T.A. Spies, C.J. Long, and C. Whitlock. 2000. Simulating historical variability in the amount of old forests in the Oregon Coast Range. Conservation Biology 14:167–180.

Zabel, R.W., M.D. Scheuerell, M.M. McLure, and J.G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20:190-200.

# 6. APPENDIX: SPECIES WITH DESIGNATED EFH IN THE ACTION AREA.

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Arrowtooth flounder | *Atheresthes stomias* | Adults | All | Clupeids, gadids, krill, shrimp, Theragra chalcogramma |
| | | Eggs | | |
| | | Larvae | | Copepod eggs, Copepod nauplii, copepods |
| Big skate | *Raja binoculata* | Adults | All | Crustaceans, fish |
| Black rockfish | *Sebastes melanops* | Adults | All | Amphipods, Cephalopods, Clupeids, Euphausiids, Mysids, polychaetes, salps |
| | *Sebastes melanops* | Juveniles | Feeding, Growth to maturity | Amphipods, barnacle cypriots, Copepods, crustacean zoea, fish larvae, Mysids, polychaetes |
| Blue rockfish | *Sebastes mystinus* | Adults | All | algae, crab, fish juveniles, fish larvae, hydroids, jellyfish, krill, salps, tunicates |
| | | Juveniles | All | algae, Copepods, Euphausiids, fish juveniles, hydroids, krill, tunicates, algae, copepods, crab, |
| | | Larvae | Feeding | |
| Bocaccio | *Sebastes paucispinis* | Adults | Feeding, Growth to maturity | Juvenile rockfish, molluscs, small fishes |
| | | Juveniles | Feeding, Growth to maturity | Copepods, euphausiids |
| Flathead sole | *Sebastes auriculatus* | Adults | All | Crabs, fish, isopods, polychaetes, shrimp |
| | | Juveniles | Feeding, Growth to maturity | Amphipods, Copepods, crabs, fish |
| Butter sole | *Isopsetta isolepis* | Adults | | Amphipods, decapod crustaceans, fish, molluscs, polychaetes, sea stars, shrimp |
| Cabezon | *Scorpaenichthys marmoratus* | Adults | | Crabs, fish eggs, lobsters, molluscs, small fishes |
| California skate | *Raja inornata* | Eggs | Unknown | |
| Chilipepper | *Sebastes goodei* | Juveniles | Feeding, Growth to maturity | Copepods, euphausiids |
| Curlfin sole | *Pleuronichthys decurrens* | Adults | All | Crustacean eggs, Echiurid proboscises, nudibranchs, polychaetes |
| Darkblotched rockfish | *Sebastes crameri* | Adults and Juveniles | | Amphipods, Euphausiids, octopi, salps, small fishes |
| | | Larvae | | |
| English sole | *Parophrys vetulus* | Adults | All | Amphipods, crustaceans, cumaceans, mollluscs, ophiuroids, polychaetes |
| | | Juveniles | Feedging, Growth to maturity | Amphipods, copepods, cumaceans, molluscs, mysids, polychaetes |
| Flathead sole | *Hippoglossoides elassodon* | Adults | All | Clupeids, fish, molluscs, mysids, polychaetes, shrimp |
| Greenstriped rockfish | *Sebastes elongatus* | Adults | All | Copepods, euphausiids, shrimp, small fishes, squids, tunicates |
| Kelp greenling | *Hexagrammos decagrammus* | Adults | All | Brittle Stars, crabs, octopi, shrimp, small fishes, snails, worms |
| | | Larvae | | Amphipods, brachyuran, copepod nauplii, copepods, euphausiids, fish larvae |
| Lingcod | *Ophiodon elongatus* | Adults | All | Demersal fish, juvenile crab, octopi, squids |
| | | Larvae | Feeding | Amphipods, copepods eggs, copepod nauplii, copepods, decapod larvae, euphausiids |

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Longnose skate | *Raja rhina* | Adults | All | |
| | | Eggs | | |
| | | Juveniles | Growth to Maturity | |
| Pacific cod | *Gadus macrocephalus* | Adults | All | Amphipods, crabs, mysids, sandlance, shrimp, Theragra chalcogramma |
| | | Juveniles | | Amphipods, copepods, crabs, shrimp |
| | | Larvae | | Copepods |
| Pacific hake | *Merluccius productus* | Adults | All | Amphipods, clupeids, crabs, Merluccius productus, rockfish, squids |
| | | Juveniles | | Euphausiids |
| Pacific ocean perch | *Sebastes alutus* | Adults | All | Copepods, euphausiids, mysids, shrimp, small fishes, squids |
| | | Juveniles | | Copepods, euphausiids |
| Pacific sanddab | *Citharichthys sordidus* | Adults | All | Clupeids, crab larvae, octopi, squids |
| Petrale sole | *Eopsetta jordani* | Adults | All | Eopsetta jordani, Euphausiids, Ophiuroids, pelagic fishes, shrimp |
| Quillback rockfish | *Sebastes maliger* | Adults | all | Amphipods, clupeids, crabs, euphausiids, fish juveniles, molluscs, polychaetes, shrimp |
| Redbanded rockfish | *Sebastes babcocki* | Adults | All | |
| Redstripe rockfish | *Sebastes proriger* | Adults | All | Clupeids, fish juveniles, squids |
| Rex sole | *Glyptocephalus zachirus* | Adults | All | Cumaceans, euphausiids, larvacea, polychaetes |
| Rock sole | *Lepidopsetta bilineata* | Adults | All | echinoderms, echiurans, fish, molluscs, polychaetes, tunicates, |
| Rosethorn rockfish | *Sebastes helvomaculatus* | Adults | All | amphipods, copepods, euphausiids |
| Rosy rockfish | *Sebastes rosaceus* | Adults | All | crabs, shrimp |
| Rougheye rockfish | *Sebastes aleutianus* | Adults | All | |
| | | Juveniles | Growth to Maturity, Feeding | |
| Sablefish | *Anoplopoma fimbria* | Adults | Growth to Maturity | Clupeids, euphausiids, octopi, rockfish, shrimp |
| | | Juveniles | Growth to Maturity | Amphipods, Cephalopods, copepods, demersal fish, Euphausiids, krill, small fishes, squids, tunicates |
| | | Larvae | Feeding | Copepod eggs, Copepod nauplii, copepods |
| Sand sole | *Psettichthys melanostictus* | Adults | All | Clupeids, crabs, fish, molluscs, mysids, polychaetes, shrimp |
| | | Juveniles | Feeding, Growth to maturity | Euphausiids, molluscs, mysids, polychaetes, shrimp |
| Sharpchin rockfish | *Sebastes zacentrus* | Adults | All | Amphipods, copepods, euphausiids, shrimp, small fishes |
| | | Juveniles | Feeding, Growth to maturity | Amphipods, copepods, euphausiids, shrimp, small fishes |
| Shortbelly rockfish | *Sebastes jordani* | Adults | All | Copepods, euphausiids |
| Shortraker rockfish | *Sebastes borealis* | Adults | All | Bathylagids, Cephalopods, Decapod crustaceans, fish, molluscs, myctophids, mysids, shrimp |
| Shortspine thornyhead | *Sebastolobus alascanus* | Adults | All | Amphipods, copepods, crabs, fish, polychaetes, Sebastolobus alascanus, Sebastolobus altivelis, shrimp |

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Silvergray rockfish | *Sebastes brevispinis* | Adults | All | |
| Soupfin shark | *Galeorhinus galeus* | Adults | All | Fish, invertebrates |
| | | Juveniles | Growth to Maturity | Invertebrates, Fish |
| Spiny dogfish | *Squalus acanthias* | Adults | All | Invertebrates, pelagic fishes, invertebrates, pelagic fishes, |
| Splitnose rockfish | *Sebastes diploproa* | Juveniles | Feeding | Amphipods, cladocerans, copepods |
| | | Larvae | | |
| Spotted ratfish | *Hydrolagus colliei* | Adults | All | algae, Amphipods, Annelids, Brittle Stars, fish, hydrolagus colliei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squids |
| | | Juveniles | Growth to Maturity | algae, Amphipods, Annelids, Brittle Stars, fish, hydrolagus colliei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squids |
| Starry flounder | *Platichthys stellatus* | Adults | Growth to Maturity | Crabs, fish juveniles, molluscs, polychaetes |
| | | Juveniles | Feeding | Amphipods, copepods, polychaetes |
| Stripetail rockfish | *Sebastes saxicola* | Adults | All | Copepods, euphausiids |
| | | Juveniles | Feeding, Growth to maturity | copepods |
| Tiger rockfish | *Sebastes nigrocinctus* | Adults | All | Amphipods, clupeids, crabs, fish juveniles, juvenile rockfish, shrimp |
| Vermilion rockfish | *Sebastes miniatus* | Adults | All | Clupeids, juvenile rockfish, krill, octopi, squids |
| Widow rockfish | *Sebastes entomelas* | Adults | All | Amphipods, Copepods, Euphausiids, Merluccius productus, salps, shrimp, squids |
| | | Juveniles | Feeding, Growth to maturity | Copepod eggs, Copepods, Euphausiid eggs |
| Yelloweye rockfish | *Sebastes ruberrimus* | Adults | All | Clupeids, cottids, crabs, gadids, juvenile rockfish, sea urchin, shrimp, snails |
| Yellowtail rockfish | *Sebastes flavidus* | Adults | All | Clupeids, Euphausiids, krill, Merluccius productus, Mysids, salps, Squids, tunicates |

| Coastal Pelagic Species | |
|---|---|
| Common Name | *Scientific Name* |
| Northern Anchovy | *Engraulis mordax* |
| Pacific Sardine | *Sardinops sagax* |
| Pacific (Chub) Mackerel | *Scomber japonicus* |
| Market squid | *Loligo opalescens* |
| Jack Mackerel | *Trachurus symmetricus* |

| Pacific Salmon | |
|---|---|
| Common Name | *Scientific Name* |
| Coho Salmon | *Oncorhynchus kisutch* |
| Chinook Salmon | *Oncorhynchus tshawytscha* |

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

**Refer to NMFS No:**
**2012/00604**

June 22, 2012

Cayla D. Morgan
Seattle Airport District Office
Federal Aviation Administration
1601 Lind Avenue SW, Suite 250
Renton, Washington 98055-4056

Re: Endangered Species Act Section 7(a)(2) Concurrence Letter and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Southwest Oregon Airport mitigation site dike repair, Coos Bay (Haynes Inlet 6th field HUC: 171003040304), Coos County, Oregon

Dear Ms. Morgan:

On February 29, 2012, the National Marine Fisheries Service (NMFS) received a request from the Federal Aviation Administration (FAA) for formal consultation under section 7 of the Endangered Species Act (ESA) on the effects of the Southwest Oregon Airport (SWORA) mitigation site dike repair (proposed action). In the request for consultation the FAA determined that the proposed action would likely adversely affect (LAA) Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) and southern distinct population segment (DPS) North American green sturgeon (*Acipenser medirostris*) (hereafter referred to as 'green sturgeon'). The FAA also determined that the proposed action is not likely to adversely affect (NLAA) southern DPS Pacific eulachon (*Thaleichthys pacificus*) (hereafter referred to as 'eulachon'), designated critical habitat for OC coho salmon, and designated critical habitat for green sturgeon. After review of the biological assessment and initiation package for the proposed action the NMFS determined that the effects of the proposed action are NLAA OC coho salmon and their designated critical habitat, green sturgeon and their designated critical habitat, and eulachon. This response to your request was prepared by NMFS pursuant section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402, and agency guidance for preparation of letters of concurrence.[1]

The NMFS also reviewed the proposed action for potential effects on essential fish habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), including conservation measures and any determination that you made regarding the potential effects of the action.

---

[1] Memorandum from D. Robert Lohn, Regional Administrator, to ESA consultation biologists (guidance on informal consultation and preparation of letters of concurrence) (January 30, 2006).

This review was pursuant to section 305(b) of the MSA, implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation.[2] In this case, NMFS concluded that the action would not adversely affect EFH. Thus, consultation under the MSA is not required for this action.

This letter is in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Data Quality Act) (44 U.S.C. 3504 (d) (1) and 3516), and underwent pre-dissemination review using standards for utility, integrity and objectivity.

**Consultation History**

On August 23, 2010, the U.S. Army Corps of Engineers (Corps) contacted NMFS requesting initiation of emergency consultation procedures to install a temporary protective structure at the SWORA mitigation site for protection of the dike. The dike had eroded from wind-wave action, combined with tidal fluctuation was limiting use of an access road needed for the landowner to access part of their property. The emergency proposal consisted of a log boom installed to take the greatest force of the wave action and halt erosion to the dike. The NMFS issued emergency conservation measures on September 7, 2010.

On February 5, 2011, NMFS received an e-mail from the contractor requesting a meeting on-site to discuss a long-term solution for dike stabilization. On February 17, 2011 NMFS met with the contractor, landowner, Oregon Department of Fish and Wildlife, SWORA and their consultants, and the Corps to determine an appropriate method to stabilize the dike.

On September 22, 2011, NMFS received a public notice from the Corps requesting comments on the proposed action. On October 3, 2011, NMFS responded to this public notice by sending the Corps a Fish and Wildlife Coordination Act letter that identified concerns regarding construction activities and the proposed action.

On February 29, 2012, NMFS received from the FAA a biological assessment (BA) and a letter requesting consultation for the effects of the proposed action to ESA-listed species and critical habitats. In the BA, the FAA determined that the proposed action was LAA OC coho salmon and green sturgeon. The FAA also determined that the proposed action was NLAA eulachon, designated critical habitat for OC coho salmon, and designated critical habitat for green sturgeon. The BA also included the FAA's determination that the proposed action would likely adversely affect EFH for Pacific salmon and coastal pelagic species.

On March 28, 2012, NMFS sent a letter requesting the FAA provide additional information required to continue with consultation on the proposed action and its effects to ESA-listed species and critical habitat. The FAA responded to NMFS' request, providing a letter on May 16, 2012. On May 25, 2012, NMFS followed up with the FAA and their consultant to obtain

[2] Memorandum from William T. Hogarth, Acting Administrator for Fisheries, to Regional Administrators (national finding for use of Endangered Species Act section 7 consultation process to complete essential fish habitat consultations) (February 28, 2001).

additional information in NMFS' request that was not clearly identified in the FAA's response.[3] After reviewing all information provided by the FAA, NMFS determined that additional information was required to continue with consultation and e-mailed the consultant with the additional information request on June 1, 2012. The consultant responded on June 4, 2012 with the requested information. The NMFS reviewed this information and initiated informal consultation on June 4, 2012.

The NMFS used information provided in the BA, Corps joint permit application (Corps No.: NWP-2006-760/4), and information from meetings and e-mails with the FAA and their consultants to complete this consultation. A complete record of this consultation is on file at the Oregon Coast Branch of the Oregon State Habitat Office in Roseburg, Oregon.

The proposed action does not qualify for programmatic biological opinion coverage (SLOPES) because it is neither a transportation or restoration project, but a project to repair and stabilize a water control structure (dike).

**Description of the Proposed Action and the Action Area**

The proposed action is the FAA's SWORA mitigation site dike repair project (Figure 1). The dike has eroded on the Coos Bay side from wind and wave activity, which has undermined the dike and its function. The proposed action will include: (1) Excavation of two meandering channels on the back side of the existing dike; (2) stabilizing the face (section A in Figure 1) of the existing dike with a rootwad structure that includes anchor logs and large rocks to hold rootwads in place (Figure 2); (3) stabilizing the outside (section B in Figure 1) northern and southern corners of the dike with riprap incorporated with rootwads (Figure 2); and (4) replacing a damaged culvert fitted with a tidegate. The dike consists of fill material and was not historically present in Haynes Inlet of Coos Bay. The dike was constructed in the early 1940s to create pasture land to serve a dairy farm.[4] In 2008, NMFS completed consultation on the SWORA taxiway C relocation and construction of an air traffic control tower (refer to NMFS No.: 2008/03298). The dike constructed in the 1940s was relocated to its current position as mitigation for the aforementioned project to restore tidal channels and tidal marshlands in the action area. During the work to relocate the dike, riprap was installed in section B (Figure 1) on the dike to strengthen these areas. The SWORA proposes to work from June to August.

***Meandering channels***. The SWORA will excavate two meandering channels behind the dike. Construction of one channel (meandering channel 1) will occur along the back side of the dike southwest of the northern side of the restored tidal area. The SWORA will connect this channel to an existing channel that runs to a tidegate that drains to the bay. The other constructed channel's location (meandering channel 2) will be along the back side of the northern stretch of the dike and connect to an existing channel at the northeast corner of the site. The SWORA will

[3] Phone conference between Cayla Morgan (FAA), Casey Storey and Rainse Anderson (WHPacific), and Jeff Young (NMFS) discussing conservation measures and potential for fish presence in excavation areas for meandering channels (May 25, 2012).

[4] Biological and EFH assessment for the SWORA proposed parallel taxiway C relocation and air traffic control tower construction (Phase II). 2006. Prepared for SWORA and W&H Pacific by Natural Resource Planning Services, Inc. (See NMFS No.: 2008/03298).

construct the channels to have an ordinary high water line (OHW) at four feet elevation with an active channel width and depth of ten and two feet. Channel construction will occur such that the channel will meander along the back side of the dike. Willow plantings will occur at the OHW and SWORA will place woody debris every 50 feet in the constructed channels (Figure 2).

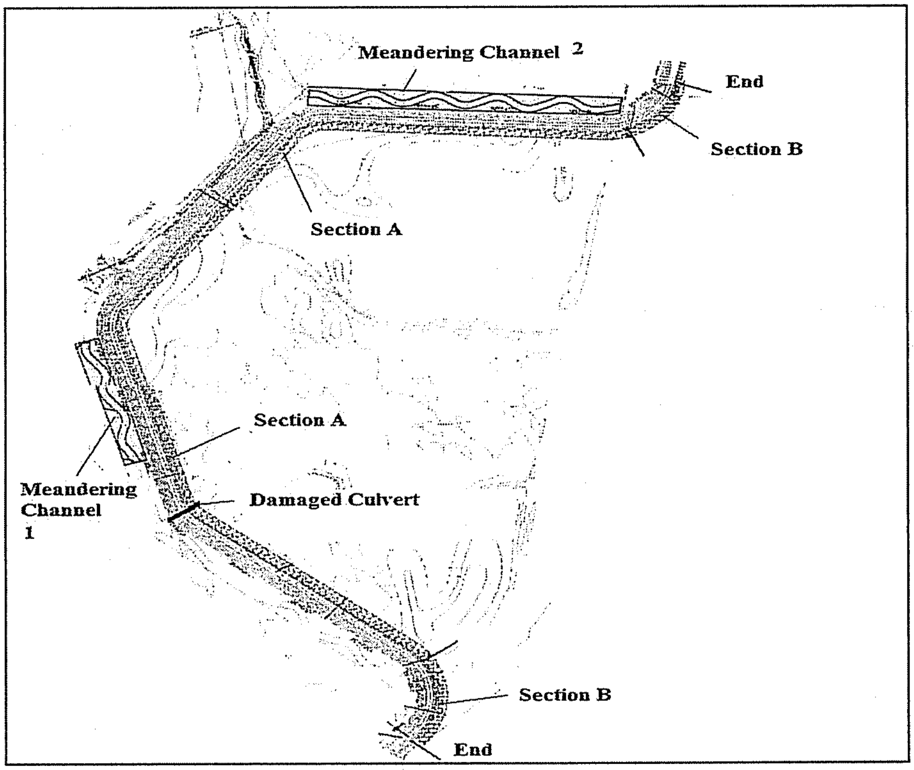



**Figure 1.** Diagram of the SWORA mitigation site dike and locations of project activities associated with the proposed action.

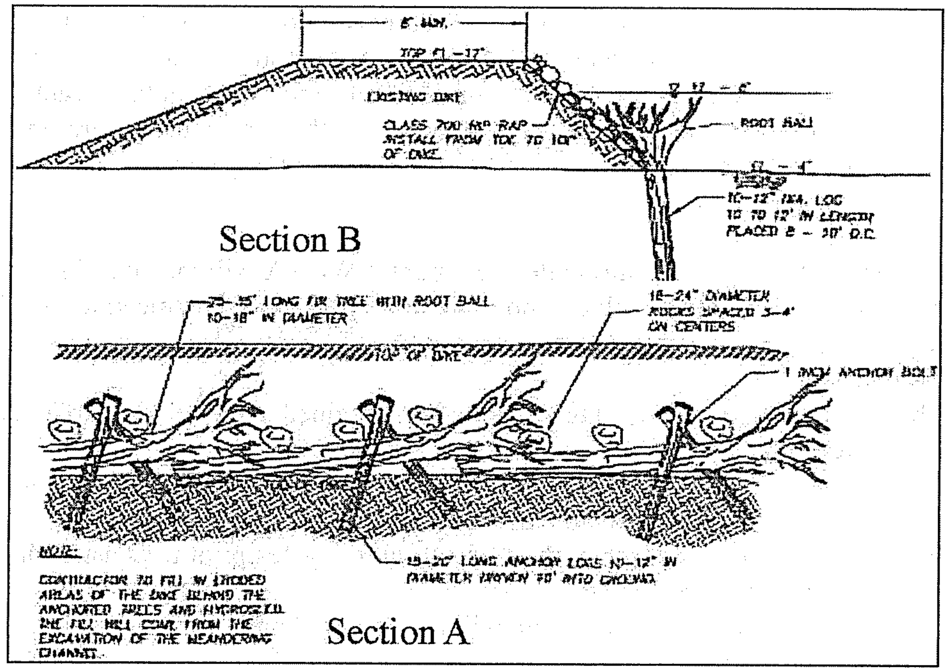



**Figure 2.** Rock riprap and rootwad treatments to stabilize the SWORA mitigation site dike.

***Dike repair and stabilization***. Using the excavated material from the construction of the meandering channels, SWORA will place identified material on the face of the dike. This dike repair will return the dike to its previous width. To stabilize the face of the dike SWORA will use two different stabilization techniques. The first (section A of Figure 2) will consist of 10- to 18-inch diameter tree sections approximately 25 to 35 feet long with rootwads attached. The SWORA will place the trees so that the rootwads overlap the stems to provide a continuous stabilization structure along the dike. To hold the tree sections in place, SWORA will place 18 to 24-inch rocks on top of the trees and pound into the ground 15- to 20-foot log sections to approximately a 10-foot depth. The SWORA will than connect these over the tree sections with a bolt to secure the tree sections in place. The second technique (section B of Figure 2) will consist of placing an approximate total of 200 feet of rock riprap from the toe to the top of the dike. When the dike was relocated to its existing location, riprap was placed in these areas to provide protection of the dike. These areas get the worst of the wind and wave action. The placement of additional riprap will strengthen these areas. The SWORA will then drive 10- to 12-foot long tree sections that are 10 to 12 inches in diameter into the ground at the toe of the riprap leaving the rootwad exposed. These will be placed every 8 to 10 feet.

***Culvert replacement***. The SWORA will replace a damaged culvert (Figure 1) that drains to Coos Bay. This culvert is fitted with a top-hinged tidegate to prevent saltwater intrusion into the pasture behind the dike. The SWORA will excavate the dike down to the culvert and replace it with a new culvert of the same size and length. The new culvert will have the same slope (zero) and will be set at the same elevation. The SWORA will place the existing tidegate on the new culvert.

The SWORA and FAA proposed conservation measures to minimize the effects to ESA-listed species and critical habitats. One of those was fish salvage. If fish were to become stranded in the excavation areas for the proposed meandering channels, then fish would be captured and removed and safely released back to the bay. The only way that fish could be present in the excavation areas is if they are washed over the dike.[3] The remaining conservation measures include the following:

1. To minimize the effects of suspended sediment, SWORA will install sediment fences and floating silt curtains at the culvert and at the ends of the existing meandering channels where constructed channels will be connected to minimize dispersion of suspended sediment.
2. All heavy equipment will be staged, parked, maintained, and fueled in upland areas at least 150 feet from the nearest waterbody and/or wetland.
3. All heavy equipment will be operated from on top of the existing dike or from work mats or platforms to reduce impacts to existing aquatic and wetland resources.
4. Sediment socks will be placed at the outlet of all tidegates prior to construction near waterways draining to each.
5. All vehicles used during construction will be inspected daily for fluid leaks and maintained appropriately.
6. Spill response kits will be on-site during construction in the event of unanticipated discharge of fuel or equipment fluids.
7. All non-work areas will be flagged, staked, or fenced prior to construction.
8. All work will be conducted during periods of dry weather to reduce the introduction of sediment to project area waterways.
9. All work within tidally influenced portions of the project area will be completed when tidal inundation is absent (low tide, low slack and incoming tides).
10. After construction activities are completed, SWORA will hydroseed all exposed soil areas.

The proposed action area is located in Haynes Inlet of the Coos Bay Frontal fifth-field watershed (HUC5: 1710030403). The action area consists of the proposed meandering channel areas (Figure 1) and 40 feet out from the backside of the dike in these areas; 50 linear feet from connection points of proposed meandering channels and existing channels; and the dike and 50 feet out from the dike towards the bay along the entire length of the dike (approximately 1,650 linear feet). The extent of the action area has been determined based on the extent of construction and the likely extent of suspended sediment dispersion.

**Description of Species and Critical Habitat**

The proposed action may affect OC coho salmon, green sturgeon, and eulachon; and designated critical habitats ESA-listed species (Table 1). The action area is designated critical habitat for OC coho salmon and green sturgeon, but not for eulachon. The critical habitat unit affected by the proposed action is the Coos Bay Frontal fifth-field watershed (HUC5: 1710030403).

**Table 1.** Federal Register notices for ESA-listed species referred to in this document.

| Species | Listing Status | Critical Habitat | Protective Regulations |
|---|---|---|---|
| OC coho salmon | T 6/20/11; 76 FR 35755 | 2/11/08; 73 FR 7816 | 2/11/08; 73 FR 7816 |
| Green sturgeon | T 4/07/06; 71 FR 17757 | 10/09/09; 74 FR 52300 | 6/02/10; 75 FR 30714 |
| Eulachon | T 3/18/10; 75 FR 13012 | 10/20/2011; 76 FR 65324 | Not applicable |

***OC coho salmon***. Adult and juvenile OC coho salmon use the action area as a migration corridor and to transition between freshwater and saltwater. Juvenile OC coho salmon also use the action area for rearing during the juvenile outmigration. The action area surrounding the project area is tidally influenced mudflats with tidal channels that provide rearing opportunities for juveniles. The NMFS is reasonably certain that few OC coho salmon juveniles will be present in the action area during project activities. Juvenile outmigration ends by mid-July and does not begin again until mid-February of the next year. Adult OC coho salmon pass by the action area on their way to Palouse and Larson sloughs as spawning begins at the beginning of September and ends in January. Migrating adults would not spend considerable time within the action area. The primary constituent elements (PCEs) of OC coho salmon designated critical habitat in the estuary are those that support migration, rearing, and successful transition between freshwater to saltwater (Table 2).

**Table 2.** PCEs of critical habitat designated for OC coho salmon and potentially affected by the proposed action with corresponding species life history events.

| Primary Constituent Elements | | Species Life History Event |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Estuarine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Salinity<br>Water quality<br>Water quantity | Adult sexual maturation and "reverse smoltification"<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |

***Green sturgeon***. The NMFS defined two distinct population segments (DPS) of green sturgeon: a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River. Green sturgeon was listed as threatened in 2006 (71 FR 17757), and includes all spawning populations south of the Eel River in California. Critical habitat for green sturgeon within Coos Bay terminates at head of tide (74 FR 52300) and includes the action area. Subadult and adult green sturgeon use the action area as habitat for growth and development to adulthood and for adult and subadult feeding. Green sturgeon are known to congregate in coastal waters and estuaries, including non-natal estuaries such as Coos

Bay (including South Slough). Beamis and Kynard (1997)[5] suggest that green sturgeon move into estuaries of non-natal rivers to feed. Data from Washington studies indicate that green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007).[6] The PCEs of designated critical habitat in the estuary are those that support subadult and adult green sturgeon growth and development and movements between estuarine and marine areas.

**Table 3.** PCEs of critical habitat designated for green sturgeon and potentially affected by the proposed action with corresponding species life history events.

| **Primary Constituent Elements** | | **Species Life History Event** |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Estuarine areas | Food resources<br>Migratory corridor<br>Sediment quality<br>Water flow<br>Water depth<br>Water quality | Adult and subadult growth and development<br>Adult and subadult seasonal holding<br>Adult and subadult movements between estuaries and marine areas |

***Eulachon***. Eulachon range from the Mad River in northern California to the Skeena River in British Columbia, Canada. They inhabit several riverine and estuarine systems along the west coast and population sizes vary between these systems. The Coos Bay population occurs in rare relative abundance. The NMFS listed eulachon as threatened under the ESA, protective regulations were issued on March 18, 2010 (75 FR 13012). The NMFS designated critical habitat for eulachon on October 20, 2011 (76 FR 65324) and the action area is not critical habitat. Eulachon adults return to freshwater from January to May and evidence suggests that adult eulachon may return as early as December to spawn (WDFW and ODFW 2001).[7] Typical spawning for eulachon occurs from January to mid-May, with the peak in February to mid-March, though there is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuarine and near-shore marine areas. When eggs hatch in 30 to 40 days, eulachon larvae immediately wash downstream to estuarine and ocean areas where they feed on phytoplankton and zooplankton. Most larvae will likely be carried past the action area during spring freshets before the proposed work period. By this time remaining larvae will likely have grown to juvenile size, which disperse to the ocean as soon as they are able. Juvenile eulachon potentially occur in the action area, but their presence will likely be migratory in nature.

---

[5] Beamis, W.E., and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. Environmental Biology of Fishes 48:167-183.

[6] Moser, M., and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/s10641-006-9028-1.

[7] WDFW (Washington Department of Fish and Wildlife) and ODFW (Oregon Department of Fish and Wildlife). 2001. Washington and Oregon eulachon management plan. Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. Online at http://wdfw.wa.gov/fish/creel/smelt/wa-ore_eulachonmgmt.pdf. November.

**Effects of the Action**

For purposes of the ESA, "effects of the action" means the direct and indirect effects of an action on the listed species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action (50 CFR 402.02). The applicable standard to find that a proposed action is NLAA listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial.[8] Beneficial effects are contemporaneous positive effects without any adverse effects to the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur.

The effects of the proposed action are reasonably likely to include: (1) Increased suspended sediments; (2) work area isolation and fish salvage; and (3) modification of nearshore habitat.

**Effects to Species**

***Increased suspended sediment***. Excavation of meandering channels, placement of excavated material to repair the dike, and placement of rock riprap and woody debris structures to stabilize the dike will disturb substrate and temporarily degrade water quality by increasing suspended sediments in the action area. Increased suspended sediments will occur along the entire linear length of the dike (1,650 feet) and extend out 50 feet towards the bay and in the proposed meandering and existing channels 50 downstream of the existing and proposed channels' connection point. The suspended sediment plumes will occur during project implementation and for the first few high tide cycles following project completion. Concentrations of suspended sediment plumes will become lower with each subsequent high tide as sediment is dispersed and stabilized.

Juvenile coho salmon exposed to increases in suspended sediment for periods as short as four hours can experience adverse physiological (as low as 17 milligrams per liter [mg/L]) and behavioral effects (as low as 30 mg/L) (Berg and Northcote 1985).[9] The potential for juvenile OC coho salmon to occur in the action area is low since the majority of individuals would have migrated past the action area to the Pacific Ocean before the proposed work period. OC coho salmon that may occur within the open water portion of the action area are likely to be exposed to concentrations below the threshold of concern. Concentrations of suspended sediments in meandering channels are reasonably unlikely to reach levels that would adversely affect OC coho salmon. Adult OC coho salmon will not be present in the action area during the work period. Therefore, the effects of increased suspended sediments are insignificant and are NLAA OC coho salmon.

Adult and subadult green sturgeon are far less sensitive to suspended sediments than salmonids. Green sturgeon usually inhabit environments with higher suspended sediment concentrations

---

[8] U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. Endangered Species Act consultation handbook: procedures for conducting section 7 consultations and conferences. March. Final. P. 3-12.

[9] Berg, L., and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

than do salmonids. Green sturgeon are likely to occupy deeper areas of Coos Bay than the action area; however, there is a low likelihood that adult and subadult green sturgeon could move into the action area to feed during high tides. Because of their high tolerance for suspended sediments, green sturgeon will not elicit an adverse response. Therefore, the effects of increased suspended sediments are insignificant and are NLAA green sturgeon.

Exposure of eulachon adults and larvae to increased suspended sediments is unlikely to occur. Adults will have migrated past the action area before the proposed work window. Juvenile eulachon occurring in the action area at this time of year would be from Palouse and Larson Sloughs. The potential for occurrence of juvenile eulachon in the action area is low because most individuals will have grown enough by the proposed work period to continue migration towards the ocean. The effects of increased suspended sediments to eulachon are likely similar to those observed in juvenile salmonids by Berg and Northcote (1985).[9] Juvenile eulachon that may occur within the open water portion of the action area are likely to be exposed to concentrations below the threshold of concern. Therefore, the effects of increased suspended sediments are insignificant and are NLAA eulachon.

***Isolation and fish salvage***. Potential for OC coho salmon, green sturgeon, and eulachon presence in the excavation area behind the dike is unlikely. The only way that fish could become present in the excavation and isolation area is from over wash of the dike by bay waters and it would have to be a sustained flow for fish to pass over the dike. Waves may wash up onto the dike during high flow events combined with high tides and significant wind and wave action, but it is unlikely that fish will be carried onto or over the dike into the excavation area. When the dike was constructed it was constructed with an eight foot top width. The top elevation of the dike is 12 feet, which was determined based on the highest measured tide of 10.26 feet.[10] It is unlikely that a sustained flow condition could exist over the dike. Therefore, effects of isolation and fish salvage are reasonably unlikely to occur to OC coho salmon, green sturgeon, and eulachon and are discountable due to the lack of presence of these species in this portion of the action area.

***Nearshore habitat modification***. Nearshore habitat modification along the approximately 1,650-foot long dike will occur. Currently the dike is eroded inside the mitigation site (section A in Figure 1) and riprap has been previously placed at both the northeast and southeast corners of the dike (section B of Figure 1). The dike in both these areas currently provides little habitat benefit for OC coho salmon, green sturgeon, and eulachon due to erosion and presence of riprap. They unlikely use it on a frequent basis. Following placement of the rootwad structure in section A, the nearshore area of this portion of the dike will provide habitat for species that OC coho salmon and eulachon consume as food and cover for OC coho salmon that rear in the action area. This will provide some benefit for rearing OC coho salmon and juvenile eulachon. In section B placement of new riprap over existing riprap will not benefit nor degrade the habitat, but maintain its current condition. The SWORA will also place some rootwads along the toe of the structure.

Green sturgeon are likely to occupy deeper habitats in the action area, but could move into shallow areas during high tide to feed. While in the action area, green sturgeon will be feeding

[10] E-mail from Casey Storey, WHPacific, to Jeff Young, NMFS discussing the constructed height of the dike in relation to the highest measured tide (June 4, 2012).

on invertebrates associated with softer bottom substrate in the tidal mudflats and not along the dike; therefore the modification of nearshore habitat along the dike will not modify the behavior of green sturgeon when present in the action area. Additionally, their forage species are unlikely to be adversely affected by the modifications of the dike face. Therefore, the effects of nearshore habitat modification are insignificant and NLAA green sturgeon.

The potential OC coho salmon and eulachon occurring in the nearshore areas of section B is low, but could occur. However, individuals migrating past the action area will not remain in these areas long enough to elicit an adverse response. Recent studies have shown that juvenile coho salmon smolts rearing in estuaries primarily use tidally inundated marshes (Cornwell *et al.* 2001, Jones *et al.* 2011).[11,12] Rearing juvenile OC coho salmon and juvenile eulachon present in the action area will primarily occupy the tidal mudflats feeding on small invertebrates, but may also occur infrequently in the nearshore area of the dike. Rootwads placed at the base of the riprap will provide some rearing opportunity, but because of other habitat available adjacent to section B and along the dike (nearshore of section A and tidal mudflats) rearing individual OC coho salmon and eulachon behavior will not be modified and they will not remain long enough to elicit an adverse response. Therefore, the effects of nearshore habitat modification are insignificant and NLAA OC coho salmon and eulachon.

**Effects to Critical Habitat**

The critical habitat unit affected by the proposed action is the Coos Bay Frontal fifth-field watershed (HUC: 1710030403). It is designated critical habitat for OC coho salmon and green sturgeon. It is not designated critical habitat for eulachon. The PCEs of OC coho salmon designated critical habitat in the action area include: (1) Forage; (2) free of artificial obstruction; (3) natural cover; (4) salinity; (5) water quality; and (6) water quantity. The PCEs for green sturgeon include: (1) Food resources; (2) migratory corridor; (3) sediment quality; (4) water flow; (5) water depth; and (6) water quality. The proposed action will affect the water quality PCE for both OC coho salmon and green sturgeon critical habitat and natural cover for OC coho salmon critical habitat.

The proposed action will degrade water quality along the length of the dike face (approximately 1,650 feet) and 50 feet into the bay from placement of excavated material to repair the dike and excavation of the dike to replace the damaged culvert. This will occur on high tides and with wind and wave action against the dike. Suspended sediment plumes will be short-term and localized with concentrations that are unlikely to reach adverse levels. Therefore, the effects of suspended sediments to the water quality PCE are NLAA critical habitats for OC coho salmon and green sturgeon. The natural cover PCE for OC coho salmon will be improved after project completion because the rootwad structure at the dike will provide additional shelter for rearing juvenile OC coho salmon. Therefore, the proposed action is NLAA the natural cover PCE of OC coho salmon critical habitat in the action area.

---

[11] Cornwell, T.J., D.L. Bottom, and K.K. Jones. 2001. Rearing of juvenile salmon in recovering wetlands of the Salmon River estuary. Oregon Department of Fish and wildlife, Information Reports 2001-05, Portland, Oregon.

[12] Jones, K.K., T.J. Cornwell, D.L. Bottom, S. Stein, H.K. Wellard, and L.A. Campbell. 2011. Recovery of wild coho salmon in Salmon River Basin, 2008-10. Monitoring Program Report Number OPSW-ODFW-2011-10, Oregon Department of Fish and Wildlife, Salem, Oregon.

**Conclusion**

Based on this analysis, NMFS concludes that all effects of the proposed action are NLAA OC coho salmon, green sturgeon, eulachon, and designated critical habitat for OC coho salmon and green sturgeon.

**Reinitiation of Consultation**

Reinitiation of consultation is required and shall be requested by the Federal agency, or by NMFS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and (1) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (2) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this concurrence letter; or if (3) a new species is listed or critical habitat designated that may be affected by the identified action (50 CFR 402.16). This concludes the ESA portion of this consultation.

Please direct questions regarding this letter to Jeff Young, fisheries biologist in the Oregon Coast Habitat Branch of the Oregon State Habitat Office, at 541.957.3389.

Sincerely,

William W. Stelle, Jr.
Regional Administrator

cc: Theresa Cook, SWORA
Benny Dean, Corps

# APPENDIX Q-7

JCEP Resource Report 3 for Fish, Wildlife, and Vegetation

# JCEP LNG TERMINAL PROJECT

## Resource Report 3- Fish, Wildlife and Vegetation

| To Verify Compliance with this Minimum FERC Filing Requirement: | See the Following Resource Report Section: |
|---|---|
| 1. Describe commercial and recreational warmwater, coldwater, and saltwater fisheries in the affected area and associated significant habitats such as spawning or rearing areas and estuaries. | Section 3.3 |
| **2.** Describe terrestrial habitats, including wetlands, typical wildlife habitats, and rare, unique, or otherwise significant habitats that might be affected by the proposed action. Describe typical species with commercial, recreational or aesthetic value. | Section 3.1<br>Section 3.2<br>Section 3.4 |
| **3.** Describe and provide the acreage of vegetation cover types that would be affected, including unique ecosystems or communities such as remnant prairie or old-growth forest, or significant individual plants, such as old-growth specimen trees. | Section 3.1<br>Section 3.2 |
| **4.** Describe the impact of construction and operation on aquatic and terrestrial species and their habitats, including the possibility of a major alteration to ecosystems or biodiversity, and any potential impact on state-listed endangered or threatened species. Describe the impact of maintenance, clearing and treatment of the project area on fish, wildlife and vegetation. Surveys may be required to determine specific areas of significant habitats or communities of species of special concern to state or local agencies. | Section 3.1<br>Section 3.2<br>Section 3.3<br>Section 3.4 |
| **5.** Identify all federally listed or proposed endangered or threatened species and critical habitat that potentially occur in the vicinity of the project. Discuss the results of the consultation requirements listed in §380.13(b) at least through §380.13(b)(5)(i) and include any written correspondence that resulted from the consultation. The initial application must include the results of any required surveys unless seasonal considerations make this impractical. If species surveys are impractical, there must be field surveys to determine the presence of suitable habitat unless the entire project area is suitable habitat. | Section 3.4 |
| **6.** Identify all federally listed essential fish habitat (EFH) that potentially occurs in the vicinity of the project. Provide information on all EFH as identified by the pertinent Federal fishery management plans that may be adversely affected by the project, and the results of abbreviated consultations with NMFS, and any resulting EFH assessments. | Section 3.3 |
| **7.** Describe site-specific mitigation measures to minimize impacts on fisheries, wildlife, and vegetation. | Section 3.1<br>Section 3.2<br>Section 3.3 |
| **8.** Include copies of correspondence not provided pursuant to paragraph (e)(5) of this section, containing recommendations from appropriate Federal and state fish and wildlife agencies to avoid or limit impact on wildlife, fisheries, and vegetation, and the applicant's, along with response to the recommendations. | Appendix A.3 |

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## CONTENTS

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)

### TABLES



### FIGURES

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## CONTENTS (Continued)



## APPENDICES

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## ACRONYMS

| | |
|---|---|
| BiOP | Biological Opinion |
| BLM | Bureau of Land Management |
| BWE | Ballast Water Exchange |
| BMPs | Best Management Practices |
| BOG | Boil-off Gas |
| BRT | Biological Review Team |
| Btu | British Thermal Unit |
| BWM | Ballast Water Management |
| CFR | Code of Federal Regulations |
| CM | Channel Mile |
| cy | Cubic Yards |
| DPS | Distinct Population Segment |
| EEZ | Economic Exclusion Zone |
| EFH | Essential Fish Habitat |
| ESA | Endangered Species Act |
| ESCP | Erosion and Sedimentation Control Plan |
| ESU | Environmentally Sensitive Unit |
| FERC | Federal Energy Regulatory Commission |
| FMP | Fishery Management Plan |
| FR | Federal Register |
| ft/sec | Feet Per Second |
| gpm | Gallons Per Minute |
| HRSG | Heat Recovery Steam Generator |
| JCEP | Jordan Cove Energy Project, L.P. |
| LNG | Liquefied Natural Gas |
| $m^3$ | Cubic Meter |
| $m^3$/hr | Cubic Meters Per Hour |
| MBTA | Migratory Bird Treaty Act |
| mm | Millimeters |
| MMBtu | Million British Thermal Units |
| MMTPA | Million Metric Tons Per Annum |
| MSL | Mean Sea Level |
| mt | Metric Ton |
| MW | Megawatt |
| NAS | National Audubon Society |
| NGA | Natural Gas Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| OAR | Oregon Administrative Rule |
| ODA | Oregon Department of Agriculture |
| ODFW | Oregon Department of Fish and Wildlife |
| OISC | Oregon Invasive Species Council |

# RESOURCE REPORT 3
# FISH, WILDLIFE AND VEGETATION

## ACRONYMS (Continued)

| | |
|---|---|
| ORBIC | Oregon Biodiversity Information Center |
| ORNHIC | Oregon Natural Heritage Program Information Center |
| OPRD | Oregon Parks and Recreation Department |
| OSWB | Oregon State Weed Board |
| PCGP | Pacific Connector Gas Pipeline |
| PFMC | Pacific Fishery Management Council |
| POC | Port Orford Cedar |
| SAV | Submerged Aquatic Vegetation |
| SPCCP | Spill Prevention, Containment, and Countermeasure Plan |
| SORSC | Southwest Oregon Regional Safety Center |
| SSNERR | South Slough National Estuarine Research Reserve |
| U.S. | United States |
| USC | United States Code |
| USCG | U.S. Coast Guard |
| USFWS | U. S. Fish and Wildlife Service |
| USFS | U. S. Forest Service |

# RESOURCE REPORT 3
# FISH, WILDLIFE, AND VEGETATION

## 3. INTRODUCTION

Jordan Cove Energy Project, L.P. (JCEP) is requesting authorization from the Federal Energy Regulatory Commission (FERC) to site, construct, and operate a natural gas liquefaction and export facility (LNG Terminal or Project), located on the bay side of the North Spit of Coos Bay, Oregon. The Project will provide a facility capable of liquefying natural gas and storing the liquefied natural gas (LNG) for export. Once the Project facilities are completed and placed in service, natural gas will be delivered to the LNG Terminal via the proposed Pacific Connector Gas Pipeline (PCGP), which will connect the Project with existing interstate natural gas pipeline systems. The authorization required for the PCGP will be addressed in a separate application filed by PCGP pursuant to Section 7(c) of the Natural Gas Act (NGA).

Natural gas received at the LNG Terminal will be cooled into liquid form and stored in two 160,000 cubic meter ($m^3$) full-containment LNG storage tanks. The proposed Project facilities will have the capability to allow export of six million metric tons per annum (MMTPA). Approximately 90 LNG carriers per year will be required to transport the LNG to locations in the United States (U.S.) and around the world.

The following facilities will be constructed for the Project:

- A pipeline gas conditioning facility consisting of two feed gas cleaning and dehydration trains with a combined natural gas throughput of approximately 1 Bscf/d;
- Four natural gas liquefaction trains, each with the export capacity of 1.5 MMTPA;
- A refrigerant storage and resupply system;
- An Aerial Cooling System (Fin-Fan);
- An LNG storage system consisting of two full-containment LNG storage tanks, each with a net capacity of 160,000 $m^3$ (1,006,000 barrels), and each equipped with three fully submerged LNG in-tank pumps sized for approximately 11,600 gallons per minute (gpm) each;
- An LNG transfer line consisting of one 2,300-foot-long, 36-inch-diameter line that will connect the shore based storage system with the LNG loading system;
- An LNG carrier cargo loading system designed to load LNG at a rate of 10,000 $m^3$ per hour ($m^3$/hr) with a peak capacity of 12,000 $m^3$/hr, consisting of three 16-inch loading arms and one 16-inch vapor return arm;
- A protected LNG carrier loading berth constructed on an Open Cell® technology sheet pile slip wall and capable of accommodating LNG carriers with a range of capacities;
- The improvement of an existing, on-site unimproved road and utility corridor to become the primary roadway and utility interconnection between the LNG Terminal and South Dunes sites, including between the pipeline gas conditioning units on the South Dunes Power Plant site and the liquefaction trains on the LNG Terminal site;
- A boil off gas (BOG) recovery system used to control the pressure in the LNG storage tanks;

- Electrical, nitrogen, fuel gas, lighting, instrument/plant air and service water facility systems;
- An emergency vent system (ground flare);
- An LNG spill containment system, a fire water system and various other hazard detection, control, and prevention systems; and
- Utilities, buildings and support facilities.

The following facility, although not jurisdictional to FERC, will also be constructed to support the Project:

- The South Dunes Power Plant, a 420 megawatt (MW) natural gas fired combined-cycle electric power plant inclusive of heat recovery steam generator (HRSG) units for the purpose of powering the refrigeration systems in the natural gas liquefaction process and supplying steam to the conditioning units.

**Purpose of Report**

The purpose of this Resource Report is to review and characterize existing scientific information for vegetation, wildlife, fish, and aquatic resources, and to identify potential direct, indirect, and cumulative effects to these resources from the construction and operation of the Project. This report also identifies mitigation, enhancement, and protection measures that can be implemented to avoid or minimize potential adverse impacts to these resources and their associated habitats.

The goal of this report is to provide a comprehensive reference document utilizing the best scientific information available for use in making sound decisions with respect to Project planning, environmental reviews, and permitting. It is intended for use by federal and state resource managers, permitting agencies, professionals engaged in habitat assessment activities, the regulatory community, and the public.

**Agency Communications**

In the preparation of this Resource Report, communications have occurred with the U. S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA) - National Marine Fisheries Service (NMFS), the Oregon Department of Fish and Wildlife (ODFW), the Oregon Biodiversity Information Center (ORBIC), and the Oregon Department of Agriculture (ODA) to identify significant terrestrial and marine biological resources, including significant habitats, federally-listed species, state-listed species, and the occurrence of Essential Fish Habitat (EFH) within the Project area. A summary of key agency contacts is presented in Table 1.8-1 (Resource Report 1 - General Project Description). Coordination and consultation with these agencies, along with surveys and assessments conducted, is documented in the attached botanical, wildlife, and fisheries reports completed for the Project.

**Report Organization**

This Resource Report is organized into five major sections and a references section. Section 3.1 discusses Vegetation, Section 3.2 Wildlife, Section 3.3 Fisheries and Marine Resources, and Section 3.4 Federal and State Threatened and Endangered Species (including proposed species and Critical Habitat). Section 3.5 briefly summarizes the overall impacts of the proposed Project, and overall mitigation, enhancement, and protection measures to address the primary impacts. References used in the development of this Resource Report are presented in Section 3.6.

**Project Area Characterization**

As discussed in Resource Report 1 – General Project Description and shown in Figure 1.1-1, the Project is located across two parcels of land on the bay side of the North spit of Coos Bay. All jurisdictional facilities except the pipeline gas conditioning facilities will be located on the western parcel (LNG Terminal site), the South Dunes Power Plant and the pipeline gas conditioning facilities will be located on the eastern parcel (South Dunes Power Plant site). The two sites will be connected by the utility and access corridor (in the aggregate, the Project site). It will include a temporary construction worker camp and compensatory mitigation sites, including the Kentuck site for wetland and estuarine resources; the Panhandle mitigation site for wetland and wildlife habitat impacts; and an eelgrass mitigation site southwest of the Southwest Oregon Regional Airport in North Bend.

## 3.1 VEGETATION

The Project will encompass a number of ecological systems that support diverse vegetation communities. The overall location was selected on the basis of avoiding, to the extent practical, unique vegetation communities and higher value wetlands. Selection of temporary construction areas was purposely restricted to upland areas to avoid impacting wetlands. Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project vicinity are included in the description of vegetation associations presented below, as applicable, and are discussed further in Section 3.4.

### 3.1.1 Existing Resources

Extensive surveys have been conducted at the Project site for botanical resources. The Project site was initially surveyed and evaluated extensively in 2005 and 2006 for the previously proposed LNG import facility. Additional surveys were conducted in 2012 and 2013 to supplement the previous surveys and ensure that all existing botanical resources are included in this evaluation. A preliminary botanical survey of the construction worker camp site across the bay was conducted in April 2013.

Vegetation in the area to be affected by construction of the Project is generally typical of vegetation and associated habitats found on the North Spit of Coos Bay. The site consists of a number of different plant associations, as well as disturbed areas resulting from the placement of fill from historical dredging operations and previous industrial use.

The proposed Kentuck and Panhandle wetland mitigation sites are also included in the discussion of the various plant communities that occur for the Project. The Kentuck site is addressed in more detail in Resource Report 2 – Water Use and Quality, which evaluates the site for use as mitigation for impacts to wetlands by the Project. The Panhandle mitigation site will be evaluated further as the use of the site for wildlife habitat and wetland mitigation moves forward.

Vegetation associations have been grouped into four main categories: forest, woodland, shrubland, and herbaceous associations (Figure 3.1-1). These classifications are based on the National Vegetation Classification System (NVCS) used for *Plant Associations of the Oregon Dunes National Recreation Area* (Christy et al. 1998), a U.S. Department of Agriculture (USDA) publication. Forests are defined as associations where tree species make up at least 60 percent of the vegetation cover. Woodland associations are defined as open stands, usually without crowns touching, and cover varies from 25 to 60 percent. Communities that generally consist of at least 25 percent shrub cover are classified as shrubland associations. Conversely, communities that generally have less than 25 percent shrub cover are defined as herbaceous associations. These associations are discussed in Section 3.1.2.

In addition to the above vegetation associations, dune forests that occur within these associations at the Project site have been classified as A through E. Dune Forest B is the largest and is slated for removal to create the access channel and slip for the LNG facility. Dune Forest C is smaller and is located north of Dune Forest B, immediately south of the Trans-Pacific Parkway. There is a sand trail that separates the two. Dune Forest A, the highest in dune forest habitat value, is located west of Jordan Lake and runs approximately 800 feet down from the utility corridor. It consists of Port Orford cedar and shore pine-Sitka spruce communities.

Additional dune forests D and E occur in shore pine/Douglas fir associations. Dune Forest D is located on the northwestern tip of the overall site, immediately south of the Trans-Pacific Parkway. Dune Forest E is located in the western portion of the South Dunes Power Plant site, immediately east of Jordan Cove Road.

Dune forests also occur in areas that will not be impacted by the Project, including in the forested wetland mosaic complex (east of Dune Forest C and north of the Roseburg Forest Products wood chip export facility) and in upland forest sites along the ridgelines throughout the complex. These dune forests are interspersed among the wetlands and consist of shore pine-Sitka spruce, shore pine-Douglas fir, and shore pine/slough sedge.

### 3.1.2 Associations

#### 3.1.2.1 Forest Associations

Forest associations are defined as trees with crowns overlapping and generally a cover of 60 to 100 percent. Evergreen forests in this association have greater than 75 percent tree cover. Forest associations within the Project site are dominated by coniferous species with scattered hardwoods that occur generally along ridges and the toe of slopes. Forests vary in seral (intermediate ecological) and mature stand stages. The youngest forests are generally located along the northern perimeter of the developed portions of the LNG Terminal site and adjacent to the Trans-Pacific Parkway. The more successionally mature forests are located in the interior portions of the site, on stabilized dune ridges, troughs, and dry deflation basins. Forest types included in this association that occur at the Project site are described below.

**Shore Pine-Douglas Fir/Wax Myrtle-Evergreen Huckleberry (Evergreen, Upland)**

Shore pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*) forests in this association occur near previously developed areas such as roads, fill sites, or industrial sites. They have been noted to occur most frequently on warm, dry ridges, and slopes on the dunes; primarily with south to west facing aspects (Christy et al. 1998). This association is characteristic of younger forest sites north of Jordan Cove. They occur in areas where dune stabilization has been achieved through recruitment of vegetation, most notably European beachgrass (*Ammophila arenaria*) and Scotch broom (*Cytisus scoparius*). This association has an open overstory dominated by shore pine with scattered Douglas fir. The shrub layer is dominated by Scotch broom and coyote bush (*Baccharis pilularis*), with scattered hairy manzanita (*Arctostaphylos columbiana*), wax myrtle (*Myrica californica*), and evergreen huckleberry (*Vaccinium ovatum*). Dominant herbaceous species include European beachgrass, silver hairgrass (*Aira caryophyllea*), little hairgrass (*A. praecox*), hairy cat's ear (*Hypochaeris radicata*), braken fern (*Pteridium aquilinum*), and sheep sorrel (*Rumex acetosella*).

Shore pine and Douglas fir forests were observed in portions of Dune Forests A, B, and C where adjacent landscapes have been altered by human or natural influences.

**Shore Pine-Sitka Spruce/Evergreen-Huckleberry (Evergreen, Upland)**

This association is common in more successionally mature forests. Stands are generally dominated by shore pine and Douglas fir, but also include Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and scattered Port Orford cedar (*Chamaecyparis lawsoniana*). The shrub understory layer ranges from dense to nearly impenetrable and is dominated with evergreen huckleberry, salal (*Gaultheria shallon*), and wax myrtle, with scattered Pacific rhododendron (*Rhododendron macrophyllum*). The herbaceous layer varies from being depauperate (diminished) to moderately covered with candy-stick (*Allotropa virgata*), rattlesnake plantain (*Goodyera oblongifolia*), and bracken fern along edges or gaps in the overstory. Dune Forest B, the largest dune forest identified within the LNG Terminal site**,** occurs within this association and consists of a mix of shore pine, Sitka spruce, and Douglas fir.

Forests within the Panhandle mitigation site are dominated by coniferous species, generally along the toe of slopes and low lying areas adjacent to shrublands, and most closely fit this association. Forests found in the site are dominated by shore pine, with scattered Sitka spruce, and western hemlock. The shrub layer in the wetland forest sites ranges from dense to nearly impenetrable and is dominated with evergreen huckleberry, salal, and wax myrtle, with scattered Pacific rhododendron. The herbaceous layer is dominated by slough sedge (*Carex obnupta*), which is found along the edge of the tree line throughout the Panhandle mitigation site area.

**Shore Pine/Scotch Broom/European Beachgrass (Evergreen, Upland)**

Although this association at the Project site contains shore pine, it is usually observed as a shrubland due to the high density of shrubby species, including Scotch broom, with limited distribution of shore pine due to the abundance of non-native species. This association is relatively widespread throughout the LNG Terminal site of the Project area and is associated with roads and other disturbed areas. The overstory within this association is generally open, averaging less than 50 percent cover of shore pine in most areas. Scotch broom cover varies from moderately dense to very dense in areas that lack a substantial canopy cover.

The herbaceous layer varies from depauperate, where there is a significant cover of Scotch broom, to moderately vegetated in areas that lack dense shrub cover. Dominant herbaceous species include European beachgrass, red fescue (*Festuca rubra*), tall fescue (*Festuca arundinaceae*), silver hairgrass, hairy cat's ear, and sheep sorrel*.* This association occurs west of the South Dunes Power Plant, north of the Roseburg Forest Products wood chip export terminal, along previous road cuts for the Trans-Pacific Parkway, and at the temporary construction worker camp site.

**Port Orford Cedar/Evergreen-Huckleberry (Evergreen, Upland)**

The Port Orford cedar and evergreen huckleberry association is described by Christy et al. (1998) as unique. It occurs in all aspects and slopes on narrow, dry stabilized dune ridges, troughs, and seasonally dry deflation basins at the southern end of the Oregon Dunes National Recreation Area immediately north of the Project site.

Port-Orford-cedar (POC) root rot disease is caused by the fungus *Phytophthora lateralis*. The disease was first discovered in POC's natural range in 1952 and since has spread throughout the POC's (host) range. The fungus invades the roots of POC and eventually colonizes the entire root system until the tree eventually dies from girdling. POC root rot disease affects both seedlings and mature trees. Evidence of infected trees includes lighter colored foliage that eventually turns red to brown. It also dyes and discolors the inner bark. The spores live in the soil and are spread through contact with contaminated soil or via free water. The disease is primarily spread through soil disturbance and spread of the disease may occur over long distances.

A small component of a well-developed Port Orford cedar/evergreen huckleberry association is located upslope from the southwestern shore of Jordan Lake, in the center of the Project site. Port Orford cedar observed at this location includes two trees upslope from the existing access trail that travels from the Roseburg Forest Products facility to Jordan Lake. Additionally, 23 Port Orford cedars were observed at sites located adjacent to Jordan Lake, in areas that will be preserved as part of the Project. Dune Forest A occurs partially within this association. Of note, the plot plan for the Project is different from that of the previously proposed LNG import terminal. The area to be disturbed by the Project now avoids this plant association.

**Shore Pine/Slough Sedge (Evergreen, Seasonally Flooded)**

This wetland forest association occurs in depressions on deflation plains and on ancient marine terraces. It was observed in the north central wetland mosaic north of the Roseburg Forest Products wood chip export terminal and is the predominant wetland type observed in the wetland forested sites found scattered throughout the Panhandle mitigation site. The understory on mounds in and around depressions is dominated by shrub species, including wax myrtle, salal, and evergreen huckleberry. Slough sedge is the single dominant herbaceous species and was observed growing in depressions and open water habitats throughout the North Spit locations of the Project.

**Red Alder/Salmonberry/Slough Sedge-Skunk Cabbage (Deciduous, Saturated)**

Red alder/salmonberry/skunk cabbage forests occur in wetland habitats adjacent to upland forested habitats, and in low flat areas adjacent to inundated wetlands. In this association, the overstory consists entirely of red alder (*Alnus rubra*) around wet areas, but transitions to shore pine in adjacent areas. Canopy cover varies from moderate to closed (more than 50 percent). Scattered clusters of dense shrubs that include salmonberry (*Rubus spectabilis*) and Hooker willow (*Salix hookeriana*) are located under the canopy. Herbaceous coverage is generally found in wet areas and consists almost entirely of slough sedge, with scattered skunk cabbage (*Lysichiton americanus*). This association has been documented in low spots in forests east of Jordan Cove Road and along the southern edge of the wetland mosaic located in the northwest part of the LNG Terminal site.

### 3.1.2.2 Woodland Associations

Woodland associations are defined as open stands, usually without crowns touching, and generally form 25 to 60 percent cover (sometimes less). They occur on all aspects of dry, well-drained, partially stabilized dune ridges, slopes, and flats between the sand and the forest edge (Christy et al. 1998). Three woodland associations occur within the LNG Terminal site, but are not well represented. They are described below.

**Shore Pine/Bearberry (Evergreen, Upland)**

The overstory for this association consists entirely of shore pine. The shrub layer is dominated by the low growing shrub bearberry (*Arctostaphylos uva-ursi*), with hairy Manzanita in scattered patches. The shore pine/bearberry association has small portions scattered throughout the

Project site, with the most substantial occurrence on the stabilized dune ridge northwest of the Roseburg Forest Products wood chip export terminal between Dune Forests B and C.

**Shore Pine/Hairy Manzanita (Evergreen, Upland)**

The shore pine/hairy manzanita association successionally replaces the shore pine/bearberry association. The overstory is moderately open and is dominated by shore pine with scattered Douglas fir trees. The shrub layer varies from moderately dense to dense in areas where the canopy is patchy. Hairy manzanita is the dominant shrub species with scattered evergreen huckleberry and bearberry along the edges. A small area of this association can be found along the eastern boundary of Dune Forest B.

#### 3.1.2.3 Shrubland Associations

Communities that consist of shrubs greater than 0.5 meter tall with generally greater than 25 percent cover and generally less than 25 percent tree cover are classified as shrubland associations. Deciduous shrubland generally has greater than 75 percent deciduous species shrub cover. The density and distribution of the shrubland association is correlated to hydrology and topography. One of the major characteristics of the shrubland association is minor variation in topography, which affects the distribution of herbs and shrubs. The lowest lying areas are frequently inundated with water and, depending on the frequency and duration of inundation, they may be dominated with emergent hydrophyte species that generally grow partly or totally submerged in water.

Shrublands within the Panhandle mitigation site are referred to as scrub-shrub wetlands, with variations in species composition and abundance throughout the site. Extensive shrublands were observed in the areas bordering open water throughout the Panhandle mitigation site and were observed dominating the landscape from the edge of the forest community to emergent wetland sites. The overstory within this shrubland varies from patchy to dense and is dominated by Hooker willow, Sitka willow (*S. sitchensis*), and Douglas spiraea (*Spiraea douglasii*), with scattered twinberry (*Lonicera involucrata*). Coniferous trees are for the most part absent in the shrubland community but may include scattered shore pine and Sitka spruce. Slough sedge is the most abundant herbaceous species.

**Hooker Willow-Crabapple/Slough Sedge-Skunk Cabbage (Deciduous, Saturated)**

Scrub-shrub communities identified for the Project site most closely resemble Hooker willow-crabapple/slough sedge-skunk cabbage association, minus the skunk cabbage. Minor variations in hydrology and topography may change the species composition drastically. This association is further described as having dwarf shrubland with shrubs less than two feet tall that provide generally greater than 25 percent cover. Tree cover is generally less than 25 percent.

The overstory within this association varies from patchy to dense and is dominated by Hooker willow, Sitka willow, and Douglas spiraea, with scattered twinberry. Evergreen (coniferous) trees are for the most part absent in the shrubland community, but may include scattered shore pine and Sitka spruce. Slough sedge is the most abundant herbaceous species. Other species include spreading rush (*Juncus effuses*), dagger-leaved rush (*Juncus ensifolius*), toad rush (*J. bufonius*), western bent-grass (*Agrostis exarata*), creeping bent-grass (*A. stolonifera*), reed canary grass (*Phalaris arundinacea),* northern willowherb (*Epilobium ciliatum*), tall mannagrass (*Glyceria elata*), and lowland cudweed (*Gnaphalium palustre*).

Hooker willow/slough sedge shrubland and Douglas spiraea saturated shrubland were observed extensively throughout wetlands west of Jordan Cove Road and southwest of Jordan Lake. In addition, this alliance is the dominant vegetation association observed in the scrub-shrub wetland habitat located in the Panhandle mitigation site.

#### 3.1.2.4 Herbaceous Associations

Communities that have generally less than 25 percent tree and shrub cover with generally greater than 25 percent herbaceous vegetation (graminoids, forbs, and ferns) are defined as herbaceous associations. Perennial vegetation for this association generally has greater than 50 percent of total herbaceous cover.

Herbaceous associations are the most variable of all the vegetation associations located in the Project site. They range from being dominated by plants that are adapted for sand burial and desiccating winds, to species that are emergent or submergent hydrophytes. They are widespread throughout the Project site, including areas that have some active sand movement and/or anthropogenic (human) disturbance. Effects from anthropogenic disturbances are reflected in the nonnative herbaceous species composition. Vegetation communities occurring in sand dune areas of the Project site are composed almost entirely of herbaceous species of plants, with no persistent woody stems above ground.

Numerous special status plant species are known to occur in herbaceous associations and are included Section 3.1.4 for unique and special status species. Federal and state-listed threatened and endangered plant species known to occur in herbaceous associations found in coastal habitats include: pink sand verbena (*Abronia umbellate,* ssp. *breviflora*), Point Reyes bird's-beak (*Cordylanthus maritimus,* ssp. *palustris*), silvery phacelia *(Phacelia argentea)*, western lily (*Lilium occidentale*), and Wolf's evening primrose *(Oenothera wolfii).* These species and their potential to occur in or near the Project are discussed further in Section 3.4.

Plant communities that occur in herbaceous associations at the Project site are described below.

**European Beachgrass (Perennial, Upland)**

Vegetation located on the active to semi-stable sand dunes is consistent with common herbaceous dune species. Dominant dune species include European beachgrass, red fescue, silver burweed (*Ambrosia chamissonis*), sand pea (*Lathyrus japonicus*), seashore lupine (*Lupinus littoralis*), beach silvertop (*Glehnia littoralis*), and beach evening primrose (*Camissonia cheiranthifolia*).

In degraded habitats such as where fill material has been deposited in the past, and near roadsides or other industrial sites, this association includes patchy non-native shrubs species, including Scotch broom. It can begin to resemble the shore pine/Scotch broom/European beachgrass association. At these sites the herbaceous vegetation is being displaced by encroaching invasive species, including European beachgrass and Scotch broom.

This association was observed in the western part of the LNG Terminal site in the dredge spoils fill site (also known as Ingram Yard) where the slip will be located and at the construction worker camp site. It was also observed in patchy distribution throughout open dune lands located north of Jordan Lake where the access/utility corridor is proposed.

**Red Fescue-Salt Rush (Perennial, Upland)**

In grasslands found on sand or fill material, red fescue is the single dominant species. Scattered red fescue was observed west of the South Dunes Power Plant site (on fill) and north of the Roseburg Forest Products export facility (on sand). At the South Dunes Power Plant site, in an area surrounded by scattered red fescue, a portion of a small dune contained the single dominant species salt rush (*Juncus lesuerii*). Red fescue-salt rush was also observed at sites where sand burial by wind driven forces limits species diversity, including in the Ingram Yard east of Henderson Marsh (western part of the LNG Terminal site).

**American Dunegrass (Perennial, Upland)**

This association includes dune lands with the single dominant species American dunegrass (*Leymus mollis*). It can be found on beaches and in foredunes, and to a lesser extent on open deflation plains and in upper estuaries. Continual sand burial and inputs of salt spray seem necessary for American dunegrass to thrive. Stands in most locations have been overrun by European beachgrass, but American dunegrass often persists in patches among the European beachgrass, which is the case of the grasses occurring on the western half of the construction worker camp site. Scattered American dunegrass was also observed west of Dune Forest B, in the Ingram Yard grassland habitat east of Henderson Marsh on previous fill deposits. Continual sand burial at this site limits competing vegetation and inputs of salt spray create the conditions necessary for this species to thrive.

**Pond Lily (Perennial, Semi-permanently Flooded)**

Other herbaceous associations are dominated by emergent hydrophytes, as described in the shrubland association section. Dominant species in semi-permanently flooded areas include yellow pond lily (*Nuphar lutea ssp. polysepala),* floating water-pennywort *(Hydrocotyle ranunculoides),* floating-leaved pondweed (*Potamogeton natans*), parrotfeather (*Myriophyllum aquaticum*), water shield (*Brasenia schreberi*), and common bladderwort (*Utricularia macrorhiza*). Pond lily habitat was observed in deep freshwater wetlands located in the Project site. This includes wetlands immediately west of Jordan Cove Road where the access/utility corridor is proposed (Wetland 2012-2 and 2013-6) and in the southern portion of Wetland E.

### 3.1.2.5 Other Plant Associations

**Maintained Grasslands**

Maintained grassland habitats observed throughout the Kentuck wetland mitigation site include native and non-native grasses and other herbaceous species associated with manicured grasslands. This site is dominated by red fescue, Kentucky bluegrass (Poa pratensis), reed canary grass (*Phalaris arundinacea*), common rush (*Juncus effuses*), and orchard grass (*Dactylis glomerata*). Wetland habitats were observed in the drainage that flows out of the levee situated along East Bay Drive at the western edge of the site. Dominant species include common rush and common cattail (*typha latifolia*). Reed canary grass, an invasive plant species, was observed in patchy distribution in areas that bordered forest sites. Tree species were planted throughout the site and include ornamental species such as blue spruce (*Picea pungens*) and poplar (*Populus trichocarpa*), as well as native tree species such as western hemlock, Sitka spruce, and Douglas fir.

**Common Cattail/Open Water**

This association includes wetland fringe sites observed adjacent to open bodies of water. These sites are limited in species diversity due to competition from common cattail which displaces other emergent vegetation. This association was observed in wetlands surrounding the existing sludge ponds at the South Dunes Power Plant site and the wetlands observed south of the Trans-Pacific Parkway in the eastern portion of the Project site.

Wetlands that occur in the Project area include emergent, scrub-shrub, forested, and estuarine intertidal, as described briefly below. A more detailed analysis is included in Resource Report 2 – Water Use and Quality, including potential effects to wetlands and proposed mitigation.

- Herbaceous emergent wetland habitat is located in low lying areas throughout the Project area. Vegetation is typically dominated by sedges, rushes, and grasses, with wetter portions of this habitat type consisting of aquatic floating and emergent plants in relatively shallow seasonally or perennially inundated areas.
- Scrub-shrub wetland habitat is commonly dominated by Hooker willow, with salmonberry and other common coastal wetland species such as slough sedge and skunk cabbage.
- Forested wetland habitat consists of wetlands that have remained undisturbed long enough to develop a consistent tree canopy. It is dominated primarily by red alder, with some areas of tree-size Hooker willow. The shrub layer is dominated by common coastal wetland species.
- Estuarine intertidal wetlands occur along the shore of Coos Bay at the mouth of the proposed slip and in an intertidal mudflat area associated with Wetland H.

**Salt Marsh Species**

Salt marshes are located along the vegetated shoreline adjacent to Jordan Cove, towards the western end of the Kentuck wetland mitigation site in areas where tidal influence occurs, and at the construction worker camp site. Dominant species include pickleweed (Salicornia virginiana), Lyngby sedge (*Carex lyngby*), salt grass (*Distichlis spicata*), and hairgrass (*Deschampsia caespitosa*). A small occurrence of salt marsh species was observed in a portion of Henderson Marsh which is located to the west and outside of the Project site, as well as in the lightly vegetated mudflat area associated with Wetland H (see Resource Report 2) that drains from the South Dunes Power Plant site into the bay.

### 3.1.3 Noxious Weeds

Noxious weeds are non-native, aggressive, and invasive plants. Species such as European beachgrass and Scotch broom are replacing native vegetation and opportunistically becoming established on sites otherwise unoccupied by grass or shrub species. The spread of noxious weeds is altering habitats and interfering with natural succession. Resource and vegetation management is necessary to maintain natural communities, successional processes, biodiversity, and ecosystem health.

Noxious weeds are classified by the Oregon State Weed Board (OSWB) as any plant that is injurious to public health, agriculture, recreation, wildlife, or any public or private property. They have become so thoroughly established and are spreading so rapidly on private, state, county, and federally owned lands in Oregon that they have been declared by Oregon Revised Statutes (ORS) 569-350 to be a menace to public welfare.

Noxious weeds have the potential to be eradicated or controlled in the state; however, steps leading to eradication and intensive control are necessary. Eradication and intensive control rests not only on private landowners and operators, but on the county, state, and federal government. To assist in control, the Oregon Department of Agriculture (ODA) Noxious Weed

Control Program and the OSWB maintain the state noxious weed list, which covers all lands within the State of Oregon.

#### 3.1.3.1 Classification of Noxious Weeds

The Noxious Weed Policy and Classification System (ODA 2013) establishes three categories for weeds within or having potential habitat in Oregon. Noxious weeds are listed as either A or B, and may be added to the T list, as directed by the OSWB, to receive priority in implementing noxious weed control projects. These classifications are defined below.

- Class “A” weeds—a weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent.
- Class “B” weeds—a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties.
- Class “T” weeds—a priority noxious weed designated by the OSWB as a target on which the Oregon Department of Agriculture (ODA) will develop and implement a statewide management plan. “T” designated noxious weeds are species selected from either the “A” or “B” list.

The Coos County Weed Board utilizes ODA’s classification system; however, it distinguishes “A” weeds as those not known to occur in Coos County but its presence in neighboring counties make future occurrence in Coos County seem imminent. “T” weeds are listed as designated priority noxious weeds for the county.

#### 3.1.3.2 Noxious Weeds Sites

The current list of noxious weeds for Coos County, including their potential to occur at the Project site, is presented as Table 3.1-1. Of those species, 14 were encountered during field surveys conducted for the Project. Eight noxious weed species have been mapped for the LNG Terminal, South Dunes Power Plant, and construction worker camp sites in Figure 3.1-2. The mapped species include: Scotch broom, Himilayan blackberry *(Rubus discolor),* European beachgrass, gorse (*Ulex europaeus*), sweet fennel (*Foeniculum vulgare*), poison hemlock (*Conium maculatum*), pampas grass (*Cortaderia jubata*), English ivy (*Hedera helix*), parrotfeather, and Italian thistle (*Carduus pycnocephalus*). Gorse and parrotfeather are listed as target “T” species by both the county and State to receive priority for prevention and control.

**Project Site**

Scotch broom, Himilayan blackberry, and European beachgrass have been observed throughout the Project site. All three species in this association are dominant species in the disturbed habitats associated with the South Dunes Power Plant site and the Roseburg Forest Products wood chip export terminal site. This association was also noted to occur in the active dune lands north of Jordan Lake. Additional species include: poison hemlock, observed in the South Dunes Power Plant site along a stretch of Jordan Cove Road; pampas grass, observed scattered throughout the South Dunes Power Plant site, with additional sporadic pockets occurring along the north-south rail line westerly to, and including, the easterly side of Jordan Cove Road; and English ivy, observed along the southern South Dunes Power Plant access road to Jordan Cove Road.

The LNG Terminal site has pockets of gorse scattered throughout the lower half of the fill area at the slip site, beginning approximately 150 feet north of the gravel access road along the Coos Bay shoreline and extending approximately 1,800 feet to the north. At the northern reach, the gorse appears to have spread in a southeasterly direction to the forested dune. Gorse is also present along the eastern edge of Henderson Marsh and along the forested dune tree line to the southern gate for the site. There are a few gorse plants at the South Dunes Power Plant site, with the majority located just south of the existing power substation. Gorse has been sprayed within the past year at the sites discussed above as part of an ongoing control program recently implemented. All visible gorse is dead.

**Construction Worker Camp**

The eastern portion of the construction worker camp site contains an infestation of Scotch broom, Himalayan blackberry, and European beachgrass. This area is an abandoned industrial site created on dredge spoils that was most recently utilized as a log deck. Noxious weeds are the dominant vegetation cover at this site. Immediately west is another former dredge spoils site separated by lowlands and tidal influence that has created a separate peninsula resembling an island. This site is covered with the singular dominant species European beachgrass. Both sites are adjacent to high quality estuarine marshlands that necessitate protection from herbicide applications for the control of noxious weeds.

#### 3.1.3.3 State and Federal Action Plans

At the state level, the Oregon Invasive Species Council (OISC) was created by the Oregon legislature (ORS 561.685) to conduct a coordinated and comprehensive effort to keep invasive species out of Oregon and to eliminate, reduce, or mitigate the impacts of invasive species already established in Oregon. The council began official business on January 1, 2002. Four main functions identified by the statute for the council include: 1) creating and publicizing a system for reporting sightings of invasive species and referring those reports to the appropriate agencies, 2) undertaking educational activities to increase awareness of invasive species issues, 3) developing a statewide plan for dealing with invasive species, and 4) funding eradication and education projects.

The OISC Action Plan for 2012-2016 (Appendix H.3) includes the mission, vision, and core values of the council, as well as key strategic actions the OISC seeks to engage in during that period. The action plan is the result of a planning effort following a statewide invasive species summit in 2011 and the completion of a management assessment of invasive species in Oregon. Each year the OISC provides an updated list of the 100 most dangerous invaders to keep out of Oregon. The list is comprised or micro-organisms, aquatic plants, land plants, aquatic invertebrates, land invertebrates, and fish species.

At the federal level, the U.S. Department of Interior's Bureau of Land Management (BLM), Coos Bay District, oversees lands in the vicinity of the Project and has lists of noxious weeds of concern described in its various resource management plans, including its *Final North Spit Plan* (2006). The BLM objective for weeds is to contain and/or reduce noxious weed infestations with an integrated pest management approach (e.g., chemical, mechanical, manual, and/or biological) and to avoid introducing or spreading noxious weed infestations in any areas. This is outlined in the BLM's multi-state environmental impact statement *Northwest Area Noxious Weed Control Program* (1985) and its supplements.

### 3.1.4 Unique and Special Status Species

Special status native vegetation classifications used for this analysis are based on the Oregon Wetland Explorer At Risk Wetland Associations Database (ORBIC 2009) and the Classifications of Native Vegetation of Oregon (ORBIC 2004). Rare vegetation classifications include both state rank (S) and global rank (G) for ORBIC Natural Heritage Ranking and are given the following numerical codes:

1. Critically imperiled because of extreme rarity or because it is somehow especially vulnerable to extinction or extirpation (gone from a portion of its former range), typically with 5 or fewer occurrences.
2. Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction or extirpation, typically with 6-20 occurrences.
3. Rare, uncommon, or threatened; but not immediately imperiled, typically with 21-100 occurrences.

Rare forest associations observed in the Project area include the shore pine-Douglas fir/wax myrtle-evergreen huckleberry (G3S3), shore pine-Sitka spruce/evergreen huckleberry (G3S3), and critically imperiled Port Orford cedar/evergreen huckleberry (G1S1). As previously noted, two Port Orford cedars are known to occur within the Project site that would be impacted. The Port Orford cedar/evergreen huckleberry forest association is sensitive because it is being decimated throughout its limited range by the POC root rot disease. In addition, the forested wetland (shore pine/slough sedge) east of Dune Forest C and the northern portion of Dune Forest B is considered rare/uncommon in ORBIC.

The shore pine/bearberry woodland association is sensitive due to its limited distribution, which is restricted to a thin band adjacent to the coastline, and the fact that it is easily damaged by human disturbances. Rare woodland associations include shore pine/bearberry (G1S1) and shore pine/hairy manzanita (G1S1). Both associations are found in limited distribution at sites associated with Dune Forest B where openings occur within the forest canopy. These associations were also observed in the Panhandle mitigation site, most notably at the interface between dune and forest habitats.

Rare herbaceous associations include red fescue-salt rush (G3S3) and American dunegrass (G1S1). Both of these rare associations were observed on significantly disturbed habitat associated with the dredge spoils fill site located east of the Henderson Marsh.

A list of the individual special status botanical species that have the potential to occur within forested, woodland, shrubland, and herbaceous associations referred to above is included in Table 3.1-2, including numerous lichen species. The list includes BLM special rankings and ORBIC state and global rankings. Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project site are not included in the list, as they discussed in detail in Section 3.4.

### 3.1.5 Along the Waterway

Vegetative communities along the route of the LNG carriers are typical of the Coos Bay region for estuaries and shorelines. Vegetated areas within the Zones of Concern consist of forest, woodland, shrubland, and herbaceous plant associations with a component of wetland areas (salt and freshwater marshes). The most prominent vegetation within this area includes a mix of herbaceous sand dunes, shore pine forests, Sitka spruce forests, salt marshes, and freshwater marshes. Marine, estuarine, lacustrine, and palustrine wetlands occur along the LNG carrier transit route. The southeastern side of the bay is urbanized and native vegetation has been modified by residential and commercial developments.

### 3.1.6 Environmental Consequences (Construction and Operation)

The majority of vegetation that will be impacted by the Project is forested associations, with minor impacts to shrublands and herbaceous wetland associations. Direct impacts are expected to include removal of a portion of the overall habitat. The most substantial direct impact to botanical resources within the study area is a reduction in the quantity of plant species (including trees) that occur in the dune forests and adjacent areas impacted. In addition, the Project would result in impacts to natural resources within the intertidal and shallow subtidal zone of Coos Bay, and a small area of freshwater emergent wetland would also be impacted. These resources provide important ecological functions to the greater Coos Bay ecosystem. Table 3.1-3 includes details on the types and amount of vegetation that will be impacted by the Project, including the acreage volumes, per 18 CFR Part 380.12(e)(3).

The Project is not expected to have a long-term significant impact to vegetation resources, as the areas that will be graded and cleared for construction are relatively common and widespread throughout the North Spit and the Project vicinity. The Project footprint was selected on the basis of avoiding, to the extent practical, unique vegetation communities and higher value wetlands. Selection of temporary construction sites was purposely restricted to upland areas to avoid impacting wetlands.

The Project will affect approximately 1.74 acres of forested wetlands and approximately 35 acres of non-forested wetlands during construction and 1.73 acres of forested wetlands and 34.34 acres of non-forested wetlands during operation (Table 2.2-1 of Resource Report 2 – Water Use and Quality). This is the total wetland area of wetlands affected, both terrestrial and non-terrestrial, and includes those wetlands that will require mitigation as well as those that do not, as described further below. In addition to the total area of wetlands affected, totals are presented in Table 2.2-1 for affected terrestrial and non-terrestrial wetlands, and for terrestrial and non-terrestrial wetlands that will require mitigation.

The approximately 35 acres of non-forested wetlands affected by construction and approximately 34 acres affected by operation include 13.07 acres of intertidal and shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass affected by the slip and access channel and the construction dock. Acreage-based mitigation for impacts to the 15.24 acres of deep subtidal habitat by creating new deep subtidal habitat is not proposed. Dredging the access channel will deepen existing deep subtidal habitat. Also, new deep subtidal habitat will be created as a product of excavating the slip, but this is not viewed as mitigation.

Approximately 1.75 acres of wetlands F and G are associated with the waste treatment ponds remaining from the remedial action at the now demolished Weyerhaeuser linerboard mill. While these wetlands are considered jurisdictional under Section 404, mitigation for the 1.75 acres will not be required as the filling of these wetlands has been authorized in the ODEQ site closure plan.

The Project site also includes approximately 45.4 acres of land with 32.3 acres of delineated wetlands that will not be disturbed by the Project and will in fact be preserved as a result of the Project. Approximately 10.9 acres (Area E3 on Figure 1.2-1 in Resource Report 1 – General Project Description) of these 45.4 acres of preserved wetlands include Henderson Marsh and are included as part of the Project site property simply to provide sufficient property under the direct control of JCEP for the thermal radiation exclusion zones. The thermal radiation exclusion zone is a modeled indication of an area that could be affected in the highly unlikely event of an LNG spill or fire at the Project site. There are no thermal radiation or vapor effects from the Project that would have an adverse effect on the wetlands during the normal operation of the Project.

The liquefaction facilities and the access/utility corridor will affect approximately 2.58 acres of forested, scrub shrub, emergent and ponded wetlands during construction and approximately 1.51 acres during operation (as indicated in Table 2.2-1). The loss of these wetlands will be mitigated by the preservation and enhancement of areas owned by JCEP and located to the north of the Project site and the Trans-Pacific Parkway. This area is referred to as the Panhandle mitigation site and will be described in detail in the mitigation plan referenced below.

The loss of 9.69 acres of intertidal and 3.38 acres of shallow subtidal wetlands, due to the construction of the slip and access channel and the construction dock, will be mitigated by the restoration of wetlands at a former golf course. This area is now known as the Kentuck wetland mitigation site. The loss of approximately 2.49 acres of eelgrass will be mitigated at a proposed eelgrass mitigation site south of the west end of the Southwest Oregon Regional Airport. Alternative eelgrass mitigation sites are currently being evaluated, with one of those areas being in Jordan Cove.

Specific impacts to dune forests occurring at the Project site and the potential for root rot disease to occur in Port Orford cedar are discussed below.

#### 3.1.6.1 Dune Forests

Dune Forest A will be impacted with the construction of the access/utility corridor and the control building/plant warehouse/maintenance building. The majority of this dune forest will be unaffected by the development of the Project. Impacts will include the removal of 1.8 acres of shore pine-Sitka spruce/evergreen huckleberry forest, 0.3 acres of shore pine-douglas fir/wax myrtle-evergreen huckleberry, and 1.9 acres of Port Orford cedar/evergreen huckleberry, including two Port Orford cedars observed northwest of Jordan Lake.

Dune Forest B will be impacted by the development of the slip, LNG loading berth, liquefaction process area, LNG storage tank area, refrigerant storage area, flare area, and laydown area. Dune Forest B includes approximately 61.4 acres of shore pine/Sitka spruce/evergreen huckleberry forest.

Nearly half of Dune Forest C is located in the sand dune area (E2), which will be partially impacted by fill during construction. A total of 5.8 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest is located in this area and has the potential to be impacted. Permanent impacts to the site are proposed to affect 6.3 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest with the development of the laydown area.

The LNG Terminal site access and fill area will impact 3.4 acres of Dune Forest D, including shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest.

Dune Forest E will be affected by the construction of the access/utility corridor and the ancillary Southern Oregon Regional Safety Center (SORSC) just east of Jordan Cove Road. The affected area includes 4.5 acres of shore pine-Douglas fir/wax myrtle-evergreen huckleberry forest and 0.6 acres of red alder/salmonberry/slough sedge-skunk cabbage forest.

#### 3.1.6.2 Port Orford Cedar

Spread of the POC root rot disease has the potential to occur at the Project site from contaminated equipment. Surveys for POC root rot disease were not conducted in the Project area, but based on what is known about the disease, it is likely to be present in the Coos Bay area, regardless of whether infected trees have been identified.

### 3.1.7 Mitigation, Enhancement, and Protection Measures

Site areas that are disturbed by construction of the Project will be stabilized by applying Best Management Practices (BMPs) for temporary sediment and erosion control measures until construction is complete, unless covered by equipment, gravel, or other covering. Site areas that are disturbed only by temporary construction activities (i.e., will not be permanently affected by a Project component) will be restored using non-invasive native plant species, to the extent practicable, to achieve stabilization of the sites and to prevent erosion of the areas disturbed.

Environmental monitoring would be conducted in all of the areas disturbed and would focus upon stabilization and prevention of erosion. This would be an ongoing activity on the Project site. In areas temporarily disturbed by construction, environmental monitoring will continue until a sufficient vegetative cover has become established. All construction activities and the operation of the facility will meet the requirements of JCEP's Upland Erosion Control, Revegetation, and Maintenance Plan (Plan) and JCEP's Wetland and Waterbody Construction and Mitigation Procedures (Procedures), including the implementation of Project-specific plans and procedures.

In addition, following the dredging activities to create the slip, all disturbed areas will be stabilized immediately with a dunegrass seed mixture compatible with Natural Resources Conservation Service (NRCS) criteria as being capable of surviving in highly permeable substrates in order to withstand seasonal soil moisture changes, loose sand, and burial and deflation from aeolian (wind) processes. Wind may erode, transport, and deposit materials, and particularly needs to be addressed in areas of the Project site with sparse vegetation and a large supply of unconsolidated sediments.

Native species will be used and if any non-native species are required for specific problem areas, species will be selected that will not become nuisance species to the surrounding areas. Should there be any areas disturbed by the excavated material haul truck road, the heavy equipment haul road, or the hydraulic slurry/decant water return pipelines that do not become part of the access and utility corridor for the LNG Terminal, they will be restored to pre-construction condition.

Impacts to wetlands will be mitigated through the implementation of an approved compensatory wetland mitigation plan. Compensatory mitigation is a method of offsetting adverse effects and is considered only after all measures to avoid and minimize impacts have been exhausted. A compensatory wetland mitigation plan has been prepared in accordance with the Oregon Department of State Lands administrative rules to address impacts to wetlands. It is provided as Appendix M.2 in Resource Report 2 – Water Use and Quality.

#### 3.1.7.1 Control of Exotic, Invasive Species

JCEP will implement treatments to remove exotic and noxious species. In addition, to avoid introducing or spreading noxious weeds or invasive species, JCEP will conduct a pre-construction survey of the Project site to identify noxious species listed by the ODA that persist despite recent and previous control efforts. Following the survey, JCEP will employ standard removal practices as approved by the BLM for the species identified on the Project site. Methods for removal that would not aid in the dispersal of these species will be used and will include the use of integrated BMPs such as fire, mechanical or manual removal, and herbicide application, as appropriate. Treated areas would be restored by spreading native seed and planting native plants. BMPs would also be implemented to prevent the further spread of noxious weeds.

JCEP will follow the BLM's existing policy and procedures for ongoing noxious weed control. Construction equipment that will be used off the Project site will be cleaned to prevent the export and spread of noxious weed species and seeds. JCEP will also use herbaceous and native dune seed mixes to limit germination of noxious weeds during the stabilization and restoration of the Project during and following construction. Once the overall Project site is stabilized and in operation, the site will be checked for noxious weed infestations and control measures will be implemented that are consistent with ODA, OISC, and BLM noxious weed control plans and policies, as applicable.

#### 3.1.7.2 Control of Diseases

JCEP will take precautions during the construction of the Project to minimize the introduction or spread of POC root rot disease from contaminated earth moving equipment. Surveys will be conducted prior to construction to identify whether the disease occurs on site and if so, measures will be taken to decontaminate equipment before leaving the site and to prevent cross contamination between soil and water. In addition, all equipment will be decontaminated before beginning work on the site. If the disease is found during pre-construction surveys, maps with precise locations will be provided to all contractors and site construction personnel to minimize and help prevent the spread of the disease to off-site locations. To ensure adequate conservation measures to address POC root rot disease are in place and implemented, JCEP will follow the BLM's existing policies and procedures.

## 3.2 WILDLIFE

A number of habitats exist on the Project site that support a variety of wildlife species as temporary or permanent residents. Approximately 178 tetrapod species (amphibians, reptiles, birds, and mammals) were recorded on or adjacent to the Project site during surveys conducted in October 2012 and during previous surveys from June to December 2005 and in early 2006 (Table 3.2-1). Terrestrial species include approximately 115 species. Approximately 151 seasonal or year-round resident bird species occur in the Project site area, and a variety of habitats suitable for migratory birds exists within the Project site boundaries. Also, as would be expected for the area, species utilizing aquatic habitats comprise the greatest occurrence by an individual species or by the number of individuals within a species. Species types and densities are directly related to season of year, preferred habitats, food resources, and protective cover.

The Project also includes compensatory mitigation sites outside of the Project footprint at Kentuck and the Panhandle for wetlands, wildlife, and estuarine habitat impacted by the Project. Although no degradation in the quality of the habitat at the mitigation sites is anticipated, they are included in this review to determine a baseline habitat.

Federal and state-listed threatened or endangered species observed or with the potential to occur in or near the Project vicinity are presented in this section and discussed in detail in Section 3.4.

### 3.2.1 Wildlife Habitat Characterizations

Characterizations of wildlife habitats potentially affected by construction of the Project were based on resource agency consultation, habitat surveys, and published reports, in accordance with the habitat categories described in the Oregon Department of Fish and Wildlife (ODFW) Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0025). The ODFW has established the following six classifications for habitats, based on dominant plant, soil, and water associations of value to the support and use of fish and wildlife:

Category 1 – irreplaceable, essential habitat

Category 2 - essential habitat

Category 3 - essential or important habitat

Category 4 - important habitat

Category 5 - habitat having a high potential to become essential or important habitat

Category 6 - habitat that has a low potential to become essential or important habitat

The ODFW habitat categories have been used to characterize wildlife habitats occurring on the Project site (Table 3.2-2). Habitat classifications for the Project site were qualified with ODFW personnel concurrence following field reconnaissance beginning in November 2006. Approved wildlife habitat categories were memorialized in November 2012 (DEA 2012). For the Project, Category 2 habitat occurs in open water, emergent wetland, forested/shrub wetland, and algae/mud/sand subtypes for surface water. The accepted ODFW wildlife habitat types and assigned categories for the Project site are shown in Figure 3.2-1 and summarized below. The Project does not have any Category 1 habitat.

#### 3.2.1.1 Upland Habitat

Upland wildlife habitat types found in the Project site are typical of the North Spit area of Coos Bay. Shore pine and Sitka spruce forests constitute the habitat with the greatest structural complexity on the North Spit and support the greatest diversity of wildlife species. The trees, snags, and down logs not found in other plant communities provide important breeding, foraging, and cover habitat for a variety of wildlife species. Upland amphibians seek cover in down logs, and many bird species (including raptors, woodpeckers, and songbirds) nest and forage in these habitats.

Emergent, shrub, and forested wetlands occurring in upland habitat are classified as Category 2 as essential wildlife habitat that is limited, but is replaceable through mitigation. Coastal dune forest and riparian forest habitats are classified as Category 3 because they are essential to wildlife but not limited. Although the unvegetated sand upland habitat formed by dunes is generally devoid of vegetation, it still provides important and essential, though not limited, habitat for a variety of wildlife and is therefore classified as important in Category 4. Upland grasslands and shrublands are also classified as Category 4.

#### 3.2.1.2 Open Water/Wetland Habitat

Open water habitats on the Project site and adjacent land are comprised of several freshwater lakes, ponds, and tidally influenced marshes on the terrestrial side of the shoreline. The marine open water environment consists of the Coos Bay estuary to the mouth of the bay, continuing westward into the open sea along the Pacific coast, and is discussed further in Section 3.3 for fisheries and marine resources. Habitats found in this environment support a rich wildlife community.

Herbaceous emergent wetland, scrub-shrub, and forested wetland habitat are all classified as Category 2 because they are essential for wildlife and limited, but can be replaced through mitigation. These habitats are used by various amphibians, birds, and invertebrates. The amount of cover and available prey or plant foods determine which species occur in these habitats. Black-tailed deer and rabbits occur throughout these communities, and songbird species feeding on plant seeds and insects take cover in the dense shrubbery. Mammalian predators such as skunks, foxes, coyotes, raccoons, mink, and bobcats prey on small mammals, birds, eggs, reptiles, and insects occurring in these habitats.

Flora and fauna usage of open water habitats occurring at the Project site (wetlands, estuarine, or marine) are generally specialized, or show strong preference for one habitat type over another. However, there are dozens of species associated with the Project area that are very well adapted to utilizing one, two, or all three of these open water habitats, as seasonal conditions warrant. Mudflats and sandflats found on the North Spit's bay side are tidally-inundated and provide foraging habitat for a variety of birds and mammals. Resident and migrant shorebirds congregate there, especially during low tides, to forage on the invertebrates in the shallow waters and exposed mudflats. The concentration of shorebirds and wading birds in these habitats provide prey for bald eagles, northern harriers, and peregrine falcons. Ravens, gulls, raccoons, mink, and skunks forage in these areas for shellfish and invertebrates. The portion of the open water habitat that will be impacted by the construction and operation of the Project is classified as Category 2 because it is essential for wildlife, and limited, but can be replaced through mitigation.

#### 3.2.1.3 Developed Habitat

Developed areas include portions of the Project site that have been significantly disturbed by previous development and industrial use, including land use activities such as demolished mill foundations/concrete pad, roads, unvegetated cut slopes, rocked yards, and maintenance building footprints. This includes paved roads, parking lots, gravel roads, concrete lay down areas, log deck storage areas, and sandy roadside areas. They have limited potential to become important or essential in the foreseeable future and are therefore classified as Category 6.

#### 3.2.1.4 Regional Wildlife Management Areas

The North Spit Area of Critical Environmental Concern is approximately 5 miles southwest of the Project site and is administered by the BLM. No other federal wildlife refuges, state game, or wildlife management areas exist in the immediate Project vicinity. Marine reserves, wildlife refuges, and coastal management areas are discussed further in Section 3.3.

### 3.2.2 Existing Resources

The proposed Project site provides suitable habitat for a number of wildlife species associated with the coastal, mid-coastal, interior foothills, and mountain terrains that construction and operation of the proposed Project could affect. The majority of wildlife species detected on or adjacent to the Project site during the 2005/2006 and 2012 surveys were birds. Approximately 107 out of 151 bird species recorded were located within the Project area. Project areas surveyed and assessed in 2012 are shown in Figure 3.2-3.

#### 3.2.2.1 Amphibians and Reptiles

The BLM recognizes 11 species of amphibians (8 salamanders, 3 frogs) occurring on the North Spit (BLM 2005). Despite the presence and continual threat of invasion by non-native bullfrogs

(*Rana catesbeiana*), native amphibians were observed within suitable habitat during the wildlife surveys conducted in 2005 and 2006 for the LNG Terminal site. Northern red-legged frogs (*Rana aurora aurora*) and northwestern salamanders (*Ambystoma gracile*) are abundant within some wetlands within the Project site. It is likely that where bullfrog have not been introduced or invaded, native amphibians are present.

The BLM has observed at least 10 species of reptiles on the North Spit (BLM 2005), including the northwestern pond turtle (*Clemmys marmorata marmorata*). However, northwestern pond turtle was not observed during limited pre-construction wildlife surveys of the Project site area (LBJ 2006). Palustrine wetlands are relatively common on the North Spit so it is likely that a substantial amphibian and reptile assemblage exists. With the exception of sea turtles, amphibians and reptiles would likely occur in terrestrial habitats along the LNG carrier transit route.

### 3.2.2.2 Birds

The Project is located in the statewide Pacific Flyway path for migratory birds. The Southern Oregon coast provides wintering and migratory habitat for birds and Coos Bay is one of a number of important areas for shorebirds between San Francisco Bay and British Columbia. Key areas for migrating shorebirds include the bay and shoreline, along with wetlands and deflation plains found throughout the North Spit. Coos Bay's extensive eelgrass beds, productive sloughs, intertidal algal flats, and substantial tidal marshes (1,726 acres) provide valuable habitat for thousands of shorebirds.

The BLM has documented 275 avian species using habitats on or near the North Spit of Coos Bay (BLM 2005). In addition, LBJ Enterprises (2006) documented 151 avian species during pre-construction surveys of the Project site, including two additional species not documented by the BLM. A mosaic of habitat types occurs within and near Coos Bay within the LNG carrier transit route zones. Some of the most important habitat types for birds include nearshore rocks and islands, beaches, dunes, coastal forests, and Palustrine and estuarine wetlands. The location of migratory bird habitat occurring within the zones of the LNG carrier transit route is shown in Figure 3.3-7, which also includes marine mammals.

Federal and state-listed threatened, endangered, or proposed species, including the brown pelican, bald eagle, short-tailed albatross, streaked horned lark, and western snowy plover are discussed in Section 3.4. Forests further inland from the Project provide habitat for the northern spotted owl and the marbled murrelet and these two species are also discussed in Section 3.4.

#### Shorebirds

Foraging habitat for shorebirds includes intertidal mudflats, rocky intertidal, estuaries, salt marshes, and beaches. Shorebirds are most often associated with exposed mudflats for foraging and salt marshes for resting and preening. The vast majority of shorebirds are migratory and non-breeders in Coos Bay. An important exception would be the western snowy plover (*Charadrius alexandrinus nivosus*), which nests on upper beaches on the North Spit of Coos Bay. Shorebirds are most likely to be encountered along the beaches of the North Spit and within the bay along tidal mudflats, salt marshes, and other exposed estuarine habitat in the 0.3 and 1.0 mile zones.

#### Waterfowl

Waterfowl habitat is as diverse as the birds themselves, varying from ocean surf to fields and open meadows to upland streams (USFWS 2007a). Coos Bay has long been recognized as an important migration and wintering waterfowl location. Waterfowl are most likely to be encountered within Coos Bay and the immediate nearshore habitat within the LNG carrier transit route zones.

**Passerines (Song Birds)**

Breeding and feeding habitat for migratory passerines is associated with terrestrial and wetland habitat within Coos Bay. Important habitat includes coastal scrub-shrub, coastal dune forest and Palustrine wetlands. In the case of swallows, human-made structures can be important structures for nesting colonies. Passerines are most likely encountered in suitable terrestrial habitats along the LNG carrier transit route 2.2 mile zone.

**Wading Birds**

Several wading bird species are residents within the Coos Bay area and the North Spit. Wading birds are typically colonial when nesting and therefore are sensitive to human disturbance. Wading birds hunt in a variety of habitat types from fields and meadows to Palustrine and estuarine wetlands. At least two historic great blue heron (*Ardea herodias*) rookeries occur within close proximity to the Project site LBJ 2006) and are discussed in Section 3.4.2 for unique and special status species. Recent field surveys have indicated that the rookeries are currently not occupied by species. Wading birds are most likely to be encountered along the LNG carrier transit route zone. A discussion of the current status of these historic rookeries is provided below.

**Birds of Prey**

Predatory birds are abundant year round residents in Coos Bay. The BLM has observed 14 species (BLM 2005), and surveys conducted by LBJ (2006) detected both peregrine falcons (*Falco peregrinus*) and bald eagles (*Haliaeetus leucocephalus*) near the Project area. Coos Bay and the North Spit provide a mosaic of habitat types with abundant prey for raptors. White-tailed kites (*Elanus leucurus*) were regularly observed during 2005 surveys, especially near Henderson Marsh. Osprey (*Pandion haliaetus*) are relatively common near river estuaries and bays and nest on human-made structures including the Roseburg Forest Products facility lights.

Predatory birds (i.e., hawks and owls) are most likely to be encountered within Coos Bay in terrestrial habitats. Osprey, falcons, and eagles may be encountered in nearshore habitats along the LNG carrier transit route. Falcons in particular are likely to be associated with salt marsh and tidal mudflats where shorebirds are likely to be abundant.

**Sea Birds**

Although the length of the Oregon coast is less than a quarter of the entire Washington, Oregon, and California coastline, over one-half of the nesting seabirds of this coastline are found along the Oregon coast (Oregon Ocean Resources Management Task Force 1991). Thirteen sea bird species breed along Oregon's coast, with offshore rocks and islands providing critical nesting habitat and important rest-over locations. Seabirds depend on relatively undisturbed coastal nesting habitats and on the rich coastal waters for food. Foraging habitat can differ by species; some species such as the sooty shearwater (*Puffinus griseus*) and the northern fulmar (*Fulmarus glacialis*) are found primarily along the mid and outer shelf, while California and western gull (*Larus californicus, L. occidentalis*) occur only in the nearshore (Oregon Ocean Resources Management Task Force 1991). Foraging sea birds can be encountered along the entire LNG carrier transit route in the 0.3 and 1.0 mile zones. Nearshore rocks and islands are of greatest importance to sea birds for nesting habitat.

**Migratory Bird Treat Act**

The Migratory Bird Treaty Act (MBTA) of 1918, as amended, provides federal protection for migratory birds, their nests, eggs, and body parts from harm, sale, or other injurious actions. The MBTA protects nearly all of the native species of birds. The only exceptions are introduced species, including English (house) sparrow, starlings, and rock dove (commonly known as park pigeons). There is no federal protection for upland game species (chuckar, pheasant, quail, and grouse), but most states protect these species. U.S. Fish and Wildlife Service (USFWS) permits are required to take, capture, relocate, or possess any of the protected species of birds or their parts, nests, or eggs. The MBTA includes a 'no take' provision and consultation with the USFWS is required if an action is determined to cause a potential take of migratory birds. The consultation determines measures to minimize or avoid these impacts.

Birds and nests are protected under MBTA, but habitat is not. Habitat is only protected when there is an active nest (a nest with chicks or eggs being tended by an adult). Empty/abandoned nests and nonviable eggs are not protected, but cannot be taken into possession without a permit during the nesting season. Outside of the nesting season, permits are not required to remove an empty or abandoned nest, or to remove or alter the structure the nest is built in or on. The MBTA policy excludes eagle nests and nest trees, which are protected under the Bald and Golden Eagle Protection Act, as amended in 1962, and threatened or endangered species, which are protected under the Endangered Species Act.

The USFWS advises that large clearing projects be conducted prior to March 1 or after August 31 to ensure most nesting birds have fledged. If construction activities occur during the nesting season, trees should be surveyed for the presence of any active nests. If there are none in the trees or the immediate area, and there are no active nests close enough for the activity of taking down trees to disturb the nesting birds, they can be removed without permits. If there should be a nest in one tree, the tree should be marked and activity limited around that area until the birds fledge, perhaps leaving that tree for the last of the project.

Unless the nests are in a location to pose a risk to human safety or the birds, there is no permit the USFWS can issue. Examples of human safety issues are permits issued to airports to protect air traffic and nests built on active power equipment which pose a fire hazard. There are no 'incidental take' permits under the MBTA. Any activity that involves habitat destruction during nesting season should proceed with caution.

### 3.2.2.3 Mammals

The BLM has documented 58 mammal species on the North Spit (BLM 2005). Pre-construction wildlife surveys conducted in the area of the Project site in 2005 and 2006 documented 16 mammal species (LBJ 2006). The Coos Bay area and North Spit provide a substantial amount of high quality habitat allowing for a diverse assemblage of mammals. For example, nine species of bats are known to occur on the North Spit (BLM 2005). While bat specific surveys were not completed during the pre-construction wildlife surveys, the mosaic of habitat types and abundant over-water foraging habitat present within the Coos Bay area suggest bat presence is high. The Pacific fisher (*Martes pennant pacificus*) and American marten (*Martes Americana*), as well as large mammals such as mountain lion (*Felis concolor*), Roosevelt elk (*Cervis elaphus roosevelti*), and black bear (*Ursus americanus*) have been documented on the North Spit (BLM 2005).

With the exception of pinnipeds (i.e., seals, sea lions) and unlikely but possible whale occurrences, all mammals encountered along the proposed LNG carrier transit route would be in terrestrial habitat types on the North Spit and the southwestern side of the bay. Bats may be encountered at any point along the proposed transit route within Coos Bay itself.

### 3.2.3 Wildlife Occurring in Project-Specific Sites

Wildlife that has the potential to occur in each major component of the Project is described below.

#### 3.2.3.1 Project Site

The natural habitat in the immediate area of the LNG Terminal has been altered by the historic use of this property, including the area east of Henderson Marsh (referred to as the Ingram Yard) that has been altered by the historical Henderson Ranch settlement and past placement of dredged material; the current Roseburg Forest Products wood chip export terminal; and the former Weyerhaeuser linerboard (paper) mill site (South Dunes Power Plant site). East of Ingram Yard, the Project site includes a dune forest where the majority of the site's natural habitats, as described in Section 3.1, remain unaltered by industrial activity. Structures located immediately adjacent to the Project site include two large buildings (Roseburg Forest Products Company north and south buildings), a few small outbuildings, and a substantial concrete lay down area east and south of the two buildings. Additionally, there are two large water tanks on the Project site within Dune Forest B along the ridgeline (see Figure 3.1-1). A dirt road provides access to the water tanks from the developed area.

East of Dune Forest B and north of the Roseburg Forest Products facility, the Project site includes an access/utility corridor that crosses along the northern boundary of the Roseburg Forest Products property and includes mature dune forests and an area of active dune. This corridor includes utilities supporting the disposal of industrial wastewater from the landfills located on the South Dunes Power Plant site. The South Dunes Power Plant site includes asphalt surfacing, gravel access roads, and previously disturbed grassland habitats. Immediately west, a mosaic of emergent and scrub-shrub wetlands interspersed in coastal dune forests occurs. This area also includes a portion of Jordan Cove Road. With the exception of the access/utility corridor, the entire Project site is bordered by the Trans-Pacific Parkway on the northern perimeter.

#### 3.2.3.2 Construction Worker Camp

The temporary construction worker camp site includes two distinct areas (eastern and western) intersected by North Point Slough. The eastern half of the site includes an abandoned industrial area that is the remains of a logging deck used to store logs until recently. The western half of the site includes a historical dredge spoils site. The highly disturbed eastern half has been filled and road prisms (gravel) have been built throughout the majority of the site. The former dredge spoils site on the western half lacks infrastructure and is occupied with an abundance of non-native weedy species, including dominant species European beachgrass and Scotch broom. High quality estuarine habitat was observed in the North Point Slough that intersects the site.

Wildlife habitat observed at the construction worker camp site includes foraging habitat for numerous species that can exist without tree cover. Breeding habitat is limited to species adapted to breeding in disturbed habitats that lack a significant tree cover. Wildlife observed (including sign) at the site include American robin (*Turdus migratorius)*, common raven (*Corvus corax*), western gull (*Larus occidentalis*), turkey vulture (*Cathartes aura*), and black-tailed deer (*Odocoileus hemionus*). Typical bird species that have potential to use the site include common species associated or adapted to disturbed habitat types, including but not limited to, common raven, American robin, foraging peregrine falcon, white-tailed kite (*Elanus leucurus*), American goldfinch (*Carduelis tristis)*, and western gull. Mammals likely to use the site include, but are not limited to, opossum (*Didelphis virginiana*), black-tailed deer, striped skunk (*Mephitis mephitis*), and raccoon (*Procyon lotor*).

#### 3.2.3.3 Compensatory Mitigation Sites

The eelgrass mitigation site is discussed under Section 3.3 for fisheries and marine resources.

**Kentuck Wetland Mitigation Site**

Kentuck Slough has been identified as an estuarine and wetland mitigation site for the Project. This site includes a previously maintained golf course that closed down several years ago and is currently being used sporadically for cattle grazing. The area consists of former golf course infrastructure that includes roads, trails, fencing, and landscaping and is surrounded by semi-rural housing.

Wildlife species observed at the site include numerous wading, ground foraging, and aerial foraging species. The diversity in habitat types present (wetland, grassland, and patchy forest sites) makes this area ideal habitat for many local species. Species observed include American crow (*Corvus brachyrhynchos)*, barn swallow (*Hirundo rustica)*, great egret (*Ardea alba)*, mallard duck (*Anas platyrhynchos)*, marsh wren (*Cistothorus palustris)*, and song sparrow (*Melospiza molodia)*. Wildlife species with potential to use the site include numerous species, including common mammal species associated with rural residential areas such as black-tailed deer, black bear (*Ursus americanus*), striped skunk, and raccoon. Numerous bird species with potential to use the site for foraging include Canada goose, great egrets, waterfowl, shorebirds, wading birds, and many more. Potential nesting habitat for raptors and other breeding birds was observed in forest sites bordering Kentuck to the south and southwest, and includes potential nesting habitat for osprey, bald eagles, and red-shouldered hawks.

On any given morning or evening, numerous bird species can be observed foraging in the Kentuck Slough immediately west of East Bay Drive that separates the estuary from the site. It is not uncommon to see numerous great egrets, geese, ducks, smaller shorebirds, and occasional great blue herons in this area. The former golf course, with its grasslands still mowed and maintained, often sits empty in comparison. If opened up to expand the estuarine and subtidal area at the site, the now marginal Kentuck site inland has the potential to become an extremely productive site where even more amphibian, bird, and mammal species would seek its shelter and prime foraging and nesting habitat.

**Panhandle Mitigation Site**

The Panhandle is a proposed wildlife and wetland mitigation site for the Project and contains habitat types typical of deflation plains found throughout the North Spit. Habitats observed at the site include forest, shrubland, and herbaceous communities.

Wildlife species with potential to occur in the Panhandle include species that require or utilize forests, shrubland, open water, and/or sand dune habitats. This habitat is exceptional for amphibian species such as northern red-legged frogs and Northwestern salamander. Bird species expected to occur include waterfowl species such as wood duck (*Aix sponsa*), Eurasian wigeon (*Anas platyrhynchos*), herons and egrets such as great egret (*Ardea alba*), and great blue heron (*Ardea herodias*), as well as numerous song birds including brown creeper (*Certhia americana*), and marsh wren (*Cistothorus palustris*). This habitat has the potential to provide nesting and foraging habitat for raptor species such as Cooper's hawk (*Accipiter cooperii*) and sharp-shinned hawk (*Accipiter striatus*). Mammal species with the potential to occur in the

Panhandle mitigation area include black bear and American beaver (*Castor Canadensis*), to name a few.

### 3.2.4 Unique and Special Status Species

Special status wildlife species occurring in Coos County are listed in Table 3.2-3, along with their rankings for local, state, national, and global occurrences. In addition, Table 3.2-4 lists the potential for occurrence of these species at various sites for the Project, including general habitat requirements.

#### 3.2.4.1 Amphibians and Reptiles

**Clouded Salamander**

The clouded salamander (*Aneides ferreus*), known to occur on the North Spit and listed as state sensitive-vulnerable, was not found during site surveys, but the dune forests in the Project area could support this species.

**Northern Red-legged Frog**

The northern red-legged frog is a federal species of concern. Habitat for the northern red-legged frog includes the vicinity of permanent waters of marshes, ponds, and other quiet bodies of water. This frog regularly occurs in damp woods and meadows some distance from water, especially during wet weather. All age classes of this species were observed at the eastern edge of Henderson Marsh and high concentrations of northern red-legged frogs were observed in multiple freshwater wetland sites throughout the Project site (LBJ 2006, SHN 2012). American bullfrogs, a known predator of the northern red-legged frog, were observed during surveys in wetlands conducted in 2005-2006, but were not observed in 2012. Though not observed, this species is a long-lived and highly adaptive species that is an opportunistic predator of small animals, including other amphibians.

**Northwestern Pond Turtle**

The northwestern pond turtle is listed as a federal species of concern and state sensitive–critical. Even though this species was not found on the Project site, it is known to occur on the North Spit. Jordan Lake and other wetlands and adjacent dunes on the Project site seem to be suitable for this turtle, although the soil may be too sandy to allow turtles to nest.

**Western Toad**

This species (state sensitive–vulnerable) was not found on the Project site and is not listed by the BLM as occurring on the North Spit.

#### 3.2.4.2 Birds

Fifteen special status bird species were observed throughout the Project area during wildlife surveys conducted in 2005-2006 and in 2012 (Figure 3.2-4). Detections of special status birds during surveys include species of grebes, waterfowl, hawks, nightjars, pigeons, flycatchers, and swallows. Special status waterfowl and grebes observed in Coos Bay and associated wetland and grassland habitats include the following species: Clark's grebe (*Aechmophorus clarkia*) and western grebe (*Aechmophorus occidentalis*), observed at sites near the bay adjacent to the Project; Aleutian cackling goose (*Branta hutchinsii leucopareia*), federally delisted, observed foraging near the airport and flying over the Project site; bufflehead (*Bucephala albeola*), observed just offshore of the Project site; horned grebe (*Podiceps auritus*), common in Coos Bay and observed offshore near the Project site; and red-necked grebe (*Podiceps grisegena*), state critical, observed offshore near the Project site.

Special status hawk and nightjar were observed at several locations at or near the Project area and were recorded as flying over or foraging. They include the following species: common nighthawk (*Chordeiles minor*), a single occurrence observed as a fly-over at the Project site; American peregrine falcon (*Falco peregrinus anatum*), federally delisted and state vulnerable, observed foraging above the southwest edge of Henderson Marsh and at the Project site; and white-tailed kite (*Elanus leucurus*), observed over Henderson Marsh and the Jordan Cove area multiple times. In addition, the Arctic peregrine falcon (*Falco peregrinus tundrius*), state sensitive–vulnerable, is reported as a rare visitor to the Oregon Coast and Coos County.

Additional special status birds include pigeon, passerine, quail, and meadow lark. They include the following species: band-tailed pigeon (*Patagioenas fasciata*), federal species of concern, recorded once at the Project site; purple martin (*Progne subis*), federal species of concern and state critical, observed multiple times during the breeding season, with active nests within view of the Project site; olive-sided flycatcher (*Contopus cooperi*), federal species of concern and state vulnerable, recorded singing near the LNG Terminal site; little willow flycatcher (*Empidonax traillii brewsteri*), state vulnerable, recorded near the South Dunes Power Plant site, mountain quail (*Oreortyx pictus*), federal species of concern and state vulnerable, observed in Dune Forest B near the water tanks; and western meadowlark (Sturnella neglecta), state critical, observed once at the Project site.

Special status bird species that are considered likely to occur (moderate to high potential for occurrence) in the Project area but have not been detected include the following: upland sandpiper (*Bartramia longicauda*), federal species of concern and state critical; black oystercatcher (*Haematopus bachmani*), federal species of concern and state vulnerable; yellow-breasted chat (*Icteria virens*), federal species of concern and state critical; acorn woodpecker (*Melanerpes formicivorus*), federal species of concern and state vulnerable; Oregon vesper sparrow (*Peoecetes gramineus affinis*), federal species of concern and state critical; western bluebird (*Sialia mexicana*), state vulnerable; Arctic peregrine falcon (*Falco peregrines tundris*), BLM sensitive; bobolink (*Dolichonyx oryzivorus*), BLM sensitive; dusky Canada goose (*Branta canadensis occidentails*), BLM sensitive; pileated woodpecker (Dryocopus pileatus), state vulnerable; and trumpeter swan (*Cygnus buccinators*), BLM sensitive.

Special status bird species considered likely to occur (moderate to high potential for occurrence) along the waterway where vessels will be traveling include the following species: Cassin's auklet (*Ptychoramphus aleuticus*), state vulnerable; rhinoceros auklet (*Cerorhinca monocerata*), state vulnerable; and tufted puffin (*Fratercula cirrhata*), state vulnerable.

In addition to the unique and special status birds discussed above, the American peregrine falcon and great blue heron warrant additional analysis, as discussed below.

**American Peregrine Falcon (Federal Delisted and State Sensitive–Vulnerable)**

The American peregrine falcon nests widely in coastal and montane areas throughout Oregon, possibly including the Coos Bay area (Adamus et al 2001). Nesting has been confirmed in the Bandon area (Adamus et al. 2001). The BLM reported it to be an uncommon, year-round resident of the North Spit (USDI 2005), while observations by local birders and ODFW local wildlife biologists indicate that it is common on the North Spit. Its habitat is difficult to characterize, as it may occur virtually anywhere and is quite variable and adaptable in its nesting and feeding habits. The American peregrine falcon requires concentrations of prey such as shorebirds, starlings, pigeons, and small ducks; elevated perch sites; and for nesting, a relatively secluded ledge on a bridge or cliff (Henny and Pagel 2003).

Ample food and nest sites occur around Coos Bay, and the McCullough Bridge could be considered a potential nest site. The Project site area itself probably does not offer any suitable nest sites, but peregrine territories are large and the site is used regularly by many prey species. There were seven sightings of this species during field surveys, including several in the Project site, and no seasonality was apparent.

**Great Blue Heron**

There is a historic great blue heron (*Ardea herodias*) rookery approximately 300 feet from Jordan Cove Road near the beginning of the road, situated approximately 2,000 feet to the east of the LNG Terminal site. This rookery was visited on November 1, 2006, during a site visit with ODFW and BLM biologists and was found to be inactive, but it still contained some nests. At that time, the BLM biologist noted that it had been inactive the previous two breeding seasons. The location of the rookery is in an area that will not be affected by the construction of the Project; however, it would be subject to construction traffic noise. It is currently subject to truck and railroad car traffic delivering chips to the Roseburg Forest Products wood chip export facility. If it were to become active again, the nesting birds could be disturbed by the existing Roseburg Forest Products traffic, as well as construction traffic for the Project.

Another historic rookery is located adjacent to the Project site on the south side of Henderson Marsh. It has not been active for several years (BLM biologist, pers comm.). Great blue herons have been observed foraging at this site during pre-construction surveys in 2005/2006 and in 2012, although no evidence of breeding in the area has been observed.

Surveys for nests were conducted on April 11, 2013, to determine if historic rookeries are being utilized this breeding season. It was determined during the survey that the rookeries are not active at this time. No nests or nest building activities were observed, although numerous detections of the great blue herons were noted foraging along the tidal flats and flying north past Jordan Cove.

### 3.2.4.3 Mammals

Special status mammals that are considered likely to occur (moderate to high potential for occurrence) include terrestrial and arboreal rodents, bats, and weasel species, the majority of which are associated with mature forest sites with sources of water.

Special status rodents with the potential to occur in the Project area include white-footed vole (*Arborimus albipes*), federal species of concern, and red tree vole (*Arborimus longicudus*), federal species of concern and state vulnerable. White footed voles are associated with stands of alders generally found in riparian areas. Red tree voles occur in old-growth stands of Douglas fir and various other mesic forest sites (i.e., that require a moderate amount of moisture).

Special status bats include the following species: Townsend's western big-eared bat (*Corynorhinus townsendii townsendii*), federal species of concern and state critical; silver haired bat (*Lasionycteris noctivagans*), federal species of concern and state vulnerable; California myotis (*Myotis californicus*), state vulnerable; long-eared myotis bat (*Myotis evotis*), federal species of concern; and Yuma myotis bat (*Myotis yumanensis*), federal species of concern. Bats are generally associated with a variety of habitat types, including caves, forests, open grasslands, and water. Due to the prevalence of freshwater habitats and forests, it is likely that special status bat species exist at the Project site.

Special status weasels include the American marten (*Martes Americana*), state vulnerable, and fisher (*Martes pennanti*),candidate for federal listing and state as sensitive–critical. The American marten is associated with large tracks of mature forests and has a habitat range that overlaps that of fishers. Dune Forest B and the Panhandle are noted to contain potential American marten habitat. The fisher is discussed in further detail below.

**Fisher (Federal Candidate Species, State Sensitive-Critical)**

The fisher is a large weasel which inhabits forests with high canopy closure, large trees and snags, large woody debris, large hardwoods, and multiple canopy layers (USFWS 2004). Fishers are known to have very large home ranges and to wander widely. They avoid areas lacking overhead canopy cover and disturbance by humans. Fishers also occupy and reproduce in some managed forest landscapes and forest stands not classified as late-successional that provide some of the habitat elements important to the species.

The fisher was nearly extirpated from Oregon by logging and trapping and is now very rare. Reintroductions have been attempted in several inland counties and there have been recent sightings in the mountains east and west of the Willamette Valley (Csuti et al. 2001). The BLM Coos Bay District wildlife sightings database contains several fisher observations in Coos County. None of these sightings were in the vicinity of the North Spit. An adult was seen near Daniels Creek just below Wren Smith Creek (about 10 miles from the Project area) in 1991 (ORNHIC). The presence of the fisher on the North Spit is unlikely given the rarity of the species and the lack of large, well-connected tracts of mature forest with continuous canopies (BLM 2006). Most forested areas on the North Spit are interspersed with areas of open sand and research indicates that fishers are reluctant to cross openings greater than 25 meters (Powell and Zielinski 1994). Furthermore, fishers on the North Spit would be separated from Coast Range populations by Highway 101, human developments, and fragmentation of mature forest. It is uncertain the extent to which fishers can recover from extirpation given that their populations are isolated and their apparent inability to colonize unoccupied areas (Aubry and Lewis 2003).

Although the species is considered of potential occurrence on the North Spit (ODFW 2012 pers comm.), and porcupines, one of the fisher's preferred prey items, are present in the Project area, there are no records of its presence and no fisher was observed during focused Project surveys. Moderate habitat for this species was found in the forested hillside and riparian areas within the Project study area; however, it is assumed that there is too much disturbance and that the forest is too immature and fragmented for the site to be used by fishers.

### 3.2.5 Environmental Consequences (Construction and Operation)

The overall area affected by the construction of the Project encompasses a total of approximately 406.8 acres, including the 251.9 acres for the Project facilities, 64.0 acres for the non-jurisdictional facilities, and 90.9 acres of temporary construction areas (Table 1.2-1, Resource Report 1, General Project Description). An additional 45.4 acres of adjacent emergent and forested wetlands (including a portion of Henderson Marsh) will not be impacted and will be avoided and preserved. These avoided habitats do not require mitigation and are not considered further. Some wildlife currently inhabiting the upland habitats on the Project site will most likely be displaced or experience some direct mortality during construction. Several areas of the Project site will remain open and can be restored to higher value habitat by contouring, landscaping, and vegetation plantings typical of the coastal dune setting of the North Spit. Restored construction areas will be converted to ODFW Habitat Category 4. A summary of habitat lost and post-construction habitat categories is listed in Table 3.2-5 and shown in Figure 3.2-2.

Direct effects to animals in terrestrial habitats along the waterway for LNG carrier traffic could include direct mortality if they were not able to flee from a spill, or the loss and/or modification of habitat in the event of an accident. It is possible that an oil or fuel leak from the LNG carriers in transit to or from the LNG Terminal could affect either aquatic or terrestrial wildlife, with the level of intensity dependent on the scope and size of the spill. These potential environmental consequences are discussed further in Section 3.5.

#### 3.2.5.1 Amphibians and Reptiles

Amphibians and reptiles, including special status species, are likely to be impacted by fill activity in 2.58 acres (LNG Terminal site, access/utility corridor, and construction worker camp) of low to mid quality wetlands impacted by fill activities. Removal of dune forest for the Project will reduce habitat for the clouded salamander, should this species occur in these areas. The sand dunes adjacent to Jordan Lake and other wetlands on the Project site will not be affected by the construction of the Project. Hence, the northwestern pond turtle should not be affected and no mitigation is proposed for this species. Jordan Lake and nearby wetlands on the east side of the Project site area may offer suitable breeding habitat for the western toad, although the species was not found on the Project site. None of these areas will be affected by the Project and no mitigation is proposed.

#### 3.2.5.2 Birds

**American Peregrine Falcon**

Potential effects to American peregrine falcon populations will be minimal. The species may lose some foraging habitat with the removal of the tidal flat during slip construction, but the species is adaptable in its feeding habits. The Project site does not offer any suitable nest sites.

**Sensitive Breeding Birds**

Ospreys nest on one of the tall lights in the Roseburg Forest Products Company yard on the east side of the Project site area. This nest is in a highly disturbed area and the birds are habituated to a high level of disturbance. It is likely that Project construction activity will agitate the birds initially, but it is expected that they will become habituated to it as well.

The forested portions of the Project site area are suitable breeding habitat for the olive-sided flycatcher, a federal species of concern, and this bird was detected regularly in small numbers during summer surveys. Some suitable nesting habitat may be lost as a result of Project construction. Specific mitigation is not proposed for this species.

**Wading Birds and Shorebirds**

The impact of the construction of the slip and access channel on wetlands will be the permanent loss of approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, and 2.49 acres of eelgrass. These are all habitat for wading birds and shorebirds. The loss of this habitat will be offset by the construction of in-kind mitigation (intertidal algal flats and intertidal unvegetated mud flats) proposed by the JCEP at the Kentuck estuarine and wetland mitigation site.

**Migratory Bird Treaty Act**

Nesting habitat for migratory birds occurs within areas that will be cleared for the Project. The Project would alter and disturb breeding and non-breeding habitat and could affect food fish populations. To a certain extent the Project has the potential to contribute to pollution levels or contamination of marine waters. Focused pre-construction surveys will allow JCEP to comply with the MBTA by ensuring that impacts to nesting birds are avoided. The loss of the approximately 9.69 acres of intertidal and 3.38 acres of shallow subtidal habitat may reduce the migratory bird feeding opportunities, although the mitigation of these losses at compensatory mitigation sites should minimize the losses and reduce the overall impact.

### 3.2.5.3 Mammals

#### American Marten

The American marten (state sensitive–vulnerable) occurs in mature, closed-canopy forests and travels through openings if sufficient cover exists. Although unlikely, occasional dispersing individuals could wander into forested portions of the Project site. Thus, loss of dune forest for the Project could potentially reduce this species' habitat should this species occur in these areas. If potential occurrence is detected during pre-construction surveys, coordination with resource agencies and monitoring of American marten would be conducted, likely following the protocol developed by the U.S. Forest Service (USFS) for detecting carnivores (USDA 1995).

#### Bats

Specific bat surveys have not been conducted, but potentially suitable foraging habitat for many species occurs in the Project area, particularly around wetlands where insect prey is probably most numerous. Unidentified bats were observed in one of the buildings on the Roseburg Forest Products Company property on July 21, 2005. Breeding and roosting sites are likely very limited due to the existing high level of industrial activity and disturbance in the Project area, as well as the absence of more typical bat habitat such as cliffs, rock outcrops, bridges, caves, mines and large snags. Habitat for those species that nest under bark is available in the Project area.

#### Fisher

Potential adverse effects to fisher populations would be unlikely. There are no records of its occurrence on the North Spit, the site is separated by U.S. Highway 101 from inland forested habitat, there is too much disturbance from previous fill deposits and industrial use of the site, the forest is too immature and fragmented, and the species is too rare in the region for Project site use to be likely.

#### Big Game

Black bear and Roosevelt elk are fairly common on the North Spit and both have been sighted in the Project area. Black-tailed deer are also numerous in the Project area and use the site regularly. The development of the Project will reduce the amount of habitat for big game species and increased vehicle traffic during construction will increase the potential for collisions. However, due to the already disturbed nature of the Project site and existing industrial activities, it is not anticipated that the Project will have any significant adverse effects on these species.

### 3.2.6 Mitigation, Enhancement, and Protection Measures

Mitigation, enhancement, and protection measures for wildlife species that have been observed or are likely to utilize habitats in the Project area include specific measures, as defined below. These measures have been developed to avoid or limit potential impacts. As defined in the Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0010), the ODFW requires or recommends, depending upon the habitat protection and mitigation opportunities provided by specific statutes, mitigation for losses of fish and wildlife habitat resulting from development actions. Pursuant to the Fish and Wildlife Habitat Mitigation Policy, the Project will provide mitigation for lost fish and wildlife habitat by developing compensatory mitigation plans, including the Kentuck and Panhandle mitigation sites for wildlife species. Wildlife mitigation will be carried out at ratios agreed upon with the ODFW.

#### 3.2.6.1 Amphibians and Reptiles

The mitigation measures below will be implemented for construction and vegetation removal activities that may impact freshwater wetlands, including ponds, ditches, and other freshwater habitats that provide habitat for these species.

1. Suitable habitat that will be impacted by construction activities has been identified for further pre-construction surveys. A qualified biologist will survey the Project site 30 days prior to construction activities to determine if the northern Pacific pond turtle, northern red-legged frog, or the clouded salamander are in or near the action area and could be impacted by construction activities. Surveys will be in accordance with current species protocols. Areas that do not contain suitable habitat for these species will be released for construction without additional requirements.
2. The JCEP and ODFW will consult regarding the location of freshwater habitats for the relocation of amphibians or reptiles discovered during pre-construction surveys at the Project site. These habitats will provide areas for species relocation outside of construction areas where habitats are either being removed, modified, or managed for Project needs. Areas identified will be mapped and agreed to prior to construction.
3. Immediately prior to construction (within 4 hours) in areas identified as potential habitat, a qualified biologist will conduct surveys for the northern Pacific pond turtle, northern red-legged frog, and the clouded salamander. Species that are found during the survey will be captured and transported to suitable habitats outside of the construction areas, as pre-determined in consultation with the ODFW. Appropriate authorizations for capture and collection will be secured by the biologist prior to pre-construction surveys.

#### 3.2.6.2 Birds

To ensure compliance with the MBTA, clearing of Project area and any activity that involves habitat destruction, including staging and grading areas, if the construction schedule allows, will be conducted prior to March 1 or after August 31 to ensure most nesting birds have fledged. If construction activities must occur during the nesting season, JCEP will conduct focused pre-construction surveys to determine if there are active migratory bird nests present to ensure that impacts to nesting birds are avoided. The surveys will be conducted within the construction limits and within 100 feet (200 feet for raptors) of the construction limits. If active nests are encountered within the limits of the survey, construction and vegetation removal activities will be halted in the immediate vicinity until a qualified biologist has determined that the individuals have fledged from the nest (evacuated). JCEP will coordinate with the USFWS prior to proceeding with construction and any consultation exchange with the USFWS will be provided to FERC.

For construction activities during the nesting season, if no active nest is encountered within the limits of the survey, construction and vegetation removal will proceed with caution with an eye out for active bird nests. Empty or abandoned nests will not be taken into possession without a permit. During the non-nesting season, permits are not required to remove an empty or abandoned nest, or to remove or alter the structure the nest is built in or on.

Structures associated with the proposed Project would be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the MBTA.

LNG carriers along the transit route could affect migratory birds should an LNG spill occur while birds are flying directly through the spill area if the birds come in direct contact with either the unignited or ignited spill, or should an ignited spill affect the habitat of the migratory birds. In order for an unignited spill to affect a bird species flying through the vapor cloud, the bird would have to be flying at a level close to the spill where the vapor concentrations would be high enough to cause asphyxiation. This is unlikely unless the spill occurs in the route to the habitat to which the bird was descending and no other habitat was available. Given the amount of migratory bird habitat along the LNG carrier transit route, this would be an unlikely scenario. If the spill was ignited, it is likely that the birds would avoid the heat and smoke of the fire. The way that an effect could occur is if the vapor cloud ignited at the exact same time that the bird flew through it. The probability of this occurring is extremely remote.

If the release of LNG near a migratory bird habitat was in the presence of an ignition source, the resulting fire could injure the habitat within the 0.3 mile zone depending on the time of the year and conditions existing at the time of the fire. Heat from such a fire would have less of an effect on habitat vegetation within the 1.0 mile zone, and no effect from a pool fire is anticipated on wetland vegetation in the 2.2 mile zone. Even if vegetation is impacted by the fire, root structures would remain and allow the plants to become re-established.

The maximum flammable range for a vapor cloud could extend to the outer limits of the 2.2 mile zone and if an ignition source were present, the resulting fire could burn back to the source of the spill, directly injuring any habitat in the path. Again, this could result in injury to parts of the habitat plants, but would not result in long term damage to the plant or the plant community. The probability of these scenarios occurring is low given the marine transit safety and security measures employed and the unlikelihood of a spill of LNG cargo due to collisions and potential terrorist attacks.

**Great Blue Heron Rookery**

Ongoing surveys of the two (currently abandoned) great blue heron rookery sites near the Project site would be conducted prior to construction. Although both rookeries have been documented to be abandoned, reuse by this species can occur. Pre-construction surveys will be conducted during seasonally appropriate nesting periods. If coordination with the ODFW and BLM determines that these agencies are conducting rookery surveys, JCEP may suspend surveys and use the results of these agency surveys. In the event that a rookery becomes active, JCEP, in consultation with ODFW biologists, will develop an appropriate mitigation plan depending on the status of construction and the potential for indirect effects. No mitigation for potential impacts will be required as long as the rookery is inactive.

#### 3.2.6.3 Mammals

Relocation of mammals ranging from small to big game species will occur as these species typically relocate from sites impacted by construction. To avoid inadvertent return of these species to the construction site, vegetation clearing will occur in a progressive manner, to encourage species to move out of the Project site to more natural lands managed by the USFS. As areas of the Project site are cleared, fencing will be installed to discourage foraging activities back onto the construction site.

#### 3.2.6.4 ODFW Wildlife Habitat

On the basis of the Oregon Administrative Rules habitat categorization scheme (OAR 635-415-0025), ODFW Fish and Wildlife Habitat Mitigation Policy (OAR 635-415-0000), and coordination with the ODFW, habitat values lost to the construction of the Project will be replaced in-kind. Replacement of the lost habitat will include the following;

- Approximately 2.49 acres of eelgrass (Habitat Category 2) will be replaced by constructing eelgrass across the bay south of the runway for the Southwest Oregon Regional Airport.
- Approximately 13.9 acres of estuarine resources (Habitat Category 2), including intertidal unvegetated sand, shallow intertidal and algal/mud/sand flats, will be mitigated by the construction of mud flat estuarine wetlands in the Kentuck wetland mitigation site.
- Approximately 2.4 acres of additional Habitat Category 2 impacted by the construction of the Project will be mitigated in accordance with Oregon Division of State Lands Wetland Mitigation requirements (OAR Division 85 and Division 90) on neighboring North Spit property owned by JCEP.
- The loss of approximately 80.8 acres of terrestrial habitat (predominately coastal dune and riparian forests) classified as Habitat Category 3 will be mitigated by in-kind habitat replacement on neighboring North Spit property. Neighboring property to be used for in-kind replacement for lost habitat will be valued in accordance with OAR 635-415-0025 as agreed upon by consultation with the ODFW.
- The loss of approximately 62.9 acres of terrestrial habitat (Habitat Category 4; predominantly grassland, shrub, herbaceous, and herbaceous shrub upland) will be mitigated by in-kind or better habitat replacement on neighboring North Spit property. Neighboring property to be used for in-kind replacement of lost habitat will be valued in accordance with OAR 635-415-0025 as agreed upon by consultation with the ODFW.

## 3.3 FISHERIES AND MARINE RESOURCES

The Coos Bay estuary is the second largest estuary in Oregon and covers approximately 54 square miles of open channels and periodically inundated tidal flats. It ranges from a mile to a mile and a half wide by 15 miles long and has approximately 30 tributaries. The major tributary flowing into Coos Bay is the Coos River. Coos Bay and its connecting waterways provide foraging, migratory, spawning, and juvenile nursery habitat to numerous species of fish and invertebrates. This area also contains important crab, clam and salmon resources, as well as marine fish such as flatfish and rockfish. It is a major migration corridor for salmon and steelhead that spawn and rear in the Coos River systems.

The fish community consists of species that are adapted to salinity fluctuations characteristic of the Coos Bay estuary, with the number of species increasing down river through the estuary towards the ocean. Some estuarine fish such as kelp greenling and starry flounder spend their entire lives within the estuary, whereas other species are seasonal. Anadromous fish species occurring in the Project area include Chinook salmon, coho salmon, chum salmon, steelhead, and coastal cutthroat trout. Anadromous salmon are generally transitory, passing through the bay in the fall as adults to Coos River, while juveniles primarily outmigrate in the spring and summer. Other seasonal inhabitants include white and green sturgeon, American shad, Pacific lamprey, surfperch, lingcod, rock greenling, sculpin, surf smelt, Pacific herring, English sole, eulachon, longfin smelt, Pacific tomcod, sand sole, and topsmelt. In addition, clams, crabs, oysters, and shrimp make up important invertebrate components of the bay. Table 3.3-1 provides a list of commonly occurring fish and invertebrate species in Coos Bay.

Historically, dredged materials have been deposited in Coos Bay in the bay, marshes, and flats to provide fill for development or to store it outside of the navigational channels. Major historical alterations of Coos Bay include dredging and in-bay spoil disposal located at approximate CM 3.0, between CM 4.0 and 5.0, below CM 6.0, and between CM 8.0 and 9.0. Jefferts (1977) reported that dredging has a relatively minor influence on the fauna of the lower reaches of the estuary, which primarily consists of coarse sediment type. The marine habitats affected by the construction of the slip and access channel and the construction dock will be approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass.

Along the western shore of the bay from CM 6.0 to CM 8.0 (including Jordan Cove) the narrow sandy shore drops off quickly into the subtidal zone and the deeper navigational channel. Ebb and flow currents through the deeper portion of the bay are swift and scour the shores so that attached vegetation is absent. Five pile dikes have been installed along the shore to retard erosion (USACE 1973). This area is an important feeding area for English sole, topsmelt, surfsmelt, herring, anchovy, coho salmon, and Chinook salmon. Fish feed on material in the water column from adjacent productive areas. Closer to shore, herring spawn at the Roseburg Forest Products Co. dock and on eelgrass beds in Jordan Cove. In addition, west of the railroad bridge at Jordan Point is a sandy area where the ODFW seines and samples large numbers of fish.

A total of over 14,000 acres of habitat is present in Coos Bay, including some 1,500 acres of eelgrass beds, an important habitat component for major estuarine resources. The flat inner portions of the bay are used by most species found in the bay. These regions are where most eelgrass beds are found.

Eelgrass habitats are common in the lower bay subsystem. These submerged aquatic vegetation (SAV) areas appear to exhibit great species diversity and are preferred by many aquatic species. Most fish species within Coos Bay utilize the flats of the lower bay at some time during the year, where a majority of the eelgrass beds exist. Color infrared aerial photographs taken near the Project site area reveal a narrow band of sparsely populated SAV near the low tide line and partially submerged along the beach west of the Roseburg dock. Field surveys indicated that approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass occur at the slip and access channel and the construction dock site (Figure 3.3-1). It is recognized that eelgrass is an annual aquatic plant and production can vary widely from year to year. However, the aerial photography and field verification provides an indication of the extent of the eelgrass within the Project area.

Salinity and other water quality characteristics vary with proximity to the estuary mouth and with the volume of freshwater entering sloughs. In general, the lower bay (below CM 9.0) is dominated by higher salinity from ocean water while the upper bay water is affected by freshwater influx that varies seasonally. Tidal flux constantly changes the salinity of the water in the channel. South Slough, at CM 1.3, is relatively saline whereas Catching Slough at approximate CM 15.5 is brackish with a much lower salinity. The abundance of fish in the lower bay increases in the summer due to higher salinity.

The Fish and Wildlife Coordination Act (FWCA) was enacted to protect fish and wildlife when federal actions result in the control or modification of a natural stream or body of water. JCEP consulted with the ODFW, USFWS, and NMFS regarding potential impacts to fish and wildlife as part of the overall state and federal permitting and authorization process for the Project.

The Oregon Parks and Recreation Department (OPRD) has statutory authority for managing Oregon's ocean shore, which includes public beaches and other intertidal areas along the entire coast. The ocean shore is defined as the land lying between extreme low tide of the Pacific Ocean and the statutory vegetation line or the line of established upland shore vegetation, whichever is farther inland (ORS 390.605). The ocean shore does not include estuaries.

### 3.3.1 Existing Habitat

#### 3.3.1.1 Coos Bay Estuarine Habitat

Much of the Coos Bay shoreline and subtidal habitat consists of unvegetated mud and sand, mixed with areas of various algae species. Algae/mud/sand flat habitat is inundated with water more frequently and for a longer duration than intertidal unvegetated sand habitat and is therefore more likely to support aquatic organisms. Clam and/or burrowing shrimp holes occur within this habitat, with varied abundance and diversity. The habitat is classified as Category 2 by the ODFW because it is essential for fish and marine species, and limited, but can be replaced through mitigation. Based on conversations with ODFW personnel, habitat at the site is limited due to its location within the Coos Bay ecosystem.

Many of the managed groundfish species occur in estuarine waters and are included under Essential Fish Habitat. Juvenile and adult life stages of cabezon can be found in shallow water bays and estuarine areas. All life stages of kelp greenling and starry flounder are found in estuarine areas. Several species of rockfish occur in estuarine areas during their juvenile and adult life stages. These include black, brown, copper, and quillback rockfish that are usually found near kelp beds off the coast in later stages. Other groundfish species that may be found in estuarine and coastal areas include Pacific cod, Pacific whiting, sablefish, bocaccio, English sole, Pacific sand dab, and rex sole which utilize nearshore nursery areas.

Salt marshes exist on the transition zone between the land and the sea in protected low-energy areas such as estuaries, lagoons, bays, and river mouths. Marsh ecosystems, like all wetlands, are a function of hydrology, soil, and biota. Tidal cycles allow salty and brackish water to inundate and drain the salt marsh, circulating organic and inorganic nutrients throughout the marsh. Water is also the medium in which most organisms live. The marshes are strongly influenced by tidal flushing and stream flow, which affect the inundation and salinity regimes of salt marsh soils. In areas with enough runoff, salt marshes transition into brackish and freshwater marshes.

Sand- and mudflats occur at extreme low water, whereas salt marsh vegetation develops where soils are more exposed to the air than inundated by tides, usually above mean sea level. Sedges, salt grasses, beach grasses, and eelgrasses dominate the shallow intertidal and subtidal habitats. Salt marshes are of paramount ecological importance because they 1) export vital nutrients to adjacent waters; 2) improve water quality through the removal and recycling of inorganic nutrients; 3) absorb wave energy from storms and act as a water reservoir to reduce damage further inland; and 4) serve an important role in nitrogen and sulfur cycling (Mitsch and Gosselink 1993, Thayer et al. 1981).

Marshes and sloughs in Coos Bay provide rearing habitat for coho salmon and brackish-water estuarine areas may also be used by juvenile coho. The Coos estuary is estimated to contain less than 10 percent of its original salt marsh habitat, due to filling, dredging, and other development. Significant portions of the salt marshes remaining are in the South Slough National Estuarine Research Reserve, a 5,000 acre natural area near Charleston, which has approximately 550 acres of intertidal habitat and contains large expanses of eelgrass beds alongside its meandering, shallow channels, providing essential habitat for many fish and shellfish species, including Dungeness crab.

The LNG carrier transit route zones within Coos Bay overlap South Slough, Pony Slough, and North Slough/Haynes Inlet. Slough habitat varies depending on the location and amount of freshwater inputs. For example, salinity and other characteristics vary with proximity to the estuary mouth and the volume of freshwater entering sloughs. In general, sloughs provide habitat for a number of estuarine fishes, commercial shellfish, and invertebrates, many of which are important food sources for salmonids. Many marshes bordering sloughs have been diked, restricting tidal flush and flow of nutrient-rich organic material into the estuary.

South Slough enters the main channel of Coos Bay less than two miles from the estuary mouth and has a high shoreline to surface area ratio resulting in diverse habitats. The upper reaches of South Slough have been set aside as a research sanctuary. Because of its proximity to the ocean, it receives more marine influence than the other slough subsystems and its north-south orientation makes it susceptible to strong north-northwest winds. South Slough is an area of sediment deposition. The marine influence, coarse sediments, and relatively undisturbed nature of the upper portion provide habitat for more species of invertebrates and fish than are found in other slough subsystems in Coos Bay. Commercial oyster culture is a major commercial use in South Slough.

Pony Slough, across the bay from Jordan Cove (near CM 9), has subtidal areas with unconsolidated bottoms, intertidal mud flats, sand-mud flats, eelgrass beds, algal beds and marshes. Eelgrass is distributed along the intertidal areas near the slough entrance and through part of the main channel. Mud flats are populated by burrowing mudflat organisms including *Corophium spinicorn,* an important amphipod in the diet of juvenile salmonids. Tide flat users harvest soft shell clams and ghost shrimp.

The North Slough subsystem extends approximately three miles north from the main body of Coos Bay at CM 9, near Jordan Cove. The Trans-Pacific Parkway separates the slough from full exposure to the main bay, and the diked system reduces tidal circulation. Water quality sampling has shown high temperatures, high coliform counts, and excessive turbidity. Low summer stream flows, incomplete mixing, livestock, log storage, and waste are thought to contribute to degraded water quality. Ghost shrimp, lugworms, American shad, shiner perch, staghorn sculpin, and starry flounder have been documented in the slough (Cummings and Schwartz 1971). Coho salmon spawn in North Creek, a tributary to the North Slough.

Eelgrass habitats are common in the lower bay subsystem and they appear to exhibit great species diversity and are preferred by many aquatic species. Previous studies (Akins and Jefferson 1973) reported that Coos Bay has 1,400 acres of lower intertidal and shallow subtidal tide flats covered by eelgrass meadows. In 1979, the ODFW conducted habitat mapping in Coos Bay and documented intertidal and subtidal aquatic beds, including documentation of SAV in Jordan Cove and across the bay from the proposed LNG Terminal in and near the mouth of Pony Slough. The largest and most contiguous beds of submerged grasses are located in both the lower and upper bay, in the North and South Sloughs, and in Haynes Inlet. Eelgrass in

Pony Slough is distributed along the intertidal areas near the slough entrance and through part of the main channel. In the fall and winter, as much as 75 percent of the eelgrass blades die back and decompose, supplying estuarine food webs with essential nutrients. In spring and summer, eelgrass beds sprout and grow, renewing the annual cycle of production.

Submerged grass meadows provide cover and food for a large number of organisms including burrowing, bottom-dwelling invertebrates; diatoms and algae; herring that deposit egg clusters on leaves; tiny crustaceans and fish that hide and feed among the blades; and larger fish, crabs, and wading birds that forage in the meadows at various tides. Eelgrass in Coos Bay provides shelter for a variety of fish and may lower predation, allowing more opportunity for foraging. The protective structure attribute of eelgrass is primarily for smaller organisms and juvenile life history stages of fishes. Orth et al. (1984) reported that shoot density, patchiness, leaf area, leaf morphology, along with the thickness, structure, and proximity of the rhizome layer to the sediment surface are the primary characteristics that affect predation rates. Structural complexity is related to fish abundance and species richness. Fish diversity and eelgrass biomass were also significantly correlated in surveys conducted in Craig, Alaska (Murphy et al. 2000).

Field surveys of the Project site conducted in September 2006 verified the extent and species composition of SAV previously identified from aerial photography as occurring in the area of the slip and access channel and construction dock. The narrow strip of SAV was found to be comprised of eelgrass (*Zostera marina*) and algae. It is recognized that eelgrass is an annual aquatic plant and production can vary widely from year to year. However, the aerial photography and field verification provides an indication of the areal extent.

#### 3.3.1.2 Along the LNG Marine Transit Route

Oregon, along with nearly every other coastal state, has jurisdiction over the seabed and its resources out to three geographical (or nautical) miles. First proposed in 1793 by then-Secretary of State Thomas Jefferson as a "temporary" seaward boundary for the United States, state jurisdiction over the "territorial sea" was finally established by Congress in the 1953 Submerged Lands Act (43 USC 1301-1315). Where offshore islands occur within the three miles, the Territorial Sea extends another three miles beyond. The Oregon Territorial Sea is 950 square nautical miles. In 1991, the Oregon Legislature required that the Territorial Sea also include the ocean shore, which is defined in state law (ORS 390.605) as the land lying between extreme low tide of the Pacific Ocean and the line of vegetation (also known as the beach zone line).

**Riparian Zones and Streams**

The LNG carrier transit route zones within Coos Bay overlap tributaries and riparian zones draining into Coos Bay. An abundance of streams drain into Coos Bay from mixed-conifer forests and developed areas. Chinook and coho salmon spawn in freshwater tributaries of Coos Bay in select areas such as pool tailouts, runs, and riffles during the fall or winter (Vronskiy 1972, Burger et al. 1985, Healey 1991). Riparian zones are typically lined with red alder, willows, and ferns. The transit route zones within Coos Bay overlap multiple small freshwater tributaries flowing into South Slough within lower Coos Bay including Hayward Creek, Day Creek, Elliot Creek, and Joe Ney Creek. In addition, lower Pony Creek is within the transit route zones that reach into the upper bay. Miner Creek and Big Creek are within the LNG carrier transit route zones along the coast, and drain directly into the Pacific Ocean near Gregory Point just north of Sunset Bay.

**Shoreline Habitat**

Sandy beaches are transitional areas between subtidal soft sediments and the terrestrial dunes or sedimentary bluffs. Ecotypes include high intertidal and mid to low intertidal areas. Fauna of sandy beach habitat are transitory and move up and down with the tides. Fish use these areas for foraging and invertebrates burrow in sand during periods of exposure. Fish utilizing submerged sandy beach habitat include surf smelt, English sole, night smelt, roughback sculpin, Pacific sand lance, and Pacific staghorn sculpin. Species utilizing the mid to low intertidal zones along sandy beaches include Dungeness and red rock crab, various species of clams, Pacific sand lance, surfperch, night smelt, and bay rays.

The shoreline in the vicinity of Coos Bay is dominated by geological features distinctive of the Klamath Mountain metamorphic province, as well as rocky shores of uplifted and tilted marine sediments. Rocky shore habitat exists south of Coos Bay, including diverse intertidal habitat, shore-associated reefs, offshore reefs, offshore rocks, and islands. Cape Arago and Gregory Point research reserves provide coastal intertidal and kelp forest habitats. The coastline just north of Coos Bay is sandy beach habitat. Nearshore environments vary from low-energy sheltered environments to more exposed coastline, subjected to high-energy wave and tidal action. Numerous groundfish species, salmon, and a number of coastal pelagic species are found in nearshore habitat. These include juvenile and adult life stages of Pacific mackerel, which occur off sandy beaches. In open bays, eggs and paralarvae of market squid are found in shallow, semi-protected nearshore areas (PFMC 1998a).

The transit route also overlaps soft bottom subtidal areas off of Coos Bay, which have primarily sandy substrates. Communities are dominated by burrowing invertebrates such as worms with shrimp, crabs, snails, bivalves, sea cucumbers, and sand dollars living on the sediment surface. Common fish include flatfish, sand lance, and burrowing sandfish.

**Rocky Shore Habitat**

The LNG carrier transit route zones overlap rocky shore habitat south of the entrance to Coos Bay. Rocky shore habitat includes all hard substrate areas along the shoreline that are alternately exposed and covered by the tides. Rocky shores contain the following ecotypes: high intertidal, mid-intertidal, low intertidal, and intertidal artificial substrates (jetties, etc.). The physical characteristics of nearshore rocky reefs reflect local shoreline geology, exposure, and currents as well as biological influences. South of Coos Bay, the coastal geology produces the complex of cliffs, reefs, and rocks of Cape Arago, which are tilted layers of sedimentary rocks. The physical environment of intertidal areas changes dramatically as the tide rises and falls, and habitat is either covered by salt water or exposed to air and the sun. Rocky intertidal habitats have an abundant and diverse biological community, including algae and other marine plants (surfgrass), attached and mobile invertebrates (sponges, anemones, barnacles, bryozoans, tunicates, mussels, crabs, snails, sea stars, urchins, brittle stars, nudibranchs, chitons, worms), fish (sculpins, gunnels, pricklebacks), marine mammals, and sea birds. Rocky shore habitat fish species include cabezon, black rockfish, and other species of rockfish.

**Rocky Reef Habitat**

The ODFW has studied a modest number of reefs along the Oregon coast. Many species are principally associated with rocky reefs and these areas are a focal point for commercial and recreational fishing. The LNG carrier transit route zones overlap portions of submerged rocky reef habitat south and north of Coos Bay, including nearshore rocky reefs near Cape Arago and deeper subtidal reefs offshore of this area, as well as a subtidal rocky reef north of Coos Bay.

Rocky subtidal habitat includes all hard substrate areas that are never exposed at low tide, including reefs, rocky reefs, rocky banks, pinnacles, and hard bottoms. Ecotypes include shallow rocky reefs with kelp beds, shallow rocky reefs without kelp beds, deep rocky reefs, and subtidal artificial substrates. Subtidal rocky reefs have a variety of microhabitats and an abundant and diverse biological community. Species utilizing shallow rocky reefs include numerous species of rockfish, greenling, sculpin, gunnel, flounder, perch, and smelt. Invertebrates include mussels, crabs, abalone, limpets, anemones, snails, sea stars, sea urchins, chitons, barnacles, and scallops. Deep rocky reefs have a rich invertebrate and fish community, with little algae. Invertebrates include sponges, anemones, snails, sea stars, and crabs. Deep nearshore reefs tend to have a higher diversity of rockfish as well as perch, lingcod, Irish lord, sole, and dogfish sharks.

**Kelp Forests**

Kelp forests are associated with rocky reefs and include subtidal marine communities that form floating canopies on the surface of the sea. Kelp forests are highly productive and create a three-dimensional aspect to the nearshore environment, providing habitat and food for hundreds of other species of plants (algae) and animals. Kelp forest ecosystems include structure-producing kelps and their myriad of associated biota such as marine mammals, fishes, crabs, sea urchins, mollusks, other algae, and epibiota (organisms living on its surface), which collectively make this one of the most diverse and productive ecosystems in the world (Steneck et al. 2002).

Kelp forests are included as SAV in subtidal marine habitat, occurring across a wide depth range, from rocky intertidal habitats to depths of 40 meters, and for some species, broad latitudinal ranges. Kelp grows on many of Oregon's shallow rocky reefs on rocky substrates between 5 and 20 meters of water, with some extending to 25 meters (ODFW 2005b). While rocky reefs of this depth range exist all along the Oregon coast, the strip of coast from Cape Arago south contains approximately 92 percent of the state's kelp beds (ODFW 2005b).

Distribution patterns of kelp are influenced by light, salinity, temperature, substrate type, and currents. Kelp forests supply many habitat functions, including: 1) supporting of large numbers of non-parasitic epiphytic organisms that live on them; 2) damping of waves and slowing of currents which enhances sediment stability and increases the accumulation of organic and inorganic material; 3) binding sediments with their holdfasts (roots), thus reducing erosion and preserving sediment microflora; and, 4) holdfasts and blades (leaves) provide horizontal and vertical complexity to habitat, which, together with abundant and varied food sources, support densities of fauna generally exceeding those in unvegetated habitats.

### 3.3.2 Existing Fish and Marine Species

#### 3.3.2.1 Fish

ODFW (2005) seining data at stations near Jordan Cove give a snapshot of the diversity of species that utilize habitat near the proposed slip location. Species seined in September and July of 2005 at McCullough Bridge (upper bay from the Project area) included Chinook salmon, shiner perch, walleye perch, northern anchovy, starry flounder, staghorn sculpin, speckled sand dab, and saddleback gunnel. Species seined in July 2005 from the Trestle station (just upbay from the Project site area) included coho salmon, Chinook salmon, shiner perch, staghorn sculpin, sand sole, white sea perch, surf smelt, and American shad. Species seined from the Pony Creek station (across and upbay from the Project site area) in July 2005 included coho salmon, Chinook salmon, shiner perch, staghorn sculpin, sand sole, white sea perch, surf smelt, jack smelt, and bay pipefish.

**Salmon**

The Coos Bay system provides migration, rearing, and feeding habitat for the following environmentally sensitive units (ESUs) of Pacific salmonids: federal species of concern Oregon Coast (OC) coastal cutthroat trout (*O. clarki clarki*); OC Chinook salmon (*Oncorhynchus tshawytscha*), state sensitive-critical; Pacific Coast chum salmon (*O. keta*), state sensitive-critical; OC steelhead (*O. mykiss*), state sensitive-vulnerable, which is also a federal species of concern; and OC coho salmon (*O. kisutch*), federally-listed as threatened under the Endangered Species Act (ESA) in February 2008.

### 3.3.2.2 Invertebrates

As one of Oregon's largest estuaries, Coos Bay provides habitat and rearing value for clams, crabs, and shrimp, which are of significant economic importance to the area, including Oregon's economically productive Dungeness crab fishery. Many invertebrates have not been thoroughly studied and updated population and distribution information is not available. Variations in substrate, attachment sites, sediments, salinities, temperatures, dissolved oxygen, and other physical factors in Coos Bay affect shellfish distribution. Shellfish distribution varies along the route from the proposed LNG Terminal to the Coos Bay harbor entrance, with principal subtidal clam beds and crab species found in the lower bay along the route.

Mapped clam and crab distributions shown on Figure 3.3-2 are based on the Shellfish and Estuarine Assessment of Coastal Oregon: Coos Bay (SEACOR) conducted in 2008 by the ODFW. Butter (Martha Washington, beefstake, quahog) and gaper (horse, horseneck, blue, Empire) clams are considered the most numerous in Coos Bay and studies conducted from the 1970s to 2009 have shown increased populations. Cockles and littlenecks (steamers) are less common and studies show their populations have been dropping since the 1970s. Softshell clams (non-native) are typically found further inland along the bay.

Oysters and shrimp distributions are mapped in Figures 3.3-3 and 3.3-4, respectively, and are based on distributions contained in Coos Bay by the Oregon Geographic Response Plan (U.S. Coast Guard 2004). There are two species of oysters in Coos Bay: the native or Olympia oyster (*Ostrea lurida*) and the commercially grown Pacific oyster (*Crassostrea gigas*). The Olympia oyster is the only oyster native to Oregon and Coos Bay is one of only a few bays where they exist in Oregon. Neither species is legal for recreational harvest. Native oyster populations are protected to encourage their recovery, but since Pacific oysters are only commercially grown they are private property.

Bringing the Olympia oyster back to Oregon's coastal waters has become a priority for natural resource managers, scientists, shellfish farmers, and recreationists. A team led by the South Slough National Estuarine Research Reserve in lower Coos Bay is conducting the science and forming the relationships necessary to make Coos Bay the epicenter of the state's restoration efforts. In 2010, the reserve received a federal start-up grant for a pilot restoration project. Since then they have re-introduced about 4 million juvenile oysters to South Slough. The project aims to build on existing research and relationships to establish a community stakeholder group committed to working collaboratively to bring the Olympia oyster back to Coos Bay.

### 3.3.2.3 Marine Mammals

The Marine Mammal Protection Act (MMPA) was enacted on October 21, 1972, and prohibits killing, harming, or harassing any marine mammal. It is based on the finding that some marine mammal species or stocks may be in danger of extinction or depletion as a result of human activities and that these populations must not be permitted to fall below their optimum sustainable population level. The MMPA was amended substantially in 1994 to provide certain exceptions to the take prohibition, including: 1) for small takes incidental to specified activities; 2) permits and authorizations for scientific research; and 3) access by Alaska Natives to marine mammal subsistence resources. The amended act also included a program to authorize and control the taking of marine mammals incidental to commercial fishing operations, the preparation of stock assessments for all marine mammal stocks in waters under U.S. jurisdiction, and studies of pinniped-fishery interactions.

In addition to the marine mammals listed below, other threatened or endangered marine mammals that may occur in the LNG carrier transit route zones are described in Section 3.4 and include whales and Steller sea lions.

**California Sea Lion**

California sea lions (*Zalophus* californianus) occur in nearshore waters along the Pacific coast from Vancouver Island, British Columbia, to Baja Mexico. North of southern California, the haulout grounds are occupied by males only who migrate north for the winter following the breeding season, which ends in mid-July (Maser et al. 1981) after the pups are born. Females and their pups remain in California all year. Males may often reach 850 pounds and 7 feet in length. Males develop a bony bump on top of their skull, which is called a sagittal crest. Females can weigh up to 220 pounds and reach 6 feet in length; females are lighter in color than the males. California sea lions are very social animals and rest together in tightly packed groups on haulout sites. The main haulout sites along the Oregon coast include Shell Island at the Simpson Reef. California sea lions forage within Coos Bay throughout the year and use dredge material islands as haul-out sites (BLM 2005). Occasionally they may be found on the North Spit's beaches (BLM 2005). The California sea lion may occur in the LNG carrier transit route zones.

**Harbor Porpoise**

The harbor porpoise (*Phocoena phoceoena*) is circumboreal in the northern hemisphere and occurs in ice-free waters. In the eastern Pacific Ocean, this species ranges from Point Barrow, Alaska, to San Diego, California. This species is the smallest cetacean in the eastern North Pacific Ocean and is considered abundant in waters off Washington and western Canada. Adult males reach up to 1.7 meters in length and females reach 1.8 meters. Adult harbor porpoises weigh up to 90 kilograms. In the Pacific, harbor porpoises feed on bottomfish, cod, herring, squid, clams, and occasionally crustaceans. Harbor porpoise could be found within the LNG carrier transit route zones.

**Harbor Seal**

Harbor seals (*Phoca vitulina*) occur in both the Pacific and Atlantic oceans north of the equator. In the Pacific, they range from Alaska to Baja Mexico and can often be seen in nearshore coastal waters, bays, estuaries, and on sandy beaches and mudflats. Harbor seals have spotted coats in a variety of colors, ranging from silver to dark brown or black. Males are slightly larger than females and the species reaches 5-6 feet in length and weigh up to 300 pounds. In Oregon, pups are born in April and May. Harbor seals are opportunistic feeders and take a variety of bottom fishes and rockfishes, small schooling fish such as herring, some salmon, and lamprey (Maser et al. 1981). Harbor seals spend half their time on land and half in the water, occasionally sleeping in the water. Harbor seals are year-round residents on the Oregon coast and can be found at Cape Arago. Harbor seals forage within Coos Bay throughout the year and use dredge material islands as haul-out sites (BLM 2005). Occasionally they may be found on the North Spit's beaches and are very sensitive to disturbance (BLM 2005). Harbor seals could occur within the LNG carrier transit route zones.

**Northern Elephant Seal**

Northern elephant seals (*Mirounga angustirostris*) occur in the North Pacific, from Baja Mexico to the Gulf of Alaska and Aleutian Islands. The elephant seal was almost extinct by the late 19$^{th}$ century but has repopulated throughout its range, having once received protection. During the breeding season, they live on offshore island beaches and a few remote locations on the mainland. The rest of the year elephant seals live offshore. Adult males reach up to 13 feet in length and weigh up to 5,000 pounds. The females are smaller at 10 feet in length and weighing less than 1,000 pounds. This species is the second largest seal in the world, after the southern elephant seal, and can dive to depths of 5,000 feet. Elephant seals breed in the winter and male elephant seals arrive first at their breeding beaches in Mexico and California to establish territories. Pups cannot survive in the water until eight to ten weeks after birth. The northernmost breeding site on the Pacific coast is Shell Island at Cape Arago, which is also the largest marine mammal haulout area on the Oregon Coast (USFWS 2007b). Elephant seals may occur in the LNG carrier transit route zones.

**Sea Otter**

The sea otter (*Enhydra lutris*) was extirpated from Oregon by the early 20$^{th}$ century; however, translocation attempts were made in Cape Arago in 1971 where 41 otters were released (Jameson 2007). The translocated populations failed and the last sea otter observation at Cape Arago was in 1991 (Jameson 2007). This species is currently extirpated in Oregon and will not be affected by the LNG carrier transit route zones.

### 3.3.3 Commercial and Recreational Fisheries

Commercial and recreational fish and invertebrates species found in Coos Bay are listed in Table 3.3-3.

#### 3.3.3.1 Commercial Fishing

Commercial fisheries in the Coos Bay estuary includes clams, bait fish, and ghost and mud shrimp (used for fishing bait), along with limited crabbing from September through December. Only 15 permits for commercial clam harvesting are issued per year for the entire state of Oregon. A company called West Coast Clams began regularly harvesting clams commercially in Coos Bay in March 2012 and has since opened up new markets for clams from Coos Bay.

Commercial ocean fisheries include boats (trollers and trawlers) targeting tuna, sablefish, salmon, groundfish, Dungeness crab, clams, and pink shrimp. Most vessels fishing offshore dock and sell their products in Coos Bay and a fisherman's market cooperative and a small commercial salmon fleet are located in Charleston. Shellfish fisheries (predominantly crab, shrimp, and clams) are of significant economic importance to the Coos Bay area.

In 2011, the total value of the catch at the fisherman's level reported by the ODFW at Charleston was $35.7 million. This was comprised of $12.7 million for fish, $23.1 million for crab and shrimp, $8,312 for clams, and $700 for other invertebrates. Within the fish category, albacore tuna, sablefish, and Chinook salmon were the highest valued catch of all the fish caught, at $4.2, $3.7, and $1.3 million, respectively. In 2011, the ODFW reported that Dungeness crab harvested from the ocean had a total value of $11.8 million at the fishermen's level. Pink shrimp had a value of $10.9 million, and spot shrimp, $182,264. Cockle and gaper clams, combined, account for only $7,069.

Although many shrimp species are found in waters off Oregon, the pink shrimp (*Pandalus jordani*), also known as the ocean shrimp, is the only one found in quantities large enough to be commercially harvested. The pink shrimp is a small shrimp in comparison to many shrimp and prawns seen in supermarkets and restaurants, and is often referred to as cocktail shrimp or salad shrimp. Pink shrimp have been harvested in Oregon since 1957 and are caught by trawl boats which generally fish between 450 to 750 feet deep on mud and muddy-sand substrates off the coast. Populations vary widely from year to year, which is common for many short-lived crustaceans. Landings in 2005 were 15 million pounds and have averaged 26 million pounds per year over the last 31 years.

The Oregon Division of State Lands (DSL) oversees six oyster claims in Coos Bay and leases for commercial operations are issued by the Port of Coos Bay and Coos County. There are four commercial growers that cultivate about 1,500 acres of non-native Pacific oysters, worth about $10 million each year. No oysters are allowed to be recreationally harvested in the bay. The closest commercial oyster lease occurs east of the Project, as mapped in Figure 3.3-3.

#### 3.3.3.2 Recreational Fishing

The main recreational catch species of fish include coho and Chinook salmon. Other recreational catch species include American shad, shiner perch, redtail surf perch, striped sea perch, white sea perch, pile perch, black rockfish, lingcod, Cabezon, red Irish lord, Pacific staghorn sculpin, surf smelt, Pacific herring, Pacific tomcod, kelp and rock greenling, blue and cooper rockfish, California halibut, and white sturgeon.

Much of the recreational angling for salmon in Coos Bay occurs in late summer and fall. It usually begins in late summer at jetty areas and moves up the bay as fish move upstream. Bank angler access on the North Spit is limited. Boat angling occurs throughout the bay, but angling is limited in some areas at times by exposure to winds. For example, the Roseburg Forest Products Co. dock area in Jordan Cove gets less boat angling use due to exposure to wind and tidal action. Other areas of concentrated angling for fall salmon are further up the bay, beginning at the railroad bridge and extending through the Marshfield and Coos River channels.

Perch fishing begins in Coos Bay in late February to early March, depending on freshwater runoff into the bay, and can continue through July. Rocks around bridge abutments and the north jetty are targeted by anglers on the outgoing tide.

Recreational fishing for sturgeon occurs between the railroad bridge and McCullough Bridge and also above the McCullough Bridge. Green sturgeon are illegal to retain and are listed as threatened under the ESA. White sturgeon can be taken year round, but the best angling is during December through March when there is a heavy freshwater plume in Coos Bay. Sturgeon anglers target areas upstream of the McCullough Bridge away from the Project site area.

The west shore of the bay at Jordan Cove contains sand-mud flats, eelgrass beds, and a fringe of estuarine wetlands that provide habitat for recreationally important ghost shrimp and mud shrimp. These shrimp are recreationally harvested at a number of locations throughout the bay

(Figure 3.3-4) and are popular among fishermen for use as bait for species such as perch, rockfish, and various groundfish species that occur in the bay.

Recreational crabbing and clamming brings year-round tourist income to the region. Crabbing occurs in the main channel areas, largely from the BLM boat ramp on the North Spit (west of the Project) to the mouth of the bay and typically is done around slack tides. Crab harvesting by boats is very productive along the western side of the lower bay west/southwest of the BLM boat dock on the North Spit. Along the eastern side of the lower bay from the Empire area south are sand and mud flats that provide some of the highest recreational effort for clams.

Six main areas for recreational shellfish are described below (ODFW 2013):

**Area 1** (South Slough) can be reached from several access points along the west side of South Slough within Charleston. This area is a large sand/mud flat that is firm enough to walk on easily in most places. Many clam species can be found in this highly marine influenced area. In sandy areas, such as those just south of the Charleston bridge, cockle raking is popular. In muddier areas, such as the “Charleston Triangle” (between the commercial docks and the bridge), gaper clams can be found readily at good tides. In areas further up South Slough soft shell clams can be found sparingly. Other clams, such as butter and littleneck clams, are found mixed throughout.

**Area 2** (North Spit) requires a boat or 4x4 vehicle for access other than hiking. This area supports several large and productive clam beds. All species common to lower bays can be found here, including gapers, butters, cockles, and littlenecks.

**Area 3** (Fossil Point and Pigeon Point) can be accessed by many points along Cape Arago Highway from Empire to Charleston. Substrate in the area varies from sand/mud to sandstone/ gravel. In the sandier areas of Pigeon Point, gapers and cockles are easily found. In gravelly areas, such as Fossil Point, butter and littleneck clams are more common.

**Area 4** (Haynes Inlet, North Slough, and Glasgow) can be reached by the nearby banks, from Highway 101 or East Bay Drive. Soft shell clams are common throughout the intertidal areas. Ghost shrimp are common in the area. Commercial oyster operations are also nearby. The oysters are private property and cannot be harvested recreationally.

**Area 5** requires a boat for crabbing. Large sandy flats in depths of 20-30 feet provide excellent bay crabbing year round. Pots may be set anywhere within this area, using caution to avoid direct placement in navigation channels.

**Area 6** includes areas for dock crabbing. In Charleston, the primary areas for dock crabbing are the commercial docks, public crab dock, and “T” docks just south of the bridge. Another popular spot is on the docks adjacent to the Empire boat ramp. Dock crabbing is often fruitful year round, but less so than boat crabbing.

### 3.3.4 Unique and Special Status Fisheries and Marine Resources

Additional species not federally or state-listed as threatened or endangered but designated as protected or sensitive by an environmental division of the local, state, or federal government are described below.

#### 3.3.4.1 Essential Fish Habitat (federal) and Essential Salmonid Habitat (State)

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1976, as amended, was enacted, along with other goals, to promote the protection of Essential Fish Habitat (EFH) in the review of projects conducted under Federal permits, licenses, or other authorities that affect or have the potential to affect EFH. The MSA requires all federal agencies to protect fisheries habitat from being lost due to disturbance and degradation and to consult with the National Marine Fisheries Service (NMFS) when an action has the potential to adversely affect EFH. EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” [16 USC § 1801(10)]. The EFH interim final rule, summarizing EFH regulations (62 FR 66531-66559), outlines additional interpretations of the EFH definition.

For the purpose of interpreting the definition of EFH, “waters” include aquatic areas that are used by fish and their associated physical, chemical, and biological properties, and may include areas historically used by fish where appropriate; “substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” means the habitat required to support a sustainable fishery and a healthy ecosystem; “fish” includes finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds; and “spawning, breeding, feeding, or growth to maturity” covers a species’ entire lifecycle.

The MSA established regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to identify and describe the habitat areas of particular concern within the EFH. When Congress reauthorized this act in 1996 as the Sustainable Fisheries Act, several reforms and changes were made. One change was to charge the NMFS with designating and conserving EFH for species managed under existing FMPs. This was intended to minimize, to the extent practicable, any adverse effects on habitat caused by fishing or non-fishing activities, and to identify other actions to encourage the conservation and enhancement of such habitat.

The Pacific Fishery Management Council (PFMC) has authority over the fisheries in the Pacific Ocean seaward of the states of California, Oregon, Washington, and Idaho. The individual FMPs addressing EFH for managed species in these areas represent the PFMC’s response to those requirements stated in Section 303(a)(7) of the MSA (16 USC §1801 et seq.). Four FMPs have been established by the PFMC, including: FMP for the groundfish in the Pacific; FMP for coastal pelagic species in the Pacific, FMP for salmon in the Pacific, and FMP for highly migratory species (tuna, sharks, and billfish). Tuna and billfish do not occur in Coos Bay but may be found seasonally offshore when the ocean’s temperature warms up.

For the Pacific salmon fishery, the PFMC identified EFH using U.S. Geological Survey hydrologic units, as well as habitat association tables and life history descriptions for each life stage. These areas encompass all streams, lakes, ponds, wetlands, and other currently viable water bodies and most of the habitat historically accessible to salmon in Washington, Oregon, Idaho, and California. In estuarine and marine areas, EFH for Pacific salmon extends from the nearshore and tidal submerged environments within state waters out to the full extent of the Exclusive Economic Zone (EEZ; 200 nautical miles).

EFH is described and identified as everywhere that species managed by the PFMC occur. Specifically, EFH is identified and described based on areas where various life stages of 90 managed species commonly occur. These include 82 species of groundfish, five coastal pelagic species (four finfish: Pacific sardine; Pacific (chub) mackerel; northern anchovy; jack mackerel and one invertebrate: market squid); and three species of salmon (Chinook, coho, and pink salmon). Table 3.3-2 lists species with designated EFH in Oregon. EFH species in Coos Bay include Chinook and coho salmon, northern anchovy, Pacific sardine, and a variety of rock and groundfish. The ODFW reports that adult and juvenile black, blue, and copper rockfish, lingcod, rock greenling, and starry flounder are found in Coos Bay year-round. It also reports that recent genetic work points to the possibility of resident copper rockfish. All habitat accessible to these managed species in the Coos Bay system is considered EFH. This includes estuarine habitat, shore environments, marsh habitat, SAV, and kelp beds. The locations of EFH within Coos Bay and the zones of the LNG carrier transit route are shown in Figure 3.3-5.

Approximately 31.5 acres of potential EFH within Coos Bay will be removed by the dredging and construction that will occur for the Project, including 29.1 acres for the slip, 1.7 acres for the construction dock, and 0.7 acre for the gas processing area. This includes approximately 9.69 acres of intertidal (unvegetated sand), 3.38 acres of shallow intertidal habitat (algae, mud, and sand), 2.49 acres of eelgrass, and 15.24 acres of deep subtidal habitat (Figure 3.3-1).

No habitat designated as EFH for species under federal management plans will be affected by the construction of the land-based elements of the Project; however, it is likely that EFH will be affected by the construction of the slip. The normal transit of LNG carriers to and from the Project will have no direct physical effect on EFH, although maintenance dredging for the access channel to the LNG Terminal ship berth will affect EFH that develops between maintenance dredging periods. Development and maintenance of the slip will temporarily affect the subtidal mudflats in the Project area; however, it will result in the production of a zone of deepwater habitat that will likely be utilized by a myriad of fish species, including the green and white sturgeon. The conversion of shore lands, grassland, and dune forest to open water for the slip will also create additional underwater habitat, which should be considered ODFW Habitat Category 3.

**Prey Dependence on EFH**

Habitat for prey items of species for which EFH has been identified in Coos Bay is essentially the same as that required by those managed species (i.e., estuarine and marine habitats). Shrimp larvae feed on phytoplankton and zooplankton. Postlarvae feed on epiphytes, phytoplankton, and detritus. Juveniles and adults prey on polychaetes, amphipods, and chironomid larvae, but also on detritus and algae (Pattillo et al. 1997). Submerged grasses are important habitat for small prey species of adult lingcod (EFH Core Team 1998).

Forage habitat components for the managed species depend to some extent on estuarine systems. Many species of groundfish and salmonids occupy inshore areas of the lower bay during juvenile stages (e.g., Chinook salmon, coho salmon, English sole, eulachon) where they feed on estuarine dependent prey, including shrimp, small fishes, and crabs. As they mature and move offshore, their diets in many cases change to include fish, although estuarine-dependent species (e.g., shrimp, crabs) can still constitute an important dietary component.

**Essential Salmonid Habitat (State)**

Pursuant to Oregon Revised Statutes (ORS) 196.810(1)(b), the Oregon Department of State Lands (DSL), in consultation with the ODFW, designates Essential Indigenous Anadromous Salmonid Habitat (ESH) areas based on field surveys and/or the professional judgment of ODFW´s district biologists. ESH is defined as the habitat necessary to prevent the depletion of native salmon species (chum, sockeye, Chinook, and Coho salmon; and steelhead and cutthroat trout) during their life history stages of spawning and rearing. The designation applies only to those species that have been listed as sensitive, threatened, or endangered by a state or federal authority, and designations are periodically reviewed and updated.

All projects proposed in ESH must be reviewed pursuant to the standards set forth in the State's Removal-Fill Law (ORS 196.600 to 196.990) and rules (OAR 141-085). An authorization from

DSL for activities involving the fill or removal of any amount of material in ESH is required unless the activity is exempt. This authorization is included in the permit issued by the DSL as part of the Joint Permit Application process with the U.S. Army Corps of Engineers. The DSL Permit for the slip and access channel has been issued to the Port. A copy is provided in Appendix O.2 of Resource Report 2 – Water use and Quality.

#### 3.3.4.2 Native American Fisheries

Historically, an essential resource for the Native Americans in Coos Bay was fish. The extensive tidal channels of the bay were habitat for dozens of species of fish. Massive spawning runs occurred in all seasons of the year, bringing salmon, herring, smelt, and other fishes in vast numbers. One of the most effective systems the local Native Americans used to harvest these fish involved weirs and traps of wooden stakes and woven lattice or basketry, often built across the mouths of tidal channels. They were typically designed to allow fish passage upstream as the tide rose, then trap the fish as the tide receded. In the mid-1900s, the stakes forming these weirs could still be observed at various sloughs in the bay. This is no longer the case, although, remnants of fishing weirs are occasionally reported by those familiar with identifying such weirs.

Modern Native Americans living in Coos Bay do fish, both recreationally and commercially, but these practices are not conducted as tribal fisheries as they are done at certain locations along the Columbia and Klamath Rivers. There is no land that is currently owned by Native American tribes in or adjacent to the Project site area. The tribes in Coos Bay currently do not have policies that regulate fishing separately from state and federal fisheries management. No information about traditional fishing sites still in use in the Project vicinity was identified during the cultural resource investigations which included consultation with tribal representatives. A more detailed discussion of the Native American fisheries is provided in the Cultural Resources Survey Report, filed as “Privileged and Confidential” (Appendix A.4 to Resource Report 4 – Cultural Resources).

#### 3.3.4.3 Marine Sanctuaries, Reserves, and Management Areas

The location of marine research reserves, reefs, and management areas along Coos Bay and within the zones of the LNG carrier transit route are shown in Figure 3.3-6 and described in the following sections. In addition, migratory marine mammal feeding and breeding grounds and bird habitat along the entire route are shown in Figure 3.3-7.

Within state waters along the coast, 1,400 offshore rocks and islands are classified as Rocks and Islands National Wildlife Refuge System, which is administered by the USFWS. There are no rocks or islands in this refuge that fall within the LNG carrier transit route zones. Shell Island which is part of the Oregon Islands National Wildlife Refuge is approximately three miles from the LNG carrier transit route and is outside of the 2.2 mile zone.

The Cape Arago headland encompasses the coastline of three OPRD parks: Sunset Bay, Shore Acres, and Cape Arago. It contains extensive, rich, and diverse intertidal and subtidal habitat, including Oregon’s largest giant kelp bed, seabird nesting sites, and large marine mammal haulouts (including threatened Steller sea lions and the only year-round elephant seal haulout in the state). Within these parks, some areas get high visitor use. More than 600,000 people visit at Sunset Bay and more than 450,000 people visit Cape Arago each year.

**Cape Arago Intertidal Research Reserve**

Marine reserves are defined by the ODFW (2006) as "areas designated to meet specific goals and are regulated to protect resources or uses from activities that may conflict with these goals." The Cape Arago Research Reserve is located just south of the mouth of Coos Bay and forms the only major rocky shoreline between Heceta Head, 55 miles to the north, and Cape Blanco, 32 miles to the south. The Reserve extends along approximately 2.5 miles of shoreline and includes North Cove, Middle Cove, South Cove and Squaw Island. Shoreline features include steep cliffs, numerous offshore rocks, extensive rocky intertidal and subtidal reefs, and small sand beaches. Sloping bedrock platforms with small surge channels are common at Sunset Bay and portions of North Cove. Steeper sloped platforms with deep surge channels are common at Middle Cove, Simpson Reef, Squaw Island, and most of North Cove. The site supports a rich and diverse community of intertidal wildlife. Several species of pinnipeds and seabirds utilize the area.

The Reserve has several prominent features. Nearshore rocks provide nesting and roosting habitat for seabirds. Squaw Island is surrounded by an extensive intertidal area. Simpson Reef, located just beyond the Reserve, provides shelter from wave energy which has resulted in a rich and extensive intertidal community. The wide variety of habitat types at Cape Arago has created a very diverse intertidal community. Cape Arago is the southernmost site in Oregon to support high densities of intertidal and subtidal purple sea urchins. Red sea urchins are also abundant here. A commercial offshore fishery exists for both urchin species but has been in decline in recent years. High diversity and abundance of algal species occur in North Cove, behind the protection of Simpson Reef. Simpson Reef is the only site in Oregon where significant kelp beds of giant kelp (*macrocystis integrifolia*) are found and kelp is extensive along much of the shoreline. Shell Island in North Cove is another unique feature, as it is entirely covered with shell fragments.

Four species of pinnipeds haulout in the reserve. Shell Island, Squaw Island, Simpson Reef and South Cove support harbor seals, California sea lions, and Steller sea lions. Shell Island has the only breeding population of elephant seals in Oregon. Peregrine falcons are also residents at the site.

According to the USFWS Oregon Islands National Wildlife Refuge website, Simpson Reef at Cape Arago is the world's northernmost pupping site for northern elephant seals, and is the largest marine mammal haulout site on the Oregon coast. Shell Island in Simpson Reef is the largest rock in the reef and is habitat for marine mammals, including the federally threatened Steller sea lion. Simpson Reef and Shell Island are located outside of the LNG carrier transit route zones, but due to their close vicinity and significant marine mammal habitat, they were included in the discussion.

**Gregory Point Subtidal Research Reserve**

Gregory Point Subtidal Research Reserve includes 57 acres of subtidal areas at Gregory Point, Lighthouse Island, and nearby Squaw Island. It is located northwest of the mouth of Sunset Bay State Park and includes all areas seaward of extreme low tide in the area. The rocky intertidal area at the site (3.5 acres) is part of the Cape Arago Research Reserve. Formations at Gregory Point are remnants of steeply upturned sedimentary rocks that underlie the Cape Arago region. Key resources of this site include seabird nesting sites on Lighthouse Island and extensive intertidal and subtidal rocky habitat between Lighthouse Island and Squaw Island. Harbor seals also use the area as a haulout. Because of its isolation, the area has been used for many years for study and research by staff and students at the nearby University of Oregon Institute of Marine Biology in Charleston.

**Marine Protected Areas**

The state of Oregon and NOAA designated the South Slough National Estuarine Research Reserve (SSNERR) as the nation's first estuarine reserve in 1974. The SSNERR is administered by the Oregon DSL, which is under the jurisdiction of State Land Board. The SSNERR is the southern extension of the Coos Bay estuary and South Slough is one of the seven inlets that combine to form the Coos Bay estuary. The SSNERR encompasses 4,765 acres and is approximately one-quarter of the South Slough watershed. The reserve includes approximately 800 acres of water and tidally influenced habitat, 115 acres of riparian habitat, and 3,850 acres of upland forest. The mixture of open water channels, tidal and freshwater wetlands, riparian areas, and forested uplands provides a diverse and biologically rich area. Several threatened and endangered and special status species occur at the reserve, including bald eagle, peregrine falcon, brown pelican, cutthroat trout, coho salmon, California pitcher plant, sea lavender, and Point Reyes bird's-beak. Management and administration at the SSNERR supports and coordinates research, education, and stewardship programs which serve to enhance a scientific and public understanding of estuaries and contribute to improved estuarine management. The SSNERR is located to the south of LNG carrier transit route 2.2 mile zone.

### 3.3.5 Environmental Consequences (Construction and Operation)

#### 3.3.5.1 Fish and Marine Species (including EFH)

Potential effects to fish and marine species are discussed below, and also in Section 3.3.5.2 for aquatic habitats and Section 3.3.5.3 for water quality. Discussion of potential effects to marine mammals is primarily included under Section 3.4.4 for environmental consequences to threatened and endangered species, as the Steller sea lion and nine species of whales are addressed in Section 3.4.

**Acoustic Effects**

All piles required for the LNG carrier berth, including docks and mooring dolphins, will be driven prior to or concurrent with the dredging of the slip on dry land. No open water pile driving will be required, thereby eliminating potential affects to fish and marine organisms from higher intensity sound waves in the water column. It is currently assumed that piles will be driven on dry land in isolation from the Bay, and soils would subsequently be removed from around them, eliminating the majority of potential land-based noise impacts.

**Impingement or Entrainment**

As discussed in Resource Report 2 – Water use and Quality, LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is likely that some organisms small enough to pass through the screens covering the carrier's intake port will be drawn in with the cooling water and will be lost from the population in the slip area; however, it is anticipated that the effect associated with the intake of cooling water will be minimal. Juvenile fish would need to be present in the slip area near the carrier's intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen. Generally the total water intake would occur over a 24-hour period during each loading period, about 90 times per year.

**Temperature**

Temperature effects are discussed in Resource Report 2 – Water Use and Quality. LNG vessels would re-circulate water for engine cooling while loading LNG at the berth to provide power for standard hoteling activities as well as running the ballast water pumps. Using conservative assumptions, the maximum heating of cooling water at the time of discharge is estimated to be approximately 3$^{o}$C (5.4$^{o}$F) above ambient temperature for a distance of 50 feet from the discharge point on the LNG vessel, with the difference decreasing with further distance. The creation of the slip results in the addition of approximately 40 acres of water surface to the Coos Bay estuary. This additional water surface will increase the amount of evaporative cooling, further decreasing the water temperature in the slip area. Considering the volume of Coos Bay, virtually no change in bay temperature would occur from heated water discharge. The tides would be continually exchanging the water and the cooling water would be discharged in the same localized area (the northeast corner of the slip). The warmer engine cooling water is not anticipated to have a significant adverse impact on the water temperature in Coos Bay because of mixing and other factors.

**Localized Changes in the Light Regime**

Localized changes in light regime have been shown to affect fish species behavior in a variety of ways. Disorientation may cause delays in migration, while avoidance responses may cause diversion of migratory routes into deeper, less protected waters. In some cases, increased light may attract both predators and potential prey species.

Lighting at the LNG Terminal and onshore facilities would likely include a mixture of low-power fluorescent lighting and higher intensity security lighting that would primarily be located on shore, in and adjacent to the slip. When an LNG carrier is not in the berth, the lighting would be reduced to that required for security. It would be focused upon the structures and not be in proximity to the water so as to serve as an attractant or deterrent to fish species. When an LNG carrier is at the berth, it would physically block the lighting on the berth from the slip waters and, due to its proximity to the slip wall, would block the fish from getting too close to the lighting on the berth. Lighting used would be similar to that already in place at other Coos Bay facilities.

Lighting on the tug dock would be low intensity lighting for safety, providing sufficient light for personnel movements on the trestle out to the tug berth and for movement on the berth itself. There is no intention to provide lighting near the water line or high intensity lighting that would be associated with activities other than the simple berthing of the tugs at this location. The reduced lighting levels near the water would reduce or eliminate any behavioral effects to fish in the Project vicinity. The final details of the lighting arrangement will be determined through consultation with NMFS in the Biological Opinion (BiOp) and other resource agencies to reduce these potential adverse effects.

**Ship Wake and Propeller Wash**

Shoreline erosion, wave heights and shoreline changes, and propwash scour are all discussed in Resource Report 2 – Water Use and Quality. Propeller wash from LNG vessels and tug boat propellers associated with the Project, as well as ship wakes breaking on shore, could cause increased erosion along the shoreline and re-suspend the eroded material within the water column. This may affect the diversity and health of the benthic community regarding food availability and feeding conditions for foraging and migrating fish species. At high concentrations, suspended sediments can affect oxygen exchange over the gills, resulting in weakened individuals or mortality. However, ship wakes associated with the operation of the slip are not expected to result in significant bank erosion or effects due to the low speed at which carriers would traverse the lower bay when approaching or departing the slip and the limited number of trips (approximately 90 round trips per year).

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds have been observed to cause occasional stranding of juvenile salmon (Pearson et al. 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al.) to cause stranding. In models and research conducted by the JCEP, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute to fish stranding within Coos Bay.

**Marine Sanctuaries, Reserves, and Management Areas**

LNG spills from LNG carriers in the transit route from the LNG Terminal should not have any effect on wildlife refuges as the closest refuge is the islands near Cape Arago that are part of the Oregon Island National Wildlife Refuge which extends down the coast south of the Coos Bay harbor entrance. This area is approximately three miles from the transit route and outside of the 2.2 mile zone. The likelihood of a vapor cloud from an LNG spill moving down to the refuge and then being ignited from an ignition source is very low since boats, aircraft, and humans are prohibited from the area and there are no ignition sources.

There is little likelihood of an LNG carrier losing steerage, running into the islands or reefs of the wildlife refuges, and either physically damaging the wildlife refuge areas or spilling LNG cargo. The LNG carriers are double hulled and in previous and similar incidents no LNG cargo has been spilled. In addition, LNG carriers will always be under tug escort when in proximity to the islands and reefs of the refuge and the tugs will keep the carriers under control in the event of a steering or other control failure.

The effect of the additional LNG carriers on refuges due to wakes disturbing mammals in haulout areas is not considered to be an issue due to the distance of the LNG carrier transit route from the refuges and the fact that the LNG carriers will be traveling at reduced speeds while in the bay. As previously described, the additional number of carriers will logically increase the chances of contact between carriers and marine mammals frequenting the refuges. However, the distance between the LNG carrier transit route and the refuges will help reduce these potential contacts to a minimum.

### 3.3.5.2 Aquatic Habitat

#### Loss of Benthic and Shoreline Habitat (including EFH)

The impact of the construction of the slip and access channel on wetlands will be the permanent loss of approximately 8.1 acres of intertidal, 3.3 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.5 acres of eelgrass. The construction dock will affect 1.6 acres of intertidal and 0.1 acre of shallow subtidal habitat and the gas processing area will affect an additional 0.7 acre of intertidal habitat.

Macroinvertebrates move, rest, find shelter, and feed on the substrate and organic material, as well as live within the substrate in these areas. The Project would physically disturb and reduce shoreline aquatic habitat, including eliminating or displacing established benthic communities and reducing prey availability in the vicinity.

Based on air photo interpretation, the distribution and spatial extent of SAV within the area to be dredged for the slip is patchy and sparse. Due to the low density and narrow extent of distribution of SAV in this area, habitat value is expected to be lower relative to the more extensive and contiguous SAV beds located elsewhere in Coos Bay. While the construction of the slip would adversely impact EFH through loss of this narrow band of SAV, the potential adverse impacts to EFH will not be substantial and dredging of the slip will create approximately 36.7 acres of new marine habitat by converting upland to subtidal habitat.

### 3.3.5.3 Water Quality

#### Turbidity Levels

Elevated turbidity levels will result from actions taken to construct the slip and the Kentuck mitigation site for estuarine habitat mitigation and south of the airport for eelgrass mitigation. Dry season construction will equate to less opportunity for precipitation-generated turbidity and will reduce the chances of juvenile fish entering the work area. Elevated turbidity from construction is expected to be localized, but would develop cumulatively for the aquatic environment affected. Turbidity plume direction movement and disbursement will be dependent on current flow. Construction during outgoing tidal flows, combined with outgoing river flows, will carry turbidity downstream. During the incoming tide, turbidity is not expected to be detectable beyond the immediate area, as tidal fluctuations and wind will drive the currents and disperse the suspended sediments into the navigation channel. Elevated turbidity levels will occur over a short time, lasting a few hours immediately after the work area is inundated by the incoming tide. The elevated turbidity levels will occur over the construction in-water work period, twice each day in relation to the high tide cycle. Turbidity is also discussed in Section 3.3.5. for slip construction and Section 3.3.5.5 for the effects of dredging on fisheries.

#### Chemical Contamination

As with all construction activities, accidental release of fuel, oil, and other contaminants may occur as the presence of construction equipment near sensitive habitats creates the potential for introduction of toxic materials from accidental spills, improper storage of petrochemicals, or mechanical failure. Operation of back-hoes, excavators, and other equipment requires the use of fuel, lubricants, etc., which, if spilled into the bay or adjacent intertidal zone, can injure or kill aquatic organisms.

Potential affects from a fuel spill, equipment malfunction, or accident is likely to be a short-term effect, but could be detrimental to aquatic habitat within the action area. Petroleum-based contaminants such as fuel, oil, and some hydraulic fluids contain poly-cyclic aromatic hydrocarbons (PAHs) which can be acutely toxic to the aquatic environment for fishes and can also cause lethal and chronic sublethal effects to aquatic organisms (Neff 1985).

Accidental spills may allow chemicals to reach Coos Bay, resulting in impacted water quality and reduced feeding opportunities for aquatic species within the action area. The large volume of water in the bay, the strong water currents and wind action, and the conservation measures proposed to minimize the amount and distance of a toxicant material spread will result in the dilution of any spill to undetectable levels in a few hours. Potential water contamination from construction activities will be controlled by the implementation of spill containment measures as specified through the permitting and approval process for the Project. However, depending on the timing, weather conditions, and response and clean-up efficiency, adverse impacts may still occur due to the proximity to aquatic habitat.

#### 3.3.5.4 Slip Construction

The construction of the slip will require the excavation of 2.3 million cubic yards (cy) of material and the dredging of 2.0 million cy of material from the slip area and dredging of 1.3 million cy from the access channel for a total of approximately 5.6 million cy. During the dredging of the slip, the water used to hydraulically convey the material dredged to the placement site will be recycled back to the dredge area as it will not be connected to the bay. Throughout this phase of the construction activity, there will be no discharges (water or turbidity) to Coos Bay. During the dredging of the access channel and removal of the berm separating the slip from the bay, the water used to hydraulically convey the material dredged to the placement site will be returned to the north side of the slip where it will mix with the water in the slip allowing any remaining turbidity to settle before mixing with water in the bay.

Much attention has been given to turbidity effects from dredging in estuaries, embayments, and enclosed waters. Turbidity from dredging can elicit a variety of benthic responses primarily because attributes of the physical environment are affected (Wiber and Clarke 2001). Large quantities of bottom material placed in suspension decrease light penetration and change the proportion of wavelengths of light reaching the bottom, leading to decreases in photosynthesis and primary productivity of benthic algae and submerged grasses. Suspended materials can prevent growth of benthic organisms, plants that provide habitat complexity, and biological structures used by some faunal species for shelter and egg attachment.

Coast and Harbor Engineering (C&H) prepared an analysis of the turbidity generated by the dredging operation at the slip and concluded that the proposed dredging activities for the slip are unlikely to have extensive adverse effects on Coos Bay. The model was developed on the basis of a sediment analysis conducted at the site of the dredging and took into consideration wind, tidal currents, seasonal flows, etc. The model approach was conservative in that it predicted turbidity levels based on dredging the entire slip while still connected to the bay, rather than the approach that is proposed by JCEP in which the majority of the slip construction will be kept isolated from the bay by a berm. Only the dredging of the berm and the access channel would occur while connected to the bay. Dredging activity would be restricted to the in-water work window of October 1 through February 15 when salmonid species are not likely present. The ambient turbidity levels in the water (generated by flows, waves, wind, and vessel traffic) create a background level of turbidity, ranging by season from 3.7 to 18.1 nephelometric turbidity units, thereby reducing the relative impact of dredging-related turbidity.

The proposed area for dredging is adjacent to the existing shipping channel, which is subject to periodic maintenance dredging. It is reported (Newell et al. 1998) that benthic communities on mud substrates in Coos Bay when disturbed by dredging recovered to pre-dredging conditions in four weeks. Thus, it is anticipated that the benthic communities in the areas to be dredged in connection with the Project will recover in the same time period, resulting in short-term effects to benthic populations on mud substrate. The dredged areas will also be subject to periodic maintenance dredging and the same cycle of disturbance and re-colonization (to an unknown extent) will likely occur. Direct mortality or injury to fish from construction equipment is not expected to occur due to mobility of the fish. Turbidity as a result of sediment re-suspension is likely to be localized and short term and is not expected to be transported up or downstream to an extent that it will kill or injure shellfish populations. Dredge operations are expected to result in effects similar to annual winter storm events, with possible higher concentrations of suspended sediments concentrated in the area of the dredging. Sessile benthic organisms (those permanently attached to a base and unable to move), shellfish, clams, and crustaceans could be injured or killed during dredging operations. Implementation of a spill plan will minimize the potential for a fuel spill and adverse effects to aquatic life and habitat during dredging.

Sedimentation and maintenance dredging requirements would likely be reduced at the access channel area over time due to natural stabilization and adjustment processes. Predicted volumes for maintenance dredging in the access channel are 26,100 cy per year after 10 years, 21,900 cy per year after 25 years, and 14,800 cy per year after 50 years.

Approximately 37,700 cy is the total maintenance dredging volume expected at year 1 and 34,600 cy is the total maintenance dredging volume expected at year 10. In the first 10 years, an approximate total of 360,000 cy would be removed and in the next 10 years approximately 330,000 cy would be removed for an approximate total of 690,000 cy in comparison to the prediction of 1.75 million cy for the previously proposed import terminal project. This is a substantial reduction in volume which in turn will reduce the demand for disposal space and the amount of turbidity associated with the dredging and disposal.

The operation of the LNG Terminal does not require or produce large quantities of hazardous materials. Solvents and paints are used during normal maintenance activities and are kept in specialized containers with secondary containment to prevent spills on the ground. Stormwater collected in areas that have no potential for contamination will be allowed to flow or be pumped directly to a system of stormwater bio-swales and ditches, which will ultimately drain to the slip. Stormwater collected in areas that are potentially contaminated with oil or grease will be pumped or will flow to oily water collection sumps. Collected stormwater from these sumps will flow though engineered oily water separator packages before discharging to the industrial wastewater pipeline. Industrial wastewater will be conveyed to the Port of Coos Bay’s existing ocean outfall pursuant to the NPDES permit. No untreated stormwater will be allowed to enter waters of the state.

During the operation of the Project, LNG carriers calling on the LNG Terminal could have accidental releases of fuels or other contaminants found on all ships. In the unlikely event that there is an accidental spill of LNG, no effects on marine life are anticipated. LNG is not toxic and if spilled on water would vaporize as it is warmed by the heat in the water. LNG is not absorbed into the water, resulting in no effects on marine life.

#### 3.3.5.5 Effects of Dredging on Fisheries

Effects of dredging on fisheries will be limited to those species found along the edge of Coos Bay where the new slip will be formed. Fish will relocate from the area of the dredging activity, with the duration of the relocation dependent on the length of time for re-colonization of food sources and habitat. Turbidity would be increased in the short-term in localized work areas and up or downstream depending on tidal action and currents. Dredging would likely create localized areas of increased (above background levels) turbidity and plumes of turbid water flowing away from the work areas in the direction of tides and currents. It is expected that sediments will settle out near work areas.

If salmonids are exposed to moderate to high levels of turbidity for prolonged periods, a number of adverse effects could occur including behavioral changes, sub-lethal effects and increased mortality from predators. Dredging is expected to create spikes of high to moderate turbidity in a localized area. Effects are not expected to be significant or measurable due to the limited area affected, timing (season) of dredging activity, and due to the short duration of proposed dredging operations. Though not anticipated to be present during the in-water work period, rearing and migrating salmonids would likely avoid active work areas.

Increased suspended sediment would affect filter-feeding organisms, including shellfish, through clogging and damaging feeding and breathing organs (Brehmer 1965, Parr et al. 1998). However, sediment re-suspension is likely to be localized and short term and is not expected to be transported up or downstream to an extent that it would kill or injure shellfish populations. There are no commercial oyster beds in the immediate vicinity of the proposed dredging areas. Sessile benthic organisms within areas to be dredged will be removed and killed. Other benthic organisms living immediately adjacent to dredge areas will be subjected to periods of high turbidity, and settling of suspended sediments, which could bury, injure or kill these organisms.

Aquatic organisms in Coos Bay are adapted to and exposed to periods of high to moderate turbidity during winter months. Dredge operations are expected to result in similar effects, possibly with higher concentrations of suspended sediments concentrated in the immediate area of the dredging.

Increases in turbidity can also reduce the depth that light penetrates in the water column, which may affect submerged plants, such as eelgrass, and temporarily reduce productivity and growth rates (Parr et al.,1998). In many bays and estuaries, and seasonally, background turbidity levels are high and organisms are able to tolerate continuous exposure to high suspended sediment concentrations for much longer than would occur during dredging operations (Peddicord and McFarland, 1978). Species living in areas where waters are normally clear, such as along a rocky coast, may be especially vulnerable to the effects of increased suspended sediments. The turbidity levels predicted to occur by conservative modeling in the area of the SAV will be well below the levels reported in the literature as resulting in adverse effects on SAV and due to the relatively short duration of the dredging (approximately 4-6 months), there are no anticipated adverse effects on SAV due to turbidity from dredging. Since the predicted turbidity levels were based on the dredging of the entire slip and not just the area inside the berm that will be left to isolate the majority of the slip construction from the waters of Coos Bay, the actual turbidity levels will be lower than what was originally predicted.

The release of organic rich sediments during dredging or disposal can result in localized removal of oxygen from the water column, which can adversely affect aquatic organisms. This effect would be temporary and tidal exchange would be expected to replenish oxygen. In most cases, where dredging and disposal occurs in open coastal waters, estuaries and bays, localized removal of oxygen has little, if any, effect on aquatic organisms (Bray et al. 1997).

The re-suspension of sediments during dredging and disposal may result in an increase in the levels of organic matter and nutrients available to aquatic organisms. The potential for algal blooms in estuarine waters is limited by turbidity and tidal flushing. Increased organic materials could increase productivity in a localized area as food for zooplankton and higher organisms is increased. This effect is expected to be insignificant based on the limited area to be affected.

Salmonids, green sturgeon, juvenile eulachon (if present), mollusks, crustaceans and other aquatic species have the potential to be adversely affected by the dredging. Neither the eulachon, green sturgeon nor the salmonids spawn near the slip site, but the eelgrass beds may provide important feeding grounds for these species, and mollusks and crustaceans utilize the intertidal zone throughout Coos Bay. However, as the amount of SAV and intertidal habitat is minimal at the slip site, impacts to fish resulting from dredging operations are expected to be short term and minimal.

#### 3.3.5.6 Ballast Water Discharge

Ballast water is discussed in depth in Resource Report 2 – Water Use and Quality. The role of ballast water as a vector for transportation and introduction of various nuisance marine species to U.S. waters has become a critical issue for many international ports in recent years. The Oregon International Port of Coos Bay is no exception to this national concern and all ships utilizing this port will be subject to the 2012 U.S. Coast Guard (USCG) Final Rule on Ballast Water Discharges. (See Final Rule on Ballast Water Discharge Standard - Standards for Living Organisms in Ships Ballast Water Discharged in U.S. Waters).

Pursuant to this Final Rule, all LNG carriers will have been required to flush their ballast tanks at least once while in the open ocean or utilize one of several USCG approved Ballast Water Management (BWM) methods in order to discharge their ballast water into the slip area while concurrently loading their LNG cargo. Because taking on ballast water would only occur at sea and the discharge of ballast water will comply with the 2012 Ballast Water Discharge Standards, the potential impact for ballast water to introduce invasive species of interest in Coos Bay will be negligible. The JCEP will continue to require that the ballast water of all LNG carriers be discharged in accordance with federal oversight and existing regulations.

#### 3.3.5.6 Emissions

Some concern has been raised as to the potential impacts to wildlife of carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), and sulfur dioxide ($SO_2$) emissions from the LNG Terminal. Since the refrigerant compressors will be driven by electric motors, the $NO_2$ emissions will be minimal. Based on data from another LNG plant, emission levels more than a very short distance from their sources will be negligible. The typically windy nature of the site will disperse these emissions quickly and it is not expected that these emissions will be a threat to wildlife.

### 3.3.6 Mitigation, Enhancement, and Protection Measures

#### 3.3.6.1 Submerged Aquatic Vegetation and Intertidal Habitat

The impact of the construction of the slip and access channel and construction dock on wetlands will be the permanent loss of approximately 9.69 acres of intertidal, 3.38 acres of shallow subtidal, 15.24 acres of deep subtidal, and 2.49 acres of eelgrass.

The proposed mitigation strategy for offsetting impacts to 3.38 acres of intertidal unvegetated sand and 9.69 acres of algal/mud/sand flats is to restore mud flats at the Kentuck wetland mitigation site. In addition, to mitigate for impacts on approximately 2.49 acres of eelgrass, JCEP will create new eelgrass habitat in an area due south of the west end of the Southern Oregon Regional Airport runway.

The airport eelgrass mitigation site appears to contain areas that are protected from wind, waves and excessive current velocities. Water clarity is fairly good compared to upper reaches of the bay. Dense patches of eelgrass scattered about the general area of the airport site were noted during the September 14, 2006, field reconnaissance (DEA). Opportunities exist to either lower high spots or build up low spots that are currently either too shallow or deep to support eelgrass. The resulting habitat increase from the mitigation site will provide benefits to the population overall by increasing the natural cover and forage production in Coos Bay. It is likely the increased quantity of habitat will offset the losses from the LNG Terminal site.

#### 3.3.6.2 EFH/ESH

To minimize impacts to EFH and ESH, the bulk of the slip construction will take place in isolation from Coos Bay by maintaining a portion of the existing shore line as a berm. Construction activity to remove the remaining portion of the existing shoreline and connect the slip with Coos Bay will be planned during the ODFW preferred work windows (October 1 through February 15) to minimize effects on vulnerable life stages of important fish species. Monitoring will be conducted before, during, and after slip construction to ensure compliance with the design and BMPs to control the release of sediments and/or inadvertent spills will be implemented. Mitigation for habitats removed or disturbed will be conducted as previously described.

#### 3.3.6.3 Shellfish Nurseries

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the shellfish species are located, the LNG will remain on the surface of the water until it vaporizes and will not have an adverse effect on the shellfish. Some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting the shellfish, given the ambient water temperatures in the transit route. If the vapor from an LNG spill were to come in contact with an ignition source the resulting fire would burn back to the spill source and would affect things on the water or in the area that came in direct contact with the fire. Shellfish nursery areas and shellfish in the water would not be affected as the fire would be above the water in the area of the spill where the vaporized LNG is at flammable levels. In either case of lower or higher water temperatures based on the spill scenario, mobile species will move out of the area until the water temperatures return to normal. LNG spills directly on shellfish nursery areas when exposed at low tide are unlikely as the LNG carriers will routinely exit the Port at slack high tide.

There is little likelihood of an LNG carrier losing steerage, running aground, and physically damaging shellfish areas as the channel geometry will serve to keep the LNG carrier within the confines of the channel. In addition the LNG carrier will always be under tug escort when in the channel. The tugs will keep the LNG carrier under control and not allow it to run aground in the event of a steering or other control failure.

#### 3.3.6.4 Import of Exotic Marine Species

Ballast water is held in the ballast tanks and cargo holds of LNG carriers to provide stability and maneuverability during a voyage when carriers are not carrying cargo, are not carrying enough cargo, or require more stability due to rough seas. LNG carriers will need to discharge their ballast water at the LNG Terminal in conjunction with the cargo loading process. Any ship originating from a foreign port of call (LNG or otherwise) has the potential to import an exotic species that could impact the habitat associated with the slip. In recent years the impacts of these effects have become critically manifested in almost all U.S. ports of call. A study by Carlton and Geller has identified 638 taxa of exotic species that have already been introduced into the Coos Bay environment. For years now, all vessels entering U.S. ports have been required to comply with ballast water management protocols, U.S. law (e.g., Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990; 1996 National Invasive Species Act), and agency programs (Department of Defense/U.S. Environmental Protection Agency regulations at 40 CFR Part 1700, which implement Section 312(n) of the Clean Water Act), and establish discharge standards for vessel ballast water.

On March 23, 2012, the USCG issued its Rule regarding Standards for Living Organisms in Ships' Ballast Water Management Discharged in U.S. Waters, which amends the existing BWM regulations and creates a standard for the allowable concentration of living organisms in ballast water discharged in U.S. waters consistent with the International Maritime Organization's International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM Conventions). This Rule will require all vessels equipped with ballast tanks bound for (or departing) U.S. ports to utilize at least one BWM method described in the Rule (77 FR 17254). The most likely convention given the advanced technologies used by LNG carriers will involve a complete ballast water exchange (BWE) in an area 200 nautical miles from any shore prior to discharging ballast water.

JCEP has assumed that the provisions of this Act and the new Rule will apply to both the import and export of nuisance species, and by compliance with this Act and Rule, the LNG carriers will neither cause nuisance species to be introduced from the discharge of ballast water into the Project site within Coos Bay or the ports of delivery for the LNG cargo.

#### 3.3.6.5 Marine Mammals

All marine mammals are protected under the Marine Mammal Protection Act of 1972. The estuarine and open ocean habitats (out to the EEZ) of the Project area could support a variety of protected marine mammals. Only the harbor seal, Steller sea lion, gray whale, and killer whale exhibit any potential to enter the bay and only the harbor seal was observed at the slip site during field surveys. Gray whales and killer whales enter Coos Bay only on an occasional basis. The Steller sea lion is expected to occur more frequently at the bay mouth, near the Charleston harbor where it is attracted to fishing-related activities, or offshore. All four species could be affected by increased shipping traffic. However, Coos Bay has historically experienced higher levels of deep draft vessel traffic (on the order of 200 ships per year versus the current rate of 50 ships plus the additional 90 LNG carriers). Accordingly, while the increase in the number of ships may result in an increased probability of ship strikes, ship strikes should still be less than what occurred a number of years ago.

In October of 2008, NMFS established its Final Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales on the premise that slower speeds result in reduced potential for whale/ship strike interactions. This Rule does not apply to shipping traffic (LNG carriers) within the Pacific Ocean. Likewise, the Port of Coos Bay does not have regulatory authority over ships in the open sea. However, once an LNG carrier enters U.S. waters and approaches the harbor coastline, a mandatory reduction in speed is required. Each carrier will also be assisted into the bay by pilot and tug vessels; therefore, transit to and from the slip will already be at slow speeds due to in-place operating protocols. Slower speeds will result in reduced potential for LNG carrier strikes and yield minimal wakes inside the bay, such that marine mammals will not be affected by the wakes of passing LNG carriers.

Recent research into whale/ship strike interactions has identified a “sound shadow” that is created by the vessel’s hull by blocking the engine noise generated at the stern from being projected forward toward the bow. This sound shadow essentially veils the engine noise thus catching whales unaware of the vessel’s presence until it is often too late to avoid the vessel or its propellers. Technology has been developed in the form of a submerged directional array that can be deployed at the vessel’s bow to fill the acoustical shadow with sounds detectible by marine mammals and thus avoid a ship strike. The use of sound projection within the bow shadow is currently not required.

JCEP will provide measures proposed by NMFS for avoidance of marine mammals to carriers transporting LNG cargo from the Project to further reduce the likelihood of adverse effects on these species. Some of the suggested measures could include the following:

- Provide training to LNG carrier crews that would include the use of a reference guide such as the “Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska” by Pieter Folkens. This is a pamphlet that could be carried on the LNG carriers.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the carrier to avoid striking protected species.
- When whales are sighted, maintain a distance of 90 meters or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce vessel speed when pods or large assemblages of cetaceans are observed near a vessel underway.
- When whales are sighted in a vessel’s path or in close proximity to a moving vessel, reduce speed or shift the engine to neutral until the whales are clear of the area or path.
- LNG crews will be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the vessel. If the injury or death is caused by a collision with the vessel, appropriate regulatory agencies (FERC or NMFS) will be notified within 24 hours of the incident. Information to be provided will include the date and location (latitude/longitude) of the strike, the vessel name, and the species or a description of the animal, if possible.

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas used as migratory routes by marine mammals, the LNG will float on the water until it vaporizes and will not have an adverse effect on the mammals unless they come in direct contact with the LNG.

#### 3.3.6.6 Project Construction

Land disturbing activities required for the construction of the Project will be confined to the existing property. During construction of the LNG storage tanks and other facilities, disturbed soils will be exposed to potential erosion. To minimize the impacts of erosion and sedimentation on surface waters, land disturbing and construction activities will be conducted in compliance with the National Pollution Discharge Elimination System (NPDES) Permit

Number 1200-C for stormwater discharges during construction activities. Stormwater runoff from the disturbed portions of the Project site will be managed in accordance with a site-specific Erosion and Sedimentation Control Plan (ESCP) included in the NPDES permit, which incorporates stormwater pollution prevention. JCEP will install all necessary erosion and sedimentation control structures in compliance with its ESCP, as well as the provisions of FERC's Plan and FERC's Procedures, both as modified. Following appropriate treatment, all construction stormwater from the Project site will be directed towards the slip.

Spills, leaks, or other releases of hazardous materials during construction of the Project could adversely impact water quality. Hazardous materials entering Coos Bay resulting from material spills being flushed into waterbodies with stormwater runoff or entering Coos Bay directly from leaks or spills at the LNG loading berth could have an adverse impact on water quality and aquatic organisms. A site-specific preliminary spill plan for the construction phase of the Project will be included as part of the NPDES permit to minimize the potential for accidental releases of hazardous materials and to establish proper protocols concerning minimization of, containment of, remediation of, and reporting of any releases which occur.

A Spill Prevention, Containment and Countermeasure Plan (SPCCP) will be prepared for the operational phase of the Project under the NPDES permit to minimize the potential for accidental releases of hazardous materials and to establish proper protocol concerning minimization, containment, remediation, and reporting of any releases which occur. This Plan will meet the requirements of 40 CFR Part 112.

## 3.4 FEDERAL AND STATE LISTED THREATENED AND ENDANGERED SPECIES

Federal agencies are required by Section 7 of the Endangered Species Act (ESA) of 1973, as amended, to ensure that any actions authorized, funded, or carried out by a federal agency do not jeopardize the continued existence of a federally-listed threatened, endangered, or proposed species, or result in the destruction or adverse modification of designated Critical Habitat of a federally-listed species. In addition, Oregon has its own ESA that requires state agencies to protect and promote the recovery of state-listed threatened and endangered species.

For the Project, FERC is required to consult with the USFWS and NMFS for federally-listed threatened and endangered species (or proposed for listing) and Critical Habitat found in the vicinity of the Project and to determine the Project's potential effects on those species or Critical Habitat. Federal candidate species and species of concern do not require federal ESA consultation. JCEP has initiated this consultation (Table 1.8-1, Resource Report 1 – General Project Description). For this report, a list was obtained from the ORBIC on October 19, 2012, for federally-listed species and Critical Habitat occurring within two miles of the Project's action area. At that time, the action area included the LNG export terminal facility, including the South Dunes Power Plant site. The ORBIC database is continually updated and the data received must be updated every six months for compliance with the ESA.

At the state level, consultation is conducted with the ODA for state-listed plant species and the ODFW for fish and wildlife species. However, state regulations pertaining to the protection of botanical resources are limited to ORS 564 and OAR Chapter 603, Division 73. State threatened and endangered plant species that could be present within the Project's boundaries have no legal protective status in Oregon because they would occur on private land and Oregon regulations only apply on all non-federal public lands (state, county, city, etc.). For fish and wildlife species, JCEP is required to coordinate and consult with the ODFW under the Oregon ESA (ORS 496, 506, and 509) and the Oregon Fish and Wildlife Habitat Mitigation Policy (OAR

345-022-0060) regarding state-listed species to ensure conservation of fish and wildlife resources and to develop a fish and wildlife habitat mitigation plan, as appropriate.

A lack of federally-listed species or Critical Habitat for a given area does not necessarily indicate there are no significant elements present, only that there is no information recorded for the site. To ensure there are no significant elements present that may be affected by the Project, the Project site and vicinity, as applicable, have been surveyed during the appropriate season for individual listed species for the county. In addition, JCEP (and its subcontractors) conducted informal consultations with Oregon agencies to determine the presence of state-listed threatened and endangered species that may be affected by the Project, per 18 CFR § 380.12(e)(4) for FERC.

From informal consultation conducted, it appears the Project may affect listed species. In compliance with Section 7 of the ESA, FERC staff is currently preparing a Biological Assessment (BA) for the Project which will be submitted to the USFWS and NMFS with a request to initiate formal consultation. The BA reviews the status of and potential effects by the Project on listed species and Critical Habitat, and includes proposed measures to avoid, minimize, or mitigate impacts on listed species. The BA also identifies and describes EFH that may be adversely affected by the Project, which requires consultation with NMFS under the Magnuson-Stevens Act.

Formal consultation concludes after the USFWS and NMFS each prepare a BiOp that includes analysis of the impact of the Project on listed species or Critical Habitat and determines whether the Project is likely to jeopardize the continued existence of listed species. Jeopardy occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the wild is appreciably reduced. For jeopardy determinations, FERC would be provided with reasonable and prudent measures that would be outlined in an incidental take statement (ITS). The ITS sets forth nondiscretionary terms and conditions, including reporting requirements, that FERC and JCEP must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions would be exempt from the take of ESA-listed species. The BiOp from NMFS would also include conservation recommendations to avoid, minimize or otherwise offset potential adverse effects on EFH, and these recommendations would become a subset of the terms and conditions found in the ITS.

The environmental analysis under this section includes species that are listed by the federal or state government as threatened, endangered, or proposed for listing. Species listed under the Marine Mammal Protection Act and those included as Essential Fish Habitat are described under Section 3.3 for fisheries and marine species.

Twenty-nine federal or state-listed threatened or endangered species, including one proposed species (streaked horned lark), potentially occur in the proposed Project area (Table 3.4-1). The following sections summarize their distributions, habitat requirements, and potential occurrence. Environmental consequences of construction and operation of the Project, including in the LNG carrier transit route, are also discussed, along with proposed mitigation, enhancement, and protection measures.

### 3.4.1 Botanical Species

Five federal and state-listed plant species were identified as having the potential to occur in the Project vicinity. The western lily is the only federally-listed species. State-listed species include the pink sand verbena, Point Reyes bird's-beak, silvery phacelia, western lily, and Wolf's evening primrose. Only one state-listed species (Point Reyes bird's-beak) has been detected within the Project area. The five species are described below.

### 3.4.1.1 Pink Sand Verbena (Federal Species of Concern, State Endangered)

The pink sand verbena (*Abronia umbellata ssp. breviflora*) is the only pinkish-purple-flowered coastal *Abronia* species in Oregon. The historic range of pink sand verbena occurs from California to British Columbia, Canada (USFWS 2006). Its present range is predominantly from Cape Blanco (Curry County) in southern Oregon to Point Reyes National Seashore in Marin County, California; however, they sporadically occur along Oregon's northern and central coast. In the northern portion of its range, most populations occur on broad beaches and/or near the mouths of creeks and rivers. The species usually occurs on beaches in fine sand between the high-tide line and the driftwood zone, and in areas of active sand movement below the foredune. Associate species include sea rocket (*Cakile maritina*), silver burweed, European beachgrass, beach silvertop, and yellow sand verbena (*Abronia latifolia)*.

Suitable habitat for the species was found along the eastern portion of the LNG Terminal site in areas of actively moving dunes and European beachgrass. Surveys conducted on the Project site in 2006 for the majority of the Project site area and in 2012 and 2013 in previously unsurveyed areas for the Project, including the construction worker camp site, did not result in the detection of any individuals (SHN 2006b; SHN 2012). The Project is not expected to affect this species.

### 3.4.1.2 Point Reyes Bird's-Beak (Federal Species of Concern, State Endangered)

Point Reyes bird's-beak (*Chloropyron maritimum ssp. Palustre*, formerly *Cordylanthus maritimus ssp. palustris*) is an annual gray-green and purple-tinged herb that grows 4 to 16 inches tall and has few branched stems. Also referred to as salt marsh bird's beak, it occurs in coastal salt marshes, typically within the zone that is periodically or frequently inundated by high tides (ORBIC 2012b; Brian 2005). Point Reye's bird's-beak inhabits the upper end of maritime salt marshes and its habitat requirements are specific: approximately 7.5 to 8.5 feet above mean lower low water (MLLW), sandy soils with soil salinity of 34 to 55 parts per thousand (ppt), and less than 30 percent bare soil in summer (ODA 2013). It flowers from June to October. Associate species include those that are tolerant of high salinity levels such as salt grass, pickleweed, fleshy jaumea (*Jaumea carnosa*), sea lavender (*Limonium californicum*), and dodder (*Cuscuta salina*). Point Reyes bird's-beak occurs along the Pacific Coast from Tillamook County, Oregon, south to Santa Clara County, California. In Oregon, the species is restricted to Netarts Bay, Yaquina Bay, and Coos Bay, with the majority of known occurrences located in Coos Bay.

Several occurrences of Point Reyes bird's-beak are located in the vicinity of the Project area (ORBIC 2012). Multiple occurrences within Jordan Cove have been observed (ORNHIC 2005; SHN 2012), as shown in Figure 3.4-1. The closest known occurrence to the Project site is located within Jordan Cove along the shoreline east and west of the South Dunes Power Plant site. Potential habitat for this species has also been observed along the shoreline south of the South Dunes Power Plant site. This habitat contains an abundance of the associated species, including pickleweed. Prior to construction, an additional survey for Point Reyes bird's-beak will be conducted during the appropriate blooming period in the area defined as potential habitat for the species.

#### 3.4.1.3 Silvery Phacelia (Federal Species of Concern, State Threatened)

Silvery phacelia (*Phacelia argentea*) is a hairy, fleshy perennial herb with thick leaves that are coated in long, straight, silvery hairs. They occupy open sand above the high tide line, open and partly stabilized sand dunes further inland, and coastal bluffs. They flower from late May to early August. Silvery phacelia occurs in Coos and Curry counties along the Oregon coast and Del Norte County in California, from the vicinity of Bandon, Oregon, south to Crescent City, California. There is one historic collection of the species from Clatsop County, Oregon, to the north in 1933, but there have been no reports of it from that area since. The majority of occurrences are in Oregon (ODA 2013).

Suitable habitat for silvery phacelia exists at the Project site in areas with active or semi-stabilized dunes and upper beach habitat where European beachgrass and red fescue-salt rush herbaceous vegetation associations occur. Surveys conducted on the Project site for the majority of the Project area did not result in the detection of silvery phacelia (SHN 2006b; SHN 2012). The Project is not expected to affect this species.

#### 3.4.1.4 Western Lily (Federal Endangered, State Endangered)

The western lily (*Lilium occidentale*) is a member of the perennial lily family (Liliaceae) and grows up to 5 feet tall with nodding red (sometimes deep orange) flowers. The species was federally-listed as endangered on August 17, 1994, and a final recovery plan was released four years later (USFWS 1998c). It inhabits 31 small, widely separated populations in freshwater marshes and swamps, coastal scrub and prairie, and openings in coastal coniferous forest (Sitka spruce dominated) along the coast of southern Oregon and northern California. It occurs within four miles of the coast, generally on marine terraces below 300 feet above mean sea level (MSL; CNDDB 2005). The western lily is considered a bog plant and grows in areas with perched water tables which are associated with one or two soil types. Occurrences within the Coos Bay area are reported to occur in Blacklock soils (ORNHIC 2005), which are deep, poorly drained soils high in organic content (Hagen 1989); however, it also grows in soils that are well drained that have a significant layer of organic soil.

The wetlands where Western lilies occur are not what are often associated with wetlands. They are in areas where the marsh is flooded in the winter but is typically very dry in the summer. The species emerges in Oregon in late March or early April and flowers in late June or July (USFWS 1998). Species typically associated with western lily include Sitka spruce, Pacific reed grass, willows, false lily-of-the-valley, and evergreen huckleberry (Imper 2003).

The closest known western lily occurrence to the Project site is approximately 5.5 miles northeast at Hauser Bog (ORNHIC 2005). There are not any records of the western lily north of Hauser and the USFWS typically considers Hauser the northern extent along the Oregon Coast for the species (Vander Heyden pers comm. 2013). Surveys were conducted at the Project site in 2006 for the majority of the Project area and again in 2012. The surveys did not result in the detection of western lily (SHN 2006b, SHN 2012). While suitable habitat is located along the terrestrial portion of the LNG carrier transit route in Coos Bay, LNG carrier traffic is not expected to affect the western lily.

#### 3.4.1.5 Wolf's Evening Primrose (Federal Species of Concern, State Threatened)

Wolf's evening primrose (*Oenothera wolfii*) is a rare species of flowering plant in the evening primrose family. It occurs in well-drained sandy soil in coastal strands, roadsides, and coastal bluffs (ODA 2013). This species is associated with a high disturbance regime and several occurrences in California are located along roadsides with sandy soil (CNDDB 2005). Wolf's evening primrose is typically associated with low elevation coastal habitats, but there have been reported occurrences in lower montane coniferous forest in California, at elevations greater than 2,500 feet above MSL (Tibor 2001).

The current range of Wolf's evening primrose is from Curry County in southern Oregon to the northern California coast. The closest known occurrence to the Project site is in Port Orford, Oregon, approximately 60 miles to the south of the Project. The species is included in this analysis as suitable habitat exists within the Project site. Surveys conducted on the Project site did not result in the detection of wolf's evening primrose (SHN 2006b, SHN 2012). The Project is not expected to affect this species.

### 3.4.2 Terrestrial Wildlife Species

#### 3.4.2.1 Reptiles and Amphibian Species

There are no terrestrial federal or state threatened or endangered (or proposed) amphibian or reptile species that occur within the Project site.

#### 3.4.2.2 Birds

Seven bird species that are federal or state-listed as threatened, endangered, or proposed have the potential to occur in the vicinity of the Project, as described below. The locations of federal species detected in the Project site vicinity are shown in Figure 3.3-7.

**Bald Eagle (Federal Delisted, State Threatened)**

The bald eagle (*Haliaeetus leucocephalus*) is a widespread breeder in Oregon, with confirmed nesting in all but four counties. When the bald eagle was delisted on July 9, 2007 (72 FR 37346-37372), legal protections provided to the bald eagle switched to the Bald and Golden Eagle Protection Act and new guidelines were developed (USFWS 2007d). The most substantive change in the guidelines was a reduction in the distance between activities and in occupied nests from 0.5 mile to 660 feet when the activity is visible from the nest (line-of-sight).

Bald eagles are usually associated with large water bodies, including lakes, rivers, and coastal nearshore habitat. Home ranges are usually about 2-3 square miles (Anthony et al. 1990, Garrett et al. 1993). Bald eagle numbers peak in late winter and early spring when breeders, transients, and winter residents are all present (Isaacs and Anthony 2003). They nest on large, prominent trees and snags, usually within a mile of water, and nests are almost always reused (Isaacs and Anthony 2003).

Bald eagles are an uncommon resident of forested habitats near water on the Oregon coast (Eltzroth 1987), including Coos County (Rodenkirk in prep.) and the North Spit (USDI 2005); however, nesting is confirmed in most of Coos County (Adamus et al. 2001). It is not believed that any suitable nest sites exist within the Project site area, but there is ample foraging habitat in and along the bay. During field surveys conducted in 2005, there were five sightings in all seasons. Only one was observed at the Project site, consisting of an incidental sighting of a perched bird, and no nests were found. The rest of the sightings were over or across the bay from the Project site (LBJ 2006). A nest site in the ORBIC database, active at least as recently as 2003, is on Mettman Ridge above Glasgow, roughly three miles from the Project site.

Bald Eagles may be encountered in any of the LNG carrier transit route zones from nearshore coastal waters to the Project site. No nests occur at the Project site and the Project is not expected to affect this species.

**Brown Pelican (Federal Delisted, State Endangered)**

The brown pelican (*Pelecanus occidentalis)*, sometimes referred to as the California brown pelican, is found in nearshore ocean waters, in large bays and river mouths, and on beaches and spits. These birds are rarely seen inland or more than 40 miles from shore and they feed mostly in shallow estuarine waters. Pelicans make extensive use of sand spits, offshore sand bars, and islets for nocturnal roosting and daily loafing, especially by nonbreeders and during the non-nesting season (USFWS 2005).

The brown pelican is considered a common to abundant post-breeding migrant on the North Spit (BLM 2005). It arrives from the south along the Oregon coast in April and becomes abundant by August and September (Eltzroth 1987, Nehls 2003a, Rodenkirk in prep.). Although most brown pelicans have withdrawn to the south by December, small numbers now winter most years in the Coos Bay area (Contreras 1998, Rodenkirk in prep.). Coos Bay adjacent to Jordan Cove is excellent habitat for this species and it was recorded foraging near the Project site more than 500 feet from the shore and loafing across the bay in moderate numbers daily during surveys in October 2012 (SHN 2012). The species was also observed during surveys conducted in 2005-2006 until early September (LBJ 2006). The Project site provides no nesting habitat for the brown pelican.

Brown pelicans may be encountered during any portion of the LNG carrier transit route but are most likely to be encountered in the coastal nearshore waters out to the 0.3 mile zone. They appear unaffected by industrial activity already taking place in and around the bay and no impact to this species is anticipated from the development of the Project.

**Marbled Murrelet (Federal Threatened, State Threatened)**

The marbled murrelet (*Brachyramphus marmoratus*) is a small, chubby seabird that has a very short neck. It was listed as threatened under the ESA on October 1, 1992, for the Pacific region (including Washington, Oregon, and California). Critical Habitat was designated for the marbled murrelet (MAMU) on May 24, 1996 (61 FR 26257-26320). Following a series of proposed revisions in 2006 and 2008, a final rule on revised Critical Habitat was issued on October 5, 2011 (76 FR 61599-61621). MAMUs are not recovering like they should be and they have a high predation rate along the coast.

MAMUs nest primarily in coastal, old growth forests within 50 miles of the coast that are characterized by large conifer trees, multi-storied stands, and moderate-to-high canopy coverage from Alaska to Monterey Bay, California. They are also known to nest in mature forests with old growth characteristics. Nest trees for MAMUs need to be 19.1 inches or greater in diameter breast height (dbh), greater than 107 feet in height, have a least one platform 4 inches or greater in diameter that occurs a minimum of 32.5 feet above the ground (due to the way the birds take off from the platform—dropping down and coming up), and have an access route through the tree canopy that a MAMU could use to approach and land on the platform. It also needs a tree branch or foliage that provides protective cover (Nelson and Wilson 2002). The platform cannot be on a snag with no cover.

MAMUs spend a majority of their life on the ocean (USFWS 2007). Nesting adults make daily foraging trips to shallow, protected, nearshore coastal waters, feeding mostly on small fish but sometimes on euphausiids (small shrimp-like crustaceans). When at sea, MAMUs are rarely found more than a few miles from the shore (Hunter et al. 2005).

The USFWS consults on projects within ¼ mile of Critical Habitat for effects from construction with heavy equipment and one mile for more complex projects such as blasting and large helicopter work (Bridgette Tuerler pers comm. 2013). The USFWS is primarily concerned about removing MAMU habitat or impacting the land or the ability of the land to grow trees. It is also concerned about possible predation to the species due to predators attracted to potential habitat in the vicinity by human activities.

For sites determined to be close to potential MAMU habitat (whether listed as Critical Habitat or not), it is assumed there will be noise associated with the proposed work and, therefore, the Project could potentially affect the species. The extent of that effect would depend on the timing, associated activities and equipment, duration, season, location, etc. If potential Critical Habitat occurs within ¼ mile of the Project, these details would need to be considered and analyzed in a Biological Assessment before the USFWS could provide concurrence, as required under the ESA.

The species is considered uncommon to rare year-round on the Oregon coast (Marshall et al 2003), but Coos Bay is within the zone of highest density (Strong et al 1995). The MAMU nests in the Elliott State Forest northeast of Coos Bay in the Oregon Coast Range, and it probably nests in the Coos Bay area as well (Adamus et al. 2001). It is considered an uncommon, year-round, offshore resident on the North Spit (BLM 2005). One to four MAMUs are observed most years during the annual Coos Bay Christmas bird count (NAS website 2012). Although none were observed during surveys conducted for the Project (LBJ 2006), it is considered possible that MAMUs could occur on the bay within the general Project area and perhaps over the Project site in transit between nesting and feeding sites. MAMUs could be also be encountered along the LNG carrier transit route, as they generally forage in the nearshore region within three miles of the shore (McShane et al. 2004).

**Northern Spotted Owl (Federal and State Threatened)**

The northern spotted owl (*Strix occidentalis caurina*) is dependent on old-growth components in coniferous forests. In Oregon, it is found in low- and mid-elevation coniferous forests in the Coast, Siskiyou, and Cascade ranges (Forsman 2003). There are many spotted owl habitat areas in the forests inland from Coos Bay. The nearest site to the Project site is approximately five miles away in the Kentuck Creek drainage (ORBIC 2012). However, the species is extremely rare on the immediate coast of Oregon (Eltzroth 1987), rare in Coos County (Rodenkirk in prep.), and absent from coastal Coos County (Adamus et al. 2001). The northern spotted owl is absent from the North Spit wildlife list (BLM 2005) and is unlikely to be encountered in any of the terrestrial habitat in or near the Project vicinity or along the LNG carrier transit route. The species is not discussed further in this document.

**Short-tailed Albatross (Federal Endangered, No State Listing)**

The short-tailed albatross (*Phoebastria albatrus*) is the largest pelagic seabird in the North Pacific. Its long, narrow wings are adapted to soaring low over the ocean. It is best distinguished from other albatrosses by its large bubblegum-pink bill. The short-tailed albatross was federally-listed as endangered throughout its range on July 31, 2000. Critical Habitat is not prudent for this species. A recovery plan, drafted in 2005, is not finalized.

Historically, millions of short-tailed albatrosses bred in the western North Pacific on several islands south of the main islands of Japan. Only two breeding colonies remain active today and both are in Japan. Single nests occasionally occur on Midway Island, Hawaii. Eggs hatch in late December through early January and chicks remain near the nest for about five months, fledging in June. After breeding, short-tailed albatrosses move to feeding areas, with juveniles remaining at sea up to ten years before returning to nest. The species is distributed widely throughout its historical foraging range of the temperate and subarctic North Pacific ocean and they are often found close to the U.S. coast. They have been known to forage up to 1,988 miles from their breeding ground (USFWS 2012).

The short-tailed albatross population is estimated to be 1,200. Of these, the total number of breeding age birds is thought to be approximately 600 birds (USFWS 2013). The worldwide population of short-tailed albatrosses continues to be in danger of extinction throughout its range due to natural environmental threats, small population size, and the small number of breeding colonies. Longline fishing, plastics pollution, oil contamination, and airplane strikes are not viewed as threats by the USFWS to the species' survival but are considered threats to the conservation and recovery of the species.

Short-tailed albatross have been documented to occur off the Oregon coast in the vicinity of Coos Bay. ORBIC data reported a number of different occurrences along the coastline that transits the Coos Bay area. In November 2006, a radio-tagged bird moved from Alaskan waters to the mouth of the Columbia River, then down the Oregon coast to Cape Blanco (between Bandon and Port Orford), then out to sea and back to the Aleutian Islands in Alaska (ORBIC 2012). From September 25-29, 2009, another radio-tagged bird moved from Alaskan waters to off the mouth of the Columbia River, then headed down the Oregon coast on September 27 and into California. Other occurrences recorded included a short-tailed albatross observed off the coast of Yachats, between Florence and Newport to the north, on April 8, 2010.

Short-tailed albatross spend much of their time feeding in nutrient-rich waters of ocean upwelling which often occur at continental shelf breaks (USFWS 2005a). The short-tailed albatross could potentially be encountered within the LNG carrier transit route zones within the EEZ.

**Streaked Horned Lark (Federal Proposed, State Sensitive-Critical)**

The streaked horned lark (*Eremophilia alpestris strigata*) is a rare subspecies of the horned lark. It migrates between Oregon and Washington with breeding populations found in the Puget Sound lowlands, Columbia River/coastal Washington, and the Willamette Valley in Oregon from late March to early August. A previous candidate for federal listing, it was proposed for listing as a threatened species under the ESA on October 11, 2012. In addition to the listing, Critical Habitat was proposed for 7 counties in Washington and 11 counties in Oregon, but did not include Coos County. The closest county with Critical Habitat is Lane County to the north.

Some individuals winter in California (Pyle 1997) and occur along the Oregon coast on migration, while a few winter on the coast. The species occurs in bare and sparsely vegetated habitats such as coastal dunes, beaches, gravel roads, airport runways, grazed pastures, and dry mudflats; however, they do not occur on rolling or steep areas at these sites. Where deflation plains occur, streaked horned larks are often behind the foredune (Pearson pers comm. 2013). Larks also occur where dredge spoils have been deposited or in areas where there is accretion (deposition) of sand causing beach areas to become wider, provided the sites are sparsely vegetated and are immediately adjacent to water. For sites not adjacent to water, the area of expanse has to be quite large, likely 300 acres or greater, although further studies are needed (Pearson pers comm. 2013).

During winter surveys conducted in 2004/2005, streaked horned larks were found on dune and beach habitat adjacent to open water with few or no trees and shrubs on the Washington coast. On the lower Columbia River they were primarily found on sparsely vegetated dredge spoils (Pearson et al. 2005). The streaked horned lark has been documented on the North Spit (BLM

2005) and may winter over on the southern Oregon coast (Pearson et al. 2005). They spend the winter in large groups of mixed subspecies of horned larks in the Willamette Valley, and in smaller flocks along the lower Columbia River and Washington Coast (Pearson et al 2005).

When new unvegetated land is created by dredge spoils and accretion, it is not used by larks for the first year or two after deposition. Once the site becomes sparsely vegetated it can be quickly colonized by larks, especially on island spoils where off-road vehicle (ORV) traffic does not occur. If the site becomes colonized by non-native beach grasses (*Ammophila spp.,* including European beachgrass) it is no longer used by streaked horned larks once it becomes densely vegetated (Pearson and Hopey 2004). There is a fairly narrow window of time when the habitat is sparsely vegetated and appropriate for larks. In addition, dredge spoils colonized by Scotch broom (*Cytisus scoparus*) or horsetail (*Equisetum sp.*) are not used by the species (Pearson et al. 2005). As sandy habitats on the coast continue to be colonized with a dense covering of beachgrass, the larks do not use these habitats for breeding or over-wintering.

There appear to be very few streaked horned larks remaining in the world (probably between 500 and 1000 birds) and preliminary genetics work suggests that the remaining birds have little genetic diversity. This result suggests that the streaked horned lark population may already be experiencing the deleterious effects of inbreeding or the results of a small founder population. The remaining populations are vulnerable to all of the threats small populations commonly face (e.g., vulnerability to environmental and demographic variability and to the loss of genetic variability)(Pearson et al. 2005).

A focused field evaluation of the Project site on the North Spit was conducted by SHN Consulting (SHN) staff on April 23, 2013, to assess the potential for streaked horned lark habitat to occur (Figure 3.4-2). One small area approximately 75' by 150' was noted at the South Dunes Power Plant site; however, it is surrounded by the previous mill site industrial footprint and is not adjacent to open water. Along the utility corridor and access road between the South Dunes Power Plant and LNG Terminal sites, sparsely vegetated portions of the rolling (and at times steep) dunes in the area was noted; again, the sites were not adjacent to open water. Small pockets of potential habitat were also noted in the upper half of the slip site, but they are surrounded by and being encroached by European beachgrass, gorse, and Scotch broom (hence making it unlikely habitat). An additional area at the northwest tip of the Project site, immediately south of the Trans-Pacific Parkway, also provides sparsely vegetated sand habitat but is not adjacent to open water.

The "weedy fields between the shoreline and dunes on the Roseburg Forest Products facility" noted in previous surveys as potential habitat (LBJ 2006) were scraped off approximately five years ago and planted with grass that has become dense. When the previous surveys were conducted in 2005 and 2006, the site was likely at the stage between unvegetated landscape and dense covering of grasses. That habitat no longer exists and the site would no longer be considered potential habitat for the streaked horned lark.

Laura Todd, USFWS Newport Field Office, in a telephone conversation with SHN staff on April 29, 2013, said the USFWS has not done long term studies regarding the streaked horned lark to date and they are not sure of the range in coastal Oregon. So far the range has been primarily noted along coastal Washington; however, the USFWS does not discount the possibility that streaked horned lark habitat could exist along the Oregon coast.

Dr. Scott Pearson, Senior Research Scientist for the Washington Department of Fish and Wildlife, has been studying avian ecology for over 20 years and his research has included focused studies on the streaked horned lark. In a telephone conversation with Dr. Pearson by

SHN staff (April 29, 2013), Pearson said he would not be surprised if streaked horned larks were found to breed on the Oregon coast as it seems the habitat is ideal. Portions of the North Spit are well-suited for lark habitat, particularly in areas where there are western snowy plovers and habitat restoration has occurred. It is possible that larks could share the same habitat with plovers. Pearson found a lark nest within 5 meters of a plover nest in Washington. They use very similar habitat, although plovers use more extreme open habitats, whereas the lark needs some vegetation.

Based on the habitat specifications provided by Dr. Pearson in addition to a literature review of reports documenting research on the streaked horned lark, although potential lark habitat appears to exist in pockets of the Project footprint, those areas do not meet the criteria described by Dr. Pearson as essential for lark occurrence. Occurrence of the streaked horned lark is not anticipated at the Project site. They may be encountered within the general Project vicinity or along the LNG carrier transit route; however, the species would likely keep a distance and avoid close interactions.

**Western Snowy Plover (Federal Threatened, State Threatened)**

The western snowy plover (*Charadrius alexandrinus nivosus*) is a small shorebird approximately 6 inches long with a thin dark bill. The Pacific Coast breeding population includes Oregon, with coastal populations typically consisting of resident and migratory birds. The North Spit of Coos Bay supports the most productive snowy plover population segment on the Oregon coast.

The Pacific Coast population of the western snowy plover was listed as a threatened species under the ESA on March 5, 1993. In addition to being listed as threatened under the ESA, Critical Habitat was designated for the Pacific Coast population in 1999 and a recovery plan for the species was developed by the USFWS (USFWS 2007b). Objectives in the recovery plan include: 1) achieving well-distributed increases in numbers and productivity of breeding adult birds, and 2) providing for long-term protection of breeding and wintering plovers and their habitat.

The southwestern portion of the North Spit is designated as Critical Habitat for the western snowy plover from the ocean beach at Horsfall to the Coos Bay north jetty and includes all federal lands at the south end. The Project site is greater than 2.5 miles from the northern extent of Critical Habitat and greater than 4.5 miles from the primary nesting areas. Nesting in Oregon may occur as early as mid-March, with peak nest initiation occurring from mid-April through mid-July. The closest nest is 2.57 miles from the Project (ORBIC 2010). On the coast, it is almost exclusively a bird of open sand beaches. It is unlikely that this species would nest in or around Jordan Cove due to the lack of primary habitat for the species. Its typical coastal nesting habitat is at the upper edge of the beach below the foredunes. It also nests on bare spits at small estuary mouths and, on the North Spit, is most prevalent on restored sand habitat east of the foredune.

Current management activities and use restrictions within the Coos Bay North Spit Recreation Management Area relative to the snowy plover population include predator management, symbolic fencing, habitat restoration, public outreach and education by BLM staff, monitoring of snowy plover populations, and recreational use restrictions in place from March 15 to September 15 of each year. Recreational use restrictions include seasonal re-routing of the foredune road along with prohibiting vehicles, camping, and dogs. Non-prohibited recreational use (i.e., jogging, beach combing, horseback riding) is restricted to the wet sand outside of roped off and signed breeding areas.

USFWS surveys conducted on the North Spit document an increase in adults from 27 in 2005 to 52 in 2012. Total adults surveyed in Oregon have increased from 100 in 2005 to 206 in 2012. The North Spit population accounts for approximately 25 percent of the total adults observed in Oregon. On the Pacific Coast (including Washington, Oregon, and California), California has the highest documented occurrence, with 1621 adults surveyed in 2012; however this number is down from 1680 adults surveyed in 2005.

There does not appear to be any typical habitat in the Project site. While an occasional individual may use the mudflats adjacent to Jordan Cove for foraging, breeding is unlikely. None were detected during field surveys conducted for the Project in 2005 and 2006, and again in 2012. Western snowy plovers may be encountered in the LNG carrier transit route zones from nearshore coastal waters to the Project.

#### 3.4.2.3 Mammal Species (Terrestrial)

**Gray Wolf (Federal Endangered, State Endangered)**

Gray wolves (*Canis lupus*) in Oregon remain listed statewide as endangered under the Oregon ESA. Wolves occurring west of Oregon Highways 395/78/95 continue to be federally protected as endangered under the federal ESA. The USFWS is in the process of evaluating the classification status of gray wolves currently listed in the contiguous U.S. In the federally listed portion of Oregon, the ODFW implements the Oregon Wolf Conservation and Management Plan (OWP) under the guidance of the Federal/State Coordination Strategy (March 2011).

Wolves occurring in Oregon today are part of the Northern Rocky Mountain wolf population. They are descendants of wolves originally captured in Canada and released in Yellowstone National Park and Idaho in the mid-1990s. Wolf numbers fluctuate throughout the year as wolves disperse, pups are born, and new packs are formed. The Oregon wolf population is officially documented at the end of each year. On December 31, 2012, the minimum Oregon population was 53 wolves. This means that at least 53 wolves were documented. It is likely that there are more, as lone wolves can be challenging to document.

Oregon's wolf population continued to increase in distribution and abundance in 2012 and at year-end the minimum wolf population was 46 wolves in six packs. All six packs met the criteria as breeding pairs. All known resident wolves occurred in Wallowa, Umatilla, Union, and Baker counties. This marks the first year that the initial OWP conservation population objective to have four breeding pairs in eastern Oregon was reached.

It is unlikely the gray wolf occurs on the North Spit and the Project vicinity, given current tracking and distribution data available (ODFW 2013). The Project is not anticipated to have any impact to the gray wolf and the gray wolf does not warrant further investigations at this time.

### 3.4.3 Fisheries (Including Marine Species)

There are no threatened or endangered fish species listed by the ODFW or NMFS that spend their entire life cycle within Coos Bay or the area where the Project will be constructed. Three federally-listed anadromous fish species spend a portion of their life cycle within the estuarine environment of Coos Bay, including the area of the access channel and slip site. Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch)*, southern distinct population segment (DPS) green sturgeon (*Acipenser medirostris*), and southern DPS Pacific eulachon (*Thaleichthys pacificus*), were federally-listed (2008, 2006 & 2010, respectively) as threatened under the ESA. These three species have not warranted listing as threatened or endangered by the State of Oregon. Use of the Coos Bay system by eulachon and green sturgeon is sporadic at best (based on various ODFW seining surveys and personal communications) and there is very little habitat available for coho salmon in the Project area.

For analysis under the ESA for fish species, the action area includes all areas to be affected directly or indirectly by the Project and not merely the immediate areas involved in the action. Typically the action area extends 500 feet upstream from the Project site and 1,500 downstream from the downstream end of the Project site in Coos Bay due to potential impacts from stormwater discharge, turbidity, contaminant dispersion, and habitat loss. The action area also incorporates the construction worker camp and the Kentuck and eelgrass bed mitigation sites.

#### 3.4.3.1 Oregon Coast Coho Salmon (Federal Threatened, State Sensitive-Critical)

Oregon Coast (OC) coho salmon are one of several anadromous salmonid species that utilize Coos Bay for migration and rearing habitat for adult and juveniles on their way to and from the ocean between marine and freshwater environments. On February 4, 2008, NMFS listed the naturally spawning populations within the Evolutionary Significant Unit (ESU) of OC coho salmon as a federal threatened species under the ESA. Critical Habitat for this ESU has been designated within several freshwater sub-basins of the Coos Bay system; however, no critical habitat exists within the Project action area.

OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population (Lawson et al. 2007). An independent population is defined as having minimal demographic influence from adjacent populations and is viable-in-isolation. An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations (McElhany et al. 2000). The Coos River population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU.

Annual spawning surveys conducted by the ODFW document the Coos River’s population’s annual abundance varies considerably from year to year. The 2012 ODFW monitoring report on the status of Oregon stocks of coho salmon for 2011 summarizes the results of status and trend monitoring for Oregon’s naturally spawning coho salmon populations through the 2011 run year (October 2011 through February 2012). Monitoring results include:

1. Abundance of naturally spawning coho salmon;
2. Density (fish/mile) of naturally spawning coho salmon;
3. Coho salmon spawn timing and distribution; and
4. Proportion of hatchery (marked) coho salmon in naturally spawning populations.

Surveys conducted at 29 sites for OC coho ESU populations on the Coos River determined fish presence at 83 percent of the sites. Annual abundance estimates of naturally spawning wild adult coho salmon in the OC coho ESU for run years 1990 through 2011 document that the Coos River’s population’s annual abundance varies considerably from year to year (Table 3.4-2). The 2011 estimates show a recent negative trend in abundance at the ESU level for the average over the past 10 years. The 2011 estimates are more symbolic of estimates from the previous 10 years.

#### 3.4.3.2 Pacific Eulachon (Federal Threatened-Southern DPS, No State Listing)

Eulachon (commonly called smelt, candlefish, or hooligan) is a small, anadromous fish from the eastern Pacific Ocean. In North America they range from northern California into the southeastern Bering Sea. On March 18, 2010, NMFS listed the southern DPS of eulachon as threatened under the ESA, followed by designating Critical Habitat for the southern DPS on October 20, 2011 (76 FR 65323). The southern DPS ranges from Nass River, British Columbia, to Mad River, California, and includes Coos Bay and its upper reaches. NMFS has not designated EFH for the Coos Bay system. Prior to being listed as threatened under the ESA in 2010, the commercial catch of eulachon from the Columbia River from 1938 to 1992 averaged approximately 2 million pounds per year. Since the mid-1990s, however, eulachon populations have decreased dramatically. Between the years of 1993 to 1996 the average annual catch dropped to approximately 43,000 pounds, a nearly 98 percent decline.

Eulachon are plankton-feeders, chiefly eating crustaceans such as copepods and euphausiids (Barraclough 1964). They typically spend three to five years in saltwater before returning to freshwater to spawn. Many sources note that runs tend to be erratic, appearing in some years but not others (NMFS 2006). They do not feed in fresh water and remain there only a few weeks to spawn (Rogers et al. 1990).

There is currently little information available about eulachon presence in Coos Bay. Monaco et al. (1990) described eulachon as rare in Coos Bay. While eulachon were mentioned as occurring in other studies conducted in the bay in 1971, Wagoner et al. (1990) stated that "eulachon may have occurred in large numbers in past years [in Coos Bay], but they have apparently not been abundant enough in recent years to attract an active dipnet fishery". More recently, Miller and Shanks (2005) surveyed the distribution of 28 identified larval and juvenile fish species in Coos Bay for more than three years between 1998 and 2001, but did not encounter eulachon.

Adults begin moving through the bay as early as December and spawning typically occurs from January to mid-May, with the peak in February to mid-March. When present, eulachon may utilize both shallow and deep water habitats within the estuary as they migrate to spawning grounds. They will only spawn in lower reaches of rivers and major tributaries (i.e., the Coos River), as they need moving water and large substrate to spawn. Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents. When the larvae reach juvenile size, they disperse to the ocean as soon as able. Juveniles may migrate out as early as February to as late as almost mid-summer (Chuck Wheeler pers comm.). Adult eulachon do not always die after spawning so they could return to the ocean.

Very little is known about the offshore distribution of adult or immature eulachon outside the spawning season, although abundances in particular locations show responses to oceanic conditions (Emmett and Brodeur 2000). Eulachon appear to live near the ocean bottom on the continental shelf at moderate depths that commonly range from 20 to 200 meters, but they may occur as deep as 500 meters (Hay and McCarter 2000).

#### 3.4.3.3 Green Sturgeon (Federal Threatened-Southern DPS, No State Listing)

Green sturgeon are long-lived, slow-growing fish, and are the most marine-oriented of the sturgeon species. Although they are members of the class of bony fishes, the skeleton of sturgeons is composed mostly of cartilage. Instead of scales sturgeon have five rows of characteristic bony plates on their body called scutes. The backbone of the sturgeon curves upward into the caudal fin, forming their shark-like tail. On the ventral, or underside, of their flattened snouts are sensory barbels and a siphon-shaped, toothless mouth.

Green sturgeon is a widely distributed and marine-oriented species. They are believed to spend the majority of their lives foraging in nearshore oceanic waters, bays, and estuaries, ranging from nearshore waters in Baja California to those in Canada. They utilize both freshwater and saltwater habitat and spawn in deep pools or holes in large, turbulent, freshwater river mainstems (Moyle et al. 1992).

There are two distinct population segments defined for green sturgeon—a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NMFS 2008). The southern DPS includes all spawning populations of green sturgeon south of the Eel River in California.

The southern DPS of the North American green sturgeon was federally-listed as threatened on April 7, 2006, under the ESA. The species has not warranted protective listing status by the State of Oregon. Studies have confirmed the migratory nature of green sturgeon between northern and southern DPS units. As such, NMFS took an inclusive approach when determining the geographical area occupied by the southern DPS and designated Critical Habitat from the Bering Sea, Alaska, to the U.S. California and Mexico border.

Younger green sturgeon reside in freshwater, with adults returning to freshwater to spawn when they are about 15 years of age and more than 4 feet in size. The species only spawns every 2 to 5 years (Moyle 2002). Adults typically migrate into freshwater beginning in late February and spawning occurs from March to July, with peak activity from April to June (Moyle et al. 1995). Specific spawning habitat preferences are unclear, but eggs likely are broadcast over large cobble substrates. They range from clean sand to bedrock substrates as well (Moyle et al. 1995). It is likely that cold, clean water is important for proper embryonic development.

The principal factor in the decline of the southern DPS is the reduction of their spawning area in California. Other threats to the southern DPS include insufficient freshwater flow rates in spawning areas, contaminants (e.g., pesticides), bycatch of green sturgeon in fisheries, potential poaching (e.g., for caviar), entrainment by water projects, influence of exotic species, small population size, impassable barriers, and elevated water temperatures. If a green sturgeon spawns in Oregon, it is not part of the southern DPS and not considered threatened under the ESA. Both southern and northern DPS green sturgeon may occur in Coos Bay, in addition to white sturgeon (Mike Gray pers comm.).

Green sturgeon spend more time in the ocean, as they have less tolerance for freshwater than white sturgeon, but they do come in and out of the bay.

The distribution of green sturgeon is not well known, although southern DPS green sturgeon are reported to congregate in coastal waters and estuaries and are present in Coos Bay. Southern DPS individuals were documented to occur by sampling in a 2006 study (Israel and May 2006). Because Coos Bay is not their natal stream, southern DPS green sturgeon are likely to be present from June through October. While in Coos Bay estuary, they are likely feeding in shallow areas and seeking out the deep water for resting.

### 3.4.3.4 Marine Mammals

Three federally-listed marine mammals with a potential to occur near the Project site are discussed below.

**Steller Sea Lion (Federal Endangered, No State Listing)**

The Steller sea lion (*Eumetopias jubatus*), also called northern sea lion, ranges along the North Pacific coast from Japan to southern California (USFWS 2007a). It breeds on rocky beaches, often on islands, and at other times is frequently seen hauled out on select coastal rocks, jetties, marinas, and navigation buoys. It forages at sea for fish and invertebrates, sometimes to several hundred miles from land. The Oregon population was estimated at over 5,000 in 2002 and productivity appears to be increasing (NOAA website). There are no rookeries in Coos County. The nearest (one of Oregon's two primary rookeries) is at Orford Reef in Curry County (Brown 1988, NMFS 1992b). There is a haul-out site at Cape Arago in Coos County, roughly ten miles from the Project site area (ORBIC, NMFS website). While an occasional Steller sea lion might enter Coos Bay and the species is included on the North Spit wildlife list (USDI 2005), there are no suitable haul-out sites within the Project site and the species is not expected to occur there.

Steller sea lion Critical Habitat includes all major Steller sea lion rookeries and associated air and aquatic zones. Critical Habitat includes an air zone that extends 3,000 feet above areas historically occupied by sea lions at each major rookery in California and Oregon, which is measured vertically from sea level. Critical habitat includes an aquatic zone that extends 3,000 feet seaward in state and federally managed waters from the baseline or basepoint of each major rookery in California and Oregon. The following are designated as Critical Habitat in Oregon:

- Rogue Reed: Pyramid Rock; and
- Orford Reef: Long Brown Rock and Seal Rock.

Based on the above information, Critical Habitat for the Steller sea lions is not designated within the LNG carrier transit route zones. However, haulout areas at Cape Arago located in the vicinity of the LNG carrier transit route are part of the Oregon Islands National Wildlife Refuge. Steller sea lions are likely to occur within the LNG carrier transit route zones.

**Gray Whale (Federal Endangered, State Endangered)**

The gray whale *(Eschrichtius robustus)* is a large baleen whale that is distributed in the northern Pacific Ocean in western and eastern stocks. The eastern Pacific stock feeds in the summer in Chukchi Sea, western Beaufort, and the northern Bering Sea. They migrate from November through early February south to lagoons on the Pacific coast of central and southern Baja California. Northward migration occurs after the calving and breeding season, from early February to May. These whales have the longest known migration of any mammal. Adult females reach 15 meters in length and males reach up to 14.3 meters and weigh up to 33,850 kilograms. Gray whales feed on benthic species that are buried in sediments.

According to OPDR (2007), gray whales are the most predominant whales seen along the Oregon coast. They migrate twice a year during winter and spring as stated above. About 200 of them feed along the coast during the summer months. Gray whales have on occasion penetrated Coos Bay beyond the Project site areas and have been seen in Coos Bay at about the same frequency as killer whales. Gray whales may be encountered in the LNG carrier transit route zones during their southern migration from November through early February or from early February to May during the northern migration.

**Southern-Resident Killer Whale (Federal Endangered, No State Listing)**

The killer whale (*Orcinus orca*) is a wide-ranging predator of the open ocean that has a worldwide distribution but is most common in the subarctic, temperate, and subantarctic waters (Maser et al. 1981). The southern resident killer whale was proposed for delisting in 2012 and is currently under review (77 FR 70733). Along the North Pacific coast, resident killer whales occur from Oregon and Washington to the Bering Sea (NMFS 2006) and their distribution is correlated to food supplies (Maser et al. 1981). This federally-listed species feeds primarily on fish and marine mammals. According to Maser et al. (1981), killer whales are most abundant in the Puget Sound in November and late summer. Most southern California killer whale sightings occur in fall, winter, and early spring. Based on this information, killer whales could be encountered in Oregon during the fall, winter, and spring, with occasional sightings throughout the year. Killer whales occasionally enter bays in pursuit of salmon and pinnipeds and have on occasion penetrated Coos Bay beyond the Project site. They could also occur within the LNG carrier transit route zones.

#### 3.4.3.5 Waterway for LNG Marine Traffic

Additional federal threatened or endangered species that could occur within the zones of the LNG carrier transit route are described below. The locations of federal threatened or endangered species are shown in Figure 3.5-2.

**Blue Whale (Federal Endangered, State Endangered)**

Blue whales (*Balaenoptera musculus*) are distributed from the equator to polar icepacks in both the northern and southern hemispheres. The eastern North Pacific population winters off Mexico and Central America and feeds off the coast from California to British Columbia during the summer and fall from June through November. Blue whales are most likely seen off the Oregon coast from late May through June and from August through October. This species is a baleen whale that feeds on euphausiids, commonly referred to as krill. Adult male blue whales reach up to 32.6 meters in length and weigh up to 133 metric tons. Females reach 33.3 meters in length and may weigh in excess of 151 metric tons. According to the OPRD (2007), occasional blue whales are sighted off the Oregon coast. Blue whales may be encountered along the LNG carrier transit route between the summer months specified above.

**Fin Whale (Federal Endangered, State Endangered)**

Fin whales (*Balaenoptera physalus*) are widely distributed throughout the world's oceans. The wintering grounds in the Pacific Ocean are from central California to Cabo San Lucas at the southern tip of the Baja California peninsula in Mexico. Their summer range extends from California to the Chukchi Sea in the southern Arctic Ocean between Alaska and Siberia. This species likely occurs along the Pacific coast from California to Washington from May to September. Adult female fin whales reach a length of 27.3 meters and a weight up to 100 metric tons. Adult males reach a length of 24.4 meters and weigh up to 89 metric tons. Fin whales are reported to return to the same feeding grounds year after year. It is not known if feeding grounds are located within the LNG carrier transit route. This species primarily feeds on euphausiids and secondly on fishes and cephalopods (i.e., squid). According to the OPRD (2007), occasional fin whales are sighted off the Oregon coast. This species may be encountered in the LNG carrier transit route from May to September.

**Humpback Whale (Federal Endangered, State Endangered)**

The humpback whale (*Megaptera novaeangliae*) is probably best known for its breaching and underwater vocalizations. This species is distributed in both the northern and southern hemispheres, from tropical waters to the edge of the polar ice. In the eastern Pacific, humpback whales have been observed from the Chukchi Sea to southern Mexico. Adult male humpbacks reach 15 meters in length and females reach up to 18 meters in length. This species feeds on benthic and pelagic euphausiids and small schooling fishes. OPRD (2007) states that humpbacks are sometimes seen off the Oregon coast at the same time as gray whales, but are not observed as frequently because their herd size is smaller. Humpbacks may be encountered in any of the three zones of the LNG carrier transit route from spring through early fall.

**North Pacific (Right) Whale (Federal Endangered, No State Listing)**

The northern right whale *(Eubalaena glacialis)* is a large baleen whale that reaches up to 18 meters and 100 tons. The winter distribution includes the Oregon coast south to central Baja California, Mexico (Maser et al. 1981). Summer distribution is in cool temperate waters in the north Pacific from the Bering Sea to latitude 50 degrees north. Northern right whales feed solely on zooplankton consisting of copepods and euphausiids and occasionally on pteropods (Maser et al. 1981). OPRD (2007) does not list the northern right whale as one of the species that may occasionally be observed along the Oregon coast. However, based on the distribution information, the northern right whale may be encountered in the LNG carrier transit route during winter months.

**Sei Whale (Federal Endangered, State Endangered)**

Sei whales (*Balaenoptera borealis*) are distributed worldwide, including an eastern Pacific stock that is found from Alaska to Mexico This species is found off the central California coast in the late summer or early fall and appears to move farther south and offshore in the winter. No information was found for this species distribution along the Oregon coast. Sei whales feed on copepods, euphausiids, sauries, anchovies, herring, sardines, squid, and jack mackerel. Adult males reach a maximum length of 17.7 meters and females reach a maximum length of 18.6 meters in the northern hemisphere. The OPRD (2007) does not list the Sei whale as one of the species that can be observed off the Oregon Coast. However, based on the information from Maser et al. (1981), this species may be encountered in the LNG carrier transit route during summer months.

**Sperm Whale (Federal Endangered, State Endangered)**

The sperm whale (*Physeter macrocephalus*) is the largest of the toothed (Odontoceti) whales and is distributed worldwide except for the pack ice of polar regions. Their diet consists of fishes and cephalopods. Adult male sperm whales may reach up to 16.8 meters in length (the average is 14.6 meters) and females grow up to 11.7 meters and weigh 37 metric tons. Sperm whales migrate toward polar regions in the summer and to temperate regions in the winter. OPRD (2007) states that sperm whales are occasionally sighted off the Oregon coast from March to September. Sperm whales may be encountered in the LNG carrier transit route from spring to fall.

#### 3.4.3.6 Sea Turtles

**Green Sea Turtle (Federal Threatened, State Endangered)**

Green sea turtles (*Chelonia mydas*) have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego south (NMFS 2007a). Green sea turtles primarily use three types of habitat: oceanic beaches (for nesting), convergence zones in the open ocean, and benthic feeding grounds in coastal areas (NMFS 2007a). Green sea turtles could potentially be encountered within the LNG carrier transit route.

**Leatherback Sea Turtle (Federal Endangered, State Endangered)**

Leatherback sea turtle (*Dermochelys coriacea*) nesting grounds are located around the world, with the largest remaining nesting assemblages found on the coasts of northern South America and West Africa (NMFS 2007). Adult leatherback sea turtles are capable of tolerating a wide range of water temperatures and have been sighted along the entire coast of the United States and as far north as the Gulf of Maine and south to Puerto Rico, the U.S. Virgin Islands (USVI), and into the Gulf of Mexico (NMFS 2007). The Pacific subspecies has declined so drastically that a Pacific Leatherback Conservation Area, wherein gillnet fishing is restricted, has been established stretching from central California to central Oregon (LBJ 2006). Leatherback sea turtles could potentially be encountered within the LNG carrier transit route.

**Loggerhead Sea Turtle (Federal Endangered, State Threatened)**

Loggerhead sea turtles (*Caretta caretta*) occupy three different ecosystems during their lives—the terrestrial zone, the oceanic zone, and the neritic (coastal) zone. Loggerhead sea turtles are circumglobal in distribution, occurring throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian oceans. Loggerhead sea turtles are the most abundant species of sea turtle found in U.S. coastal waters (NMFS 2007b). Occasional sightings are reported along the coasts of Washington and Oregon, but most records are of juveniles off the coast of California (NMFS 2007b). Loggerhead sea turtles could potentially be encountered within the LNG carrier transit route.

**Olive Ridley Sea Turtle (Federal Threatened, No State Listing)**

The olive ridley sea turtle (*Lepidochelys olivacea*) occurs within the tropical regions of the Pacific, Atlantic, and Indian oceans. Important nesting areas for the olive ridley include the west coast of Mexico and Central America (NMFS 1998). Olive ridley sea turtle populations had declined from former times but olive ridleys are still the most abundantly nesting turtle on the Pacific coast (Cornelius 1982). This species does not nest in the United States, but during feeding migrations olive ridley turtles nesting in the East Pacific may disperse into waters off the U.S. Pacific coast as far north as Oregon. Though remote, Olive ridley sea turtles could potentially be encountered within the LNG carrier transit route.

### 3.4.4 Environmental Consequences (Construction and Operation)

Environmental consequences for the construction and operation of the Project that have not been previously addressed in the individual sections for vegetation, wildlife, and fisheries are discussed below as they specifically relate to ESA-listed species. The most notable consequences of the Project will be the permanent loss of vegetation and wildlife habitat at the Project site. Overall potential LNG-related environmental consequences from the construction and operation of the proposed LNG export facility are discussed in Section 3.5. Of note, if an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the endangered or threatened species are located, the LNG will float briefly on the water until it vaporizes and will not have an adverse effect on the species unless they come in direct contact with the LNG.

#### 3.4.4.1 Botanical Resources

**Western Lily (Federal Endangered, State Endangered)**

The western lily is one of the rarest plants on the west coast. No effects to the species are anticipated by the Project. During surveys conducted to detect its presence it has been absent from the Project site and the areas to be impacted by the Project are not expected to include western lily habitat.

**Point Reyes Bird's Beak (Federal Species of Concern, State Endangered)**

The primary threat to Point Reyes bird's-beak is habitat loss due to development. The species is also threatened by off-road vehicle use, water pollution, and habitat alteration due to invasion by non-native dense-flowered cordgrass (*Spartina densiflora*), which has not been observed at the Project site. Suitable habitat for the Point Reyes bird's-beak will be impacted by fill required for the gas processing facility and South Dunes laydown area. Though individual Point Reyes bird's-beak has not been identified in the areas of impact by the Project, large communities of the species exist in neighboring areas.

#### 3.4.4.2 Terrestrial Wildlife

No direct impacts to threatened or endangered terrestrial wildlife species are anticipated as a result of the construction of the Project.

**Bald Eagles (Federal Delisted, State Threatened)**

Potential effects to bald eagle populations will be minimal. Foraging habitat occurs in and along the bay, but no suitable nesting habitat exists in the area where construction will occur. The Bald and Golden Eagle Protection Act requires protection of this species from disturbance within 660 feet from nest sites. While no nests were observed at the Project site and the nearest reported nest site in the ORBIC database, active at least as recently as 2003, is on Mettman Ridge above Glasgow, roughly three miles from the Project site, a pre-construction survey will be conducted to ensure that there is no inadvertent disturbance to this species.

**California Brown Pelican**

In the past, brown pelicans have been impacted by human disturbances at nesting colonies and roosting habitats. Nesting and roosting habitats within the Coos Bay estuary have not been documented and the species is not believed to breed in or near the Project site. Potential effects to brown pelican populations by the Project are anticipated be minimal. Foraging habitat for this species exists in Coos Bay adjacent to Jordan Cove and the brown pelican has been observed in the Project area near the proposed slip location. Noise and human activities associated with construction and operation of the proposed Project are likely to be the only direct effect to brown pelicans to the extent that brown pelicans occur near one or more of the Project's action areas. However, the possibility of adverse effects to the species is expected to be minimal as they would avoid these areas and the Coos Bay estuary provides ample foraging for the species outside of the impact area.

Onshore fish cleaning stations at various locations throughout the bay, often associated with boat ramps, have been mentioned as possibly attracting brown pelicans to possibly feed on offal (Marshall et al. 2006). The closest designated fish cleaning station is located inland at the Empire boat ramp more than two miles to the southwest on the other side of the bay. The Project is not anticipated to have a measurable effect on the foraging route of pelicans related to the Project.

**Marbled Murrelet**

The effects of the Project to be considered for MAMUs include disturbance and habitat impacts. While the Project does not occur within ¼ mile of designated Critical Habitat, its proximity to the coast requires evaluation of the Project vicinity to determine if there is habitat (i.e., nesting platforms) that may be affected by noise disturbance and human activities. Human activities attract corvids (i.e., crows, ravens, jays, magpies, etc.) to the area, largely from food and garbage related to construction activities. This gives the corvids an opportunity to have predation to MAMUs if there is nesting habitat in the vicinity. The single largest cause of murrelet nest failure found in Nelson and Hamer (1995b) was predation in 56 percent of failed nests, due mostly to corvids.

In surveys conducted for the Project (LBJ 2006, SHN 2012) no potential MAMU habitat was detected within the Project vicinity. Potential adverse effects to marbled murrelet populations will be minimal since this species does not nest on the Project site. MAMUs could occur along the bay or fly over the Project site while in transit between nesting and feeding sites. Conservation measures proposed in Section 3.4.5 would ensure that the Project site will be kept clear of construction debris and food wastes that could attract predators. No impact to MAMUs is anticipated from the construction or operation of the Project.

**Northern Spotted Owl**

No potential effects to northern spotted owl populations will occur because this species is absent from coastal Coos County and therefore not expected to occur in or near the Project site.

**Short-tailed Albatross**

Short-tailed albatross may occur within the EEZ coastal zone used by LNG carrier traffic. The species have infrequently collided with airplanes in flight but collisions with ships are unknown and are expected to be unlikely. Although the annual ship traffic will increase due to the proposed Project, LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tugboats from 50 miles offshore to the Port. Short-tailed albatross are expected to avoid LNG marine traffic.

The effects of a cargo spill from an LNG carrier would be quite different from results of spills from crude or refined petroleum ships. Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting the potential food species (squid, fish, eggs of flying fish, shrimp, and other crustaceans) in the water. Ignited LNG would affect species on the water surface but not species submerged in the water.

Based on the double-hulled construction of LNG carriers and the outstanding operating and safety record of LNG carriers, the probability of any incidents that could result in the loss of LNG cargo is extremely low. Any potential spills that could affect short-tailed albatrosses offshore would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

No mitigation, enhancement, or protection measures are proposed to specifically conserve short-tailed albatross.

**Streaked Horned Lark**

Industrial development has reduced habitat available to breeding and wintering larks. Construction and operation activities occurring on or near habitat used by streaked horned larks migrating through Coos Bay or wintering over could negatively affect foraging, causing the birds to flee or to spend more time alert and less time foraging.

Potential adverse effects to streaked horned lark populations are anticipated to be negligible. It has been determined that suitable habitat does not exist in or near the Project site due to the lack of proximity to open water at the few locations where sparsely vegetated lark habitat potentially exists. In addition, encroachment by European beachgrass and other noxious weed species increasingly makes potential habitat unlikely to be used by the larks, especially given the vast amounts of potential habitat on the North Spit and along that coast that remain relatively undisturbed by human influence. While an occasional individual may show up on a mudflat in the vicinity to forage, streaked horned larks are not expected in the Project site.

**Western Snowy Plover**

Stockpiling of material dredged from the slip area was proposed as part of the import terminal project. Due to the snowy plover population on the North Spit, there was a concern that a stockpile area could attract snowy plover individuals from this population. To address this concern, stockpiling is no longer part of the Project. Potential adverse effects to snowy plover populations will be minimal because there does not appear to be any nesting habitat within the Project site. While an occasional individual may show up on a mudflat, snowy plovers are not expected in the Project area.

Some concern exists that the construction of the Project might increase the local predator population, but it is not expected since snowy plover predators already occur on the site and the Project does not include the addition of any elements (with the exception of increased human activity) likely to attract them. Snowy plover predators identified along the Oregon coast include the American crow, common raven, red fox, raccoon, striped skunk, black rat, and feral cat. An increase in the numbers of these predators could be detrimental to the recovery of snowy plover populations.

Threats to western snowy plover habitat include introduction of European beachgrass that encroaches on the available nesting and foraging habitat; disturbance from humans, dogs, and off-highway-vehicles in important foraging and nesting areas; and predators such as the American crow and common raven (FWS 2005f). Increased nest predation of western snowy plovers by corvids within the Project area and in affected occupied stands is possible, particularly if corvids are attracted to construction sites by trash or discarded food. However, the distance to the closest documented nest negates this probability.

Increased predator density related to increased human presence and habitat removal was identified as a potential concern related to terminal construction. Jordan Cove has identified measures to minimize impacts. During construction and operation, the Project site would be kept clear of construction debris and food wastes that could attract predators such as birds (e.g., American crows) and mammals (e.g., rats, raccoons). Covered, animal-proof receptacles would be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. During construction the site would be policed on a daily basis to remove any food or other debris left by construction workers. During operations the facility and grounds would be regularly inspected to assure that no garbage is allowed to accumulate. This should minimize predation on snowy plover eggs and chicks; however, corvids and other predators could still be attracted to the area due to the increased activity.

### 3.4.4.3 Fisheries and Marine Species

For the purposes of this report, fisheries and marine species include federally-listed fish, marine mammals and sea turtles that have the potential to be affected by construction and operation of the Project or by the marine traffic generated along the LNG export facility transit route.

Impacts on the aquatic environment by the Project which could in turn affect fish and marine species include turbidity, chemical contamination, loss of benthic and shoreline habitat, acoustic effects from pile driving, and stranding of sea life from ship wakes. In addition, effects on aquatic resources if an unignited LNG spill were to occur along the LNG carrier transit route or if the vapor from an LNG spill were to come in contact with an ignition source resulting in a fire are remote possibilities. Analysis of these effects, along with the beneficial effects from restoration of estuary functions, are discussed in Section 3.3.6 and are incorporated by reference for this section. Additional environmental consequences related to these potential effects on federally-listed species from construction and operation of the Project are discussed below.

**OC Coho Salmon**

Direct and indirect effects from Project actions would likely affect OC coho salmon due to turbidity, potential chemical contamination, and interim habitat loss. The proposal to complete in-water work between July 1 and August 31 results in fewer OC coho salmon exposed to the activities and serves to minimize, but not eliminate, exposure to direct adverse conditions. OC coho salmon will have minimal habitat loss, but that loss will result in adverse effects to the species due to permanent loss of forage at the slip site. Beneficial estuarine compensatory mitigation is proposed to compensate for the loss of forage and ecological functions by re-introducing intertidal habitat subject to tidal flushing; however, a delay of several years is expected before the area reaches full ecological potential.

Essential physical and biological features (PCEs) for estuaries include whether an area is free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between freshwater and saltwater, natural cover, and forage. The action area for the proposed eelgrass mitigation site for the Project contains one or more PCEs within the acceptable range of values required to support the biological processes for which the species use the habitat. Coho salmon adults and smolts would migrate through this area and use the area to make the physiological transition between marine and freshwater environments. There would not be any loss of estuarine wetlands (i.e., diking and filling) for the proposed mitigation and the net result would be increased habitat value in the Coos Bay estuary. The site, located south of the airport's runway extension project, is considered to provide relatively low ecological function, which mitigation could improve.

Coho salmon outmigrating in Coos Bay are typically larger than sub-yearling juvenile Chinook salmon and are much less susceptible to stranding from potential ship wakes than the smaller Chinook salmon in Coos Bay. As noted for the model of the waves in Section 3.3.6, ship wakes would be generally small and similar to naturally occurring waves. Considering the conditions, including vessels entering and leaving at high slack tide, low vessel speed, and wave height within normal range, along with infrequent occurrence of susceptible fish, it appears unlikely that LNG carrier traffic would contribute to juvenile coho salmon stranding.

Some loss of juvenile salmon could occur from entrainment and impingement in the cooling water required for the LNG carriers while loading LNG at the berth. This potential would be the same as any deep draft vessel while loading or unloading cargo. However, few coho salmon would be as small as 60 mm since most would be outmigrating at age 1+ and would likely be greater than 120 mm. Many of the juvenile coho salmon would actively be able to avoid being entrained or impinged. Also, the location of the intakes on most LNG carriers would be near the inner portion of the slip away from the main channel. This may, depending on coho salmon distribution, reduce the overall chance of coho salmon being in the vicinity of the intakes.

NMFS (2008) in their assessment of effects of loss of juvenile coastal coho salmon from local airport expansion assumed 4 percent of Coos Bay coho salmon smolts survived to return as adults. Even so, due to the extremely small portion of total water intake relative to the volume of Coos bay, the relative portion of juvenile salmonids that would suffer direct mortality would be small, unless fish were highly concentrated at the point of intake. The population appears to have a 96 percent mortality rate before returning as adults. Even if a salmon individual was adversely affected, the mortability rate relative to the natural mortality rate of the overall population is not anticipated to be significant.

Depending on their reaction to localized changes in the light regime in the Project action area, coho salmon may have migration delays, be moved into less protected deepwater habitat, or they may become more susceptible to predation as light increases predators' ability to see fish.

Actual distribution of juvenile coho salmon within the Project action area is unknown. However, juvenile salmonid studies in the lower Columbia River observed that juvenile coho salmon were in greater abundance away from the shoreline areas, often in deep water during their outmigration (Johnsen and Sims 1973, Dawley et al. 1986, Ledgerwood et al. 1991). Carson et al. (2001) found that in the lower Columbia River less than 20 percent of all fish were found along the shore and were about evenly split between the channel and channel margins. Based on studies in the Columbia River, there is no reason to suggest that the water intake area on vessels moored at the LNG Terminal would have any higher abundance of juvenile salmonids than the rest of the bay area, and in fact it may be lower as the fish would have to enter the off-channel slip that is out of the main flow region. Coho salmon migrating to the ocean would likely be more closely associated with the main channels than the nearshore area and the inset slip, reducing their chance of encountering the intakes.

**Euchalon (Southern DPS)**

The potential for eulachon to be affected by the Project would occur during seasonal migrations by adults to inland rivers to spawn and the outmigration of larvae and juveniles after hatching. Eulachon do not feed in fresh water and their presence in Coos Bay would be limited. Given the deep and shallow water habitats available along the bay transit route, there is a low likelihood that there would be a significant impact on the spawning runs of eulachon in Coos Bay. Adults could avoid the LNG carriers in the channel by using the shallow areas of the channel that the LNG carriers will not be using. In addition, the effects of LNG carrier traffic on spawning runs is not one of the threats listed by NMFS for the eulachon.

Eulachon are not anticipated to be present in shoreline wave areas where they could potentially be stranded. From the analysis of potential fish strandings from ship wakes discussed in Section 3.3.6, Pearson et al. (2006) conducted an extensive stranding study in the Columbia River and sampled shoreline areas in all seasons. Even though eulachon were present in the river system, the study did not report the capture of any eulachon, indicating they may not be present in shoreline waves to be stranded. As with coho salmon, eulachon would likely utilize the intertidal and eelgrass mitigation sites (once developed) for the transition between marine and freshwater environments.

The likelihood of effects to larval and juvenile stages of eulachon as they outmigrate through the Coos Bay estuary is anticipated to be minimal. During this downstream dispersal period, if the larvae somehow ended up in the slip waters they could potentially be entrained in the LNG carriers during the intake of cooling water. However, as the larvae are carried by currents and tides, it would seem highly likely that they would be carried past the slip and would not be drawn into slip waters. Once the larvae have grown to juvenile size, they naturally disperse to the ocean as soon as they are able. Any juveniles occurring in the Project action area would be migratory in nature. The low number of all stages of eulachon that are likely to be in Coos Bay further reduces the potential for the species to be affected by the Project.

**Green Sturgeon**

Southern DPS green sturgeon occurring in the Project area are expected to reside primarily in the deeper waters of the bay, depending on the time of day, tidal cycle, and activity. Project-induced turbidity or chemical contamination is discountable due to green sturgeon spatial distribution. Indirect effects may occur from the construction fill of approximately 10.6 acres of shallow water habitat for prey species consisting of ghost shrimp and clams. However, in addition to the compensatory estuarine habitat mitigation that will be implemented for the Project, there is extensive shallow water habitat available for foraging throughout the bay. The construction fill will have no impact on population spatial structure or diversity of green sturgeon.

**Marine Mammals**

Potential effects to the Steller sea lions and whales that may be encountered along the LNG carrier transit route include environmental contaminants, impacts to foraging areas, debris, and vessel collisions. Direct effects could include injury and/or mortality due to ship strikes and potential adverse effects from a ship spill and/or release of LNG at sea. Spills and/or released LNG could indirectly affect whales by impacting forage species.

Potential adverse effects to Steller sea lion populations will be minimal because sea lions do not normally occur as far into Coos Bay as the Project site. Sea lions tend to stay closer to the harbor entrance and are known to frequent the Charleston boat harbor and also to haul out on the northeast spit of clam island (created by dredge spoils). While an occasional individual might enter Coos Bay, there are no suitable haul-out sites within the Project site and the species is not expected to occur there.

Of the federally-listed whales, gray whales and killer whales are the only species that have been known to occasionally enter Coos Bay beyond the Project site, although this is an infrequent occurrence. Potential adverse effects to these populations in Coos Bay is anticipated to be minimal.

Eight species of federally listed whales have been identified that could potentially occur off the coast of Oregon. These species tend to feed during the summer in the northern latitudes and migrate to the tropical southern latitudes in the winter for breeding. However, whales could be encountered off the coast of Oregon throughout the year. The Project area applicable to whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head. Within the EEZ area, effects to whales would be associated with LNG carriers inbound and outbound from the LNG Terminal. All of these whale species are federally protected under the Marine Mammal Protection Act (MMPA).

The Project may affect whales because they may occur within the EEZ analysis area during operation of the Project. The proposed action would increase shipping traffic (LNG carriers, tugs and barge units) within the EEZ analysis area. However, the Project is not likely to adversely affect whales because:

- Existing information indicates ship strikes to whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to whales over known frequencies of incidents.
- JCEP would provide a ship strike avoidance measures package to shippers calling on the LNG Terminal. The package will consist of multiple measures to avoid striking marine mammals.

- LNG carriers approaching and departing from the Port of Coos Bay would be traveling slowly and escorted by tractor tugs.
- Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting the mammals in the water. Ignited LNG would affect species on the water surface but not mammals submerged in the water.

Conservation measures include the development of a plan to minimize potential ship strikes to cetaceans, and possibly other listed (Steller sea lion, sea turtles) and non-listed marine species by LNG carriers. LNG carriers would transit to and from the slip at slow speeds (between 4 to 6 knots once inside the Coos Bay navigation channel) and would result in minimal wakes, such that marine mammals would not be affected by the wakes of passing LNG carriers.

There is an ongoing threat of ship strikes to whales; however, from available accounts (Laist et al. 2001; Jensen and Silber 2003) ship-whale collisions occur fairly infrequently. Ship strikes of blue whales averaged 0.6 deaths or injury per year (1 death or injury per 1.67 year) in Pacific waters between 2002 and 2006 (Carreta et al. 2008). During six years, from 2002 to 2007, one blue whale was struck and killed by a ship off the coast of Oregon (Barre 2008). That computes to 0.17 blue whale death per year due to ship strikes in Oregon and Washington coastal waters. The likelihood of a ship-whale collision varies by species of whale. Researchers have found that fin and humpback whales are struck by ships relatively often (Laist et al. 2007), while killer whales have only rarely been documented as being injured or killed by a collision (Jensen and Silber 2003; NMFS 2008). However, it is assumed that many ship strikes with whales are unknown and unreported.

The incremental LNG carrier traffic of 90 ships per year plus the three attending tugs over the current annual Port traffic of approximately 50 ships will, logically, result in a higher probability of potential incidents of ships hitting species in the water. However, most mobile species will be able to avoid interaction with moving objects in the waterway.

If an unignited LNG spill were to occur along the LNG carrier transit route in the areas where the endangered or threatened species are located (Figures 3.5-2 and 3.5-3), the LNG will float on the water until it vaporizes and will not have an adverse effect on the species, unless they come in direct contact with the LNG. Some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting the species in the water, given the ambient water temperatures in the transit route. If the vapor from an LNG spill were to come in contact with an ignition source the resulting fire would burn back to the spill source and would affect species on the water or in the area that come in direct contact with the fire. Species in the water would not be affected as the fire would be above the water in the area of the spill where the vaporized LNG is flammable. In either case of lower or higher water temperatures based on the spill scenario, mobile species will move out of the area until the water temperatures return to normal.

**Sea Turtles**

Potential effects to sea turtles that may be encountered along the LNG carrier transit route include environmental contaminants, impacts to foraging areas, debris, and vessel collisions. Direct effects of the Project include injury and/or mortality due to ship strikes and potential adverse effects from a ship spill and/or release of LNG at sea, as discussed for marine mammals. Spills and/or released LNG could indirectly affect sea turtles by impacting forage species.

Increased LNG carrier traffic may increase potential vessel strikes to sea turtles within the EEZ analysis area. They can be injured or killed when struck by a vessel, especially by an engaged propeller. Based on their warm water requirements, sea turtles are likely to only be occasional visitors to waters as far north as Oregon. Given the low population and occurrence of sea turtles in Oregon coastal waters, the increase of LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to sea turtles. LNG carriers approaching or departing from the Port of Coos Bay would be traveling slowly and escorted by tractor tugs within 50 nautical miles offshore of the LNG Terminal. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because reports of strandings in California are more frequent. LNG carriers are expected to transit at least 50 miles off the coast and so would be expected to avoid nearshore feeding areas.

Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting sea turtles in the water. Ignited LNG would affect species on the water but not sea turtles submerged in the water.

### 3.4.5 Mitigation, Enhancement, and Protection Measures

General mitigation, enhancement, and protection measures to reduce potential adverse effects to botanical and wildlife resources are included in Section 3.1.7 and 3.2.7, respectively. General measures to address potential adverse effects to fish and marine species from the construction of the slip and access channel for the LNG Terminal, land disturbing activities from the construction of the Project, dredging for the slip and access channel, maintenance dredging for the facility and LNG carrier route, ballast water discharge, the intake of cooling water for carriers while at the LNG berth are discussed in Section 3.3.7. These measures are incorporated by reference in this section. Additional conservation measures specific to individually listed species are discussed below.

A BA for all federal species that have the potential to be affected by the Project is required, as previously discussed, to comply with Section 7 of the ESA. JCEP will not begin construction and/or use of any of the proposed facilities, including related ancillary areas for staging, storage, temporary work areas, and new or to-be-improved access roads, until 1) the BiOp has been issued for federally-listed species; 2) associated state and federal authorizations and permits are in place; and 3) JCEP has received written notification from the FERC that construction and/or implementation of conservation measures may begin.

#### 3.4.5.1 Botanical Resources

**Western Lily**

Although the western lily has not been observed in the surveys conducted to date, to ensure that this species will not be affected by the Project, pre-construction surveys will be conducted. If surveys find an occurrence, the results would be reported immediately to the USFWS and ODA to initiate coordination and consultation to ensure potential effects to the western lily are mitigated with appropriate conservation measures, as required by Section 7 of the ESA.

**State-Listed Species**

To ensure that state-listed species will not be affected by the Project, pre-construction surveys of the affected areas of the Project site will be conducted for Point Reyes bird's-beak, pink sand verbena, silvery phacelia, and Wolf's evening primrose. Although the surveys are not required by any state or federal regulations, voluntary actions will help prevent further declines of species populations and avoid the potential need for future listing.

If a survey finds an occurrence of any state threatened or endangered species, the results will be reported and additional coordination and consultation will be initiated with the ODA and other appropriate resource agencies. This may include following existing relocation and monitoring guidance. The Point Reyes bird's beak, in particular, is a hemi-parasite that attaches to a host plant and any relocation efforts will propose removing the area around existing plants.

#### 3.4.5.2 Wildlife

**Birds**

Bald Eagle

Pre-construction surveys of the Project site for the bald eagles will be conducted by a qualified biologist. Surveys will include a search for active nests in appropriate habitat in areas in and adjacent to the Project that may provide nesting habitat. If a bald eagle nest is located less than 660 feet (line-of-site) from the planned Project construction activities, the planned Project construction activities will be adjusted accordingly or resumed as planned until one of the following has occurred:

1. The nesting season is over and the individuals have either successfully raised young and they have fledged and left the nest site;
2. Nest abandonment has been determined by the appropriate state or federal regulatory agency, and authorization for work has been given within the nesting season; or
3. Project activities are relocated more than 660 feet (line-of-sight) from the active nest.

Streaked Horned Lark

Bird surveys conducted to date did not identify the presence of the streaked horned lark within the Project vicinity. No mitigation measures are anticipated.

Western Snowy Plover

JCEP reviewed a list of conservation measures provided by the USFWS, BLM, and ODFW through the JCEP Interagency Task Force Working Group for the LNG import facility previously proposed. JCEP agreed to provide funding as enumerated below. The funding would be provided to the entity as defined by the agencies and it would be the responsibility of the particular entity to administer the funding. It should be noted that these measures were developed partially in response to the concern that a previous Port stockpile site proposed would provide potential habitat. The Port stockpile site is no longer part of the Project. JCEP is willing to provide the funding on the condition that no additional requirements would be placed on the Project relative to the snowy plover issue (other than those discussed in this section). JCEP is also requesting that the funding of these conservation measures be used in part to contribute to other habitat mitigation requirements imposed by the ODFW.

Funding by JCEP at present includes:

- Year 1 (when construction begins) JCEP would provide $60,000 for fencing, signage, application of shell hash, tree removal, and one year of maintenance.

- Years 2 and 3 JCEP would provide $30,000 each year for annual maintenance, a beachgrass elimination grant, and shell hash.
- Years 4 to 2018 JCEP would provide $10,000 for annual maintenance.

In addition to these conservation measures, JCEP has agreed to mitigate Project impacts to western snowy plovers through implementation of BMPs, along with education and outreach programs. Increased predator density related to increased human presence and habitat removal was identified as potential concerns related to Project construction. JCEP will address these concerns through the following BMPs discussed below.

Eliminating human sources of food in proximity to breeding locations (e.g., parking areas) adjacent to coastal breeding areas such as uncovered garbage and littered food scraps may indirectly help reduce predator numbers or help prevent their numbers from increasing. During construction and operation, the Project site will be kept clear of construction debris and food wastes that could attract predators. Covered, animal proof receptacles will be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. During construction the site would be policed on a daily basis to remove any food or other debris left by construction workers. During operations the Project site would be regularly inspected to assure that no garbage is allowed to accumulate.

Structures associated with the Project will be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately, in coordination and consultation with the USFWS. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the MBTA.

The placement of dredged material on land will be regularly policed to ensure that no denning is occurring in the hillocks. This should not be as significant a concern, as proposed placement areas will be part of the construction activities and the continuous activities will discourage use by individual birds. If necessary, nylon mesh or other exclusion fencing would be installed around the perimeter of the placement areas to prevent the establishment of coyote or skunk dens until the slopes are stabilized or constructed upon.

Surveys previously conducted indicate that 76 percent of beach visitors were unaware of restrictions associated with snowy plovers. This indicates that increased education could have a significant impact on public awareness of issues surrounding snowy plovers. Furthermore, the USFS at the Oregon Dunes National Recreation Area and BLM staff have reported that the majority of contacted individuals are more willing to comply with beach use restrictions after better understanding the reasons for them.

The JCEP would train all construction and operations staff on the need for snowy plover conservation, current snowy plover regulations and recreational use restrictions, and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on a leash, and remaining on established roads and trails. The training program would be developed based on guidance provided in Appendix K of the 2007 Plover Recovery Plan, or would be contracted for through State/local agencies or organizations who may have pre-existing plover education and outreach programs experience. Prior to implementation, the training program would be submitted for comment to members of the Western Snowy Plover Working Team.

Environmental training would also be provided to operational personnel to ensure that all personnel are aware of and comply with the management tools in place to affect the recovery and maintenance of the snowy plover population on the North Spit. Printed educational materials would be posted at the Project site for the life of the Project. Materials would also be distributed to existing North Spit employers for their use in training their personnel. The types of educational materials may vary, but could include posters, table tents, maps, brochures, or factsheets. Numerous sources for existing educational materials are provided in Appendix K of the Plover Recovery Plan.

Intensive biological monitoring of snowy plover on the North Spit is presently being conducted by ORBIC and the population is one of the most closely monitored snowy plover populations on the West Coast. JCEP will fund one additional entry level Wildlife Services position dedicated to snowy plover predator monitoring and control during the 42-month construction period. This staff member would be employed by Oregon Wildlife Services, which is administered by the U.S. Department of Agriculture and Animal and Plant Health Inspection Services. The specific duties of this additional staff member would be determined by Wildlife Services based on North Spit management needs, but would concentrate on predator management. This additional position would allow Wildlife Services to better evaluate predator densities and more quickly and effectively respond in the unlikely event that predator pressure on the North Spit increases during Project construction.

In the event that a clearly demonstrable and sustained decrease in snowy plover productivity is detected by the ongoing ORBIC monitoring, JCEP would coordinate with the USFWS, ORBIC, Wildlife Services, BLM, OPRD, ODFW, and other interested parties to identify adaptive management strategies, as appropriate, to help reverse any such trend.

#### 3.4.5.3 Fisheries (included Marine Species)

Conservation measures developed for the Project within the Project action area to conserve other fish and marine species in Section 3.3.7 would also benefit coho salmon, eulachon, and green sturgeon if they are present during the construction and operation of the Project. Additional species-specific mitigation, enhancement, and protection measures are discussed below.

**Whales**

Routine activities of the LNG Terminal after construction include primarily traffic of LNG carriers and associated maritime activities. Listed marine species may be affected by the associated increase in ship traffic and could be harmed or killed from chance collisions with vessels, from eating floating plastic debris from slip site related activities, or through exposure to hydrocarbons from accidental oil spills. LNG carriers will transit to and from the slip at slow speeds that will result in minimal wakes, such that marine mammals will not be affected by the wakes of passing LNG carriers. JCEP will provide the LNG fleet servicing the LNG Terminal with measures proposed by NMFS for avoidance of marine mammals and sea turtles to further reduce the likelihood of adverse effects on these species. Mitigation, protection, and enhancement measures to address all of these potential effects are described in further detail below.

JCEP would request all LNG carriers calling on the LNG Terminal to reduce speeds to 10 knots or less within 30 nautical miles of the entrance to Coos Bay during the whale migratory period. During the 96-hour pre-notification process to be followed by all LNG carriers calling on the LNG Terminal, JCEP would check with the NMFS for information on the migratory patterns of whales within the route of the LNG carrier and would inform the ship's master of the patterns reported by NMFS. JCEP would request that all LNG carrier operators consult current whale sighting information prior to calling on the LNG Terminal and be aware of the reported locations of whales and plan their operations accordingly. LNG carriers would be requested to reduce their speed to 10 knots or less when mother and calf pairs, groups, or large assemblages are observed near an underway LNG carrier. LNG carriers would be requested to route around and maintain a 100-yard distance from the whales observed and to avoid crossing in front of the whales and maintain a parallel route, if possible.

JCEP would provide a ship strike avoidance measures package to shippers calling on the LNG LNG Terminal. This package would include the measures proposed by NMFS for avoidance of marine mammals to further reduce the likelihood of adverse effects on these species. Some of the suggested measures include the following:

- Provide training to LNG carrier crews, including the use of a reference guide such as the *Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska* by Pieter Folkens. This is a pamphlet that would be provided to LNG carriers calling on the LNG Terminal and would be included as part of the terminal use agreement to the shippers.
- Provide a copy of the NMFS CD-rom-based training program entitled *A Prudent Mariner's Guide to Right Whale Protection* as part of a ship strike avoidance measures package to all LNG carriers calling on the LNG Terminal. While this CD-rom-based training program is specific to right whales, NMFS has stated that the guidance and avoidance measures are also applicable to fin, humpback, and sperm whales.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the ship to 10 knots or less to avoid striking protected species.
- When whales are sighted maintain a distance of 90 meters (or 100 yards) or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce ship speed to ten knots or less when pods or large assemblages of cetaceans are observed near an underway ship.
- When whales are sighted in a ship's path or in proximity to a moving ship, reduce speed to 10 knots or less or shift the engine to neutral until whales are clear of the area or path of the ship. LNG carrier masters would be requested to provide reports of sightings of marine mammal while in the EEZ action area and to provide the report upon docking at the LNG Terminal. This reporting request would be included in the Ship Strike Avoidance Measures Package provided to each LNG carrier calling on the LNG Terminal and compliance with the measures and the reporting would be included in all terminal service agreements with shippers.

LNG carrier crews would be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the ship. If the injury or death is caused by collision with the ship, appropriate regulatory agencies (FERC or NMFS) would be notified within 24 hours of the incident. Information to be provided would include the date and location (latitude/longitude) of the strike, the ship name, the species, or a description of the animal, if possible.

JCEP has been working with the Coast Guard and ODE in the development of an LNG Management Plan. The LNG Management Plan is the primary process used in reducing risk through proper mitigation measures. The interagency group has been given a step by step process in how risk is mitigated in both safety and security issues.

As part of the LNG Management Plan, JCEP is proposing that LNG carriers would not be allowed to move past the 50-mile voluntary traffic lanes offshore unless it is acceptable for them to continue into the LNG Terminal. In addition, JCEP is also proposing that LNG carriers would not be allowed to anchor offshore the Oregon coast. The New Carrissa incident occurred when a ship inappropriately anchored in heavy seas just off the coast. LNG carriers would only be allowed to enter closer than 50 miles when all conditions are suitable to enter the Port.

Further, JCEP has committed to providing tractor tugs to escort each LNG carrier into the port and to the berth. This type of tug has not been previously available in the Port. These tugs have the capability to fully maneuver the LNG carriers even without ship power.

**Sea Turtles**

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of whales and possibly Steller sea lions are observed near an underway ship would provide some protection to green turtles. However, it is highly unlikely that sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines, and LNG Management Plan to minimize risk of spills and releases at sea that were described for whales apply to sea turtles.

## 3.5 REFERENCES

Aagard, K., H.R. Sanborn and R.W. Sternberg. 1971. A fluvial and hydrographic survey of Coos Bay, Oregon. Submitted to Weyerhaeuser Company, North Bend, OR. 16 pp.

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindely and M.L. Moser. 2002. Status review for North American Green Sturgeon, *Acipenser medirostric*. National Marine Fisheries Service Southwest and Northwest Fisheries Science Centers and North Carolina Cooperative Fish and Wildlife Research Unit.

Adamus, P. R., K. Larsen, G. Gillson, and C. R. Miller. 2001. Oregon Breeding Bird Atlas. CD-ROM.OFO Special Publication No. 16.Oregon Field Ornithologists, Eugene.

Akins, G. and C. Jefferson. 1973. Coastal wetlands of Oregon; a natural resource inventory report. Oregon Coastal Conservation Dev. Comm.Florence. 159 pp.

Altman, B. 2003. Horned Lark. Pp. 425-248 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. OregonStateUniversity Press, Corvallis.

Anchor Environmental CA, L.P. 2003. Literature review of effects of resuspended sediments due to dredging operations. Prepared for Los Angeles Contaminated Sediments Task Force, Los Angeles, CA. Anchor Environmental CA, L.P. One Park Plaza Suite 600 Irvine, CA. June.

Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Anthony, R. G., M. C. Hansen, M. Sandler, N. V. Marr, C. A. Schuler, and R. S. Lutz. 1990. Short-term effects of triploid grass carp on waterfowl and Bald Eagles at Devil’s Lake, Oregon. Unpubl.rep., Oreg. Coop. Wildl. Res. Unit, Oreg. State Univ., Corvallis.

Armstrong, R.h., Hermans, M.C., Koski, K., and Willson, M.F. 2006. Eulachon: A Review fo Biology and an Annotated Bibliography, Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, Juneau, Alaska.

Arneson, R.J. 1975. Seasonal variation in tidal dynamics, water quality, and sediments in the Coos Bay estuary. M.S. thesis.Oregon State University, Corvallis.250 pp.

Baker, C.A. 1978. A study of estuarine sedimentation in South Slough, Coos Bay, Oregon. M.S. thesis.Portland State University, Portland.104 pp.

Baker, P. 1995. Review of ecology and fishery of the Olympia oyster, *Ostrea lurida* with annotated bibliography. *J. Shellfish Res.* 14(2):501-518

Baker, P., N.B. Terwilliger. 1999. Reestablishment of a native oyster: Implications for population distribution and structure. *J. Shellfish Res.* 19(1):687

Behnke, R.J. 1979. Monograph of the native trouts of the genus Salmo of western North America. 163 p. (Available Regional Forester, 11177 West 8th Avenue, PO Box 25127, Lakewood, CO 80225.).

Behnke, R.J. 1992. Native trout of western North America. Am. Fish. Soc, Bethesda, 275p. Biological Review Team (BRT). 2003. Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead. Draft Report. Northwest Fisheries Science Center, Seattle, Washington; Southwest Fisheries Science Center, Santa Cruz Laboratory, Santa Cruz, California. February 2003.

Bisson, P.A., and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 2:371-374.

Bourke, R.H., B. Glenne and B.W. Adams. 1971. The nearshore physical oceanographic environment of the Pacific Northwest coast. Oregon State University Reference 71-45.Department of Oceanography, OSU, Corvallis.

Bourne, N. and D.W. Smith. 1972. The effect of temperature on the larval development of the horse clam, *Tresus capax* (Gould). *Proc. Natl. Shellfish. Assoc.* 62:35-37

Bray, R.N., A.D. Bates and J.M.Land. 1997. Dredging-A handbook for engineers. Second Edition. Arnold, London.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. *Lichens of North America*. New Haven:YaleUniversity Press. 795 pp.

Brown, R.F. 1988. Assessment of pinniped populations in Oregon, April 1984 to April 1985.NMFS-NWAFC Proc. Rept. 88-05.44 pp.

Brumbaugh, R. and R. Reppert. 1994. *National Wetland Mitigation Banking Study: First phase report.* Institute for Water Resources Water Resources Support Center, U.S. Army Corps of Engineers, Alexandria, Virginia 22315 From: http://www.iwr.usace.army.mil/iwr/pdf/94wmb4.pdf Accessed April 4, 2006.

Burger, C.V., R.L. Wilmot and D.B. Wangaard. 1985. Comparison of spawning areas and times for two runs of Chinook salmon (*Oncorhynchus kisutch*) in the Kenai River, Alaska. Can. J. Fish.Aquat. Sci. 42:693-700.

Burt, W.V. and W.B. McAllister. 1959. Recent studies in the hydrography of Oregon estuaries. Fish. Comm. Oreg. Res. Briefs 7(1): 14-27.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples and F.W. Waknitz. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Technical Memorandum NMFS-NWFSC-27. August 1996.

California Department of Fish & Game, Wildlife & Habitat Data Analysis Branch. (August 6, 2005). California Natural Diversity Database.Sacramento: CDFG.

California Department of Fish and Game. 2006. *California Natural Diversity Database*. Online: http://www.dfg.ca.gov/whdab/html/cnddb.html.

Carlton, James T & Geller, Jonathan, B. 1993. Ecological Roulette: The Global Transport of Nonindigenous Marine Organism. Science, Vol. 261..

Carroll, J.C. and R.N. Winn. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Brown Rock Crab, Red Rock Crab, and Yellow Crab

Chew, K.K. and A.P. Ma. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)–common littleneck clam. U.S. Fish Wildl.Serv. Biol. Rep. 82(11).U.S. Army Corps of Engineers, TR EL-82-4.22 pp.

Christy J. A., J. S. Kagan, and A. M. Wiedemann.(1998). *Plant Associations of the Oregon Dunes National Recreation Area, Siuslaw National Forest, Oregon*. NR: U.S. Department of the Agriculture, Forest Service Pacific Northwest Region. Technical Paper R6-NR-ECOL-TP-09-98.123 pp.

Christy, J. A. 2002. *Limbella fryei (*Williams*)* Ochyra. Red Data Sheet, Oregon Natural Heritage Program, 821 SE 14th Ave., Portland, OR, USA. Viewed on 3-27-06 at www.artdata.slu.se/guest/ SSCBryo/fact_doc/Limbella_fryei.PDF

Cleaver, F.C. 1951. Fisheries Statistics of Oregon. Contribution Number 16.Fish Commission of Oregon, Department of Research.Portland, Oregon.

Collins, M.A. 1995. Dredging induced near-filed resuspended sediment concentrations and source strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Comyns, B.H. 1997. Growth and mortality of fish larvae in the north central Gulf of Mexico and implications to recruitment. Ph.D. diss., Lousiana State Univ., Baton Rouge, LA.199 p.

Connor, P.M. 1972. Acute toxicity of heavy metals to some marine larvae. Marine Pollution Bulletin, 3, pp.190-192.

Contreras, A. 1998. Birds of Coos County, Oregon: Status and distribution. Cape Arago Audubon Soc. and Oreg.Field Ornithol.(Spec. Publ. 12), Eugene.

Copeland, B.J. 1998. Salt Marsh Restoration: Coastal Habitat Enhancement. North Carolina Sea Grant College Program, Raleigh, NC.32 pp.

Cornelius, S.E. 1982. Status of Sea turtles along the Pacific coast of Middle America. Pages 211-219 in K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Inst. Press, Washington, D.C. 583 pp.

Couch, D. and T.J. Hassler. 1989. Species Profiles: Life histories and environmental

Crowder, L.C., S.J. Lyman, W.F. Figuiera and J. Priddy. 2000. Source-sink dynamics and the problem of siting marine reserves. Bull. Mar. Sci. 66: 799-820.

Currin, Rebecca. (November 2012). Email correspondence between Rosalind Litzky and Rebecca Currin, Botanist about ODA regulations about state endangered and threatened species.

Csuti, B., T. A. O'Neil, M. M. Shaughnessy, E. P. Gaines, and J. C. Hak. 2001. Atlas of Oregon Wildlife, 2nd ed. Oregon State University Press, Corvallis. 525 pp.

Cummings, T.E. and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Coastal Rivers Investigation Report 70-11. Fish Comm. Oregon.22 pp.

DeWitt, J.W. 1954. A survey of the coastal cutthroat trough, *Salmo clarki clarki Richardson*, in California, Calif. Fish Game 40:329-335.

Dicken, S.N., C.L. Johannessen and B. Hanneson. 1961. Some recent physical changes of the Oregon coast. Department of Geography, University of Oregon, Eugene.151 pp.

Eltzroth, M. S. 1987. Checklist of the Birds of Oregon, 4th ed. Audubon Society of Corvallis.17 pp.

Environmental Protection Information Center (EPIC). 2001. Petition to list the North American Green Sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the Endangered Species Act. Petition To National Marine Fisheries Service by Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California, petitioners.

Erickson, D.L., J.A. North, J.E. Hightower, J. Weber, and L. Lauck. 2002. Movement and habitat use of green sturgeon Acipenser medirostris in the Rogue River, Oregon, USA. Journal of Applied Ichthyology 18 (2002) 565-569.

Essential Fish Habitat (EFH) Core Team for West Coast Groundfish. 1998. Appendix: Life History Descriptions for the West Coast Groundfish. National Marine Fisheries Service. Seattle, WA. June, 1998. Available: http://www.nwr.noaa.gov/1sustfsh/efhappendix/page1.html

Farr, R.A. and J.C. Kern. 2004. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Farr, R.A. and T.A. Rien. 2002. Green Sturgeon Population Characteristics In Oregon.

Farr, R.A., M.L. Hughes, and T.A. Rien. 2001. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R.

Farr, R.A., M.L. Hughes, and T.A. Rien. 2003. Green Sturgeon Population Characteristics In Oregon. Annual Progress Report to U.S. Fish and Wildlife. Project Number: F-178-R

Federal Register Vol. 71 No. 129. July 6, 2006. Northern Right Whale (*Eubalaena glacialis*)

Federal Register. 2001. Endangered and threatened wildlife and plants: 90-day finding for a petition to list green sturgeon as threatened under the Endangered Species Act. 14 December 2001, pages 64793-64794.

Fleming, K. 1999. Northern Anchovy. *In*: Orsi, James J., editor. Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary, California. http://www.estuaryarchive.org/archive/orsi_1999

Florida Institute of Oceanography. 1996. Impacts and Direct Effects of Sand Dredging for Beach Renourishment on the Benthic Organisms and Geology of the West Florida Shelf.

Report to Dept. of Interior MMS. September. Available at http://www.mms.gov/sandandgravel/PDF/flben.pdf

Forsman, E. D. 2003. Spotted Owl. Pp. 319-320 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: a community profile. U.S. Fish and Wildlife Service Biological Rep. 85 (7.2).152 pp.

Garrett, M. G., J. W. Watson, and R. G. Anthony. 1993. Bald Eagle home ranges and habitat use in the Columbia River estuary. J. Wildl. Manage. 57:19-27.

Gaumer, T.F., G.P. Robart and A. Geiger. 1978. Oregon bay clam distribution, abundance, planting sites and effects of harvest. Annual Report October 1, 1977 to September 30, 1978. Oregon Department of Fish and Wildlife. 65 pp.

Gaumer, T.F.,D. Demory and L. Osis. 1973. 1971 CoosBay resource use study. Fish Comm. Oregon. 30 pp.

Gerstein, Edmund, R. Undated. Parametric Projectors Protecting Marine Mammals From Vessel Collisions, 157th Meeting Lay Language Papers.

Glavich, D. A. 2003. "The Distribution, Ecology, and Taxonomy of *Bryoria spiralifera* and *B. pseudocapillaris*on the Samoa Peninsula, Humboldt Company, Coastal Northern California," The Bryologist: Vol. 106, No. 4, pp. 588–595. Omaha: American Bryological and Lichenological Society, Inc.

Grant, J. and B. Thorpe. 1991. Effects of suspended sediment on growth, respiration, and excretion of the soft-shell clam (*Mya arenaria* ). *Can. J. Fish.Aquat. Sci.* 48(7):1285-1292

Groot, C. and L. Margolis (eds). 1991. Pacific Salmon Life Histories. UBC Press, Vancouver. 543 pp.

Gross, M.R. 1987. Evolution of Diadromy in Fishes. Am. Fish. Soc. Symp. 1:14-25Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*).Pp. 311-294 in C. Groot and L. Morgolis (eds.), Pacific Salmon Life Histories.UBC Press.Vancouver, B.C., Canada.

Guerra-Garcia, J.M.; J. Corzo; and Carlos Garcia-Gomez. 2003. Short-term benthic recolonization after dredging in the Harbour of Ceuta, North Africa. Marine Ecology, Vol. 24, Number 3, Sept. pp. 217-229(13).

Haagen, J. T. (1989). *Soil Survey of CoosCountyOregon*. NR:U.S. Department of Agriculture, Soil Conservation Service in cooperation with Oregon Agricultural Experiment Station.

Healey, M.C. 1982. The ecology of juvenile salmon in Georgia Strait, British Columbia, p. 203-229. In: W.J. McNeil and D.C. Himsworth (eds), Salmon Ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pp. 311-294 in C. Groot and L. Morgolis (eds.), Pacific Salmon Life Histories.UBC Press.Vancouver, B.C., Canada.

Henny, C. J., and J. E. Pagel. 2003. Peregrine Falcon. Pp. 166-170 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds.Oregon State University Press, Corvallis.

Hickman, J. C. ed. 1993. *The Jepson Manual*. Berkeley: University of California Press Berkeley.

Hitchcock, C.L., and A. Cronquist.(1973). Flora of the Pacific Northwest. NR: University of Washington Press.

Hjort, R.C., P.L. Hulett, L.D. LaBolle and H.W. Li. 1984. Fish and invertebrates of revetments and other habitats, the Willamette River, Oregon. Technical Report E-84-9 prepared for US Army Corps of Engineers under Intra-Army Order No. WESRF-82-106.83 pp. + Appendices.

Hoffnagle, J. and R. Olson. 1974. The salt marshes of the Coos Bay Estuary. Port Coos Bay Comm. and University of Oregon Institute of Marine Biology, Charleston. 86 pp.

Hornig, S., A. Sterling and S.D. Smith. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Ghost Shrimp and Blue Mud Shrimp.

Hostick, G. 1974. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Fish Commission Oregon Coastal Rivers Investigation Information Report 74-11. 22 pp.

Houde, E.D. and J.A. Lovdal. 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Estuar. Coast. Shelf Sci. 18:403-419.

Hunter, J. E., D. Fix, G. A. Schmidt, and J. C. Power. 2005. *Atlas of the Breeding Birds of Humboldt County, California*. Seattle: Reischling Press, Inc. pp. 440.

Imper, D. K. 2003. Letter from D. Imper at Arcata Field Office (U.S. Fish and Wildlife Service) to Roseburg Office (U.S. Fish and Wildlife Service).

Imper, D. K. and John O. Sawyer, PhD. October 1992. *Botanical Survey of the Crescent City Marsh wildlife Area*. Arcata: CSU& CDFG.

Imper, David K. (February 18, 2003). "Port Orford Sewage Offshore Discharge—Proposed Drilling Location." unpublished letter/email to Rob Burns, USFWS Roseburg Office. Arcata: FWO.

Isaacs, F. B., and R. G. Anthony. 2003. Bald Eagle. Pp. 140-144 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

Jameson, R. J. 2007. U.S. Geologic Survey: Translocated Sea Otter populations off the Oregon and Washington Coasts. Viewed on 3-27-2007 at http://biology.usgs.gov/s+t/SNT/noframe/pn175.htm

Jarvis, R. L. 2003. Canada Goose. Pp. 82-86 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds.Oregon State University Press, Corvallis.

Jefferts, C.A. 1977. The vertical distribution of infauna: a comparison of dredged and undredged areas in Coos Bay, Oregon. M.S. thesis.Oregon State University, Corvallis.45 pp.

Johnson, O.W., M.H. Ruckelshaus, W.S. Grant, F.W. Waknitz, A.M. Garrett, G.J. Bryant, K. Neely, and J.J. Hard. 1999. Status Review of Coastal Cutthroat Trout from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-37. January

Johnson, O.W., R.S. Waples, T.C. Wainwright, K.G. Neely, F.W. Waknitz, and L.T. Parker. 1994. Status review of Oregon's Umpqua River sea-run cutthroat trout. NOAA Technical Memorandum NMFS-NWFSC-15. Available: http://www.nwfsc.noaa.gov/pubs/tm/TM15/techmemo15.html

Johnson, O.W., T.A. Flagg, D.J. Maynard, G.B. Milner and F.W. Waknitz. 1991. Status review for Lower Columbia River Coho Salmon. NOAA F/NWC-202. June.

Johnson, O.W., W.S. Grant, R.G. Kope, K. Neely, F.W. Waknitz, and R.S. Naples. 1997. Status Review of Chum Salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-32. December

Johnston, J.M. 1982. Life histories of anadromous cutthroat with emphasis on migratory behavior. In E.L. Brannon and E.O. Salo (eds.), Proceedings of the salmon and trout migratory behavior symposium, p. 123-127. Univ. Washington, Seattle.

Kalt, Jen. (Winter 2006). "Crescent City Marsh and Western Lily Threatened by Two Proposed Developments," Darlingtonia. Arcata: CNPS, North Coast Chapter.

Kennedy, V.S. and J.A. Mihursky. 1971. Upper temperature tolerances of some estuarine bivalves. *Chesapeake Sci.* 12(4):193-204

Kjelson, M.A., P.F. Raguel, and F.W. Fisher. 1982. Life history of fall run-Chinook salmon, Oncorhynchus tshawytscha, in the Sacramento-San Joaquin Estuary, California. In Estuarine Comparison, edited by V.S. Kennedy, pp.393-411.Academic Press, New York, New York.

Koski, K.V. 2009. *The Fate of Coho Salmon Nomads: The Story of an Estuarine-Rearing Strategy Promoting Resilience*, The Nature Conservancy Alaska Field Office, Juneau, Alaska.

Kraeg, B. 1979. Natural resources of Coquille estuary. Estuary inventory report Vol. 2, No. 7. ODFW, Corvallis. 48 pp.

Lagerquist, B. A. and and Mate, B.R. Humpback Whale Sightings off the Oregon and Northern California Coast, During Summer 2002. Hatfield Marine Sciences Center, Oregon State University. No date

LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. *A Framework for Assessing the Need for Seasonal Restrictions on Dredging and Disposal Operations. Technical Report D-91-1,*U.S. Army Engineer Waterways Experiment Station, Dredged Material Research Program, Vicksburg, MS. 74 pp.

Lauten, D. J., K. A. Castelein, E. Seckinger, and E. P. Gaines. 2006. The distribution and reproductive success of the western snowy plover along the Oregon coast – 2005. Unpubl. Rep. ORNHIC, Portland. 60 pp.

Lawson, P.W., E. Bjorkstedt, M. Chilcote, C. Huntington, J. Mills, K. Moore, T. Nickelson, G. Reeves, H. Stout and T.C. Wainwright. 2004. Identification of historical populations of coho salmon (Onchorhynchus kisutch) in the Oregon Coast Evolutionarily Significant Unit. Northwest Fisheries Science Center 2032 SE OSU Drive, NewportOR97365.

LBJ Enterprises (LBJ). 2006. *2006-2006 Pre-construction wildlife surveys for proposed Jordan Cove Liquified Natural Gas Plant, Coos Bay, Oregon*. May 10, 2006 Revised December 26, 2006.

Levy, D.A. and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish.Aquat. Sci. 39:270-276.

Li, H.W., C.B. Schreck and R.A. Tubb. 1984. Comparison of habitats near spur dikes, continuous revetments, and natural banks for larval, juvenile and adult fishes of the Willamette River. Water Resources Research Institute, WRRI-95. Oregon State University, Corvallis, Oregon.15 pp.

Lister, D.B., C.E. Walker and M.A. Giles. 1971. Cowichan River Chinook salmon escapements and juvenile production 1965-1967. Can. Fish.Serv. 1971-3, 8 p.

Litle, K. and J.K. Parrish (eds). 2003. Where the River Meets the Sea: Case Studies of Pacific Northwest Estuaries. Pacific Northwest Coastal Ecosystems Regional Study, Seattle.

Lopez-Jamar, E.; J. Mejuto. 1988. Infaunal benthic recolonization after dredging operations in La Coruna Bay, NW Spain. Cahiers de Biologie Marine CBIMA5, Vol. 29, Number 1, pg. 37-49.

Macleod, J. 1970. Shad census study report-Coos-Millicoma rives. Oregon Game Commission, Portland.

Marshall, D. B., M. G. Hunter, and A. L. Contreras, Eds. 2003. Birds of Oregon: A General Reference. State University Press, Corvallis.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness.*Natural History of Oregon Coast Mammals*. U.S. Department of Agriculture, Forest Service, General Technical Report PNW-133, 1981.

Matthiessen, C.G. 1960. Observations on the ecology of the soft clam, *Mya arenaria*, in a salt pond. *Limn. Oceanogr.* 5(3): 291-300

McCauley, J.E.; R.A. Parr and D.R. Hancock. 1977. Benthic infauna and maintenance dredging: a case study. Water Research, Vol. 11, Number 2, pg. 233-242.

Methot, R.D. 1981. Spatial covariation of daily growth rates of larval northern anchovy, *Engraulis mordax*, and northern lampfish, *Stenobrachius leucopsarus*. Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 178: 424-431.

Miller, J. A., and A. L. Shanks. 2004. Ocean-estuary coupling in the Oregon upwelling region: the abundance and transport of juvenile fish and larval invertebrates. Marine Ecology Progress Series 271:267-279.

Miller, R.J. and E.L. Brannon. 1982. The origin and development of life history patterns in Pacific salmonids. In Brannon, E.L., and E.O. Salo (eds.), Proceedings of the Salmon and Trout Migratory Behavior Symposium, p. 296-309. School of Fisheries, Univ. Wash., Seattle.

Minerals Management Service (MMS). 1996. East Florida Shelf Benthic Repopulation Study. Feb. Available at www.gomr.mms.gov.

Misitano, D.A. 1977. Species composition and relative abundance of larval and post larval fishes in the Columbia River Estuary, 1973. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 75(1): 218-222.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. New York, Van Nostrand Reinhold.

Moffat & Nichol.2006. Jordon Cove LNG Terminal Coos Bay, Oregon, report on turbidity due to dredging. MNI Project No. 5797 Document No. 5797RP0009. Prepared for Black & Veatch and Jordon Cove Energy Project, L.P.

Moore, J.W., K.D. Martin and M.E. Gray.2000. Coos Bay salinity intrusion study-the effects of deepening the shipping channel on striped bass and other fish populations. ODFW Contract Number W66QKZ01017672.

Morgan, B. and K. Melcher. 2003. Sturgeon tagging project in select coastal estuaries 2003. Oregon Department of Fish and Wildlife, Columbia River Management, Clackamas, OR.

Morris, R.H., D.P. Abbott and E.C. Haderlie. 1980. Intertidal invertebrates of California. Stanford University Press, Stanford.

Moyle, P.B., P.J. Foley and R.M. Yoshiyama. 1992. Status of green sturgeon, *Acipencer medirostris*, in California. Final Report submitted to National Marine Fisheries Service, Terminal Island, CA.

Musick, J.A. and M.M. Harbin. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25(11): 6-30.

Myers, J.M., R.G. Kope, G.J. Bryant, D.Teel, L.J. Lierheimer, T.C. Wainwright, W. S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35. February 1998

Nakamura, G. and J.K. Nelson. (2001). *Selected Rare Plants of Northern California*. NR: University of California Agricultural and Natural Resources. Publication Number 3395.

Narver, W.W. 1970. Diel vertical movements and feeding of underyearling sockeye salmon and the limnetic zooplankton in Babine Lake, British Columbia. J. Fish. Res. Board Can. 27:281-316.

National Audubon Society. Website: http://www.audubon.org/bird/cbc/index.html.

National Marine Fisheries Service, 2009. Designation of Critical Habitat for the Southern Distinct Population Segment of Green Sturgeon, Final ESA Section 4(b) (2) Report, October 2009.

National Marine Fisheries Service. 2008. Coho ESU Critical Habitat Designations. Federal Register (73 FR 7816)

National Marine Fisheries Service. 2008. Formal Consultation for the Coos Bay airport Expansion in North Bend, Coos County, Oregon, NMFS No. 2008/03298.

National Marine Fisheries Service. 2008. Speed Restrictions to Reduce Ship Collisions with Right Whales, Federal Register (73 FR 60173).

National Marine Fisheries Service. 2011. Biological Opinion for the Ocean Terminals Dock Construction, sheet Pile, and Placement of Fill, Coos Bay, Coos County, Oregon, NMFS Consultation No. 2011/03866.

National Marine Fisheries Service. 2012. ESA/EFH Concurrence Letter for Southwest Oregon Airport Mitigation Site Dike Repair, Coos Bay, Coos County, Oregon, NMFS No. 2012/00604.

National Marine Fisheries Service and the U.S. Fish and Wildlife Service. 1998. Recovery Plan for U.S. Pacific Populations of the Olive Ridley Turtle (*Lepidochelys olivacea*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and the U.S. Fish and Wildlife Service. 2006. Killer whale fact sheet. Viewed on 3-26-2007 at http://www.nwr.noaa.gov/Marine-Mammals/Whales-Dolphins-Porpoise/Killer-Whales/ESA-Status/upload/kwfactsheet.pdf

National Marine Fisheries Service, 50 CFR § 226.202. Stellar Sea Lion

National Marine Fisheries Service.1992b. Recovery plan for the Steller sea lion (*Eumetopia jubatus*).Prepared by the Steller Sea Lion Recovery Team for the National Marine Fisheries Service, Silver Springs, MD.92 pp.

National Marine Fisheries Service. 2009. Designation of Critical Habitat for the Southern Distinct Population of Green Sturgeon, Final ESA Section 4 (b)(2) Report. National Marine Fisheries Service, Silver Spring, MD.

National Marine Protected AreasCenter. 2007. South Slough National Estuarine Reserve. Viewed on 3/22/07 at http://mpa.gov/helpful_resources/south_slough.htm.

National Marine Protected Areas of the United States. Viewed on 3-27-07 at http://mpa.gov/helpful_resources/south_slough.htm)

National Oceanic and Atmospheric Administration (NOAA) and South Slough National Estuarine Research Reserve. 2005. Enhanced Coastal Observational System and Predictive Hydrodynamic Model for Improvement Management of the Coos Bay Estuary, Oregon.

National Oceanic and Atmospheric Administration (NOAA). 2007. Office of Protected Resources: Leatherback Turtle (*Dermochelys coriacea*). Viewed on 3-23-2007 at http://www.nmfs.noaa.gov.pr/species/turtles/leatherback.htm

National Oceanic and Atmospheric Administration (NOAA). 2007a. Office of Protected Resources: Green Turtle (*Chelonia mydas*). Viewed on 3-26-2007 at http://www.nmfs.noaa.gov/pr/species/turtles/green.htm

National Oceanic and Atmospheric Administration (NOAA). 2007b. Office of Protected Resources: Loggerhead Turtle (*Caretta caretta*). Viewed on 3-26-2007 at http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm

National Oceanic and Atmospheric Administration. Website: http://66.102.7.104/search?q=cache:49aLQdRyYDAJ:www.nwr.noaa.gov/1srd/Recovery/domains/willow/WMU_Plan/pdfs/TechApps/AppendixB/AppB-8_StellerSeaLions.pdf+oregon+status+%22northern+sea+lion%22&hl=enNehls, H. B. 2003a. Brown Pelican. Pp. 53-54 *in* Birds of Oregon: A General Reference. D. B. Marshall, M. G. Hunter, and A. L. Contreras, Eds. Oregon State University Press, Corvallis.

National Oceanic and Atmospheric Administration (NOAA). 2008. Impacts to Marine Fisheries Habitat from NonFishing Activities in the Northeastern United State, NOAA Technical Memorandum NMFS-NE-209.

National Oceanic and Atmospheric Administration (NOAA). March 2010. Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California; NMFS Technical Memorandum NMFS-NWFSC-105.

National Oceanic and Atmospheric Administration (NOAA). 2013. *Bringing the Olympia Oyster Home* (Coos Bay, Oregon), National Estuarine Research Reserve system Science Collaborative, www.nerrs.noaa.gov.

National Oceanic and Atmospheric Administration (NOAA). 2013. U.S. Pacific Marine Mammal Stock Assessments: 2012, NOAA Technical Memorandum: NOAA-TM-NMFS-SWFSC-504. NMFS, Southwest Fisheries Science Center.

Neave, F. 1961. Pacific salmon: ocean stocks and fishery developments. Pac. Sci. Congr. Proc. 1957(10):59-62.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727.

Newell, R.C., L.J. Seiderer and D.R. Hitchcock. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: an Annual Review 36: 127-178.

Northern Pacific Coast.University of Washington Press, United States.

Northwest Area Committee. (December 2004). Coos Bay, Oregon Geographic Response Plan (GRP).

Oberrecht, Kenn. No date. Salmon and Trout in Estuaries.South Slough National Estuarine Research Reserve. Viewed on 3-29-07 at http://www.oregon.gov/DSL/SSNERR/docs/EMIpubs/salmon.pdf

Oregon Biodiversity Information Center.(2010). *Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources*. Portland:Portland State University.

**---.** (October 19, 2012). data request results. NR:Portland State University.

Oregon Department of Agriculture. 2006. Noxious Weed Policy and Classification System. Oregon Department of Agriculture, Noxious Weed Control Program, Salem, OR.

Oregon Department of Environmental Quality (DEQ). 1978. STORET retrieval data. Unpub.water quality data.

Oregon Department of Fish and Wildife. 2006. Website: http://ftp.dfw.state.or.us/fish/commercial/landing_stats/2004/.

Oregon Department of Fish and Wildlife (ODFW). 1979. Habitat classification and inventory methods for the management of Oregon estuaries. Prepared by Research and Development Section ODFW for Oregon Land Conservation and development Commission.

Oregon Department of Fish and Wildlife (ODFW). 1979. Natural resources of Coos Bay estuary. Prepared by ODFW Research and Development Section for Oregon Land Conservation and Development Commission.Vol. 2, No. 6.

Oregon Department of Fish and Wildlife (ODFW).1998. Coos Basin creel survey-1998.ODFW Charleston, Oregon. Unpublished reports on file ODFW Charleston, OR.

Oregon Department of Fish and Wildlife (ODFW).1999. Coos Bay, Coos and Millicoma Rivers and Coquille River creel surveys-1999.ODFW Charleston, Oregon. Unpublished reports on file at ODFW Charleston, OR.

Oregon Department of Fish and Wildlife (ODFW). 2001. Oregon marine fisheries 2000 status report. Compiled by ODFW Marine Resources Program, Newport, Oregon. March.

Oregon Department of Fish and Wildlife (ODFW). 2002. Relationships Between Bank Treatment / Nearshore Development and Anadromous/ Resident Fish in the Lower Willamette River, Annual Progress Report, May 2000-June 2001.

Oregon Department of Fish and Wildlife (ODFW). 2003. Relationships Between Bank Treatment / Nearshore Development and Anadromous/ Resident Fish in the Lower Willamette River, Annual Progress Report, July 2001-June 2002.

Oregon Department of Fish and Wildlife (ODFW). 2005a. Oregon native fish status report 2005 public draft Volume I-species management unit summaries. ODFW, 3406 Cherry Avenue N.E., Salem Oregon 97303-4924.

Oregon Department of Fish and Wildlife (ODFW). 2005b. DRAFT Oregon's Nearshore Marine Resources Management Strategy. ODFW, Marine Resources Program, 2040 SE Marine Science Drive, Newport, Oregon 97365.

Oregon Department of Fish and Wildlife (ODFW). 2006. Comments submitted to Oregon Department of Energy on Resource Reports for the Jordon Cove Energy Project and for the Pacific Connector Gas Pipeline Project. September 8. Oregon Department of Energy, 625 Marion Street NE, Salem OR 97301-3737.

Oregon Department of Fish and Wildlife (ODFW). January 2006. Oregon's Nearshore Strategy. ODFW, Marine Resources Program, 2040 SE Marine Science Drive, Newport, Oregon 97365.

Oregon Department of Fish and Wildlife (ODFW). 2008. Background documents, Oregon Fish and Wildlife Commission, Marine Reserves Briefing, Newport, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2008/2009. Shellfish and Estuarine Assessment of Coastal Oregon (SEACOR) Study, Coos Bay, Oregon.

Oregon Department of Fish and Wildlife. 2012. Oregon Recreational Dungeness Crab Fishery, 2007-2011, Newport, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2013. Oregon Wolf Conservation and Management, 2012 Annual Report, Salem, Oregon.

Oregon Department of Parks and Recreation.2007. Whale Watching Center website.Viewed on 3/22/07 at http://www.whalespoken.org/OPRD/PARKS/WhaleWatchingCenter/watch_weeks.shtml Oregon Division of State Lands.Viewed on 3-27-07 at http://www.oregon.gov/DSL/SSNERR/interpcenter.shtml.

Oregon Division of State Lands (DSL). 2007. South Slough National Estuarine Research Reserve. Viewed on 3/22/07 at: http//www.oregon.gov/DSL/SSNERR/interpcenter.shtml.

Oregon Invasive Species Council.(Accessed 2012)."100 Most Dangerous Invaders to Keep Out." Accessed at: http://www.oregon.gov/oisc/Pages/most_dangerous.aspx

*Oregon Estuary Plan Book*. 1987. URL: www.inforain.org/mapsatwork/oregon estuary/.

Oregon Natural Heritage Program Information Center (June 2005). Data request results. NR: ORNHIC.

Oregon Ocean Resources Management Task Force. 1991. *The Oregon Ocean Plan*. 117 pp.

Oregon Secretary of State. (2011). "Oregon Revised Statutes (ORS 564)." Salem: OSS.

---. (October 15, 2012). "Administrative Rules, Department of Agriculture, Division 73, Plants: Wildflowers and Endangered, Threatened, and Candidate Species." Salem: OSS.

Oregon Plan for Salmon and Watershed. 2008. *Recovery of Wild Coho Salmon in Salmon Basin*, Report No. OPSW-ODFW-2009-10.

Oregon Wetlands Joint Venture. 1994. *Joint Venture Implementation Plans: Southern Oregon Coast*. From: http://www.ohjv.org/pdfs/southern_oregon_coast.pdf. Site accessed: April 3, 2006.

Pacific Fishery Management Council (PFMC). 1998a. Final environmental assessment/regulatory review for Amendment 11 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon, (October 1998). http://www.pcouncil.org/groundfish/gffmp/gfall.html

Pacific Fishery Management Council (PFMC). 1998b. Appendix D - description and identification of EFH for the coastal pelagic species FMP. Amendment 8 to the Coastal Pelagic Species FMP. December 1998. Pp. 26-38.

Pacific Fishery Management Council (PFMC). 1998c. Essential Fish Habitat - West Coast Groundfish. Modified from: Final EA/Regulatory Impact Review for Amendment 11 to the Pacific Coast Groundfish FMP. October 1998. Available: http://swr.ucsd.edu/hcd/grndfsh.pdf

Pacific Fishery Management Council (PFMC). 1999. Appendix A - identification and description of Essential Fish Habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. August 1999. Available: http://www.pcouncil.org/Salmon/a14efh/efhindex.html

Pacific Fishery Management Council (PFMC). 2001. Second draft - fishery management plan and environmental impact statement for U.S. West Coast-based fisheries for highly migratory species. May 2001. Available: http://www.pcouncil.org/HMS/2draftfmp/2fmpindex.html

Pacific States Marine Fisheries Commission (PSMFC). 1996. White sturgeon. Available: http://www.psmfc.org/habitat/edu_wsturg_fact.html

Parr, R.A. 1974. Harbor dredging and benthic fauna: a case study. M.S. thesis, Oregon State University, Corvallis, Oregon.114 pp.

Partnership for Coastal Watershed. 2013. Bird trends, Cape Arago Audubon Society Coos Bay Christmas Bird County.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco, 1997.Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries. Vol. II: Species life history summaries. ELMR Rep. No. 11.NOAA/NOS Strategic Environmental Assessment Div., Silver Spring, MD.377 p.

Pauly, G.B. Van Der Raay and D. Troutt. 1988. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Pacific oyster.

Pauly, G.B., D.A. Armstrong, R. Van Citter and G.L. Thomas. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Dungeness Crab.

Pearcy, W. G. 1962. Ecology of an estuarine population of winter flounder *Pseudopleuronectes americanus* (Walbaum). Bulletin of the Bingham Oceanographic Collection **18**:1-78.

Pearcy, W., and S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? Fishery Bulletin **72**:201-213.

Peddicord, R.K. and V.A. McFarland. 1978. *Effects of Suspended Dredged Material on Aquatic Animals.* U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, Technical Report D-78-29, 102 pp. + app.

Pennekamp, J.S. and M.P. Quaak. 1990. Impact on the environment of turbidity caused by dredging. Terra et Aqua, 42, pp.10-20.

Pennekamp, J.S., R.C. Eskamp, W.F. Rosenbrand, A. Mullie, G.L. Wessel, T. Arts and I.K. Decibel. 1996. Turbidity caused by dredging; viewed in perspective. Terra et Aqua, 64, pp.10-17.

Percy, K.L., D.A. Bella, C. Sutterlin and P.C. Klingeman. 1974. Description and information sources for Oregon estuaries. Sea Grant Coll. Prog., Oreg. State Univ., Corvallis.294 pp.

Perdue, J.A., J.H. Beattie and L.K. Chew. 1981. Some relationships between gametogenic cycle and summer mortality phenomenon in the Pacific Oyster (*Crassostrea gigas*) in WashingtonState. *J. Shellfish Res.* 1(1):9-16.

Pitcher, T.J. 1986. Functions of shoaling in teleosts. In Fisher, T.J. (ed.), The behavior of teleost fishes, p. 294-337. Johns Hopkins Univ. Press, Baltimore, MD.

Pojar, J. and A. MacKinnon, eds. (1994). Plants of the Pacific NorthwestCoast: Washington, Oregon, British Columbia & Alaska. Vancouver: Lone Pine Publishing.

Pyle, P. 1997. Identification Guide to North American Birds, Part 1. Slate Creek Press, Bolinas, CA. 732 pp.

Recht, F. 1999. Yaquina and AlseaBays are important salmon habitat. Pacific States Marine Commission, 205 SE Spokane Street, Suite 100, Portland, Oregon97202

Reimers, P.E. 1971. The movement of yearling coho salmon through Sixes River Estuary. Fish Comm. Oregon, Coastal Rivers Investigation Info. Rep. 71-2, 15 p.Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Reimers, P.E. and R.E. Loeffel. 1967. The length of residence of juvenile fall Chinook salmon in selected Columbia River tributaries. Fish Comm. Oreg. 13, 5-19 p.requirements of coastal fishes and invertebrates (Pacific Northwest): Olympia Oyster.

Rheault, R.B. 2002. Eelgrass is great, but shellfish aquaculture is better. Available at http://www.ecsga.org/libraryitems/eelgrass.htm

Rich, A.A. 1997. Testimony of Alice A. Rich, Ph.D., regarding water rights applications for the Delta Wetlands Project, proposed by Delta Wetlands Properties for Water Storage on Webb Tract, BaconIsland, BouldinIsland, and Holland Tract in Contra Costa and San JoaquinCounties. July.Calif. Dept. of Fish and Game Exhibit DFG-7. Submitted to State Water Resources Control Board.

Rich, W.H. 1920. Early history and seaward migration of Chinook salmon in the Columbia and SacramentoRivers. U.S. Bureau of Fisheries Bulletin 37:2-73.

Richardson, S. 1973. Abundance and distribution of larval fishes in waters off Oregon, May-October 1969, with special emphasis on the northern anchovy, *Engraulis mordax*. Fishery Bulletin **71**:697-711.

Richardson, S., and W. Pearcy. 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fishery Bulletin **75**:125-145.

Rien, T.A. and R.P. Beamesderfer. 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society 123:255-265, 1994.

Rien, T.A., L.C. Burner, R.A. Farr, M.D. Howell and J.A. North. 2001. Green sturgeon population characteristics in Oregon. Oregon Department of Fish and Wildlife 17330 Southeast Evelyn Street Clackamas, OR 97015. Project Number: F-178-R.

Rien, T.A., R.P. Beamesderfer and C.A. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks for white sturgeon. California Fish and Game 80:161-170.

Robinson, A.M. and W.P. Breese. 1982. The spawning season of four species of clams in Oregon. *J. Shellfish Res*. 2(1):55-57

Rodenkirk, T. In prep.Status and distribution of Bird Species of Coos County, Oregon.

Rosenkeeter, J., K. Dugi and C. Ide.1970. Coos Bay estuary report, Area A-1.Unpublished data, Oregon Institute of Marine Biology, University of Oregon, Charleston, Oregon.

Salo, E.O. 1991. Life history of chum salmon (*Oncorhynchus keta*) Pages 231-309 in Groot. C. and L. Margolis (eds.). 1991 Pacific salmon life histories.Vancouver, British Columbia.

Sandercock, F.K. 1991. Life history of coho salmon (Oncorhynchus kisutch). Pages 395-446 in Groot and Margolis (ed). Pacific Salmon Life Histories. UBC Press, Vancouver, Canada

Sanders, G. 1985. Summary of age, sex, run timing, and length-weight characteristics of Alaska steelhead, p. 29-49. In Alaska Dep. Fish Game, Alaska Steelhead Workshop 1985, unpubl. manuscr., 134 p. (Available from Environmental and Technical Services Division, National Marine Fisheries Service, 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)

Sayce, C.D. and D.F. Tufts. 1972. The effects of high water temperature on the razor clam, *Siliqua patula* (Dixon). *Proc. Natl. Shellfish. Assoc.* 62:31-34

Schlosser, S. and J. Bloeser. 2006. The collaborative study of juvenile rockfish, cabezon, and kelp greenling habitat associations between Morro Bay, California and Newport, Oregon. February. Final Report to: Pacific States Marine Fisheries Commission Summarizing data for 2003, 2004, and 2005.

Schreck, C.B., H.W. Li, R.C. Hjort and C.S. Sharpe. 1986. Stock identification of Columbia River Chinook salmon and steelhead trout. Final Report to Bonneville Power Administration, Contract DE-A179-83BP13499, Project 83-451, 184 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208).

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish.Res. Board Can. 966p.

Sedell, J.R. and J.L. Frogatt. 1984. Importance of streamside forests to large rivers – the isolation of the Willamette River, Oregon, USA, from its floodplain by snagging and streamside forest removal: International Vereinigung fuer Theoretische und Angewandte Limnologie Verhandlugen, v. 22, P. 1828-1834.

Sedell, J.R. and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. In Armantrout, N.B. (ed.), Acquisition and utilization of aquatic habitat inventory information, p. 210-222. American Fisheries Society, Western Division, Bethesda, MD.

Seymour, A.H. 1956. Effects of temperature upon young Chinook salmon. PhD dissertation, University of Washington, Seattle, Washington.

Seymour, A.H. 1956. Effects of temperature upon young Chinook salmon. PhD dissertation, University of Washington, Seattle, Washington.

Shapovalov L. and A.C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo Gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddel Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game, Fish Bull.98, 375 p.

SHN Consulting Engineers & Geologists, Inc. 2006a. Sediment sampling and analysis plan, Jordon Cove, Coos Bay, Oregon. SHN 365 N. 4th Street, Coos Bay, OR.

SHN Consulting Engineers & Geologists, Inc. 2006b. Botanical Resources Assessment Report, Jordan Cove Energy Project Coos County, Oregon. SHN 365 N. 4th Street, Coos bay, OR. March.

SHN Consulting Engineers & Geologists, Inc. (November 2012). Botanical Resources Assessment Report." Coos Bay:SHN.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. Pp. 343-364 in V.S. Kennedy (ed.) Estuarine Comparisons. Academic Press, New York. 709 pp.

Slotta, L.S., C.K. Sollitt, D.A. Bella, D.H. Hancock, J.E. McCauley and R. Parr. 1973. Effects of hopper dredging and in-channel spoiling in Coos Bay, Oregon. Oregon State University, Corvallis.147 pp.

Smith, P.E. 1985. Year class strength and survival of O-group clupeoids. *In* proceedings of the symposium on the biological characteristics of herring and their implications for management, pp 69-82. Ed. By J.R. Brett, Canadian Journal of Fisheries and Aquatic Sciences: 42(Suppl. I): 1-278.

Sorenson, D.L., M.M. McCarthy, E.J. Middlebrooks and D.B. Porcella. 1977. Suspended and dissolved solids effects on freshwater biota. EPA-600/3-77-042.U.S. Environmental Protection Agency, Corvallis, OR.

South Slough National Estuarine Research Reserve (NERR). South Slough NERR Management Plan (2006)

Steneck R.S., M.H. Graham, B.J. Bourque, D. Corbett, J.M. Erlandson, J.A. Estes and M.J. Tegner. 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation.

Stern, E.M. and W.B. Stickle. 1978. *Effects of Turbidity and Suspended Material in Aquatic Environments: Literature Review.* U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, Technical Report D-78-21, 117 pp.

Stevens, Thompson and Runyan, Inc. (STR). 1974. Coos-Curry environmental protection program: Vol 1-water resources management plan; Vol 2-Technical appendix. Coos-Curry Council of Governments.Coos Bay.

Strathmann, M.F. 1987. Reproduction and development of marine invertebrates of the

Strong, C. S., B. S. Keitt, W. R. McIver, C. J. Palmer, and I. Gafney. 1995. Distribution and population estimates of Marbled Murrelets at sea in Oregon during the summers of 1992 and 1993. Pp. 339-352 *in* Ecology and conservation of the Marbled Murrelet (C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, eds.). U.S. Dept. Agric., For.Serv. Gen. Tech. Rep. PSW-GTR-152.Albany, CA.

Sulkin, S.D. and G. McKeen. 1994. Influence of temperature on larval development of four co-occurring species of the Brachyuran genus *Cancer*. *Mar. Bio.* 118(4):593-600

Sumner, F.H. 1972. A contribution to the life history of the cutthroat trout in Oregon with emphasis on the coastal subspecies, *Salmo clarki clarki Richardson*. OregonState Game Comm., Corvallis, OR 142 p.

Taylor, E.B. 1990a. Environmental correlates of life-history variation in juvenile Chinook salmon, Oncorhynchus tshawytscha (Walbaum). J. Fish Biol. 37:1-17.

Taylor, E.B. 1990b. Phenotypic correlates of life-history variation in juvenile Chinook salmon Oncorhynchus tshawytscha. J. Anim. Ecol. 59:455-468.

Thayer, G.W., W.J. Kenworthy and M.S. Fonseca. 1984. The ecology of seagrass meadows of the AtlanticCoast: A community profile. U. S. Fish and Wildlife Service, FWS/OBS-84/02.147 pp.

Tibor, David, P., ed. (2001). *Inventory of Rare and Endangered Plants of California, 6th Edition; Special Publication No. 1*.Sacramento: California Native Plant Society.

Trotter, P.C. 1989. Coastal cutthroat trout: a life history compendium. Transactions of the American Fisheries Society 118: 463-473.

U. S. Coast Guard. 2012. Standards for Living Organisms in Ships Ballast Water Discharged in U.S. Waters – Federal Register (77 FR 17254)

U.S.Coast Guard. 2004. Coos Bay, Oregon Geographic Response Plan (GRP). Marine Safety Office Portland Planning Department 6767 N. Basin Ave.Portland, OR97217-3992.

U.S. Army Corps of Engineers (USACE). 1975. Coos Bay, Oregon, deep draft navigation project: environmental impact statement, draft supplement. Portland District.Vol.I and II.

U.S. Army Corps of Engineers (USACE).1998. Coos Bay sediment evaluation report. NR: NR.

U.S. Army Corps of Engineers (USACE).1999. Coos Bay sediment evaluation report. NR: NR.

U.S. Army Corps of Engineers (USACE).2005. Coos Bay sediment quality evaluation report. NR: NR. https//www.nwp.usace.army.mil/ec/h/hr/Reports/Coos_Bay/CoosBat-2004.pdf.

U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC). 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. USACE ERDC TN-DOER-E9.May.

U.S. Department of Agriculture (1995).“General Technical Report PSW-GTR-157. American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection.” Forest Service:Pacific Southwest Research Station.

U.S. Fish and Wildlife Service.(1973). *Federal Endangered Species Act of 1973*, as amended. NR: USFWS.

U.S. Fish and Wildlife Service (USFWS). 2004. Establishment of Two Experimental Populations of Wolf’s Evening Primrose, Final Report, USFWS Section 6 Grant No. OR-EP-2, Seg. 15.

U.S. Fish and Wildlife Service (USFWS). 2006. Letter to FERC regarding review of draft Resource Reports for the construction, operation, and maintenance of the Jordon Cove Energy Project (JCEP) liquefied natural gas (LNG) import terminal on the North Spit of Coos Bay, Oregon; (FERC Docket Nos. PF06-25-000 and PF06-26-000).FERC 888 First Street, N.E., Room 1A, Washington D.C. 20426.

U.S. Fish and Wildlife Service. 2005. Brown Pelican (*Pelecanus occidentalis*) Information viewed 11-2-2005 at http://ecos.fws.gov/docs/life_histories/B02L.html

U.S. Fish and Wildlife Service. 2007. Marbled Murrelet (Brachyramphus marmoratus marmoratus): Endangered Species Fact Sheet. Viewed on 3-23-2007 at http://www.fws.gov/oregonfwo/EndSpp/FactsBirds/MarMurlet.htm

U.S. Fish and Wildlife Service. 2007a. Oregon islands National Wildlife Refuge website. Viewed on 3-28-07 at http://www.fws.gov/refuges/profiles/index.cfm?id=13599)

U.S. Fish and Wildlife Service. 2007b. OregonCoast Wildlife Refuge Complex. Viewed on 3-29-07 at http://www.fws.gov/oregoncoast/wildlife.htm.

U.S. Fish andWildlife Service.(2007c) National Wetland Inventory website. Viewed on March 28, 2007 at http://www.fws.gov/nwi/ (1987)

U.S. Fish and wildlife Service. (2007d) National Bald Eagle Management Guidelines. 23pp. NR:USFWS.

United States Department of the Interior, Bureau of Land Management. 1994. *Coos Bay District Proposed Resource Management Plan Environmental Impact Statement Map Package.*

US Department of the Interior, Bureau of Land Management, Coos Bay District, Umpqua Field Office. 2005. *Coos Bay District Final North Spit Plan, An Update to the CoosBay Shorelands Plan of 1995.*

US Department of the Interior, Bureau of Land Management.(NR). “Table 3: Bureau Sensitive and Assessment Plant Species Documented (D) and Suspected (S) on the North Spit by Scientific Name, Common Name or Group, Presence, Status, and Habitat.” North Bend: BLM, Coos Bay District.

US Department of the Interior, Bureau of Land Management. 2005. Draft North Spit Plan. Coos Bay District, Umpqua Field Office.98 pp.

US Department of the Interior, Bureau of Land Management. 2007. National Landscape Conservation System. Viewed on March 27, 2007 at http://www.blm.gov/or/resources/nlcs/index.php

US Department of the Interior, Bureau of Land Management.March 2005a. Status Report: *Cordylanthus maritimus Bentham ssp. palustris (Behr) Chuang and Heckard (Point Reyes bird's-beak).*North Bend: BLM, Coos Bay District.

Vronskiy, B.B. 1972. Reproductive biology of the Kamchatka River Chinook salmon (*Oncorhychus tshawytscha* (Walbaum)). J. Ichthyol. 12:259-273.

Wagoner, L.J., K.K. Jones, R.E. Bender, J.A. Butler, D.E. Demory, T.F. Gaumer, J.A. Hurtado, W.G. Mullarky, P.E. Reimers, N.T. Richmond and T.J. Rumreich. 1990. Coos River fish management plan.Oregon Department of Fish and Wildlife.

Ward, D.L. (ed.). 1992. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Final Research Report.Oregon Department of Fish and Wildlife.Funded by Port of Portland.92 pp.

Ward, D.L. and A.A. Nigro. 1992. Differences in fish assemblages among habitats found in the lower Willamette River, Oregon: application of and problems with multivariate analysis. Fisheries Research. 13:119-132.

Ward, D.L. and R.A. Farr. 1989. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.16 pp.

Ward, D.L. and R.A. Farr. 1990. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.13 pp.

Ward, D.L. and R.A. Farr. 1991. Effects of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.12 pp.

Ward, D.L., A.A. Nigro, R.A. Farr and C.J. Knutsen. 1994. Influence of waterway development on migrational characteristics of juvenile salmonids in the lower Willamette River, Oregon. North American Journal of Fisheries Management 14: 362-371.

Ward, D.L., P.J. Connolly, R.A. Farr and A.A. Nigro. 1988. Feasibility of evaluating the impacts of waterway development on anadromous and resident fish in PortlandHarbor. Annual Progress Report.Fish Research Project.Oregon Department of Fish and Wildlife, Portland, Oregon.58 pp.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D. J. Teel, R.G. Kope, and R.S. Waples. 1995. Status Review of Coho Salmon from Washington, Oregon, and California NOAA Technical Memorandum NMFS-NWFSC-24 September 1995. NOAA.

Wilsey and Ham. 1974. Estuarine resources of the OregonCoast. A natural resource inventory report to the Oregon Coastal Conservation and Development Commission.233 pp.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific coast of North America. J. Fish. Res. Board Can. 23(3):365-393.

Wood , E.F., W.E. Odum, and J.C. Zieman. 1969. Influence of sea grasses on the productivity of coastal lagoons. pp. 495-502. *In*, A. Ayala Castanares and F. B. Phleger, Eds.

*Coastal Lagoons*.Universidad Nacional Autonoma de Mexico, Ciudad Universitaria, Mexico, D. F.

# TABLES

FIGURES

# APPENDIX A.3
## Correspondence

# APPENDIX B.3

Botanical Resources Assessment Report
Jordan Cove Energy Project
Coos County, Oregon

# APPENDIX C.3

## 2005-2006 Pre-Construction Wildlife Surveys for Proposed Jordan Cove Liquefied Natural Gas Plant, Coos Bay, Oregon

# APPENDIX D.3

## Wildlife Assessment and Survey Report, Jordan Cove Energy Project, Coos Bay, Oregon

# APPENDIX E.3

## Jordan Cove Fisheries Report
## October 2006

# APPENDIX F.3

Report on Zooplankton Sampling Adjacent to the Proposed Jordan Cover LNG Terminal

Oregon Institute of Marine Biology Survey Report
January 2011

# APPENDIX G.3

## Noxious Weed Policy and Classification System (ODA) 2013

# APPENDIX H.3

## Oregon Invasive Species Council Action Plan 2012-2016

# APPENDIX I.3

## USFWS Final Snowy Plover Recovery Plan 2007

# Status review update of Southern Resident killer whales

Michael J. Ford

Conservation Biology Division
Northwest Fisheries Science Center
National Marine Fisheries Service

July 31, 2013

*We are much more interested in conserving actual morphological, ecological and genetic diversity than in structuring conservation around a nebulous taxonomic level about which, in the past, there has been so much disagreement – Mallet 1995*

## Acknowledgements

Phil Morin, Barb Taylor, Robin Waples, Marilyn Dalhleim, Lynne Barre, Candice Emmons Robyn Angliss and Brad Hanson provided valuable comments on an earlier draft of this report. Kristy Long provided the summary of public comments.

## Introduction

On August 2, 2012, the National Marine Fisheries Service received a petition submitted by the Pacific Legal Foundation on behalf of the Center for Environmental Science Accuracy and Reliability, Empresas DelBosque, and Coburn Ranch to delist the endangered Southern Resident killer whale (SRKW) distinct population segment (DPS) under the Endangered Species Act (ESA). On November 28, 2012, NMFS published a 90-day finding (77 FR 70773) that the petition presented substantial scientific information indicating that the petitioned action may be warranted and that NMFS would initiate a status review. The petition focused specifically on issues of taxonomy and whether the SRKW constituted a DPS, and NMFS therefore determined that the status review would also focus on these issues rather than on the extinction risk status of the SRKW more broadly.

On March 21, 2013, after a public comment period on the 90-day finding, the NMFS Northwest Region requested that the Northwest Fisheries Science Center conduct a scientific review and evaluation of the petition, the key scientific papers cited in the petition, the biological information received from the public, and any other best available relevant information. Specifically, the Northwest Region requested the Center to consider if there is new best available information that would lead to different conclusions from those of the 2004 BRT (Krahn *et al.* 2004) regarding the existence of a North Pacific resident killer whale taxon (species or subspecies) or the discreteness or significance of the SRKW with reference to this taxon. This report is intended to address the Northwest Region's request.

## Summary of taxonomic issues addressed by the 2004 BRT

In evaluating the status of the southern resident killer whales (SRKW), the previous NMFS biological review teams (BRTs) had to explicitly address the issue of the uncertain taxonomy of the killer whale. These issues are discussed extensively in the BRT reports (Krahn *et al.* 2004; Krahn *et al.* 2002) and in the report of the NMFS Workshop on Cetacean Taxonomy (Reeves *et al.* 2004). Briefly, at the time of the first SRKW status review (Krahn *et al.* 2002), the most recently published taxonomy of killer whales placed them in a single polytypic species, *Orcinus orca*, as described by Linnaeus in 1758 (Heyning *et al.* 1988; Rice 1998). However, the 2002 BRT report stated that killer whale taxonomy was uncertain and that several authors had recently proposed new *Orcinus* species on the basis of morphological variation and potential reproductive isolation among ecologically distinct populations of killer whales in Antarctica (Berzin *et al.* 1983; Mikhalev *et al.* 1981) and the North Pacific (Baird 2000). Even general reviews of *O. orca* taxonomy, while ultimately concluding that *O. orca* should probably be considered a single species, also emphasized the uncertain taxonomy. For example, Heyning and Dahlheim (1988, p.

5, emphasis added) noted that "The genus *Orcinus currently* is considered monotypic by most authorities with geographic variation noted in size and color pattern, but *a worldwide systematic review is needed*" and "Until more substantial data are presented, a *conservative* view of recognizing only one highly variable species *probably* is warranted."

Faced with this taxonomic uncertainty, the 2002 BRT evaluated a wide variety of potential taxonomic scenarios and considered the DPS status of SRKW within hypothesized taxa (see Table 8 in Krahn *et al.* 2002). Ultimately, the BRT remained uncertain about both the global taxonomy of killer whales and whether or not the SRKW met the criteria to be considered a DPS, and faced with this uncertainty NMFS concluded that listing the SRKW under the ESA was not warranted. The agency noted the taxonomic uncertainty described by the BRT, and as a result indicated it would reassess its decision after a reconsideration of killer whale taxonomy (NMFS 2002).

Subsequent to the 2002 "not warranted" finding, in 2004 NMFS initiated another status review in response to a finding by a U.S. District Court that in using a possibly outdated taxonomy, NMFS failed to make use of the best data available. In addition to initiating a new status review, NMFS also held a cetacean taxonomy workshop that, in part, reviewed and summarized information relating to the uncertainties surrounding killer whale taxonomy (Reeves *et al.* 2004). Based on the findings of the workshop and new genetic data analyzed after the 2002 status review, the 2004 BRT concluded that the North Pacific resident killer whales satisfied Reeve's *et al.* (2004) criteria for being a subspecies (Krahn *et al.* 2004, p. 41). Specifically, the BRT cited studies noting differences between the resident and transient ecotypes in external morphology, reproductive isolation in sympatry, foraging behavior and diet; acoustic dialects and vocal behavior, and mtDNA and nuclear genetic characteristics (see Krahn *et al.* 2002; 2004). The 2004 BRT further concluded that the SRKW population met the USFWS & NMFS (1996) criteria for being a DPS of the North Pacific resident subspecies, citing differences between the SRKW and other resident populations in ecological setting, range, genetic variation, and behavioral and cultural traits (Krahn *et al.* 2004). The BRT emphasized, however, that there was some scientific uncertainty related to both the taxonomic and DPS conclusions.

## Summary of the substantive points made in the petition

After a brief summary of killer whale natural history, the petition notes that there are varying scientific opinions regarding the definition of species, and that the definitions of sub-species and other intraspecific terms such as Distinct Population Segments (DPS) are subject to even greater uncertainty and scientific debate. The petition notes that splitting taxa ever more finely does not necessarily result in conservation benefits and may result in a false perception of risk.

The petition then briefly summarizes the current *Orcinus* taxonomy, followed by a more extensive summary of the Workshop on Cetacean Taxonomy convened by

NMFS in 2004 (Reeves *et al.* 2004). After summarizing some of the conclusions in the workshop report, the petition concludes that the workshop participants were unable to identify additional species within the currently recognized species *O. orca*. The petition further indicates that in the petitioners' opinion NMFS contradicted the workshop's recommendations when it concluded that the North Pacific fish-eating ('resident') killer whales are a subspecies of *O. orca*, and that the southern resident population is a DPS of this subspecies.

The petition follows with considerable discussion questioning whether the ESA allows for identification of DPS within subspecies, a legal question beyond the scope of this biological review.

Finally, the petition reviews some published studies related to the question of whether the North Pacific resident killer whales meet the criteria for subspecies designation, focusing on the lack of a Latin trinomial name for the proposed subspecies, and the genetic, morphological or ecological evidence as it relates to the question of subspecies status. The review focuses considerable attention (nearly six pages) on a recent genetic study by Pilot *et al.* (2010), arguing that the study provides clear evidence that the putative North Pacific resident killer whale subspecies is not genetically isolated from other killer whale populations. The petition concludes by reviewing some of the morphological, behavioral, and ecological differences among the North Pacific killer whale ecotypes, arguing that these are likely to be largely learned behaviors and therefore not important to consider when identifying subspecies or conservation units. See the Appendix for a detailed review of the biological arguments made in the petition.

## Summary of public comments

The public comment period on the 90-day finding closed on January 28, 2013. The Northwest Region received over 2,750 comments. Despite the request for specific scientific and commercial information, the vast majority of commenters simply noted their opposition to the petition to delist SRKWs, while a handful of comments supported the petition. The Northwest Region did, however, receive several substantive comments regarding both the biological and legal aspects of the DPS determination as raised in the petition. The substantive points raised in the comments are briefly summarized in Table 1.

**Table 1 -- Summary of Substantive Public Comments Received on Pacific Legal Foundation (PLF) 2012 Petition to Delist Southern Resident Killer Whale (SRKW) Distinct Population Segment (DPS).**

| Organization/ Commenter | Summary of comments |
|---|---|
| Marine Mammal Commission (MMC) | • Disagrees that the petition may be warranted; recommends reversing 90-day finding and devoting resources to higher priorities<br>• Listing SRKW as a DPS of a subspecies is appropriate, using 2nd prong of Chevron analysis (*Chevron USA v. Natural Resources Defense Council*) as applied to the definition of a DPS<br>• Recommends that consistent with NMFS precedent and applicable case law, NMFS interpret ESA definition of "species" to include DPSs of both species and subspecies<br>• Research has identified multiple, geographically distinct populations of killer whales that have unique behavioral and ecological traits<br>• MMC believes PLF's arguments related to Pilot *et al.* 2010 are incorrect and inconsistent; references several new papers on genetics and speciation<br>• Pilot *et al.* 2010 findings are not sufficient to refute treatment of North Pacific residents as a putative subspecies or the designation of SRKWs as a DPS<br>• Pilot *et al.* 2010 does not provide conclusive evidence of recent mating between SRKWs and other resident populations or between resident killer whales and any other regional ecotype; used unusually liberal criteria to assign parentage based on genetic data<br>• Parsons *et al.* in review found that "estimates of genetic distance between two predominant North Pacific ecotypes [resident and transient] indicate negligible levels of gene flow." |
| Humane Society of the United States | • Opposes further consideration of the petition as it does not present substantial scientific information that the listing is no longer warranted; population is appropriately listed as endangered<br>• Disagrees with the petitioners that SRKWs are an unlistable entity under the ESA<br>• Basing conclusion that the population is not a subspecies on limited male-mediated gene flow between populations from Pilot *et al.* 2010 ignores more recent work by Ford *et al.* 2011 that detected no gene flow among populations |
| Center for Biological Diversity | • Petition fails to present substantial information that SRKWs are not a DPS; does not comport with ESA's plain language, ignores NMFS policy, and disregards scientific record that indicates significant speciation of the global taxon<br>• ESA allows NMFS to designate a DPS of a subspecies; if ESA were ambiguous, NMFS' DPS policy allows designation of a subspecies and deserves deference; case law cited by petitioners does not support their claim<br>• Data and information support speciation for North Pacific and SRKW populations such as genetic data; morphological data, including body size; behavioral variation including vocalization, food preference, and social organization |
| Animal Legal Defense Fund (ALDF) | • Opposes delisting petition on legal as well as scientific bases<br>• Petition mischaracterizes Pilot *et al.* 2010 and Morin *et al.* 2010 and took conclusions out of context<br>• Petitioners legal argument is inconsistent with case law and statutory interpretation |

| | |
|---|---|
| | • ALDF counters the three primary assumptions in the petition – (1) ESA does not require formal taxonomic recognition, (2) Pilot *et al.* 2010 does not contradict a subspecies designation, (3) Morin *et al.* 2010 unequivocally urges a subspecies designation<br>• ALDF also organized a comment campaign, we received hundreds of individual comments opposing the delisting |
| Rus Hoelzel | • Clarifies Pilot *et al.* 2010 conclusions<br>• Does not believe a subspecies must be defined before designating a DPS; see examples in Fallon *et al.* 2007 using genetic markers to designate DPSs where a subspecies has not been designated<br>• Notes that gene flow is allowed when determining discreteness<br>• Notes the petition does not address significance<br>• Supports current DPS listing |
| The Whale Museum | • Opposes delisting petition; supports 2004 status review and listing<br>• Pilot *et al.* 2010 do not reference cross ecotype mating involving SRKWs; Barrett-Lennard *et al.* 2000 supports reproductive isolation too<br>• SRKW DPS is both discrete and significant |
| Orca Conservancy | • Opposes delisting petition<br>• MMPA does not provide adequate protection for SRKWs; ESA allows protection from indirect threats, requires section 7 consultations and permits, allows more citizen oversight and recourse<br>• Morin *et al.* 2010 is more reliable than Pilot *et al.* 2010 because it relies on more base pairs and more microsatellites, which contradict conclusion of interbreeding in modern times |
| Northwest Environmental Defense Center | • Petition is inconsistent with science, court decisions on the prior listing, and the ESA.<br>• Economic concerns listed in the petition cannot be considered and would not be resolved even with delisting<br>• NMFS is within its statutory authority to list SRKW DPS<br>• Current science supports and requires the continued protection of SRKW DPS – pinnipeds can tell residents apart from transients based on acoustics; SRKWs are a demographically closed population; best available science has not changed much since 2005<br>• MMPA protections alone are insufficient to protect and recover – procedural issues (jeopardy and adverse mod), takings, and legal tools in ESA |
| Miami Seaquarium | • Agrees with petitioner that SRKW DPS is not a listable entity; ESA does not authorize listing a DPS of a subspecies; North Pacific subspecies itself is a "nonexistent and scientifically unjustifiable" listing unit<br>• "Taxonomic inflation" is occurring – unjustified elevation of subspecies to species and populations to subspecies or DPSs<br>• 2005 listing of SRKW DPS as endangered resulted in collateral issues including impacts on CA farmers and whether to include Lolita in the listing. Notes that PLF filed its petition to delist SRKW DPS "long before" PETA/ALDF filed their petition to add Lolita to the SRKW DPS. NMFS should carefully and promptly consider the PLF petition, which if granted would negate the need to consider these collateral issues. |
| Animal Welfare Institute, CBD, Center for Whale Research, EarthJustice, | • Petition is based on a narrow and incorrect construction of ESA and the best scientific and commercial data available; incorrect legal arguments and one-sided interpretation of science; do not, and cannot, address or demonstrate that status has improved or threats have been reduced<br>• ESA defines "species" broadly; authorizes listing a DPS of a subspecies - |

| | |
|---|---|
| Friends of the Earth, Friends of the San Juans, International Marine Mammal Project of Earth Island Institute, Marine Mammal Connection Society, NRDC, Oceana, Orca Network, Dr. David Bain, Will Anderson, Dr. Samuel Wasser | Congress did not intend DPSs to be constrained by taxonomy; designating DPSs of subspecies is consistent with longstanding agency interpretations<br>• PLF arguments lack merit; the justification included does not support those arguments<br>• Focus on genetics and interbreeding is misplaced as genetic data is not the sole evidence for determining "markedly separate" populations<br>• Significant scientific evidence supports designation of SRKW population as a DPS – physical separation from other KW populations; morphological data, including body size, supports speciation of NP and SRKW populations; and behavioral variation, including vocalization, food preference, and social organization meet DPS criteria<br>• SRKWs meet the ESA listing criteria – EarthJustice provides a five factor analysis |
| Whale and Dolphin Conservation | • Opposes petition; threats continue and delisting is not appropriate<br>• Notes the ESA definition of "species" and NMFS' interpretation unambiguously refute PLF's legal argument as has been the case with their recent attempts to challenge other ESA listings<br>• Notes that the DPS policy does not prohibit listing if occasional gene flow occurs beyond the listed population; Pilot *et al.*'s main conclusion from their data emphasized social cohesion of killer whales to produce genetic differences between populations despite capacity for dispersal outside their groups. |
| Change.org – Bruce Gorcyzcki | • J, K, and L pods don't associate or interbreed with other ecotypes in the North Pacific<br>• SRKWs have been determined as a discrete population with their own social groupings, dialect and behaviors<br>• SRKWs' absence from the ecosystem would upset the balance |
| Individual – Ruth Muzzin | • Petition should be denied as it does not present new information, such as population numbers, and does not demonstrate that the DPS has recovered or become extinct; none of the delisting criteria are met<br>• NMFS has listed a DPS of a subspecies previously – e.g., ringed seals, bearded seals, and Atlantic sturgeon |
| Individual – David Bain | • Describes characteristics of "newer" and "older" species in an evolutionary sense with respect to reproductive isolation, morphology (dorsal fin and jaw sizes), and geographic isolation<br>• Transients are older species and distinct in all ways species are expected to differ<br>• Residents and offshore have reached a plateau, but additional differentiation would be expected over evolutionary time, though reproductive isolation is occurring; overlap in color patters and range; SRKWs appear the only group of residents to use the CA current system thereby giving them a slightly different ecological niche.<br>• Morin *et al.* 2010 found the evidence of interbreeding in Pilot *et al.* 2010 was an artifact attributable to incomplete DNA sequencing<br>• SRKWs should be considered a subspecies and are eligible for ESA listing regardless of whether a DPS of a subspecies is eligible. Endangered status should be retained. |
| Individual – Sharon Grace | • Petition is without merit<br>• Commenter references many threats and effects on population abundance and social structure<br>• Notes Pilot *et al.* 2010 examples are not SRKWs; some inbreeding is okay for DPS designation |

| | |
|---|---|
| Individual – Jodi Smith | • Morin *et al.* 2010 confirms that genes are slow to change over time, making differentiation difficult even though it happens<br>• In addition to genetic isolation, SRKWs are distinct based on social organization, dietary preference, and behavior. Recent evidence from a review of Southern Hemisphere killer whale populations is likely to conclude distinction as well (de Bruyn *et al.* 2013)<br>• Delisting SRKWs will not alleviate water restrictions for CA farmers as many other threats exist for CA spawning salmon |

## Taxonomic issues, general principles

The petition states that it is motivated in part by a general concern about "taxonomic inflation", or the tendency to increasingly split taxa into smaller subunits based on minor differences between putative taxa (petition p. 11). The petition notes that this can be a problem even at the species level, but seems particularly concerned with the incorrect identification of subspecies, due in part to a lack of consistent and rigorous subspecies definitions in the scientific literature (petition, p. 11).

The petition is correct in its conclusion that taxonomic uncertainty is a practical and conceptual problem for implementing conservation policy, particularly under laws such as the Endangered Species Act that rely on designation of particular species or intraspecific groups of organisms for special protections. Even the definition of a species is subject to ongoing scientific debate, with dozens of species concepts circulating in the scientific literature and debate about whether species are 'real' entities or simply categories invented for human convenience (Hey *et al.* 2003; Mallet 1995). As the petition notes, subspecies concepts have been subject to less intensive theoretical treatment than have species, but even so there are numerous definitions of subspecies in the scientific literature (reviewed by Haig *et al.* 2006). Other definitions of intraspecific groupings, such as Evolutionarily Significant Units (e.g., Crandall *et al.* 2000; Moritz 1994; Waples 1991), Distinct Population Segments (DPS; USFWS *et al.* 1996), and stocks (Dizon *et al.* 1992; McElhany *et al.* 2000) have also been the subject of considerable scientific debate and controversy ( reviewed by Ford 2003; Fraser *et al.* 2001).

The petition focuses considerable attention on the societal costs associated with designating insufficiently discrete taxa, but does not discuss the converse conservation problem of failing to identify discrete taxa when they exist. Failure to identify species, subspecies or other intraspecific varieties when they do in fact exist has clear conservation costs, mostly notably the potential loss of such unique groups through failure to protect them. This problem has been extensively discussed in the scientific literature, and has provided the motivation for several explicit definitions of both subspecies and ESUs (Avise *et al.* 1990; Crandall *et al.* 2000). The potential for outdated or incorrect taxonomy, particularly at the subspecies level, has been a motivation for more explicit subspecies definitions and suggestions to review outdated taxonomic designations (Haig *et al.* 2006). For example, with regard to designation of cetacean species and subspecies, Reeves *et al.* (2004) noted that

> *There has been a tendency to err in the direction of avoiding designating too many taxa rather than making sure that all potentially recognized taxa have been designated. In other words, the direction of precaution toward stability in traditional taxonomy has not been appropriate for conservation.*

and

> *Cetacean taxonomy in the latter half of the 20th century was conservative in part as an over-reaction to the excessive splitting that occurred during the 19th century.* (p. 30)

In other words, at least in Reeves *et al.*'s view, the currently accepted cetacean taxonomy tends to err on the side of lumping discrete taxa together rather than splitting them apart. To facilitate accurate designation of new cetacean taxa, particularly at the subspecies level, Reeve's *et al.* recommended the following definition of subspecies:

> *In addition to the use of morphology to define subspecies, the subspecies concept should be understood to embrace groups of organisms that appear to have been on independent evolutionary trajectories (with minor continuing gene flow), as demonstrated by morphological evidence or at least one line of appropriate genetic evidence. Geographical or behavioral differences can complement morphological and genetic evidence for establishing subspecies. As such, subspecies could be geographical forms or incipient species.* (p. 7).

Based on the discussion above, the problem of how to deal with taxonomic uncertainty in applying laws such as the ESA is not a new issue. Neither are concerns about wasting resources or causing economic harm through listing of inappropriately designated taxa. For example, the issue of balancing the competing tensions of conserving genetic resources but doing so when only biologically warranted was a motivating factor in the development of both the NMFS ESU concept (Waples 1991) and the joint USFWS & NMFS DPS policy (USFWS *et al.* 1996). It is beyond the scope of this review to attempt to resolve all of the bigger picture issues surrounding the intersection of taxonomy and conservation status. In developing and applying its policy on DPS, however, NMFS did explicitly consider the need to identify conservation units under the ESA at an appropriate scale.

## New information since 2004

In this section we briefly summarize information relevant to both the taxonomic and DPS questions that has been published in the scientific literature since the 2004 status review.

## Morphology and color variation

The only published quantitative analysis of variation in pigmentation patterns in North Pacific killer whales remains that of Baird and Stacey (1988), which found significant differences between residents and transients and among resident populations in the frequencies of alternative saddle patch patterns. Several authors (Baird 2000; Dahlheim *et al.* 2008; Ford *et al.* 2000 ) have also described qualitative differences in morphology among the three Pacific ecotypes. All of these studies except for Dahlheim *et al.* (2008) were considered by the 2004 BRT in their status review report.

While not describing morphological variation *per se*, a study by Zerbini *et al.* (2007) demonstrated that the ecotypes can be unambiguously distinguished based on visual appearance of dorsal fin shape and saddle patch pigmentation. In that study, ecotype determination of unknown groups of whales was made independently by both visual examination of photographs and genetic analysis of the mtDNA control region. In all 32 cases where both photographs and genetic data were available, the ecotype designation based on the photographs matched that based on the mtDNA control region.

Since 2004, there have been multiple studies published on morphological and ecological variation among Antarctic killer whales, confirming and extending the more preliminary information that was available to the 2004 BRT. Pitman and Ensor (2003) describe field observations and descriptions of three distinct types of Antarctic killer whale (designated A, B, and C) differentiated by size, pigmentation, habitat and apparent prey preferences. The C type appeared to correspond to *O. glacialis*, a dwarf form of killer whale previous described by Berzin and Vladimirov (1983) but not generally accepted as a distinct species due to small sample size and lack of a type specimen (Heyning *et al.* 1988). Pitman *et al.* (2007) used aerial photographs to quantify the length distribution of a sample of 221 Type C whales, and confirmed this type as smaller than the Type A whales. Based on historical and contemporary photographs, Pitman *et al.* (2011) described a new “Type D” killer whale characterized by a very small eye patch and somewhat bulbous head and inhabiting the Southern Ocean between 40 and 60 degree south. More recently, Olsen *et al.* (2012) observed groups of east Antarctic killer whales that were intermediate in some morphological characters between types B and C.

## Feeding ecology and diet

Since the 2004 BRT report, several additional studies have been published on the diet and feeding ecology of North Pacific killer whales. Herman *et al.* (2005 ) and Krahn *et al.* (2007) examined variation in organic contaminants and fatty acid composition of blubber biopsy samples and carbon and nitrogen stable isotope ratios in dermal samples from 169 samples (between the two studies), obtained primarily from the Gulf of Alaska and the Aleutian Islands but including some samples from Puget Sound and the U.S. west coast. All three ecotypes were represented, although the number of offshore samples was small (4 in the 2005 study and 9 in the 2007 study). The studies found significant variation among the three ecotypes in fatty acid profiles and contaminant burdens and ratios, likely reflective of different diets and foraging locations (Figure 1). Nitrogen stable isotope ratios also differed significantly between transients and residents, with transients having more enriched $^{15}$N levels consistent with a marine mammal diet. Offshores had nitrogen ratios that were between residents and transients, and not significantly different from either. Alaskan residents sampled from different areas also varied considerably in both nitrogen and carbon stable isotope profiles, presumably reflecting differences in foraging location and/or prey types.

Ford and Ellis (2006) and Hanson *et al.* (2010) conducted field observations of resident killer whale predation combined with genetic analysis of prey remains and field collected fecal samples to evaluate resident killer whale diets in the Salish Sea. Both studies observed predation of only fish, and analysis of prey remains and fecal DNA indicated a summer diet dominated by Chinook salmon (*Oncorhynchus tshawytscha*). Dahlheim and White (2010) describe foraging behavior and prey preferences for Alaskan transient killer whales. Killer whale diet information, including considerable unpublished data, was further reviewed by an independent science panel in 2012 (Hilborn *et al.* 2012; NMFS 2013).

In the Antarctic, Pitman and Durban (2012) described a field study of foraging behavior of Type B killer whales, documenting predation of primarily Weddell seals (*Leptonychotes weddellii*) using a cooperative hunting behavior that involved washing the seals off of ice flows. Olsen *et al.* (2012) described Type A and B killer whales in a common feeding aggregation. Foote *et al.* (2009) describe variation in stable isotope ratios and tooth wear potentially indicative of two killer whale foraging types in the North Atlantic.

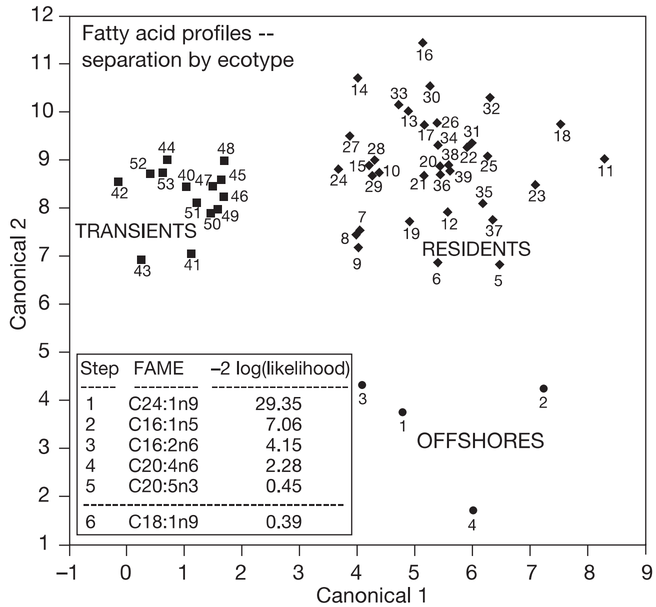



**Figure 1 -- Orcinus orca. First 2 discriminant functions showing separation of killer whale ecotypes based on fatty acid profiles of the blubber biopsies. Reproduced from Herman *et al.* (2005).**

Deecke *et al.* (2005) found significant differences in the acoustic behavior of transients and residents during foraging events, with transients calling significantly less frequently than residents. The difference appears to be related to hearing abilities of their preferred prey; marine mammals have excellent hearing in the frequency range of the killer whale calls while fish do not. These results are consistent with earlier work (Deecke *et al.* 2002) demonstrating that harbor seals displayed predator avoidance behavior during playback experiments using transient calls but not during experiments using resident calls. Deecke *et al.* (2011) and Beck *et al.* (2011) found differences in group size and acoustic behavior between seal-eating and fish-eating killer whales in the North Atlantic. Based on the phylogenetic relationships between the Atlantic and Pacific populations (Foote *et al.* 2011b; Morin *et al.* 2010), Beck *et al.* (2011) concluded that such foraging specialization and associated behaviors must have arisen independently in both oceans and be fairly plastic traits. Dahlheim *et al.* (2008) describe foraging behavior of offshore killer whales including highly worn teeth suggesting feeding on abrasive prey such as sharks. Ford *et al.* (2011a) collected prey samples from offshore killer whales and identified the prey as Pacific sleeper sharks (*Somniosus pacificus*). On a research cruise off the Oregon and Washington coasts in spring of 2013, an offshore whale was observed foraging on Chinook salmon (NWFWC unpublished data).

## Genetics

The genetic information available at the time of the 2004 status review consisted of several studies focusing on variation in the mtDNA control region and at multiple nuclear microsatellite loci (see tables 1 and 2 of Krahn *et al*. 2004). Two studies, both in the form of preliminary reports, were cited as being particularly influential due to their large sample sizes: a global study of 211 killer whales analyzed at 17 microsatellite loci (Hoelzel 2004), and a similar study of 219 whales sequenced at the mtDNA control region (LeDuc *et al.* 2004). Both studies produced a somewhat inconclusive picture of population structure, as summarized by Krahn *et al.* (2004, p. 15-16):

> *The understanding of killer whale population genetic structure has expanded considerably since the 2002 status review. In particular, the mtDNA differentiation among eastern North Pacific resident, transient, and offshore populations can now be seen in the context of variation worldwide. The most notable result from the new mtDNA data is the lack of strong mtDNA structure worldwide, suggesting that the current distribution of killer whales populations may be relatively young on an evolutionary scale (e.g., several hundred thousand years compared to the ≈5 million year old age of the Orcinus genus [Waples and Clapham 2004]) and possibly associated with a population bottleneck followed by a worldwide expansion. With respect to identifying conservation units, one of the implications of the new data is that the relative degree of mtDNA divergence among populations is not necessarily a good predictor of the length of time that the populations have evolved independently. For example, killer whales with the same haplotype as in Southern Residents have also been found in Alaska, Russia, Newfoundland, and the United Kingdom (Figure 2). Evolutionarily, these whales with the southern resident haplotype are almost certainly more closely related to other geographically proximate populations than to each other (a hypothesis supported by the microsatellite data, Table 3) and therefore, share a mtDNA haplotype purely by chance. Because of this finding, it would be inappropriate to rely heavily on simple mtDNA divergence as a criterion for identifying conservation units, especially on a global scale. On a local scale, however, mtDNA clearly remains useful for helping to identify populations, especially when combined with other types of information.*
>
> *In addition to more mtDNA data, the amount of nuclear microsatellite data has expanded greatly in the last 2 years, both in terms of whales and loci analyzed. Within the eastern North Pacific, both the mtDNA and microsatellite data remain consistent with a hypothesis of four to five resident populations, at least two to three transient populations and at least one offshore population (Figure 1). The issue of whether any contemporary gene flow occurs among eastern North Pacific populations remains unresolved, but the microsatellite data are consistent with either low levels of gene flow (at most a few mating events among populations per generation) or divergence times of at least several hundred to several thousand years (M. Ford 2004, Hoelzel 2004). Despite some uncertainty about the evolutionary history that produced the current patterns of variation, both the mtDNA and the microsatellite data indicate a high degree*

*of contemporary reproductive isolation among eastern North Pacific killer whale populations.*

As we discuss below, our understanding of global killer whale population structure has improved considerably since 2004, although some uncertainties remain.

We identified 10 studies of the genetic population structure of killer whales that have been published since the 2004 status review (Table 2). Three of these – Hoelzel *et al.* (2007), LeDuc *et al.* (2008), and Pilot *et al.* (2010) – are expanded and published versions of the preliminary reports considered by the 2004 BRT (Hoelzel 2004, LeDuc and Taylor 2004).

Hoelzel *et al.* (2007) analyzed 203 killer whales sampled from the North Pacific (including samples of the resident, transient and offshore ecotypes) and Iceland at 16 microsatellite loci and the mtDNA control region (~1000 bp). Similar to preliminary results reported to the 2004 BRT (Hoelzel 2004), they found significant differentiation among all groups of samples but estimated that rates of gene flow among most groups, including between ecotypes, was significantly greater than zero. Among North Pacific resident groups, they found that genetic differentiation at microsatellite loci was proportional to geographic distance between the groups. The most geographically distant resident groups had similar levels of genetic divergence to that between the residents and the transients. Using genetic assignment tests, they identified 5 putative migrant individuals, but none between residents and transients. In fitting a model of divergence with migration, they estimated low but non-zero (< 1 migrant/generation) rates of gene flow between residents and transients, and between the Alaskan resident and Icelandic groups. From the same type of analysis, they estimated that the divergence time between residents and transients was 4000 – 36,000 years ago, depending on mutation rate assumptions, and hypothesized that most if not all of the population structure observed evolved after the most recent glacial maximum.

Using the same data, Pilot *et al.* (2010) expanded upon Hoelzel *et al.*'s (2007) results by conducting a parentage analysis within and among populations in order to directly estimate contemporary gene flow. The study also extended the assignment test analyses of Hoelzel *et al.* (2010) using two additional methods. Out of 213 samples, they found a total of 3 putative first generation migrants (individuals sampled from a population but with a genetic profile more similar to a different population), and 8 putative second generation migrants (individuals inferred to be the offspring of a first generation migrant). Of these 11 putative migrants, 8 were within the same ecotype (exchanges between California and Alaska transients, or between Alaskan and Russian residents), 2 were between transients and the Icelandic group (both second generation), and 1 was between transients and offshores (second generation). Using a model fitting approach, rates of gene flow between residents and transients and from the offshores into residents and transients were estimated to be <1% per generation. Rates of gene flow from both residents and transients into the offshore group were estimated to 2.2 – 3.6%. Gene flow rates between resident populations were estimated to be 0.5% - 2.4%, except for the rates between Russian and Bering Sea groups and between Bering Sea and Alaskan groups which were much higher (14% - 28%).

Pilot et al's parentage analysis identified at least one parent for 95 individuals, but more than half these (57) were rejected by the authors as spurious. The remaining parentage assignments suggested low dispersal (42/43 maternal assignments were to a mother within the offspring's population) and very high male-mediated gene flow (10/22 paternal assignments were to a male not in the offspring's population). No parentage assignments were made between members of different ecotypes. The authors suggested that the discrepancy between the low rates of intra-ecotype gene flow estimated by using assignment tests and model-fitting and the high rates estimated from parentage analysis could be explained by a recent range expansion leading to increasing contact among formally isolated populations. Another possible explanation, suggested by the large number of assignments rejected as spurious, is that the parentage analysis may not have had sufficient power to exclude all false paternity assignments.

Ford *et al.* (2011b) conducted a similar parentage and assignment test analysis, but focused the parentage analysis exclusively on the southern resident population and did not attempt to identify potential parents outside of this population. The authors did test for the presence of first generation immigrants into the SRKW population, however, and found no evidence of recent gene flow into the SRKW population.

Another significant development in our understanding of global killer whale population structure has resulted from sequencing full ~16,390 bp mitochondrial genomes from a large number of individuals (Morin *et al.* 2010). Sequencing the full mitogenome has increased the number mtDNA base pairs examined by over 16 fold compared to the earlier studies that focused exclusively on the ~1000 bp control region. This increase in sequence evaluated has greatly improved the resolution of the estimated mtDNA gene trees, and significantly altered our understanding of killer whale population structure, particularly as it relates to the degree of divergence among some of the known ecotypes.

Morin *et al.* (2010) sequenced and analyzed full mitochondrial genomes from 139 killer whales sampled primarily from the North Pacific, North Atlantic, and Antarctic areas, with a smaller number of additional samples from the tropical Pacific. In contrast to earlier results based on only the control region, the phylogenetic tree constructed from the full length mitogenome sequences showed strong genetic structure associated with many of the previously identified ecotypes (Figure 2). In particular, the North Pacific residents, North Pacific transients, North Pacific offshores, and Antarctic type B and type C groups each formed distinct monophyletic clades. The North Pacific transients were particularly divergent from most other killer whale groups, including the sympatric residents and offshores. For example, there were 57 fixed sequence differences between the transients and the residents and offshores. The estimated time to the most recent common ancestor of all of the mtDNA haplotypes was ~700,000 years, and the divergence time between the haplotypes characterizing the residents and those characterizing the offshores was 177,000 years ago. Haplotypes characterizing the Antarctic B and C types were estimated to share a common ancestor 155,000 years ago. The Antarctic B and C types were also each found to have a sequence substitution inferred to be due to natural selection (Foote *et al.* 2011a). Based on the clear genetic divergence among ecotypes, combined with divergence at microsatellite loci and previously reported morphological and ecological differences, Morin *et al*. (2010) concluded that the North Pacific transients and Antarctic B and C types each met criteria for being considered full species, and the other known ecotypes (North Pacific residents, offshores, North Atlantic populations, and the Antarctic A type) each met criteria for being considered distinct subspecies, but could be elevated to species with if additional data supported evolutionary distinctiveness.

Utilizing the same dataset of mitogenome sequences, Foote *et al.* (2011b) conducted additional analyses on the relationship between North Pacific and North Atlantic populations. Based on the structure of the mitogenome tree, they suggested that over the past ~300,000 years there have been several episodes of migration of whales between the Pacific and Atlantic oceans. The timing and pattern of these inferred episodes further suggested that the Pacific resident and transient ecotypes may have initially diverged in allopatry (transients in Pacific, residents in Atlantic), and then subsequently came into contact following a migration event of residents back into the Pacific. Using the same isolation-divergence model used by Hoelzel *et al.* (2007), Foote *et al.* (2011b) also found non-zero but extremely low rates of bi-directional female gene flow between the Atlantic and Pacific (< 1 migrant / 150,000 years).

Foote *et al.* (Foote *et al.* 2009; Foote *et al.* 2011c)conducted analyses focused on understanding killer whale population structure within the North Atlantic, and found evidence for two ecological types (fish eating/mammal eating) similar to what has been observed in the Pacific and Antarctic. Genetically, the fish eating whales from Norway and Iceland formed a genetically distinct grouping based on both mtDNA control region (1000bp) sequences and microsatellite variation. Other groups of populations, particularly from Gibraltar and the Canary Islands, also clearly formed discrete populations based on the microsatellite variation, but clustered with other groups (Pacific offshores, Antarctic type A) in the mtDNA tree.

Parsons *et al.* (2013) conducted a study of population structure of a large (462) sample of resident and transient killer whales from the Gulf of Alaska, the Aleutian Islands and the Sea of Okhotsk. The focus of the study was primarily on elucidating population structure within each ecotype, but the study is also the largest study to date (in terms of whales and loci) of nuclear genetic variation between the resident and transient ecotypes. Using two different assignment methods, all samples with sufficient data (n> 20 loci) assigned unambiguously to their known ecotype. When individuals with greater levels of missing data were included, a single individual (missing data at 15/27 loci) assigned to the 'incorrect' ecotype at a low level of confidence (0.54). These results, combined with the lack of any shared mtDNA haplotypes, led the authors to conclude that there is at most negligible gene flow between the two ecotypes.

**Table 2 – Summary of published genetic analyses of killer whale population structure since the 2004 status review**

| Study[1] | Geographic focus | Number of samples | Type of data |
|---|---|---|---|
| Hoelzel *et al.* (2007), Pilot *et al.* (2010) | North Pacific plus Iceland | 203 | Microsatellites (16), mtDNA control region (~1000 bp) |
| LeDuc *et al.* (2008) | Antarctic (with comparison to published data in Pacific and Atlantic) | 80 | mtDNA control region (~1000 bp) |
| Foote *et al.* (2009) | North Atlantic | 125 | mtDNA control region (partial) |
| Morin *et al.* (2010), Foote *et al.* (2011b), Foote *et al.* (2011a) | North Pacific, North Atlantic, Antarctic, some tropical | 143 | mtDNA full genome (~16,390 bp) |
| Foote *et al.* (2011c) | North Atlantic (with comparison to published data in Pacific and Antarctic) | 85 | mtDNA control region and full genomes; microsatellites (17) |
| Ford *et al.* (2011b) | Southern Residents, North Pacific | 78 | Microsatellites (26) |
| Parsons *et al.* (2013) | North Pacific | 462 | mtDNA control region (~1000 bp); microsatellites (27) |

[1]Separate papers based on largely the same data are grouped.

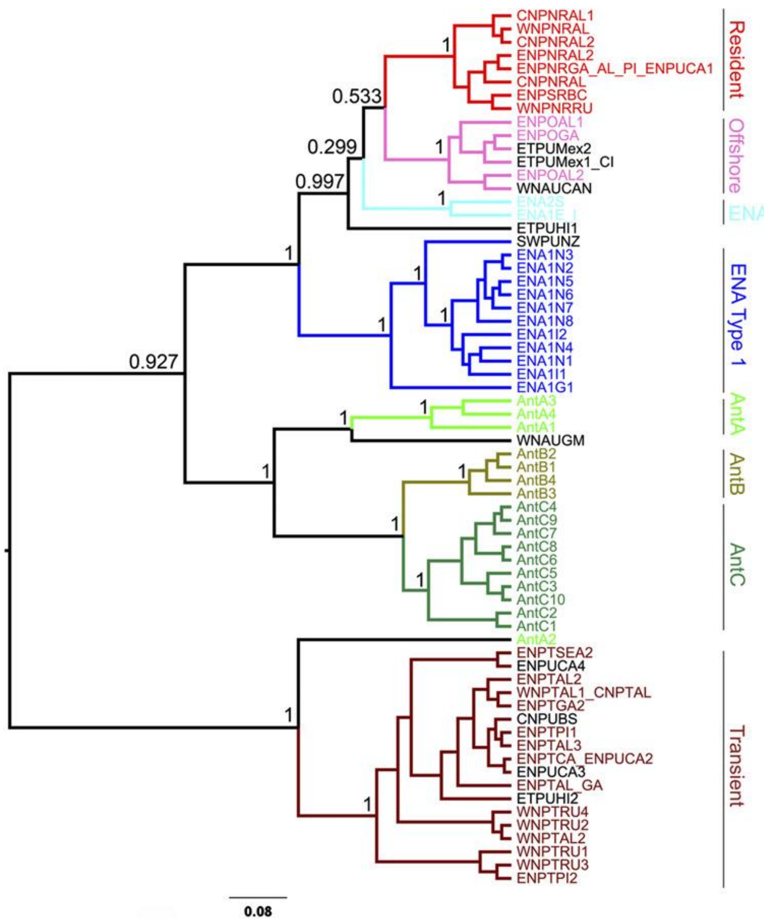



**Figure 2 -- Whole mitochondrial genome phylogeny of 66 unique killer whale haplotypes. Posterior probabilities are indicated for nodes of interest. Whales of known type are indicated in color, and those of unknown type are in black type. Reproduced from Morin *et al.* (2010).**

### *Summary, genetics*

Our understanding of killer whale population structure has improved considerably since 2004, due both to analysis of new samples, larger numbers of nuclear loci, and the collection of full mitogenome data. At least at the high latitude areas examined, the full mitogenome trees are much more geographically and ecotypically structured than was true of the control region trees available in 2004. The genetic studies published since 2004 also clearly support earlier suggestions of differentiation between some of the Antarctic ecotypes.

Despite the greater resolution provided by the mitogenome data compared to that of only the control region sequences, the total depth of the mitochondrial phylogeny within *O. orcus* remains relatively shallow compared to the levels of divergence typically observed between mammalian sister species. For example, Johns and Avise (1998), Avise *et al.* (1998) and Baker and Bradley (2006) have reviewed divergence at the mitochondrial cytochrome-b gene for a large number of mammal sister species, and levels of divergence are typically >5%, although some are much lower. The divergence between resident and transient killer whales is ~0.4% (based on sequences from Morin *et al.* (2010)), suggesting that if the ecotypes are species they are relatively young species. The relatively shallow divergence could also be consistent with incipient speciation (Riesch *et al.* 2012), or with subspecies (Reeves *et al.* 2004).

Evaluating variation at multiple nuclear genes is also important for gaining a full understanding of population structure, both to reduce the stochastic noise associated with inference at a single locus such as mtDNA and to ensure that population processes mediated by male gene flow are evaluated.

Studies of nuclear variation published since 2004 have provided results consistent with what was available to the 2004 BRT, albeit with considerable improvements in terms of numbers of samples and loci analyzed. In 2013, as in 2004, all published studies of killer whale population structure that use nuclear loci have utilized microsatellites, although the number of loci has increased from 17 (Hoelzel 2004) to 27 in the most recent study (Parsons *et al.* 2013). The studies that have most directly attempted to estimate rates of gene flow among populations using nuclear loci (Hoelzel *et al.* 2007, Pilot *et al.* 2010), estimate no contemporary gene flow between the North Pacific residents and either transients or offshores, and at most very little contemporary gene flow between transients and offshores. The most sophisticated estimates of historical gene flow (the Ima2-based estimates from Hoelzel *et al.* 2007) are all <1 migrant/generation among the Pacific ecotypes. The largest available study of microsatellite variation among North Pacific killer whales (Parsons *et al.* 2013) also found no evidence for contemporary gene flow between residents and transients. Estimates of rates of gene flow within the North Pacific resident populations vary somewhat, but most analyses indicate little gene flow, particularly into or out of the more southern populations. All of these results continue to strongly support the 2004 BRT's conclusion that there is a "… high degree of contemporary reproductive isolation among eastern North Pacific killer whale populations" (Krahn *et al.* 2004, p. 16).

Our understanding of killer whale population structure outside of the North Pacific has also progressed considerably since 2004. Studies of variation among killer whale groups in the Antarctic (Leduc *et al.* 2008; Morin *et al.* 2010) in particular have confirmed the presence of distinct groups that correspond to the ecological/morphological groups previously identified (Pitman *et al.* 2003; Pitman *et al.* 2007). Population structure in the Atlantic is also starting to be elucidated (Foote *et al.* 2009), as is the relationship between the North Atlantic and North Pacific (Foote *et al.* 2011b).

Despite this considerable progress, it is also clear that a full understanding of killer whale structure at a global scale remains incomplete. There have been no published genetic studies focusing on samples from tropical areas (although Morin *et al.* 2010 included some tropical samples), and large portions of the killer whale's range, including the coasts of South America, Africa, Australia, and eastern North America, remain essentially unanalyzed.

In addition to the lack of sampling in some areas, the issue of the evolutionary age of the Pacific ecotypes and of killer whale populations worldwide remains somewhat uncertain and subject to varying estimates. Based on the low levels of mtDNA control region divergence, Hoelzel *et al.* (2002) hypothesized that killer whales globally experienced a population bottleneck 145,000 to 210,000 years ago. By fitting population genetic models to microsatellite and mtDNA control region data, Hoelzel *et al.* (2007) estimated the divergence time between the Pacific ecotypes at 20,000-30,000 years ago. In contrast, Morin *et al.* (2010) estimated the time to the most recent common ancestor of the killer whale mitogenomes that characterize the ecotypes to be 170,000 to 700,000 years ago, implying a much deeper divergence time than had been estimated previously. However, Hoelzel *et al.* (2007) estimated divergence times between populations, whereas Morin *et al.* (2010) estimated divergence time among gene sequences and these estimates are not expected to be the same (topic reviewed by Edwards *et al.* 2000). Hoelzel *et al.*'s estimate was based on a much smaller mtDNA segment than the Morin *et al.* estimate, but Hoelzel's estimate also included information from nuclear loci. In addition, all of these estimates are sensitive to the estimated or assumed mutation rate, which differed between the studies. It is therefore not immediately obvious which of these estimates is more reflective of the true evolutionary age of the ecotypes, or even that these estimates are necessarily inconsistent with each other. Additional nuclear sequence data is likely to improve the precision of the estimated divergence times.

### Review papers

Riesch *et al.* (2012) and Foote (2012) recently reviewed evidence for ongoing ecological speciation among killer whale ecotypes. Riesch *et al.* focus particularly on the role that cultural factors might play in promoting ecological divergence and reproductive isolation. Both reviews conclude that most if not all of the behavioral, ecological and perhaps even some of the morphological (e.g., size) differences between the North Pacific ecotypes are likely to be non-heritable, culturally transmitted traits. Riesch *et al.* concluded that the reproductive and social isolation observed among ecotypes is largely culturally based, and there is no evidence for either pre or post-zygotic reproductive incompatibility. Ultimately, Riesch *et al.* concluded that there is not sufficient evidence to conclude that the ecotypes are currently separate species or subspecies, but rather that "We could be witnessing the early stages of an adaptive radiation of killer whales, whereby a variety of incipient species are beginning to exploit diverse ecological niches, or conversely, we could be looking at an old and continuing process by which new ecotypes periodically form and become extinct again." Foote (2012) evaluates much of the same information, and concludes that it is very hard to prove conclusively from field data alone that the specific process of ecological speciation (Schluter 2001; Schluter 2009) is occurring in killer whales or any "non-model" organism. Foote suggests that genome scans, by identifying specific functional genes subject to natural selection, might be a fruitful way to evaluate the causes of divergence in such systems. de Bruyn *et al.* (2013) recently reviewed information on Southern hemisphere killer whales both in Antarctica and in temperate latitudes and concluded that there is relatively little information on the social structure and ecology of killer whales in this region and that firm designation of ecotypes outside of the North Pacific may be premature.

## Summary and Conclusions

### Determination of the Taxon

Based on several lines of evidence, including differences in morphology, behavior, diet and feeding ecology, acoustical dialects and practices, and both mtDNA and nuclear DNA variation, the 2004 BRT concluded (with some uncertainty) that the North Pacific resident killer whales were a subspecies of *O. orca* distinct from the sympatric transient whales (Krahn *et al.* 2004, p. 40-41). With somewhat less confidence, the BRT also concluded that the North Pacific resident subspecies consisted of only the North Pacific residents, and did not include killer whales of the offshore ecotype or fish-eating killer whales from elsewhere in the world.

After reviewing information in the petition, the public comments, and the scientific literature published in the nine years since the 2004 status review, we found no new information that would likely lead to a different conclusion from that of the 2004 BRT. In particular, all of the new genetic data and analyses published since 2004 (Table 2), including the Pilot *et al.* (2010) paper discussed extensively by the petition, are either consistent with or strengthen the 2004 BRT's conclusion that there is a high degree of contemporary reproductive isolation among the North Pacific killer whale ecotypes. No genetic analysis published since the 2004 status review has indicated a higher level of interbreeding among the ecotypes than was indicated by the analyses considered by the 2004 BRT.

In addition to new genetic analyses, the studies on feeding ecology and diet published since 2004 are also generally consistent with or strengthen the 2004 BRT's conclusions that the ecotypes differ in diet and feeding ecology. The one new study that touches indirectly on morphological differences between the ecotypes (Zerbini *et al.* 2007) supports the 2004 BRT's conclusion (based on earlier literature) that the ecotypes can be morphologically differentiated. No new information on acoustics or behavior contradicts the conclusions of the 2004 BRT. Recent observations (NWFSC unpublished data) indicate that offshores consume at least some Chinook salmon, but stable isotope and tooth wear data also indicate substantial dietary differences. The petition discusses numerous questions regarding the morphological, behavioral and ecological data cited by the 2004 BRT, but does not raise issues not already discussed by the BRT or the 2004 Taxonomic workshop.

A broader scientific consensus regarding whether the North Pacific ecotypes are a subspecies of *O. orca* remains mixed, as was the case at the time of the 2004 BRT (Krahn *et al.* 2004; Reeves *et al.* 2004). Some experts have suggested that the ecotypes clearly meet criteria for subspecies or species designation (Morin *et al.* 2010), and at least one scientific society (the Society for Marine Mammalogy) now formally recognizes North Pacific residents and transients as subspecies (Committee on Taxonomy 2012). Other experts are less certain that either species or subspecies status is currently appropriate, based on some estimates of non-zero male mediated gene flow among ecotypes (Hoelzel public comments; de Bruyn *et al.* 2013; Riesch *et al.* 2012). Some of this lack of consensus appears to be related to differing conceptions of subspecies definitions rather than substantial disagreement about the biological differences characterizing the ecotypes.

Although the 2004 BRT concluded that the North Pacific resident killer whales meet the criteria for being a subspecies, the BRT expressed some uncertainty about whether to also include Pacific offshores, tropical Pacific killer whales, and by extension perhaps also Atlantic fish-eating killer whales in this subspecies as well (Krahn *et al.* 2004, pp. 40-41). The data available since 2004 tend to strengthen the BRT's conclusion that the North Pacific resident killer whales are taxonomically distinct from the sympatric offshores and allopatric populations of killer whales in the tropics and Atlantic. In particular, Morin *et al.* (2010) found that the North Pacific residents form a monophyletic mtDNA clade distinct from offshores, Atlantic whales and the limited number of Pacific tropical whales included in the study (Figure 1). Estimated rates of gene flow between residents and Atlantic populations differ greatly between studies, but generally suggest that such gene flow is occurring on evolutionary rather than ecological time scales. The fact that the three Pacific ecotypes retain their genetic and ecological distinctiveness when in sympatry also strongly suggests they are currently on divergent evolutionary trajectories. Nonetheless, as was the case in 2004 clearly demarcating the phylogenetic boundaries of the resident taxon remains somewhat uncertain and the rationale for taxonomically distinguishing the residents from the offshores and from fish eating whales in the Atlantic appears somewhat less compelling than taxonomically distinguishing transients from other North Pacific killer whales.

Taken together, however, the best available information clearly strengthens the lines of evidence cited by the 2004 BRT (Krahn *et al.* 2004) to support the designation of the North Pacific resident and transient killer whales as an unnamed subspecies of *O. orca.*

## Determination of the DPS

As of December 31, 2012, the SRKW population consisted of 84 individuals divided into three pods (26 in J, 19 in K, and 39 in L) (Center for Whale Research and NWFSC unpublished data). An additional captive animal originating from the SRKW population and with a genotype consistent with a southern resident origin (Hoelzel *et al.* 2007; Hoelzel pers. com.), "Lolita", has resided at the Miami Seaquarium since her capture in August of 1970 (Hoyt 1981). Lolita's original pod is not known with certainty, but her acoustic calls are typical of L pod (Ford 1987; Candice Emmons, personal communication).

The 2004 BRT concluded that there was strong evidence that the SRKW are discrete as defined by the 1996 DPS policy, citing significant genetic differentiation, separate demographic trajectories, differences in core and summer range, and behavioral differences with other resident populations (Krahn *et al.* 2004, p 44). The BRT was less certain that the SRKW met the DPS policy's criteria for significance, but concluded (by a 2-to-1 margin) that they did, citing differences in ecological setting, range, marked differences in genetic variation, and potential cultural differences.

The new information subsequent to 2004 is consistent with and generally strengthens the conclusion that the SRKW are a discrete population within the North Pacific resident taxon. In particular, recent genetic studies all indicate that SRKW are significantly differentiated from other resident populations. New information on the winter range of SRKW provides for a considerably more complete picture than was available in 2004, and continues to indicate that the SRKW (particularly L and K pods) have a winter and summer range distinct from other resident populations, although it does overlap substantially with the northern resident population. A recent analytical comparison of demographic rates found significant differences in both survival and fecundity rates between the southern resident population and the northern resident population, providing further evidence of demographic discreteness (Ward *et al.* 2013). In short, as in 2004 all the available information clearly indicates that the southern residents are a distinct population.

Compared to 2004, new information related to the significance of the SRKW to the North Pacific resident taxon provides a somewhat more nuanced picture. Each of the factors listed by the 2004 BRT in support of the significance criteria is discussed below with reference to new information.

Ecological setting and range – The 2004 BRT noted that the southern residents appeared to occupy a distinct ecological setting, being the only North Pacific resident population to spend substantial time in the California Current ecosystem and having a diet somewhat different from other resident populations, particularly those in Alaska. The BRT also cited the possibility that the southern residents historically utilized the large runs of salmon to the Sacramento and Columbia River as a major source of prey. With regard to range, the BRT noted that the southern residents were the only resident population to be observed to spend time in Puget

Sound and off the coasts of Washington, Oregon and California and that if they were to go extinct this would result in a significant gap/reduction in the resident's range.

New information since 2004 generally continues to support most of these conclusions, but also challenges some of them. In particular, new information on the coastal distribution of the southern and northern resident populations confirms that the southern residents spend substantial time in coastal areas of Washington, Oregon and California and utilize salmon returns to these areas (NWFSC unpublished data). However, there is also new information indicating that the Northern Resident population may also spend more time off the Washington coast than was previously believed (Riera *et al.* 2011; NWFSC unpublished data), and the known northern range of the southern residents is now Chatham Strait in SE Alaska based on photographs taken in 2007 (John Ford, DFO, pers. com). In addition, diet information on the Alaskan resident populations indicates that some of these populations also consume salmon, although not the Chinook salmon that dominate the southern and northern resident diets (Saulitis *et al.* 2000). Updated diet data from the southern and northern resident populations confirms that these two populations have very similar diets and consume many of the same salmon stocks (Ford *et al.* 2010; Hanson *et al.* 2010). Overall, the southern residents remain unique in occupying the most southern part of the resident's range, and are clearly occupying a somewhat different ecological setting from populations in Alaska and further west around the Pacific Rim. The southern portion of the southern resident's range is also quite distinct from that of the northern resident population, but the southern and northern residents clearly share a similar ecological setting throughout much of their range.

Genetic differentiation – Genetic data available since 2004 confirms or strengthens the conclusions that the southern resident population is genetically differentiated from other resident populations. In particular, there are no new data to change the 2004 BRT's conclusions that the southern resident population differs markedly from other North Pacific resident populations at both nuclear and mitochondrial genes.

Behavioral and cultural diversity – The 2004 BRT noted several instances of known and apparent cultural differentiation among resident killer whale populations, and hypothesized, based on studies in other long-lived mammals, that such diversity could be important for the survival of the North Pacific resident taxon as a whole. Since 2004, several studies have contributed further information to this topic. For example, Ward *et al.* (Ward *et al.* 2013; 2011) found significant differences in survival among the three southern resident pods and between the southern and northern resident populations. These differences are likely related to differences in diet and habitat use, both of which appear to be culturally determined. Riesch *et al.* (2012) and Foote (2012) reviewed cultural differences, particularly acoustic behavior and prey preferences, among killer whale populations and ecotypes, and concluded that such cultural differences may be leading to reproductive isolation and subsequent ecological speciation. On the whole, therefore, the available data appear consistent with the BRT's conclusion that such cultural differences may be important factors in the overall viability of the resident killer whale taxon.

Overall, new information on genetics and behavioral and culture diversity available since 2004 is consistent with or strengthens the 2004 BRT's conclusion that the southern resident killer whale population meets the significance criteria of the DPS policy. New information on ecological setting and range tends to weaken the 2004 BRT's conclusion somewhat, as it indicates greater overlap in range or diet with other resident and offshore populations than was previously believed. Overall, the new information available since 2004 appears consistent with the 2004 BRT's conclusion that southern resident killer whales are likely to be a DPS of the unnamed North Pacific resident subspecies.

## Appendix – Review of specific points made in the petition

### Workshop on Cetacean Taxonomy

p. 14 – "No experts in the field of cetacean taxonomy were included to inform the workshop participants." The list of participants is in Appendix 1 of workshop report (Reeves *et al.* 2004). It contains multiple experts on cetacean taxonomy, such John Heyning, Marilyn Dahlheim, William Perrin, and James Mead. In the paragraph preceding the sentence quoted above, the petition references papers by Perrin, Heyning and Dahlheim as authoritative on killer whale taxonomy.

p. 14 – 17 – In summarizing the Cetacean Taxonomy workshop, the petition fails to mention that among the workshop's conclusions was that "Overall, a majority of participants felt that Resident- and Transient-type killer whales in the ENP [Eastern North Pacific] probably merited species or sub-species status." (Reeves *et al.* 2004 pp. 5 and 72).

p. 17 – "Most importantly of all, the workshop contained the following: [C]onsideration of whether to add the 'southern resident' killer whales of the eastern North Pacific to the U.S. Endangered Species List hinged on poorly understood evolutionary relationships between this population and killer whales globally (LJ/04/KW10). In the absence of a fundamental understanding and agreement on the number of species and subspecies of killer whales, consensus could not be reached on whether this whale population was significant to the taxon to which it belongs."

The petitioners present this statement as a conclusion of the workshop. However, the text quoted appears in the first page of the workshop report and is referring to the inability of the 2002 BRT (Krahn *et al.* 2002) to reach a consensus on killer whale taxonomy. In other words, this statement is describing the motivation for the workshop, not the workshop's conclusion.

p. 17-18 – The discussion of the 2006 listing fails to cite the BRT reports (Krahn *et al.* 2002, 2004) and the discussions therein regarding killer whale taxonomy and population structure.

### Scientific basis for identification of subspecies

p. 26 – "Contradicting the scientific consensus in the cetacean's [sic] workshop, and without any support from the broader taxonomic community, the Service unilaterally created a killer whale subspecies – the North Pacific residents – based apparently on geographic distribution."

This statement is misleading. With regard to killer whale taxonomy, the taxonomy workshop report stated: "Overall, a majority of participants felt that the Resident- and Transient-type killer whales in the ENP probably merit at least species or subspecies status." (Reeves *et al.* 2004, p. 72). In addition, the BRT report discusses multiple lines of evidence both for and against sub-species, and clearly does not rely solely on geography (Krahn *et al.* 2004).

p. 26, 27 – The petition notes that NMFS has not provided a Latin trinomial for the hypothesized North Pacific Resident sub-species, and suggests that "… the Service has chosen to ignore 275 years of biological classification and taxonomic nomenclatural convention…". The issue of nomenclature was in fact explicitly discussed in the BRT report, which noted that all the biological issues surrounding the subspecies will need to be resolved before the nomenclature can be settled (Krahn *et al.* 2004, p. 18). In addition, the Cetacean Taxonomy Workshop report contains a section that specifically discusses unnamed subspecies, noting several examples and concluding that "Designation of unnamed subspecies can provide a mechanism for allowing recognition of highly differentiated forms without having to wait until its nomenclature is settled." (Reeves *et al.* 2004, p. 8). The Society for Marine Mammalogy also recognizes the residents and transients as unnamed subspecies of *O. orca* (Committee on Taxonomy 2012).

## Genetic data

The petition relies heavily on a recent paper, Pilot *et al.* (2010), that uses a variety of analyses to estimate rates of interbreeding among groups of killer whales (see section above for a summary of this paper). Much of the petition's discussion of this paper is misleading, misrepresenting both the results of the Pilot *et al.* study and how these results combine with the results of other studies to provide a more complete description of killer whale population structure.

p. 29 – "Pilot *et al.* (2010) reported that comparative assessments of kinship, parentage, and dispersal reveal high levels of kinship and male-mediated gene flow within local populations, including among ecotypes that are highly divergent within the mtDNA phylogeny."

Using the parentage and assignment methods the petition appears to prefer, Pilot *et al.* found a single putative instance of interbreeding (gene flow) between whales from different the Pacific ecotypes – an offshore whale that genetically assigned to the transient ecotype (Pilot *et al.* 2010 Appendix S3). They found no instances of putative interbreeding between the residents and transients or residents and offshores. We therefore disagree with petition's conclusion that Pilot *et al.* (2010) found "high levels" of male mediated gene flow among ecotypes. Another, larger study (in terms of whales sampled and loci genotyped) found no instances of interbreeding among ecotypes (Parsons *et al.* 2013).

p. 29 – "In contrast to the Service's insistence that its speculative unnamed North Pacific resident subspecies (and Southern Resident DPS) are genetically isolated, Pilot *et al.* (2010) show that they are not."

The 2004 BRT did not claim that the ecotypes were completely isolated, merely that there was a "… high degree of contemporary reproductive isolation…" (Krahn *et al.* 2004 p. 16). The petition's claims to the contrary, the Pilot *et al.* (2010) results show that there is at most rare and episodic contemporary gene flow between the transient and offshore ecotypes and no evidence of contemporary gene flow between the resident and offshore ecotypes or the resident and transient ecotypes. Using model fitting methods to estimate historical gene flow, Pilot *et al.* (2010) estimate that there has been low (generally < 1%) rates of gene flow among the ecotypes historically (see Table 5 of Pilot *et al.* 2010). These rates are consistent with the BRT's interpretation of a high degree of reproductive isolation, and are also consistent with the information available to the 2004 BRT when it made its evaluation (see Tables 4 and 5 of Hoelzel 2004).

p. 30 – "The significance of the findings of Pilot *et al.* (2010) is threefold. First, they demonstrate with data that social interactions among killer whale pods do occur in the wild and they occur more frequently than has been reported (i. e., many interactions are simply "missed" by human observers who cannot watch a vast area of ocean to take note of killer whale pod interactions, 24 hours a day, 7 days a week, year round)."

Actually, Pilot *et al.* (2010) only studied patterns of genetic data, and contained no data or analysis of social interactions.

p. 30 – "The genetic data provide evidence that these inter-pod social interactions occur, and that they can and do result in mating among individuals in different pods, including mating among individuals of different ecotypes (i.e., between resident and transient killer whales)."

As we explain above, Pilot *et al.* (2010) found no direct evidence at all of mating between resident and transient killer whales (see Appendix S3 of Pilot *et al.*), and their indirect (model fitting) methods indicated that rates of gene flow between residents and transients were less than one half a percent (Table 5 of Pilot *et al.*). Pilot *et al.* did find somewhat higher rates of gene flow among resident populations (ie, within the resident ecotype), but even these were very low for all pairs of populations except between Russia and the Bering Sea and Bering Sea and Alaska: "In residents, very high gene flow rates were revealed from RU to BS (0.28) and from BS to AR (0.14), and much lower rates (ranging from 0.005 to 0.024) between other pairs of resident populations." (p. 26).

p. 33 – "Therefore, if only mtDNA is considered in an analysis, the loss of mtDNA variation in populations (also referred to as lineage sorting) can give an erroneous appearance of populations (and putative species) being genetically isolated because they are trying to maintain taxonomic differences (i.e., Morin *et al.* 2010) while at the same time ecotypes and populations are not isolated for nuclear genetic variation. This is precisely the case with killer whales, a fact the Service did not acknowledge in its 2005 listing of the killer whale DPS, or in its 2011 status review of the population."

There are multiple inaccuracies with this statement and the discussion of mtDNA patterns that surrounds it in the Petition. First, the BRT explicitly discussed the strengths and limitations of mitochondrial (maternal) and nuclear genetic markers (see pp. 22-23 of Krahn *et al.* 2002 and p. 16 of Krahn *et al.* 2004). Second, the statement seems to imply that North Pacific killer whales ecotypes and populations are not strongly differentiated at nuclear loci. This is simply not correct: Hoelzel *et al.* (2007), Pilot *et al.* (2010), Morin *et al.* (2010), and Parson *et al.* (2013) all describe patterns of microsatellite (nuclear) variation among populations, and all find significant levels of divergence consistent with generally low rates of gene flow (typically < 1 migrant/generation among ecotypes and very much less for some analyses). A preliminary version of one of these analyses (Hoelzel 2004) was discussed extensively by the 2004 BRT (Krahn *et al.* 2004 pp. 11-13).

With regard to 'lineage sorting' of mtDNA, this phenomena was explicitly considered by the BRT (see Krahn *et al.* 2002 p. 23 paragraph 3), who ultimately concluded that much of mtDNA variation among populations was in fact random and due to stochastic events. That conclusion, although reasonable at the time, must now be updated based on the new whole mitogenome data of Morin *et al.* (2010), which shows that when whole mitogenomes are considered patterns of mtDNA variation among killer whales are not at all random but instead are very highly correlated with ecotype. This new result, combined with the new nuclear data reported in the same paper and by Hoelzel *et al.* (2007), Pilot *et al.* (2010) and Parsons *et al.* (2013), in fact strengthens the original conclusion of the BRT that North Pacific killer whale ecotypes are highly reproductively isolated from each other.

p. 34 – "Thus, outbreeding occurs (particularly those in different ecotypes) but is limited by the frequency of interactions in the ocean, rather than by killer whales trying to maintain taxonomic or population isolation."

The implication that the only factor limiting interbreeding between resident killer whales and transient killer whales is infrequent opportunity for interactions in the ocean is not consistent with the available data. For example, both residents and transients are frequently observed in the Salish Sea, often on the same day and in the same general location but have never been observed to interact or socialize (Baird 2000). The ocean is indeed vast, but the resident and transient ecotypes have a primarily coastal distribution, have a long distance means of potentially locating each other through their acoustic calls, and are frequently sighted in the same general vicinity by human observers (see e.g. Table 2 of Zerbini *et al.* 2007). It therefore seems highly implausible that only lack of random encounters is limiting gene flow between ecotypes.

p. 35 – "Thus, the Service has erroneously attributed the patterns of genetic variation and behavior between ecotypes to genetic differences, when learned behaviors are responsible for these ecotypes."

It seems reasonable to conclude that "patterns of genetic variation" have a genetic basis. With regard to the behavioral and ecological differences among the ecotypes, the BRT never concluded that these traits were genetically based. For example, the 2004 BRT report summarized arguments for and against multiple species of North Pacific killer whales, and in the "Arguments for a single species" section noted: "Foraging specializations and other behavioral characteristics such as distinct vocalizations may be learned and therefore are not good indicators of species status (Barrett-Lennard and Heise 2004)." The BRT did consider the ecological, social and foraging differences among the ecotypes as one of several lines of evidence for subspecies status (Krahn *et al.* 2004, p. 39-40), but never claimed that these were genetically based characteristics. In discussing the factors leading to the conclusion that the southern resident killer whales are a DPS, the BRT discussed ecological setting, range, genetic differentiation, and behavioral and cultural diversity (Krahn *et al.* 2004 p. 44-45). In other words, in its DPS determination the BRT stated explicitly that it was considering behavioral and cultural factors in addition to genetic variation in assessing DPS status, consistent with USFWS and NMFS policy on DPS determination.

p. 36 – "In sum, there is no competent genetic evidence to support the designation of the North Pacific resident whale population as a subspecies."

At a minimum, this is a debatable point. Rates of contemporary gene flow have been estimated as zero between the residents and either the transient and offshore ecotypes (Pilot *et al.* 2010, Ford *et al.* 2011, Parsons *et al.* 2013). The three ecotypes can be unambiguously identified using either mtDNA or nuclear genetic data (Morin *et al.* 2010, Parsons *et al.* 2013) or photographs (Zerbini *et al.* 2007). These genetic differences are maintained in sympatry, a factor even biologists concerned about taxonomic inflation view as important evidence of taxonomic distinctiveness (Zachos *et al.* 2013). There is no question that there is some uncertainty regarding the taxonomic status of the North Pacific ecotypes and that it is possible for reasonable experts to come to somewhat different conclusions (see pp. 41 and 45 of Krahn *et al.* 2004, for example). But to conclude that there is "no competent genetic evidence" is inconsistent with the available information.

## Morphological data

p. 36 - 38 – "The Service fails to distinguish the difference between variation that is primarily due to environmental influences on development, such as body size, and variation that has a genetic basis." "In the listing decision, references to morphological differences that distinguish ecotypes are based upon studies that are anecdotal, qualitative, or pseudo-quantitative in nature (Baird & Stacey 1988; Baird 2000). There are no data to substantiate objectively actual distribution of these traits in the wild. There are no data to support the genetic basis for variation in these traits (e.g., body size, which is primarily influenced by environment rather than genetics in most mammals). Further, there are no data to support the presumption that the morphological differences in question have any functional significance (i.e., they confer a survival advantage to an ecotype). The Service's key morphological "evidence" to describe three ecotypes of killer whales in the 2005 listing rule is subjective, or involves incomplete qualitative comparisons, or both (Table 1)."

In fact, the 2004 BRT noted similar points in evaluating the morphological data (see Krahn *et al.* p. 38), and with the exception of the saddle patch pigmentation trait never claimed that the morphological differences among the ecotypes were necessarily genetically based or proven to be adaptive. Indeed, the criteria for subspecies designation suggested by Reeves *et al.* (2004) and used by the BRT do not require that morphological variation be proven to either genetically based or adaptive in order for it be used as one of several factors to delineate subspecies. It is also important to note that at the time of the status reviews in 2002-2004 (and even now) relatively little data were available for offshore killer whales.

Nonetheless, we agree with the petitioners that much of the information on morphological variation within and among the North Pacific ecotypes is qualitative in nature and would benefit from additional quantitative analysis. It is important to note, however, that the qualitative differences among the ecotypes that have been described are based on decades of field observations by biologists who have spent their entire careers studying killer whales. The BRT therefore felt comfortable including these descriptions as one of several lines of information related to potential taxonomic status. Subsequent to the 2004 BRT report, the analyses of Zerbini *et al.* (2007) indicates that at least when comparing multiple individuals of each ecotype the groups can be reliably distinguished on the basis of morphology.

p. 39 – "Saddle patches are another morphological trait used to treat the North Pacific resident whale population as a separate subspecies. Yet again there is substantial overlap among ecotypes, and the categories of patterns have been described differently by different authors. Evans *et al.* (1984) described three patterns, while Baird and Stacey (1988) described five. As shown in the line drawings from each paper on the following page (Evans *et al.* 1984; Baird and Stacey 1988), there is no overlap in the patterns, yet the Service relied on this subjective classification in its listing decision even in the absence of supporting data such as field notes, photographs, or measurements. Finally, the Service did not acknowledge another source of error in classifying saddle patch patterns: saddle patches are not always symmetrical. Therefore, different classifications can be obtained depending upon which side of the killer whale is photographed, leading to erroneous assignments."

The BRT did not use or cite the Evans *et al.* (1984) study, which was focused on patterns of killer whale pigmentation at a global scale and did not include ecotype information. The Baird and Stacey (1988) paper clearly cites the sources of the photographs they analyzed, which are from readily available publications. The publication also clearly stated that only photographs of the left side of the whales were used. The Petition speculates that right-hand-side photographs may produce different results, but provides no analysis to back up this statement.

p. 42 – "The Service fails to recognize the evolutionarily more parsimonious explanation that the behavioral traits it uses to distinguish among supposed subspecies or ecotypes are learned rather than the result of genetic differences."

As was noted above, the BRT reports never concluded that variation in vocalization or behavioral traits is genetically based.

p. 42-42 – "In a recent paper, Rehn *et al.* (2010) reported that a killer whale vocalization associated with high arousal behaviors is common to all killer whales and does not vary regardless of pod, ecotype, or location in the Pacific. Thus, this innate behavior is consistent with the killer whale's current classification as a single species"

The experimental design of the Rehn *et al.* (2010) paper was to examine isolated, non-interacting, groups of killer whales in order to find common and thus presumably innate call types. While the finding of such a call type certainly is consistent with the known evolutionarily recent common ancestry of the ecotypes, it is not strong evidence that they belong to a single species. Indeed, the Pacific ecotypes and killer whales worldwide share a great many traits due to common ancestry. For that matter, they share a great many traits in common with other delphinids. However, simply sharing traits is obviously not strong evidence that two putative taxa are conspecific or are not reproductively isolated. Humans and chimpanzees, for example, share ~99% of their genomes (Mikkelsen *et al.* 2005), but few would argue that they are not distinct species.

p. 48 – "An unbiased method would have used DNA amplification primers and reaction conditions capable of detecting types of potential prey other than just fish (i.e., marine mammals, birds, and squid). Such a method would use a pair of conserved DNA amplification primers for animals (i.e., 16sRNA), or combinations of primers that would amplify fish, marine mammals, birds, and squid, followed by application of culture independent methods (e.g., PCR, cloning of PCR products, and sequencing of the clone library). That would provide DNA sequences from virtually all animal DNAs in a sample, even if they are at low frequency. This method is widely used in microbial genomics and forensics, and is needed to detect total diversity of the prey items in the sample (Hugenholtz *et al.* 1998)."

The petition is correct that primers used in the Hanson *et al.* (2010) study were designed specifically to detect fish prey. This was in part to avoid amplifying DNA from the killer whales being sampled. However, another study (Ford *et al.* 2011b) did use 16s ribosomal DNA primers to obtain PCR amplicons from ~200 killer whale fecal samples collected from the southern resident population, including many of the same samples used in the Hanson (2010) study. These primers have been demonstrated to amplify both harbor seal and harbor porpoise, two common marine mammals preyed upon by transient killer whales. In controlled experiments in which harbor seal or harbor porpoise DNA was mixed with killer whale DNA and amplified and sequenced using these primers, the harbor porpoise and harbor seal sequences were readily detectable, along with that of killer whale. Using the same primers and methods, marine mammal sequences (other than killer whale) were not detected in any of the >200 fecal samples collected from the field (Hempelmann 2012).

## References


Avise, J., and R. Ball, 1990 Principles of genealogical concordance in species concepts and biological taxonomy. Oxford surveys in evolutionary biology **7:** 45-67.

Avise, J. C., D. Walker and G. C. Johns, 1998 Speciation durations and Pleistocene effects on vertebrate phylogeography. Proceedings of the Royal Society B-Biological Sciences **265:** 1707-1712.

Baird, R. W., 2000 The killer whale -- foraging specializations and group hunting, pp. 127-153 in *Cetacean societies: field studies of dolphins and whales*, edited by J. Mann, R. C. Connor, P. L. Tyack and H. Whitehead. University of Chicago Press, Chicago.

Baird, R. W., and P. J. Stacey, 1988 VARIATION IN SADDLE PATCH PIGMENTATION IN POPULATIONS OF KILLER WHALES (ORCINUS-ORCA) FROM BRITISH-COLUMBIA, ALASKA, AND WASHINGTON STATE. Canadian Journal of Zoology-Revue Canadienne De Zoologie **66:** 2582-2585.

Baker, R. J., and R. D. Bradley, 2006 Speciation in mammals and the genetic species concept. Journal of Mammalogy **87:** 643-662.

Beck, S., S. Kuningas, R. Esteban and A. D. Foote, 2011 The influence of ecology on sociality in the killer whale (Orcinus orca). Behavioral Ecology.

Berzin, A. A., and V. L. Vladimirov, 1983 A NEW SPECIES OF KILLER WHALE (CETACEA, DELPHINIDAE) FROM THE ANTARCTIC WATERS. Zoologichesky Zhurnal **62:** 287-295.

Committee on Taxonomy, 2012 List of marine mammal species and subspecies. Society for Marine Mammology, http://www.marinemammalscience.org, consulted on April 25, 2013.

Crandall, K. A., O. R. P. Bininda-Emonds, G. M. Mace and R. K. Wayne, 2000 Considering evolutionary processes in conservation biology. Trends in Ecology and Evolution **15:** 290-295.

Dahlheim, M. E., A. Schulman-Janiger, N. Black, R. Ternullo, D. Ellifrit *et al.*, 2008 Eastern temperate North Pacific offshore killer whales (Orcinus orca): Occurrence, movements, and insights into feeding ecology. Marine Mammal Science **24:** 719-729.

Dahlheim, M. E., and P. A. White, 2010 Ecological aspects of transient killer whales Orcinus orca as predators in southeastern Alaska. Wildlife Biology **16:** 308-322.

de Bruyn, P. J. N., C. A. Tosh and A. Terauds, 2013 Killer whale ecotypes: is there a global model? Biological Reviews **88:** 62-80.

Deecke, V. B., J. K. B. Ford and P. J. B. Slater, 2005 The vocal behaviour of mammal-eating killer whales: communicating with costly calls. Animal Behaviour **69:** 395-405.

Deecke, V. B., M. Nykanen, A. D. Foote and V. M. Janik, 2011 Vocal behaviour and feeding ecology of killer whales Orcinus orca around Shetland, UK. Aquatic Biology **13:** 79-U186.

Deecke, V. B., P. J. B. Slater and J. K. B. Ford, 2002 Selective habituation shapes acoustic predator recognition in harbour seals. Nature **420:** 171-173.
Dizon, A. E., C. Lockyer, W. F. Perrin, D. P. Demaster and J. Sisson, 1992 Rethinking the stock concept: a phylogeographic approach. Conservation Biology **6:** 24-36.
Edwards, S. V., and P. Beerli, 2000 Perspective: Gene divergence, population divergence, and the variance in coalescence time in phylogeographic studies. Evolution **54:** 1839-1854.
Foote, A. D., 2012 Investigating ecological speciation in non-model organisms: a case study of killer whale ecotypes. Evolutionary Ecology Research **14:** 447-465.
Foote, A. D., P. A. Morin, J. W. Durban, R. L. Pitman, P. Wade *et al.*, 2011a Positive selection on the killer whale mitogenome. Biology Letters **7:** 116-118.
Foote, A. D., P. A. Morin, J. W. Durban, E. Willerslev, L. Orlando *et al.*, 2011b Out of the Pacific and Back Again: Insights into the Matrilineal History of Pacific Killer Whale Ecotypes. PLoS ONE **6.**
Foote, A. D., J. Newton, S. B. Piertney, E. Willerslev and M. T. P. Gilbert, 2009 Ecological, morphological and genetic divergence of sympatric North Atlantic killer whale populations. Molecular Ecology **18:** 5207-5217.
Foote, A. D., J. T. Vilstrup, R. de Stephanis, P. Verborgh, S. C. A. Nielsen *et al.*, 2011c Genetic differentiation among North Atlantic killer whale populations. Molecular Ecology **20:** 629-641.
Ford, J., and G. Ellis, 2006 Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series **316:** 185–199.
Ford, J. K. B., G. M. Ellis and K. C. Balcomb, 2000 *Killer whales: The natural history and genealogy of Orcinus orca in British Columbia and Washington State. Second edition.* . UBC Press, Vancouver, BC, Canada.
Ford, J. K. B., G. M. Ellis, C. O. Matkin, M. H. Wetklo, L. G. Barrett-Lennard *et al.*, 2011a Shark predation and tooth wear in a population of northeastern Pacific killer whales. Aquatic Biology **11:** 213-224.
Ford, J. K. B., B. M. Wright, G. M. Ellis and J. R. Candy, 2010 Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p.
Ford, M. J., 2003 Conservation Units and Preserving Diversity in *Salmonid perspectives on evolution*, edited by A. Hendry. Oxford University Press, Oxford.
Ford, M. J., M. B. Hanson, J. A. Hempelmann, K. L. Ayres, C. K. Emmons *et al.*, 2011b Inferred Paternity and Male Reproductive Success in a Killer Whale (Orcinus orca) Population. Journal of Heredity **102:** 537-553.
Fraser, D. J., and L. Bernatchez, 2001 Adaptive evolutionary conservation: towards a unified concept for defining conservation units. Molecular Ecology **10:** 2741-2752.
Haig, S. M., E. A. Beever, S. M. Chambers, H. M. Draheim, B. D. Dugger *et al.*, 2006 Taxonomic considerations in listing subspecies under the US Endangered Species Act. Conservation Biology **20:** 1584-1594.

Hanson, M., R. Baird, J. Ford, J. Hempelmann-Halos, D. Van Doornik *et al.*, 2010 Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. Endangered Species Research **11:** 69-82.

Hempelmann, J., 2012 Memorandum from Jennifer Hemplemann to Michael Ford. November 20, 2012 (via email).

Herman, D. P., D. G. Burrows, P. R. Wade, J. W. Durban, C. O. Matkin *et al.*, 2005 Feeding ecology of eastern North Pacific killer whales, Orcinus orca, from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. Marine Ecology Progress Series **302:** 275-291.

Hey, J., R. S. Waples, M. L. Arnold, R. K. Butlin and R. G. Harrison, 2003 Understanding and confronting species uncertainty in biology and conservation. Trends in Ecology & Evolution **18:** 597-603.

Heyning, J., and M. Dahlheim, 1988 Orcinus orca. Mammalian Species **304:** 1-9.

Hilborn, R., S. Cox, F. Gulland, D. Hankin, N. Hobbs *et al.*, 2012 The Effects of Salmon Fisheries on Southern Resident Killer Whales: Final Report of the Independent Science Panel. Prepared with the assistance of D.R. Marmorek and A.W. Hall, ESSA Technologies Ltd., Vancouver, B.C. for National Marine Fisheries Service (Seattle. WA) and Fisheries and Oceans Canada (Vancouver. BC). xv + 61 pp. + Appendices. .

Hoelzel, A. R., 2004 Report on killer whale population genetics for the BRT review on the status of the Southern Resident population. Unpubl. report to BRT. (Available from L. Barre, NOAA Fisheries, NWR, 7600 Sand Point Way NE, Seattle, WA 98115.), pp.

Hoelzel, A. R., J. Hey, M. E. Dahlheim, C. Nicholson, V. Burkanov *et al.*, 2007 Evolution of population structure in a highly social top predator, the killer whale. Molecular Biology and Evolution **24:** 1407-1415.

Hoelzel, A. R., A. Natoli, M. E. Dahlheim, C. Olavarria, R. W. Baird *et al.*, 2002 Low worldwide genetic diversity in the killer whale (*Orcinus orca*): implications for demographic history. Proceedings of the Royal Society of London, Series B **269:** 1467-1473.

Hoyt, E., 1981 *The whale called killer*. E.P. Dutton, New York.

Johns, G. C., and J. C. Avise, 1998 A comparative summary of genetic distances in the vertebrates from the mitochondrial cytochrome b gene. Molecular Biology and Evolution **15:** 1481-1490.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss *et al.*, 2004 2004 Status review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act, pp. 73 in *NOAA Technical Memorandum*. Northwest Fisheries Science Center, Seattle.

Krahn, M. M., D. P. Herman, C. O. Matkin, J. W. Durban, L. Barrett-Lennard *et al.*, 2007 Use of chemical tracers in assessing the diet and foraging regions of eastern North Pacific killer whales. Marine Environmental Research **63:** 91-114.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor *et al.*, 2002 Status Review of Southern Resident killer whales (Orcinus orca) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-54. 133pp.

LeDuc, R., and B. Taylor, 2004 Revision of meeting document LJ/04/KW7, Mitochondrial sequence variation in North Pacific killer whales, Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management, April 30–May 2, 2004, La Jolla, California. Unpubl. report to BRT. (Available from L. Barre, NOAA Fisheries, NWR, 7600 Sand Point Way NE, Seattle, WA 98115.).

Leduc, R. G., K. M. Robertson and R. L. Pitman, 2008 Mitochondrial sequence divergence among Antarctic killer whale ecotypes is consistent with multiple species. Biology Letters **4:** 426-429.

Mallet, J., 1995 A SPECIES DEFINITION FOR THE MODERN SYNTHESIS. Trends in Ecology & Evolution **10:** 294-299.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright and E. P. Bjorkstedt, 2000 Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC **42:** 156p.

Mikhalev, Y., M. ivashin, V. Savusin and F. Zelenaya, 1981 The distribution and biology of killer whales in the Southern Hemisphere. Report of the International Whaling Commission **1:** 551-566.

Mikkelsen, T. S., L. W. Hillier, E. E. Eichler, M. C. Zody, D. B. Jaffe *et al.*, 2005 Initial sequence of the chimpanzee genome and comparison with the human genome. Nature **437:** 69-87.

Morin, P. A., F. I. Archer, A. D. Foote, J. Vilstrup, E. E. Allen *et al.*, 2010 Complete mitochondrial genome phylogeographic analysis of killer whales (Orcinus orca) indicates multiple species. Genome Research **20:** 908-916.

Moritz, C., 1994 Defining 'evolutionarily significant units' for conservation. Trends in Ecology and Evolution **9:** 373-375.

NMFS, 2002 Endangered and Threatened Wildlife and Plants: 12-Month Finding for a Petition To List Southern Resident Killer Whales as Threatened or Endangered Under the Endangered Species Act (ESA). Federal Register **67:** 44133-44138.

NMFS, 2013 Effects of Salmon Fisheries on Southern Resident Killer Whales. [http://www.nwr.noaa.gov/protected_species/marine_mammals/cetaceans_whales_dolphins_porpoise/toothed_whales/killer_whales/southern_resident_killer_whale/effects_of_salmon_fisheries_on_southern_resident_killer_whales.html](http://www.nwr.noaa.gov/protected_species/marine_mammals/cetaceans_whales_dolphins_porpoise/toothed_whales/killer_whales/southern_resident_killer_whale/effects_of_salmon_fisheries_on_southern_resident_killer_whales.html), pp.

Olson, P. A., P. Ensor and S. Kuningas, 2012 Observations of killer whales off East Antarctica, 82-95E, in 2009. Journal of Ceacean Research and Management **12:** 61-64.

Parsons, K., J. Durban, A. Burdin, V. Burkanov, R. Pitman *et al.*, 2013 Geographic patterns of genetic differentiation among killer whales in the northern Pacific. Journal of Heredity **doi: 10.1093/jhered/est037**.

Pilot, M., M. E. Dahlheim and A. R. Hoelzel, 2010 Social cohesion among kin, gene flow without dispersal and the evolution of population genetic structure in the killer whale (Orcinus orca). Journal of Evolutionary Biology **23:** 20-31.

Pitman, R., and P. Ensor, 2003 Three forms of killer whales (*Orcinus orca*) in Antarctic waters. Journal of Ceacean Research and Management **5:** 131-139.

Pitman, R. L., and J. W. Durban, 2012 Cooperative hunting behavior, prey selectivity and prey handling by pack ice killer whales (Orcinus orca), type B, in Antarctic Peninsula waters. Marine Mammal Science **28:** 16-36.

Pitman, R. L., J. W. Durban, M. Greenfelder, C. Guinet, M. Jorgensen *et al.*, 2011 Observations of a distinctive morphotype of killer whale (Orcinus orca), type D, from subantarctic waters. Polar Biology **34:** 303-306.

Pitman, R. L., W. L. Perryman, D. Leroi and E. Eilers, 2007 A dwarf form of killer whale in Antarctica. Journal of Mammalogy **88:** 43-48.

Reeves, R., W. Perrin, B. Taylor, C. Baker and S. Mnesnick, 2004 Report of the workshop on shortcomings of cetacean taxonomy in relation to needs of conservation and management, April 30-May2, 2004 La Jolla, California. . NOAA-TM-NMFS-SWFSC-363**:** 94pp.

Rice, D. W., 1998 *Marine Mammals of the World. Systematics and Distribution.* Allen Press, Lawrence, KS.

Riera, A., J. K. B. Ford, J. Hildebrand and N. Chapman, 2011 Acoustic monitoring of killer whale populations off the west coast of Vancouver Island. Journal of the Acoustic Society of America **129:** 2607.

Riesch, R., L. G. Barrett-Lennard, G. M. Ellis, J. K. B. Ford and V. B. Deecke, 2012 Cultural traditions and the evolution of reproductive isolation: ecological speciation in killer whales? Biological Journal of the Linnean Society **106:** 1-17.

Saulitis, E., C. Matkin, L. Barrett-Lennard, K. Heise and G. Ellis, 2000 FORAGING STRATEGIES OF SYMPATRIC KILLER WHALE (ORCINUS ORCA) POPULATIONS IN PRINCE WILLIAM SOUND, ALASKA. Marine Mammal Science **16:** 94-109.

Schluter, D., 2001 Ecology and the origin of species. Trends in Ecology & Evolution **16:** 372-380.

Schluter, D., 2009 Evidence for Ecological Speciation and Its Alternative. Science **323:** 737-741.

USFWS, and NMFS, 1996 Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register **61:** 4722.

Waples, R. S., 1991 Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. Marine Fisheries Review **53:** 11-22.

Ward, E., M. Ford, R. Kope, J. Ford, A. Velez-Espino *et al.*, 2013 Estimating the impacts of Chinook salmon abundance and prey removal by ocean fishing on Southern Resident killer whale population dynamics. NOAA Technical Memorandum NMFS-NWFSC **in prep**.

Ward, E. J., B. X. Semmens, E. E. Holmes and K. C. Balcomb, 2011 Effects of Multiple Levels of Social Organization on Survival and Abundance. Conservation Biology **25:** 350-355.

Zachos, F. E., M. Apollonio, E. V. Barmann, M. Festa-Bianchet, U. Gohlich *et al.*, 2013 Species inflation and taxonomic artefacts-A critical comment on recent trends in mammalian classification. Mammalian Biology **78:** 1-6.

Zerbini, A. N., J. M. Waite, J. W. Durban, R. LeDuc, M. E. Dahlheim *et al.*, 2007 Estimating abundance of killer whales in the nearshore waters of the Gulf of

Alaska and Aleutian Islands using line-transect sampling. Marine Biology **150:** 1033-1045.

NOAA Technical Memorandum NMFS-NE-209

# Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Regional Office
Gloucester, Massachusetts
February 2008

## Recent Issues in This Series:

191. **Essential Fish Habitat Source Document: Northern Shortfin Squid, *Illex illecebrosus*, Life History and Habitat Characteristics. 2nd ed.** By Lisa C. Hendrickson and Elizabeth M. Holmes. November 2004. v + 36 p., 13 figs., 1 table. NTIS Access. No. PB2005- 101437. [*Online publication only.*]

192. **Essential Fish Habitat Source Document: Atlantic Herring, *Clupea harengus*, Life History and Habitat Characteristics. 2nd ed.** By David K. Stevenson and Marcy L. Scott. July 2005. vi + 84 p., 40 figs., 7 tables. NTIS Access. No. PB2005-107567. [*Online publication only.*]

193. **Essential Fish Habitat Source Document: Longfin Inshore Squid, *Loligo pealeii*, Life History and Habitat Characteristics. 2nd ed.** By Larry D. Jacobson. August 2005. v + 42 p., 20 figs., 1 table. NTIS Access. No. PB2005-110684. [*Online publication only.*]

194. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2005**. By Gordon T. Waring, Elizabeth Josephson, Carol P. Fairfield, and Katherine Maze-Foley, eds. Dana Belden, Timothy V.N. Cole, Lance P. Garrison, Keith D. Mullin, Christopher Orphanides, Richard M. Pace III, Debra L. Palka, Marjorie C. Rossman, and Fredrick W. Wenzel, contribs. March 2006. v + 392 p., 45 figs, 79 tables, 5 app., index. NTIS Access No. PB 2007-104395.

195. **A Large Marine Ecosystem Voluntary Environmental Management System Approach to Fisheries Practices**. By Frank J. Gable. December 2005. v + 84 p., 38 figs., 10 tables. NTIS Access. No. PB____-______.

196. **Essential Fish Habitat Source Document: Haddock, *Melanogrammus aeglefinus*, Life History and Habitat Characteristics. 2nd ed**. By Jon K.T. Brodziak. December 2005. vi + 64 p., 27 figs., 2 tables. NTIS Access. No. PB2006-103439. *[Online publication only.]*

197.Withdrawn from series.

198. **Essential Fish Habitat Source Document: Bluefish, *Pomatomus saltatrix*, Life History and Habitat Characteristics. 2nd ed**. By Jon K.T. Brodziak. December 2005. vi + 89 p., 48 figs., 5 tables, 1 app. NTIS Access. No. PB2006-103439. *[Online publication only.]*

199. **Distribution and Abundance of Fish Eggs Collected during the GLOBEC Broad-Scale Georges Bank Surveys, 1995-1999**. By John D. Sibunka, Donna L. Johnson, and Peter L. Berrien. August 2006. iv + 72 p., 28 figs., 1 table. NTIS Access. No. PB2008-107379. *[Online publication only.]*

200. **Essential Fish Habitat Source Document: Black Sea Bass, *Centropristis striata*, Life History and Habitat Characteristics (2nd ed.** By Amy F. Drohan, John P. Manderson, and David B. Packer. February 2007. vi + 68 p., 33 figs., 2 tables. NTIS Access No. PB2008-107378. *[Online publication only.]*

201. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2006**. By Gordon T. Waring, Elizabeth Josephson, Carol P. Fairfield, and Katherine Maze-Foley, eds. Dana Belden, Timothy V.N. Cole, Lance P. Garrison, Keith D. Mullin, Christopher Orphanides, Richard M. Pace III, Debra L. Palka, Marjorie C. Rossman, and Fredrick W. Wenzel, contribs. March 2007. vi + 378 p., 92 figs, 84 tables, 5 app., index. NTIS Access No. PB2007-112570.

202. **Evaluation of Northern Right Whale Ship Strike Reduction Measures in the Great South Channel of Massachusetts**. By RL Merrick and TVN Cole. March 2007. NTIS Access No. PB 2008-107377.

203. **Essential fish habitat source document: Spiny dogfish, *Squalus acanthias*, life history and habitat characteristics, 2nd edition**. By LL Stehlik. December 2007. NTIS Access No. PB2008-107376.

204. **An Evaluation of the Northeast Region's Study Fleet pilot program and Electronic Logbook System: Phases I and II**. By Michael C. Palmer, Susan E. Wigley, John J. Hoey, and Joan E. Palmer. December 2007. NTIS Access No PB2008-107374.

205. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2007**. By GT Waring, E Josephson, CP Fairfield, and K Maze-Foley, Editors. November 2007. NTIS Access No _______.

206. **Growth of Black Sea Bass (Centropristis striata) in Recirculating Aquaculture Systems.** By Dean M. Perry, David A. Nelson, Dylan H. Redman, Stephan Metzler, and Robin Katersky. October 2007. NTIS Access No. PB2008-107374.

207. **Analysis of Atlantic Sea Scallop (Placopecten magellanicus) Fishery Impacts on the North Atlantic Population of Loggerhead Sea Turtles (Caretta caretta).** By Richard Merrick and Heather Haas. February 2008. NTIS Access No PB2008-107373.

208. **Global Applications of the Large Marine Ecosystem Concept 2007-2010.** By Kenneth Sherman, Marie-Chirstine Aquarone, and Sally Adams. June 2007. NTIS Access No. PB______-_______.

**NOAA Technical Memorandum NMFS-NE-209**

This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

# Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States

Michael R Johnson[1], Christopher Boelke[1], Louis A Chiarella[1], Peter D Colosi[1], Karen Greene[2], Kimberly Lellis-Dibble[3], Heather Ludemann[4], Michael Ludwig[5], Sean McDermott[1], Jill Ortiz[1], Diane Rusanowsky[6], Marcy Scott[1], and Jeff Smith[7]

*[1]NOAA Fisheries Service (NOAA), Northeast Regional Office, 55 Great Republic Dr., Gloucester, MA 01930*
*[2]NOAA, James J. Howard Marine Science Lab, 74 Magruder Rd., Highlands, NJ 07732*
*[3]Current Address: Univ. of Rhode Island, Dept. of Natural Resources Science, Coastal Institute in Kingston, 1 Greenhouse Rd., Kingston, RI 02881*
*[4]Current Address: 646 Shotwell St., San Francisco, CA 94110*
*[5]Current Address: Ocean and Coastal Consultants, 35 Corporate Dr., Suite 1200 Trumbull, CT 06611*
*[6]NOAA, Milford Lab, 212 Rogers Ave., Milford, CT 06460*
*[7]NOAA, Office of Habitat Conservation, 1315 East-West Highway, Silver Spring, MD 20910*

**US DEPARTMENT OF COMMERCE**
**Carlos M Gutierrez, Secretary**
**National Oceanic and Atmospheric Administration**
**Vice Admiral Conrad C Lautenbacher, Jr, USN (ret), Administrator**
**National Marine Fisheries Service**
**James W Balsiger, Acting Assistant Administrator for Fisheries**
**Northeast Regional Office**
**Gloucester, Massachusetts**

**February 2008**

## Editorial Notes

**Species Names:** The NEFSC Editorial Office's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes, mollusks, and decapod crustaceans and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals. Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species.

**Statistical Terms:** The NEFSC Editorial Office's policy on the use of statistical terms in all technical communications is generally to follow the International Standards Organization's handbook of statistical methods.

**Internet Availability:** This issue of the NOAA Technical Memorandum NMFS-NE series is being published both in hard copy and as a Web document in PDF format and can be accessed at: http://www.nefsc.noaa.gov/nefsc/publications/.

# TABLE OF CONTENTS

# LIST OF TABLES

# PREFACE

The genesis of this report was a technical workshop held in Mystic, CT, on January 10-12, 2005 entitled "Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities." The workshop and report were conceived by the Northeast Region Essential Fish Habitat Steering Committee which is composed of representatives from NOAA National Marine Fisheries Service Northeast Regional Office (NERO), NOAA National Marine Fisheries Service Northeast Fisheries Science Center (NEFSC), New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), and the Atlantic States Marine Fisheries Commission (ASMFC). The workshop was sponsored jointly by NOAA National Marine Fisheries Service, NEFMC and ASMFC.

The original intent of the workshop was to provide the necessary information to the NEFMC and MAFMC to assist them in updating the nonfishing impact analyses within their Fishery Management Plans as required by the Essential Fish Habitat (EFH) regulations. As work progressed, we realized that this information would be extremely useful to a much larger audience of agencies, consultants, and components of the public involved in marine and aquatic habitat assessment activities, and so this comprehensive report was developed. For this reason, the scope of impact assessment for this report was expanded to include a more general approach to coastal fishery habitat and is not limited to EFH. Our goal is to ensure that the best scientific information is available for use in making sound decisions with respect to the various environmental reviews and permitting processes conducted within the marine environment.

The comprehensive nature of this report required extensive collaboration among the authors, which includes NOAA National Marine Fisheries Service staff within the NERO Habitat Conservation Division and Headquarters Office of Habitat Conservation (OHC). We would like to thank the participants of the technical workshop who graciously provided their time and expertise towards identifying and assessing the range of impacts that threaten coastal resources in the northeast region of the United States (see appendix for list of participants). We would particularly like to thank the following individuals for their advice, time, and valuable assistance in the preparation and review of this report: Claire Steimle, Northeast Fishery Science Center (NEFSC) – Library Assistance; numerous staff of the NOAA Library; numerous reviewers, including Jen Costanza, Kathi Rodrigues, Dr. David Stevenson, and David Tomey– NOAA National Marine Fisheries Service, NERO; Jeanne Hanson – NOAA National Marine Fisheries Service, Alaska Regional Office; Joanne Delaney – NOAA National Marine Sanctuaries Program; and Ruth M. Ladd –US Army Corps of Engineers, New England District. In addition, we appreciate the advice provided by the technical and editorial reviewers at the NEFSC: Donna A. Busch, Dr. Jarita Davis, Dr. Ashok Deshpande, Dr. David Dow, Laura Garner, Dr. Jon Hare, Clyde L. MacKenzie, Jr., Donald G. McMillan, Dr. Thomas Noji, Dave Packer, and Dr. Robert Reid.

Louis A. Chiarella
Chair, Northeast Region
Essential Fish Habitat Steering Committee

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACZA | ammoniacal copper zinc arsenate |
| ANS | aquatic nuisance species |
| ATOC | Acoustic Thermometry of Ocean Climate |
| AVS | acid volatile sulfides |
| BMP | best management practice |
| BOD | biological oxygen demand |
| C | Celsius |
| CCA | chromated copper arsenate |
| cm | centimeters |
| CSOs | combined sewer overflows |
| CWA | Clean Water Act |
| dB | decibel |
| DC | direct current |
| DDE | dichlorodiphenyl dichloroethylene |
| DDT | dichlorodiphenyl trichloroethane |
| DNA | deoxyribonucleic acid |
| DO | dissolved oxygen |
| ELMR | Estuarine Living Marine Resources |
| EMF | electromagnetic field |
| EEZ | Exclusive Economic Zone |
| EFH | essential fish habitat |
| ESP | electric service platform |
| F | Fahrenheit |
| FMP | fishery management plan |
| ft | feet or foot |
| GIS | geographic information system |
| HAB | harmful algal bloom |
| HARS | Historic Area Remediation Site |
| HEA | Habitat Equivalency Analysis |
| Hz | Hertz |
| IPCC | Intergovernmental Panel on Climate Change |
| km | kilometer |
| L | liter |
| LC50 | chemical concentration which causes the death of 50% of the experimental test animals |
| LFAS | low frequency active sonar |
| LNG | liquefied natural gas |
| LWD | large woody debris |
| m | meter |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| ml | milliliter |
| mm | millimeter |
| MMS | Minerals Management Service |
| MOA | Memorandum of Agreement |
| MPRSA | Marine Protection, Research, and Sanctuaries Act |

| | |
|---|---|
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MSD | marine sanitation device |
| NATO | North Atlantic Treaty Organization |
| NEFMC | New England Fishery Management Council |
| NEPA | National Environmental Policy Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | nonpoint source |
| NS&T | National Status and Trends |
| NRC | National Research Council |
| OCS | Outer Continental Shelf |
| PAH | polycyclic aromatic hydrocarbons |
| PCB | polychlorinated biphenyl |
| pH | the measure of acidity or alkalinity of a solution |
| POP | persistent organic pollutant |
| PPCP | pharmaceuticals and personal care products |
| ppt | parts per thousand |
| s | second |
| SAV | submerged aquatic vegetation |
| SCUBA | self-contained underwater breathing apparatus |
| SURTASS | Surveillance Towed Array Sensor System |
| TBT | tributyltin |
| THC | thermohaline circulation |
| TOC | total organic carbon |
| TOY | time-of-year |
| US ACE | United States Army Corps of Engineers |
| US EPA | United States Environmental Protection Agency |
| μA | microamp |
| μg | micrograms |
| μV | microvolt |

# GLOSSARY OF TERMS

| | |
|---|---|
| alevins | young salmonid fish distinguished by an attached yolk sac |
| alkalinity | the quantitative capacity of water to neutralize an acid |
| amnesic shellfish poisoning | caused by domoic acid, an amino acid, as the contaminant of shellfish |
| anadromous | migrating from the sea to fresh water to spawn |
| anoxia | complete absence of oxygen in aquatic habitats |
| anthropogenic | effects, processes, or materials that are derived from human activities |
| aquatic nuisance species | introduced (nonnative) organisms that produce harmful impacts on aquatic natural resources |
| autotrophic | a class of organism that produces organic compounds from carbon dioxide as a carbon source, by using either light or reactions of inorganic chemical compounds, as a source of energy; also known as a producer in a food chain |
| beach nourishment | the replacement of sand on an eroded beach from an outside source such as an offshore sand deposit, an inlet tidal delta, or an upland sand quarry |
| benthic | in or associated with the seafloor |
| benthos | organisms living on, in, or near the bottom of water bodies |
| bioaccumulation | the accumulation of substances, such as pesticides, methylmercury, or other organic chemicals in an organism or part of an organism |
| biocide | a chemical substance capable of killing different forms of living organisms (e.g., pesticide) |
| borrow pit | an excavation dug to provide material for fill elsewhere; used in aggregate or mineral mining and in beach nourishment |
| carcinogenic substance | cancer causing agent |
| catadromous | migrating from fresh water to the sea to spawn |
| climax community | a community of organisms the composition of which is more or less stable and in equilibrium with existing natural environmental conditions |

| | |
|---|---|
| creosote | a brownish oily liquid consisting chiefly of aromatic hydrocarbons obtained by distillation of coal tar and used especially as a wood preservative |
| cytolysis | the dissolution or destruction of a cell |
| demersal | dwelling at or near the bottom of a body of water |
| denitrification | the process of reducing nitrate and nitrite (highly oxidized forms of nitrogen available for consumption by many groups of organisms) into gaseous nitrogen |
| desalination | any of several processes that remove the excess salt and other minerals from water in order to obtain fresh water suitable for consumption or irrigation |
| diadromous | migratory between fresh and salt waters |
| diel | occurring on a daily basis, such as vertical migrations in some copepods and fish |
| dissolved oxygen | a measure of the amount of gaseous oxygen dissolved in an aqueous solution |
| echolocation | the biological sonar used by dolphins and whales for navigation and foraging |
| ecosystem | a natural unit consisting of all plants, animals, and microorganisms in an area functioning together with all the nonliving physical factors of the environment |
| endocrine disruptor | an exogenous (outside the body) agent that interferes with the production, release, transport, metabolism, binding, action, or elimination of natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes |
| entrainment | the voluntary or involuntary movement of aquatic organisms from the parent water body into a surface diversion or through, under, or around screens, resulting in the loss of the organisms from the population |
| epibiota | attached plants and animals that settle and grow on natural or artificial surfaces |
| epipelagic | part of the open ocean comprising the water column from the surface down to approximately 200 meters |
| estrogenic substances | compounds that mimic female steroid hormones or inhibit male steroid hormones |

| | |
|---|---|
| eutrophication | enrichment of nutrients causing excessive plant growth that can reduce oxygen concentration and kill aquatic organisms |
| extirpate | to eliminate completely certain populations within the range of a given species |
| gas supersaturation | the overabundance of gases in turbulent water, such as at the base of a dam spillway, which can cause a fatal condition in fish |
| genotype | the genetic constituents in each cell of an organism |
| glacial till | an unsorted, unstratified mixture of fine and coarse rock debris deposited by a glacier |
| hardpan | a layer of hard subsoil or clay |
| headwater | the source of water for a river or stream |
| heterotrophic | a class of organism that requires organic substrates to get its carbon for growth and development; also known as a consumer in the food chain |
| hydrophobicity | the property of being water-repellent or tending to repel and not absorb water |
| hyperplasia | an increase in the number of the cells causing an organ or tissue to increase in size |
| hypersaline | salinity well in excess of that of sea water |
| hypertrophy | an increase in the size of an organ or in a select area of the tissue caused by an increase in the size of cells, while the number stays the same |
| hyporheic zone | saturated zone under a river or stream, composed of substrates with interstices filled with water |
| hypoxia | a low oxygen condition in aquatic habitats |
| ichthyoplankton | eggs and larvae of fish that drift in the water column |
| immunotoxicity | adverse effects on the functioning of the immune system that result from exposure to chemical substances |
| impingement | involuntary contact and entrapment of aquatic organisms on the surface of intake screens caused by the approach velocity exceeding the swimming capability of the organism |
| littoral zone | also called the intertidal zone, it lies between the high tide mark and the low tide mark |

| | |
|---|---|
| lotic | pertaining to running water, as opposed to lentic or still waters |
| macroinvertebrate | an animal lacking a backbone and visible without the aid of magnification |
| meroplankton | organisms that are planktonic for only a part of their life cycles, usually the larval stage |
| methylmercury | formed from inorganic mercury by the action of anaerobic organisms that live in aquatic systems and sediments; a bioaccumulative environmental toxin |
| mutagenic | agent causing genetic mutations |
| neurotoxic shellfish poisoning | shellfish poisoning caused by exposure to a group of polyethers called brevetoxins |
| oligohaline | brackish water with a salinity of 0.5 to 5.0 parts per thousand |
| organochlorides | a large, diverse group of organic compounds containing at least one covalently bonded chlorine atom, some of which are considered to be persistent organic pollutants and are harmful to the environment (e.g., PCB, DDT, chlordane, dioxins) |
| organometal | A member of a broad class of compounds whose structures contain both carbon and a metal (e.g., methylmercury and tetra-ethyl lead) - persistent and bioaccumulative environmental toxins |
| osmoregulation | the physiological mechanism for the maintenance of an optimal and constant fluid concentration and pressure in and around the cells |
| paralytic shellfish poisoning | caused by a group of toxins elaborated by planktonic algae (dinoflagellates, in most cases) upon which the shellfish feed |
| parr | developmental stage of young salmonid fish that follows the fry and lasts for one to three years in their native stream before becoming smolts |
| pelagic | associated with the water column |
| phytoplankton | microscopic plants that drift in the water column |
| planktivorous | feeding on plankton (e.g., most fish larvae and many pelagic fishes) |
| pycnocline | a layer of rapid change in water density with depth mainly caused by changes in water temperature and salinity |
| radionuclide | an atom with an unstable nucleus that can occur naturally but can also be artificially produced; also known as radioisotope |

| | |
|---|---|
| redd | an area in gravel where salmonids bury their eggs; also known as nests or gravel nests |
| reflective turbulence | changes in water velocity caused by wave energy reflection from solid structures in the nearshore coastal area, resulting in increased turbidity |
| riparian | land directly adjacent to a stream, lake, or estuary |
| salmonid | belonging to, or characteristic of the family salmonidae, which includes salmon, trout, and whitefish |
| sedimentation | the deposition by settling of suspended solids |
| siltation | sedimentary material consisting of very fine particles intermediate in size between sand and clay |
| smoltification | a suite of physiological, morphological, biochemical, and behavioral changes, including development of the silvery color of adults and a tolerance for seawater, that take place in young salmonid fish they prepare to migrate downstream and enter the sea |
| soil infiltration | the passage of water through the surface of the soil into the soil profile via pores or small openings |
| spermatogenesis | the process by which male gametes are formed in many sexually reproducing organisms |
| synergistic | combined effects being greater than the sum of individual effects |
| tailwater | an area immediately below a dam where the river water is cooler than normal and rich in nutrients |
| tannins | astringent, plant polyphenol compounds that bind and precipitate proteins; used in manufacturing inks and dyes |
| thermocline | a vertical temperature gradient in some layer of a body of water that is appreciably greater than the gradients above and below it |
| time-of-year restrictions | seasonal constraints for dredging to avoid or minimize impacts of sensitive periods in the life-history of an organism, such as spawning, egg development, and migration |
| tonne | sometimes referred to as a metric tonne, the measurement of mass equal to 1,000 kilograms |
| trophic level | the position that an organism occupies in a food chain |

| | |
|---|---|
| turbidity | the cloudiness or haziness of water caused by individual particles or suspended solids |
| volitional fish passage | any type of structure that provides fish passage over, through, or around an obstruction in a river or stream (e.g., dam) that can be successfully achieved under the fish's own power (as opposed to trap and truck methods) |
| xenobiotic | a chemical which is found in an organism but which is not normally produced or expected to be present in it (e.g., pollutants, such as dioxins or PCB congeners) |

# INTRODUCTION

## Report Purpose

This report stems from a workshop entitled "Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities," which was held January 10 – 12, 2005 in Mystic, CT. The workshop convened a group of experts in the field of environmental, marine habitat, and fisheries impact assessment from federal and state government agencies. The goals of the workshop were to: (1) describe known and potential adverse effects of human induced, nonfishing activities on fisheries habitats; (2) create a matrix of the degree of impacts associated with various activities in riverine, estuarine, and marine habitats; and (3) develop a suite of best management practices (BMPs) and conservation recommendations that could be used to avoid or minimize adverse impacts to fisheries habitats. Refer to Chapter One-Technical Workshop on Impacts to Coastal Fisheries Habitat from Nonfishing Activities, for a detailed summary of the technical workshop.

The general purpose and goals of this report are to:

1. Identify human activities that may adversely impact Essential Fish Habitat (EFH) and other coastal fishery habitat. As Stevenson et al. (2004) characterized the impacts to EFH from fishing activities in the northeast region, the focus of this report is on nonfishing activities.
2. Review and characterize existing scientific information regarding human-induced impacts to EFH and other coastal fishery habitat.
3. Provide BMPs and conservation measures that can be implemented for specific types of activities that avoid or minimize adverse impacts to EFH and other coastal fishery habitat.
4. Provide a comprehensive reference document for use by federal and state marine resource managers, permitting agencies, professionals engaged in marine habitat assessment activities, the regulated community, and the public.
5. Ensure that the best scientific information is available for use in making sound decisions with respect to project planning, environmental assessment, and permitting.

The National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service is mandated to protect and conserve fishery resources, an activity which includes engaging in consultation with federal agencies on actions that may adversely affect NOAA's trust resources. It is anticipated that the information in this report will be used to assist federal agencies and their consultants in the preparation of impact assessments for EFH and other NOAA's trust resources. In addition, this report will assist National Marine Fisheries Service habitat specialists in: (1) reviewing proposed projects; (2) considering potential impacts that may adversely affect NOAA's trust resources; and (3) providing consistent and scientifically supported conservation recommendations. This report will also provide insight for the public and the regulated community on the issues of concern to National Marine Fisheries Service along with approaches to design and implementation of projects that avoid and minimize adverse effects to fish habitat.

## Organization of the Report

The document is organized by activities that may potentially impact EFH and other fishery habitat occurring in riverine, estuarine/coastal, and marine/offshore areas. Chapter One describes the technical workshop that was conducted and presents the results of those discussions and habitat impact evaluations. The major activities that were identified as impacting these three habitat areas include:

- coastal development
- energy-related activities
- alteration of freshwater systems
- marine transportation
- offshore dredging and disposal
- physical and chemical effects of water intake and discharge facilities
- agriculture and silviculture
- introduced/nuisance species and aquaculture
- global effects and other impacts

Each subsequent chapter characterizes impacts associated with the major activities listed above. Each chapter describes the adverse effects of various activities on fishery habitat and the species associated with those habitats, provides the scientific references to support those findings, and concludes with best management practices or conservation recommendations that could be implemented to avoid or minimize those particular adverse effects. Although the activities and effects identified in the technical workshop are reflected in the appropriate chapter, the reader may notice some minor variation in the order and content if the chapter author(s) failed to locate information in the literature on a specific topic or believed additional discussion of effects were warranted. The preparers of this report have attempted to summarize the current knowledge of impacts and effects from existing and potential activities in the coastal areas of the northeast region of the United States. However, the reader should not consider the information in the report as comprehensive for all activities and impacts on fishery habitats. For more detailed analyses and understanding, the reader should refer to the cited references and the most current literature regarding specific activities and impacts.

The BMPs and conservation measures provided in this report are designed to minimize or avoid the adverse effects of human activities on fishery habitat and to promote the conservation and enhancement of fishery habitat. The BMPs and conservation measures provided in this report reflect many of the conservation principals recommended in Hanson et al. (2003). These general principles include: (1) nonwater-dependent actions should not be located in fishery habitat if such actions may have adverse impacts on those resources; (2) activities that may result in significant adverse affects on fishery habitat should be avoided where less environmentally harmful alternatives are available; (3) if alternatives do not exist, the impacts of these actions should be minimized; and (4) environmentally sound engineering and management practices should be employed for all actions that may adversely affect fishery habitat.

The conservation measures and BMPs included with each activity present a series of practices or steps that can be undertaken to avoid or minimize impacts to fishery habitats. Not all of these suggested measures are applicable necessarily to any one project or activity that may adversely affect habitat. More specific or different measures based on the best and most current scientific information may be developed as part of the project planning or regulatory processes. The conservation recommendations and BMPs provided represent a generalized menu of the types of measures that can contribute to the conservation and protection of fishery habitat and other coastal aquatic habitats.

The final chapter contains a brief discussion of the purpose and application of compensatory mitigation used to offset adverse effects on fishery habitat. We have chosen to include a discussion on compensatory mitigation in its own chapter because its application is not generally considered a best management practice or a recommendation to conserve fishery habitat. Instead, compensatory mitigation is a method of offsetting adverse effects after they have occurred. For that reason, compensatory mitigation should be considered only after all measures to avoid and then minimize impacts have been exhausted. Compensatory mitigation should never be used as a first-line conservation measure.

Some of the impact types described in one chapter may also be found in other chapters containing similar impacts or activities. Therefore, the reader may find some redundancy in the various chapters. Because the report's focus was to describe the impacts to living marine resources and habitats associated with specific anthropogenic activities and often have similar adverse affects on living marine resources, some redundancy in the descriptions of impacts between various chapters was unavoidable.

## Characterization of Habitat in the Northwest Atlantic Ocean

The general focus of this report pertains to effects on marine, estuarine, and diadromous fishes and their habitats. However, the preparers of the report have attempted to provide a broad perspective of coastal aquatic habitat and the organisms that depend upon those habitats in an ecosystem context. Although the report often refers to "fishery habitat" or "fish," the definitions of these resources should not necessarily be limited to any particular regulatory or management mandate, such as EFH. The authors have attempted to include information on known or potential impacts that may affect the ecological functions and values for habitats for all species of fish and invertebrates. Because the focus of this report is on impacts to fish and fishery habitats, we have included only limited discussions on impacts specific to marine mammals and sea turtles.

Habitats provide living things with the basic life requirements of nourishment and shelter (Stevenson et al. 2004). According to Deegan and Buchsbaum (2005), a habitat includes the physical environment, the chemical environment, and the many organisms that compose a food web. This report employs a similarly broad definition to discuss the multitude of adverse effects on habitats in the coastal northeastern United States. For example, the quality of the water in which aquatic organisms live, feed, and reproduce is a facet of their habitat, and the presence of contaminants or alterations to the water has important implications on the health of those organisms. Habitats may also provide a broader range of benefits to the ecosystem, such as the way seagrasses physically stabilize the substrate and help recirculate oxygen and nutrients (Stevenson et al. 2004). These habitats do not exist in isolation but are linked through ecological and oceanographic processes that are a part of the larger ecosystem. For example, the movement of the water plays a major role in the interconnection of habitats by transporting nutrients, food, larvae, sediments, and pollutants among them (Tyrrell 2005).

The northwest Atlantic Ocean includes a broad range of habitats with varying physical and biological properties extending from the cold waters of the Gulf of Maine south to the more temperate climate of the Mid-Atlantic Bight. In this region, the oceanographic and physical processes interact to form a network of expansively to narrowly distributed habitat types (Stevenson et al. 2004). The offshore component of this region, also known as the Northeast US Continental Shelf Ecosystem (Sherman et al. 1996), is composed of four distinct subregions: the Gulf of Maine, Georges Bank, the Mid-Atlantic Bight, and the continental slope (Stevenson et al. 2004). In addition, the region contains freshwater rivers and streams that flow towards the sea into numerous bays and estuaries that serve as important refuge and nursery areas for marine species. This report focuses on the three major systems composing this ecosystem: riverine, estuarine/nearshore, and marine/offshore environments.

The habitat classifications described by Jury et al. (1994) and adopted by NOAA as a national standard for organizing its Estuarine Living Marine Resources (ELMR) program's database are useful because they facilitate consideration of physico-chemical interactions in water quality and habitat impacts and implications for aquatic organisms. Conveniently, this approach also aligns with ambient suspended sediment and particulate loads because maximum turbidity zones of temperate, well-mixed estuaries typically coincide with low salinity regions (Herman and Heip 1999). Accordingly, this report has used the three ELMR salinity ranges developed for coastal aquatic habitats to describe "riverine" (<0.5 ppt), "estuarine/nearshore" (0.5-25.0 ppt), and "marine/offshore" (>25.0 ppt) conditions.

## *Riverine*

Riverine habitats, located along the coast of New England and the Mid-Atlantic, provide essential habitat to anadromous and catadromous ("diadromous") fishes. These habitats include freshwater streams, rivers, streamside wetlands, and the banks and associated vegetation that may be bordered by other freshwater habitats (NEFMC 1998). Depending upon the local water velocity and other physical characteristics, riverine systems may include a variety of benthic substrates ranging from exposed bedrock, cobble, and other hard bottom types to extremely unconsolidated, soft bottom material. These features have a great bearing on the fish and invertebrate species that may be present.

Riverine habitats serve multiple purposes including migration, feeding, spawning, nursery, and rearing functions. An important component of a river system also includes the riparian corridor. The term "riparian" refers to the land directly adjacent to a stream, lake, or estuary. A healthy riparian area has vegetation supporting prey items (e.g., insects); contributes necessary nutrients; provides large woody debris that creates channel structure and cover for fish; and provides shade, which controls stream temperatures (NEFMC 1998).

## *Estuarine/nearshore*

Estuaries are the bays and inlets influenced by both the ocean and rivers that serve as the transition zone between fresh and salt water. In the northeastern United States, they also may include the substantial inland reaches of large river systems where salinities exceed 0.5 ppt. For instance, ocean tides influence the lower 153 miles of the Hudson River, and oligohaline salinities (0.5 pp – 5 ppt) can extend well inland under low flow conditions. Typically, the northernmost intrusion of brackish water does not extend past the city of Poughkeepsie, nearly 75 miles north of The Battery at the southern tip of Manhattan, NY.

Estuaries support a community of plants and animals that are adapted to the zone where fresh and salt waters mix. Estuarine habitats fulfill fish and wildlife needs for reproduction, feeding, refuge, and other physiological necessities (NEFMC 1998). Coastal and estuarine features such as salt marshes, mud flats, rocky intertidal zones, sand beaches, and submerged aquatic vegetation are critical to inshore and offshore habitats and fishery resources of the northeastern United States (Stevenson et al. 2004). For example, healthy estuaries include eelgrass beds that protect young fish from predators, provide habitat for fish and wildlife, improve water quality, and can help stabilize sediments. In addition, mud flats, high salt marshes, and saltmarsh creeks also provide productive shallow water habitat for epibenthic fishes and decapods. Inshore habitats are dynamic and heterogeneous environments that support the majority of marine and anadromous fishes at some stage of development (NEFMC 1998).

### *Marine/offshore*

The Gulf of Maine is an enclosed coastal sea, characterized by relatively cold waters and deep basins with a patchwork of various sediment types. Georges Bank is a relatively shallow coastal plateau that slopes gently from north to south and has steep submarine canyons on its eastern and southeastern edge. It is characterized by highly productive, well-mixed waters and strong currents. The Mid-Atlantic Bight is composed of the sandy, relatively flat, gently sloping continental shelf from southern New England to Cape Hatteras, NC. The continental slope begins at the continental shelf break and continues eastward with increasing depth until it becomes the continental rise. It is fairly homogenous, with exceptions at the shelf break, some of the canyons, the Hudson Shelf Valley (offshore New York), and areas of glacially rafted hard bottom (Stevenson et al. 2004).

The offshore benthic habitat features include sand waves, shell aggregates, gravel beds, boulder reefs, and submerged canyons which provide nursery areas for many fish species (NEFMC 1998). Many marine organisms inhabit the stable offshore environment for multiple stages of their life history.

## Essential Fish Habitat

In 1996, the US Congress declared that “one of the greatest long-term threats to the viability of the commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States” (Magnuson-Stevens 1996, sec. 2.a.9.). Along with this declaration, Congress added new habitat conservation provisions to the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the federal law that governs US marine fisheries management. The MSA requires that fishery management plans describe and identify essential fish habitat, minimize adverse effects on habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat. Essential fish habitat has been defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (Magnuson-Stevens 1996, sec. 3.10.).

The MSA also requires federal agencies to consult with the Secretary of Commerce, acting through the NOAA’s National Marine Fisheries Service, on all actions authorized, funded or undertaken, or proposed to be authorized or undertaken by the agency, that may adversely affect EFH. The process developed for conducting these EFH consultations is described in the EFH regulations (50 CFR §600.905 – 920). In summary, federal agencies initiate consultation by preparing and submitting an EFH assessment to the National Marine Fisheries Service that describes the action, analyzes the potential adverse effects of the action on EFH, and provides the agency’s conclusions regarding the effects of the action on EFH. In response, the National Marine Fisheries Service provides the agencies with conservation recommendations to conserve EFH by avoiding, minimizing, mitigating, or otherwise offsetting the adverse effects to EFH. Adverse effect is defined as any impact which reduces the quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of or injury to benthic organisms, prey species, and their habitat and other ecosystem components. Adverse effects may be site-specific or habitat-wide, including individual, cumulative, or synergistic consequences of actions [50 CFR §600.910(a)]. This broad definition of adverse effects has been employed in this report to describe the various activities and sources of nonfishing impacts that can degrade fisheries habitat.

Once the National Marine Fisheries Service provides conservation recommendations, the federal action agencies must provide a detailed response in writing to the Nationial Marine Fisheries Service. The response must include measures proposed for avoiding, mitigating, or offsetting the impact of a proposed activity on EFH. If the federal action agency chooses not to adopt National Marine Fisheries Service's conservation recommendations, it must explain its reasons for not following the recommendations.

## Impacts to Habitat

Habitat alteration and disturbance occur from natural processes and human activities. Deegan and Buchsbaum (2005) placed human impacts to marine habitats into three categories: (1) permanent loss; (2) degradation; and (3) periodic disturbance. Permanent loss of habitat can result from activities such as wetland filling, coastal development, harbor dredging, and offshore mining operations (Robinson and Pederson 2005). Habitat degradation may be caused by physical changes, such as increased suspended sediment loading, overshadowing from new piers and wharves, as well as introduction of chemical contamination from land-based human activities (Robinson and Pederson 2005). Periodic disturbances are created by activities such as trawling and dredging for fish and shellfish and maintenance dredging of navigation channels.

The primary differences between these three categories are that permanent loss is irreversible, habitat degradation may or may not be reversible, and periodic disturbance is generally reversible once the source of disturbance is removed (Deegan and Buchsbaum 2005). These authors indicate that recovery times for degraded habitat depend on the nature of the agent causing the degradation and the physical characteristics of the habitat. Recovery times for periodic disturbances will vary depending on the intensity and periodicity of the disturbance and the nature of the habitat itself. Natural fluctuations in habitats, such as storms and long-term climatic changes, occur independently of anthropogenic impacts.

Deegan and Buchsbaum (2005) state that "habitat quantity is a measure of the total area available, while habitat quality is a measure of the carrying capacity of an existing habitat." Generally, activities that lead to a permanent loss of habitat reduce the quantity of habitat, whereas habitat degradation and periodic disturbances result in a loss of habitat quality. The reduced quality of habitat (e.g., siltation, eutrophication, and alteration of salinity and food webs) may be equally damaging to the biological community as a loss in habitat quantity. As Deegan and Buchsbaum (2005) have noted, "the physical structure of the habitat does not need to be directly altered for negative consequences to occur." For example, reductions in water quality can impair and limit the ability of aquatic organisms to grow, feed, and reproduce.

The end point of gradual declines in the quality of habitat can be the complete loss of habitat structure and function (Deegan and Buchsbaum 2005). Losses of habitat quantity and quality may reduce the ability of a region to support healthy and productive fish populations. From the population perspective, the loss of habitat quantity and quality creates stresses on a population. Populations that are stressed by one or more factors can be more susceptible to stresses caused by other factors (Robinson and Pederson 2005), resulting in cumulative effects. These authors call for a holistic approach to fishery management: one that considers the interactions among exploitation, contaminants, and habitat degradation on various fish stocks.

Lotze et al. (2006) show that severe depletion of marine resources (i.e., 50% reduction in abundance level) first began with the onset of European colonization. This study found that 45% of species depletions and 42% of extinctions involved multiple human impacts, mostly exploitation and habitat loss. Seventy eight percent of resource recoveries are attributed to both habitat protection and restricted exploitation, while only 22% of recoveries are attributed to reduced exploitation alone (Lotze et al. 2006). These authors also conclude that reduced exploitation, increased habitat protection, and improved water quality need to be considered together and that the cumulative effects of multiple human interventions must be included in both management and conservation strategies.

## References for Introduction


Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Herman P, Heip C. 1999. Biogeochemistry of the MAximum TURbidity zone of Estuaries (MATURE): some conclusions. Journal of Marine Systems 22:89-104.

Jury S, Field J, Stone S, Nelson D, Monaco M. 1994. Distribution and abundance of fishes and invertebrates in North Atlantic estuaries. Silver Spring (MD): NOAA/NOS Strategic Environmental Assessments Division. ELMR Report 13. 221 p.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-9.

Magnuson-Stevens Fishery Conservation and Management Act. 1996. P.L. 94-265, 16 U.S.C. 1801 et seq. [Internet]. [cited 2008 Jul 31]. Available from: http://www.nmfs.noaa.gov/sfa/magact/.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Robinson WE, Pederson J. 2005. Contamination, habitat degradation, overfishing - An "either-or" debate? In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 1-10.

Sherman, K, Jaworski NA, Smayda TJ, editors. 1996. The Northeast Shelf Ecosystem: assessment, sustainability, and management. Cambridge (MA): Blackwell Science. 564 p.

Stevenson D, Chiarella L, Stephan D, Reid R, Wilhelm K, McCarthy J, Pentony M. 2004. Characterization of the fishing practices and marine benthic ecosystems of the Northeast U.S. Shelf, and an evaluation of the potential effects of fishing on essential fish habitat. Woods Hole (MA): National Marine Fisheries Service, Northeast Fisheries Science Center, NOAA Technical Memorandum NMFS-NE-181. 179 p.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

# CHAPTER ONE: TECHNICAL WORKSHOP ON IMPACTS TO COASTAL FISHERIES HABITAT FROM NONFISHING ACTIVITIES

## Introduction

A technical workshop was hosted by the Northeast Region Essential Fish Habitat Steering Committee on January 10-12, 2005 in Mystic, CT, to seek the views and recommendations of approximately 40 scientists, resource managers, and other marine resource professionals on threats to fishery habitat from nonfishing activities in the northeast coastal region. The participants of the workshop, entitled *Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities*, were federal and state environmental managers and regulators, as well as individuals from academic institutions and other organizations that have expertise and knowledge of various human-induced impacts on coastal environmental resources. A list of workshop participants and their affiliations is provided in the appendix of this report. The workshop's primary purpose was to convene marine resource professionals to review and evaluate existing information on nonfishing impacts for the purpose of updating, as necessary, fishery management plans under the New England and Mid-Atlantic Fishery Management Councils. In addition, the National Marine Fisheries Service sought to develop a nonfishing impacts reference document for use by professionals engaged in marine habitat assessment, permitting agencies, and state and federal marine resource managers. The information gathered during the workshop was used by the Northeast Region's Habitat Conservation Division staff to prepare selected chapters in the report. In general, the activities and effects contained within the various chapters of this report reflect the categories of activities and effects evaluated and discussed during the workshop.

The specific goals/tasks of the workshop included:

1. Identify all known and potential adverse effects for each category of nonfishing activity by life history strategies or stages (i.e., benthic/demersal and pelagic) and ecosystem strata (i.e., riverine, estuarine, and marine). This list of activities may also include adverse impacts to identified prey species or other specific life history requirements for species.
2. Create a matrix of nonfishing impacts for life history strategies/stages and ecosystem strata and ask the participants of the workshop to score the severity of each impact by using a relative scoring method.
3. Develop a suite of conservation measures and best management practices (BMPs) intended to avoid and minimize the adverse effects on fishery habitat and resources.
4. Identify possible information and data limitations and research needs in assessing impacts on fishery habitat or measures necessary to avoid and minimize those impacts.

Conservation measures were, to the extent possible, based on methods and technologies that have been evaluated through a scientific, peer-reviewed process. The intent was to develop recommendations that provide resource managers and regulators with specific methods and technologies yet have flexibility in their applications for various locations or project types. Ideally, providing a suite of conservation measures appropriate for various activities would give the end user several options of recommendations to consider.

Based upon the results of the workshop and effects scoring, some recommended research needs were developed. Identified research needs included basic life history requirements for some species and habitat types, physiological and biochemical responses of organisms to various physical and chemical perturbations and stressors, and technological advances in understanding or solutions to impact assessment and mitigation. Refer to the Conclusions and Recommendations chapter at the end of this report for a discussion on recommended research.

The format of the two-day workshop consisted of a series of breakout sessions, attended by the workshop participants, which represented the primary categories of nonfishing activities believed to threaten fishery resources and habitats in the northeast coast. There were ten separate breakout sessions conducted during the workshop, which are reflected in the chapters of this report. For each of the breakout sessions, a matrix of activities and known or potential adverse effects to fishery habitat, prepared by the workshop organizers, was reviewed by the workshop participants. The participants were encouraged to openly discuss and evaluate the relevance and significance for each of the activities and effects and to provide any additional activities and effects not included in the matrix. A large number of nonfishing activities occur within the coastal region and have a wide range of effects and intensities on fishery habitat. Each activity type and effect identified was evaluated in the context of life history strategies or stages (i.e., benthic and demersal) and ecosystem type or strata (i.e., riverine, estuarine/nearshore, and marine/offshore), in order to identify the importance of those factors. Following an open discussion, the participants were asked to score, by life history strategies/stages and ecosystem strata, the various activities and adverse effects on the impact matrix. In addition, participants were asked to include specific and relevant "conservation recommendations" and BMPs to avoid and minimize adverse effects to fishery habitat and resources.

On the last day of the workshop, the participants engaged in an informal discussion on the significance of cumulative effects and how multiple and additive effects can influence impacts to fishery habitat and resources. While the discussions were general in nature and few specifics of cumulative effects were discussed, there was a general agreement that cumulative effects are important and should play a larger role in assessment of habitat impacts. We found that the scores provided by the participants in the impact matrices for most breakout sessions to be relatively consistent throughout. While the variability in scores for some impact categories was high, we believe that the mean and median values for most effects' scores provide an accurate reflection of professional judgment by the participants. The relatively high variability in the scores of some activity types and effects may be due to varying interpretations of ecosystem strata and life history strategies or stages by the participants.

## Effects Scoring System

Because one workshop goal was to assess the severity or degree of threat for known and potential impacts to fishery habitats, the workshop organizers strived to develop a semiquantitative scoring system that could measure the relative impacts for each activity and effect based upon the professional judgment of the participants. Developing defined values for measuring the significance of adverse effects for an activity is difficult and can depend upon the type of habitat being affected; the characteristic, intensity, and duration of the activity and disturbance; and a number of natural physical, chemical, and biological processes that may be occurring in the area and at the time of the activity. For this reason, the workshop organizers chose a semiquantitative scoring system with a range from 0 to 5, with a 1 being the lowest impact and a 5 being the highest impact. A "0" was used if an impact is not expected to occur or is not applicable, and a "UN" (unknown) was used if the participant does not know the degree of impact for a particular activity.

We believe that a relative scoring method that allows for flexibility and professional judgment in assigning a value for an effect is better than an absolute scoring system that has discreet and predefined values. Using a relative scoring range of 0 through 5 provided the participants a choice from a continuum of impact values for each effect and avoids the difficulty in finding consensus for the definition of predefined values. We then calculated the mean and median values of each effect and assigned a qualitative value of the threat for each effect by using the following criteria:

If either the mean or median value was greater than or equal to 4.0, a "high" index score was assigned; if the mean value was between 2.1 and 3.9, a "medium" index score was assigned; and if the mean value was less than or equal to 2.0, a "low" index score was assigned.

Note: We defined the "high" index score to include either mean or median values in order to be risk averse in identifying activities that are known to be or may be a potentially high threat. Only mean values were used in assessing "medium" and "low" index scores.

## Workshop Summary

The results of the workshop scoring in each session are listed in Table 1 through 10. "High," "medium," and "low" index scores are notated as H, M, and L, respectively. As might be expected, there were positive correlations between the highest scoring effects and the ecosystem types in which those activities generally occur. For example, the high scoring effects in the alteration of freshwater systems and agriculture and silviculture sessions were generally all in the riverine ecosystem. Except for the offshore dredging and disposal session, there were fewer effects that were scored high in the marine/offshore ecosystem compared to the riverine and estuarine/nearshore ecosystems. This suggests the participants viewed the intensity of effects from nonfishing impacts to decrease as the distance from the activity increases. As one might expect, many of the far field effects that scored high were those activities that affect the water column (e.g., ocean noise, impacts to water quality) or effects that are capable of being transported by currents (oil spills or drilling mud releases). In addition, the global effects and other impacts session had high scores more evenly distributed across all ecosystems because of the nature of the impacts discussed in this session (e.g., climate change, atmospheric deposition, ocean noise). The number of activities and threats identified in the coastal development session were greater than other sessions because of the cross cutting nature of activities associated with human coastal development. Because of this, some activity types and effects assessed in the coastal development session were discussed to some degree in other sessions.

Some sessions had index scores with relatively high variability. For example, the scores for all activity types of the offshore dredging and disposal session had relatively low mean values and high standard deviations for effects in the estuarine/nearshore ecosystem. About half of the participants in this session either did not provide a score for impacts in the riverine or estuarine/nearshore ecosystems, or they marked them as "not-applicable." Participants who provided a score for these two ecosystems generally scored them relatively high. This suggests a difference in participants' interpretation of where "offshore" activities are located. Specifically, some individuals may consider the "offshore" area to be within close enough proximity of the nearshore and estuarine environments to adversely affect these areas, while others may perceive the "offshore" area to be too far removed to have a noticeable effect. There were activities in other sessions, such as beach nourishment in coastal development, with scores with high standard deviations. The high variability in perceived threats may be a reflection of regional perspectives. While the majority of the participants involved in this workshop were from the New England region, about one-quarter of the participants were from the mid-Atlantic or southeast regions where beach nourishment projects are much more common. The associated impacts to benthic habitats from beach nourishment are also generally thought to be greater in the New England (where cobble or hard bottom habitats may be present) and south Atlantic (where live bottom habitats may be present) regions than in the mid-Atlantic. However, because the responses of the workshop participants were anonymous, it was not possible to test this hypothesis.

Many of the effects that were scored as high in the workshop sessions were those that are well documented in the literature as having adverse effects on coastal resources. For example, nutrient enrichment and siltation/sedimentation effects were scored as high in nearly all workshop sessions, demonstrating the widely accepted views that these impacts translate to general reductions in the quality and quantity of fishery resources and habitats. Some of the more unexpected results of the workshop session scores are those effects that had high mean and/or median values but may be a topic that does not have a wealth of research documenting those impacts. Some of these results may be based upon a collective judgment by the participants that these activities or effects require additional scientific investigations to resolve the perceived risks and concerns. In several of these effects or activities, the authors of the associated report chapters were unable to locate information in the scientific literature regarding those threats. For example, release of pharmaceuticals and endocrine disruptors were two effects that were scored high in the workshop session, and yet the potential scope and intensity of adverse effects that these chemicals have on fishery resources has not been thoroughly investigated.

Those activities and effects considered by the workshop participants to have "high" threats to fishery habitat warrant further investigations, including research in characterizing and quantifying these impacts on fishery resources, as well as investigating methods for avoiding and/or minimizing the impacts. Refer to the Conclusions and Recommendations chapter for further discussions regarding the workshop results.

**Table 1. Habitat impact categories in coastal development workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Nonpoint Source Pollution and Urban Runoff | Nutrient loading/eutrophication | H | H | M | H | H | M |
| | Loss/alteration of aquatic vegetation | H | H | L | H | H | L |
| | Release of petroleum products | M | M | M | M | M | M |
| | Alteration of water alkalinity | M | M | L | M | M | L |
| | Release of metals | H | H | M | M | H | M |
| | Release of radioactive wastes | M | M | L | M | M | L |
| | Release of pesticides | H | H | M | H | H | M |
| | Release of pharmaceuticals | H | M | L | H | H | L |
| | Alteration of temperature regimes | H | M | L | H | M | L |
| | Sedimentation/turbidity | H | H | L | H | H | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Introduction of pathogens | M | M | L | M | M | L |
| Road Construction and Operation | Release of sediments in aquatic habitat | H | M | L | M | M | L |
| | Increased sedimentation/turbidity | H | H | L | H | H | L |
| | Impaired fish passage | H | M | L | H | H | L |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | H | L | H | H | L |
| | Introduction of exotic invasive species | M | M | L | M | M | L |
| | Loss/alteration of aquatic vegetation | H | H | L | H | H | L |
| | Altered tidal regimes | H | H | L | H | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Fragmentation of habitat | H | M | L | H | H | L |
| | Altered salinity regimes | M | M | L | M | M | L |
| Flood Control/ Shoreline Protection | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered sediment transport | H | H | L | H | H | L |
| | Alteration/loss of benthic habitat | H | H | L | M | M | L |
| | Reduction of dissolved oxygen | M | M | L | M | M | L |
| | Impaired fish passage | H | M | L | H | M | L |
| | Alteration of natural communities | H | M | L | M | M | L |
| | Impacts to riparian habitat | H | M | L | H | M | L |
| | Loss of intertidal habitat | H | H | L | M | H | L |
| | Reduced ability to counter sea level rise | H | H | L | M | H | L |
| | Increased erosion/accretion | H | H | L | H | H | L |
| Beach Nourishment | Altered hydrological regimes | M | M | L | M | M | L |
| | Altered temperature regimes | L | L | L | L | L | L |
| | Altered sediment transport | M | M | L | M | M | L |
| | Alteration/loss of benthic habitat | M | M | L | L | M | L |
| | Alteration of natural communities | M | M | M | L | M | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |

**Table 1 (continued). Habitat impact categories in coastal development workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshor | Riverine | Estuarine/ Nearshore | Marine/ Offshor |
| Wetland Dredging and Filling | Alteration/loss of habitat | H | H | L | H | H | L |
| | Loss of submerged aquatic vegetation | H | H | L | M | H | L |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Reduction of dissolved oxygen | M | M | L | M | M | L |
| | Release of nutrients/eutrophication | M | M | L | M | M | L |
| | Release of contaminants | M | M | L | M | M | L |
| | Altered tidal prism | M | M | L | M | M | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Loss of fishery productivity | H | H | L | H | H | L |
| | Introduction of invasive species | M | M | L | M | M | L |
| | Loss of flood storage capacity | H | H | L | H | H | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |
| Overwater Structures | Shading impacts to vegetation | M | M | L | M | M | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Benthic habitat impacts | M | M | L | M | M | L |
| | Increased erosion/accretion | M | M | L | M | M | L |
| | Eutrophication from bird roosting | M | M | L | M | M | L |
| | Shellfish closures because of bird roosting | H | M | L | M | M | L |
| | Changes in predator/prey interactions | H | H | L | H | H | L |
| Pile Driving and Removal | Energy impacts | M | M | L | M | M | L |
| | Benthic habitat impacts | M | M | L | M | M | L |
| | Increased sedimentation/turbidity | M | M | L | M | M | L |
| | Contaminant releases | M | M | L | M | M | L |
| | Shading impacts to vegetation | M | M | L | M | M | L |
| | Changes in hydrological regimes | M | M | L | M | M | L |
| | Changes in species composition | M | M | L | M | M | L |
| Marine Debris | Entanglement | M | M | L | M | M | L |
| | Ingestion | L | M | L | M | M | M |
| | Contaminant releases | L | M | L | L | M | M |
| | Introduction of invasive species | M | M | L | M | M | M |
| | Introduction of pathogens | L | M | L | L | M | M |
| | Conversion of habitat | L | M | L | L | M | L |

**Table 2. Habitat impact categories in energy-related activities workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Petroleum Exploration, Production, and Transportation | Underwater noise | M | M | M | M | M | M |
| | Habitat conversion | H | H | H | H | H | M |
| | Loss of benthic habitat | M | H | M | M | M | M |
| | Contaminant discharge | M | H | M | M | H | M |
| | Discharge of debris | M | M | M | M | M | L |
| | Oil spills | H | H | H | H | H | H |
| | Siltation/sedimentation/turbidity | M | M | M | M | M | M |
| | Resuspension of contaminants | M | H | M | M | M | L |
| | Impacts from clean-up activities | H | H | M | M | H | M |
| Liquified Natural Gas | Habitat conversion | H | H | M | M | M | M |
| | Loss of benthic habitat | H | H | M | M | M | L |
| | Discharge of contaminants | H | H | H | H | H | H |
| | Discharge of debris | M | M | M | M | M | L |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | M |
| | Resuspension of contaminants | M | H | M | M | H | L |
| | Entrainment/impingement | M | M | M | M | H | M |
| | Alteration of temperature regimes | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | L | M | M | L |
| | Underwater noise | M | M | M | H | H | M |
| | Release of contaminants | H | H | M | H | H | M |
| | Exclusion zone impacts | M | M | L | M | M | L |
| | Physical barriers to habitat | M | M | M | M | M | L |
| | Introduction of invasive species | H | H | M | H | M | M |
| | Vessel impacts | H | H | L | M | M | L |
| | Benthic impacts from pipelines | H | H | M | M | M | M |
| Offshore Wind Energy Facilities | Loss of benthic habitat | M | H | H | L | M | M |
| | Habitat conversion | M | H | H | L | M | M |
| | Siltation/sedimentation/turbidity | L | M | M | L | M | M |
| | Resuspension of contaminants | L | M | L | L | M | L |
| | Alteration of hydrological regimes | L | M | M | L | M | M |
| | Altered current patterns | L | M | M | L | M | M |
| | Alteration of electromagnetic fields | L | L | L | L | L | L |
| | Underwater noise | L | L | M | L | M | H |
| | Alteration of community structure | M | H | M | L | H | M |
| | Erosion around structure | L | M | M | L | L | L |
| | Spills associated w/ service structure | M | H | M | L | M | M |

**Table 2 (continued). Habitat impact categories in energy-related activities workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Wave/Tidal Energy Facilities | Habitat conversion | H | H | M | M | M | M |
| | Loss of benthic habitat | H | H | M | M | M | L |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | L |
| | Resuspension of contaminants | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | M | M | H | L |
| | Altered current patterns | M | M | M | M | H | M |
| | Entrainment/impingement | M | M | L | H | H | M |
| | Impacts to migration | M | M | L | H | M | L |
| | Electromagnetic fields | L | L | L | L | L | L |
| Cables and Pipelines | Loss of benthic habitat | H | H | M | L | M | L |
| | Habitat conversion | H | H | M | M | M | M |
| | Siltation/sedimentation/turbidity | M | H | M | M | M | M |
| | Resuspension of contaminants | H | H | M | M | M | M |
| | Altered current patterns | M | M | M | L | M | L |
| | Alteration of electromagnetic fields | L | L | L | L | L | L |
| | Underwater noise | L | L | L | L | M | M |
| | Alteration of community structure | M | M | M | M | M | M |
| | Erosion around structure | L | M | M | L | M | M |
| | Biocides from hydrostatic testing | M | M | M | M | M | M |
| | Spills associated w/ service structure | H | H | M | M | M | M |
| | Physical barriers to habitat | H | H | H | L | L | L |
| | Impacts to submerged aquatic vegetation | M | H | M | M | M | L |
| | Water withdrawal | M | M | L | H | H | L |
| | Impacts from construction activities | M | H | H | M | M | M |
| | Impact from maintenance activities | M | M | M | L | M | M |
| | Thermal impacts associated with cables | L | L | L | L | L | L |
| | Impacts associated with armoring of pipe | M | M | M | L | L | L |
| | Impacts to migration | H | H | H | L | L | L |

**Table 3. Habitat impact categories in alteration of freshwater systems workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Dam Construction /Operation | Impaired fish passage | H | H | L | H | H | L |
| | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered temperature regimes | H | H | L | H | M | L |
| | Altered sediment/ large woody debris transport | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Alteration of extent of tide | H | H | L | H | H | L |
| | Alteration of wetlands | H | H | L | H | H | L |
| | Change in species communities | H | M | L | H | M | L |
| | Bank erosion because of drawdown | M | L | L | M | L | L |
| | Riparian zone development | H | M | L | H | M | L |
| | Acute temperature shock | H | M | L | H | M | L |
| Dam Removal | Release of contaminated sediments | H | H | L | H | M | L |
| | Alteration of wetlands | H | M | L | H | M | L |
| Stream Crossings | Impacts to fish passage | H | M | L | H | M | L |
| | Alteration of hydrological regimes | H | M | L | H | M | L |
| | Bank erosion | H | L | L | M | L | L |
| | Habitat conversion | H | M | L | H | M | L |
| Water Withdrawal/ Diversion | Entrainment and impingement | M | M | L | H | M | L |
| | Impaired fish passage | H | H | L | H | H | L |
| | Altered hydrological regimes | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Altered temperature regimes | H | H | L | H | M | L |
| | Release of nutrients/eutrophication | H | M | L | H | M | L |
| | Release of contaminants | H | M | L | H | M | L |
| | Altered stream morphology | H | L | L | H | M | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Change in species communities | H | M | L | H | H | L |
| | Alteration in groundwater levels | H | L | L | H | L | L |
| | Loss of forested/palustrine wetlands | H | L | L | H | L | L |
| | Impacts to water quality | H | M | L | H | M | L |
| | Loss of flood storage | M | L | L | M | L | L |

**Table 3 (continued). Habitat impact categories in alteration of freshwater systems workshop session (N=13)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Dredging and Filling, Mining | Reduced flood water retention | H | M | L | H | M | L |
| | Reduced nutrient uptake and release | M | M | L | M | M | L |
| | Reduced detrital food source | H | M | L | M | M | L |
| | Altered hydrological regimes | H | M | L | H | M | L |
| | Increased storm water runoff | H | M | L | H | M | L |
| | Loss of riparian and riverine habitat | H | M | L | H | M | L |
| | Altered stream morphology | H | M | L | H | L | L |
| | Altered stream bed characteristics | H | M | L | H | M | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Release of nutrients/eutrophication | H | M | L | H | H | L |
| | Release of contaminants | H | M | L | H | M | L |
| | Loss of submerged aquatic vegetation | H | H | L | H | H | L |
| | Change in species communities | H | H | L | H | M | L |

**Table 4. Habitat impact categories in marine transportation workshop session (N=18)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Construction and Expansion of Ports and Marinas | Loss of benthic habitat | H | H | H | M | M | M |
| | Siltation/sedimentation/turbidity | H | H | M | M | M | M |
| | Contaminant releases | H | H | M | M | H | M |
| | Altered hydrological regimes | H | H | L | H | H | L |
| | Altered tidal prism | M | H | L | M | H | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Underwater blasting/noise | M | M | L | M | M | M |
| | Loss of submerged aquatic vegetation | H | H | M | H | H | M |
| | Conversion of substrate/habitat | H | H | M | M | M | M |
| | Loss of intertidal flats | H | H | L | L | M | L |
| | Loss of water column | M | M | L | H | H | L |
| | Altered light regime | M | M | L | M | M | L |
| | Derelict structures | M | M | L | M | M | L |
| Operations and Maintenance of Ports and Marinas | Contaminant releases | H | H | M | M | M | M |
| | Storm water runoff | H | H | M | M | M | L |
| | Underwater noise | M | M | L | M | M | L |
| | Alteration of light regimes | M | M | L | M | M | L |
| | Derelict structures | M | M | L | L | L | L |
| | Mooring impacts | M | M | L | L | L | L |
| | Release of debris | M | M | L | M | L | L |
| Operation and Maintenance of Vessels | Impacts to benthic habitat | H | H | L | M | M | L |
| | Resuspension of bottom sediments | M | M | L | M | M | L |
| | Erosion of shorelines | M | M | L | M | M | L |
| | Contaminant spills and discharges | M | H | M | M | H | M |
| | Underwater noise | M | M | M | M | M | M |
| | Derelict structures | M | M | L | L | L | L |
| | Increased air emissions | L | L | L | L | L | L |
| | Release of debris | M | M | L | L | L | L |
| Navigation Dredging | Conversion of substrate/habitat | H | H | M | M | M | L |
| | Loss of submerged aquatic vegetation | H | H | M | H | H | L |
| | Siltation/sedimentation/turbidity | H | H | M | H | M | L |
| | Contaminant releases | H | H | M | M | M | M |
| | Release of nutrients/eutrophication | M | M | M | M | M | L |
| | Entrainment and impingement | M | M | M | M | M | L |
| | Underwater blasting/noise | M | M | L | M | M | L |
| | Altered hydrological regimes | H | H | L | H | M | L |
| | Altered tidal prism | M | M | L | M | M | L |
| | Altered current patterns | M | M | L | M | M | L |
| | Altered temperature regimes | H | H | L | M | M | L |
| | Loss of intertidal flats | H | H | L | H | H | L |
| | Loss of wetlands | H | H | L | H | H | L |
| | Contaminant source exposure | M | M | M | M | M | L |

**Table 5. Habitat impact categories in offshore dredging and disposal workshop session (N=22)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Offshore Mineral Mining | Loss of benthic habitat types | L | L | H | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | L |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Changes in bottom topography | L | L | M | L | L | L |
| | Changes in sediment composition | L | L | H | L | L | L |
| | Sediment transport from site (erosion) | L | L | M | L | L | L |
| | Impacts to water quality | L | L | M | L | L | M |
| | Release of contaminants | L | L | M | L | L | M |
| | Change in community structure | L | L | H | L | L | M |
| | Changes in water flow | L | L | M | L | L | M |
| | Noise impacts | L | L | L | L | L | M |
| Petroleum Extraction | Contaminant releases | L | L | H | L | L | H |
| | Drilling mud impacts | L | L | H | L | L | H |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Release of debris | L | L | M | L | L | L |
| | Noise impacts | L | L | M | L | L | M |
| | Changes in light regimes | L | L | M | L | L | M |
| | Habitat conversion | L | L | M | L | L | M |
| | Pipeline installation | L | L | M | L | L | L |
| Offshore Dredge Material Disposal | Burial/disturbance of benthic habitat | L | M | H | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | M |
| | Siltation/sedimentation/turbidity | L | L | M | L | L | M |
| | Release of contaminants | L | L | M | L | L | M |
| | Release of nutrients/eutrophication | L | L | M | L | L | M |
| | Altered hydrological regimes | L | L | M | L | L | M |
| | Altered current patterns | L | L | M | L | L | M |
| | Changes in bottom topography | L | L | M | L | L | L |
| | Changes in sediment composition | L | L | H | L | L | L |
| | Changes in water bathymetry | L | L | M | L | L | L |
| Fish Waste Disposal | Introduction of pathogens | L | L | H | L | L | H |
| | Release of nutrients/eutrophication | L | L | H | L | L | H |
| | Release of biosolids | L | L | H | L | L | M |
| | Loss of benthic habitat types | L | L | H | L | L | L |
| | Behavioral affects | L | L | M | L | L | M |
| Vessel Disposal | Release of contaminants | L | L | M | L | L | M |
| | Conversion of substrate/habitat | L | L | H | L | L | M |
| | Changes in bathymetry | L | L | M | L | L | L |
| | Changes in hydrodynamics | L | L | M | L | L | M |
| | Changes in community structure | L | L | H | L | L | M |
| | Impacts during deployment | L | L | M | L | L | M |
| | Release of debris | L | L | M | L | L | L |

**Table 6. Habitat impact categories in chemical effects: water discharge facilities workshop session (N=19)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Sewage Discharge Facilities | Release of nutrients/eutrophication | H | H | H | H | H | H |
| | Release of contaminants | H | H | H | H | H | H |
| | Impacts to submerged aquatic vegetation | H | H | M | H | H | M |
| | Reduced dissolved oxygen | H | H | M | H | H | M |
| | Siltation/sedimentation/turbidity | H | H | M | H | H | M |
| | Impacts to benthic habitat | H | H | M | M | M | M |
| | Changes in species composition | H | H | M | H | H | M |
| | Trophic level alterations | H | H | M | H | H | M |
| | Introduction of pathogens | H | H | M | M | H | M |
| | Introduction of harmful algal blooms | H | H | H | H | H | M |
| | Bioaccumulation/biomagnification | H | H | H | H | H | M |
| | Behavioral avoidance | M | H | M | M | H | M |
| | Release of pharmaceuticals | M | M | M | M | M | M |
| Industrial Discharge Facilities | Alteration of water alkalinity | H | M | M | M | M | L |
| | Release of metals | H | H | M | M | M | M |
| | Release of chlorine compounds | H | H | M | H | H | M |
| | Release of pesticides | H | H | M | H | H | M |
| | Release of organic compounds | H | H | H | M | H | M |
| | Release of petroleum products | H | H | M | M | H | M |
| | Release of inorganic compounds | H | H | M | H | H | M |
| | Release of organic wastes | M | M | M | M | M | M |
| | Introduction of pathogens | M | M | M | M | M | M |
| Combined Sewer Overflows | Potential for all of the above effects | H | H | H | H | H | H |

**Table 7. Habitat impact categories in physical effects: water intake and discharge facilities workshop session**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Discharge Facilities | Scouring of substrate | M | M | L | L | L | L |
| | Turbidity/sedimentation | H | H | M | M | M | L |
| | Alteration of sediment composition | H | H | M | L | L | L |
| | Reduced dissolved oxygen | H | H | M | H | H | L |
| | Alteration of salinity regimes | H | H | L | H | H | M |
| | Alteration of temperature regimes | H | H | M | H | H | M |
| | Conversion/loss of habitat | M | M | M | M | M | M |
| | Habitat exclusion/avoidance | H | H | L | H | H | L |
| | Restrictions to migration | H | H | L | H | H | L |
| | Acute toxicity | M | H | M | H | H | M |
| | Behavioral changes | M | M | L | M | M | L |
| | Cold shock | M | M | M | H | M | L |
| | Stunting of growth in fishes | M | M | L | M | M | L |
| | Attraction to flow | H | H | M | H | H | M |
| | Alteration of community structure | H | H | M | H | H | M |
| | Changes in local current patterns | M | M | L | M | M | L |
| | Physical/chemical synergies | M | H | M | M | M | M |
| | Increased need for dredging | H | H | L | H | H | L |
| | Ballast water discharge | H | H | M | M | M | M |
| | Gas-bubble disease/mortality | M | M | L | M | H | L |
| | Release of radioactive wastes | H | H | M | H | H | M |
| Intake Facilities | Entrainment/impingement | H | H | H | H | H | H |
| | Alteration of hydrological regimes | H | H | M | H | H | L |
| | Flow restrictions | H | H | L | H | H | L |
| | Construction related impacts | H | M | M | M | M | M |
| | Conversion/loss of habitat | H | H | M | H | H | M |
| | Seasonal loss of habitat | M | M | L | M | M | M |
| | Backwash (cleaning of system) | M | M | L | M | M | L |
| | Alteration of community structure | H | H | L | H | H | L |
| | Increased need for dredging | H | H | M | H | H | L |
| | Ballast water intake | H | H | M | H | H | M |

**Table 8. Habitat impact categories in agriculture and silviculture workshop session (N=11)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Cropland, Rangelands, Livestock, and Nursery Operations | Release of nutrients/eutrophication | H | H | L | H | H | L |
| | Bank/soil erosion | H | H | L | M | M | L |
| | Altered temperature regimes | M | M | L | M | M | L |
| | Siltation/sedimentation/turbidity | H | H | L | H | H | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Entrainment and impingement | M | L | L | H | L | L |
| | Impaired fish passage | M | L | L | H | M | L |
| | Reduced soil infiltration | M | L | L | M | L | L |
| | Release of pesticides | H | H | L | H | M | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Soil compaction | M | M | L | M | L | L |
| | Loss/alteration of wetlands | H | H | L | M | M | L |
| | Land-use change (post agriculture) | H | M | L | H | M | L |
| | Introduction of invasive species | M | M | L | M | L | L |
| | Introduction of pathogens | H | M | L | M | M | L |
| | Endocrine disruptors | H | H | L | H | H | L |
| | Change of community structure | M | M | L | M | M | L |
| | Change in species composition | H | M | L | M | M | L |
| Silviculture and Timber Harvest Activities | Reduced soil infiltration | M | M | L | M | L | L |
| | Siltation/sedimentation/turbidity | H | M | L | H | M | L |
| | Altered hydrological regimes | M | M | L | M | M | L |
| | Impaired fish passage | M | L | L | H | M | L |
| | Bank/soil erosion | H | M | L | H | M | L |
| | Altered temperature regimes | H | M | L | H | M | L |
| | Release of pesticides | H | H | L | H | H | L |
| | Release of nutrients/eutrophication | H | H | L | H | H | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Loss/alteration of wetlands | H | M | L | H | M | L |
| | Soil compaction | M | L | L | M | L | L |
| Timber and Paper Mill Processing Activities | Chemical contaminant releases | H | H | L | H | H | L |
| | Entrainment and impingement | M | L | L | H | M | L |
| | Thermal discharge | H | L | L | M | L | L |
| | Reduced dissolved oxygen | H | M | L | H | M | L |
| | Conversion of benthic substrate | H | M | L | M | L | L |
| | Loss/alteration of wetlands | M | M | L | M | M | L |
| | Alteration of light regimes | M | L | L | M | L | L |

**Table 9. Habitat impact categories in introduced/nuisance species and aquaculture workshop session (N=14)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Introduced/ Nuisance Species | Habitat alterations | H | H | M | M | M | M |
| | Trophic alterations | M | H | M | M | M | M |
| | Gene pool alterations | H | H | M | H | H | M |
| | Alterations of communities | H | H | M | M | H | M |
| | Introduced diseases | M | H | M | M | H | M |
| | Changes in species diversity | H | H | H | H | H | M |
| | Alteration in health of native species | M | M | M | M | M | M |
| | Impacts to water quality | M | M | M | M | M | M |
| Aquaculture | Discharge of organic waste | M | H | M | M | M | M |
| | Seafloor impacts | M | H | M | M | M | M |
| | Introduction of exotic invasive species | H | H | M | M | H | M |
| | Food web impacts | H | H | M | H | H | M |
| | Gene pool alterations | H | H | M | H | M | M |
| | Impacts to water column | M | M | M | M | H | M |
| | Impacts to water quality | M | H | L | M | H | M |
| | Changes in species diversity | M | H | M | M | H | M |
| | Sediment deposition | H | H | M | L | L | L |
| | Introduction of diseases | M | H | M | M | M | M |
| | Habitat replacement/exclusion | H | H | M | M | M | L |
| | Habitat conversion | H | H | M | M | H | M |

**Table 10. Habitat impact categories in global effects and other impacts workshop session (N=17)**

| Activity Type | Potential Effects | Habitat Impact Categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Life History/Ecosystem Type | | | | | |
| | | Benthic/Demersal Stages | | | Pelagic Stages | | |
| | | Riverine | Estuarine/ Nearshore | Marine/ Offshore | Riverine | Estuarine/ Nearshore | Marine/ Offshore |
| Climate Change | Alteration of hydrological regimes | H | H | M | H | H | H |
| | Alteration of temperature regimes | H | H | H | H | H | H |
| | Changes in dissolved oxygen | H | H | M | H | H | M |
| | Nutrient loading/eutrophication | M | H | M | M | M | M |
| | Release of contaminants | H | H | M | M | M | M |
| | Bank/soil erosion | H | M | L | M | M | L |
| | Alteration in salinity | M | H | M | M | H | M |
| | Alteration of weather patterns | H | H | M | H | H | H |
| | Alteration of alkalinity | M | M | M | M | M | M |
| | Changes in community structure | H | H | H | H | H | H |
| | Changes in ocean/coastal use | M | M | M | M | M | M |
| | Changes in ecosystem structure | M | H | L | M | H | L |
| | Loss of wetlands | H | H | L | H | H | L |
| Ocean Noise | Mechanical injury to organisms | M | M | H | M | M | H |
| | Impacts to feeding behavior | M | M | M | M | M | M |
| | Impacts to spawning behavior | M | M | M | M | M | M |
| | Impacts to migration | M | M | M | M | M | M |
| | Exclusion of organisms to habitat | M | M | M | M | M | M |
| | Changes in community structure | M | M | M | M | M | M |
| Atmospheric Deposition | Nutrient loading/eutrophication | H | H | M | H | H | M |
| | Mercury loading/bioaccumulation | H | H | M | H | H | H |
| | Polychlorinated biphenyls and other contaminants | H | H | M | H | H | M |
| | Alteration of ocean alkalinity | M | M | M | M | M | M |
| | Alteration of climatic cycle | M | M | M | M | M | M |
| Military/ Security Activities | Exclusion of organisms to habitat | L | L | M | L | M | M |
| | Noise impacts | M | M | M | M | M | H |
| | Chemical releases | M | H | M | M | M | M |
| | Impacts to tidal/intertidal habitats | M | M | L | L | M | L |
| | Blasting injuries from ordinances | M | M | M | M | M | M |
| Natural Disasters and Events | Loss/alteration of habitat | H | H | M | H | H | M |
| | Impacts to habitat from debris | M | M | M | M | M | L |
| | Impacts to water quality | M | H | M | H | H | M |
| | Impacts from emergency response | M | M | L | M | M | L |
| | Alteration of hydrological regimes | M | M | M | M | M | L |
| | Changes in community composition | M | H | M | M | M | M |
| | Underwater landslides | L | L | M | L | L | M |
| Electromag-netic Fields | Changes to migration of organisms | M | M | M | M | M | M |
| | Behavioral changes | M | M | M | M | M | M |
| | Changes in predator/prey relationships | L | M | M | M | M | M |

# CHAPTER TWO: COASTAL DEVELOPMENT

## Introduction

Urban growth and development in the United States continues to expand in coastal areas at a rate approximately four times greater than that in other areas of the country (Hanson et al. 2003). Although loss of coastal wetlands to development has decreased in the last several decades, the percentual rate of loss has remained similar to that of the 1920-1950 periods (Valiela et al. 2004). Rate of loss of coastal wetlands was estimated to be 0.2% per year from 1922-1954, while loss rates from 1982-1987 were approximately 0.18% per year (Valiela et al. 2004). The construction of urban, suburban, commercial, and industrial centers and corresponding infrastructure results in land use conversions that typically remove vegetation and create additional impervious surface. At least one study has correlated ecosystem-level changes with the addition of impervious surfaces in coastal, urbanized areas. Holland et al. (2004) found reduced abundance of stress-sensitive macroinvertebrates and altered food webs in headwater tidal creeks when impervious cover exceeded 20-30% land cover. In fact, measurable adverse changes in the physical and chemical environment were observed when the impervious cover exceeded 10-20% land cover (Holland et al. 2004). Runoff from impervious surfaces and storm sewers is the most widespread source of pollution into the nation's waterways (USEPA 1995).

This chapter discusses the various sources of anthropogenic pollution, as well as other impacts to fishery habitat associated with coastal development. This report has employed the broad definition of adverse effect provided in the essential fish habitat (EFH) regulations to include "direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components." (50 CFR § 600.810). For this reason, impacts to the health and physiology of the fishery resources from physical, chemical, and biological factors are included. There are a number of impacts discussed in this chapter that overlap to some degree with those in other chapters of this report. We have attempted to minimize redundant information, and references to other chapters are provided when the topic has been treated in more detail elsewhere in the report.

## Discharge of Nonpoint Source Pollution and Urban Runoff

The major threats to marine and aquatic habitats are a result of increasing human population and coastal development, which contribute to an increase in anthropogenic pollutant loads. These pollutants are released into estuarine and coastal habitats by way of point and nonpoint source discharges.

The US Environmental Protection Agency (US EPA) defines "nonpoint source" as anything that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act, which refers to "discernable, confined and discrete conveyance" from which pollutants are or may be discharged (for discussions of point source pollution and discharges, see the chapters on Chemical Effects: Water Discharge Facilities and Physical Effect: Water Intake and Discharge Facilities). Nonpoint source (NPS) pollution comes from many diffuse sources. Land runoff, precipitation, atmospheric deposition, seepage, and hydrologic modification are the major contributors to NPS pollution. The general categories of NPS pollution are: sediments, nutrients, acids and salts, metals, toxic chemicals, and pathogens. While all pollutants can become toxic at high enough levels, a number of compounds can be toxic at relatively low levels. The US EPA has identified and designated these compounds as "priority pollutants." Some of these "priority pollutants" include: (1) metals, such as cadmium, copper, chromium, lead, mercury, nickel, and zinc that arise from industrial operations, mining, transportation, and agriculture use; (2) organic compounds, such as pesticides, polychlorinated biphenyl (PCB) congeners, solvents, petroleum hydrocarbons, organometallic compounds, phenols, formaldehyde, and biochemical methylation of metals in aquatic sediments; (3) dissolved gases, such as chlorine and ammonium; (4) anions, such as cyanides, fluorides, sulfides, and sulphates; and (5) acids and alkalis (USEPA 2003a).

While our understanding of the individual, cumulative, and synergistic effects of all contaminants on the coastal ecosystem are incomplete, pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). Although the effects of NPS pollution are usually lower in severity than are those of point source pollution, they may be more widespread and damaging to fish and their habitats in the long term. NPS pollution may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for a long time. When population impacts are finally detected, they may not be tied to any one event or source, and they may be difficult to correct, clean up, or mitigate. Increasing human populations and development within coastal regions generally leads to an increase in impervious surfaces, including but not limited to roads, residential and commercial development, and parking lots. Impervious surfaces cause greater volumes of run-off and associated contaminants in aquatic and marine waters.

Urban runoff is generally difficult to control because of the intermittent nature of rainfall and runoff, the large variety of pollutant source types, and the variable nature of source loadings (Safavi 1996). The 2000 National Water Quality Inventory (USEPA 2002) reported that runoff from urban areas is the leading source of impairment in surveyed estuaries and the third largest source of impairment in surveyed lakes. Urban areas can have a chronic and insidious pollution potential that one-time events such as oil spills do not.

It is important to note that the affects of pollution on coastal fishery resources may not necessarily represent a serious, widespread threat to all species and life history stages. The severity of the threat that individual pollutants may represent for aquatic organisms depends upon the type and concentration of the chemical compound and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong bottom currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas near or within enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile life history stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

### *Nutrient loading and eutrophication*

In the northeastern United States, highly eutrophic conditions have been reported in a number of estuarine and coastal systems, including Boston Harbor, MA, Long Island Sound, NY/CT, and Chesapeake Bay, MD/VA (Bricker et al. 1999). While much of the excess nutrients within coastal waters originates from sewage treatment plants, nonpoint sources of nutrients from municipal and agricultural run-off, contaminated groundwater and sediments, septic systems, wildlife feces, and atmospheric deposition from industry and automobile emissions contribute significantly (Hanson et al. 2003; USEPA 2005). Failing septic systems contribute to NPS pollution and are a negative consequence of urban development. The US EPA estimates that 10-25% of all individual septic systems are failing at any one time, introducing feces, detergents, endocrine disruptors, and chlorine into the environment (Hanson et al. 2003). Sewage waste contains significant amounts of organic matter that cause a biochemical oxygen demand, leading to eutrophication of coastal waters (Kennish 1998) (see also the chapter on Chemical Effects: Water Discharge Facilities). O'Reilly (1994) found that extensive hypoxia in the northeastern United States has been more chronic in river-estuarine systems from Chesapeake Bay to Narragansett Bay, RI, than in systems to the north, except for episodic low dissolved oxygen in Boston Harbor/Charles River, MA, and the freshwater portion of the Merrimack River, MA/NH. The US EPA's National Coastal Condition Report II (USEPA 2004) reported similar trends in northeast coast estuaries and also noted signs of degraded water quality in estuaries north of Cape Cod, MA. Although the US EPA report found much of the Acadian Province (i.e., Maine and New Hampshire) to have good water quality conditions, it identified Great Bay, NH, as only having fair to poor conditions (USEPA 2004).

Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including: reductions in submerged aquatic vegetation (SAV) through reduced light transmittance, epiphytic growth, and increased disease susceptibility (Goldsborough 1997); mass mortality of fish and invertebrates through poor water quality; and alterations in long-term natural community dynamics. The effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (*Pseudopleuronectes americanus*) (Bejda et al. 1992). Short and Burdick (1996) correlated eelgrass losses in Waquoit Bay, MA, with anthropogenic nutrient loading primarily as a result of an increased number of septic systems from housing developments in the watershed. The environmental effects of excess nutrients and elevated suspended sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

There is evidence that nutrient overenrichment has led to increased incidence, extent, and persistence of blooms of nuisance and noxious or toxic species of phytoplankton; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from planktonic algae (O'Reilly 1994). Heavily developed watersheds tend to have reduced stormwater storage capacity, and the various sources of nutrient input can increase the incidence, extent, and persistence of harmful algal blooms (O'Reilly 1994). See also the chapters on Introduced/Nuisance Species and Aquaculture and Chemical Effects: Water Discharge Facilities for more information on harmful algal blooms.

### *Introduction of pathogens*

Introduction of pathogens to aquatic habitats has become more common and widespread over the last 30 years, and various factors may be responsible, including NPS pollution from highly urbanized areas (O'Reilly 1994). Urban runoff typically contains elevated levels of pathogens, including bacteria, viruses, and protozoa, often a result of introductions of bacteria from leaking septic systems, agricultural manure, domestic animals, wildlife, and other sources of NPS pollution and can lead to beach and shellfish harvesting area closures (USEPA 2005). Pathogens are generally harmful to human health through the consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). While many pathogens affecting marine organisms are associated with upland runoff, there are also naturally occurring marine pathogens that affect fish and shellfish (Shumway and Kraeuter 2000). Some naturally occurring pathogens, such as bacteria from the genus *Vibrio*, or the dinoflagellate *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species requires additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997).

## *Sedimentation and turbidity*

Land runoff from coastal development can result in an unnatural influx of suspended particles from soil erosion having negative effects on riverine, nearshore, and estuarine ecosystems. Impacts from this include high turbidity levels, reduced light transmittance, and sedimentation which may lead to the loss of SAV and other benthic structure (USEPA 2005; Orth et al. 2006). Other effects include disruption in the respiration of fishes and other aquatic organisms, reduction in filtering efficiencies and respiration of invertebrates, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991; Wilber and Clarke 2001; USEPA 2005). For example, Breitburg (1988) found the predation rates of striped bass (*Morone saxatilis*) larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory. De Robertis et al. (2003) found reductions in the rate of pursuit and probability of successful prey capture in piscivorous fish at turbidity levels as low as 10 nephelometric turbidity units, while the prey consumption of two species of planktivorous fish were unaffected at this turbidity level. In another laboratory study, rainbow smelt (*Osmerus mordax*) showed signs of increased swimming activity at suspended sediment concentrations as low as 20 mg/L, suggesting fish responded to increased suspended sediment concentrations with an "alarm reaction" (Chiasson 1993).

## *Release of petroleum products*

Petroleum products consist of thousands of chemical compounds that can be toxic to marine life including polycyclic aromatic hydrocarbons (PAH), which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). PAH have been found to be significantly higher in urbanized watersheds when compared to nonurbanized watersheds (Fulton et al. 1993). By far, the largest amount of petroleum released through human activity comes from the use of petroleum products (e.g., cars, boats, paved urban areas, and two-stroke engines) (ASMFC 2004). Most of the petroleum consumption activities are land-based; however, rivers and storm and wastewater streams carry the petroleum to marine environments such as estuaries and bays. Although individual petroleum product releases are small, they are widespread and common and when combined, they contribute nearly 85% of the total petroleum pollution from human activities (ASMFC 2004).

Petroleum products can be a major stressor on inshore fish habitats. Short-term impacts include interference with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fishes, especially early life-history stages (Gould et al. 1994). PAH can degrade aquatic habitat, consequently interfering with biotic communities and may be discharged into rivers from nonpoint sources, including municipal run-off and contaminated sediments. Oil has been shown to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others and, in general, the early life stages (i.e., eggs and larvae) of organisms are most sensitive (Gould et al. 1994; Rice et al. 2000).

Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. The water column may be polluted with oil as a result of wave action and currents dispersing the oil. Benthic habitat and the shoreline can be covered and saturated with oil, leading to the protracted damage of aquatic communities, including the disruption of population dynamics. Oil can persist in sediments for decades after the initial contamination, causing disruption of physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996). These changes may lead to disruption of community organization and dynamics in affected regions and permanently diminish fishery habitat. Carcinogenic and mutagenic properties of oil compounds have been identified (Larsen 1992; Gould et al. 1994). For more detail on oil spills, see the chapter on Energy-related Activities.

### *Alteration of water alkalinity*

Fishery resources are known to be sensitive to changes in water alkalinity. Rivers and the brackish waters of estuaries are especially sensitive to acidic effluents because of the lower buffering capacity of freshwater as compared to that of salt water. The influx of pH altering flows to aquatic habitats can hinder the sustainability of fisheries. Municipal run-off, contaminated groundwater, and atmospheric deposition are potential nonpoint sources of acid influx to aquatic habitats. Acidification may disrupt or prevent reproduction, development, and growth of fish (USFWS and NMFS 1999). Osmoregulatory problems in Atlantic salmon (*Salmo salar*) smolts have been demonstrated to be related to habitats with low pH (Staurnes et al. 1996). Low pH in estuarine waters has been shown to cause cellular changes in the muscle tissues of Atlantic herring (*Clupea harengus*), which may lead to a reduction in swimming ability (Bahgat et al. 1989).

### *Alteration of temperature regimes*

Alteration of natural temperature regimes can occur in riverine and estuarine ecosystems because of land runoff from urbanized areas. Radiant heating from impervious surfaces, such as concrete and asphalt can increase the water temperature of streams, rivers, and bays. The removal of shoreline and riparian vegetation can reduce shading effects and raise the water temperature of creeks and ponds that drain into larger water bodies. Temperature influences biochemical processes, behavior (e.g., migration), and physiology of aquatic organisms (Blaxter 1969), and long-term thermal pollution may change natural community dynamics.

Because warmer water holds less oxygen than colder water does, increased water temperatures reduce the dissolved oxygen concentration in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. In addition, increased water temperatures in the upper strata of the water column can increase water column stratification, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries with excess nutrients (Kennedy et al. 2002). Stratification could also affect primary and secondary productivity by suppressing nutrient upwelling and mixing in the upper regions of the water column, potentially altering the composition of phytoplankton and zooplankton. Impacts to the base of the food chain would not only affect fisheries but could impact entire ecosystems.

### *Release of metals*

Metal contaminants are found in the water column and can persist in the sediments of coastal habitat, including urbanized areas, as well as fairly uninhabited regions, and are a potential environmental threat (Larsen 1992; Readman et al. 1993; Buchholtz ten Brink et al. 1996). High levels of metals, such as mercury, copper, lead, and arsenic, are found in the sediments of New England estuaries because of past industrial activity (Larsen 1992) and may be released into the water column during navigation channel dredging or made available to organisms as a result of storm events. Some activities associated with shipyards and marinas have been identified as sources of metals in the sediments and surface waters of coastal areas (Milliken and Lee 1990; USEPA 2001; Amaral et al. 2005). These include copper, tin, and arsenic from boat hull painting and scraping, hull washing, and wood preservatives. Treated wood used for pilings and docks releases copper compounds that are applied to preserve the wood (Poston 2001; Weis and Weis 2002). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). Refer to the Overwater Structures section of this chapter for more information on treated wood products and their effects on aquatic organisms. Urban stormwater runoff often contains metals from automobile and industrial facilities, such as mercury, lead (used in batteries), and nickel and cadmium (used in brake linings). Refer to the chapter on Marine Transportation for more information on channel dredging and storm water impacts from marinas and shipyards.

At low concentrations, metals may initially inhibit reproduction and development of marine organisms, but at high concentrations, they can directly contaminate or kill fish and invertebrates. Shifts in phytoplankton species composition may occur because of metal accumulation and may lead to an alteration of community structure by replacing indigenous producers with species of lesser value as a food source for consumers (NEFMC 1998). Metals are known to produce a number of toxic effects on marine fish species, including skeletal deformities in Atlantic cod (*Gadus morhua*) from cadmium exposure (Lang and Dethlefsen 1987), larval developmental deformities in haddock (*Melanogrammus aeglefinus*) from copper exposure (Bodammer 1981), and reduced viable hatch rates in winter flounder embryos and increased larval mortality from silver exposure (Klein-MacPhee et al. 1984). Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977). Copper may also bioaccumulate in bacteria and phytoplankton (Milliken and Lee 1990). Metals have been implicated in disrupting endocrine secretions of aquatic organisms, potentially disrupting natural physiological processes (Brodeur et al. 1997; Thurberg and Gould 2005). Refer to the Chemical Effects: Water Discharge Facilities chapter for a broader discussion on endocrine-disrupting chemicals. While long-term impacts do not appear significant in most marine organisms, metals can move upward through trophic levels and accumulate in fish (bioaccumulation) at levels that can eventually cause health problems in human consumers (NEFMC 1998). See also Global Effects and Other Impacts chapter for mercury loading/bioaccumulation via the atmosphere.

## *Release of radioactive wastes*

Radioactive wastes may be a potential threat to aquatic habitats used by fish and shellfish species. Fishery resources may accumulate radioactive isotopes in tissues that could lead to negative effects on the resource and consumers (ICES 1991). Potential sources of radioactive wastes are urban stormwater runoff, municipal landfills, atmospheric deposition, contaminated groundwater, and sediments (e.g., past offshore dumping locations [NEFMC 1998]).

## *Release of toxic compounds*

Many different toxic compounds, including "priority pollutants" described previously, have been found in urban runoff (USEPA 2005). The US EPA reported that at least 10% of urban runoff samples contained toxic pollutants (USEPA 2005). Organic contamination contained within urban runoff, particularly chlorinated and aromatic compounds, has been implicated in causing immuno-suppression in juvenile chinook salmon (*Oncorhynchus tshawytscha*) (Arkoosh et al. 2001). The organophosphate insecticide, malathion, has been implicated in the mass mortality of American lobsters (*Homarus americanus*) in Long Island Sound during 1999 (Balcom and Howell 2006). In addition, impairment of immune response and stress hormone production were identified as examples of the sublethal effects from exposure of this compound on American lobsters (Balcom and Howell 2006). Refer to the subsections release of metals, pesticides, and herbicides in this chapter for additional information on toxic compounds.

### *Release of pesticides and herbicides*

Although agricultural run-off is a major source of pesticide pollution in aquatic systems, residential areas are also a notable source (see Agriculture and Silviculture chapter for a discussion on agricultural runoff of pesticides). Other sources of pesticide discharge into coastal waters include atmospheric deposition and contaminated groundwater (Meyers and Hendricks 1982). Pesticides may bioaccumulate in the ecosystem by retention in sediments and detritus then ingested by macroinvertebrates, which in turn are eaten by larger invertebrates and fish (ASMFC 1992). For example, winter flounder liver tissues taken in 1984 and 1985 in Boston and Salem Harbors in Massachusetts were found to have the two highest mean concentrations of total dichlorodiphenyl trichloroethane (DDT) found in all New England sites sampled (NOAA 1991). Samples taken of soft parts from softshelled clams (*Mya arenaria*) during the same time period indicated that Boston Harbor mussels were moderately to highly contaminated with DDT when compared to nationwide sites (NOAA 1991).

There are three basic ways that pesticides can adversely affect the health and productivity of fisheries: (1) direct toxicological impact on the health or performance of exposed fish; (2) indirect impairment of the productivity of aquatic ecosystems; and (3) loss or degradation of habitat (e.g., aquatic vegetation) that provides physical shelter for fish and invertebrates (Hanson et al. 2003).

For many marine organisms, the majority of effects from pesticide exposures are sublethal, meaning that the exposure does not directly lead to the mortality of individuals. Sublethal effects can be of concern, as they impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003). Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish (Moore and Waring 2001; Gould et al. 1994). For example, evidence has shown that DDT and its chief metabolic by-product, dichlorodiphenyl dichloroethylene (DDE), can act as estrogenic compounds, either by mimicking estrogen or by inhibiting androgen effectiveness (Gilbert 2000). DDT has been shown to cause deformities in winter flounder eggs and Atlantic cod embryos and larvae (Gould et al. 1994). Generally, however, the sublethal impacts of pesticides on fish health are poorly understood.

The direct and indirect effects that pesticides have on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems (Preston 2002). This factor includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as macroinvertebrates that are prey species for fish. Because pesticides are specifically designed to kill insects, it is not surprising that these chemicals are relatively toxic to insects and crustaceans that inhabit river systems and estuaries. The use of pesticides to control mosquitoes has been suggested as a potential factor in the mass mortality of American lobsters in Long Island Sound during 1999 (Balcom and Howell 2006). Recent lab studies have shown that lobsters are considerably more sensitive to the effects of the mosquito adulticide, malathion, than are any other species previously tested. Sublethal effects (i.e., impairment of immune response and stress hormone production) occur at concentrations in parts per billion and at concentrations much lower than those observed to cause lethal effects (Balcom and Howell 2006). Lab studies have shown that American lobsters have a 96-hour LC50 (i.e., Lethal

Concentration 50- the duration and chemical concentration which causes the death of 50% of the test animals) of 33.5 ppb with immunotoxicity resulting at 5 ppb, suggesting a high sensivity in this species to both lethal and sublethal toxicity effects from malathion in seawater (De Guise et al. 2004).

Herbicides may alter long-term natural community structure by hindering aquatic plant growth or destroying aquatic plants. Hindering plant growth can have notable effects on fish and invertebrate populations by limiting nursery and forage habitat. Chemicals used in herbicides may also be endocrine disrupters, exogenous chemicals that interfere with the normal function of hormones (NEFMC 1998). Coastal development and water diversion projects contribute substantial levels of herbicides entering fish and shellfish habitat. A variety of human activities such as noxious weed control in residential development and agricultural lands, right-of-way maintenance (e.g., roads, railroads, power lines), algae control in lakes and irrigation canals, and aquatic habitat restoration results in contamination from these substances.

### *Conservation measures and best management practices (BMPs) for discharge of nonpoint source pollution and urban runoff (adapted from Hanson et al. 2003)*

1. Remove unnecessary impervious surfaces such as abandoned parking lots and buildings from riparian and shoreline areas and reestablish wetlands and native vegetation, whenever possible. Construction of new impervious surfaces should be avoided or minimized.
2. Implement BMPs for sediment control during construction and maintenance operations, including: avoiding ground disturbing activities during the wet season; minimizing the temporal and spatial extent of the disturbance; using erosion prevention and sediment control methods; maintaining natural buffers of vegetation around wetlands, streams, and drainage ways; and avoiding building activities in areas of steep slopes and areas with highly erodable soils. Whenever appropriate, recommend the use of methods such as sediment ponds, sediment traps, bioswales, or other facilities designed to slow runoff and trap sediment and nutrients (USEPA 1993).
3. Protect, enhance, and restore vegetated buffer zones along streams and wetlands that include or influence fishery habitat.
4. Manage stormwater to duplicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.
5. Encourage proposed residential and commercial developments to utilize municipal wastewater facilities capable of treating sewage to the maximum extent practicable. Any proposed residential developments utilizing septic systems should include modern, state of the art systems. Ensure that they are properly sited and maintained.
6. Encourage communities to implement “smart-growth” development and land-use planning that reduces urban sprawl and minimizes impervious surfaces.
7. Encourage the use of nontreated wood materials in construction near aquatic environments.
8. Incorporate integrated pest management and BMPs as part of the authorization or permitting process to ensure the reduction of pesticide contamination in fishery habitat (Scott et al. 1999).
9. Avoid the use of pesticides and herbicides in and near aquatic habitats.
10. Refrain from aerial spraying of pesticides on windy days.
11. Address nonpoint source pollution by assessing cumulative impacts of past, present, and foreseeable future development activies on aquatic habitats in the review process.

## Commercial and Domestic Water Use

Freshwater withdrawn for human use from riverine environments can alter natural current and sedimentation patterns, water quality, water temperature, and associated biotic communities (NEFMC 1998). Natural freshwater flows are subject to human alteration through water diversion for agriculture and industrial uses and modifications to the watershed. An increasing demand for potable water, combined with inefficient use of freshwater resources and natural events (e.g., droughts) have led to serious ecological damage worldwide, as well as in New England (Deegan and Buchsbaum 2005). For example, the flow of the Ipswich River in Massachusetts has been reduced to about one-half historical levels because of water withdrawals for human uses and about one-half of the native fish species on the river have been eliminated or greatly reduced (Bowling and Mackin 2003). Water withdrawal for freshwater drinking supply, power plant coolant systems, and irrigation occurs along urban and suburban areas, causing potential detrimental effects on aquatic habitats. The water withdrawal limits the amount of freshwater flowing into estuaries, which can affect the health and productivity of the ecosystem. For example, diversion of freshwater leading to increased salinities can result in oysters relocating upstream where less suitable habitat may be available and in areas subjected to higher levels of pollution (MacKenzie 2007). Urbanization leads to increases in the amount of impervious surface (e.g., roads and parking lots), which causes water to flow off the land more quickly than if the land was undeveloped and forested, reducing the natural recharge of groundwater. Alteration of the natural hydroperiod can affect circulation patterns in estuarine systems, leading to both short-term and long-term changes (Deegan and Buchsbaum 2005). In addition, the use of desalinization plants to meet industrial and municipal water needs may further alter chemical and physical environments by discharging hypersaline water into the aquatic ecosystem. Refer to the chapters on Physical Effects: Water Intake and Discharge Facilities and Alteration of Freshwater Systems for additional information on domestic and commercial freshwater usage.

### *Conservation measures and best management practices for commercial and domestic water use (adapted from Hanson et al. 2003)*

1. Ensure that the design of water diversion projects provide adequate passage, water quality, and proper timing of water flows for all life history stages of anadromous fish and that they maintain and restore adequate channel, floodplain, riparian, and estuarine conditions.
2. Incorporate juvenile and adult fish passage facilities on water diversion projects.
3. Seasonal restrictions should be used to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

## Road Construction and Operation

The building and maintenance of roads can affect aquatic habitats by increasing rates of erosion, debris slides, landslides, sedimentation, introduction of exotic species, and degradation of water quality (Furniss et al. 1991; Hanson et al. 2003). Paved and dirt roads introduce an impervious or semipervious surface into the landscape, which intercepts rain and increases runoff, carrying soil, sand, and other sediments (Ziegler et al. 2001) and oil-based materials more quickly into aquatic habitats. Roads constructed near streams, wetlands, and other sensitive areas may cause sedimentation in these habitats and further diminish flood plain storage capacity, subsequently increasing the need for dredging in those systems. Sedimentation and the release of contaminants into aquatic habitats can be acute following heavy rain and snow and as a result of improper road maintenance activities. Even carefully designed and constructed roads can be a source of sediment and pollutants if they are not properly maintained (Hanson et al. 2003).

The effects of roads on aquatic habitat include: (1) contaminant releases; (2) increased release of sediments; (3) reduced dissolved oxygen; (4) changes in water temperature; (5) elimination or introduction of migration barriers; (6) changes in stream flow; (7) introduction of nonnative plant species; (8) altered salinity regimes; and (9) changes in channel configuration.

### *Contaminant releases*

Roads constructed near or adjacent to aquatic habitats can be a source of chemical contaminants, such as deicing chemicals, road salt, fertilizers, and herbicides to control roadside vegetation and petroleum products from vehicles or from the road asphalt itself (Furniss et al. 1991).

Nationally, an estimated 18 million tons of deicing salt, primarily sodium and calcium chlorides, are used each year and state and local governments spend approximately $10 million annually to remediate road salt contamination (USEPA 2005). Road salts dissolve and enter adjacent soils, groundwater, and surface waters through runoff, which can cause toxicity in plants, fish, and other aquatic organisms. These effects are particularly pronounced in smaller water bodies adjacent to salted areas. Stormwater runoff from roads can contain oil, grease, and other hydrocarbons from asphalt, wearing of tires, deposition from automobile exhaust, and oiling of roadsides and unpaved roads with crankcase oil (USEPA 2005). Refer to the Discharge of Nonpoint Source Pollution and Urban Runoff section of this chapter for information on impacts from stormwater runoff.

### *Sedimentation, siltation, and turbidity*

The rate of soil erosion around roads is primarily a function of storm intensity, surfacing material, road slope, and traffic levels (Hanson et al. 2003). In addition, road maintenance activities such as road sanding to prevent icing and road repair can also cause sedimentation in adjacent aquatic habitats. For roads located in steep terrain, mass soil movement triggered by roads can last for decades after roads are built (Furniss et al. 1991). Surface erosion results in increased deposition of fine sediments (Bilby et al. 1989; MacDonald et al. 2001; Ziegler et al. 2001), which has been linked to a decrease in salmon fry emergence, decreased juvenile densities, and increased predation in some species of salmon (Koski 1981).

### *Reduced dissolved oxygen*

The introduction of stormwater runoff from roads can increase the organic loads in adjacent streams and rivers, increasing the biological oxygen demand and reducing dissolved oxygen concentrations. Reduced dissolved oxygen concentrations can cause direct mortality of aquatic organisms or result in sub-acute effects such as reduced growth and reproductive success. Bejda et al. (1992) found that the growth of juvenile winter flounder was significantly reduced when dissolved oxygen (DO) levels were maintained at 2.2 mg/L or when DO varied diurnally between 2.5 and 6.4 mg/L for a period of 11 weeks.

### *Loss and alteration of vegetation and altered temperature regimes*

Roads located near streams often involve the removal of riparian vegetation for construction and safety and maintenance. Roads built adjacent to streams result in changes in water temperature and increased sunlight reaching the stream as riparian vegetation is removed and/or altered in composition (Hanson et al. 2003). Roads can also alter natural temperature regimes in riverine and estuarine ecosystems because of radiant heating effect from the road surfaces. Riparian vegetation is an important component of rearing habitat for coldwater species, such as salmonids, providing shade for maintaining cool water temperatures, food supply, and channel stability and structure (Furniss et al. 1991).

Temperature effects biochemical processes, behavior (e.g., migration), and physiology of aquatic organisms (Blaxter 1969), and long-term thermal pollution may change natural community dynamics. In addition, increased water temperatures can reduce the dissolved oxygen concentration in bodies of water that are not well mixed. This may exacerbate eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States.

### *Impaired fish passage*

Roads can also reduce or eliminate upstream and downstream fish passage through improperly placed culverts at road-stream crossings (Belford and Gould 1989; Clancy and Reichmuth 1990; Evans and Johnston 1980; Furniss et al. 1991). Improperly designed stream crossings adversely effect fish and aquatic organisms by blocking access to spawning, rearing, and nursery habitat because of: (1) perched culverts constructed with the bottom of the structure above the level of the stream, effectively acting as dams and physically blocking passage; and (2) hydraulic barriers to passage are created by undersized culverts which constrict the flow and create excessive water velocities (Evans and Johnston 1980; Belford and Gould 1989; Furniss et al. 1991; Jackson 2003). Smooth-bore liners made from high density plastic help meet the goal of passing water and protecting roadways from flooding, but they greatly increase flow velocities through the passage. Culverts can be plugged by debris or overtopped by high flows. Road damage, channel realignment, and extreme sedimentation from roads can cause stream flow to become too shallow for upstream fish movement (Furniss et al. 1991). Additional information on impaired fish passage is discussed in the Alteration of Freshwater Systems chapter of this report.

### *Introduction of exotic invasive species*

Roads can be the first point of entry for nonnative, opportunistic grass species that are seeded along road cuts or introduced from seeds transported by tires and shoes (Greenberg et al. 1997; Lonsdale and Lane 1994). Nonnative plants may be able to move away from the roadside and into aquatic sites, where they may out-compete native species and alter the structure and function of the aquatic ecosystem (see also the chapter on Introduced/Nuisance Species and Aquaculture).

### *Altered hydrological regimes*

Roads can result in adverse effects to hydrologic processes. They intercept rainfall directly on the road surface, in road cut banks, and as subsurface water moving down the hillslope; they also concentrate flow, either on the road surfaces or in adjacent ditches or channels (Hanson et al. 2003). Roads can divert or reroute water from flow paths that would otherwise be taken if the road were not present (Furniss et al. 1991). The hydrology of riverine and estuarine systems can be affected by fragmentation of the habitat caused by the construction of roads and culverts (Niering 1988; Mitsch and Gosselink 1993). These structures also reduce natural tidal flushing and interfere with natural sediment-transport processes, all of which are important functions that maintain the integrity of coastal wetlands (Tyrrell 2005). As discussed previously, roads can alter flood plain storage patterns. These hydrological changes may lead to increased erosion and sedimentation in adjacent streams.

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002).

### *Altered tidal and salinity regimes*

As discussed above, roads can alter hydrologic processes by rerouting flow paths and concentrating stormwater flow towards salt marsh and tidal creeks. Together with the removal of vegetation adjacent to roads, a large and rapid influx of freshwater can alter the salinity regime and species composition of estuarine habitats. Roads and culverts can also restrict the flow in tidal creeks, lowering the head-of-tide, altering the estuarine community, and restricting the access of anadromous fish.

### *Altered stream morphology*

The geometry of a stream is affected by the amount of water and sediment that the stream carries. These factors may be altered by roads and stream crossings. Adjustments to stream morphology are usually detrimental to fish habitat (Furniss et al. 1991). Alteration of stream morphology can change stream velocity and increase sedimentation of the streambed, which can have adverse effects on spawning and migration of anadromous fish.

### *Conservation measures and best management practices for road construction and operation (adapted from Hanson et al. 2003)*

1. Roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes.
2. Build bridges for crossing aquatic environments, rather than utilizing culverts, whenever possible. If culverts must be used, they should be sized, constructed, and maintained to match the gradient, flow characteristics, and width of the stream so as to accommodate a 100-year flood event, but equally to provide for seasonal migratory passage of adult and juvenile fish.
3. Design bridge abutments to minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible.
4. Specify erosion control measures in road construction plans.
5. Avoid side casting of road materials into streams.
6. Use only native vegetation in stabilization plantings.
7. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Maintain roadway and associated stormwater collection systems properly.
9. Control the practice of roadway sanding and the use of deicing chemicals during the winter to minimize sedimentation and introduction of contaminants into nearby aquatic habitats. Sweep and remove sand after winter to reduce sediment loading in streams and wetlands.
10. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for road construction projects.

# Flood Control/Shoreline Protection

As human populations in coastal areas grow, development pressure increases and structures are often constructed along the coastline to prevent erosion and stabilize shorelines. The protection of coastal development and human communities from flooding can result in varying degrees of change in the physical, chemical, and biological characteristics of existing shoreline and riparian habitat. Attempts to protect "soft" shorelines such as beaches to reduce shoreline erosion are inevitable consequences of coastal development. Structures placed for coastal shoreline protection include breakwaters, jetties and groins, concrete or wood seawalls, rip-rap revetments (sloping piles of rock placed against the toe of the dune or bluff in danger of erosion from wave action), dynamic cobble revetments (natural cobble placed on an eroding beach to dissipate wave energy and prevent sand loss), and sandbags (Hanson et al. 2003). These structures are designed to slow or stop the shoreline from eroding, but in many cases the opposite occurs as erosion rates increase along the adjacent areas. Many shoreline "hardening" structures, such as seawalls and jetties, tend to reduce the complexity of habitats and the amount of intertidal habitats (Williams and Thom 2001). Generally, "soft" shoreline stabilization approaches (e.g., beach nourishment, vegetative plantings) have fewer adverse effects on hydrology and habitats.

Flood control measures in low-lying coastal areas include dikes, ditches, tide gates, and stream channelization. These measures are generally designed to direct water away from flood prone areas and, in the case of tide gates, prevent tidal water and storm surge from entering these areas. Adjacent aquatic habitat can become altered, and short- and long-term impacts to local fish and shellfish populations may be associated with the presence of the erosion control structures. Coastal marshes typically have a gradient of fresh to salt tolerant vegetation. These coastal wetland systems drain freshwater through tidal creeks that eventually empty into the bay or estuary. The use of water control structures can have long-term adverse effects on tidal marsh and estuarine habitats by interfering with the exchange of fresh and brackish water within the marsh habitat.

## *Altered hydrological regimes*

Water control structures within marsh habitats intercept and carry away freshwater drainage, block freshwater from flowing across seaward portions of the marsh, increase the speed of runoff of freshwater to the bay or estuary, lower the water table, permit saltwater intrusion into the marsh proper, and create migration barriers for aquatic species (Hanson et al. 2003). In deep channels where anoxic conditions prevail, large quantities of hydrogen sulfide may be produced that are toxic to marsh grasses and other aquatic life. Long-term effects of flood control on tidal marshes include land subsidence (sometimes even submergence), soil compaction, conversion to terrestrial vegetation, reduced invertebrate populations, and general loss of productive wetland characteristics (Hanson et al. 2003). Alteration of the hydrology of coastal salt marshes can reduce estuarine productivity, restrict suitable habitat for aquatic species, and result in salinity extremes during droughts and floods.

## *Altered temperature regimes*

Shoreline modifications, including the construction of seawalls and bulkheads, invariably involve the removal of shoreline vegetation which eliminates shading and can cause increased water temperatures in rivers and the nearshore intertidal zone (Williams and Thom 2001). Conversely, increased shading from seawalls and bulkheads constructed along shorelines may unnaturally reduce local light levels and primary production rates and reduce water temperatures of the water column adjacent to the structures (Williams and Thom 2001). Tide gates prevent or reduce tidal flushing to an area, causing stagnant water behind the structure and increased water temperature regimes (Williams and Thom 2001). Breakwaters and jetties can also alter hydrological processes which may result in altered fluctuations of nearshore temperature (Williams and Thom 2001).

### *Reduced dissolved oxygen*

Breakwaters and jetties affect nearshore hydrological processes, as well as river flow and tidal currents when these structures are placed at the mouth of rivers and estuaries (Williams and Thom 2001). This can alter the timing and volume of water exchange to rivers, bays, and estuaries and result in reductions in water circulation and dissolved oxygen concentrations for some areas, particularly when combined with eutrophic conditions. Flood control structures, such as tide gates, dikes, and ditches, can restrict the exchange of water within wetlands, which can create stagnant conditions and reduce dissolved oxygen concentrations (Spence et al. 1996; Williams and Thom 2001).

### *Altered sediment transport and increased erosion/accretion*

As discussed above, shoreline stabilization structures such as breakwaters, jetties, and groins affect nearshore hydrological processes which can alter wave energy and current patterns that, in turn, can affect littoral drift and longshore sediment transport (Williams and Thom 2001). In comparisons between natural and seawalled shorelines, Bozek and Burdick (2005) found no statistically significant effects on several salt marsh processes in Great Bay, NH. However, at high-energy sites, the authors found trends indicating greater sediment movement and winnowing of fine grain sediments adjacent to seawalls (Bozek and Burdick 2005).

These structures can also impact sediment budgets in estuaries and rivers. Alterations to sediment transport can affect bottom habitats, beach formation, and sand dune size (Williams and Thom 2001). Hardened shorelines, from the construction of seawalls, groins, and revetments, directly affect nearshore sediment transport by impounding natural sediment sources. Shoreline structures can cause beach erosion and accretion in adjacent areas. Long-term, chronic impacts may result in a reduction of intertidal habitat, bottom complexity, and associated soft-bottom plant and animal communities (Williams and Thom 2001). In tidal marshes, floodgates and dikes restrict sediment transport which is a natural part of the marsh accretion process. The use of these structures can result in subsidence of the marsh and loss of salt marsh vegetation.

### *Alteration and loss of benthic and intertidal habitat*

As discussed above, breakwaters, jetties, and groins can affect nearshore hydrological processes, such as wave energy and current patterns and, in turn, can have detrimental impacts on benthic habitats. Increased sedimentation as a result of reflective turbulence (changes in water velocity caused by wave energy reflection from solid structures in the nearshore coastal area) and turbidity can reduce or eliminate vegetated shallows (Williams and Thom 2001). In addition, these structures can alter the geomorphology of existing habitats, resulting in a large-scale replacement of soft-bottom, deepwater habitat with shallow and intertidal, hard structure habitats (Williams and Thom 2001). Alterations to the shoreline as a result of bulkhead and other hard shoreline structures can increase wave energy seaward of the armoring, causing scouring of bottom sediments and loss of salt marsh vegetation.

### *Altered stream morphology*

Flood and erosion control structures such as bulkheads, levees, and dikes built along streams and rivers, as well as the canalization of streams and rivers, result in simplified riverine habitat and a reduction in pools and riffles that provide habitat for fish (Spence et al. 1996). In addition, altered stream hydrology and morphology can change sediment grain size and reduce the organic matter available to small organisms that serve as prey for larger species in the food web (Williams and Thom 2001).

### *Impacts to riparian habitat*

As discussed above, shoreline modifications such as the construction of seawalls and bulkheads, involve the removal of shoreline vegetation which eliminates shading and can cause increased water temperatures in rivers and the nearshore, intertidal zone (Williams and Thom 2001). The loss of riparian vegetation reduces the forage and cover for aquatic organisms and the input of large woody debris and smaller organic detritus, including leaves (Spence et al. 1996).

### *Impaired fish passage*

Tide gates and other flood control structures can eliminate or restrict access of fish to salt marshes. Tide gates can create physical barriers for estuarine fish species that utilize salt marsh wetlands for feeding and early development. High flow rates at tide gates or culvert openings can prevent small fish from accessing critical marsh and freshwater habitat. In some cases, fish can become trapped behind tide gates, preventing them from accessing deeper water and potentially stranding them during periods of low water (Williams and Thom 2001).

### *Alteration of natural communities*

Armoring of shorelines to prevent erosion and maintain or create shoreline real estate simplifies habitats, reduces the amount of intertidal habitat, and negatively affects nearshore processes and the ecology of coastal species (Williams and Thom 2001). For example, Chapman (2003) found a paucity of mobile species associated with seawalls in a tropical estuary, compared with surrounding areas. In that study, approximately 50% of taxa found on natural rocky shorelines were absent on constructed seawall, and seawalls were found to have a diminished proportion of rare taxa. Alterations to the shoreline from hydraulic action include increased energy seaward of the armoring from reflected wave energy, narrowing of the dry beach, coarsening of the substrate, steepening of the beach slope, reduction of sediment storage capacity, a loss of organic debris, and a reduction of downdrift sediment (Williams and Thom 2001). Bozek and Burdick (2005) found no statistically significant effects of seawalls on salt marsh processes in Great Bay, NH; however, their data indicated seawalls tended to eliminate the high-diversity vegetative zones at the upper border of the salt marsh. Installation of breakwaters and jetties can result in community changes, including burial or removal of resident biota, changes in the habitat structure, alteration in prey and predator interaction, and physical obstructions that can alter the recruitment patterns of larvae (Williams and Thom 2001).

### *Reduced ability to counter sea-level rise*

The effect of shoreline erosion and land subsidence will likely be exacerbated by sea-level rise because of global climate change. Sea level rose 10-20 cm (4-8 inches) in the 20$^{th}$ century and may rise another 18-59 cm (7-23 inches) by 2100 (IPCC 2007). As sea levels continue to rise, salt marshes, mudflats, and coastal shallows must be able to shift horizontally without interruption from natural or manmade barriers (Bigford 1991). Hard structures, such as seawalls, bulkheads, and jetties may inhibit the shoreward migration of marsh wetlands (Kelley 1992) and SAV beds (Orth et al. 2006). In addition, global climate change is expected to cause greater precipitation and more intense storms in the mid-high latitudes in the northern hemisphere (Nedeau 2004). Along with rising sea levels, these factors may exacerbate coastal erosion and increase the apparent need for shoreline protection. See Global Effects and Other Impacts chapter for more information on global climate change.

### *Conservation measures and best management practices for flood control/shoreline protection (adapted from Hanson et al. 2003)*

1. Avoid or minimize the loss of coastal wetlands as much as possible, including encouraging coastal wetland habitat preservation. Preservation of coastal upland buffers between buildings and wetlands may allow for the inland migration of wetlands as sea levels rise.
2. Avoid the diking and draining of tidal marshlands and estuaries, whenever possible.
3. Use "soft" approaches (such as beach nourishment, vegetative plantings, and placement of large woody debris), in lieu of "hard" shoreline stabilization and modifications (such as concrete bulkheads and seawalls, concrete or rock revetments), whenever possible.
4. Ensure that the hydrodynamics and sedimentation patterns are properly modeled and that the design avoids erosion to adjacent properties when "hard" shoreline stabilization is deemed necessary.
5. Include efforts to preserve and enhance fishery habitat (e.g., provide new gravel for spawning or nursery habitats; remove barriers to natural fish passage; and use of weirs, grade control structures, and low flow channels to provide the proper depth and velocity for fish) to offset impacts from proposed riparian habitat and stream modifications.
6. Construct a low-flow channel to facilitate fish passage and help maintain water temperature in reaches where water velocities require armoring of the riverbed.
7. Replace in-stream fish habitat by installing boulders, rock weirs, and woody debris and by planting riverine aquatic cover vegetation to provide shade and habitat.
8. Avoid installing new water control structures in tidal marshes and freshwater streams. If the installation of new structures cannot be avoided, ensure that they are designed to allow optimal fish passage and natural water circulation.
9. Ensure water control structures are monitored for potential alteration of water temperature, dissolved oxygen concentration, and other parameters.
10. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning, egg, and larval development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
11. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for flood control and shoreline protection projects.

## Beach Nourishment

Beach nourishment, the process of mechanically or hydraulically placing sediments (i.e., sand and gravel) directly on an eroding shore to restore or form a protective or desired recreational beach, has been steadily increasing along the eastern US coastline since the 1960s (Greene 2002). Beaches and shorelines are dynamic, constantly eroding and accreting because of exposure to waves, currents, and wind. Beach nourishment serves as a "soft," sacrificial barrier to protect the beach and property along the coast from storm and flood damage. Between 1923 and 2004, it is estimated that approximately 515 million cubic yards of beach sediment have been deposited on the

US east coast barrier island shoreline from Maine to Florida, including 966 instances of beach nourishment at 343 locations (Valverde et al. 1999; PSDS 2005).

Beach nourishment as a protective measure against coastal flooding and storm damage may be considered less of an impact to marine organisms and fishery habitat than are most “hard” structure solutions discussed in the previous section. However, beach nourishment can have a number of short- and long-term impacts on fishery resources, including displacing benthic organisms during and after nourishment, interference with respiration and feeding in finfish and filter feeding invertebrates, temporary removal of benthic prey, burial of habitat that serves as foraging and shelter sites, potential burial of demersal and benthic species, and mortality of species at vulnerable life stages, such as eggs, larvae, and juveniles (Greene 2002). Sand or cobble material needed for beach nourishment is generally dredged from offshore areas, referred to as borrow or mining sites, and either hydraulically pumped through pipes or loaded onto barges for transfer and placement on the beach. Fish and invertebrates in and around the borrow site can be subjected to entrainment, sedimentation, and increased turbidity during the dredging and transport of the beach material. In addition, the creation of borrow pits may alter the bottom topography and sediment transport processes in offshore habitats and form depressions with low-dissolved oxygen. Nourished beaches seldom last as long as natural beaches, and natural coastal processes erode the replenished sand, requiring additional nourishment of those beaches (Pilkey and Dixon 1996). The life span of a nourished beach can be highly variable and primarily dependent upon storm intensity and frequency following the completion of a project. According to Pilkey and Dixon (1996), the life span of most nourished beaches is 2-5 years. Beach nourishment projects are often conducted at a high economic cost, and they can represent a long-term and cumulative impact on the marine biological community.

Increased global precipitation, more intense storms, and sea level rise predicted for the mid-high latitudes in the northern hemisphere because of global climate change will likely exacerbate erosional forces on beaches (Nedeau 2004) and increase the frequency of beach renourishment to protect eroding shoreline. See Global Effects and Other Impacts chapter for more on global climate change.

### *Altered hydrological regimes*

Sand removed from borrow sites can potentially affect the geomorphology of offshore sand bars and shoals that absorb incoming waves, causing greater wave energy and/or change refraction patterns (Greene 2002). This may increase the erosion rate at the nourished beach and adjacent, nonnourished beaches. In addition, nourished beaches tend to have altered sediment grain size, shape, and distribution across the beach, which can lead to changes in the hydrodynamic patterns in the intertidal beach zone (Pilkey and Dixon 1996; Greene 2002).

In addition, the conditions in deeply excavated borrow pits can become anaerobic during certain times of the year. The dissolved oxygen concentration within these deep pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984). For example, construction grade aggregate removal in Raritan Bay, NJ, Long Island Sound, and the intercoastal waterway in New Jersey have left deep pits and large depressions that are more than twice the depth of the surrounding area. The pits have remained chemically, physically, and biologically unstable with limited biological diversity for more than five decades. These borrow pits in Raritan Bay were found to possess depressed benthic communities and elevated levels of highly hydrated and organically enriched sediments (Pacheco 1984).

### Altered sediment transport

Longshore transport of sediments may be affected by the creation of borrow pits, which can be deep depressions taking several years to refill and can alter the nearshore sediment budget (Greene 2002). Longshore sediment transport may also be affected in the nearshore environment if material placed on the beach is not compatible with natural or historic material. In addition, nearshore rock groins are sometimes constructed in order to reduce erosion of the nourished beach, which alters the downdrift of sediment and may starve adjacent beaches of sand.

### Alteration/loss of benthic habitat

Sand infauna and sessile benthic organisms in the path of dredging equipment at the borrow site are generally removed and killed during mining. In addition, some mobile organisms, such as crustaceans and larval and juvenile fish, can be entrained by the dredge equipment. Following mining, species diversity of benthic infaunal organisms within borrow pits drops precipitously, but recolonization in sandy sediments typically occurs through larval transport and migration of postsettlement life-stages (i.e., juveniles and adults) (Greene 2002).

Benthic fauna at the beach site will be killed by burial following nourishment unless an organism is capable of burrowing through the overburden of sand (Greene 2002). Several factors determine survival of beach invertebrate fauna, including the ability for vertical migration through the sand overburden and the recruitment potential of larvae, juveniles, and adult organisms from adjacent areas (Greene 2002). Peterson et al. (2000) found an 86-99% reduction in the abundance of dominant species of beach macro-invertebrates ten weeks after nourishment on a North Carolina beach. These observations were made between the months of June and July, when the abundances of beach macro-invertebrates are typically at their maximum and providing the important ecosystem service of feeding abundant surf fishes and ghost crabs (Peterson et al. 2000).

### Alteration of natural communities

The recovery of the benthic infauna at a borrow site is dependent upon a number of factors, including the amount of material removed, the fauna present at the site and surrounding area prior to dredging, and the degree of sedimentation that occurs following dredging (Greene 2002). For sand habitats, the recovery time of benthic infauna within borrow sites has been reported to be as rapid as less than one year, while other studies have indicated recovery may take greater than five years (Greene 2002). Some differences in recovery time may be attributed to the fact that most benthic infauna recolonization studies look at abundance of individuals but fail to measure trophic level changes and the life history of individuals in the samples (Greene 2002). The postdredging benthic community may function very differently than does the predredging community. The borrow pits may require several years to refill with sediment and may contain a greater silt content than do the surrounding areas (Greene 2002). Generally, the degree of alteration of the sediment composition appears to be the largest factor in determining long-term impact at a borrow site (Greene 2002). The dissolved oxygen concentration within borrow pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984).

Similar to the findings on the recovery of benthic infauna at borrow sites, results of studies assessing the recovery of organisms at nourished beaches are highly variable (Greene 2002). While some studies conclude that beach infauna populations may recover to predredging levels between two to seven months, other studies suggest recovery times are much longer (Greene 2002). Peterson et al. (2000) found a large reduction in prey abundance and body size of benthic macroinvertebrates at a nourished intertidal beach that likely translated to trophic level impacts on surf zone fishes and shorebirds.

### *Increased sedimentation/turbidity*

High turbidity in the water column and sedimentation on adjacent benthic habitats can result from resuspension of sediment at the discharge pipe and from sediment winnowing from the nourished beach into the surf zone. In addition, turbidity can also increase between the borrow site and the target beach when sand is lost during hopper loading, from leaks in the pipelines carrying sand to the beach, and from the dredging activity at the borrow site itself. High turbidity and suspended sediments can be persistent in the nearshore waters long after a beach is nourished if mud balls, silt, and clays are present in the mined sediment (Greene 2002).

Generally, the severity of the effects of suspended sediments on aquatic organisms increases as a function of sediment concentration and the duration of exposure (Newcombe and Jensen 1996). Some of the effects of suspended sediments on marine organisms can include altered foraging patterns and success (Breitburg 1988), gill abrasion and reduced respiratory functions, and death (Wilber and Clark 2001). The sensitivity of species to suspended sediments is highly variable and dependent upon the nature of the sediment and the life history stage of the species. The eggs and larval stages of marine and estuarine fish are generally highly sensitive to suspended sediment exposures compared to some freshwater taxa studied (Wilber and Clark 2001). Sedimentation from beach nourishment may also have adverse effects on invertebrates that serve as prey for fish (Greene 2002). Refer to the Marine Transportation and Offshore Dredging and Disposal chapters for more information regarding turbidity and sedimentation impacts on aquatic organisms.

### *Conservation measures and best management practices for beach nourishment (adapted from Hanson et al. 2003)*

1. Avoid sand mining in areas containing sensitive marine benthic habitats (e.g., spawning and feeding sites, hard bottom, cobble/gravel substrate, shellfish beds).
2. Avoid beach nourishment in areas containing sensitive marine benthic habitats adjacent to the beach (e.g., spawning and feeding sites, hard bottom, cobble/gravel substrate).
3. Conduct beach nourishment during the winter and early spring, when productivity for benthic infauna is at a minimum; this may minimize the impacts for some beach sites.
3. Assess source material for compatibility with that of material to be placed on beach (e.g., grain size and shape, color). Slope of nourished beach should mimic the natural beach profile.
4. Use upland beach material sources, if compatible, to avoid impacts associated with offshore sand mining.
5. Preserve, enhance, or create beach dune and native dune vegetation in order to provide natural beach habitat and reduce the need for nourishment.
6. Monitor turbidity during operations, and cease operations if turbidity exceeds predetermined threshold levels at the beach and borrow sites.
7. Implement seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning season, egg, and larval development period). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Address the cumulative impacts of past, present, and foreseeable future development activies on aquatic habitats by considering them in the review process for beach nourishment projects.

## Wetland Dredging and Filling

The dredging and filling of coastal wetlands for commercial and residential development, port, and harbor development directly removes important wetland habitat and alters the habitat surrounding the developed area. Even development projects that appear to have minimal individual wetland impacts can have significant cumulative effects on the aquatic ecosystem. This section discusses the impacts on fishery habitat from dredging and filling freshwater and tidal wetlands for development purposes. Additional information on dredging and filling in freshwater wetlands and rivers and streams is provided in the chapter on Alteration of Freshwater Systems, and dredging and disposal of dredge material in subtidal habitats (e.g., navigation channel dredging and marine mining) have been addressed in the chapters on Marine Transportation and Offshore Dredging and Disposal. The primary impacts to fishery habitat from the introduction of fill material in or adjacent to wetlands include: (1) physical loss of habitat; (2) loss or impairment of wetland functions; and (3) changes in hydrologic patterns.

The discharge of dredge and fill materials are regulated under Section 404 of the Clean Water Act (CWA) of 1972 for all "waters of the United States," which include both freshwater and tidal wetlands. Some of the types of discharge of fill material covered under Section 404 of the CWA include: (1) placement of fill that is necessary to the construction of a structure or impoundment; (2) site development fills for recreational, industrial, commercial, or residential uses; (3) causeway or road fills, dams, or dikes; (4) artificial islands; (5) property protection and/or reclamation devices such as riprap, groins, seawalls, breakwaters, and revetments; (6) beach nourishment; (7) levees; (8) fill for structures such as sewage treatment facilities, intake and outfall pipes associated with power plants and subaqueous utility lines; and (9) artificial reefs.

### *Loss and alteration of wetland vegetation*

Salt marsh wetlands serve as habitat for early life history stages of many fish species, as well as shellfish, crabs, and shrimp, which use the physical structure of the marsh grasses as refuge from predators (Tyrrell 2005). Smaller fish, such as mummichog (*Fundulus heteroclitus*), Atlantic silverside (*Menidia menidia*), sticklebacks (*Gasterosteids*, spp.), and sheepshead minnow (*Cyprinidon variegates*), rely on salt marshes for parts of their life cycles. These species form the prey base of many larger, commercially important species such as a number of flounder species, black sea bass (*Centropristis striata*), and bluefish (*Pomatomus saltatrix*) (Collette and Klein-MacPhee 2002).

Filling wetlands removes productive habitat and eliminates the important functions that both aquatic and many terrestrial organisms depend upon. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) caused by degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Niering 1988; Mitsch and Gosselink 1993).

### *Altered hydrological regimes*

The discharge of dredged or fill material into aquatic habitats can modify current patterns and water circulation by obstructing the flow or by changing the direction or velocity of water flow and circulation. As a result, adverse changes can occur in the location, structure, and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; the deposition of suspended particulates; the rate and extent of mixing of dissolved and suspended components of the water body; and water stratification (Hanson et al. 2003). Altering the hydrology of wetlands can affect the water table, groundwater discharge, and soil salinity, causing a shift in vegetation patterns and quality of the habitat. Hydrology can be affected by fragmenting the habitat caused by the construction of roads and residential development or by building bulkheads, dikes, levees, and other structures designed to prevent or remove floodwater from the land around the wetlands (Niering 1988; Mitsch and Gosselink 1993). These structures also reduce natural tidal flushing and interfere with natural sediment-transport processes, all of which are important functions that maintain the integrity of the marsh habitat (Tyrrell 2005). Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005). Alteration of the hydrology and soils of salt marsh wetlands has led to the invasion of an exotic haplotype of the common reed (*Phragmites australis*), which has spread dramatically and degraded salt marsh habitats along the Atlantic coast (Posey et al. 2003; Tyrrell 2005).

### *Loss of flood storage capacity*

Coastal wetlands absorb and store rain and urban runoff, buffering upland development from floods. In addition, coastal marshes provide a physical barrier that protects upland development from storm surge. As a result, the loss and alteration of coastal wetlands can cause upland development to be more prone to flooding from storms and heavy rains. Furthermore, altering the hydrological regimes of wetlands through construction of dikes, levees, and tide gates can redirect floodwater towards rivers and estuaries and bypass the natural flood storage functions of coastal wetlands.

### *Altered current patterns*

Replacing wetlands with roads, buildings, and other impervious surfaces increases the volume and intensity of storm water runoff, which can accelerate the rate of coastal erosion. Placing dredge material onto intertidal mud habitats can dramatically alter tidal flow. These effects can change the geomorphology and current patterns of rivers and estuaries and adversely affect habitat suitability for certain species. For example, counter current flows set up by freshwater discharges into estuaries are important for larvae and juvenile fish entering those estuaries. Behavioral adaptations of marine and estuarine species allow larvae and early juveniles to concentrate in estuaries (Deegan and Buchsbaum 2005).

### *Altered temperature regimes*

The loss of riparian and salt marsh vegetation can increase the amount of solar radiation reaching streams and rivers and results in an increase in the water temperatures of those water bodies (Moring 2005). Replacing coastal wetlands with impervious surfaces such as asphalt, which absorb more solar radiation than does vegetation, tends to raise the water temperature in adjacent aquatic environments. Altered temperature regimes have the ability to affect the distribution; growth rates; survival; migration patterns; egg maturation and incubation success; competitive ability; and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003b). In freshwater habitats of the northeastern United States, the temperature regimes of cold-water fish such as salmon, smelt, and trout may be exceeded, leading to local extirpation of these species (Moring 2005). The removal of riparian vegetation can also have the effect of lowering water temperatures during winter, which can increase the formation of ice and delay the development of incubating fish eggs and alevins in salmonids (Hanson et al. 2003).

### *Release of rutrients/eutrophication*

When functioning properly, riparian and tidal wetlands support denitrification of nitrate-contaminated groundwater. While sediment particles can bind to some nutrients, resuspension of sediments following a disturbance tends to cause a rapid release of nutrients to the water column (Lohrer and Wetz 2003). Coastal wetlands reduce the risk of eutrophication in estuaries and nearby coastal waters (Tyrrell 2005) by absorbing nutrients in groundwater and storm water. Eliminating or degrading coastal wetlands through dredge and fill activities can eliminate these important wetland functions and adversely affect estuarine and marine ecosystems.

### *Release of contaminants*

The removal of wetlands eliminates an important wetland function: pollution filtration (Niering 1988; Mitsch and Gosselink 1993). Wetlands are capable of absorbing metals, pesticides, excess nutrients, oxygen-consuming substances, and other pollutants that would otherwise be transported directly to aquatic environments. In addition, dredging and filling of wetlands can release contaminants that have accumulated in the sediments into adjacent aquatic habitats.

### *Increased sedimentation/turbidity*

When functioning properly, riparian and tidal wetlands filter sediment and runoff from floodplain development. Siltation, sedimentation, and turbidity impacts on riverine and estuarine habitats can be worsened by the loss and replacement of wetlands with impervious surfaces. Suspended sediments in aquatic environments reduce the availability of sunlight to aquatic plants, cover fish spawning areas and food supply, interfere with filtering capacity of filter feeders, and can clog and harm the gills of fish (USEPA 2003b).

### *Loss of fishery productivity*

Hydrological modifications from dredge and fill activities and general coastal development are known to increase the amount of run-off entering the aquatic environment and may contribute to the reduced productivity of fishery resources. Many wetland dependent species, such as mummichog, Atlantic silverside, sticklebacks, and sheepshead minnow, are important prey for larger, commercially important species such as a number of flounder species, black sea bass, and bluefish (Collette and Klein-MacPhee 2002). Although there have been sharp declines or collapses of many estuarine-dependent fisheries in the United States, attributing reductions in fishery productivity directly to losses of wetland habitat can be complicated (Deegan and Buchsbaum 2005). Recent wetland losses can be quantified for discrete regions and the nation as a whole; however, a number of other factors, such as overfishing, cultural eutrophication, and altered input of freshwater caused by flood control structures, probably all contribute to a reduction in the productivity of fisheries. Since the implementation of the Clean Water Act in 1972, the major problems for coastal habitats have changed from outright destruction to more subtle types of degradation, such as cultural eutrophication (Deegan and Buchsbaum 2005).

### *Introduction of invasive species*

A nonnative haplotype of the common reed, *Phragmites australis,* has expanded its range along the entire east coast of the United States, primarily in wetland habitats disturbed by nutrient loading and hydrological alterations of salt marsh wetlands (Posey et al. 2003). *Phragmites* is tolerant of low-salinity conditions in salt marshes, which can occur with tidal restrictions from the construction of tide gates, bulkheads, and dikes. Under these conditions, *Phragmites* can out-compete native salt marsh vegetation such as *Spartina* sp. (Burdick et al. 2001; Deegan and Buchsbaum 2005). Salt marshes that are dominated by *Phragmites* may have reduced function and productivity compared to that of salt marshes consisting of native marsh vegetation (Tyrrell 2005).

### *Conservation measures and best management practices for wetland dredging and filling (adapted from Hanson et al. 2003)*

1. Apply a sequence of measures to avoid, minimize, and mitigate adverse impacts in wetlands to all proposed dredging projects. Dredging and filling within wetlands should be avoided to the maximum extent practicable.
2. Consider only "water-dependent" dredge and fill projects in wetlands and only after upland alternatives have been investigated.
3. Do not dispose dredge material in wetlands, and ensure that these materials meet or exceed applicable state and/or federal water quality standards.
4. Identify and characterize fishery habitat functions/services in the project areas prior to any dredge and fill activities.
5. Identify the direct and indirect affects of wetland fills on fishery habitat during proposed project reviews, including alterations of hydrology and water quality as a result of the proposed project.
6. Assess the cumulative impact from past, current, and all reasonably foreseeable future dredge and fill operations that impact aquatic habitats via federal, state, and local resource management and permitting processes.
7. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Undertake activities in wetlands, if required, using only low ground pressure vehicles.
9. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for wetland dredge and fill projects.

## Overwater Structures

With increasing coastal development comes a concomitant interest in the construction and operation of waterfront facilities, the use of coastal waterways, and the environmental implications of these activities (Barr 1993). Overwater structures include commercial and residential piers and docks, floating breakwaters, moored barges, rafts, booms, and mooring buoys. These structures are typically located from intertidal areas to areas of water depths approximately 15 m below mean low water (i.e., the shallow subtidal zone). Light, wave energy, substrate type, depth, and water quality are the primary factors controlling the plant and animal assemblages found at a particular site. Overwater structures and associated use activities can alter these factors and interfere with key ecological functions such as spawning, rearing, and the use of refugia. Site-specific factors (e.g., water clarity, current, depth) and the type and use of a given overwater structure determine the occurrence and magnitude of these impacts (Hanson et al. 2003).

### Shading impacts to vegetation

Overwater structures create shade which reduces the light levels below the structure. Shading from overwater structures can reduce prey organism abundance and the complexity of the habitat by reducing aquatic vegetation and phytoplankton abundance (Haas et al. 2002). The size, shape, and intensity of the shadow cast by a particular structure are dependent upon its height, width, construction materials, and orientation. In field studies conducted in Massachusetts, the most significant factors affecting shading impacts on eelgrass were the height of the structure above vegetation, orientation of the dock, and dock width (Burdick and Short 1999). High and narrow piers and docks produce narrower and more diffuse shadows than do low and wide structures. Increasing the numbers of pilings used to support a pier increases the shade cast by pilings on the under-pier environment. In addition, less light is reflected underneath structures built with light-absorbing materials (e.g., wood) than from structures built with light-reflecting materials (e.g., concrete or steel). Under-pier light levels have been found to fall below threshold amounts for the photosynthesis of diatoms, benthic algae, eelgrass, and associated epiphytes and other autotrophs. Eelgrass and other macrophytes can be reduced or eliminated, even through partial shading of the substrate, and have little chance to recover (Kenworthy and Hauners 1991). Structures that are oriented north-south produce a shadow that moves across the bottom throughout the day, resulting in a smaller area of permanent shade than those that are oriented east-west (Burdick and Short 1999; Shafer 1999). In a report investigating effects of residential docks in south Florida, Smith and Mezich (1999) found approximately 40% of the docks surveyed had additions fixed to them (e.g., boat lifts and cradles, floating docks, finger piers). These structural additions increased the dock area (and seagrass impacts) and ranged from 16-77%, and contributed to mean seagrass impacts of 47% beyond the footprint of the dock.

Similar shading impacts to salt marsh vegetation from docks and piers have been reported. A study in Connecticut measuring the density and average plant height of salt marsh vegetation below docks and adjacent areas found a reduction in vegetative reproductive capacity caused by the presence of docks (Kearney et al. 1983). This study concluded that the height of the dock was a strong determining factor in the effects to salt marsh vegetation.

### Altered hydrological regimes

Alterations to wave energy and water transport from overwater structures can impact the nearshore detrital foodweb by altering the size, distribution, and abundance of substrate and detrital materials (Hanson et al. 2003). The disruption of longshore transport can alter substrate composition and can present potential barriers to the natural processes that build spits and beaches and provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning (Hanson et al. 2003).

### Contaminant releases

Kennish (2002) identified a number of contaminants associated with overwater structures that can be released into the aquatic environment, including detergents, petroleum products, and copper. Treated wood used for pilings and docks releases contaminants into the aquatic environment. Creosote-treated wood pilings and docks commonly release PAH and other chemicals, such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA), which are applied to preserve the wood (Poston 2001; Weis and Weis 2002). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). The presence of CCA in the food chain can also cause a localized reduction in species richness and diversity (Weis and Weis 2002). These preservatives are known to leach into marine waters after installation, but the rate of leaching is highly variable and dependent on many factors, including the age of the treated wood. Concrete or steel, on the other hand, are relatively inert and do not leach contaminants into the water.

### *Benthic habitat impacts*

Additional impacts associated with overwater structures may include damage to seagrasses and substrate scour from float chains and anchors (Kennish 2002). Docks located in intertidal areas that are exposed during low tides result in vessels resting on the substrate, which may impact shellfish beds, SAV, and intertidal mudflats. Vessels operating in shallow water to access docks may cause a resuspension of bottom sediments and may physically disrupt aquatic habitats, such as bank and shoreline (Barr 1993) and SAV through "prop dredging" (Burdick and Short 1999). Barr (1993) identified a number of potential impacts to aquatic ecosystems from resuspension of sediments caused by vessel activity, including reductions in primary productivity (e.g., phytoplankton and SAV), alteration of temperature, dissolved oxygen and pH of the water, abrasion and clogging of fishes gill filaments, and reductions in egg development and the growth of some fishes and invertebrates. Glasby (1999) found that epibiota on pier pilings at marinas subject to shading were markedly different than those in surrounding rock reef habitats. Shading by overwater structures may be responsible for the observed reductions in juvenile fish populations found under piers and the reduced growth and survival of fishes held in cages under piers, when compared to open habitats (Able et al. 1998; Duffy-Anderson and Able 1999).

### *Increased erosion/accretion*

Pilings can alter adjacent substrates with increased deposition of sediment from changes in current fields or shell material deposition from piling communities. Changes in substrate type can alter the nature of the flora and fauna native to a given site. Kearney et al. (1983) found that docks and pier walkways cause shading impacts to salt marsh vegetation, reduce plant root mat, and may lead to soil erosion in the area of the structures. In the case of pilings, native dominant communities typically associated with sand, gravel, mud, and eelgrass substrates may be replaced by communities associated with shell hash substrates (Penttila and Doty 1990; Nightingale and Simenstad 2001; Haas et al. 2002). In addition to impacts to eelgrass habitat from overwater structures, Penttila and Doty (1990) found that changes to current fields around structures caused altered sediment distribution and topography that created depressions along piling lines.

### *Changes in predator/prey interaction*

Fish use visual cues for spatial orientation, prey capture, schooling, predator avoidance, and migration. The reduced-light conditions found under an overwater structure limit the ability of fish, especially juveniles and larvae, to perform these essential activities (Hanson et al. 2003). In addition, the use of artificial lighting on docks and piers creates unnatural nighttime conditions that can increase the susceptibility of some fish to predation and interfere with predator/prey interactions (Nightingale and Simenstad 2001).

### *Cumulative effects*

While the effect of some individual overwater structures on fishery habitat may be minimal, the overall impact may be substantial when considered cumulatively. For example, although shading impacts on seagrasses may affect a relatively small area around overwater structures, fragmentation of seagrass beds along a highly developed shoreline or within a bay can be considerable. Fragmentation of seagrass habitat can lower the integrity of the remaining seagrass beds, leaving it more susceptible to other impacts (Burdick and Short 1999). The additive effect of these structures increases the overall magnitude of impact, reduces the ability of the habitat to support native plant and animal communities, and makes the habitat more susceptible to damage from storms and disease.

### *Conservation measures and best management practices for overwater structures (adapted from Hanson et al. 2003)*

1. Use upland boat storage whenever possible to minimize need for overwater structures.
2. Locate overwater structures in sufficiently deep waters to avoid intertidal and shade impacts, to minimize or preclude dredging, to minimize groundings, and to avoid displacement of SAV, as determined by a preconstruction survey.
3. Design piers, docks, and floats to be multi-use facilities serving multiple homeowners in order to reduce the overall number of such structures and the nearshore habitat that is impacted.
4. Incorporate measures that increase the ambient light transmission under piers and docks. Some of these measures include: maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint; grated decking material; using the fewest number of pilings necessary to support the structures to allow light into under-pier areas and minimize impacts to the substrate; and aligning piers, docks, and floats in a north-south orientation to allow the path of the sun to cross perpendicular to the length of the structure and reduce the duration of shading.
5. Encourage seasonal use of docks and off-season haul-out.
6. Avoid placing floating docks in areas supporting SAV. Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal zone, and ensure that adequate water depth is available between the substrate and the bottom of the float throughout all tide cycles.
7. Incorporate float stops in dock proposals when it is impracticable or impossible to avoid placing floating docks in water deep enough to avoid contact with the bottom to avoid mechanical and/or hydraulic damage to the substrate from the float during low tides. Float stops should be designed to provide a minimum of 2 ft of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
8. Conduct in-water work during the time of year when managed species and prey species are least likely to be impacted.
9. Avoid the use of treated wood timbers or pilings to the extent practicable. The use of alternative materials such as untreated wood, concrete, or steel is recommended. Concrete and steel pilings are generally considered to be less damaging, since they help reflect light under docks and generally do not release contaminants into the aquatic environment.
10. Orient artificial lighting on docks and piers such that illumination of the surrounding waters at night is avoided.
11. Address the cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the review process for overwater structure projects.

## Pile Driving and Removal

Pilings provide support for the decking of piers and docks; they function as fenders and dolphins to protect structures, support navigation markers, and are used to construct breakwaters and bulkheads. Materials used in pilings include steel, concrete, wood (both treated and untreated), plastic or a combination thereof, and they are usually driven into the substrate with impact hammers or vibratory hammers (Hanson et al. 2003). Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers utilize a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. While impact hammers are able to drive piles into most substrates (e.g., hardpan, glacial till), vibratory hammers are limited to softer, unconsolidated substrates (e.g., sand, mud, gravel). Piles can be removed by using a variety of methods, including vibratory hammer, direct pull, clamshell grab, or cutting/breaking the pile below the mudline. Vibratory hammers can be used to remove all types of pile, including wood, concrete, and steel. Broken stubs are often removed with a clamshell and crane. In other instances, piles may be cut or broken below the mudline, leaving the buried section in place (Hanson et al. 2003).

### *Sound energy impacts*

Pile driving with impact hammers can generate intense underwater sound pressure waves that may adversely affect fish species and their habitats. These pressure waves have been shown to injure and kill fish (CalTrans 2001; Longmuir and Lively 2001). Injuries directly associated with pile driving include rupture of the swimbladder and internal hemorrhaging, but these have been poorly studied (CalTrans 2001).

### *Benthic habitat impacts*

The extraction of piles can result in altered sediment composition and depressions in the bottom, which may cause erosion and loss of sediment. Bottom depressions may fill in with fine sediments and silt, changing the characteristics of the benthic habitat. Removal of piles may cause sediments to slough off and elevate the suspended sediment concentrations at the work area (Hanson et al. 2003). The subsequent sedimentation and turbidity can impact adjacent sensitive habitats, such as SAV.

### *Increased sedimentation/turbidity and contaminant releases*

The primary adverse effect of removing piles is the suspension of sediments, which may result in harmful levels of turbidity and release of contaminants contained in those sediments. Contaminants contained within the sediments in the area of pilings can become available to aquatic plants and animals when pilings are extracted from the substrate. Sediment plumes may also be created around the pilings when they are installed, although it is usually much less than the turbidity created during removal. Some turbidity may be generated when piles are installed or removed with hydraulic jets, although this technique may not be widely used in the northeast coastal region. Vibratory pile removal tends to cause the sediments to slough off, resulting in relatively low levels of suspended sediments and contaminants (Hanson et al. 2003). Vibratory removal of piles may be preferable in some circumstances because it can be used on all types of piles, providing that they are structurally sound. Breaking or cutting the pile below the mudline may suspend only small amounts of sediment, providing the stub is left in place and little digging is required to access the pile. Direct pull or use of a clamshell to remove broken piles, however, may suspend large amounts of sediment and contaminants. When the piling is pulled from the substrate with these two methods, sediments clinging to the piling will slough off as it is raised through the water column, producing a potentially harmful plume of turbidity and/or contaminants. The use of a clamshell may suspend additional sediment if it penetrates the substrate while grabbing the piling (Hanson et al. 2003). For more information on turbidity and sedimentation, consult the chapters on Physical Effects: Water Intake and Discharge Facilities and Marine Transportation. Additional information on contaminant releases can be reviewed in the Chemical Effects: Water Discharge Facilities chapter.

### *Conservation measures and best management practices for pile driving and removal (adapted from Hanson et al. 2003)*

1. Drive piles during low tide periods when substrates are exposed in intertidal areas.
2. Use a vibratory hammer to install piles, when possible. Under those conditions where impact hammers are required for reasons of seismic stability or substrate type, it is recommended that the pile be driven as deep as possible with a vibratory hammer prior to the use of the impact hammer.
3. Implement measures to attenuate the sound or minimize impacts to aquatic resources during piling installation. Methods to mitigate sound impacts include, but are not limited to, the following:
    a. Surround the pile with an air bubble curtain system or dewatered cofferdam.
    b. Drive piles during low water conditions for intertidal areas.
    c. Utilize appropriate work windows that avoid impacts during sensitive times of year (e.g., anadromous fish runs and spawning, larval, and juvenile development periods).
4. Remove creosote-coated piles completely rather than cutting or breaking off if the pile is structurally sound.
5. Minimize the suspension of sediments and disturbance of the substrate when removing piles. Measures to help accomplish this include, but are not limited to, the following:
    a. Remove piles with a vibratory hammer when practicable, rather than with the direct pull or clamshell method.
    b. Remove the pile slowly to allow sediment to slough off at or near the mudline.
    c. Hit or vibrate the pile first to break the bond between the sediment and pile to minimize the potential for the pile to break, as well as reduce the amount of sediment sloughing off the pile during removal.
    d. Encircle the pile or piles with a silt curtain that extends from the surface of the water to the substrate.
6. Fill all holes left by the piles with clean, native sediments, if possible.
7. Place piles on a barge equipped with a basin to contain all attached sediment and runoff water after removal. Creosote-treated timber piles should be cut into short lengths to prevent reuse, and all debris, including attached, contaminated sediments, should be disposed of in an approved upland facility.
8. Drive broken/cut stubs with a pile driver sufficiently below the mudline to prevent release of contaminants into the water column as an alternative to their removal.
9. Use seasonal restrictions to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for pile driving projects.

## Marine Debris

Marine debris is a chronic problem along much of the US coast, resulting in littered shorelines and estuaries and creating hazards for marine organisms. Marine debris consists of a large variety of anthropogenic materials such as generic litter, hazardous wastes, and discarded or lost fishing gear and can have varying degrees of negative effects on the coastal ecosystem (Hanson et al. 2003). It generally enters waterways indirectly through rivers and storm drains or by direct ocean dumping. Several laws and regulatory programs exist to prevent or control the disposal of industrial wastes and the release of marine debris from ocean sources, including commercial merchant vessels (e.g., galley waste and other trash), recreational boaters and fishermen, offshore oil and gas exploration and facilities, military and research vessels, and commercial fishing vessels (Cottingham 1988). Despite these laws and regulations, marine debris continues to adversely impact our waters (Hanson et al. 2003). See the Marine Transportation chapter for more information on marine debris.

Land-based sources of marine debris account for approximately 80% of the marine debris on the beaches and in the waters of the Gulf of Maine (Hoagland and Kite-Powell 1997), as well as other coastal areas of the United States (Hanson et al. 2003). Land-based debris can originate from a wide variety of sources, including combined sewer overflows and storm drains; storm-water runoff; landfills; solid waste disposal; manufacturing facilities; poorly maintained garbage bins; floating structures (i.e., docks and piers); and general littering of beaches, rivers, and open waters (Cottingham 1988; Hanson et al. 2003). Plastics account for 50-60% of marine debris collected from the Gulf of Maine (Hoagland and Kite-Powell 1997).

### *Entanglement and ingestion*

Entanglement and ingestion of marine debris by marine species is known to affect individuals of at least 267 species worldwide, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (Laist 1997). Plastic debris may be ingested by seabirds, fish and invertebrates, sea turtles, and marine mammals, which can obstruct the animal's intestinal tract and cause infections and death (Cottingham 1988). A study of marine debris ingestion by seabirds in the southern Atlantic Ocean found that 73% of all birds sampled had ingested some type of marine debris, and plastics composed 66% of all debris occurrences (Copello and Quintana 2003).

### *Introduction of invasive species*

Marine debris discarded from commercial cargo and recreational vessels are one of the primary methods of transporting nonindigenous marine life around the world, some of which have become invasive species that can alter the structure and function of aquatic ecosystems (Valiela 1995; Carlton 2001; Niimi 2004). Refer to the chapters on Marine Transportation, and Introduced/Nuisance Species and Aquaculture for more information on invasive species.

### *Contaminant releases and introduction of pathogens*

The type of debris from land-based sources can include raw or partially treated sewage, litter, hazardous materials (e.g., PAH, paint, solvents), and discarded trash. The typical floatable debris from combined sewer overflows includes street litter, sewage containing viral and bacterial pathogens, pharmaceutical by-products from human excretion, and pet wastes. It may contain condoms, tampons, and contaminated hypodermic syringes, all of which can pose physical and biological threats to fishery habitat (Hanson et al. 2003). Toxic substances in plastics, for example, can persist in the environment and bioaccumulate through the food web and can kill or impair fish and invertebrates that use habitat polluted by these materials.

### *Conversion of habitat*

Because of the wide range and diversity of sources and materials contributing to marine debris, the effects on aquatic habitats are likewise wide-ranging and diverse. Floating or suspended trash can directly affect fish and invertebrates that may consume or are entangled by the debris. Debris that settles to the bottom of rivers, estuaries, and open ocean areas may continue to cause environmental problems. Plastics and other materials with a large surface area can cover and suffocate sessile animals and plants. Debris can be transported by currents to other areas where it can become snagged and attached to benthic reefs, damaging these sensitive habitats.

### *Conservation measures and best management practices for marine debris (adapted from Hanson et al. 2003)*

1. Require all existing and new commercial construction projects near the coast (e.g., marinas and ferry terminals, recreational facilities, boat building and repair facilities) to develop and implement refuse disposal plans.
2. Encourage proper trash disposal in coastal and ocean settings.
3. Provide resources to the public on the impact of marine debris and guidance on how to reduce or eliminate the problem.

## References for Coastal Development


Able KW, Manderson JP, Studholme AL. 1998. The distribution of shallow water juvenile fishes in an urban estuary: The effects of manmade structures in the lower Hudson River. Estuaries 21(4B):731-44.

Amaral M, Lee V, Rhodes J. 2005. Environmental guide for marinas: controlling nonpoint source and storm water pollution in Rhode Island: best management practices for marinas. [Internet]. Narragansett (RI): University of Rhode Island, Coastal Resources Center, Rhode Island Sea Grant. [cited 2007 Dec 28]. Available from: http://seagrant.gso.uri.edu/BMP/BMP.html.

Arkoosh MR, Clemons E, Huffman P, Kagley AN, Casillas E, Adams N, Sanborn HR, Collier TK, Stein JE. 2001. Increased susceptibility of juvenile chinook salmon to vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries. Journal of Aquatic Animal Health 13(3):257-68.

[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

[ASMFC] Atlantic States Marine Fisheries Commission. 2004. NRC report outlines the impacts of oil on marine fish habitat. Habitat Hotline Atlantic 11(3):1-5.

Bahgat FJ, King PE, Shackley SE. 1989. Ultrastructural changes in the muscle tissue of *Clupea harengus* L. larvae induced by acid pH. Journal of Fish Biology 34:25-30.

Balcom B, Howell P. 2006. Responding to a resource disaster: American lobsters in Long Island Sound 1999-2004. Groton (CT): University of Connecticut, Connecticut Sea Grant. CTSG-06-02. 22 p.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth symposium on coastal and ocean management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Belford DA, Gould WR. 1989. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management 9(4):437-45.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Bilby RE, Sullivan K, Duncan SH. 1989. The generation and fate of road-surface sediment in forested watersheds in southwestern Washington. Forest Science 35(2):453-68.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology: Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New

York (NY): Academic Press. p 177-252.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Bodammer JE. 1981. The cytopathological effects of copper on the olfactory organs of larval fish (*Pseudopleuronectes americanus* and *Melanogrammus aeglefinus*). Copenhagen (Denmark): ICES CM-1981/E: 46.

Bowling A, Mackin K. 2003. The state of the Ipswich River. Ipswich (MA): Ipswich River Watershed Association. 9 p.

Bozek CM, Burdick DM. 2005. Impacts of seawalls on saltmarsh plant communities in the Great Bay Estuary, New Hampshire USA. Wetlands Ecology and Management 13:553-68.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Bricker SB, Clement CG, Pirhalla DE, Orlando SP, Farrow DRG. 1999. National estuarine eutrophication assessment: effects of nutrient enrichment in the Nation's estuaries. Silver Spring (MD): NOAA, NOS, Special Projects Office and the National Centers for Coastal Ocean Science. 71 p.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Burdick DM, Buchsbaum R, Holt E. 2001. Variation in soil salinity associated with expansion of *Phragmites australis* in salt marshes. Environmental and Experimental Botany 46(3):247-61.

Burdick DM, Short FT. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23(2):231-40.

Caltrans. 2001. San Francisco-Oakland Bay Bridge East Span seismic safety project, pile installation demonstration project, fisheries impact assessment. Sacramento (CA): California Department of Transportation. 59 p.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chapman MG. 2003. Paucity of mobile species on constructed seawalls: effects of urbanization on biodiversity. Marine Ecology Progress Series 264:21-9.

Chiasson AG. 1993. The effects of suspended sediment on rainbow smelt (*Osmerus mordax*): a laboratory investigation. Canadian Journal of Zoology 71:2419-24.

Clancy CG, Reichmuth DR. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management 10(2):244-6.

Collette BB, Klein-MacPhee G, editors. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine. 3rd ed. Washington (DC): Smithsonian Institution Press. 748 p.

Copello S, Quintana F. 2003. Marine debris ingestion by southern giant petrels and its potential relationship with fisheries in the Southern Atlantic Ocean. Marine Pollution Bulletin 46(11):1504-15.

Cottingham D. 1988. Persistent marine debris: challenge and response: the federal perspective. Fairbanks (AK): Alaska Sea Grant. Report No. 88-1.

Deegan LA, RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

De Guise S, Maratea J, Perkins C. 2004. Malathion immunotoxicity in the American lobster (*Homarus americanus*) upon experimental exposure. Aquatic Toxicology 66(4):419-25.

DeLorenzo ME, Scott GI, Ross PE. 2001. Toxicity of pesticides to aquatic microorganisms: a review. Environmental Toxicology and Chemistry 20(1):84-98.

De Robertis A, Ryer CH, Veloza A, Brodeur RD. 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60:1517-1526.

Duffy-Anderson JT, Able KW. 1999. Effects of municipal piers on the growth of juvenile fishes in the Hudson River estuary: a study across a pier edge. Marine Biology 133(3):409-18.

Evans WA, Johnston B. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington (DC): US Department of Agriculture, Forest Service. 163 p.

Fulton MH, Scott GI, Fortner A, Bidleman TF, Ngabe B. 1993. The effects of urbanization on small high salinity estuaries of the southeastern United States. Archives of Environmental Contamination and Toxicology 25(4):476-84.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19th ed. Bethesda (MD): American Fisheries Society. p 297-323.

Gilbert SF. 2000. Developmental biology. [Internet]. Sunderland (MA): Sinauer Associates. 6th ed. [updated 2007 Oct 17; cited 2006 May 17]. Available from: http://www.ncbi.nlm.nih.gov/

Glasby TM. 1999. Effects of shading on subtidal epibiotic assemblages. Journal of Experimental Marine Biology and Ecology 234:275-90.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. 68 p + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Greenberg CH, Crownover SH, Gordon DR. 1997. Roadside soils: a corridor for invasion of xeric scrub by nonindigenous plants. Natural Areas Journal 17(2):99-109.

Greene K. 2002. Beach nourishment: a review of the biological and physical impacts. Washington (DC): ASMFC. Habitat Management Series #7. 179 p.

Haas MA, Simenstad CA Jr, Cordell JR, Beauchamp DA, Miller BS. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA. [Internet]. Seattle (WA): Washington State Transportation Center (TRAC), University of Washington, and Washington State Department of Transportation. Final Research Report WA-RD 550.1. [cited 2008 Jul 9]. 114 p. Available from: http://depts.washington.edu/trac/bulkdisk/pdf/550.1.pdf

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hoagland KD, Carder JP, Spawn RL. 1996. Chapter 15: Effects of organic toxic substances. In: Stevenson RJ, Bothwell ML, Love RL, editors. Algal ecology: freshwater benthic ecosystems. San Diego (CA): Academic Press. p 469-96.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Holland AF, Sanger DM, Gawle CP, Lerberg SB, Santiago MS, Riekerk GHM, Zimmerman LE, Scott GI. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298(2):151-78.

[IPCC] Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 996 p. Available from: http://www.ipcc.ch.

[ICES] International Council for the Exploration of the Sea. 1991. Report of the study group on ecosystem effects of fishing activities. 11-15 March 1991; Lowestoft, England. Copenhagen (Denmark): ICES C.M. 1991/G:7 Session Y.

Jackson SD. 2003. Design and construction of aquatic organism passage at road-stream crossings: ecological considerations in the design of river and stream crossings. In: Irwin CL, Garrett P, McDermott KP, editors. 2003 Proceedings of the International Conference on Ecology and Transportation; 2003 Aug 24-29; Lake Placid, NY. Raleigh (NC): Center for Transportation and the Environment, North Carolina State University. p 20-9.

Kearney VF, Segal Y, Lefor MW. 1983. The effects of docks on salt marsh vegetation. Hartford (CT): Connecticut Department of Environmental Protection, Water Resources Unit. 22 p.

Kelley JT. 1992. Sea-level change and coastal erosion in the western Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Regional Synthesis Series No. 1. p 27-44.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Kennish MJ. 1998. Pollution impacts on marine biotic communities. Boca Raton (FL): CRC Press.

Kennish MJ. 2002. Impacts of motorized watercraft on shallow estuarine and coastal marine environments. Journal of Coastal Research Special Issue 37:1-202.

Kenworthy JW, Hauners DE. editors. 1991. The light requirements of seagrasses: proceedings of a workshop to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses. Beaufort (NC): NMFS Beaufort Laboratory. NOAA Technical Memorandum NMFS-SEFC-287. 179 p.

Klein-MacPhee G, Cardin JA, Berry WJ. 1984. Effects of silver on eggs and larvae of the winter flounder. Transactions of the American Fisheries Society 113(2):247-51.

Koski KV. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapport Et Proces-Verbaux Des Reunions Du Conseil International Pour L'Exploration De La Mer (ICES) 178:330-3.

Laist DW. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe JM, Rogers

DB, editors. Marine debris: sources, impacts, and solutions. New York (NY): Springer. p 99-139.

Lang T, Dethlefsen V. 1987. Cadmium in skeletally deformed and normally developed Baltic cod (*Gadus morhua* L.). Copenhagen (Denmark): ICES CM-1987/ E:30. 18 p.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Lohrer AM, Wetz JJ. 2003. Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek. Marine Pollution Bulletin 46(9):1156-63.

Longmuir C, Lively T. 2001. Bubble curtain systems for use during marine pile driving. New Westminister (BC), Canada: Fraser River Pile and Dredge LTD. 9 p.

Lonsdale WN, Lane AM. 1994. Tourist vehicles as vectors of weed seeds in Dadoed National Park, northern Australia. Biological Conservation 69(3):277-83.

MacDonald LH, Sampson RW, Anderson DM. 2001. Runoff and road erosion at the plot and road segment scales, St John, US Virgin Islands. Earth Surface Processes and Landforms 26:251-72.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Meyers TR, Hendricks JD. 1982. A summary of tissue lesions in aquatic animals induced by controlled exposures to environmental contaminants, chemotherapeutic agents, and potential carcinogens. Marine Fisheries Review 44(12):1-17.

Milliken AS, Lee V. 1990. Pollution impacts from recreational boating: a bibliography and summary review. Narragansett (RI): Rhode Island Sea Grant. National Sea Grant Depository Publication # RIU-G-002.

Mitsch WJ, Gosselink JG. 1993. Wetlands. 2$^{nd}$ ed. New York (NY): Van Nostrand Reinhold. 722 p.

Moore A, Waring CP. 2001. The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar* L.). Aquatic Toxicology 52:1-12.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant

College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1991. Status and trends in concentrations of selected contaminants in Boston Harbor sediments and biota. Seattle (WA): National Ocean Service, Office of Oceanography and Marine Assessment. NOAA Technical Memorandum NOS OMA 56.

Nedeau E. 2004. Effects of climate change on the Gulf of Maine region. [Internet]. Gulf of Maine Council on the Marine Environment. [cited 2008 Jul 9]. 12 p. Available from: http://www.gulfofmaine.org/summit/ClimateChangeKbase.pdf.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Niering WA. 1988. The Audubon Society nature guides. Wetlands. New York (NY): Alfred A. Knopf. 638 p.

Nightingale BJ, Simenstad CA Jr. 2001. Overwater structures: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 9]. 133 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finalmar.pdf.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, William SL. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Pacheco A. 1984. Final report, Seasonal occurrence of finfish and larger invertebrates at three sites in Lower New York Harbor, 1981-1982. Sandy Hook (NJ): NOAA/NMFS. Special report for USACE, New York District. 53 p.

Penttila D, Doty D. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Olympia (WA): Washington Department of Fisheries. Draft Progress Report. 41 p.

Peterson CH, Hickerson DHM, Johnson GG. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16(2):368-78.

Pilkey OH, Dixon KL. 1996. The Corps and the shore. Washington (DC): Island Press. 272 p.

Posey MH, Alphin TD, Meyer DL, Johnson JM. 2003. Benthic communities of common reed *Phragmites australis* and marsh cordgrass *Spartina alterniflora* marshes in Chesapeake Bay. Marine Ecology Progress Series 261:51-61.

Poston T. 2001. Treated wood issues associated with overwater structures in freshwater and marine environments. [Internet]. Olympia (WA): Washington State Departments of Transportation, Fish and Wildlife, and Ecology. White Paper. [cited 2008 Jul 9]. 85 p. Available from: http://wdfw.wa.gov/hab/ahg/finaltw.pdf.

Preston BL. 2002. Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment. Environmental Management 29(3):311-23.

[PSDS] Program for the Study of Developed Shorelines. 2005. The U.S. beach nourishment experience: including New England, east coast barrier islands, Pacific coast and Gulf of Mexico shorelines. [Internet]. Cullowhee (NC): Western Carolina University, c2006. [Cited 2008 Jul 9]. Available from: http://psds.wcu.edu/1038.asp.

Readman JW, Kwong LLW, Grondin D, Bartocci J, Villeneuve JP, Mee LD. 1993. Coastal water contamination from triazine herbicide used in antifouling paints. Environmental Science and Technology 27(9):1940-2.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Safavi HR. 1996. Quality control of urban runoff and sound management. Hydrobiologia: Diapause in the Crustacea:131-41.

Scott GI, Fulton MH, Moore DW, Wirth EF, Chandler GT, Key PB, Daugomah JW, Strozier ED, Devane J, Clark JR, and others. 1999. Assessment of risk reduction strategies for the management of agricultural nonpoint source pesticide runoff in estuarine ecosystems. Toxicology and Industrial Health 15:200-13.

Shafer DJ. 1999. The effects of dock shading on the seagrass *Halodule wrightii* in Perdido Bay, Alabama. Estuaries 22(4):936-43.

Short FT, Burdick DM. 1996. Quantifying, eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19(3):730-9.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Smith KN, Mezich RR. 1999. Blending management and research for protection of manatee habitat in Florida: the seagrass dock effect. In: Poster presentation at the 15th Biennial International Estuarine Research Federation Conference; 1999 Sep 25-30; New Orleans, LA. Port Republic (MD): Coastal and Estuarine Research Federation.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

[USEPA] US Environmental Protection Agency. 1993. Guidance specifying management measures for sources of nonpoint pollution in coastal waters. [Internet]. Washington (DC): US EPA Office of Water. EPA-840-B-92-002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/OWOW/NPS/MMGI.

[USEPA] US Environmental Protection Agency. 1995. National water quality inventory: 1994 Report to Congress. Washington (DC): US EPA Office of Water. EPA-841-R-95-005.

[USEPA] US Environmental Protection Agency. 2001. National management measures guidance to control nonpoint source pollution from marinas and recreational boating. Washington (DC): EPA Office of Water. EPA-841-B-01-005.

[USEPA] US Environmental Protection Agency. 2002. National water quality inventory: 2000 Report to Congress. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-R-02-001. [cited 2008 Jul 9]. Available from: http://www.epa.gov/305b/2000report/.

[USEPA] US Environmental Protection Agency. 2003a. Guide for industrial waste management. Washington (DC): US EPA Office of Solid Waste. EPA-530-R-03-001.

[USEPA] US Environmental Protection Agency. 2003b. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2004. National coastal condition report II.

[Internet]. Washington (DC): US EPA Office of Research and Development/ Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

Valiela I. 1995. Marine ecological processes, 2nd ed. New York (NY): Springer-Verlag.

Valiela I, Rutecki D, Fox S. 2004. Salt marshes: biological controls of food webs in a diminishing environment. Journal of Experimental Marine Biology and Ecology 300(1-2):131-59.

Valverde HR, Trembanis AC, Pilkey OH. 1999. Summary of beach nourishment episodes on the U.S. East Coast Barrier Islands. Journal of Coastal Research 15(4):1100-18.

Vandermeulen JH, Mossman D. 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences 53:1741-53.

Weis JS, Weis P. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-10.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White Paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. 99 p. [cited 2008 Jul 9]. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

Ziegler AD, Sutherland RA, Gaimbelluca TW. 2001. Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads. Earth Surface Processes and Landforms 26(3):235-50.

# CHAPTER THREE: ENERGY-RELATED ACTIVITIES

## Petroleum Exploration, Production, and Transportation

### *Introduction*

The exploration, production, and transportation of petroleum have the potential to impact riverine, estuarine, and marine environments on the northeastern US coast. Petroleum exploration, production, and transportation are a particular concern in areas such as the Gulf of Maine and Georges Bank, which support important fishery resources and represent significant value to the US economy. Although petroleum exploration and production do not currently occur within the northeast coastal and offshore region, the transportation of oil and gas (i.e., pipelines and tankers) and the associated infrastructure are widespread. It is expected that issues relating to petroleum development will continue to gain importance as world energy costs and demands rise. The Energy Policy Act of 2005 (Pub. L. 109-58, § 357, 42 U.S.C. §15912) authorizes the Minerals Management Service (MMS) to perform surveys (exploration) for petroleum reserves on the Outer Continental Shelf (OCS) of the United States. The OCS is the submerged lands, subsoil, and seabed lying between the United States' seaward jurisdiction and the seaward extent of federal jurisdiction.

Petroleum exploration involves seismic testing, drilling sediment cores, and test wells in order to locate potential oil and gas deposits. Petroleum production includes the drilling and extraction of oil and gas from known reserves. Oil and gas rigs are placed on the seabed and as oil is extracted from the reservoirs, it is transported directly into pipelines. While rare, in cases where the distance to shore is too great for transport via pipelines, oil is transferred to underwater storage tanks. From these storage tanks, oil is transported to shore via tanker (CEQ 1977). According to the MMS, there are 21,000 miles of pipeline on the United States OCS. According to the National Research Council (NRC), pipeline spills account for approximately 1,900 tonnes per year of petroleum into US OCS waters, primarily in the central and western Gulf of Mexico (NRC 2003).

The major sources of oil releases as a result of petroleum extraction include accidental spills and daily operational discharges. The NRC estimates the largest anthropogenic source of petroleum hydrocarbon releases into the marine environment is from petroleum extraction-related activities. Approximately 2,700 tonnes per year in North America and 36,000 tonnes per year worldwide are introduced to the marine environment as a result of "produced waters" (NRC 2003). "Produced waters" are waters that are pumped to the surface from oil reservoirs which cannot be separated from the oil. Produced waters are either injected back into reservoirs or discharged into the marine environment (NRC 2003). Over 90% of the oil released from extraction activities is from produced water discharges which contain dissolved compounds (i.e., polycyclic aromatic hydrocarbons, PAH) and dispersed crude oil (NRC 2003). These compounds stay suspended in the water column and undergo microbial degradation or are sorbed onto suspended sediments and are deposited on the seabed. Elevated levels of PAH in sediments are typically found up to 300 m from the discharge point (NRC 2003).

While petroleum extraction and transportation can result in impacts to the marine environment, it is important to note that natural seeps contribute to approximately 60% of all petroleum hydrocarbons that are released into the marine environment (NRC 2003). In addition, land-based runoff and discharges by two–stroke recreational boating engines account for nearly 22% of the total petroleum released into the marine environment in North America (NRC 2003).

## Underwater noise

Oil and gas activities generate noise from drilling activities, construction, production facility operations, seismic exploration, and supply vessel and barge operations that can disrupt or damage living marine resources. The effects of oil exploration-related seismic energy may cause fish to disperse from the acoustic pulse with possible disruption to their feeding patterns (Marten et al. 2001). Larvae and young fish are particularly sensitive to noise generated from underwater seismic equipment. Noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement and feeding), interfering with echolocation and communication, or injuring hearing organs (Richardson et al. 1995). Noise issues related to petroleum tanker traffic can adversely affect fishery resources within the marine environment, particularly within estuarine areas which host much of the nation's petroleum land-based port activities. Refer to the chapters on Marine Transportation and Global Effects and Other Impacts for information regarding impacts to fishery resources from underwater noise.

## Habitat conversion and loss

Petroleum extraction and transportation can lead to a conversion and loss of habitat in a number of ways. Activities such as vessel anchoring, platform or artificial island construction, pipeline laying, dredging, and pipeline burial can alter bottom habitat by altering substrates used for feeding or shelter. Disturbances to the associated epifaunal communities, which may provide feeding or shelter habitat, can also result. The installation of pipelines associated with petroleum transportation can have direct and indirect impacts on offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats. The destruction of benthic organisms and habitat can occur through the installation of pipelines on the sea floor (Gowen 1978). Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if facilities are left in place after production ends.

The discharge of drilling cuttings (i.e., crushed sedimentary rock) during petroleum extraction operations can result in varying degrees of change to the sea floor and affect feeding, nursery, and shelter habitat for various life stages of marine organisms. Cuttings may adversely affect bottom-dwelling organisms at the site by burial of immobile forms or forcing mobile forms to migrate. The accumulation of drill cuttings on the ocean floor can alter the benthic sedimentary environment (NRC 2003).

Physical damage to coastal wetlands and other fragile areas can be caused by onshore infrastructure and pipelines associated with petroleum production and transportation. Physical alterations to habitat can occur from the construction, presence, and eventual decommissioning and removal of facilities such as islands or platforms, storage and production facilities, and pipelines to onshore common carrier pipelines, storage facilities, or refineries. For additional information regarding impacts of pipelines associated with petroleum production, refer to the section on Cables and Pipelines in this chapter of the report.

## Contaminant discharge

A variety of contaminants can be discharged into the marine environment as a result of petroleum extraction operations. Waste discharges associated with a petroleum facility include drilling well fluids, produced waters, surface runoff and deck drainage, and solid-waste from wells (i.e., drilling mud and cuttings) (NPFMC 1999). In addition to crude oil spills, chemical, diesel, and other contaminant spills can occur with petroleum-related activities (NPFMC 1999).

Produced waters contain finely dispersed oil droplets that can stay suspended in the water column or can settle out into sediments. Produced waters are generally more saline than seawater and contain elevated concentrations of radionuclides, metals, and other contaminants. Elevated levels of contaminated sediments typically extend up to 300 m from the discharge point (NRC 2003). In estuarine waters, higher saline produced waters can affect the salt wedge and form dense saltwater plumes.

The discharge of oil drilling mud can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. The addition of contaminants can reduce or eliminate the suitability of the water column and substrate as habitat for fish species and their prey. The discharge of oil-based drill cuttings are currently not permitted in US waters; however, where oil-based drill cuttings have been discharged, there is evidence that sediment contamination and benthic impacts can occur up to 2 km from the production platform (NRC 2003).

The petroleum refining process converts crude oil into gasoline, home heating oil, and other refined products. The process of refining crude oil into various petroleum products produces effluents, which can degrade coastal water quality. Oil refinery effluents contain many different chemicals at different concentrations including ammonia, sulphides, phenol, and hydrocarbons. Toxicity tests have shown that most refinery effluents are toxic, but to varying extents. Some species are more sensitive and the toxicity may vary throughout the life cycle. Experiments have shown that not only can the effluents be lethal, but they can often have sublethal effects on growth and reproduction (Wake 2005). Field studies have shown that oil refinery effluents often have an adverse impact on aquatic organisms (i.e., an absence of all or most species), which is more pronounced in the area closest to the outfall (Wake 2005).

The operation of oil tankers can discharge contaminants into the water column and result in impacts to pelagic and benthic organisms. Older tankers that do not have segregated ballast tanks (i.e., completely separated from the oil cargo and fuel systems) can discharge ballast water containing contaminants (NRC 2003).

### *Discharge of debris*

Petroleum extraction and transportation can result in the discharge of various types of debris, including domestic wastewater generated from offshore facilities, solid-waste from wells (i.e., drilling mud and cuttings), and other trash and debris from human activities associated with the facility (NPFMC 1999). Debris, either floating on the surface, suspended in the water column, covering the benthos, or along the shoreline can have deleterious impacts on fish and shellfish within riverine habitat, as well as in benthic and pelagic habitats in the marine environment (NEFMC 1998). Debris from petroleum extraction and transportation activities can be ingested by fish (Hoagland and Kite-Powell 1997). Reduction and degradation of habitat by debris can alter community structure and affect the sustainability of fisheries.

### *Oil spills*

In even moderate quantities, oil discharged into the environment can affect habitats and living marine resources. Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS and in nearshore coastal areas and can occur from a number of sources, including equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms (Hanson et al. 2003). Oil spills can also be attributed to support activities associated with product recovery and transportation and can also involve various contaminants including hazardous chemicals and diesel fuel (NPFMC 1999).

Oil, characterized as petroleum and any derivatives, can be a major stressor to inshore fish habitats. Oil can kill marine organisms, reduce their fitness through sublethal effects, and disrupt the structure and function of the marine ecosystem (NRC 2003). Short-term impacts include interference with the reproduction, development, growth and behavior (e.g., spawning and feeding) of fishes, especially at early life-history stages (Gould et al. 1994). Petroleum compounds are known to have carcinogenic and mutagenic properties (Larsen 1992). Various levels of toxicity have been observed in Atlantic herring (*Clupea harengus*) eggs and larvae exposed to crude oil in concentrations of 1-20 ml/L (Blaxter and Hunter 1982). Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. These impacts may eventually lead to disruption of community organization and dynamics in affected regions. Oil can persist in sediments for years after the initial contamination (NRC 2003), interfering with physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996).

Oil spills can have adverse effects to both subtidal and intertidal vegetation. Direct exposure to petroleum can lead to die off of submerged aquatic vegetation (SAV) in the first year of exposure. Certain species which propagate by lateral root growth rather than seed germination may be less susceptible to oil in the sediment (NRC 2003). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Kelp located in low energy environments can retain oil in their holdfasts for extended periods of time. Oil spills are known to cause severe and long-term damage to salt marshes through the covering of plants and contamination of sediments. Lighter and more refined oils such as No. 2 fuel oil are extremely toxic to smooth cordgrass (*Spartina alterniflora*) (NRC 2003). Impacts to salt marsh habitats from oil spills depend on type, coverage, and amount of oil. Oil spills within salt marshes will likely have a greater impact in the spring growing season, compared to the dormant periods in the fall and winter.

Habitats that are susceptible to damage from oil spills include the low-energy coastal bays and estuaries where heavy deposits of oil may accumulate and essentially smother intertidal and salt marsh wetland communities. High-energy cobble environments are also susceptible to oil spills, as oil is driven into sediments through wave action. For example, many of the beaches in Prince William Sound, AK, with the highest persistence of oil following the *Exxon Valdez* oil spill were high-energy environments containing large cobbles overlain with boulders. These beaches were pounded by storm waves following the spill, which drove the oil into and well below the surface (Michel and Hayes 1999). Oil contamination in sediments may persist for years. For example, subsurface oil was detected in beach sediments of Prince William Sound twelve years after the *Exxon Valdez* oil spill, much of it unweathered and more prevalent in the lower intertidal biotic zone than at higher tidal elevations (Short et al. 2002).

Oil can have severe detrimental impacts on offshore habitats, although the effects may not be as acute as in inshore, sheltered areas. Offshore spills or wellhead blowouts can produce an oil slick on surface waters which can disrupt entire pelagic communities (i.e., phytoplankton and zooplankton). The disruption of plankton communities can interfere with the reproduction, development, growth, and behavior of fishes by altering an important prey base.

Physical and biological forces act to reduce oil concentrations (Hanson et al. 2003). Generally, the lighter fraction aromatic hydrocarbons evaporate rapidly, particularly during periods of high wind and wave activity. Heavier oil fractions typically pass through the water column and settle to the bottom. Suspended sediments can adsorb and carry oil to the seabed. Hydrocarbons may be solubilized by wave action which may enhance adsorption to sediments, which then sink to the seabed and contaminate benthic sediments (Hanson et al. 2003). Tides and hydraulic gradients allow movement of soluble and slightly soluble contaminants (e.g., oil) from beaches to surrounding streams in the hyporheic zone (i.e., the saturated zone under a river or stream, comprising substrate with the interstices filled with water) where pink salmon (*Oncorynchus* *gorbuscha*) eggs incubate (Carls et al. 2003). Oil can reach nearshore areas and affect productive nursery grounds, such as estuaries that support high densities of fish eggs and larvae. An oil spill near a particularly important hydrological zone, such as a gyre where fish or invertebrate larvae are concentrated, could also result in a disproportionately high loss of a population of marine organisms (Hanson et al. 2003). Epipelagic biota, such as eggs, larvae and other planktonic organisms, would be at risk from an oil spill. Planktonic organisms cannot actively avoid exposure, and their small size means contaminants may be absorbed quickly. In addition, their proximity to the sea surface can increase the toxicity of hydrocarbons several-fold and make them more vulnerable to photo-enhanced toxicity effects (Hanson et al. 2003).

Many factors determine the degree of damage from a spill, including the composition of the petroleum compound, the size and duration of the spill, the geographic location of the spill, and the weathering process present (NRC 2003). Although oil is toxic to all marine organisms at high concentrations, certain species and life history stages of organisms appear to be more sensitive than others. In general, the early life stages (i.e., eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Some marine species may be particularly susceptible to hydrocarbon spills if they require specific habitat types in localized areas and utilize enclosed water bodies, like estuaries or bays (Stewart and Arnold 1994).

Small but chronic oil spills may be a particular problem to the coastal ecosystem because residual oil can build up in sediments. Low-levels of petroleum components from such chronic pollution have been shown to accumulate in fish tissues and cause lethal and sublethal effects, particularly at embryonic stages. Effects on Atlantic salmon (*Salmo salar*) from low-level chronic exposure to petroleum components and byproducts (i.e., polycyclic aromatic hydrocarbons [PAH]) have been shown to increase embryo mortality, reduce growth (Heintz et al. 2000), and lower the return rates of adults returning to natal streams (Wertheimer et al. 2000).

As spilled petroleum products become weathered, the aromatic fraction of oil is dominated by PAH as the lighter aromatic components evaporate into the atmosphere or are degraded. Because of its low solubility in water, PAH concentrations probably contribute little to acute toxicity (Hanson et al. 2003). However, lipophilic PAH (those likely to be bonded to fat compounds) may cause physiological injury if they accumulate in tissues after exposure (Carls et al. 2003; Heintz et al. 2000). Even concentrations of oil that are diluted sufficiently to not cause acute impacts in marine organisms may alter certain behavior or physiological patterns. For example, “fatty change,” a degenerative disease of the liver, can occur from chronic exposure to organic contaminants such as oil (Freeman et al. 1981).

Sublethal effects that may occur with exposure to PAH include impairment of feeding mechanisms for benthic fish and shellfish, growth and development rates, energetics, reproductive output, juvenile recruitment rates, increased susceptibility to disease and other histopathic disorders (Capuzzo 1987), and physical abnormalities in fish larvae (Urho and Hudd 1989). Effects of exposure to PAH in benthic species of fish include liver lesions, inhibited gonadal growth, inhibited spawning, reduced egg viability and reduced growth (Johnson et al. 2002). Gould et al. (1994) summarized various toxicity responses to winter flounder (*Pseudopleuronectes americanus*) exposed to PAH and other petroleum-derived contaminants, including liver and spleen diseases, immunosuppression responses, tissue necrosis, altered blood chemistry, gill tissue clubbing, mucus hypersecretion, altered sex hormone levels, and altered reproductive impairments. For Atlantic cod (*Gadus morhua*) exposed to various petroleum products, responses included reduced growth rates, gill hyperplasia, increased skin pigmentation, hypertrophy of gall bladder, liver disease, delayed spermatogenesis, retarded gonadal development and other reproductive impairments, skin lesions, and higher parasitic infections (Gould et al. 1994).

## *Oil spill clean-up activities*

There are a number of oil spill response and cleanup methods available. Chemical dispersants are used primarily in open water environments. Dispersants contain surfactant chemical that under proper mixing conditions and concentrations attach to oil molecules and reduce the interfacial tension between oil molecules (NOAA 1992). This allows oil molecules to break apart and thus break down the oil slick. Depending on the environmental conditions and biological resource present, dispersants can result in acute toxicity. Exposure to high concentrations of oil dispersants has been shown to block the fertilization of eggs and induce rapid cytolysis of developing eggs and larvae in Atlantic cod (Lonning and Falk-Petersen 1978). Other methods of cleanup for open water spills include in-situ burning and nutrient and microbial remediation. In each case, impacts are dependent on the resources present in the particular location. Other forms of shoreline cleanup include the use of sorbents, trenching, sediment removal, and water flooding/pressure washing. Sediment removal and pressure washing will result in direct impact to the benthos. Trampling and cutting of salt marsh vegetation during cleanup activities can be severe, causing damage to plants and forcing oil into the sediments. However, impacts associated with the cleanup activities need to be weighed against the impacts created by the the spill itself.

## *Siltation, sedimentation, and turbidity*

Exploratory and construction activities may result in resuspension of fine-grained mineral particles, usually smaller than silt, in the water column. Fish and invertebrate habitat may be adversely affected by elevated levels of suspended particles (Arruda et al. 1983), which can result in both lethal and sublethal impacts to marine organisms (Newcombe and MacDonald 1991; Newcombe and Jensen 1996). Short-term impacts from increases in suspended particles may include high turbidity, reduced light, and sedimentation which may lead to the loss or complexity of benthic habitat (USFWS and NMFS 1999). Suspended particles can reduce light penetration and lower the rate of photosynthesis and the primary productivity of the aquatic area, especially if the turbidity is persistent (Gowen 1978). Groundfish and other fish species can suffer reduced feeding ability and limited growth if high levels of suspended particles persist in the water column. Other problems associated with suspended solids include disrupted respiration and water transport rates in marine organisms, reduced filtering efficiencies in invertebrates, reduced egg buoyancy, disrupted ichthyoplankton development, reduced growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Gowen 1978; Messieh et al. 1991; Barr 1993). Demersal eggs of fish and invertebrates can be adversely impacted by sediment deposition and suffocation. For example, hatching is delayed for striped bass (*Morone saxatilis*) and white perch (*Morone americana*) exposed to sediment concentrations as low as 100 mg/L for 1 day (Wilber and Clarke 2001). Berry et al. (2004) reported a decreased hatching success for winter flounder eggs with increasing depth of burial by sediment. No hatching occurred at burial depths of approximately 2 mm. Breitburg (1988) found the predation rates of striped bass larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory. Anadromous fish passage in estuarine and riverine environments can also be adversely impacted by increased turbidity. For example in laboratory experiments, rainbow smelt (*Osmerus mordax*) showed signs of increased swimming activity at suspended sediment concentrations as low as 20 mg/L, suggesting fish responded to increased sediment concentrations with an “alarm reaction” (Chiasson 1993).

Shallow water environments, rocky reefs, nearshore and offshore rises, salt and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than are open-water habitats. This is due, in part, to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978).

### *Conservation recommendations and best management practices for petroleum exploration, production, and transportation (adapted from Hanson et al. 2003)*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area. Construction should be sited to minimize impacts to fishery resources.
2. Avoid the discharge of produced waters into marine and estuarine environments. Reinject produced waters into the oil formation whenever possible.
3. Avoid discharge of drilling mud and cuttings into the marine, estuarine, and riverine environment.
4. Avoid placing roads and bridges and structures associated with petroleum exploration and production in the nearshore marine environment. Particular care should be made to avoid SAV, intertidal flats, and salt marsh habitat.
5. Use methods to transport oil and gas that limit the need for handling in sensitive fishery habitats.
6. Use horizontal directional drilling for installation of pipelines in areas containing sensitive habitats, whenever possible.
7. Provide for monitoring and leak detection systems at oil extraction, production, and transportation facilities that preclude oil from entering the environment.
8. Evaluate impacts to habitat during the decommissioning phase, including impacts during the demolition phase.
9. Schedule dredging and excavation activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Ensure that oil extraction, production, and transportation facilities have developed and implemented adequate oil spill response plans. Assist government agencies responsible for oil spills (e.g., US Coast Guard, state and local resource agencies) in developing response plans and protocols, including identification of sensitive marine habitats and development and implementation of appropriate oil spill-response measures.
11. Potential adverse impacts to marine resources from oil spill clean-up operations should be weighed against the anticipated adverse affects of the oil spill itself. The use of chemical dispersants in nearshore areas where sensitive habitats are present should be avoided.
12. Address the cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the review process for petroleum exploration, production, and transportation projects.

## Liquefied Natural Gas (LNG)

### *Introduction*

Liquefied Natural Gas (LNG) is expected to provide a large proportion of the future energy needs in the northeastern United States. In recent years there has been an increase in proposals for new LNG facilities, including both onshore and offshore facilities from Maine to Delaware. In the northeastern United States, there are currently onshore LNG facilities operating in Everett, MA, and Cove Point, MD, and two offshore LNG facilities have been approved to operate in Massachusetts Bay.

The LNG process cools natural gas to its liquid form at approximately -260 degrees Fahrenheit (F). This reduces the volume of natural gas to approximately 1/600$^{th}$ of its gaseous state volume, making it possible for economical transportation with tankers. Upon arrival at the destination, the LNG is either regasified onshore or offshore and sent out into an existing pipeline infrastructure, or transported onshore for storage and future regasification. The process of regasification occurs when LNG is heated and converted back to its gaseous state. LNG facilities can utilize either "open loop," "closed loop," or "combined loop" systems for regasification. Open loop systems utilize warm seawater for regasification, and closed loop systems generally utilize a recirculating mixture of ethylene glycol for regasification. Combined loop systems utilize a combination of the two systems.

Onshore LNG facilities generally include a deepwater access channel, land-based facilities for regasification and distribution, and storage facilities. Offshore facilities generally include some type of a deepwater port with a regasification facility and pipelines to transport natural gas into existing gas distribution pipelines or onshore storage facilities. Deepwater ports require specific water depths and generally include some form of exclusion zone for LNG vessel and/or port facility security.

### *Habitat conversion and loss*

The conversion of habitat and/or the loss of benthic habitats can occur from the construction and operation of LNG facilities. The placement of pipelines and associated structures on the seafloor can impact benthic habitats from physical occupation and conversion of the seafloor. The installation of pipelines can impact shellfish beds, hard-bottomed habitats, and SAV (Gowen 1978). Plowing or trenching for pipeline installation and side-casting of material can lead to a conversion of substrate and habitat. Placement of anchors for the construction of the deepwater port facilities can have direct impact to the substrate and benthos.

Because of the large size of LNG tankers, dredging may need to occur in order to access onshore terminals. The deepening of channel areas and turning basins can result in permanent and temporary dredging impacts to fishery habitat, including the loss of spawning and juvenile development habitat caused by changes in bathymetry, suitable substrate type, and sedimentation. Disruption of the areas from dredging and sedimentation may cause spawning fish to leave the area for more suitable spawning conditions. Dredging, as well as the equipment used in the process such as pipelines, may damage or destroy other sensitive habitats such as emergent marshes and SAV, including eelgrass beds (Mills and Fonseca 2003) and macroalgae beds. The stabilization and hardening of shorelines for the development of upland facilities can lead to a direct loss of SAV, intertidal mudflats, and salt marshes that serve as important habitat for a variety of living marine resources. See the Marine Transportation, Offshore Dredging and Disposal, and Coastal Development chapters for more detailed information on impacts from dredging.

### *Discharge of contaminants*

Discharge of contaminants can occur as a result of spills during offloading procedures associated with either onshore or offshore facilities. There is limited information and experience regarding the aquatic impacts resulting from an LNG spill; however, because of the toxic nature of natural gas, acute impacts to nearby resources and habitats can be expected.

Biocides (e.g., copper and aluminum compounds) are often utilized in the hydrostatic testing of pipelines. LNG tankers utilize large amounts of seawater for regasification purposes (i.e., open-loop system), for engine cooling, and for ship ballast water. Biocides are commonly utilized to prevent pipeline and engine fouling from marine organisms and are subsequently discharged into surrounding waters. Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977). The release of contaminants can reduce or eliminate the suitability of water bodies as habitat for fish species and their prey. In addition, contaminants, such as copper and aluminum, can accumulate in sediments and become toxic to organisms contacting or feeding on the bottom.

### *Discharge of debris*

LNG facilities can result in the discharge of debris, including domestic waste waters generated from the offshore facility, and other trash and debris from human activities associated with the facility (NPFMC 1999). Impacts from the discharge of debris from LNG are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Siltation, sedimentation, and turbidity*

LNG construction activities may result in increased suspended sediment in the water column caused by dredging, the installation of pipelines, anchors and chains, and the movement of vessels through confined areas, and upland site development. Impacts from siltation and sedimentation from LNG are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Entrainment and impingement*

Intake structures for traditional power plants can result in impingement and entrainment of marine organisms through the use of seawater for cooling purposes (Enright 1977; Helvey 1985; Callaghan 2004). Likewise, intake structures utilized for the LNG regasification process can result in impingement and entrainment of living marine resources. “Open-loop” LNG regasification systems utilize seawater for warming into a gaseous state and are typically utilized when ambient water temperatures are greater than about 45°F. In addition, “combined loop” systems can utilize seawater for partial regasification. Depending on the geographic location and the water depth of the intake pipe, phytoplankton, zooplankton, and fish eggs and larvae can be entrained into the system. Juvenile fish can also be impinged on screens of water intake structures (Hanson et al. 1977; Hanson et al. 2003). Normal ship operations utilize intake structures for ballast water and engine cooling and can result in additional impingement and entrainment of resources, as well.

The entrainment and impingement impacts on aquatic organisms from LNG facilities have the potential to be substantial. For example, an assessment of impacts of a proposed LNG facility in the Gulf of Mexico determined that an open-loop regasification system could utilize 176 million gallons of water per day, which may entrain 1.6 billion fish and 60 million shrimp larvae per year, 3.3 billion fish eggs per year, and 500 billion zooplankton per year (R. Ruebsamen, pers. comm.). Additional entrainment and impingement impacts were expected for vessel ballast and cooling water uses. In the northeastern United States, an offshore LNG regasification facility approved in Massachusetts Bay with a closed-loop system has estimated annual mortality rates caused by vessel ballast and cooling water for the eggs and larvae for Atlantic mackerel (*Scomber scombrus*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), and Atlantic cod of 8.5 million, 7.8 million, 411,000, and 569,000, respectively (USCG 2006).

### *Alteration of temperature regimes*

The operation of LNG facilities can result in the alteration of temperature regimes. Discharge of water from engine cooling operations can be at temperatures up to 10°F higher than surrounding waters. Water utilized for the purposes of regasification could be discharged at temperatures colder than the surrounding water by about 10-15°F. Changes in water temperatures can alter physiological functions of marine organisms, including respiration, metabolism, reproduction, and growth. In riverine and estuarine environments, changes to water temperatures can impact the egg and juvenile life stages of Atlantic salmon (USFWS and NMFS 1999). Thermal effluent in inshore habitat can cause severe problems by directly altering the benthic community or adversely affecting marine organisms, especially egg and larval life stages (Pilati 1976; Rogers 1976). For example, the seaward migration of juvenile American shad (*Alosa sapidissima*) are cued to water temperatures (Richkus 1974; MacKenzie et al. 1985), and temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969; Stanley and Colby 1971).

### *Alteration of hydrological regimes*

The operation of LNG facilities can affect the hydrology of confined waterbodies, waterbodies with limited flows such as streams and rivers, and estuaries fed by streams and rivers. Depending upon the characteristics of the waterbody and the nature of the water intake and discharge, altered stream flow can result in reductions in stream flow and subsequent degradation of ecosystem functions (Reiser et al. 2004).

### *Alteration of salinity regimes*

The operation of LNG tankers can result in the alteration of hydrological regimes caused by the discharge of brine from onboard desalination operations. For example, the operation of LNG tankers within riverine and estuarine environments can impact anadromous fish by altering salinity regimes (Dodson et al. 1972; Leggett and O'Boyle 1976) and affecting the ability of fish to access migration corridors.

### *Underwater noise*

Underwater noise sources generate sound pressure that can disrupt or damage marine life. LNG activities generate noise from construction, production facility operations, and tanker traffic. Larvae and young fish are particularly sensitive to noise generated from underwater seismic equipment. It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement, feeding), interfering with echolocation and communication or injuring hearing organs (Richardson et al. 1995). Noise issues related to LNG tanker traffic may adversely affect fishery resources in the marine environment, particularly in estuarine areas where some LNG port activities are located or proposed. A more thorough review of underwater noise can be found in the chapter on Global Effects and Other Impacts.

### *Exclusion zones*

Because of security concerns, LNG tankers and terminals include safety and exclusion areas. Different types of restrictions are put in place based on the distance from the facility. However, restrictions on commercial and recreational fishing activities around the LNG facilities can lead to a displacement of fishing effort to other/adjacent areas. This in turn, may increase fishing effort and habitat impacts to more ecologically sensitive areas.

## *Introduction of invasive species*

Introductions of nonnative invasive species into marine and estuarine waters are a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species can be released unintentionally when ships release ballast water (Hanson et al. 2003; Niimi 2004). Hundreds of species have been introduced into United States waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). LNG tankers entering US waters are generally loaded with cargo and do not need to release large amounts of ballast water. However, even small amounts of released ballast water have the potential to contain invasive exotic species. In addition, as vessels are unloaded and ballast is taken on in US waters, the water may contain species that are potentially invasive to other locations. The transportation of nonindigenous organisms to new environments can have severe impacts on habitat (Omori et al. 1994), change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce exotic lethal disease. Refer to the chapters on Marine Transportation and Introduced/Nuisance Species and Aquaculture for more information on invasive species and shipping.

## *Conservation recommendations and best management practices for LNG facilities*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
2. Recommend the use of "closed loop" systems, which minimize the volume of water utilized for regasification, over "open loop" systems. This will serve to minimize the level of impingement and entrainment of living marine resources.
3. Locate facilities that use surface waters for regassification and engine cooling purposes away from areas of high biological productivity, such as estuaries.
4. Design intake structures to minimize entrainment or impingement.
5. Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter the temperature regimes of the receiving waters, which could cause a change in species assemblages and ecosystem function. Strategies should be implemented to diffuse the heated effluent.
6. Avoid the use of biocides (e.g., aluminum, copper, chlorine compounds) to prevent fouling where possible. The least damaging antifouling alternatives should be implemented.
7. Implement operational monitoring plans to analyze impacts resulting from intake and discharge structures and link them to a plan for adaptive management.
8. Provide for monitoring and leak detection systems at natural gas production and transportation facilities that preclude gas from entering the environment.
9. Schedule dredging and excavation activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Address cumulative impacts of past, present, and foreseeable future development projects on aquatic habitats by considering them in the project review process of LNG facilities construction and operations. Based on evaluation of the foreseeable impacts to fishery habitats, a determination can be made regarding the most suitable location and operational procedures for LNG facilities. Ideally, such an analysis would be done at the regional or national level based on natural gas usage and need.

11. Ensure that gas production and transportation facilities have developed and implemented adequate gas spill response plans. Assist government agencies responsible for gas spills (e.g., US Coast Guard, state and local resource agencies) in developing response plans and protocols, including identification of sensitive marine habitats and development and implementation of appropriate gas spill-response measures.

## Offshore Wind Energy Facilities

### *Introduction*

Offshore wind energy facilities (windmills) convert wind energy into electricity through the use of turbines. An offshore facility generally consists of a series of wind turbine generators, an inner-array of submarine electric cables that connect each of the turbines, and a single electric service platform (ESP). Electricity is transmitted from the ESP to an onshore facility through one or a series of submarine cables.

While there are no operating offshore wind facilities in the United States at the writing of this report, there is an increasing number of proposals to develop offshore wind facilities within the northeast region. The construction and operation of offshore wind facilities has the potential to adversely affect fishery habitats.

### *Habitat conversion and loss*

The construction of offshore wind turbines and support structures can result in benthic habitat conversion and loss because of the physical occupation of the natural substrate. Scour protection around the structures, consisting of rock or concrete mattresses, can also lead to a conversion and loss of habitat. For example, the total seafloor area occupied by 130 wind turbines, ESP and associated scour mats for an offshore wind farm proposed in Nantucket Sound, MA, is expected to be approximately 3.21 acres (USACE 2004). Should scour around cables and the base of structures occur, subsequent substrate stabilization activity would lead to additional impact on benthic habitat. Likewise, the burial and installation of submarine cable arrays can impact the benthic habitat through temporary disturbance from plowing and from barge anchor damage. In some cases, plowing or trenching for cable installation can permanently convert benthic habitats when top layers of sediments are replaced with new material. The installation of cables and associated barge anchor damage can adversely affect SAV, if those resources are present in the project area. Cable maintenance, repairs, and decommissioning can also result in impacts to benthic resources and substrate.

### *Siltation, sedimentation, and turbidity*

The construction of wind turbine and support structures can cause increased turbidity in the water column and sedimentation impacts on adjacent benthic habitats. Likewise, the subsurface installation of underwater cables can result in similar impacts. Most of these impacts are relatively short-term and should subside after construction is completed. Maintenance and repairs of wind turbines and submarine electric cables can be expected to persist during the operation of the wind generator facilities. Increased sedimentation and turbidity during the decommissioning of wind energy facilities could be greater than the construction impacts if all submarine structures were to be removed. Siltation, sedimentation, and turbidity impacts related to the construction and maintenance activities from offshore wind energy projects are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### Alteration of hydrological regimes

The placement of wind energy facilities, especially large arrays or "farms," in marine and estuarine habitats may affect hydrological regimes by altering tidal and current patterns. Altered current patterns could affect the distribution of eggs and larvae and the distribution of species within estuaries and bays, as well as the migration patterns of anadromous fishes.

### Alteration of electromagnetic fields

Background direct current electric fields originate from the metallic core of the Earth and the electric currents flowing in the upper layer of the Earth's crust. The strength of this geomagnetic field is highest at the magnetic poles and the lowest at the equator. Marine fishes, such as elasmobranches and anadromous fishes, utilize natural electromagnetic fields (EMFs) for navigation and migratory behavior (Gill et al. 2005). Studies have shown sharks and rays are capable of detecting artificial EMFs (Meyer et al. 2005), and some species have a remarkable sensitivity to electric fields in seawater (Kalmijn 1982). Some species of fish have shown sensitivity to underwater EMFs, including several species of sharks (i.e., *Scyliorhinus canicula, Mustelus canis,* and *Prionace glauca)* and thornback skate (*Raja clavata*) (Kalmijn 1982); and sea lamprey (*Petromyzon marinus*), eels (*Anguilla sp.*), Atlantic cod, plaice (*Pleuronectes platessa*), yellowfin tuna (*Thunnus albacares*) and Atlantic salmon (Gill et al. 2005). Electrical cables associated with offshore wind energy facilities produce EMFs (and induced electric fields) which could interfere with fish behavior. However, at the present time there is no conclusive evidence that EMFs have an adverse effect on marine species (Gill et al. 2005).

### Underwater noise

Underwater noise during construction of turbines may have impacts to hearing in fish and may cause fish to disperse with possible disruption to their feeding and spawning patterns. Underwater noise from the operation of wind turbines may decrease the effective range for sound communication in fish and mask orientation signals (Wahlberg and Westerberg 2005). Atlantic salmon and cod have been shown to detect offshore windmills at a maximum distance of about .04 km to 25 km at high wind speeds (i.e., >13 m/s), and noise from turbines can lead to permanent avoidance by fish within ranges of about 4 m (Wahlberg and Westerberg 2005). Noise from construction of wind farms (e.g., pile driving) could have significant effects on fish (Hoffmann et al. 2000). It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (e.g., movement, feeding), interfering with echolocation and communication or injuring hearing organs (Richardson et al. 1995). A more thorough review of underwater noise can be found in the chapter on Global Effects and Other Impacts.

### Alteration of community structure

Offshore wind energy facilities have the potential to alter the local community structure of the marine ecosystem. There is significant debate as to whether the presence of underwater vertical structures (e.g., oil platforms) contribute to new fish production by providing additional spawning and settlement habitat or simply attract and concentrate existing fishes (Bohnsack et al. 1994; Pickering and Whitmarsh 1997; Bortone 1998). The aggregation of fish in the vicinity of the wind turbine structures may subject certain species to increased fishing. Additive and synergistic effects of multiple stressors, such as the presence of electric cables on the seafloor and underwater sound generated by the turbines, could have cumulative effects on marine ecosystem and community dynamics (e.g., predator-prey population densities, migration corridors).

### *Discharge of contaminants*

An ESP serves as a connection point for the inner-array of cables as well as a staging area for maintenance activities. Hazardous materials that may be stored at the ESP include fluids from transformers, diesel fuel, oils, greases and coolants for pumps, fans and air compressors. Discharge of these contaminants into the water column can affect the water quality in the vicinity of the offshore wind facility. Further information regarding the impacts of oil spills and contaminants can be found in the Petroleum Exploration, Production, and Transportation section of this chapter, and the chapters on Coastal Development and Chemical Affects: Water Discharge Facilities of the report.

### *Conservation recommendations and best management practices for offshore wind energy facilities*

1. Conduct preconstruction biological surveys in consultation with resource agencies to determine the extent and composition of biological populations or habitat in the proposed impact area.
2. Avoid placing cables associated with offshore wind facilities near sensitive benthic habitats, such as SAV.
3. Use horizontal directional drilling to avoid impacts to sensitive habitats, such as salt marshes and intertidal mudflats.
4. Make contingency plans and response equipment available to respond to spills associated with service platforms.
5. Use scour protection for turbines and associated structures and cables to the minimum practicable in order to avoid alteration and conversion of benthic habitat.
6. Bury cables to an adequate depth in order to minimize the need for maintenance activities and to reduce conflicts with other ocean uses.
7. Time construction of facilities to avoid impacts to sensitive life stages and species. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for offshore wind energy facilities construction and operations.

## Wave and Tidal Energy Facilities

### *Introduction*

Wave power facilities involve the construction of stationary or floating devices that are attached to the ocean floor, the shoreline, or a marine structure like a breakwater with exposure to adequate "wave climate." Ocean wave power systems can be utilized in the offshore or nearshore environments. Offshore systems can be situated in deep water, typically in depths greater than 40 m (131 ft). Some examples of offshore systems include the Salter Duck, which uses the bobbing motion of the waves to power a pump that creates electricity. Other offshore devices use hoses connected to floats that move with the waves. The rise and fall of the float stretches and relaxes the hoses, which pressurizes the water, which in turn rotates a turbine. In addition, some seagoing vessels can be built to capture the energy of offshore waves. These floating platforms create electricity by funneling waves through internal turbines.

Wave energy can be utilized to generate power from the nearshore area in three ways:

1. Floats or pitching devices generate electricity from the bobbing or pitching action of a floating object. The object can be mounted to a floating raft or to a device fixed on the ocean floor. A

similar device, the pendulor, is a wave-powered device consisting of a rectangular box, which is open to the sea at one end. A flap is hinged over the opening and the action of the waves causes the flap to swing back and forth. The motion powers a hydraulic pump and a generator.

2. Oscillating water columns generate electricity from the wave-driven rise and fall of water in a cylindrical shaft. The rising and falling water column drives air into and out of the top of the shaft, powering an air-driven turbine.
3. Wave surge or focusing devices, also called "tapered channel" or "tapchan" systems, rely on a shore-mounted structure to channel and concentrate the waves, driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity by using standard hydropower technologies (USDOE 2003).

Tidal energy facilities are designed to generate power in tidal estuaries through the use of turbines. A barrage, or dam, can be placed across a tidal river or estuary. This design utilizes a build-up of water within a headpond to create a differential on either side (depending on the tide), and then the water is released to turn the turbines. While less efficient, tidal power facilities can also utilize water currents to turn turbines. Turbines can be designed in a number of ways and include the "helical-type" turbines, as well as the "propeller-type" turbines. Turbines are generally placed within areas of fast moving water with strong currents to take advantage of both ebb and flow tides. For impacts associated with conventional hydropower facilities, refer to the chapter on Alteration of Freshwater Systems.

### *Habitat conversion and loss*

The construction of tidal and wave energy facilities includes the placement of structures within the water column, thus converting open water habitat to anthropogenic structure. The placement of support structures, transmission lines, and anchors on the substrate will result in a direct impact to benthic habitats which serve as feeding or spawning habitats for various species. Large-scale tidal power projects which utilize a barrage can cause major changes in the tidal elevations of the headpond which can affect intertidal habitat. Alterations in the range and duration of tide flow can adversely affect intertidal communities that rely on specific hydrological regimes. Mud and sand flats may be converted to subtidal habitat, while high saltmarsh areas that may be normally flooded only on the highest spring tides can become colonized by terrestrial vegetation and invasive species (Gordon 1994).

### *Siltation, sedimentation, and turbidity*

Construction of tidal facilities in riverine and estuarine areas can result in increased sedimentation. Structures placed within riverine and estuarine habitats can reduce the natural transport of sediments and cause an accretion of silt and sediments within impoundments. Deposition of sediments can adversely impact benthic spawning habitats of various anadromous fish species, including riffle and pool complexes. Clean gravel substrates, which are preferred by rainbow smelt and Atlantic salmon, can be subjected to increased siltation from alterations in the sediment transport. Shallow water environments, rocky reefs, nearshore and offshore rises, salt, and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than open-water habitats. This is due, in part, to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978). Impacts from siltation and sedimentation from wave and tidal power facilities are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

## Alteration of hydrological regimes

Water circulation patterns and the tidal regimes can be altered during the operation of a barrage-type tidal facility. This can result in poor tidal flushing of the headwaters of estuaries and rivers and can lead to decreased water quality and increases in water temperature (Rulifson and Dadswell 1987). Altered current patterns could affect the distribution of eggs and larvae and the distribution of species within estuaries and bays as well as the migration patterns of anadromous fishes. Hydrological regimes may also be impacted by flows passing through and around tidal turbines and support structures.

## Entrainment, impingement, and other impacts to migration

Water control structures, such as dams, alter the flow, volume, and depth of water within impoundments and below the structures. Water impoundments tend to stratify the water column, increasing water temperatures and decreasing dissolved oxygen levels. Projects operating as "store and release" facilities can drastically affect downstream water flow and depth, resulting in dramatic fluctuations in habitat accessibility, acute temperature changes and an overall decline in water quality (NEFMC 1998). The construction of dams, with either inefficient or nonexistent fish bypass structures, has been a major cause of the population decline of US Atlantic salmon (USFWS and NMFS 1999). Tidal energy facilities located within estuaries or riverine environments have the potential to directly impact migrating fish (Dadswell et al. 1986). Dadswell and Rulifson (1994) reported various physical impacts to fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, including mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found between 21-46% mortality rates for tagged American shad passing through the turbine. The physical presence of tidal power facilities can impact the return of diadromous fishes to natal rivers (Semple 1984). Refer to the chapter on Alteration of Freshwater Systems for further information on impacts from water control structures.

## Alteration of electromagnetic fields

Electrical distribution cables associated with ocean wave-power facilities produce EMFs similar to offshore wind energy facilities and may interfere with fish behavior (Gill et al. 2005). Refer to the discussion under the Offshore Wind Energy Facilities in this chapter for information on the affects of EMFs.

## Conservation recommendations and best management practices for wave and tidal energy facilities

1. Do not permit the construction of barrage-type tidal energy facilities because of the potential for large impacts to the ecosystem and migratory fishery resources.
2. Require preconstruction assessments for analysis of potential impacts to fishery resources for all projects. Assessments should include comprehensive monitoring of the timing, duration, and utilization of the area by diadromous and resident species, potential impacts from the project, and contingency planning using adaptive management.
3. Do not site projects in areas that may result in adverse effects to sensitive marine and estuarine resources and habitats.
4. Avoid project siting of any wave or tidal energy facility within riverine, estuarine, and marine ecosystems utilized by diadromous species.
5. Time construction of facilities to avoid impacts to sensitive life stages and species. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

6. Include impacts associated with the decommissioning and/or dismanteling of wave or tidal energy facility as part of the environmental analyses. Contingency for removal of structures should be required as part of any permits or licenses.
7. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for wave and tidal facilities construction and operations.

# Cables and Pipelines

## *Introduction*

With the continued development of coastal regions comes greater demand for the installation of cables, utility lines for power and other services, and pipelines for oil and gas. The installation of pipelines, utility lines, and cables can have direct and indirect impacts on the offshore, nearshore, estuarine, wetland, beach, and rocky shore coastal zone habitats.

## *Habitat conversion and loss*

The installation of cables and pipelines can result in the loss of benthic habitat from dredging and plowing through the seafloor. This can result in a direct loss of benthic organisms, including shellfish. Construction impacts can result in long-term or permanent damage, depending on the degree and type of habitat disturbance and best management practices employed for a project. The installation of pipelines can impact shellfish beds, hard-bottomed habitats, and SAV (Gowen 1978). Cables can damage complex habitats containing epifaunal growth during installation, if allowed to "sweep" along the bottom while being positioned into the correct location. Shallow water environments, rocky reefs, nearshore and offshore rises, salt and freshwater marshes (wetlands), and estuaries are more likely to be adversely impacted than are open-water habitats. This is due to their higher sustained biomass and lower water volumes, which decrease their ability to dilute and disperse suspended sediments (Gowen 1978). Benthic organisms, especially prey species, may recolonize disturbed areas, but this may not occur if the composition of the substrate is drastically changed or if pipelines are left in place after production ends.

Pipelines installed on the seafloor or over coastal wetlands can alter the environment by causing erosion and scour around the pipes, resulting in escarpments on coastal dune and salt marshes, and on the seafloor. Alterations to the geomorphology of coastal habitats from pipelines can exacerbate shoreline erosion and fragment wetlands. Because vegetated coastal wetlands provide forage and protection to commercially important invertebrates and fish, marsh degradation caused by plant mortality, soil erosion, or submergence will eventually decrease productivity.

Pipelines are generally buried below ground by digging trenches or canals. Digging trenches may change the coastal hydrology by: (1) facilitating rapid drainage of interior marshes during low tides or low precipitation; (2) reducing or interrupting freshwater inflow and associated littoral sediments; and (3) allowing saltwater to move farther inland during periods of high tides (Chabreck 1972). Saltwater intrusion into freshwater marsh often causes a loss of salt-intolerant emergent plants and SAV (Chabreck 1972; Pezeshki et al. 1987). Soil erosion and a net loss of organic matter may also occur (Craig et al. 1979).

Conversion of benthic habitat can occur if cables and pipelines are not buried sufficiently within the substrate. Conversion of habitats can also occur in areas where a layer of fine sediment is underlain with coarser materials. Once these materials are plowed for pipeline/cable installation, they can be mixed with underlying coarse sediment, and thus, alter the substrate composition. This can adversely affect the habitat of benthic organisms which rely on soft sand or mud habitats. The armoring of pipeline with either rock or concrete can result in permanent habitat alterations if placed within soft substrate. The placement of cables and pipelines often necessitates removal of hard bottom or rocky habitats in the pipeline corridor. These habitats are removed by using explosives or mechanical fracturing and can result in a reduction of available hard bottom substrate and habitat complexity.

Subsea pipelines that are placed on the substrate have the potential to create physical barriers to benthic invertebrates during migration and movement. In particular, the migration of American lobster (*Homarus americanus*) between inshore and offshore habitats can be adversely affected if pipelines are not buried to sufficient depths (Fuller 2003). Furthermore, erosion around buried pipelines and cables can lead to uncovering of the structure and the formation of escarpements. This, in turn, can interfere with the migratory patterns of benthic species.

### *Siltation, sedimentation, and turbidity*

The installation of cables and pipelines can lead to increased turbidity and subsequent sedimentation, caused by either the plowing or jetting method of installation. Elevated siltation and turbidity during cable and pipeline installation is typically short-term and restricted to the area surrounding the cable and pipeline corridor. However, pipelines that are left unburied and exposed can cause erosion of the substrate and cause persistent siltation and turbidity in the surrounding area. Maintenance activities related to cables and pipelines, as well as removal for decommissioned cables and pipelines, can release suspended sediments into the water column. Long-term effects of suspended sediment include reduced light penetration and lowered photosynthesis rates and the primary productivity of the area (Gowen 1978). Impacts from siltation, sedimentation, and turbidity from cables and pipelines are similar to those described in the Petroleum Exploration, Production, and Transportation section of this chapter.

### *Release of contaminants*

Petroleum products can be released into the environment if pipelines are broken or ruptured by unintentional activities, such as shipping accidents or deterioration of pipelines. A review of impacts from petroleum spills can be found in the Petroleum Exploration, Production, and Transportation section of this chapter. In addition, resuspension of contaminants in sediments, such as metals and pesticides, during pipeline installation can have lethal and sublethal effects to fishery resources (Gowen 1978). Contaminants may have accumulated in coastal sediments from past industrial activities, particularly in heavily urbanized areas. Metals may initially inhibit reproduction and development of marine organisms, but at high concentrations they can directly or indirectly contaminate or kill fish and invertebrates. The early life-history stages of fish are the most susceptible to the toxic impacts associated with metals (Gould et al. 1994). The release of contaminants can reduce or eliminate the suitability of water bodies as habitat for fish species and their prey. In addition, contaminants, such as copper and aluminum, can accumulate in sediments and become toxic to organisms contacting or feeding on the bottom.

Impacts to sensitive wetland and subtidal habitats can be avoided during pipeline and cable installation using horizontal directional drilling techniques, which allow the pipe or cable to be installed in a horizontal drill hole below the substrate. "Frac-outs" (i.e., releases of drilling mud or other lubricants, such as bentonite mud) can occur during the drilling process, and material can escape through fractures in the underlying rock. This typically happens when the drill hole encounters a natural fracture in the rock or when insufficient precautions are taken to prevent new fractures from occurring. Fishery habitats can be adversely affected if a "frac-out" occurs during the installation process and discharges drilling mud or other contaminants into the surrounding area.

Cranford et al. (1999) found that chronic intermittent exposure to sea scallops (*Placopecten magellanicus*) of dilute concentrations of operational drilling wastes, characterized by acute lethal tests as practically nontoxic, can affect growth, reproductive success, and survival.

Maintenance of cables and pipelines can also result in subsequent impacts to the aquatic environment. The maintenance of pipelines includes the "pigging" of pipelines to clean out residual materials from time-to-time. The release of these materials into the surrounding environment can lead to water quality impacts and contamination of adjacent benthic habitats. For example, biocides (e.g., copper and aluminum compounds) are often utilized in the hydrostatic testing of pipelines and are subsequently discharged into surrounding waters. Laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 µg/L and 1,000 µg/L, respectively, and vertical migration of larvae was impaired at copper concentrations of greater than 300 µg/L (Blaxter 1977).

### *Alteration of electromagnetic fields*

Underwater electrical distribution cables produce EMFs that may interfere with fish behavior (Gill et al. 2005). However, at the present time there is no conclusive evidence that EMFs have an adverse effect on marine species (Gill et al. 2005). See also the discussion of underwater EMFs in the Offshore Wind Energy Facilities section of this chapter and the Global Effects and Other Impacts chapter of the report.

### *Underwater noise*

The installation of cables and pipelines can produce underwater noise that may disrupt or damage fishery resources. Noise from construction activities (e.g., pile driving) can have significant effects on fish (Hoffmann et al. 2000). Larvae and young fish are particularly sensitive to noise generated from underwater explosives during blasting. It is also known that noise in the marine environment may adversely affect marine mammals by causing them to change behavior (movement, feeding), interfering with echolocation and communication, or injuring hearing organs (Richardson et al. 1995).

### *Alteration of community structure*

The construction of pipelines and other underwater structures has the potential to alter the local community structure of the marine ecosystem. There is significant debate as to whether the presence of underwater vertical structures (e.g., oil platforms) contribute to new fish production by providing additional spawning and settlement habitat or simply attract and concentrate existing fish within an area (Bohnsack et al. 1994; Pickering and Whitmarsh 1997; Bortone 1998). Underwater pipelines are anthropogenic structures that could have similar attraction and production issues relating to fishery management. As with wind turbines and offshore LNG facilities, aggregation of fishes in the vicinity of pipeline structures may subject certain species to increased fishing pressure. By altering the age and species composition in the area around pipelines, predator/prey interactions and reproduction can be altered, and these changes may have community-level affects on fisheries.

### *Conservation recommendations and best management practices for cables and pipelines (adapted from Hanson et al. 2003)*

1. Align crossings along the least environmentally damaging route. Sensitive habitats such as hard-bottom (e.g., rocky reefs), SAV, oyster reefs, emergent marsh, and mud flats should be avoided.

2. Use horizontal directional drilling where cables or pipelines would cross sensitive habitats, such as intertidal mudflats and vegetated intertidal zones, to avoid surface disturbances. Measures should be employed to avoid/minimize impacts to sensitive fishery habitats from potential frac-outs, including:
    a. The use of nonpolluting, water-based lubricants should be required.
    b. Drill stem pressures should be monitored closely so that potential frac-outs can be identified.
    c. Drilling should be halted, if frac-outs are suspected.
    d. Above ground monitoring should be employed to identify potential frac-outs.
    e. Spill clean-up plan and protocols should be developed, and clean-up equipment should be on-site to quickly respond to frac-outs.
3. Avoid construction of permanent access channels since they disrupt natural drainage patterns and destroy wetlands through excavation, filling, and bank erosion.
4. Backfill excavated wetlands with either the same or comparable material capable of supporting similar wetland vegetation. Original marsh elevations should be restored.
5. Use existing rights-of-way whenever possible to lessen overall encroachment and disturbance of wetlands.
6. Bury pipelines and submerged cables where possible. Unburied pipelines or pipelines buried in areas where scouring or wave activity eventually exposes them can result in impacts to invertebrate migratory patterns.
7. Use silt curtains or other types of sediment control in order to protect sensitive habitats and resources.
8. Limit access for equipment to the immediate project area avoid access through sensitive resources.
9. Avoid the use of open trenching for installation. Methods in which the trench is immediately backfilled reduce the impact duration and should therefore be employed when possible.
10. Conduct construction during the time of year that will have the least impact on sensitive habitats and species. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
11. Evaluate impacts to habitat during the decommissioning phase, including impacts during the demolition phase and impacts resulting from permanent habitat losses.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats in the review process for cable and pipeline construction and operations.
13. Ensure that oil and gas pipeline systems include leak detection capabilities to minimize potential impacts from spills.

## References for Energy-related Activities


Arruda JA, Marzolf GR, Faulk RT. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. Ecology 64(5):1225-35.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth flatfish biology conference- poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology: Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New York (NY): Academic Press. p 177-252.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Blaxter JHS, Hunter JR. 1982. The biology of the clupeoid fishes. In: Blaxter JHS, Russel FS, Yonge M, editors. Advances in marine biology – Vol. 20. New York (NY): Academic Press. p 187-91.

Bohnsack JA, Harper DE, McClellan DB, Hulsbeck M. 1994. Effects of reef size on colonization and assemblage structure of fishes at artificial reefs off southeastern Florida, U.S.A. Bulletin of Marine Science 55(2-3):796-823.

Bortone SA. 1998. Resolving the attraction-production dilemma in artificial reef research: Some yeas and nays. Fisheries 23(3):6-10.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Callaghan TP. 2004. Entrainment and impingement of organisms in power plant cooling. In: Cleveland CJ, editor. Encyclopedia of Energy, Vol. 2. Amsterdam (The Netherlands): Elsevier. p 447-57.

Capuzzo JM. 1987. Biological effects of petroleum hydrocarbons: assessment of experimental results. In: Boesch DF, Rabalais NN, editors. Long-term environmental effects of offshore oil and gas development. London (England): Elsevier Applied Science. p 343-410.

Carls MG, Thomas RE, Lilly MR, Rice SD. 2003. Mechanism for transport of oil-contaminated groundwater into pink salmon redds. Marine Ecology Progress Series 248:245-55.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chabreck RH. 1972. Vegetation, water, and soil characteristics of the Louisiana coastal region. Baton Rouge (LA): LSU Agricultural Experimental Station.

Chiasson AG. 1993. The effects of suspended sediment on rainbow smelt (*Osmerus mordax*): a laboratory investigation. Canadian Journal of Zoology 71:2419-24.

[CEQ] Council on Environmental Quality. 1977. Oil and gas in coastal lands and waters. Washington (DC): US Government Printing Office. 153 p.

Craig NJ, Turner RE, Day JW Jr. 1979. Land Loss in coastal Louisiana (U.S.A.). Environmental Management 3(2):133-44.

Cranford PJ, Gordon DC Jr, Lee K, Armsworthy SL, Tremblay GH. 1999. Chronic toxicity and physical disturbance effects of water- and oil-based drilling fluids and some major constituents on adult sea scallops (*Placopecten magellanicus*). Marine Environmental Research 48(3):225-56.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: A region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Dadswell MJ, Rulifson RA, Daborn GR. 1986. Potential impact of large-scale tidal power developments in the upper Bay of Fundy on fisheries resources of the northwest Atlantic. Fisheries 11(4):26-35.

Dodson JJ, Leggett WC, Jones RA. 1972. The behavior of adult American shad (*Alosa sapidissima*) during migration from salt to fresh water as observed by ultrasonic tracking techniques. Journal of the Fisheries Research Board of Canada 29(10):1445-9.

Drake LA, Jenkins PT, Dobbs FC. 2005. Domestic and international arrivals of NOBOB (no ballast on board) vessels to lower Chesapeake Bay. Marine Pollution Bulletin 50(5):560-5.

Enright JT. 1977. Power plants and plankton. Marine Pollution Bulletin 8(7):158-61.

Freeman HC, Uthe JF, Sangalang GB, Garside ET. 1981. Contaminant/liver histopathology in Canadian Atlantic cod (*Gadus morhua*). Copenhagen (Denmark): ICES CM-1981/ E: 50.

Fuller C. editor. 2003. A workshop on the potential effects of the construction and operation of subsea pipelines on lobster movement and behavior. Blue Atlantic Lobster Workshop Proceedings; 2003 Jun 24; Providence, RI. Willington (CT): ENSR International. 152 p.

Gill AB, Gloyne-Phillips I, Neal KJ, Kimber JA. 2005. The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms-a review. Final Report: Collaborative Offshore Wind Energy Research into the Environment. London (England): COWRIE 1.5 Electromagnetic Fields Review. 128 p.

Gordon DC Jr. 1994. Intertidal ecology and potential power impacts, Bay of Fundy, Canada. Biological Journal of the Linnean Society 51(1-2):17-23.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Gowen AW. 1978. The environmental effects of outer continental shelf (OCS) pipelines. Initial findings. Boston (MA): New England River Basins Commission 4:24-43.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Heintz RA, Rice SD, Wertheimer AC, Bradshaw RF, Thrower FP, Joyce JE, Short JW. 2000. Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha* after exposure to crude oil during embryonic development. Marine Ecology Progress Series 208:205-16.

Helvey M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47:18-26.

Helvey M. 2002. Are southern California oil and gas platforms essential fish habitat? ICES Journal of Marine Science 59(Suppl.):S266-S271.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Hoffman E, Astrup J, Larsen F, Munch-Petersen S. 2000. Effects of marine windfarms on the distribution of fish, shellfish, and marine mammals in the Horns Rev Area. Lyngby (Denmark): Danish Institute for Fisheries Research. Report to ELSAMPROJEKT A/S. Report No. Baggrundsrapp 24. 42 p.

Johnson LL, Collier TK, Stein JE. 2002. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAH) to protect estuarine fish. Aquatic Conservation: Marine and Freshwater Ecosystems 12(5):517-38.

Kalmijn AJ. 1982. The electric and magnetic field detection in Elasmobranch fishes. Science 218(4575):916-18.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Leggett WC, O'Boyle RN. 1976. Osmotic stress and mortality in adult American shad during transfer from saltwater to freshwater. Journal of Fish Biology 8(6):459-69.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Lonning S, Falk-Petersen IB. 1978. The effects of oil dispersants on marine eggs and larvae. Astarte 11:135-8.

MacKenzie C, Weiss-Glanz LS, Moring JR. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. Washington (DC): US Fish and Wildlife Service. Biological Report 82(11.37). 18 p.

Marten K, Herzing D, Poole M, Newman-Allman K. 2001. The acoustic predation hypothesis: Linking underwater observations and recordings during Odontocete predation and observing the effects of loud impulsive sounds on fish. Aquatic Mammals 27(1):56-66.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Meyer CG, Holland KN, Papastamatiou YP. 2005. Sharks can detect changes in the geomagnetic field. Journal of the Royal Society Interface 2(2):129-30.

Michel J, Hayes MO. 1999. Weathering patterns of oil residues eight years after the *Exxon Valdez* oil spill. Marine Pollution Bulletin 38(10):855-63.

Mills KE, Fonseca MS. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-34.

[NOAA] National Oceanic and Atmospheric Administration. 1992. An introduction to coastal habitats and biological resources for oil spill response. Seattle (WA): Hazardous Materials Response and Assessment Division. Report No. HMRAD 92-4.

[NRC] National Research Council. 2003. Oil in the sea III: inputs, fates and effects. Washington (DC): National Academy Press.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe CP, MacDonald DD. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11(1):72-82.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

[NPFMC] North Pacific Fisheries Management Council. 1999. Environmental Assessment for Amendment 55 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area; Amendment 55 to the Fishery Management Plan for Groundfish of the Gulf of Alaska; Amendment 8 to the Fishery Management Plan for the King and Tanner Crab Fisheries in the Bering Sea and Aleutian Islands; Amendment 5 to the Fishery Management Plan for Scallop Fisheries off Alaska; Amendment 5 to the Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska, Essential Fish Habitat. Anchorage (AK): NPFMC. 367 p.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

Pezeshki SR, Delaune RD, Patrick WH Jr. 1987. Response of the freshwater marsh species, *Panicum hemitomon* Schult., to increased salinity. Freshwater Biology 17(2):195-200.

Pickering H, Whitmarsh D. 1997. Artificial reefs and fisheries exploitation: a review of the ‘attraction versus production’ debate, the influence of design and its significance for policy. Fisheries Research 31(1-2):39-59.

Pilati DA. 1976. Cold shock: biological implications and a method for approximating transient environmental temperatures in the near-field region of a thermal discharge. Science of the Total Environment 6(3):227-37.

Reiser DW, Chapin D, DeVries P, Ramey MP. 2004. Flow regime and ecosystem interactions in spring dominated streams: Implications for selecting instream flow methods. Hydroecologie Appliquee 14(1):93-104.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

Richkus WA. 1974. Factors influencing the seasonal and daily patterns of alewife (*Alosa pseudoharengus*) migration in a Rhode Island river. Journal of the Fisheries Research Board of Canada 31:1485-97.

Rogers CA. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. Fisheries Bulletin 74(1):52-8.

Rulifson RA, Dadswell MJ. 1987. Mortality of fish passing through tidal, low-head hydropower turbines and possible mitigation strategies. In: Proceedings of Ocean 87: the ocean-an international workplace; 1987 Sep 28-Oct 1; Halifax, Nova Scotia. Columbia (MD): Marine Technology Society and IEEE Ocean Engineering Society. p 944-9.

Semple JR. 1984. Possible effects of tidal power development in the upper Bay of Fundy on anadromous fish passage. In: Update on the environmental consequences of tidal power in the upper reaches of the Bay of Fundy. Dartmouth (Nova Scotia): Canadian Technical Report of the Fisheries and Aquatic Sciences No. 1256:565-75.

Short JW, Lindeberg MR, Harris PM, Maselko J, Rice SD. 2002. Vertical oil distribution within the intertidal zone 12 years after the *Exxon Valdez* oil spill in Prince William Sound, Alaska. Proceedings of the 25th Arctic and Marine Oilspill Program Technical Seminar. Ottawa (Ontario): Minister of Supply and Services Canada. p 57-72.

Stanley JG, Colby PJ. 1971. Effects of temperature on electrolyte balance and osmoregulation in the alewife (*Alosa pseudoharengus*) in fresh and sea water. Transactions of the American Fisheries Society 100(4):624-38.

Stewart PL, Arnold SH. 1994. Environmental requirements Atlantic herring (*Clupea harengus harengus*) in eastern Canada and its response to human impacts. Dartmouth (Nova Scotia): Canadian Technical Report of Fisheries and Aquatic Sciences 2003: ix + 37p.

Urho L, Hudd R. 1989. Sublethal effects of an oil spill on fish (herring) larvae in the northern Quark, in the Baltic. In: Blaxter JHS, Gamble JC, Westernhagen HV, editors. The early life history of fish; 1988 Oct 3-5; Bergen, Norway. Third ICES Symposium: Rapports et Proces-Verbaux Des Reunions 191. Copenhagen (Denmark): International Council for the Exploration of the Sea. p 494.

[USACE] US Army Corps of Engineers. 2004. Cape Wind Energy Project Draft Environmental Impact Statement (Cape Wind DEIS). Vol. 1. Concord (MA): US Army Corp of Engineers, New England District.

[USCG] US Coast Guard. 2006. Environmental impact statement/environmental impact report for the Neptune LNG deepwater port license application. Washington (DC): USCG-2005-22611.

[USDOE] US Department of Energy. 2003. A consumer's guide to energy efficiency and renewable energy: Ocean wave power. [Internet]. [updated 2003 Feb 7; cited 2007 Dec 19]. Available from: http://www.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50009.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

Vandermeulen JH, Mossman D. 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in winter flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences 53:1741-53.

Wahlberg M, Westerberg H. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Progress Series 288:295-309.

Wake H. 2005. Oil refineries: a review of their ecological impacts on the aquatic environment. Estuarine, Coastal and Shelf Science 62:131-40.

Wertheimer AC, Heintz RA, Thedinga JF, Maselko JM, Rice SD. 2000. Straying of adult pink salmon from their natal stream following embryonic exposure to weathered *Exxon Valdez* crude oil. Transactions of the American Fisheries Society 129(4):989-1004.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

# CHAPTER FOUR: ALTERATON OF FRESHWATER SYSTEMS

## Introduction

Freshwater riverine and riparian habitats located in the northeastern coastal United States provide important habitat for the growth, survival, and reproduction of diadromous fishes and are critical to maintaining healthy estuarine ecosystems. Some of the diadromous fish (species that migrate between freshwater and saltwater for specific life history functions) inhabiting the Northeast include Atlantic salmon (*Salmo salar*), striped bass (*Morone saxatilis*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), rainbow smelt (*Osmerus mordax*), Atlantic sturgeon (*Acipenser oxyrinchus*), shortnose sturgeon (*Acipenser brevirostrum*), and American eel (*Anguilla rostrata*). Not only are diadromous fishes subject to environmental impacts in the marine environment, but they also encounter dams, pollution, effects of urbanization, and habitat changes in freshwater (Moring 2005). In addition, some forage species that are important prey for marine fisheries depend upon freshwater habitats for portions of their life cycle. The health and availability of freshwater systems and the preservation and maintenance of associated functions and values are vital to the diversity, health, and survival of marine fisheries.

Free flowing rivers, ponds, and lakes act as migratory corridors, spawning, nursery, and rearing areas and provide forage and refuge for life stages of these species. Riverine and riparian corridors, and palustrine and lacustrine wetlands provide important functions and values for resident and migratory fish, freshwater mussels, reptiles, amphibians, and insects (Chabreck 1988). Riparian corridors provide shade, nutrients, and habitat enhancing debris in riverine systems (Bilby and Ward 1991), which are essential elements necessary for these aquatic resources to thrive. In addition to supporting aquatic resources, freshwater wetlands perform important and broad ecological functions by reducing erosion, attenuating floodwater velocity and volume, improving water quality by the uptake of nutrients, and reducing sediment loads (Howard-Williams 1985; De Laney 1995; Fletcher 2003). Freshwater habitats are intricately connected to terrestrial and coastal ecosystems, making them vulnerable to a wide array of anthropogenic disturbances that can alter the functions, values, quantity, and accessibility of freshwater wetlands used by migratory fish (Beschta et al. 1987; Naiman 1992).

Biological, chemical, and physical threats to freshwater environments from terrestrial and aquatic sources have led to habitat fragmentation and degradation (Bodi and Erdheim 1986; Wilbur and Pentony 1999; USEPA 2000; Kerry et al. 2004). In particular, nonfishing activities, such as mining, dredging, fill placement, dam construction and alterations of hydrologic regimes, thermal discharges, and nonpoint source pollution have degraded and eliminated freshwater habitats (Zwick 1992; Wilbur and Pentony 1999; Hanson et al. 2003). Examples of nonpoint source pollution include urban stormwater and agricultural runoff (e.g., petroleum products, metals, pesticides, fertilizers, and animal wastes). Refer to the Coastal Development and Agriculture and Silviculture chapters for more detailed discussion on nonpoint source pollution. The federal Clean Water Act (CWA) has eliminated certain types of disposal activities, limited fill activities, and otherwise resulted in improved protection of the nation's wetlands and waterways. Despite these and other regulations to protect aquatic habitat, anthropogenic impacts continue, dramatically affecting fish habitat, including prey species and fisheries (Wilson and Gallaway 1997; Bodi and Erdheim 1986; Hanson et al. 2003; Ormerod 2003; Kerry et al. 2004).

## Dam Construction and Operation

The history and effects of dam construction on passage and habitat is well documented (Larinier 2001; Heinz Center 2002). Among the major identified causative factors of the population demise of Atlantic salmon, dam construction and operation may be the most dramatic (NEFMC 1998; Parrish et al. 1998; USFWS and NMFS 1999). In the United States, 76,000 dams have been identified in the National Inventory of Dams by the US Army Corps of Engineers and the Federal Emergency Management Agency (Heinz Center 2002). This number may be as high as 2 million when small-scale dams are included (Graf 1993). Dam construction and operation in the northeastern United States have occurred for centuries to provide power generation, navigation, fire and farm ponds, reservoir formation, recreation, irrigation, and flood control. Important for the local economy when originally constructed, today many of these structures are obsolete, unused, abandoned, or decaying. Fish passages in any given river system may not be consistent or effective throughout, limiting the ability for Atlantic salmon and many other migratory and resident species to reach necessary habitat. Sections 18 and 10j of the Federal Power Act require fish passage and protection and mitigation for damages to fish and wildlife, respectively, at hydroelectric facilities.

The effects of dam construction and operation on fisheries and aquatic habitat include: (1) complete or partial upstream and downstream migratory impediment; (2) water quality and flow patterns alteration; (3) thermal impacts; (4) alterations to the floodplain, including riparian and coastal wetland systems and associated functions and values; (5) habitat fragmentation; (6) alteration to sediment and nutrient budgets; and (7) limitations on gene flow within populations.

### *Impaired fish passage*

The construction of dams with either no fish passage or ineffective passage was the primary agent of the population decline of US Atlantic salmon (USFWS and NMFS 1999; NEFMC 1998). By 1950, less than 2% of the original habitat for Atlantic salmon in New England was accessible because of dams (Buchsbaum 2005). Dams physically obstruct passage and alter a broad range of habitat characteristics essential for passage and survival. Without any mechanism to get around a dam, there is no upstream passage to spawning and nursery habitat. Fish that gather at the base of the dam will either spawn in inadequate habitat, die, or return downstream without spawning. The presence of a fish passage structure does not necessarily ensure access to upstream habitat. Even with a structure in place, passage is contingent on many factors, including water-level fluctuations, altered seasonal and daily flow regimes, elevated temperatures, reduced water velocities, and discharge volumes (Haro et al. 2004).

Safe, timely, and effective downstream passage by fish is also hindered by dams. The time required for downstream migration is greatly increased because of reduced water flows within impoundments (Raymond 1979; Spence et al. 1996; PFMC 1999). This delay results in greater mortality associated with predation and the physiological stress associated with migration. Downstream passage for fish is hindered or prevented while passing over spillways and through turbines (Ruggles 1980; NEFMC 1998) and by entrainment or impingement on structures associated with a hydroelectric facility. Dadswell and Rulifson (1994) reported on the physical impacts observed in fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, which included mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found 21-46% mortality rates for experimentally tagged American shad passing through the turbine.

Fragmentation of aquatic habitat caused by dams can result in a loss of genetic diversity and spawning potential that may make populations of fish more vulnerable to local extirpation and extinctions, particularly for species functioning as a metapopulation (Morita and Yamamoto 2002).

### *Altered hydrologic, salinity, and temperature regimes*

Dams and dam operations alter flow patterns, volume, and depth of water within impoundments and below the dam. These hydrological alterations tend to increase water temperatures, stratify the water column, and decrease dissolved oxygen concentrations in the water impoundments. Projects operating as "store and release" facilities can drastically affect downstream water flow and depth, resulting in dramatic fluctuations in habitat accessibility, acute temperature changes, and overall water quality. Although large, impounding dams have the ability to alter the hydrology of large segments or entire rivers, smaller, run-of-the river dams that do not contain impoundments generally have little or no ability to alter downstream hydrology (Heinz Center 2002).

Reductions in river water temperatures are common below dams if the intake of the water is from lower levels of the reservoir. Stratification of reservoir water not only affects temperature but can create oxygen-poor conditions in deeper areas and, if these waters are released, can degrade the water quality of the downstream areas (Heinz Center 2002).

By design, dams often reduce peak flows as flood control measures. However, reductions of peak flows can decrease the physical integrity of the downstream river because the floodplains (including side channels, islands, bars, and beaches) are not as extensively connected to the river (Heinz Center 2002). In addition, dams can also reduce low flows during periods of drought and when dam operators reduce water releases in order to maintain water levels in the impoundments (Heinz Center 2002).

Dams with deep reservoirs have high hydrostatic pressures at the bottom and can force atmospheric gases into solution. If these waters are released below the dam, either by water spilling over dams or through turbines, it can cause dissolved gas supersaturation, resulting in injury or death to fish traversing the dam (NEFMC 1998; Heinz Center 2002).

Tidal fresh habitat is limited to a narrow zone in river systems where the water is tidally influenced, yet characteristically fresh (i.e., < 0.5 ppt salinity). This narrow habitat type may be altered or lost because of dam construction and operations.

### *Alteration of stream bed and stream morphology*

The construction of a dam fragments habitat, altering both upstream and downstream biogeochemical processes and resulting in a wide array of direct and indirect cumulative impacts (Poff et al. 1997; Heinz Center 2002). Multiple habitat variables are affected by dams, principally streambed properties (Spence et al. 1996), the transport of sediments and large woody debris (Spence et al. 1996; PFMC 1999), and overall stream morphology.

Dams typically reduce peak flows as a flood control measure and can reduce low flows when water releases are reduced to save water during drought. As the range of flows in the river are decreased, the width of the active portion of the watershed is reduced and the river channel shrinks (Heinz Center 2002).

### *Altered sediment/large woody debris transport*

Dams affect the physical integrity of watersheds by fragmenting the lengths of rivers, changing their hydrologic characteristics, and altering their sediment regimes by trapping most of the sediment entering the reservoirs and disrupting the sediment budget of the downstream landscape (Heinz Center 2002). Because water released from dams is relatively free of sediment, downstream reaches of rivers may be altered by increased particle size, erosion, channel shrinkage, and deactivation of floodplains (Heinz Center 2000).

Large woody debris (LWD) and other organic matter are often removed from rivers containing dams, as well as for other reasons, such as aesthetics, road and bridge maintenance, and commercial and recreational uses. Organic debris provides habitat for a variety of aquatic organisms, such as Atlantic salmon, by promoting habitat complexity, including the formation of pool and riffle complexes and undercut banks (Montgomery et al. 1995; Abbe and Montgomery 1996; Spence et al. 1996). Removing organic debris may change the structure, function, and value of the river system. From a broader perspective, removal of LWD from a river system disrupts a link between the forest and the sea (Maser and Sedell 1994; NRC 1996; Collins et al. 2002; Collins et al. 2003).

### *Riparian zone development and alteration of wetlands*

Riparian wetlands may be lost to water level increases upstream and flow alterations downstream of the dam. Generally, the greater the storage capacity of a dam, the more extensive are the downstream geomorphological and biological impacts (Heinz Center 2002). Lost wetlands result in a loss of floodplain and flood storage capacity, and thus a reduced ability to provide flood control during storm events. A healthy riparian corridor is well vegetated, harbors prey items, contributes necessary nutrients, provides LWD that creates channel structure and cover for fish, and provides shade, which controls stream temperatures (Bilby and Ward 1991; Hanson et al. 2003). When vegetation is removed from riparian areas, water temperatures tend to increase and LWD is less common. The result is less refuge for fish, fundamental changes in channel structure (e.g., loss of pool habitats), instability of stream banks, and alteration of nutrient and prey sources within the river system (Hanson et al. 2003). Riparian zone development can be considered a secondary effect of dam construction. Residential, recreational, and commercial development may result from the associated impoundment.

### *Changes to native aquatic communities*

Impoundments can concentrate predators and disease carrying organisms and disrupt fish development, thereby altering the community structure at various trophic levels and potentially changing the natural habitat and fishery dynamics of the aquatic habitat. In addition, the loss of wetlands by the increased impoundment level and reduction of freshwater input and sediments below the dam can have potentially serious impacts on both fish and invertebrate populations (NEFMC 1998).

Impoundments also create an opportunity for nonnative species to become established. Common carp (*Cyprinus carpio*), northern pike (*Esox lucius*), and walleye (*Sander vitreus*) are a few examples. These species have the ability to dramatically alter local habitats and aquatic communities. In some instances, introduced species such as smallmouth bass (*Micropterus dolomieu*) become managed as a sport fish to the exclusion of native species. Over time, these introduced species become accepted as part of the “natural” condition. Like the changes associated with creating an impoundment, these introduced species can change the community dynamics of the riverine system.

### *Conservation measures and best management practices for dam construction and operation (adapted from Hanson et al. 2003 and PFMC 1999)*

1. Avoid the construction of new dam facilities, where possible.
2. Retrofit existing dams with efficient and functional upstream and downstream fish passage structures.
3. Construct and design facilities with efficient and functional upstream and downstream adult and juvenile fish passage which ensures safe, effective, and timely passage.
4. Construct dam facilities with the lowest hydraulic head practicable for the project purpose. Site the project at a location where dam height can be reduced.
5. Consider all upstream passage types, including natural-like bypass channels, denil-type and vertical slot fishways, Alaskan steeppass, fishlifts, etc. Volitional passage is preferable to trap and truck methods.
6. Downstream passage should prevent adults and juveniles from passing through the turbines and provide sufficient water downstream for safe passage.
7. Operate facilities to create flow conditions that provide for passage, water quality, proper timing of life history stages, and properly functioning channel conditions, and to avoid strandings and redd (i.e., spawning nest) dewatering. Run-of-river, such that the volume of water entering an impoundment exits the impoundment with minimal fluctuation of the headpond, is the preferred mode of operation for fishery and aquatic resource interests. Water flow monitoring equipment should be installed upstream and downstream of the facility. Generally, fluctuations in headpond water levels should be kept between 6 and 12 inches.
8. Coordinate maintenance and operations which require drawdown of the impoundment with state and federal resource agencies to minimize impacts to aquatic resources.
9. Use seasonal restrictions for construction, maintenance, and operations of dams to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Develop water and energy conservation guidelines for integration into dam operation plans and into regional and watershed-based water resource plans.
11. Encourage the preservation of LWD, whenever possible. If possible, relocate debris as opposed to removing it completely. Remove LWD only to prevent damage to property or threats to human health and safety.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for dam construction and operation.
13. Consider the removal of a dam when it is feasible (see the following section on dam removal).

## Dam Removal

A number of factors may be considered in determining the efficacy of removing a dam, including habitat restoration, safety, and economics (Babbitt 2002; Heinz Center 2002). Dam removal provides overall environmental benefits to freshwater habitats and aquatic resources. The recovery of some anadromous species, such as Atlantic salmon and rainbow smelt, may be dependent on targeted dam removals, principally those dams blocking passage to high quality spawning and rearing habitat. Dam removal reconnects previously fragmented habitat, allowing the natural flow of water, sediment, nutrients, and the genetic diversity of fish populations and reestablishes floodplains and riparian corridors (Morita and Yokota 2002; Nislow et al. 2002).

The Heinz Center (2002) provides a thorough overview of environmental, economic, and social issues to consider when evaluating dam removal. Because there are a number of concerns and interests surrounding dams and their use, the overall benefits of dam removal must be weighed against all potential adverse impacts. It is important to bear in mind that although the removal of a dam may reverse most of the undesirable changes, it is unlikely to restore completely the natural conditions because of other dams on the river and the other anthropogenic effects on streams, such as channel control and land use management (Heinz Center 2002).

For many local residents, the impoundments created by these dams define a way of life for the community. Changing the existing conditions may not necessarily be perceived as good for all parties. For example, an impoundment may contain stocked game fish which provide recreational opportunities for the community. Dam removal may eliminate these species or bring about interactions with formerly excluded diadromous species. However, because dams alter sediment and nutrient transport processes and raise water levels upstream of the structure, dam removal can result in short and long-term impacts upstream and downstream.

The effects of dam removal on fisheries and aquatic habitat include: (1) release of contaminants; (2) short-term water quality degradation; (3) flow pattern alteration; (4) loss of benthic and sessile invertebrates; and (5) alterations of the riparian landscape and associated functions and values.

### *Release of contaminated sediments and short-term water quality degradation*

Dam removal typically results in an increased transfer of sediments downstream of the dam, while the spatial and temporal extent of sediment transfer depends on the size of the dam and total sediment load. Sediments accumulated behind dams can bind and adsorb contaminants that when remobilized after the removal of a dam have the potential to adversely affect aquatic organisms including the eggs, larvae, and juvenile stages of finfish, filter feeders, and other sedentary aquatic organisms (Heinz Center 2002). For example, a reduction in macroinvertebrate abundance, diatom richness, and algal biomass has been attributed to the downstream transport of fine sediments previously stored within a dam impoundment (Thomson et al. 2005). However, as fine sediment loads are reduced and replaced by coarser materials in the streambed, macroinvertebrate and finfish assemblages should recover from the disturbance (Thomson et al. 2005). Dam removal can impact overall water quality during and after the demolition phase, although these are typically temporary effects that generally do not result in chronic water quality degradation (Nechvatal and Granata 2004; Thomson et al. 2005).

### *Flow pattern alteration*

Dam removal generally changes downstream conditions by increasing the water and sediment discharges which tend to decrease channel gradients and increase stream depths and widths (Heinz Center 2002). In addition, flood events may increase; reactivate the floodplain; and reconnect side channels, islands, bars, and beaches. Reconnecting and increasing the active floodplain may help reduce low flow conditions in a river. Removal of a dam restores the natural timing of peak and low flows, which have important consequences for the biological components of the ecosystem. For example, seed production among native trees and spawning migrations of anadromous fish species often coincides with peak flows in the spring (Heinz Center 2002).

### *Loss of benthic and sessile invertebrates*

As discussed above, remobilized sediments after the removal of a dam have the potential to adversely affect aquatic organisms including benthic and sessile invertebrates. However, although water quality often is degraded immediately following removal, the abundance and diversity of aquatic invertebrates should increase as the sediment budget and hydrology of the river approaches a natural equilibrium (Heinz Center 2002).

## *Alteration of wetlands*

Lowering the water level will alter the wetland structure upstream of the old dam site and the associated wildlife assemblage. Lowering of impoundments can result in the alteration of existing wetlands (Nislow et al. 2002). As water levels recede, fringing wetlands may be lost while new wetlands are formed along the new riparian border. Newly exposed stream banks may need armoring or other erosion control methods to protect them. The history of the project, geomorphology of the watershed, and location in the river system, among other factors, will dictate the types of environmental issues dam removal will present. Geomorphic effects of downstream sediment transport may have long-term implications (Pizzuto 2002). However, many of these impacts are short-term, dissipating with time as the river system comes to a natural equilibrium (Bushaw-Newton et al. 2002; Thomson et al. 2005).

## *Conservation measures and best management practices for dam removal (adapted from Hanson et al. 2003)*

1. Conduct a comprehensive evaluation of the historic and existing hydrology, hydraulics, and sediment transport prior to the decision to remove a dam to assess possible adverse and cumulative effects of the removal of the structure on the watershed. Dam removal assessments should adopt a watershed scale of analysis.
2. Conduct an assessment of the biotic component of the effected area, particularly if anadromous fish restoration is one of the objectives of the dam removal. For example, the assessment may include characterization of the historic distribution and abundance of fish species, their various life history habitat requirements, and their limiting environmental factors. The assessment should also evaluate the predicted physical and chemical conditions following dam removal to determine if additional restoration may be necessary.
3. Conduct sufficient testing to evaluate the type, extent, and level of contamination upstream of the dam prior to the decision to remove a dam. Contaminated sediments, if extensively present, may require mechanical or hydraulic removal prior to the removal of the dam.
4. Conduct sufficient evaluation of the streambed within the impoundment to plan for any necessary streambed modifications.
5. Consider the possible necessity for removal of the dam in stages to control the release of sediments, if sediments are expected to be released downstream.
6. Schedule dam removal during the less sensitive time of year for aquatic resources, particularly outside the expected migratory period. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
7. Plan for revegetating the newly exposed stream bank with native vegetation.
8. Establish a contingency plan in the event that the stream channel needs modification (addition of riffle and pool complex, added features to create habitat complexity, meanders, etc.) to facilitate fish passage and habitat functions.
9. Establish a monitoring protocol to evaluate success of the restoration for fish passage and utilization.
10. Conduct outreach to the public to provide an understanding of the benefits of dam removal.

# Stream Crossings

Stream crossings are characterized as any structure providing access over a stream, river, or other water body for transportation purposes (e.g., roads, utilities). The feasibility of effective fish passage at stream crossings may be complex. Land ownership, utility crossing, flood protection for low-lying properties, and safety along the transportation corridor must be considered. Unfortunately, many transportation corridors interact and interfere with fisheries corridors (i.e., streams and rivers). These transportation corridors require structures for crossing rivers, streams, and other water bodies. If improperly designed, stream crossings can alter, degrade, fragment or eliminate aquatic habitat and potentially impede, or eliminate, passage for resident and migratory species (Evans and Johnston 1980; Belford and Gould 1989; Clancy and Reichmuth 1990; Furniss et al. 1991; USGAO 2001; Jackson 2003). Until recently, the primary concerns related to designing these structures were cost, designed load capacity, and hydraulics. Furthermore, common practice for repairing deficient structures often resulted in maintaining inadequate stream crossing conditions (e.g., "slip-lining" with smaller diameter pipe, lining of culvert with concrete, or replacing the structure in-kind).

Some American states and Canadian provinces have recognized the concerns relating to fish passage and stream crossings. For example, the Maine Department of Transportation and Commonwealth of Massachusetts Riverways Program, among others, have independently published guidelines for addressing fish passage at stream crossings (MEDOT 2004; MRP 2005). These and similar documents provide extensive information regarding fish and aquatic organism passage, habitat continuity, and wildlife passage requirements for environmentally-sound and safe transportation across streams, rivers, and other waterbodies.

The construction, maintainance, and operation of roadways at stream crossings can also affect aquatic habitats by increasing rates of erosion, debris slides or landslides and sedimentation, introduction of exotic species, and degradation of water quality (Furniss et al. 1991; Hanson et al. 2003). However, the focus of this chapter is the design and operation of the fish passage structure. Refer to the Coastal Development chapter in this report for information pertaining to impacts associated with roadways and vehicular traffic at stream crossings.

## *Impacts to fish passage*

Improperly designed stream crossings can block fish and aquatic organism passage in a variety of ways, including: (1) perched culverts constructed with the bottom of the structure above the level of the stream effectively act as a dam and physically block passage; and (2) hydraulic barriers to passage are created by undersized culverts which constrict the flow and create excessive water velocities (Evans and Johnston 1980; Belford and Gould 1989; Furniss et al. 1991; Jackson 2003). Smooth-bore liners made from high density plastic help meet the goal of passing water and protecting roadways from flooding, but they greatly increase flow velocities through the passage. Conversely, oversized culverts with large, flat bottom surfaces reduce water depth. Insufficient water depths may also be another hydraulic impediment to passage (Haro et al. 2004). In situations where water velocities are not physically limiting and water depths are sufficient, the impediments to passage may be a lack of resting pools. Many stream crossings, particularly longer culverts, are placed over wide stretches of river. Fish may not be capable of burst speeds and sustained swimming throughout the length of the crossing. Under such conditions, migrating fish are unable to reach spawning habitat.

### *Alteration of hydrologic regimes*

Undersized and/or improperly placed stream crossings can also affect water quality. Undersized structures can act as dams, impounding water and increasing water temperature. In extreme cases, if flows are sufficiently reduced and the impounded area deep enough, increased surface temperatures can create thermal stratification and reduce dissolved oxygen. In addition, as water flows through the structure the temperature of the water can rise, affecting aquatic organisms downstream. Undersized culverts can also cause flooding upstream of the crossing, affecting upland and riparian habitat.

### *Conservation measures and best management practices for stream crossings*

1. Design stream crossings for the target finfish species and various age classes. Other aquatic species, such as amphibians, reptiles, and mammals, should also be considered in the designs, as they play a role in healthy ecosystems.
2. Design structures to provide safe and timely passage to minimize injury and limit excessive predation.
3. Design and install new structures in a manner not to interfere with fish and aquatic organism passage and that complies with all applicable regulations.
4. Design structures to provide sufficient water depth and maintain suitable water velocities for target species during the migration season. Consider seasonal headwater and tailwater levels and how variations in them could affect passage of all aquatic life stages. Design considerations may include constructing a low flow channel, weir structure, energy dissipation pools, and designing structures for bank full width.
5. Consider the presence of nonnative, invasive aquatic species in fish passage design for stream crossings, particularly where the crossing may present an existing barrier to passage.
6. Design the structure to maintain or replicate natural stream channel and flow conditions to the greatest extent practicable. An open bottom arch or bridge is preferred. The structure should be able to pass peak flows in accordance with state and federal regulations. Ensure sufficient hydrologic data have been collected.
7. Bury culverts and pipes sufficiently to replicate a natural streambed. Doing so will also provide habitat functions, such as resting pools and reduced water velocities for longer structures.
8. Match the gradient of the stream crossing with the natural stream channel grade. Perched culverts should be removed, wherever practicable.
9. Maintain or stabilize upstream and downstream channel and bank conditions if the stream crossing structure causes erosion or accretion problems. Use of native vegetation should be required for erosion control and sediment stabilization.
10. Ensure the location and overall design of the fish passage structure and the stream crossing are compatible with local stream conditions and stream geomorphology.
11. Ensure that materials for the fish passage structure are nontoxic to fish and other aquatic organisms. Pressure treated lumber should be avoided.
12. Develop construction design and methods for repairing and replacing stream crossings that take into account fish passage requirements.
13. Conduct in-water construction activities during a time of year that would have the least environmental impacts to aquatic species (e.g., low flow seasons). Temporary diversions and coffer dams may be suitable alternatives with proper planning. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

14. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in the review process for stream crossing projects.

## Water Withdrawal and Diversion

Freshwater is becoming limited because of natural events (e.g., droughts), increasing commercial and residential demand of potable water, and inefficient use. Freshwater is diverted for human use from groundwater, lakes, and riverine environments or is stored in impoundments. The withdrawal or impoundment of water can alter natural current and sedimentation patterns, water quality, water temperature, and associated biotic communities (NEFMC 1998). Natural freshwater flows are subject to alteration through water diversion and use and modifications to the watershed such as deforestation, dams, tidal restrictions, and stream channelization (Boesch et al. 1997). Water withdrawal for freshwater drinking supply, power plant cooling systems, and irrigation occurs along urban and agricultural areas and may have potentially detrimental effects on aquatic habitats. Increased water diversion is associated with human population growth and development (Gregory and Bisson 1997). Water diversion is not only associated with water withdrawal and impoundment, but it also represents water discharges, which alter the flow and velocity and have associated water quality issues (Hanson et al. 2003). Water withdrawal in freshwater systems can also affect the health of estuarine systems. Refer to the Physical Effects: Water Intake and Discharge Facilities and Coastal Development chapters for additional information on the affects of water withdrawal on estuarine systems.

The effects of water withdrawal and diversion on freshwater fishery habitat can include: (1) entrainment and impingement; (2) impaired fish passage; (3) alteration of flow and flow rates, and processes associated with proper flows; (4) degradation of water quality (e.g., water temperature, dissolved oxygen) associated with proper water depth, drainage, and sedimentation patterns; (5) loss and/or degradation of riparian habitat; and (6) loss of prey and forage.

### *Entrainment and impingement*

The diversion of water for power plant cooling and other reservoirs results in entrainment and impingement of invertebrates and fishes (especially early life-history stages of fish) (NEFMC 1998). Fish and invertebrate populations may be adversely affected by adding this source of mortality to the early life stage which often determines recruitment and strength of the year-class. Important habitat for aquatic organisms around water intakes may become unavailable for recruitment and settlement (Travnichek et al. 1993).

### *Impaired fish passage and altered hydrologic regimes*

Water diversion and the withdrawal or discharge of water can result in a physical barrier to fish passage (Spence et al. 1996). Excessive water withdrawal can greatly reduce the usable river channel. Rapid reductions or increases in water flow, associated with dam operations for example, can greatly affect fish migratory patterns. Depending on the timing of reduced flows, fish can become stranded within the stream channel, in pools, or just below the river in an estuary system.

### *Water quality degradation*

The release of water with poor quality (e.g., altered temperatures, low dissolved oxygen, and the presence of toxins) affects migration and migrating behavior. The discharge of irrigation water into a freshwater system can degrade aquatic habitat (NRC 1996) by altering currents, water quality, water temperature, depth, and drainage and sedimentation patterns. Both water quantity and quality can greatly affect the usable zone of passage within a channel (Haro et al. 2004). Altered temperature regimes have the ability to affect the distribution; growth rates; survival; migration patterns; egg maturation and incubation success; competitive ability; and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003). In freshwater habitats of the northeastern United States, the temperature regimes of cold-water fish such as salmon, smelt, and trout may be exceeded leading to extirpation of the species in an area. Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005).

### *Release of contaminants*

Irrigation discharges are often associated with contaminants and toxic materials (e.g., metals, pesticides, fertilizers, salts, and nutrients) and possibly introduced pathogens, all of which stress the habitat and aquatic organisms (USEPA 2003). Studies evaluating pesticides in runoff and streams generally find that concentrations can be relatively high near the application site and soon after application but are significantly reduced further downstream and with time (USEPA 2003). However, some pesticides used in the past (e.g., dichlorodiphenyl trichloroethane [DDT]) are known to persist in the environment for years after application.

Soil transported from irrigated croplands and rangelands usually contains a higher percentage of fine and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides and herbicides (Duda 1985; USEPA 2003). In addition, irrigation water has a natural base load of dissolved mineral salts, and return flows convey the salt to the receiving streams or groundwater reservoirs. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that aquatic functions are impaired. However, if the process of water diversion and the return flow of saline drainage water is repeated many times along a stream or river, downstream habitat quality can become progressively degraded (USEPA 2003).

### *Siltation and sedimentation*

Water diversions can alter sediment and nutrient transport processes (Christie et al. 1993; Fajen and Layzer 1993), which can hinder benthic processes and communities. Suspended sediments in aquatic environments can reduce the availability of sunlight to aquatic plants, interfere with filtering capacity of filter feeders, and clog and harm the gills of fish (USEPA 2003). Increased suspended sediments may degrade or eliminate spawning and rearing habitats, impede feeding, negatively affect the food sources of fishes, severely alter the aquatic food web, and thus negatively affect the growth and survival of diadromous fish. Fine sediments are potentially detrimental to Atlantic salmon development and survival during all life stages. For example, sediments can fill interstitial spaces, embedding the substrate and preventing oxygenated water from reaching the incubating eggs within redds and inhibiting the removal of waste metabolites; eliminate refuge utilized by fry and parr to avoid predators; create a homogeneous environment which can lead to lower fish densities; reduce macroinvertebrate abundance; and decrease the depth and area of pools utilized by juveniles and adults (Danie et al. 1984; Fay et al. 2006). In addition, Breitburg (1988) found the predation rates of striped bass larvae on copepods to decrease by 40% when exposed to high turbidity conditions in the laboratory.

### *Loss of wetlands and flood storage*

Healthy riparian corridors are well vegetated, support abundant prey items, maintain nutrient fluxes, provide LWD that creates channel structure and cover for fish, and provide shade, which controls stream temperatures (Bilby and Ward 1991; Hanson et al. 2003). Riparian wetland vegetation can be affected by long-term or frequent changes in water levels caused by water withdrawals and diversions. Removal of riparian vegetation can impact fish habitat by reducing cover and shade, by reducing water temperature fluctuations, and by affecting the overall stability of water quality characteristics (Christie et al. 1993). As river and stream water levels recede because of withdrawals, fringing wetlands may be lost and armoring or other erosion control methods may be needed to protect newly exposed stream banks. The results are less refuge for fish, fundamental changes in channel structure (e.g., loss of pool habitats), instability of stream banks, and alteration of nutrient and prey sources within the river system (Hanson et al. 2003). The changes to the natural habitat caused by irrigation water discharges can potentially lead to large-scale aquatic community changes. Changes in flow patterns may affect the availability of prey and forage species. In conjunction with anthropogenic watershed changes, water diversions and associated riparian impacts have been associated with the increase in some harmful algal blooms (Boesch et al. 1997), which further impact an array of aquatic habitat characteristics. Lost wetlands correlate to a loss of floodplain and flood storage capacity, and thus a reduced ability to act as flood control during storm events.

For additional information on water diversion impacts, refer to the Physical Affects: Water Intake and Discharge Facilities, Chemical Affects: Water Discharge Facilities, and Agriculture and Silviculture chapters in this report.

### *Conservation measures and best management practices for water withdrawal/ diversion (adapted from Hanson et al. 2003)*

1. Design projects to create flow conditions adequate to provide for passage, water quality, proper timing for all life history stages, and avoidance of juvenile stranding and redd (i.e., spawning nest) dewatering, as well as to maintain and restore properly functioning channel, floodplain, riparian, and estuarine conditions.
2. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
3. Establish adequate instream flow conditions for anadromous fish.
4. Design intakes with minimal flows to prevent impingement/entrainment (e.g., ≤0.5 feet per second).
5. Screen water diversions on fish-bearing streams, as needed.
6. Design thermal discharges such that ambient stream temperatures are maintained or a zone of passage is provided to maintain suitable temperatures for fish passage.
7. Incorporate juvenile and adult fish passage facilities on all water diversion projects.
8. Whenever possible, contaminants and sediments should be removed from water discharge prior to entering rivers and other aquatic habitats.
9. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in water withdrawal project review processes.

## Dredging and Filling

The dredging and filling of riparian and freshwater wetlands directly remove potentially important habitat and alter the habitat surrounding the developed area. Expansion of navigable waterways is associated with economic growth and development and generally adversely affects benthic and water-column habitats. Routine dredging is required to maintain the desirable depth as the created channel fills with sediment. Direct removal of riverine habitat from dredge and fill activities may be one of the biggest threats to riverine habitats and anadromous species (NEFMC 1998).

Dredge and fill activities in riverine and riparian habitats can affect fisheries habitat in a number of ways, including: (1) reducing the ability of the wetland to retain floodwater; (2) reducing the uptake and release of nutrients; (3) decreasing the amount of detrital food source, an important food source for aquatic invertebrates (Mitsch and Gosselink 1993); (4) converting habitats by altering water depth or the substrate type (i.e., substrate conversion); (5) removing aquatic vegetation and preventing natural revegetation; (6) hindering physiological processes to aquatic organisms (e.g., photosynthesis, respiration) caused by increased turbidity and sedimentation (Arruda et al. 1983; Cloern 1987; Dennison 1987; Barr 1993; Benfield and Minello 1996; Nightingale and Simenstad 2001); (7) directly eliminating sessile or semimobile aquatic organisms via entrainment or smothering (Larson and Moehl 1990; McGraw and Armstrong 1990; Barr 1993; Newall et al. 1998); (8) altering water quality parameters (i.e., temperature, oxygen concentration, and turbidity); (9) releasing contaminants such as petroleum products, metals, and nutrients (USEPA 2000); (10) reducing dissolved oxygen through reduced photosynthesis and through chemical processes associated with the release of reactive compounds in the sediment (Nightingale and Simenstad 2001).

Filling wetlands removes productive habitat and eliminates the important functions that both aquatic and many terrestrial organisms depend upon. For example, the loss of wetland habitats reduces the production of detritus, an important food source for aquatic invertebrates; alters the uptake and release of nutrients to and from adjacent aquatic and terrestrial systems; reduces wetland vegetation, an important source of food for fish, invertebrates, and water fowl; hinders physiological processes in aquatic organisms (e.g., photosynthesis, respiration) because of degraded water quality and increased turbidity and sedimentation; alters hydrological dynamics, including flood control and groundwater recharge; reduces filtration and absorption of pollutants from uplands; and alters atmospheric functions, such as nitrogen and oxygen cycles (Mitsch and Gosselink 1993).

### *Flood storage capacity*

Impervious surfaces decrease the capacity of a watershed to absorb pulses of freshwater input (e.g., heavy rain, snowmelt). Similarly, stormwater drain systems decrease the storage by directing water directly into a nearby wetland or river system. The rate and volume of stormwater runoff from land into rivers and streams is greater in watersheds with high percentages of impervious surface cover and extensive drainage systems, which reduce the stormwater storage capacity (American Rivers 2002). Measurable adverse changes in the physical and chemical environment were observed when the impervious cover exceeded 10-20% of the land cover (Holland et al. 2004). Flashy, high-velocity pattern of flows and associated pulse of contaminants from upland sources can have long-term, cumulative impacts on freshwater wetlands and riverine, estuarine, and marine ecosystems. As development continues throughout the region, the ability to minimize loss of flood storage capacity and mitigate consequences of increasing coverage of impervious surfaces will be significant planning issues (American Rivers 2002). Refer to the Coastal Development chapter for additional information on stormwater runoff and nonpoint source pollution.

Impacts associated with dredging and filling of aquatic habitats and wetlands are discussed in greater detail in the Offshore Dredging and Disposal Activities, Marine Transportation, and Coastal Development chapters of this report.

### *Conservation measures and best management practices for dredging and filling (adapted from Hanson et al. 2003)*

1. Avoid the filling of wetlands and riparian habitat whenever possible. Ensure proposed dredge and fill projects in wetlands are water-dependent.
2. Utilize best management practices (BMPs) to limit and control the amount and extent of turbidity and sedimentation. Standard BMPs may include constructing silt fences, coffer dams, and operational modification (e.g., hydraulic dredge rather than mechanical dredge).
3. Require the use of multiple-season biological sampling data (both pre- and post-construction) when appropriate to assess the potential and resultant impacts on habitat and aquatic organisms.
4. Test sediment compatibility for open-water disposal per the US Environmental Protection Agency (US EPA) and US Army Corps of Engineers requirements for inshore and offshore, unconfined disposal.
5. Plan dredging and filling activities to avoid submerged aquatic vegetation and special aquatic sites. This may include the placement of pipes for hydraulic dredging and anchoring of barges and other vessels associated with the dredging project.
6. Design the dredge footprint to avoid littoral zone habitat, and appropriate buffers should be in place to protect these areas from wind driven waves and boat wakes.
7. Schedule dredging activities when the fewest species and least vulnerable life stages are present. Appropriate work windows can be established based on the multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
8. Reference all dredging projects in a geographical information system (GIS) compatible format for long-term evaluation.
9. Identify sources of sedimentation within the watershed that may exacerbate repetitious maintenance activities. Implement appropriate management techniques to control these sources.
10. Address cumulative impacts of past, present, and foreseeable future dredging operations on aquatic habitats by considering them in the review process.

## Mining

Most modern mining operations in the northeast US region involve bulk mineral commodities (aggregates such as sand, gravel, and crushed stone), but the region has a long history of mineral mining for mica, feldspar, copper, iron, gold, silver, and coal, as well as peat (Lepage et al. 1991; Boudette 2005; VADMME 2007). While some mineral mining continues in this region, many operations have ceased entirely (Lepage 1991). Some of these abandoned mines have become a source of groundwater or surface water contamination and have been identified by the US EPA's Superfund Program (USEPA 2007) and other nonfederal programs for cleanup. Currently, the US EPA Superfund Program lists cleanup sites on the Susquehanna River in Pennsylvania from coal mining and tributaries leading to East Penobscot Bay in Maine and the Connecticut River in Vermont from copper and other metal mining.

Few active mining sites in the northeast US region currently affect fishery resources as they generally are not located adjacent to or in rivers that support didromous fish. In addition, because access for diadromous fish to historic spawning grounds has been adversely affected by dams and poor water quality throughout the region (Moring 2005), the potential adverse effects of mining operations on these species have been reduced in recent times. Nonetheless, some sand and gravel extraction projects occur within rivers and their tributaries of the northeast US region. Although limited information is available on this subject, it appears the number of active sand and gravel operations that may adversely affect diadromous fish in the northeast US region is relatively small compared to other regions of the United States. However, considering the potential direct and indirect effects from historic and current mining activities on long-term water quality and health of diadromous species, a brief discussion on this topic is warranted in this section.

Mining within riverine habitats may result in direct and indirect chemical, biological, and physical impacts to habitats within the mining site and surrounding areas during all stages of operations (NEFMC 1998). On-site mining activities include exploration, site preparation, mining and milling, waste management, decommissioning and reclamation, and abandonment. Mining operations often occur in urban settings or around existing or historic mining sites; however, mining in remote settings where human activity has caused little disruption and aquatic resources are most productive may cause significant impacts (NRC 1999). Existing state and federal regulations have been established to restrict various environmental impacts associated with mining operations. However, the nature of mining will always result in some alteration of habitat and natural resources (NRC 1999).

Some of the impacts associated with the extraction of material from within or near a stream or river bed include: (1) disruption of preexisting balance between sediment supply and transporting capacity, leading to channel incision and bed degradation; (2) increased suspended sediment, sediment transport, turbidity, and gravel siltation; (3) alteration in the morphology of the channel and decreased channel stability; (4) direct impacts to fish spawning and nesting habitats (redds), juveniles, and prey items; (5) alteration of the channel hydraulics during high flows caused by material stockpiled or left abandoned; (6) removal of instream roughness, including LWD; (7) reduced groundwater elevations and stream flows caused by dry pit or wet pit mining; and (8) destruction of the riparian zone during extraction operations (Pearce 1994; Packer et al. 2005). In addition, structures used in mining extraction and transportation often cause additional impacts to wetland and riverine habitats (Starnes and Gasper 1996). Other impacts include fragmentation and conversion of habitat, alteration of temperature regimes, reduction in oxygen concentration, and the release of toxic materials.

### *Mineral mining*

Although there is a long history of mining in the northeast region of the United States, few active mineral mining operations remain that are located in or adjacent to streams or rivers in this region, and even fewer mineral mining operations occur in streams and rivers utilized by diadromous fish. Nonetheless, mineral mining has occurred in the northeast US region in the past, as evidenced by a number of completed and ongoing remediation sites in areas that have supported or historically supported diadromous fish (USEPA 2007). A brief discussion on the potential impacts to aquatic habitats is provided below.

The effects of mineral mining on riverine habitat depend on the type, extent, duration, and location of the mining activity. Surface mining typically involves suction dredging, hydraulic mining, panning, sluicing, strip mining, and open-pit mining. Surface mining has a greater potential impact on riverine habitat than does underground or shaft mining, depending on other aspects of the mining activities, including processing and degree of disturbance (Spence et al. 1996; Hanson et al. 2003). Elimination of vegetation, topographic alterations, alteration of soil and subsurface geological structure and alteration of surface and groundwater hydrologic regimes are potential effects of surface mining (Starnes and Gasper 1996). Soil erosion and sediment runoff may be the greatest impact of surface mining, contributing a greater sediment load per area of disturbance compared with other activities because of the degree of soil, topographic, and vegetation disturbance (Nelson et al. 1991).

### *Sand and gravel mining*

Sand and gravel are the most valuable and extensively exploited nonfuel mineral resources in the eastern US region and are mined in all states from Virginia to Maine (Bolen 2007). According to Starnes and Gasper (1996), sand and gravel extraction is the least regulated of all mining industries, and approximately 80% of this resource is extracted under jurisdiction of state and local laws only. These authors state that sand and gravel mining is "widely used in large US rivers and can increase the sediment bed load through resuspension, physically eliminate benthic organisms, and destroy fish spawning and nursery areas, all of which ultimately change aquatic community composition" (Starnes and Gasper 1996); however, they do not identify specific rivers that are affected or state whether the rivers support diadromous fish species. The Virginia Department of Mines, Minerals and Energy states, "Sand and gravel are extracted from coastal sand pits, river terraces or dredged from the rivers themselves" (VADMME 2007). In 2005, over 15,000 tons of sand were mined from two operations along the Roanoke River in Virginia (VADMME 2007). In addition, a dredge and fill permit was granted by the US Army Corps of Engineers to allow sand extraction in the St. John River, ME, for use in road sanding operations (USACE 2005). Although sand and gravel mining may not be a significant threat to diadromous fish in the northeast US region at this time, at least some activity is currently taking place, and any increase in activity represents potential future threat.

Gravel and sand mining operations can involve wet-pit mining (i.e., removal of material below the water table); dry pit mining on beaches, exposed bars, and ephemeral streambeds; or subtidal mining. Impacts associated with sand and gravel mining in riverine environments are similar to mineral mining impacts and include: turbidity plumes and resuspension of sediment and nutrients, removal of spawning habitat, and alteration of stream channel morphology. These physical perturbations often lead to alteration of migration patterns, physical and thermal barriers to upstream and downstream migration, increased fluctuation in water temperature, decrease in dissolved oxygen, high mortality of early life stages, increased susceptibility to predation, and loss of suitable habitat (Packer et al. 2005). For information pertaining to impacts associated with mining and dredging in marine habitats refer to the chapter on Offshore Dredging and Disposal Activities.

### *Peat mining*

Peat is mined in the United States primarily for horticultural and industrial purposes, including a filtration medium to remove toxic materials and a fuel/oil absorbent (Jasinski 2007). Peat mining occurs in a number of states in the northeast US region, although at relatively small scales. In Maine, at least one peat mining operation exists in the Narraguagus River watershed, which burns mixtures of peat and wood chips to generate electricity (Lepage et al. 1991; USFWS and NMFS 1999).

The impacts associated with peat mining include the release of contaminants (i.e., peat fiber, arsenic residues, and other toxic chemicals), siltation, increased stormwater runoff from roads and other unvegetated areas, and altered hydraulic flow regimes (NEFMC 1998; USFWS and NMFS 1999). Peat mining has been associated with acidic conditions in eastern Maine watersheds, such as Narraguagus River, and has been identified as a potential contributor to Atlantic salmon declines (USFWS and NMFS 1999).

### *Alteration of stream bed and stream morphology*

Surface mining can alter channel morphology by making the stream channel wider and shallower and removing the natural sediment load. Consequently, the suitability of stream reaches as rearing habitat may decrease, especially during summer low-flow periods when deeper waters are important for survival. Gravel bar skimming or "scalping," which involves the removal of the surface from gravel bars without excavating below the low water flow level, can significantly impact aquatic habitat (Packer et al. 2005). Bar skimming creates a wide, flat cross section in the stream channel, which eliminates confinement of the low flow channel. A reduction in pool frequency may adversely affect migrating adults that require holding pools (Spence et al. 1996). Changes in the frequency and extent of bedload movement and increased erosion and turbidity can also remove spawning substrates, scour redds, result in a direct loss of eggs and young, or reduce their quality by deposition of increased amounts of fine sediments. These changes can affect the early life stages of Atlantic salmon, which exhibit an affinity for specific habitat types (Fitzsimons et al. 1999; Hedger et al. 2005). Extraction of sand and gravel in riverine ecosystems can directly eliminate the amount of gravel available for spawning if the extraction rate exceeds the deposition rate of new gravel in the system. Gravel excavation also reduces the supply of gravel to downstream habitats. The extent of suitable spawning habitat may be reduced where degradation reduces gravel depth or exposes bedrock (Spence et al. 1996). Associated with stream morphology alterations are resultant increased temperatures from a reduction in summer base flows; altered width to depth ratios; decreased riparian vegetation; decreased dissolved oxygen concentration as water temperatures increase; decreased nutrients from loss of floodplain connection and riparian vegetation; and decreased food production (e.g., loss of invertebrate prey populations) (Spence et al. 1996).

### *Sedimentation and siltation*

Sedimentation effects of mining may be immediate or delayed. During gravel extraction, for example, fine material can travel long distances downstream in the form of turbidity plumes. Silt can also be released during peat mining operations (USFWS and NMFS 1999). Sedimentation may be a delayed effect because gravel removal typically occurs at low flow when the stream has the least capacity to transport fine sediments out of the system. Increased sedimentation results when the spring freshet inundates an extraction area that is less stable than before mining operations. The extent and duration of sedimentation and siltation is likely to be higher than normal as unstable sediment washes freely into the system during higher rates of flow, acting as a migratory barrier to anadromous fish, such as Atlantic salmon, and increasing entrainment of sediment in downstream habitat. The result can be a degradation or loss of spawning and rearing habitat within the system (Spence et al. 1996).

### *Release of contaminants*

Peat mining can negatively impact diadromous fish, including Atlantic salmon, from the discharge of low pH water containing peat silt and dissolved metals and pesticides (USFWS and NMFS 1999). However, only one peat mining operation has been identified on the Narraguagus

River in Maine, and monitoring efforts at the site suggests that impacts are being controlled (USFWS and NMFS 1999).

Although current mineral mining operations in the northeast region of the United States are not a significant threat to rivers supporting diadromous fish, the effects of historic mining operations continue to be remediated (USEPA 2007). Harmful or toxic materials can be released directly from mining operations, including processing and machinery. Mining can introduce high levels of metals, sulfuric acid, mercury, cyanide, arsenic, and processing reagents into waterways. Water pollution by metals and acids is associated with mineral mining because ores, rich in sulfides, are commonly mined to extract gold, silver, copper, zinc, and lead (NRC 1999). In combination with anoxic conditions, sulfur-containing sediments can create additional levels of toxicity in addition to acid conditions (Brouwer and Murphy 1995). The improper handling or discharge of tailings and settling ponds can result in a direct loss of living aquatic resources as a result of decreased water quality and increased concentration levels of toxic substances. Locating settling ponds in unstable or landslide prone upland sites makes them prone to dangerous, instantaneous releases of large quantities of toxins. Groundwater and surface water may be incidentally contaminated by leaching of toxic substances from upland settling ponds.

### *Conservation measures and best management practices for mining (adapted from Hanson et al. 2003 and Packer et al. 2005)*

1. Use upland aggregate sources before beginning any mining activities in active channels or floodplains.
2. Avoid mining operations in rivers and streams identified as important migratory pathways, spawning, and nursery habitat for anadromous fish.
3. Conduct a thorough assessment and characterization of aquatic resources, sediments, and potential sources of point and nonpoint contaminants prior to gravel removal.
4. Design, manage, and monitor sand and gravel mining operations to minimize potential direct and indirect impacts to riverine habitat if operations cannot be avoided. This includes, but is not limited to, migratory corridors, foraging and spawning areas, and stream/river banks.
5. Minimize the spatial extent and the depth of mine extraction operation to the maximum extent practicable.
6. Schedule necessary in-water activities when the fewest species and least vulnerable life stages are present. Seasonal restrictions should be used to avoid impacts to habitat during species critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
7. Identify upland or off-channel (where channel will not be captured) gravel extraction sites as alternatives to gravel mining in or adjacent to rivers and streams identified as important pathways for anadromous fish, if possible.
8. Utilize best management practices to avoid spills of dirt, fuel, oil, toxic materials, and other contaminants. Prepare a spill prevention plan and maintain appropriate spill containment and water repellent/oil absorbent cleanup materials on the project location.
9. Treat wastewater (e.g., acid neutralization, sulfide precipitation, reverse osmosis, electrochemical, or biological treatments) and recycle onsite to minimize discharge to streams. Treat wastewater before discharge for compliance with state and federal clean water standards.
10. Reclaim mining wastes that contain contaminants such as metal, acids, arsenic, or other substances if leachate could enter aquatic habitats through surface or groundwater.

11. Use best management practices to minimize opportunities for sediment to enter streams and waterways. Methods such as contouring, mulching, silt curtains, and settling ponds should be part of the operations plan. Monitor turbidity during operations and alter operations if turbidity levels reach or exceed a predetermined level.
12. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in mining project review processes.

# Emerging Issues for Freshwater Systems

## *Endocrine disruptors, pharmaceuticals, and nanoparticles*

Growing concerns have mounted in response to the effects of endocrine-disrupting chemicals on humans, fish, and wildlife (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). One of the sources of endocrine disrupting compound is the effluent of residential and commercial wastewater treatment facilities, as well as agricultural runoff (USGS 2002). Some of the chemicals shown to be estrogenic include polychlorinated biphenyl (PCB), dieldrin, DDT, phthalates, and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture and may be present in irrigation water. Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Refer to the Chemical Effects: Water Discharge Facilities chapter for more information on endocrine disruptors. In addition to endocrine disrupting compounds, recent studies have found municipal wastewater effluent entering streams and rivers containing human and veterinary pharmaceuticals, including antibiotics and natural and synethetic hormones (USGS 2002).

Other recent concerns are the release of substances referred to as nanoparticles into the aquatic environment. Nanoparticles, such as fullerenes (e.g., 60-carbon molecules often referred to as "buckyballs") may have great potential for use in the pharmaceutical, lubricant, and semiconductor industries, as well as applications in energy conversion. However, the micro-fine particulate waste generated from the production and use of nanoparticles may adversely affect the distribution, feeding, ecology, respiration, and nutrient regeneration of microorganisms, such as bacterivorous and herbivorous protozoa, protists, and phagotrophic or mixotrophic microalgae (Colvin 2003).

## *Harmful algal blooms*

Impervious surfaces and stormwater drain systems can increase the rate and volume of stormwater runoff into rivers and streams. This direct flushing of water generates large pulses of runoff into rivers and streams, carrying with it nutrients and a wide-range of pollutants that flow into estuaries and coastal areas. Nutrient-rich waters have been associated with harmful algal blooms (HABs), which can deplete the oxygen in the water during bacterial degradation of algal tissue and can result in hypoxic or anoxic "dead zones" and large-scale fish kills in rivers, estuaries, and coastal areas (Deegan and Buchsbaum 2005; MDDNR 2007). For example, HABs have been responsible for fish kills in the freshwater portions of the Potomac River in Virginia and the Corsica River in Maryland, as well as in the Potomac and Chesapeake Bay estuaries (MDDNR 2007). HABs affecting Gulf of Maine waters have resulted in shellfish bed closures and mortalities to endangered marine mammals (NOAA 2008; WHOI 2008). While the causes of HABs in coastal waters of New England are unclear, large pulses of freshwater rivers and streams in the region as a result of elevated rainfall and snowmelt in the spring are being examined as contributing factors in creating conditions favorable for algal growth (NOAA 2008). Refer to the Coastal Development and Introduced/Nuisance Species and Aquaculture chapters for more information on HABs.

### *Introduced and nusiance species*

Introductions of nonnative nuisance species are a significant threat to freshwater and coastal ecosystems in the United States (Carlton 2001). Nonnative species may be released intentionally (i.e., fish stocking and pest control programs) or unintentionally during industrial shipping activities (e.g., ballast water releases), aquaculture operations, recreational boating, biotechnology, or from aquarium discharge (Hanson et al. 2003; Niimi 2004). For example, increased competition for food sources between the invasive exotic zebra mussel (*Dreissena polymorpha*) and open-water commercial and recreational species have altered the trophic structure in the Hudson River estuary, NY, by withdrawing large quantities of phytoplankton and zooplankton from the water column, thus increasing competition with planktivorous fish (Strayer et al. 2004). Refer to the Introduced/Nuisance Species and Aquaculture chapter for information on introduced and nuisance species.

## References for Alteration of Freshwater Systems

Abbe TB, Montgomery DR. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers-Research and Management 12(2-3):201-21.

American Rivers, Natural Resources Defense Council, Smart Growth America. 2002. Paving our way to water shortages: how sprawl aggravates the effects of drought. [Internet]. Washington (DC): Smart Growth America. [cited 2007 Dec 21]. 31 p. Available from: http://www.smartgrowthamerica.org/waterandsprawl.html.

Arruda JA, Marzolf GR, Faulk RT. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. Ecology 64(5):1225-35.

Babbitt B. 2002. What goes up, may come down: learning from our experiences with dam construction in the past can guide and improve dam removal in the future. BioScience 52(8):656-8.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Belford DA, Gould WR. 1989. An evaluation of trout passage through six highway culverts in Montana. North American Journal of Fisheries Management 9(4):437-45.

Benfield MC, Minello TJ. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fishes 46:211-6.

Beschta RL, Bilby RE, Brown GW, Holtby LB, Hofstra TD. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo EO, Cundy TW, editors. Streamside management: forestry and fishery interactions. Seattle (WA): University of Washington, College of Forest Resources. p 191-232.

Bilby RE, Ward JW. 1991. Characteristics and function of large woody debris in streams draining old-growth, clearcut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48:2499-508.

Bodi FL, Erdheim E. 1986. Swimming upstream: FERC's failure to protect anadromous fish. Ecology Law Quarterly 13(1):7-50.

Boesch DF, Anderson DM, Horner RA, Shumway SE, Tester PA, Whitledge TE. 1997. Harmful algal blooms in coastal waters: options for prevention, control and mitigation. Silver Spring (MD): NOAA Coastal Ocean Office. NOAA Coastal Ocean Program Decision Analysis Series No. 10. 46 p. + appendix.

Bolen W. 2007. Sand and Gravel, Construction. US Geological Survey Minerals Yearbook-2005. [Internet]. US Department of the Interior, US Geological Survey. [updated 2008 May 19; cited 2008 Jul 15]. 21 p. Available from:

http://minerals.usgs.gov/minerals/pubs/commodity/sand_&_gravel_construction/sandgmyb05.pdf.

Boudette EL. 2005. Gold in New Hampshire. [Internet]. Concord (NH): New Hampshire Department of Environmental Services. Environmental Fact Sheet CO-GEO-1. [cited 2008 Jul 15]. 4 p. Available from: http://www.des.state.nh.us/factsheets/geo/geo-1.htm.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Brouwer H, Murphy T. 1995. Volatile sulfides and their toxicity in freshwater sediments. Environmental Toxicology and Chemistry 14 (2):203-8.

Buchsbaum R. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Bushaw-Newton KL, Hart DD, Pizzuto JE, Thomson JR, Egan J, Ashley JT, Johnson TE, Horwitz RJ, Keeley M, Lawrence J, and others. 2002. An integrative approach towards understanding ecological responses to dam removal: the Manatawny Creek study. Journal of the American Water Resources Association 38 (6):1581-99.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chabreck RA. 1988. Coastal marshes: ecology and wildlife management. Minneapolis (MN): University of Minnesota Press. 138 p.

Christie RW, Allen DE, Jobsis GJ. 1993. Diversions. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 181-186.

Clancy CG, Reichmuth DR. 1990. A detachable fishway for steep culverts. North American Journal of Fisheries Management 10(2):244-6.

Cloern JE. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7(11-12):1367-81.

Collins BD, Montgomery DR, Haas AD. 2002. Historical changes in the distribution and functions of large wood in Puget lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences 59:66-76.

Collins BD, Montgomery DR, Sheikh AJ. 2003. Reconstructing the historic riverine landscape of the Puget lowland. In: Bolton S, Montgomery DR, Booth D, Wall L, editors. Restoration of Puget Sound rivers. Seattle (WA): University of Washington Press. p 79-128.

Colvin VL. 2003. The potential environmental impact of engineered nanomaterials. Nature Biotechnology 21:1166-70.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: a region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Danie DS, Trial JG, Stanley JG. 1984. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (North Atlantic)-Atlantic salmon. Washington (DC): US Fish and Wildlife Service, FWS/OBS-82/11.22 and the US Army Corps of Engineers, TR EL-82-4. 19 p.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dennison WC. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany 27(1):15-26.

De Laney TA. 1995. Benefits to downstream flood attenuation and water quality as a result of constructed wetlands in agricultural landscapes. Journal of Soil and Water Conservation 50:620-6.

Duda AM. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Water Resources Bulletin 21(2):225-34.

Evans WA, Johnston B. 1980. Fish migration and fish passage: a practical guide to solving fish passage problems. Washington (DC): US Department of Agriculture, Forest Service. 163 p.

Fajen OF, Layzer JB. 1993. Agricultural practices. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 257-67.

Fay C, Bartron M, Craig S, Hecht A, Pruden J, Saunders R, Sheehan T, Trial J. 2006. Status review for anadromous Atlantic salmon (*Salmo salar*) in the United States. [Internet]. Report to the National Marine Fisheries Service and US Fish and Wildlife Service. [cited 2008 Jul 15]. 294 p. Available from: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsalmon.pdf.

Fitzsimons JD, Fodor G, Williston B, Carl L, Gentile T. 1999. Spawning habitat selection and suitability for Atlantic salmon. In: IAGLR '99. The 42nd Conference of the International Association for Great Lakes Research: Great Lakes, Great Science, Great Cities; 1999 May 24-28; Cleveland (OH): Case Western Reserve University. p A32-3.

Fletcher R. 2003. Loss of wetlands: how are bird communities affected? [Internet]. American Institute of Biological Sciences, c2000-2007. [cited 2007 Dec 21]. Available from: http://www.actionbioscience.org/environment/fletcher.html.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 297-323.

Graf WL. 1993. Landscapes, commodities, and ecosystems: the relationship between policy and science for American rivers. In: Sustaining our water resources (1993) Commission on geosciences, environment and resources (CGER). Washington (DC): National Academy Press. p 11-42.

Gregory SV, Bisson PA. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In: Stouder DJ, Bisson PA, Naiman RJ, editors. Pacific Salmon and their ecosystems: status and future options. New York (NY): Chapman and Hall. p 277-314.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Haro A, Castro-Santos T, Noreika J, Odeh M. 2004. Swimming performance of upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fisheries and Aquatic Sciences 61(9):1590-601.

Hedger RD, Dodson JJ, Bergeron NE, Caron F. 2005. Habitat selection by juvenile Atlantic salmon: the interaction between physical habitat and abundance. Journal of Fish Biology 67:1054-71.

Heinz Center. 2002. Dam removal: science and decision making. Washington (DC): The H. John Heinz III Center for Science, Economics, and the Environment. 236 p.

Holland AF, Sanger DM, Gawle CP, Lerberg SB, Santiago MS, Riekerk GHM, Zimmerman LE, Scott GI. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298(2):151-78.

Howard-Williams C. 1985. Cycling and retention of nitrogen and phosphorus in wetlands: theoretical and applied perspective. Freshwater Biology 15(4):391-431.

Jackson SD. 2003. Design and construction of aquatic organism passage at road-stream crossings: ecological considerations in the design of river and stream crossings. In: Irwin CL, Garrett P, McDermott KP, editors. 2003 Proceedings of the International Conference on Ecology and Transportation; 2003 Aug 24-29; Lake Placid, NY. Raleigh (NC): Center for Transportation and the Environment: North Carolina State University. p 20-9.

Jasinski SM. 2007. USGS Minerals Yearbook: peat. [Internet]. US Department of the Interior, US Geological Survey. [cited 2008 Jul 15]. 6 p. Available from: http://minerals.usgs.gov/minerals/pubs/commodity/peat/myb1-2006-peat.pdf.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Kerry J, Boorse D, Buchsbaum R. 2004. Effect of nutrient enrichment and salinity on salt marsh invertebrates in the Plum Island Estuary. Biological Bulletin 207:174.

Larinier M. 2001. Environmental issues, dams and fish migration. In: Dams, fish and fisheries: opportunities, challenges and conflict resolution. Rome (Italy): FAO Fisheries Technical Paper No. 419. p 45-89.

Larson K, Moehl CE. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): Washington Sea Grant, University of Washington. p 102-12.

Lepage CA, Foley ME, Thompson WB. 1991. Mining in Maine: past, present, and future. [Internet]. Augusta (ME): Maine Geological Survey. Open-File 91-7. [updated 2005 Oct 6; cited 2007 Dec 21]. 11 p. Available from: http://www.maine.gov/doc/nrimc/mgs/explore/mining/minemaine.htm.

[MEDOT] Maine Department of Transportation. 2004. Fish passage policy and design guide. 2nd ed. [Internet]. Augusta (ME): Maine Department of Transportation. 80 p. [updated 2005 Jan 3; cited 2007 Dec 21]. Available from: http://www.maine.gov/mdot-stage/environmental-office-homepage/documents.

[MDDNR] Maryland Department of Natural Resources. 2007. Harmful algae blooms in Maryland. [Internet]. [cited 2007 Dec 21]. Five articles available from: http://www.dnr.state.md.us/bay/hab/index.html.

Maser C, Sedell JR. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. Delray Beach (FL): St. Lucie Press. 200 p.

[MRP] Massachusetts Riverways Program. 2005. Massachusetts stream crossings handbook. [Internet]. Boston (MA): Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Department of Fish and Game. [cited 2007 Dec 21]. Available from: http://www.mass.gov/dfwele/river/programs/rivercontinuity/guidancedoc.htm.

McGraw K, Armstrong D. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): University of Washington Sea Grant. p 113-31.

Mitsch WJ, Gosselink JG. 1993. Wetlands. 2nd ed. New York (NY): Van Nostrand Reinhold. 722 p.

Montgomery DR, Smith RD, Schmidt KM, Pess GR. 1995. Pool spacing in forest channels. Water

Resources Research 31(4):1097-105.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

Morita K, Yamomoto S. 2002. Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations. Conservation Biology 16(5):1318-23.

Morita K, Yokota A. 2002. Population viability of stream-resident salmonids after habitat fragmentation: a case study with white-spotted charr (*Salvelinus leucomaenis*) by an individual based model. Ecological Modelling 155:85-94.

Naiman RJ, editor. 1992. Watershed management: balancing sustainability and environmental change. New York (NY): Springer-Verlag New York. 542 p.

[NOAA] National Oceanic and Atmopheric Administration. 2008. Worst New England Harmful Algal Bloom in 30 Years. [Internet]. Silver Spring (MD): NOAA; Center for Sponsored Coastal Ocean Research (CSCOR). [updated 2008 May 14; cited 2008 Sep 22]. Available from: http://www.cop.noaa.gov/news/fs/ne_hab_200505.html.

[NRC] National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. Washington (DC): National Academy Press. 452 p.

[NRC] National Research Council. 1999. Hardrock mining on federal lands. Appendix B. Potential environmental impacts of hardrock mining. Washington (DC): National Academy Press. p 149-168.

Nechvatal M, Granata T. 2004. Dam removal as a solution to increase river water quality. In: Self sustaining solutions for streams, wetlands, and watersheds; 2004 Sep 12-15; St. Paul, MN. St. Joseph (MI): American Society of Agricultural and Biological Engineers.

Nelson RL, McHenry M, Platts WS. 1991. Mining. In: Meehan WR, editor. Influences of forest and rangeland management in salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 425-58.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol 1.

Nightingale B, Simenstad CA Jr. 2001. Dredging activities: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 15]. 119 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finaldrg.pdf.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Nislow KH, Magilligan FJ, Fassnacht H, Bechtel D. 2002. Effects of dam impoundment on the flood regime of natural floodplain communities in the upper Connecticut River. Journal of the American Water Resources Association 38(6):1533-48.

Ormerod SJ. 2003. Current issues with fish and fisheries: editor's overview and introduction. Journal of Applied Ecology 40(2):204-13.

[PFMC] Pacific Fisheries Management Council. 1999. Appendix A: identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Amendment 14 to the Pacific Coast Salmon Plan. [Internet]. Portland (OR). [updated 2007 May 8; cited 2007 Dec 21]. Available from: http://www.pcouncil.org/salmon/salfmp/a14.html.

Packer DB, Griffin K, McGlynn KE. 2005. National Marine Fisheries Service national gravel extraction guidance. [Internet]. Washington (DC): US Department of Commerce. [Internet]. NOAA Technical Memorandum NMFS-F/SPO-70. [cited 2008 Jul 15]. 27 p. Available from: http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm.

Parrish DL, Behnke RJ, Gephard SR, McCormick SD, Reeves GH. 1998. Why aren't there more Atlantic salmon (*Salmo salar*)? Canadian Journal of Fisheries and Aquatic Sciences 55(Suppl. 1):281-7.

Pearce JB. 1994. Mining of seabed aggregates. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 48-50.

Pizzuto J. 2002. Effects of dam removal on river form and process. BioScience 52(8):683-91.

Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE, Stromberg JC. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47:769-84.

Raymond HL. 1979. Effects of dams and impoundments on migrations of juvenile Chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-29.

Ruggles CP. 1980. A review of the downstream migration of Atlantic salmon. Halifax (Nova Scotia): Freshwater and Anadromous Division, Resource Branch, Department of Fisheries and Oceans. Canadian Technical Report of the Fisheries and Aquatic Sciences No. 952. ix + 39 p.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Starnes LB, Gasper DC. 1996. Effects of surface mining on aquatic resources in North America. Fisheries 21(5):24-6.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Thomson JR, Hart DD, Charles DF, Nightengale TL, Winter DM. 2005. Effects of removal of a small dam on downstream macro invertebrate and algal assemblages in a Pennsylvania stream. Journal of the North American Benthological Society 24(1):192-207.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

[USACE] US Army Corps of Engineers. 2005. Maine programmatic general permit no. NAE-2005-584 (2005 Jul 5). Concord (MA): Army Corps of Engineers, New England District.

[USEPA] US Environmental Protection Agency. 2000. Environmental screening checklist and workbook for the water transportation industry. Washington (DC): US EPA Office of Water. EPA-305-B-00-004.

[USEPA] US Environmental Protection Agency. 2003. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 15]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2007. US EPA Superfund Program. [Internet]. [updated 2007 Dec 18; cited 2007 Dec 21]. Available from: http://www.epa.gov/superfund/index.htm.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. p 1-131.

[USGAO] US General Accounting Office. 2001. Restoring fish passage through culverts on Forest Service and BLM lands in Oregon and Washington could take decades. Washington (DC): US GAO. GAO-02-136. 29 p.

[USGS] US Geological Survey. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams. [Internet]. Reston (VA): US Geological Survey. USGS Fact Sheet FS-027-02. [cited 2008 Jul 15]. 2 p. Available from: http://toxics.usgs.gov/pubs/FS-027-02/pdf/FS-027-02.pdf.

[VADMME] Virginia Department of Mines, Minerals, and Energy. 2007. Mineral Resources. [Internet]. Richmond (VA): VADMME. [cited 2007 Dec 28]. Fourteen articles available from: http://geology.state.va.us/DMR3/Mineralresources.shtml.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Wilson WJ, Gallaway BJ. 1997. Synthesis in applied fish ecology: twenty years of studies on effects of causeway development on fish populations in the Prudhoe Bay Region, Alaska. American Fisheries Society Symposium 19:326-39.

[WHOI] Woods Hole Oceanographic Institute. 2008. Northeast PSP, New England harmful algal bloom/red tide information. [Internet]. Woods Hole (MA): WHOI. [updated 2008 May 30; cited 2008 Sep 22]. Available from: http://www.whoi.edu/northeastpsp/.

Zwick P. 1992. Stream habitat fragmentation-a threat to biodiversity. Biodiversity and Conservation 1:80-97.

# CHAPTER FIVE: MARINE TRANSPORTATION

## Introduction

The demand for increased capacity of marine transportation vessels, facilities, and infrastructure is a global trend that is expected to continue in the future. This demand is fueled by a need to accommodate growing vessel operations for cargo handling activities and human population growth in coastal areas. As coastal areas continue to grow, there is a concomitant increase in the demand for water transportation services and recreational opportunities.

It is also important to note that coastal areas under high developmental pressure are often located adjacent to productive and sensitive aquatic environments. Historically, human settlements in the northeastern United States were probably established on the basis of availability to food resources and marine transportation. Coastal features such as estuaries and embayments satisfied these needs as they are highly productive ecosystems ideal for fishing, farming, or hunting and are sheltered waters that provide access to rivers and the ocean for transportation purposes. Today, urban growth and development in coastal areas are growing at a rate approximately five times that of other areas of the country and over one-half of all Americans live within 50 miles of the coast (Markham 2006). The continued demand on the coast today is likely attributed to the highly desirable aesthetic quality and recreational opportunities, including access to fishing, beaches, and boating.

The expansion of port facilities, vessel operations, and commercial and recreational marinas can have adverse impacts on fishery habitat. The growth of the marine transportation industry is accompanied by land-use changes, including over-water or in-water construction, filling of aquatic habitat and wetlands, and increased maintenance activities. Although some categories of habitat impacts resulting from activities related to port and marina construction and maintenance and vessel operations may be minimal and site specific, the cumulative effects of these activities over time can have substantial impacts on habitat.

The construction of new ports and marinas typically involves the removal of sediments by dredging from intertidal and subtidal habitats in order to create navigational channels, turning basins, anchorages, and berthing docks for the size and types of vessels expected to use the facilities. For existing ports and marinas, dredging is generally conducted on a routine basis in order to maintain the required depths as sediment is transported and deposited into the channels, basins, anchorages, and docks. The construction of new ports and marinas, or the expansion of existing facilities, is often referred to as "improvement" dredging; whereas, dredging existing ports and marinas in order to maintain an assigned or authorized depth is generally referred to as "maintenance" dredging. Because the chemical, physical, and biological impacts associated with both "improvement" and "maintenance" dredging are similar in nature, both types of dredging are discussed in the Navigation Dredging section of this chapter. Other impacts associated with newly constructed and expanded ports and marinas are covered under the Construction and Expansion of Ports and Marinas section of this chapter.

## Construction and Expansion of Ports and Marinas

Construction of ports and marinas can change physical and chemical habitat parameters such as tidal prism, depth, water temperature, salinity, wave energy, sediment transport, and current velocity. Alterations to physical characteristics of the coastal ecosystems can cause adverse effects to biological parameters, such as the composition, distribution, and abundance of shellfish and submerged aquatic vegetation (SAV). These changes can impact the distribution of nearshore habitats and affect aquatic food webs.

### Loss and conversion of habitat

Port and marina facilities are typically located in areas containing highly productive intertidal and subtidal habitats, including saltmarsh wetlands and SAV. Coastal wetlands provide a number of important ecological functions, including foraging, spawning/breeding, protection from predators, as well as nutrient uptake and release and retention of storm and floodwaters. Vegetated wetlands and intertidal habitats are some of the most highly productive ecosystems in the world, and support one or more life stages of important commercial and recreational fishery resources in the United States (Dahl 2006). One of the most obvious habitat impacts related to the construction of a port or marina facility is alteration or loss of physical space taken up by the structures required for such a facility. The construction of ports and marinas can alter or replace salt marsh, SAV, and intertidal mud flat habitat with "hardened" structures such as concrete bulkheads and jetties that provide relatively few ecological functions. Boston Harbor, MA, exemplifies a northeastern coastal port transformed by expansive dredging and filling of former shallow estuarine waters and salt marsh wetlands. Between 1775 and 1980, wetland filling within the harbor extensively altered the shoreline, with the airport alone amounting to 2,000 acres of filled intertidal salt marsh wetlands (Deegan and Bushbaum 2005).

Over-water structures, such as commercial and residential piers and docks, floating breakwaters, barges, rafts, booms, and mooring buoys are associated with port and marina facilities and are constructed over both subtidal and intertidal habitats. Although they generally have less direct physical contact with benthic habitats than in-water structures, float, raft, and barge groundings at low tides and the scouring of the substrate by the structures and anchor chains can be substantial. Piles and other in-water structures can alter the substrate below and adjacent to the structures by providing a surface for encrusting communities of mussels and other sessile organisms, which can create shell deposits and shift the biota normally associated with sand, gravel, mud, and eelgrass substrates to those communities associated with shell hash substrates (Penttila and Doty 1990; Nightingale and Simenstad 2001a).

Shoreline armoring is an in-water activity associated with the construction and operation of marinas and ports, intended to protect inland structures from storm and flood events and to prevent erosion that is often a result of increased boat traffic. Armoring of shorelines to prevent erosion and maintain or create shoreline development simplifies habitats, reduces the amount of intertidal habitat, and affects nearshore processes and the distribution of aquatic communities (Williams and Thom 2001). Hydraulic effect alterations to the shoreline include increased energy seaward of the armoring from reflected wave energy, which can exacerbate erosion by coarsening the substrate and altering sediment transport (Williams and Thom 2001). Installation of breakwaters and jetties can also result in community changes, including burial or removal of resident biota, changes in cover, preferred prey species, predator interaction, and the movement of larvae (Williams and Thom 2001). Chapman (2003) found a paucity of mobile species associated with seawalls in a tropical estuary, compared with surrounding areas.

### Altered light regimes and loss of submerged aquatic vegetation

Alteration of the light regimes in coastal waters can affect primary production, including the distribution and density of SAV, as well as the feeding and migratory behavior of fish. Over-water structures shade the surface of the water and attenuate the sunlight available to the benthic habitat under and adjacent to the structures. The height, width, construction materials used, and the orientation of the structure in relation to the sun can influence how large a shade footprint an over-water structure may produce and how much of an adverse impact that shading effect may have on the localized habitat (Fresh et al. 1995; Burdick and Short 1999; Shafer 1999; Fresh et al. 2001). High, narrow piers and docks produce more diffuse shadows which have been shown to reduce shading impacts to SAV (Burdick and Short 1999; Shafer 1999).

The density of pilings can also determine the amount of light attenuation created by dock structures. Piling density is often higher in larger, commercial shipping ports than in smaller recreational marinas, as larger vessels and structures often require a greater number of support structures such as fenders and dolphin piles. Light limitations caused by pilings can be reduced through adequate spacing of the pilings and the use of light reflecting materials (Thom and Shreffler 1996; Nightingale and Simenstad 2001a). In addition, piers constructed over solid structures, such as breakwaters or wooden cribs, would further limit light transmittance and increase shading impacts on SAV.

Although shading impacts are greatest directly under a structure, the impacts on SAV may extend to areas adjacent to the structure as shadows from changing light conditions and adjacent boats or docks create light limitations (Burdick and Short 1999; Smith and Mezich 1999). A decrease in SAV and primary productivity can impact the nearshore food web, alter the distribution of invertebrates and fish, and reduce the abundance of prey organisms and phytoplankton in the vicinity of the over-water structure (Kahler et al. 2000; Nightingale and Simenstad 2001a; Haas et al. 2002).

The sharp light contrasts created by over-water structures because of shading during the day and artificial lighting at night can alter the feeding, schooling, predator avoidance, and migratory behaviors of fish (Nightingale and Simenstad 2001a; Hanson et al. 2003). Fish, especially juveniles and larvae, rely on visual cues for these behaviors. Shadows create a light-dark interface which may increase predation by ambush predators and increase starvation through limited feeding ability (Able et al. 1999; Hanson et al. 2003). In addition, the migratory behavior of some species may favor deeper waters away from shaded areas during the day and lighted areas may affect migratory movements at night, contributing to increased risk of predation (Nightingale and Simenstad 2001a).

### *Altered temperature regimes*

Shoreline modifications, including the construction of seawalls and bulkheads, can alter nearshore temperature regimes and natural communities. Modified shorelines invariably contain less shoreline vegetation than do natural shorelines, which can reduce shading in the nearshore intertidal zone and cause increases in water temperatures (Williams and Thom 2001). Conversely, seawalls and bulkheads constructed along north facing shorelines may unnaturally reduce light levels and reduce water temperatures in the water column adjacent to the structures (Williams and Thom 2001).

### *Siltation, sedimentation, and turbidity*

The construction of a new port or marina facility is usually associated with profound changes in land use and in-water activities. Because a large proportion of the shoreline associated with a port is typically replaced with impervious surfaces such as concrete and asphalt, stormwater runoff is exacerbated and can increase the siltation and sedimentation loads in estuarine and marine habitats. The upland activities related to building roads and buildings may cause erosion of topsoil which can be transported through stormwater runoff to the nearshore aquatic environment, increasing sedimentation and burying benthic organisms. Construction and expansion of ports and marinas generally include dredging channels, anchorages, and berthing areas for larger and greater numbers of vessels, which contribute to localized sedimentation and turbidity. In addition, the use of underwater explosives to construct bulkheads, seawalls, and concrete docks may temporarily resuspend sediments and cause excessive turbidity in the water column and impact benthic organisms. Refer to the section on Navigation Dredging later in this chapter for information on channel dredging.

Impacts associated with increased suspended particles in the water column include high turbidity levels, reduced light transmittance, and sedimentation which may lead to reductions or loss of SAV and other benthic habitats. Elevated suspended particles have also been shown to adversely affect the respiration of fish, reduce filtering efficiencies and respiration of invertebrates, reduce egg buoyancy, disrupt ichthyoplankton development, reduce the growth and survival of filter feeders, and decrease the foraging efficiency of sight-feeders (Messieh et al. 1991; Barr 1993).

Structures such as jetties and groins may be constructed to reduce the accretion of sediment in navigable channels, so by design they alter littoral sediment transport and change sedimentation rates. These structures may reduce sand transport, cause beach and shoreline erosion to down drift areas, and may also interfere with the dispersal of larvae and eggs along the coastline (Williams and Thom 2001). Substrate disturbance from pile driving and removal can increase turbidity, interfere with fish respiration, and smother benthic organisms in adjacent areas (Mulvihill et al. 1980). In addition, contaminants in the disturbed sediments may be resuspended into the water column, exposing aquatic organisms to potentially harmful compounds (Wilbur and Pentony 1999; USEPA 2000; Nightingale and Simenstad 2001b). Refer to the Coastal Development chapter for a more detailed discussion on impacts related to pile driving and removal.

### *Contaminant releases*

The construction of ports and marinas can alter natural currents and tidal flushing and may exacerbate poor water quality conditions by decreasing water circulation. Bulkheads, jetties, docks, and pilings can create water traps that accumulate contaminants or nutrients washed in from land based sources, vessels, and facility structures. These conditions may create areas of low dissolved oxygen, dinoflagellate blooms, and elevated toxins.

Contaminants can be released directly into the water during construction activities associated with new ports and marinas or indirectly through storm water runoff from land-based operations. Accidental and incidental spills of petroleum products and other contaminants, such as paint, degreaser, detergents, and solvents, can occur during construction operations of a facility. Large amounts of impervious surfaces at ports and marinas can increase, and in some cases direct, stormwater runoff and contaminants into aquatic habitats. The use of certain types of underwater explosives to construct bulkheads, seawalls, and concrete docks may release toxic chemicals (e.g., ammonia) in the water column that can impact aquatic organisms.

Wood pilings and docks used in marina and port construction are often treated with chemicals such as chromated copper arsenate, ammoniacal copper zinc, and creosote to help extend the service of the structures in the marine environment. These preservatives can leach harmful chemicals into the water that have been shown to produce toxic affects on fish and other organisms (Weis et al. 1991). Creosote-treated wood for pilings and docks has also been used in marine environments and has been shown to release polycyclic aromatic hydrocarbons (PAH) continuously and for long periods of time after installation or treatment; whereas other chemicals that are applied to the wood, such as ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA), tend to leach into the environment for shorter durations (Poston 2001). Affects from exposure of aquatic organisms to PAH include carcinogenesis, phototoxicity, immunotoxicity, and disturbance of hormone regulation (Poston 2001). The rate and duration that these preservatives can be leached into marine waters after installation are highly variable and dependent on many factors, including the length of time since the treatment of the wood and the type of compounds used in the preservatives. The toxic effects of metals such as copper on fish are well known and include body lesions, damage to gill tissue, and interrupted cellular functions (Gould et al. 1994). These chemicals can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). The presence of CCA in the food chain may cause localized reductions in species richness and diversity (Weis and Weis 2002). Concrete, steel, or nontreated wood are relatively inert and generally do not leach contaminants into the water.

Dredging and filling of intertidal and subtidal habitats can resuspend sediments into the water column that may have been contaminated by nearby industrial activities. Information on contaminant releases from dredging can be found in the Navigation Dredging section of this chapter and the Chemical Effects: Water Discharge Facilities chapter of the report.

### *Altered tidal, current, and hydrologic regimes*

One of the primary functions of a marina or port is to shelter and protect boats from wave energy. In-water structures of ports and marinas such as bulkheads, breakwaters, jetties, and piles result in localized changes to tidal and current patterns. These alterations may exacerbate poor water quality conditions in these facilities by reducing water circulation. In addition, in-water structures interfere with longshore sediment transport processes resulting in altered substrate amalgamation, bathymetry, and geomorphology. Changing the type and distribution of sediment may alter key plant and animal assemblages, starve nearshore detrital-based foodwebs, and disrupt the natural processes that build spits and beaches (Nightingale and Simenstad 2001a; Hanson et al. 2003).

The protected, low energy nature of marinas and ports may alter fish behavior as juvenile fish show an affinity to structure and may congregate around breakwaters or bulkheads (Nightingale and Simenstad 2001a). These alterations in behavior may make them more susceptible to predation and may interfere with normal migratory movements.

### *Underwater blasting and noise*

Noise from underwater blasting and in-water construction generates intense underwater sound pressure waves that may adversely affect marine organisms. These pressure waves have been shown to injure and kill fish (Caltrans 2001; Longmuir and Lively 2001; Stotz and Colby 2001). Fish are known to use sound for prey and predator detection as well as social interaction (Richard 1968; Myrberg 1972; Myrberg and Riggio 1985; Hawkins 1986; Kalmijn 1988), and underwater blasting and noise may alter the their distribution and behavior (Feist et al.1996).

Generally, aquatic organisms that possess air cavities (i.e., lungs and swim bladders) are more susceptible to underwater blasts than those without (Keevin et al. 1999). In addition, smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and the eggs and embryos tend to be particularly sensitive; however, fish larvae tend to be less sensitive to blasts than eggs or post-larvae fish, probably because the larvae stages do not yet possess air bladders (Wright 1982; Keevin et al. 1999).

Blasting may be used for dredging new navigation channels and boat basins or expanding existing channels in areas containing rock substrates, boulders, and ledges. The construction of new in-water structures, such as bulkheads, seawalls, and concrete docks also may involve blasting. Blasting represents a single point of disturbance with a restricted, and often predictable, mortality zone. In addition, blasting engineers purposefully focus the blast energy towards fracturing rock substrate and prevent excess energy from being released into the water column (Keevin et al. 1999). Techniques used to prevent blasting damage to structures in the vicinity of a project, such as bubble curtains, may be effective mitigation measures for reducing blasting impacts on aquatic biota (Keevin et al. 1999). Although the use of bubble curtains have been shown to be effective at minimizing pressure wave impacts on fish (Keevin et al. 1997; Longmuir and Lively 2001), the difficulty of deploying bubble curtains in field conditions may reduce the efficacy of this technology in mitigating these effects (Keevin et al. 1997).

Unlike blasting, pile driving is a repeating sound disturbance that can last for extended periods of time during construction. There are several factors which affect the type and intensity of sound pressure waves during pile driving, including the size and material of the piling, the firmness of the substrate, and the type of pile-driving hammer that is used (Hanson et al. 2003). Wood and concrete piles produce lower sound pressures than do steel piles. Pile driving in firmer substrate, which requires more energy, will produce more intense sound pressures (Hanson et al. 2003). Both impact hammers and vibratory hammers are commonly used when driving pilings into the substrate. Vibratory hammers produce sounds with more energy in the lower frequencies (15-26 Hz), compared to higher frequency noise generated by impact hammers (100-800 Hz) (Carlson et al. 2001). The behavioral response elicited by fish differs in these two ranges of sound frequencies. Fish respond to sounds similar to vibratory hammers by consistently displaying an avoidance response and not habituating to the sound despite repeated exposure (Dolat 1997; Knudsen et al. 1997; Sand et al. 2000). In contrast to vibratory hammers, fish may be initially startled by an impact hammer but eventually become habituated and no longer respond to the stimuli. Acclimation to the sound may place fish in more danger as they remain in range of potentially harmful sound pressure waves (Dolat 1997). Refer to the chapter on Global Effects and Other Impacts for additional information on underwater noise impacts to aquatic organisms.

### *Conservation recommendations and best management practices for construction and expansion of ports and marinas*

1. Encourage federal, state, and local authorities to assist port authorities and marinas in developing management plans that avoid and minimize impacts to the coastal environment and that are consistent with coastal zone management plans.
2. Encourage implementation of environmental management systems for ports and marinas that incorporate strong operational controls and best management practices (BMPs) into existing job descriptions and work instruction.
3. Encourage marinas to participate in NOAA/US EPA's Coastal Nonpoint Program and the Clean Marina Initiative.
4. Explore alternative port developments such as satellite ports and offshore terminals, which may decrease some impacts associated with traditional inshore port facility developments.
5. Conduct site suitability analyses for new or proposed expansion of port and marina facilities to reduce and avoid habitat degradation or loss. Some of the analyses that should be conducted include identifying alterations to current and circulation patterns, water quality, bathymetric and topographic features, fisheries utilization and species distributions, and substrate features.
6. Conduct pre- and post-project biological surveys over multiple growing seasons to assess impacts on submerged and emergent aquatic vegetation communities.
7. Site new or expansions of port and marina facilities in deep-water areas to the maximum extent practicable to avoid the need for dredging. Areas that are subject to rapid shoaling or erosion will likely require more frequent maintenance dredging and should be avoided.

8. Avoid areas identified as supporting high abundance and diversity of species (e.g., SAV beds, intertidal mudflats, emergent wetlands, fish spawning areas) when locating new or expanded port and marina facilities.
9. Encourage the use of preproject surveys by qualified biologists/botanists to identify and map invasive plants within the proposed project area, and develop and implement an eradication plan for nonnative species.
10. Consider excavating uplands as a less-damaging alternative for new or expanded port and marina facilities instead of dredging intertidal or shallow subtidal habitat. However, water quality modeling should be conducted to evaluate potential impacts associated with enclosed and poorly flushed marinas.
11. Retain and preserve marine riparian buffers to maintain intertidal microclimate, flood and stormwater storage capacity, and nutrient cycle.
12. Consider low-wake vessel technology and appropriate vessel routes in the facility design and permitting process to minimize impacts to shorelines and shallow water habitats. Vessel speeds should be adapted to minimize wake damage to shorelines, and no-wake zones should be considered in highly sensitive areas, such as fish spawning habitat and SAV beds.
13. Do not locate new port and marina facilities in areas that have reduced tidal exchange and/or shallow water habitats, such as enclosed bays, salt ponds, and tidal creeks.
14. Implement construction designs for new ports and marinas to facilitate good tidal exchange and surface water movement and provide an adequate migratory corridor for fish. When possible, structures that impede tidal exchange and that may interfere with the movement of marine organisms, such as solid breakwaters, should be avoided.
15. Ensure that new ports and marinas incorporate BMPs in the construction operation plans that prevent and minimize the release of contaminants and debris caused by construction equipment and activities. The plan should include a spill response plan and training, and spill response equipment should be installed and maintained properly on-site.
16. Implement seasonal restrictions when necessary to avoid construction-related impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods).
17. For structures located over SAV, the amount of light reaching vegetation below the dock should be maximized by providing adequate height over the water, minimizing the width of the dock, and orienting the length of the dock in a north-south direction.
18. The use of wood preservatives, such as creosote, ACZA and CCA should be avoided, where possible. If CCA treated wood must be used, the wood can be presoaked for several weeks or the wood can be coated with plastic sheath to reduce/eliminate leaching. Concrete and steel pilings are generally considered to be less damaging, since they reflect light more than wood docks and generally do not release contaminants into the aquatic environment. However, concrete pilings and docks generally increase the overall size of the overwater structure and may not be preferable in areas containing SAV.
19. Site floating docks, which limit light transmittance more than elevated structures, only in nonvegetated areas. When used, floating docks should either be located in areas of adequate depth so that adequate clearance between the float and the bottom is maintained, or fitted with structures (i.e., float stops) that prevent the float from contacting the bottom. Float stops should be designed to provide a minimum of 2 feet of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
20. Orient night lighting such that illumination of the surrounding waters is avoided.

21. Reduce sound pressure impacts during pile installation by using wood or concrete piles, rather than hollow steel piles which produce intense, sharp spikes of sound that are more damaging to fish.
22. Use technologies that have been designed to reduce the adverse effects of underwater sound pressure waves such as air bubble curtains and metal or fabric sleeves to surround the pile. Air bubble systems must have adequate airflow, and the pile should be fully contained to ensure that sound attenuation is successful.
23. Conduct pile driving during low tides in intertidal and shallow subtidal areas.
24. Employ vibratory hammers when removing old piles to help minimize the release of suspended sediments, silt, and contaminants into the water column; these may be preferable over direct pull or the use of a clamshell dredge.
25. Reduce or eliminate the amount of sediment released into the water column by cutting the pile off below the mudline and leaving the stub in place when removing old piles.
26. Mitigate impacts to marine organisms, particularly those with air cavities (i.e., swim bladders and lungs), from underwater blasting by employing BMPs such as focusing the blast energy towards a solid rock substrate rather than towards the water column; installing noise attenuating devices such as air curtains; conducting the blasting during periods of low-water or low-tide; using delayed blasts that produce sequenced, lesser-charged explosions that reduce the shockwave; stemming (capping) the charge bore hole with material that contains the blast; and repelling charges that frighten fish from the blast area prior to blasting (Keevin 1998).
27. Consult federal and state resource agencies prior to work that involves blasting to assess the marine resource utilization of the area. Biological surveys may be required to assess the presence of fishery resources. Time-of-year restrictions should be employed to avoid impacting sensitive species and life history stages that use the area. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
28. Integrate measures to reduce nonpoint source (NPS) pollution, such as a stormwater management plan into the design, maintenance, and operation of a port or marina. Some examples of BMPs for stormwater management include (adapted from Amaral et al. 2005):
    a. Minimize the amount of impervious surfaces surrounding the port or marina facility and maintain a buffer zone between the coastal zone and upland facilities.
    b. Implement runoff control strategies to decrease the amount of contaminants entering marine waters from upland sources. This can be accomplished by using alternative surface materials such as crushed gravel, decreasing the slope of surfaces towards the waters' edge, and installing filtering systems or settling ponds.
    c. Designate specific enclosed areas for maintenance activities such as sanding, painting, engine repairs. Use tarp enclosures or spray booths for abrasive blasting to prevent residue from reaching surface waters.
    d. Provide and maintain appropriate storage, transfer, containment, and disposal facilities for liquid hazardous material, such as solvents, antifreeze, and paints.
29. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in port and marina review processes.

## Operation and Maintenance of Ports and Marinas

Existing ports and marinas can be a source of impacts to fishery resources and habitat that may differ from those relating to construction and expansion of new facilities. These impacts may be associated with the operation of the facilities, equipment impacts, and stormwater runoff. Examples of port or marina impacts include chronic pollution releases, underwater noise, altered light regimes, and repeated physical disturbances to benthic habitats.

### *Contaminant release and storm water runoff*

Ports and marinas can be a source of contaminants directly associated with facility activities and by stormwater runoff from the facility and the surrounding urbanized areas. The long-term operation of a marina or port can provide a chronic presence of contaminants to the localized area that can have an adverse effect on the quality of fishery habitat and population dynamics (Wilbur and Pentony 1999).

The oil and fuel that accumulates on dock surfaces, facilities properties, adjacent parking lots, and roadways may enter coastal waters through stormwater runoff and snowmelt. Oil and fuel contains PAH and other contaminants that are known to bioaccumulate in marine organisms and impact the marine food web (Nightingale and Simenstad 2001a; Amaral et al. 2005). In addition, these contaminants can persist in bottom sediments where they can be resuspended through a variety of activities such as propeller scouring and dredging. Marina activities such as vessel refueling, engine repair, and accidental vessel sinking may increase the risk of fuel and oil contamination of the surrounding environment (Amaral et al. 2005).

Marina facilities such as storage areas for paint, solvents, detergents, and other chemicals may pose a risk of introducing additional contaminants to the marine environment resulting in both acute and chronic toxicity to marine biota (Amaral et al. 2005). These products are often a routine and essential part of marina or port operations, and if handled and stored improperly they can increase the risk of accidental spillage. Various port and vessel maintenance activities may contribute to metal contamination to the surrounding waters. For example, elevated levels of copper are often associated with ports and marinas, especially those with a high density of recreational boats because of the type of antifouling paints used on those boats. A number of other metals have been detected in the sediments and surface waters of marinas, including arsenic (used in paints and wood preservatives), zinc (leached from anodes used to reduce corrosion of boat hulls and motors), mercury (used in float switches for bilge and other storage tank pumps), lead (used in batteries), nickel, and cadmium (used in brake linings) (USEPA 2001). However, stormwater runoff may be the primary source of copper in most marinas in urban areas (Warnken et al. 2004).

Wooden pilings and docks in marinas and ports are typically treated with some type of preservative, such as chromated copper arsenate, ammoniacal copper zinc, and creosote. These preservatives can leach harmful chemicals into the water that have been shown to have toxic effects on fish and other organisms (Weis et al. 1991). Concrete, steel, or nontreated wood are relatively inert and do not leach contaminants into the water. Refer to this chapter's section on Construction and Expansion of Ports and Marinas and the Coastal Development chapter for more information on the affects of copper and other wood preservatives on aquatic resources.

Because marinas and ports typically contain large areas of impervious surfaces and are located at the interface between land and water, stormwater runoff can be greater at these facilities compared with other types of land uses. The organic particulates that are washed into marine waters from the surrounding surfaces can add nutrients to the water and cause eutrophication in bays and estuaries. A number of sources of organic matter from ports and marinas can degrade water quality and reduce dissolved oxygen concentrations, including sewage discharges from recreational and commercial boats, trash tossed overboard, fish wastes disposed of into surface waters, pet wastes, fertilizers, and food wastes (USEPA 2001). Eutrophication often leads to abnormally high phytoplankton populations, which in turn can reduce the available light to SAV beds. Changes in water quality caused by eutrophication can sometimes have a more severe impact on seagrass populations than shading from over-water structures or physical uprooting by vessel and float groundings (Costa et al. 1992; Burdick and Short 1999).

### Release of debris

Solid waste is another problematic issue associated with port and marina operations. A great deal of solid waste is generated through daily operations of a commercial port as well as the recreational activities of a marina. This waste may include plastics such as fishing line, bottles, tarps, food containers, and shopping bags, or paper products and other materials, which can be released as debris into the surface waters through accidental loss from vessels or through stormwater runoff from upland facilities. Activities such as sanding, pressure washing, sand blasting, and discarding rags and oil/fuel filters can contribute to marine debris if improper handling and disposal is allowed (USEPA 2001). If this waste is collected and disposed of properly the impacts to the environment can be minimized (Amaral et al. 2005). Plastics are a large component of the trash released into marine waters, accounting for 50-60% of marine debris collected from the Gulf of Maine (Hoagland and Kite-Powell 1997). Plastics contain toxic substances that can persist in the environment and bioaccumulate through the food web, impairing metabolic functions in fish and invertebrates that use habitats polluted by plastic debris. Some chemicals found in plastics, known as “endocrine disruptors,” may interfere with the endocrine system of aquatic organisms (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as “environmental hormones” that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts.

Marine debris can directly affect fish and invertebrates that may consume or become entangled by the debris. Plastic debris may be ingested by seabirds, fish and invertebrates, sea turtles, and marine mammals, which can cause infections and death of the animal (Cottingham 1988). Debris can be transported by currents to other areas where it can become snagged and attached to benthic habitat, damaging sensitive reef habitat. Additional information on impacts associated with marine debris can be found under Operation and Maintenance of Vessels section of this chapter and in the Coastal Development chapter of this report.

### Underwater noise

The ambient noises emanating from ports and marinas are from a combination of boat propellers, engines, pumps, generators, and other equipment within vessels and shore-side equipment. In coastal areas the sounds of cargo and tanker traffic are multiplied by complex reflected paths from scattered and reverberated noises caused by littoral geography. Commercial and private fishing boats, pleasure craft, personal watercraft (i.e., jet skis), industrial vessels, public transport ferries, and shipping safety and security services such as tugs boats, pilot boats, enforcement vessels, and coastal agency support craft generate sounds that can impact marine organisms, particularly fish and marine mammals. Exposure to continuous noise may also create a shift in hearing thresholds for marine organisms resulting in hearing losses at certain frequency ranges (Jasny et al. 1999). Refer to the Global Effects and Other Impacts chapter and the Operation and Maintenance of Vessels and the Construction and Expansion of Ports and Marinas sections in this chapter for more information on underwater noise.

### *Derelict structures*

Increased vessel activity in and around port and marina operations increase the probability of the grounding of vessels, which may not always be removed immediately from the aquatic environment. In addition to being public health and navigational hazards, derelict or abandoned vessels can cause various impacts to coastal habitats. Grounded vessels can physically damage and smother benthic habitats, create changes in wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht et al. 2001; Zelo and Helton 2005). However, the most common environmental threat of a derelict or abandoned vessel is the release of oil or other pollutants. These hazardous materials may be part of a vessel's cargo, fuel and oil related to vessel operations, or chemicals contained within the vessel's structure which may be released over time through decay and corrosion. Refer to the Operation and Maintenance of Vessels section of this chapter for more information on impacts associated with derelict structures and grounded vessels.

### *Mooring and floating dock impacts*

Vessel mooring impacts, although localized, can reduce habitat quality and complexity. Accidental vessel groundings can smother or crush shellfish, scour vegetation, and disturb substrates (Nightingale and Simenstad 2001a). Disturbance of substrates can lead to increased turbidity, reduced light penetration, decreased dissolved oxygen levels, and the possible resuspension of contaminants. In addition, moored vessels contacting the bottom during low tides can cause the bottom habitat in the area of the mooring to be unavailable for fish and other marine biota during the time the vessel is resting on the bottom. Vessels that contact the bottom can create scouring of the substrate and result in permanent alteration or loss of benthic habitats, such as eelgrass. Demersal eggs (e.g., Atlantic herring [*Clupea harengus*]) and larvae that utilize an area can also be destroyed from the impact of the vessel or shading. Floating piers and docks may also alter wave energy, current patterns, and longshore sediment transport, especially in areas that experience strong current velocities (Nightingale and Simenstad 2001a).

Depending upon the type and configuration, the mooring tackle itself may cause impacts to substrate and benthos, including SAV. Typical vessel moorings consist of an anchor connected to a surface buoy by a long length of heavy chain. In most moorings, some portion of the anchor chain drags and often scours the bottom and forms a depression in the sediment surface (Walker et al. 1989). In areas influenced strongly by tides and currents or wind, the bottom scouring takes on a circular or "V" configuration when the anchor chain is allowed to drag along the bottom as the vessel or buoy swings with the tide or wind (Nightingale and Simenstad 2001a). The resulting scour holes allow further erosion and loss of the physical integrity of the habitat, which can lead to fragmentation of seagrass meadows (Walker et al. 1989; Hastings et al. 1995). Hastings et al. (1995) attributed an approximate 18% direct loss of seagrass habitat from boat moorings in one bay in Western Australia. Refer to the Coastal Development chapter of this report for a more detailed discussion on impacts from overwater structures.

### *Alteration of light regimes*

As discussed in other sections of this chapter, overwater structures shade the surface of the water and attenuate the light available to benthic habitat under and adjacent to the structures. The height, width, construction materials used, and orientation of the structure in relation to the sun can influence how large a shade footprint an over-water structure may produce and how much of an adverse impact that shading effect may have on the benthic habitat (Burdick and Short 1999; Shafer 1999; Fresh et al. 2001; Nightingale and Simenstad 2001a). Refer to the chapter on Coastal

Development and the Construction and Expansion of Ports and Marinas section of this chapter for more information on docks structures and light attenuation.

### *Conservation recommendations and best management practices for the operation and maintenance of ports and marinas (adapted from Amaral et al. 2005; Hanson et al. 2003)*

1. Consider environmental impacts through port development and operations plans, including:
    a. assess all activities at facility and identify potential environmental impacts
    b. determine compatibility with port environmental practices and assess available control technologies
    c. evaluate and monitor effectiveness of control technologies
    d. develop and implement environmental management
2. Encourage marinas to participate in NOAA/US EPA's Coastal Nonpoint Program and the Clean Marina Initiative.
3. Ensure that marina and port facility operations have an oil spill response plan in place, which has been shown to improve the response and recovery times of oil spills.
4. Ensure that marina or port facilities have adequate oil spill response equipment accessible and clearly marked. Oil spill response equipment may include oil booms, absorbent pads, and oil dispersant chemicals.
5. Use dispersants that remove oils from the environment, rather than those that simply move them from the surface to the ocean bottom.
6. Install automatic shut-off nozzles at fuel dispensing sites and require the use of fuel/air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel oil spilled into surface waters by vessels using fuel stations.
7. Promote the use of oil-absorbing materials in the bilge areas of all boats with inboard engines.
8. Place containment berms around fixed pieces of machinery that use oil and gas within the facility.
9. Encourage public education and signage to promote proper disposal of solid debris and polluting materials.
10. Encourage the proper disposal of materials produced and used by the operation, cleaning, maintenance, and repair of boats to limit the entry of solid and contaminated waste into surface waters.
11. Recommend the placement of garbage containers to supervised areas and use containers that have lids in order to reduce the potential for litter to enter the marine environment.
12. Promote the use of pumpout facilities and restrooms at marinas and ports to reduce the release of sewage into surface waters. Ensure that these facilities are maintained and operational, and provide these services at convenient times, locations, and reasonable cost. In addition, promote the use of these facilities through public education and signage.
13. Develop a harbor management plan which addresses the maintenance and operation of pumpout facilities.
14. Prevent the disposal of fish waste or other nutrient laden material in marina or port basins through the use of public education, signage, and by providing alternate fish waste management practices.
15. Ensure that measures to reduce NPS pollution, such as a stormwater management plan, are integrated into the maintenance and operation of a port or marina.

16. Recommend site-specific solutions to NPS pollution by considering the frequency of marina operations and potential pollution sources. Management practices should be tailored to the specific issues of each marina.
17. Encourage the removal of unnecessary impervious surfaces surrounding the port or marina facility and maintain a buffer zone between the aquatic zone and upland facilities.
18. Ensure that stormwater runoff from parking lots and other impervious surfaces is collected and treated to remove contaminants prior to delivery to any receiving waters. This can be accomplished by using alternative surface materials such as crushed gravel, decreasing the slope of surfaces towards the water's edge, and installing filtering systems or settling ponds.
19. Recommend that specific, enclosed areas are designated for maintenance activities such as sanding, painting, engine repairs. Using tarp enclosures or spray booths for abrasive blasting will also prevent residue from reaching surface waters.
20. Ensure that facilities provide for appropriate storage, transfer, containment, and disposal facilities for harmful liquid material, such as solvents, antifreeze, and paints.
21. Recommend that facilities provide a containment system and a filtering and treatment system for vessel wash down wastewater.
22. Ensure that floating structures, including barges, mooring buoys, and docks are located in adequate water depths to avoid propeller scour and grounding of vessel and floating structures. When floating docks cannot be located in adequate depth to avoid contact on the bottom at low tides, recommend that float stops (structural supports to prevent the float from resting on the bottom) are installed. Float stops should be designed to provide a minimum of 2 feet of clearance between the float and substrate to prevent hydraulic disturbances to the bottom. Greater clearances may be necessary in higher energy environments that experience strong wave action.
23. Recommend anchoring techniques and mooring designs that avoid scouring from anchor chains. For example, anchors that do not require chains (e.g., helical anchors) or moorings that use subsurface floats to prevent anchor chains from dragging the bottom are some designs that should be considered.
24. When moorings with anchor chains cannot be avoided, recommend that areas prone to high current and wind velocity be avoided, where the sweep of the anchor chain on the bottom can cause the greatest damage.
25. Recommend the use of concrete, nontreated wood or steel dock materials to avoid the leaching of contaminants associated with wood preservatives.

## Operation and Maintenance of Vessels

Vessel activity in coastal waters is generally proportional to the degree of urbanization and port and harbor development within a particular area. Benthic, shoreline, and pelagic habitats may be disturbed or altered by vessel use, resulting in a cascade of cumulative impacts in heavy traffic areas (Barr 1993). The severity of boating-induced impacts on coastal habitats may depend on the geomorphology of the impacted area (e.g., water depth, width of channel or tidal creek), the current velocity, the sediment composition, the vegetation type and extent of vegetative cover, as well as the type, intensity, and timing of boat traffic (Yousef 1974; Karaki and vanHoften 1975; Barr 1993). Recreational boating activity mainly occurs during the warmer months which coincide with increased biological activity in east coast estuaries (Stolpe and Moore 1997; Wilbur and Pentony 1999). Similarly, frequently traveled routes such as those traveled by ferries and other transportation vessels can impact fish spawning, migration, and recruitment behaviors through noise and direct disturbance of the water column (Barr 1993).

Other common impacts of vessel activities include vessel wake generation, anchor chain and propeller scour, vessel groundings, the introduction of invasive or nonnative species, and the discharge of contaminants and debris (Hanson et al. 2003).

### *Impacts to benthic habitat*

Vessel operation and maintenance activities can have a wide range of impacts to benthic habitat, ranging from minor (e.g., shading of SAV) to potentially large-scale impacts (e.g., ship groundings and fuel or toxic cargo spills). Direct disturbances to bottom habitat can include propeller scouring and vessel wake impacts on SAV and other sensitive benthic habitats and direct contact by groundings or by resting on the bottom at low tides while moored. Propeller scarring can result in a loss of benthic habitat, decrease productivity, potentially fragment SAV beds, and lead to further erosion and degradation of the habitat (Uhrin and Holmquist 2003). Eriksson et al. (2004) found that boating activities can have direct and indirect impacts on SAV, including drag and tear on plant tissues resulting from increased wave-action, reduction in light availability caused by elevated turbidity and resuspension of bottom sediments, and altered habitat and substrate that causes plants to be uprooted and can inhibit recruitment. The disturbance of sediments and rooted vegetation decreases habitat suitability for fish and shellfish resources and can effect the spatial distribution and abundance of fauna (Nightingale and Simenstad 2001a; Uhrin and Holmquist 2003; Eriksson et al. 2004).

### *Resuspension of bottom sediments/turbidity*

The degree of sediment resuspension and turbidity that is produced in the water column from vessel activity is complex but is generally dependent upon the wave energy and surge produced by the vessel, as well as the size of the sediment particles, the water depth, and the number of vessels passing through an area (Karaki and vanHoften 1975; Barr 1993). These activities typically increase turbidity and sedimentation on SAV and other sensitive benthic habitats (Klein 1997; Barr 1993; Nightingale and Simenstad 2001a; Eriksson et al. 2004). Studies investigating sedimentation impacts on eelgrass have found that experimental burial of 25% of the plant height can result in greater than 50% mortality (Mills and Fonseca 2003). Klein (1997) reported that turbidity generated by boats operating in shallow waters can exceed safe levels by up to 34-fold.

The resuspension of sediments can affect habitat suitability for fish and shellfish resources and effect the spatial distribution and abundance of fauna (Nightingale and Simenstad 2001a; Uhrin and Holmquist 2003; Eriksson et al. 2004). The egg and larval stages of marine and estuarine fish are generally highly sensitive to suspended sediment exposures (Wilber and Clark 2001), and juvenile fish may be susceptible to gill injury when suspended sediment levels are high (Klein 1997). Sedimentation and turbidity impacts associated with boating may be more pronounced in areas that contain shallow water habitat where the bottom is composed of fine sediments (Klein 1997).

### *Shoreline erosion*

Wave energy caused by industrial and recreational shipping and transportation can have substantial impacts on aquatic shoreline and backwater areas which can eventually cause the loss and disturbance of shoreline habitats (Karaki and vanHoften 1975; Barr 1993; Klein 1997). Vessel wakes along frequently traveled routes can cause shoreline erosion, damage aquatic vegetation, disturb substrate, and increase turbidity. Wave energy and surge produced by vessels are dependent upon a number of factors, including the size and configuration of the vessel hull, the size of the vessel, and the speed of the vessel (Karaki and vanHoften 1975; Barr 1993). The degree of erosion on shorelines caused by vessels is complex, but it is generally dependent upon the wave energy and surge produced by the vessel and the slope of the shoreline, the type of sediment (e.g., clay, sand), and the type and amount of shoreline vegetation, as well as the characteristics of the water body (e.g., water depth and bottom topography) and distance between the vessel and shoreline (Karaki and vanHoften 1975; Barr 1993).

### Contaminant spills and discharges

A variety of substances can be discharged or accidentally spilled into the aquatic environment, such as gray water (i.e., sink, laundry effluent), raw sewage, engine cooling water, fuel and oil, vessel exhaust, sloughed bottom paint, boat washdown water, and other vessel maintenance and repair materials that may degrade water quality and contaminate bottom sediments (Cardwell et al. 1980; Cardwell and Koons 1981; Krone et al. 1989; Waite et al. 1991; Hall and Anderson 1999; Hanson et al. 2003).

Industrial shipping and recreational boating can be sources of metals such as arsenic, cadmium, copper, lead, and mercury (Wilbur and Pentony 1999). Metals are known to have toxic effects on marine organisms. For example, laboratory experiments have shown high mortality of Atlantic herring eggs and larvae at copper concentrations of 30 μg/L and 1,000 μg/L, respectively, and impairment of vertical migration for larvae at copper concentrations greater than 300 μg/L (Blaxter 1977). Copper may also bioaccumulate in bacteria and phytoplankton (Milliken and Lee 1990). Metals may enter the water through various vessel maintenance activities such as bottom washing, paint scraping, and application of antifouling paints (Amaral et al. 2005). For example, elevated copper concentrations in the vicinity of shipyards have been associated with vessel maintenance operations such as painting and scraping of boat hulls (Milliken and Lee 1990). Studies have shown a positive relationship between the number of recreational boats in a marina and the copper concentrations in the sediments of that marina (Warnken et al. 2004). Copper and an organotin, called tributyltin (TBT), are common active ingredients in antifouling paints (Milliken and Lee 1990). The use of TBT is primarily used for large industrial vessels to improve the hydrodynamic properties of ship's hulls and fuel consumption, while recreational vessels typically use copper-based antifouling paints because of restrictions introduced in the Organotin Antifouling Paint Control Act of 1988 (33 U.S.C. 2401), which bans its use on vessels less than 25 m in length (Milliken and Lee 1990; Hofer 1998).

Herbicides are also used in some antifouling paints to inhibit the colonization of algae and the growth of seaweeds on boat hulls and intake pipes (Readman et al. 1993). Similar to copper, the highest concentrations of herbicides in nearshore waters are associated with recreational marinas, which may be because of a higher frequency of use of these types of antifouling paints for pleasure boats compared to commercial vessels (Readman et al. 1993). The leaching of these chemicals into the marine environment could affect community structure and phytoplankton abundance (Readman et al. 1993).

Fuel and oil spills can affect animals directly or indirectly through the food chain. Fuel, oil, and some hydraulic fluids contain PAH which can cause acute and chronic toxicity in marine organisms (Neff 1985). Toxic effects of exposure to PAH have been identified in adult finfish at concentrations of 5-50 ppm and the larvae of aquatic species at concentrations of 0.1-1.0 ppm (Milliken and Lee 1990). Small, but chronic oil spills are a potential problem because residual oil can build up in sediments and affect living marine resources. Even though individual releases are small, they are also frequent and when combined they contribute nearly 85% of the total input of oil into aquatic habitats from human activities (ASMFC 2004). Incidental fuel spills involving small vessels are probably common events, but these spills typically involve small amounts of material and may not necessarily adversely affect fishery resources. Larger spills may have significant acute adverse affects, but these events are relatively rare and usually involve small geographic areas.

Outboard engines, as opposed to inboard engines that are generally used for larger, commercial vessels, are unique in that their exhaust gases cool rapidly and leave some hydrocarbon components condensed and in the water column rather than being released into the atmosphere (Moore and Stolpe 1995). Outboard engine pollution, particularly from two-cycle engines, can contribute to the concentrations of hydrocarbons in the water column and sediment (Milliken and Lee 1990). Two-cycle outboard engines accomplish fuel intake and exhaust in the same cycle and tend to release unburned fuel along with the exhaust gases. In addition, two-cycle engines mix lubricant oil with the fuel, so this oil is released into the water along with the unburned fuel. There are over 100 hydrocarbon compounds in gasoline, including additives to improve the efficiency of the fuel combustion (Milliken and Lee 1990). Once discharged into the water, petroleum hydrocarbons may remain suspended in the water column, concentrate on the surface, or settle to the bottom (Milliken and Lee 1990).

Any type of fuel or oil spill has the potential to cause impacts to organisms and habitats in the water column, on the bottom, and on the shoreline, but it is unknown to what extent these effects are individually or cumulatively significant. Effects on fish from low-level chronic exposure may increase embryo mortality, reduce growth, or alter migratory patterns (Heintz et al. 2000; Wertheimer et al. 2000). For more details on the impacts of oil or fuel spills, see the chapter on Energy-related Activities.

Gray water and sewage discharge from boats may impact water quality by increasing nutrient loading and biological oxygen demand of the local area and through the release of disease causing organisms and toxic substances (Thom and Shreffler 1996; Klein 1997). Positive correlations between boating activity levels and elevated levels of fecal coliform bacteria in nearshore coastal waters have been reported (Milliken and Lee 1990). Although the Clean Water Act (CWA) of 1972 makes it illegal to discharge untreated wastes into coastal waters and the Federal Water Pollution Control Act requires recreational boats be equipped with marine sanitation devices (MSDs), it is legal to discharge treated wastes, and illegal discharges of untreated waste may be common (Milliken and Lee 1990; Amaral et al. 2005). Despite these laws, many vessels may not be equipped with MSDs and on-shore pumpout stations are not common (Amaral et al. 2005). Impacts from vessel waste discharges may be more pronounced in small, poorly flushed waterways where pollutant concentrations can reach unusually high levels (Klein 1997).

### *Underwater noise*

The noise generated by vessel operations is usually concentrated in ports, marinas, and heavily used shipping lanes or routes and may impact fish spawning, migration, and recruitment behaviors (Hildebrand 2004). Exposure to continuous noise may also create a shift in hearing thresholds for marine organisms resulting in hearing losses at certain frequency ranges (Jasny et al. 1999). Reducing vessel noise is a difficult task because of the economic incentives that encourage the expansion of commercial shipping and the lack of alternatives for efficient global transport of large and high tonnage material (Hildebrand 2004).

Small craft with high-speed engines and propellers (e.g., recreational boats with outboard engines) typically produce higher frequency noise than do larger vessels that generate substantial low-frequency noise because of their size and large, slow-speed engines and propellers (Kipple and

Gabriele 2004). A noise study of three size-classes of vessels (i.e., small, 17-30 feet; medium, 50-100 feet; and large, >100 feet) in Glacier Bay, AK, found that, on average, overall sound levels were higher for the larger vessel categories (Kipple and Gabriele 2004). However, vessel sound levels in this study were generally measured at vessel speeds less than 10 knots, and the investigators found increasing sound levels with greater vessel speed (Kipple and Gabriele 2004). Scholik and Yan (2002) reported significant elevation of the auditory threshold of the fathead minnow (*Pimephales promelas*), after exposure to noise from an idling 55 horsepower outboard motor. Furthermore, the frequencies of the noise from the outboard engine corresponded to the frequencies of the fish's auditory threshold shifts, specifically in this species' most sensitive hearing range (1.0-2.0 kHz).

Commercial shipping vessels are a major source of low frequency (5-500 Hz) noise in the marine environment and may be one of the most pervasive sources of anthropogenic ocean noise (Jasny et al. 1999; Stocker 2002; Hildebrand 2004). Low frequencies travel long distances in the marine environment, which is probably why these frequencies are also used by marine mammals for communication (Jasny et al. 1999). Ship noise is generated from the use of engines and other on-board mechanical devices such as pumps, cooling systems, and generators, as well as movement of water across the hull and propellers (Stocker 2002; Hildebrand 2004). These sounds are amplified and transferred to the water through the ship's hull (Stocker 2002). The size and frequency of use for commercial vessels traversing the ocean and nearshore waters may explain why they are considered a major source of noise impacts compared to the more numerous fishing and pleasure craft found in coastal waters (Hildebrand 2004).

There are several factors which influence sound attenuation in shallow coastal waters including temperature variations or thermoclines, bottom geography, and sediment composition. Vessel noise may reverberate or scatter off geological features and anthropogenic structures in the water (Stocker 2002).

Sonar is another source of anthropogenic noise attributed to vessel operation. It is used for various purposes such as depth sounding and fish finding and can vary in range depending on the use (15-200 kHz for commercial navigation, 1-20 kHz for other positioning and navigation, and 100-3,000 Hz for long range sonar) (Stocker 2002). Refer to the Global Effects and Other Impacts chapter of this report for more information on ocean noise.

### *Release of debris*

As discussed in the Operation and Maintenance of Ports and Marinas section of this chapter, the release of solid waste in coastal waters is a considerable concern. Billions of pounds of debris are dumped into the oceans each year (Milliken and Lee 1990), and vessel traffic is a significant source of this waste because of accidental loss, routine practices of dumping waste, and illegal dumping activities (Cottingham 1988). Entanglement in or ingestion of this debris can cause fish, marine mammals, and sea birds to become impaired or incapacitated, leading to starvation, drowning, increased vulnerability to predators, and physical wounds (Milliken and Lee 1990). Marine debris can also cause direct physical damage to habitat features through smothering or physical disturbance.

Plastics are an especially persistent form of solid waste. Plastics tend to concentrate along coastal areas because they float on the surface and can be transported by ocean currents (Milliken and Lee 1990). Commercial fishing, merchant vessel, cruise ship, and recreational boats are major contributors to marine plastic debris (Cottingham 1988; Milliken and Lee 1990). Cottingham (1988) estimated that merchant vessels are the primary source of plastic refuse in New England. Refer to the Operation and Maintenance of Ports and Marinas section in this chapter for information on plastic debris and the Coastal Development chapter of this report for more information on general marine debris.

### *Abandoned and derelict vessels*

Derelict or abandoned vessels can cause a variety of impacts to habitats and are public health and navigational hazards. Grounded vessels may physically damage and smother benthic habitats, create changes in wave energy and sedimentation patterns, and scatter debris across sensitive habitats (Precht et al. 2001; Zelo and Helton 2005). The potential impact footprint of a grounded vessel can be much larger than the vessel itself as vessels move or break up during storm events, which can scour bottom habitat, amplify impacts, and complicate removal (Zelo and Helton 2005). The physical impacts of a grounded vessel can be greater in shallow water since the wreck is more likely to be unstable and move, may break up more rapidly because of wave and current forces, and is more likely to need urgent removal because of navigation concerns which may lead to additional resource impacts (Michel and Helton 2003). Refer to the Offshore Dredging and Disposal Activities chapter of this report for information regarding intentional sinking of vessels for disposal and creation of artificial reefs.

The most common environmental threat of a derelict or abandoned vessel is the release of oil or other pollutants. These hazardous materials may be part of a vessel's cargo, fuel and oil related to vessel operations, or chemicals contained within the vessel's structure which may be released through decay and corrosion over time. Rusting vessel debris can also cause iron enrichment in enclosed areas, which has been associated with harmful algal blooms (Helton and Zelo 2003; Michel and Helton 2003).

The historical focus of laws regarding derelict or abandoned vessels was the protection of the property rights of shipowners and the recovery of cargo (Michel and Helton 2003). Existing federal laws and regulations do not provide clear authority or funding to any single agency for the removal of grounded or abandoned vessels that harm natural resources but which are not otherwise obstructing or threatening to obstruct navigation or threatening a pollution discharge (Helton and Zelo 2003). In many cases vessels are abandoned and are left to continually damage the marine environment because a responsible party cannot be identified or a funding source for removal cannot be secured (Zelo and Helton 2005). Physical impacts, in particular, can persist for decades when vessels are left in the marine environment, and in some cases simply removing a vessel is enough to allow natural recolonization of benthic organisms (Zelo and Helton 2005).

Removal of a derelict vessel will ensure that the vessel does not become a navigation hazard to other ships and that hazardous materials are not released during storms which can damage the wreckage further. It also ensures that abandoned vessels do not become illegal dumpsites for oil, industrial waste, and other hazardous materials, including munitions (Helton and Zelo 2003). Salvage and wreck removal activities can result in unintended habitat impacts. For example, fuel spillage may occur during salvage operations of a wrecked vessel. The potential for collateral impacts should be considered when planning a salvage operation (Michel and Helton 2003). Wrecks in shallow water are often removed and scuttled in deep water to prevent further damage to more vulnerable, nearshore benthic habitats and to avoid the risks involved in bringing an unstable vessel into port (Michel and Helton 2003).

Although many of the habitat impacts described above can be averted if derelict vessels are removed while still afloat, abandoned and neglected floating vessels can also create habitat impacts (Zelo and Helton 2005). These vessels may shade seagrass beds, scour subtrates with anchor chains, or release pollutants from decaying hull materials and paints (Sunda 1994; Negri et al. 2002; Smith et al. 2003; Zelo and Helton 2005).

## *Nonnative and invasive species*

Nonnative species, some of which are invasive, have been introduced to coastal areas through industrial shipping and recreational boating (Omori et al. 1994; Wilbur and Pentony 1999; Hanson et al. 2003; Pertola et al. 2006). These introductions can be in the form of fouling organisms on the bottom of vessels as they are transported between water bodies or through the release of ballast water from large commercial vessels. Modern ships can carry 10 to 200 thousand tons of ballast water at a time and transport marine organisms across long distances and in relatively short time periods (Hofer 1998). This expeditious travel increases the risk that the organisms taken up in ballast water will be viable when introduced into a distant port or marina during deballasting (Wilbur and Pentony 1999). Pertola et al. (2006), in an investigation of dinoflagellates and other phytoplankton from the ballast tank sediments of ships at ports in the northeastern Baltic Sea, found a large assemblage of germinated dinoflagellate cysts in 90% of all ships and at all ports sampled. Ship traffic can transport, in large numbers, nonnative and invasive species of phytoplankton that can be harmful to native aquatic species (Pertola et al. 2006). The nonnative green algae (*Codium fragile*), is an example of a species that has invaded the northeastern US coast, the eastern Atlantic Ocean, Mediterranean Sea, and New Zealand and has displaced native species of *Codium* (Walker and Kendrick 1998; Tyrrell 2005). Shipping has been implicated as the major agent of spread of this species (Walker and Kendrick 1998), as well as of the zebra mussel (*Dreissena polymorpha*) (Strayer et al. 2004). This invasive species has been shown to have had an adverse effect on the populations of some native species of fish (e.g., *Alosa* spp.), as well as phytoplankton, zooplankton, aquatic vegetation, water chemistry, and zoobenthos (Strayer et al. 2004).

Introduced species can adversely impact habitat qualities and functions by altering the community structure, competing with native species, and introducing exotic diseases (Omori et al. 1994; Wilbur and Pentony 1999; Carlton 2001). Additional discussion of the effects of introduced species can be found in the chapters on Introduced/Nuisance Species and Aquaculture and Physical Effect: Water Intake and Discharge Facilities.

## *Conservation recommendations and best management practices for vessel operation and maintenance*

1. Encourage marinas to participate in NOAA/US EPA’s Coastal Nonpoint Program and the Clean Marina Initiative.
2. Ensure that commercial ships and port facilities have oil-spill response plans in place which improve response and recovery in the case of accidental spillage.
3. Ensure that commercial ships and or port facilities have adequate oil-spill response equipment accessible and clearly marked.
4. Use dispersants that remove oils from the environment rather than dispersants that simply move them from the surface to the ocean bottom.
5. Promote the use of oil-absorbing materials in the bilge areas of all boats with inboard engines.
6. Promote the use of fuel/air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel and oil spilled into surface waters during fueling of boats.
7. Encourage recreational boats to be equipped with marine sanitation devices (MSDs) to prevent untreated sewage to be pumped overboard.
8. Encourage ship designs that include technologies capable of reducing noise generated and transmitted to the water column, such as the use of muffling devices already required for land-based machinery that may help reduce the impacts of vessel noise.

9. The effects of proposed and existing vessel traffic and associated underwater noise should be assessed for potential impacts to sensitive areas such as migration routes and spawning areas for marine animals.
10. Exclude vessels or limit specific vessel activities such as high intensity, low-frequency sonar, to known sensitive marine areas if evidence indicates that these activities have a substantial adverse effect to marine organisms.
11. Promote education and signage on all vessels to encourage proper disposal of solid debris at sea.
12. Encourage the use of innovative cargo securing and stowing designs that may reduce solid debris in the marine environment from the transportation of commercial cargo.
13. Use appropriate equipment and techniques to salvage and remove grounded vessels and follow all necessary state and federal laws and regulations. If possible, avoid using the propulsion systems of salvage tugs that can cause propeller wash and scour the bottom. Instead, moor the tugs and use a ground tackle system to provide maneuvering and pull.
14. Minimize additional seafloor damage when a derelict vessel has to be dragged across the seafloor to deep water by following the same ingress path. Alternatively, identify the least sensitive, operationally feasible towpath. Dismantling derelict vessels in place when stranded close to shore may cause less environmental impact than dredging or dragging a vessel across an extensive shallow habitat.
15. Reduce the risk of a sudden release of the entire cargo when a submerged derelict vessel contains hazardous aqueous solutions that pose limited environmental risks, such as mild acids and bases, by allowing the release of the cargo under controlled conditions. The controlled release plan can include water-quality monitoring to validate the calculated dilution rates and plume distance assumptions. All applicable state and federal laws and regulations regarding the release of chemicals into the water should be followed.
16. Develop a contingency plan for uncontrolled releases during vessel salvage operations. The salvage plan should include a risk assessment to determine the most likely release scenarios and use the best practices of the industry.
17. Schedule nonemergency salvage operations while including environmental considerations to minimize potential impacts on natural resources. Environmental considerations include periods when few sensitive species are present, avoidance of critical reproductive periods, and weather patterns that influence the trajectory of potential releases during operations
18. Choose a scuttling site for a derelict vessel in a deep-water location in federal or Exclusive Economic Zone (EEZ) waters that does not contain any sensitive resources or geological hazards. Ensure that all proposed disposal of vessels in the open ocean adheres to state and federal guidance and regulations, including section 102(a) of the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act), and under 40 CFR § 229.3 of the US EPA regulations. Refer to the Offshore Dredging and Disposal Activities chapter for additional recommendations and BMPs for the disposal of vessels.

## Navigation Dredging

### *Introduction*

Channel dredging is a ubiquitous and chronic maintenance activity associated with port and harbor operation and vessel activity (Barr 1987; NEFMC 1998). Navigational dredging occurs in rivers, estuaries, bays, and other areas where ports, harbors, and marinas are located (Messieh and El-Sabh 1988). The locations of these facilities often coincide with sensitive aquatic habitats that are vital for supporting fishery production (Newell et al. 1998).

For the purposes of navigation, dredging can be generally classified as either creating new or expanded waterways with greater profiles, depths, and scope or as maintenance of existing waterways for the purpose of maintaining established profiles, depths, and scope. Although the latter category represents the most common dredging scenario, new construction, or "improvement" dredging as it is sometimes called, has become increasingly common at larger ports and harbors throughout the United States. Several corresponding factors have likely led to greater need for navigational "improvements" and increases in the operating depths and the sizes of existing ports and harbors, including: (1) increased demand for marine cargo and transportation; (2) expansion of commercial fleets; (3) increased demand for larger capacity commercial and recreational vessels; and (4) increased urbanization and infrastructure development along the coast (Messieh et al. 1991; Wilbur and Pentony 1999; Nightingale and Simenstad 2001b). In particular, this demand for larger capacity commercial cargo vessels has led to an increased competition among the major coastal ports to provide facilities to accommodate these vessels. Improvement dredging may occur in areas that have not previously been subjected to heavy vessel traffic and dredging activities, such as new commercial marinas or the creation of a new channel or turning basin in an existing port or marina facility. Because improvement dredging is often conducted in areas that have been less affected by previous dredging and vessel activities, the impacts are generally more severe than the impacts associated with regular maintenance dredging activities unless the sediments involved in the maintenance dredging contain high levels of contaminants (Allen and Hardy 1980).

Maintenance dredging is generally required in most navigation channels and port and marina facilities because of the continuous deposition of sediments from freshwater runoff or littoral drift. Navigation channels require maintenance dredging to remove accumulated sediments, typically conducted on a temporal scale of one to ten years (Nightingale and Simenstad 2001b). Alterations in sedimentation patterns of estuaries resulting from increased coastal development and urbanization often increases the sediment influx and the frequency for maintaining existing channels and ports. Dredging for other purposes, such as aggregate mining for sand and gravel, conveyance of flood flows, material for beach nourishment, and removal of contaminated sediments or construction of subtidal confined disposal of contaminated sediments, may be done separately or in conjunction with navigation dredging (Nightingale and Simenstad 2001b). Refer to the Offshore Dredging and Disposal Activities chapter of this report for more information on offshore aggregate mining and to the Coastal Development chapter of this report contains information on the affects of beach nourishment and other coastal development activities.

There is a variety of methods and equipment used in navigation dredging, and a detailed explanation and assessment is beyond the scope of this report. However, one can categorize dredging activities as either using hydraulic or mechanical equipment. The type of equipment used for navigation dredging primarily depends on the nature of the sediments to be removed and the type of disposal required. Some of the factors that determine the equipment type used are the characteristics of the material to be dredged, the quantities of material to be dredged, the dredging depth, the distance to the disposal area, the physical environmental factors of the dredging and disposal area, the contamination level of sediments, the methods of disposal, the production (i.e., rate of material removed) required, and the availability of the dredge equipment (Nightingale and Simenstad 2001b).

Hydraulic dredging involves the use of water mixed with sediments that forms a slurry, which is pumped through a pipeline onto a barge or a hopper bin for off-site disposal. To increase the productivity of the dredging operation (i.e., maximizing the amount of solid material transported to the disposal site), some of the water in the sediment slurry may be allowed to overflow out of the hopper which can increase the turbidity in the surrounding water column. If the disposal site is relatively close to the dredge site, the slurry may be pumped through a pipeline directly to the disposal site (e.g., beach disposal).

Mechanical dredging typically involves the use of a clamshell dredge, which consists of a bucket of hinged steel that is suspended from a crane. The bucket, with its jaws open, is lowered to the bottom and as it is hoisted up, the jaws close and carry the sediments to the surface. The sediments are then placed in a separate barge for transport to a disposal site. Bucket dredges tend to increase the suspended sediment concentrations compared to hydraulic dredges because of the resuspension created as sediment spills through the tops and sides of the bucket when the bucket contacts the bottom, during withdrawal of the bucket through the water column, and when it breaks the water's surface (Nightingale and Simenstad 2001b). Closed or "environmental" buckets are designed to reduce the sediment spill from the bucket by incorporating modifications such as rubber seals or overlapping plates and are often used in projects involving contaminated sediments.

The location and method of disposal for dredged material depends on the suitability of the material determined through chemical, and often, biological analyses conducted prior to the dredging project. Generally, sediments determined to be unacceptable for open water disposal are placed in confined disposal facilities or contained aquatic disposal sites and capped with uncontaminated sediments. Sediments that are determined to be uncontaminated may be placed in open-water disposal sites or used for beneficial uses. Beneficial uses are intended to provide environmental or other benefits to the human environment, such as shoreline stabilization and erosion control, habitat restoration/enhancement, beach nourishment, capping contaminated sediments, parks and recreation, agriculture, strip mining reclamation and landfill cover, and construction and industrial uses (Nightingale and Simenstad 2001b). Open water disposal sites can be either predominantly nondispersive (i.e., material is intended to remain at the disposal site) or dispersive (i.e., material is intended to be transported from the disposal site by currents and/or wave action (Nightingale and Simenstad 2001b). The potential for environmental impacts is dependent upon the type of disposal operation used, the physical characteristics of the material, and the hydrodynamics of the disposal site. Refer to the chapter on Offshore Dredging and Disposal Activities for more detailed information on dredge material disposal.

Dredging to deepen or maintain ports, marinas, and navigational channels involves a number of environmental effects to fishery habitats, including the direct removal or burial of demersal and benthic organisms and aquatic vegetation, alteration of physical habitat features, the disturbance of bottom sediments (resulting in increased turbidity), contaminant releases in the water column, light attenuation, releases of oxygen consuming substances and nutrients, entrainment of living organisms in dredge equipment, noise disturbances, and the alteration of hydrologic and temperature regimes. Dredging is often accompanied by a significant decrease in the abundance, diversity, and biomass of benthic organisms in the affected area and an overall reduction in the aquatic productivity of the area (Allen and Hardy 1980; Newell et al. 1998). The rate of recovery of the benthic community is dependent upon an array of environmental variables which reflect interactions between sediment particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long time periods (Newell et al. 1998).

### *Loss or conversion of benthic habitat and substrate*

Alterations in bathymetry, benthic habitat features, and substrate types caused by navigational dredging activities may have long-term effects on the functions of estuarine and other aquatic environments. The effects of an individual project are proportional to the scale and time required for a project to be completed, with small-scale and short-term dredging activities having less impact on benthic communities than long-term and large-scale dredging projects (Nightingale and Simenstad 2001b). Dredging can have cumulative effects on benthic communities, depending upon the dredging interval, the scale of the dredging activities, and the ability of the environment to recover from the impacts. The new exposed substrate in a dredged area may be composed of material containing more fine sediments than before the dredging, which can reduce the recolonization and productivity of the benthos and the species that prey upon them.

The impacts to benthic communities vary greatly with the type of sediment, the degree of disturbance to the substrate, the intrinsic rate of reproduction of the species, and the potential for recruitment of adults, juveniles, eggs, and larvae (Newell et al. 1998). Following a dredging event, sediments may be nearly devoid of benthic infauna, and those that are the first to recolonize are typically opportunistic species which may have less nutritional value for consumers (Allen and Hardy 1980; Newell et al. 1998).

In general, dredging can be expected to result in a 30-70% decrease in the benthic species diversity and 40-95% reduction in number of individuals and biomass (Newell et al. 1998). Recovery of the benthic community is generally defined as the establishment of a successional community which progresses towards a community that is similar in species composition, population density, and biomass to that previously present or at nonimpacted reference sites (Newell et al. 1998). The factors which influence the recolonization of disturbed substrates by benthic infauna are complex, but the suitability of the postdredging sediments for benthic organisms and the availability of adjacent, undisturbed communities which can provide a recruitment source are important (Barr 1987; ICES 1992). Rates of benthic infauna recovery for disturbed habitats may also depend upon the type of habitat being affected and the frequency of natural and anthropogenic disturbances. Benthic infauna recovery rates may be less than one year for some fine-grained mud and clay deposits, where a frequent disturbance regime is common, while gravel and sand substrates, which typically experience more stability, may take many years to recover (Newell et al. 1998). Post-dredging recovery in cold waters at high latitudes may require additional time because these benthic communities can be comprised of large, slow-growing species (Newell et al. 1998).

### *Loss of submerged aquatic vegetation*

Submerged aquatic vegetation provides food and shelter for many commercially and recreationally important species, attenuates wave and current energy, and plays an important role in the chemical and physical cycles of coastal habitats (Thayer et al. 1997). The loss of vegetated shallows results in a reduction in important rearing and refugia functions utilized by migrating and resident species. Seagrass beds are more difficult to delineate and map than some other subtidal habitats because of their spatial and temporal dynamic nature, making these habitats more vulnerable to being inadvertently dredged (Thayer et al. 1997; Deegan and Buchsbaum 2005). Dredging causes both direct and indirect impacts to SAV. The physical removal of plants through dredging is a direct impact, while the reduction in light penetration and burial or smothering that is a result of the turbidity plumes and sedimentation created by the dredge are indirect impacts (Deegan and Buchsbaum 2005). While SAV may regrow in a dredged area if the exposure to excessive suspended sediments is not protracted and most of the accumulated sediments are removed by currents and tides after dredging ceases (Wilber et al. 2005), the recolonization by SAV may be limited if the bottom sediments are destabilized or the composition of the bottom sediments is altered (Thayer et al. 1997). Even when bottom sediments are stabilized and are conducive to SAV growth, channel deepening may result in the area having inadequate light regimes necessary for the recolonization of SAV (Barr 1987).

Dredge and fill operations require a permit review process which is regulated by state and federal agencies. Advancement in understanding the physical impacts of dredging on SAV and recognition of the ecological significance of these habitats has allowed special consideration for SAV beds during the permit review process. Most reviewing agencies discourage dredging activities in or near SAV beds as well as in areas that have been historically known to have SAV and areas that are potential habitats for SAV recruitment (Orth et al. 2002).

While the physical disturbance to SAV beds from dredge activities may have significant localized effects, water quality problems such as eutrophication, pollution and sedimentation have resulted in large-scale declines to SAV in some areas of the northeastern US coast (Goldsborough 1997; Deegan and Buchsbaum 2005; Wilber et al. 2005). The small, localized disturbance of SAV associated with dredging may be viewed as a significant impact in the context of diminished regional health and distribution resulting from stressors such as poor water quality and cumulative effects such as dredging, boating (propeller scour), and shoreline alteration (Goldsborough 1997; Thayer et al. 1997; Deegan and Buchsbaum 2005). The environmental effects of excess nutrients and sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

### *Loss of intertidal habitat and wetlands*

Intertidal habitats (e.g., mud and sand flats) and wetlands (e.g., salt marsh) are valuable coastal habitats which support high densities and diversities of biota by supporting biological functions such as breeding, juvenile growth, feeding, predator avoidance, and migration (Nightingale and Simenstad 2001b). These valuable habitats are also some of the most vulnerable to alterations through coastal development, urbanization, and the expansion of ports and marinas.

The loss of intertidal habitat and the deepening of subtidal habitat during dredging for marina development and for navigation can alter or eliminate the plant and animal assemblages associated with these habitats, including SAV and shellfish beds (Nightingale and Simenstad 2001b; MacKenzie 2007). Dredging in intertidal habitats can alter the tidal flow, currents, and tidal mixing regimes of the dredged area as well as other aquatic habitats in the vicinity, leading to changes in the environmental parameters necessary for successful nursery habitats (Barr 1987). Dredging in tidal wetlands can also encourage the spread of nonnative invasive organisms by removing or disturbing the native biota and altering the physical and chemical properties of the habitat (Hanson et al. 2003; Tyrrell 2005).

Navigational dredging converts shallow subtidal or intertidal habitats into deeper water environments through the removal of sediments (Nightingale and Simenstad 2001b, Deegan and Buchsbaum 2005). The historical use of dredged materials was to infill wetland, salt marshes, and tidal flats in order to create more usable land. The Boston Harbor, MA, area is a prime example of this historical trend, where thousands of acres of salt marsh and intertidal wetlands have been filled over time (Deegan and Buchsbaum 2005). Filling wetlands eliminates the biological, chemical, and physical functions of intertidal habitat such as flood control, nutrient filter or sink, and nursery habitat. Although direct dredging and filling within intertidal wetlands are relatively rare in recent times, the lost functions and values of intertidal wetlands and the connectivity between upland and subtidal habitat is difficult and costly to create and restore (Nightingale and Simenstad 2001b).

### *Underwater noise*

Fish can detect and respond to sounds for many life history requirements, including locating prey and avoiding predation, spawning, and various social interactions (Myrberg 1972; Myrberg and Riggio 1985; Kalmijn 1988). The noise generated by pumps, cranes, and by the mechanical action of the dredge itself has the ability to alter the natural behavior of fish and other aquatic organisms. Feist et al. (1996) reported that pile-driving operations had an affect on the distribution and behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*). Fish may leave an area for more suitable spawning grounds or may avoid a natural migration path because of noise disturbances.

The noise levels and frequencies produced from dredging depend on the type of dredging equipment being used, the depth and thermal variations in the surrounding water, and the topography and composition of the surrounding sea floor (Nightingale and Simenstad 2001b; Stocker 2002). However, dredging activities from both mechanical and hydraulic dredges produce underwater sounds that are strongest at low frequencies and because of rapid attenuation of low frequencies in shallow water, dredge noise normally is undetectable underwater at ranges beyond 20-25 km (Richardson et al. 1995). Although the noise levels from large ships may exceed those from dredging, single ships usually do not produce strong noise in one area for a prolonged period of time (Richardson et al. 1995). The noise created during dredging can produce continuous noise impacts for extended periods of time (Nightingale and Simenstad 2001b).

### *Siltation, sedimentation, and turbidity*

Dredging degrades habitat quality through the resuspension of sediments which creates turbid conditions and can release contaminants into the water column, in addition to impacting benthic organisms and habitat through sedimentation. Turbidity plumes ranging in the hundreds to thousands mg/L are created and can be transported with tidal currents to sensitive resource areas. Alterations in bottom sediments, bottom topography, and altered circulation and sedimentation patterns related to dredge activities can lead to shoaling and sediment deposition on benthic resources such as spawning grounds, SAV, and shellfish beds (Wilber et al. 2005; MacKenzie 2007). Early life history stages (eggs, larvae, and juveniles) and sessile organisms are the most sensitive to sedimentation impacts (Barr 1987; Wilber et al. 2005). Some estuarine and coastal habitats are prone to natural sediment loads and sediment resuspension because of the relatively dynamic nature of the ecosystems; therefore, most organisms adapted to these environments have tolerance to some level of suspended sediments and sedimentation (Nightingale and Simenstad 2001b).

The reconfiguration of sediment type and the removal of biogenic structure during dredging may decrease the stability of the bottom and increase the ambient turbidity levels (Messieh et al. 1991). This increased turbidity and sedimentation can reduce the light penetration of the water column which then can adversely affect SAV and reduce primary productivity (Cloern 1987; Dennison 1987; Wilbur and Pentony 1999; Mills and Fonseca 2003; Wilbur et al. 2005). The combination of decreased photosynthesis and the interaction of the suspended material with dissolved oxygen in the water may result in short-term oxygen depletion (Nightingale and Simenstad 2001b).

If suspended sediment loads remain high, fish may experience respiratory distress and reduced feeding ability because of sight limitations, while filter feeders may suffer a reduction in growth and survival (Messieh et al.1991; Barr 1993; Benfield and Minello 1996; Nightingale and Simenstad 2001b). Prolonged exposure to suspended sediments can cause gill irritation, increased mucus production, and decreased oxygen transfer in fish (Nightingale and Simenstad 2001b; Wilber et al. 2005). Reduced dissolved oxygen concentrations and increased water temperatures may be cumulative stressors that exacerbate the effects of respiratory distress on fish from extended exposure to suspended sediments (Nightingale and Simenstad 2001b). In addition, mobile species may leave an area for more suitable feeding or spawning grounds, or avoid migration paths because of turbidity plumes created during navigational dredging.

Increased turbidity and sedimentation may also bury benthic organisms and demersal fish eggs. The depth of burial and the density of the substrate may limit the natural escape response of some organisms that are capable of migrating vertically through the substrate (Barr 1987; Wilber et al. 2005). In addition, anoxic conditions in the disturbed sediments may decrease the ability of benthic organisms to escape burial (Barr 1987). Short-term burial, where sediment deposits are promptly removed by tides or storm events, may have minimal effects on some species (Wilber et al. 2005). However, even thin layers of fine sediment have been documented to decrease gas exchange in fish eggs and adversely affect the settlement and recruitment of bivalve larvae (Wilber et al. 2005). An in-situ experiment with winter flounder (*Pseudopleuronectes americanus*) eggs exposed to sediment deposition from a navigational dredging project found a slightly lower larval survival rate compared to control sites, but the differences were not statistically significant (Klein-MacPhee et al. 2004). However, the viability of the larvae in this experiment was not monitored beyond burial escapement. Similarly, laboratory experiments with winter flounder eggs buried to various depths (i.e., control, <0.5 mm, and up to 2 mm) indicated a decreased hatch success and delayed hatch with increasing depth; but differences were not statistically significant (Berry et al. 2004). The same study also exposed winter flounder eggs to both clean, fine-grained sediment and highly contaminated, fine-grained sediment at various depths from 0.5-6.0 mm. The investigators found that eggs buried to depths of 4 mm with clean sediments did not hatch, while eggs buried to depths of 3 mm with contaminated sediments had little or no hatching success (Berry et al. 2004). Although there are clearly adverse effects to sessile benthic organisms and life stages from sedimentation from dredging activities, additional investigations are needed to assess lethal and sublethal thresholds for more species and under different sediment types and quality. In addition, better understanding about the relationship between natural and anthropogenic sources of suspended sediments and population-level effects is needed.

The use of certain types of dredging equipment can result in greatly elevated levels of fine-grained particles in the water column. Mechanical dredging techniques such as clam shell or bucket dredges usually increase suspended sediments at the dredge site more than hydraulic dredge techniques such as hopper or cutterheads, unless the sediment and water mixture (slurry) removed during hydraulic dredging is allowed to overflow from the barge or hopper and into the water column, a technique often used to reduce the number of barge trips required (Wilber and Clarke 2001). Mechanical dredges are most commonly used for smaller projects or in locations requiring maneuverability such as close proximity to docks and piers or in rocky sediments (Wilber et al. 2005), although small hydraulic dredges can be used to reduce suspended sediment concentrations in the dredging area and minimize impacts on adjacent benthic habitats, such as SAV or shellfish beds.

Seasonal or time-of-year (TOY) restrictions to dredging activities are used to constrain the detrimental affects of dredging to a timeframe that minimizes impacts during sensitive periods in the life history of organisms, such as spawning, egg development, and migration (Nightingale and Simenstad 2001b; Wilber et al. 2005). Segregating dredging impacts by life history stages provides a means for evaluating how different impacts relate to specific organisms and life history strategies (Nightingale and Simenstad 2001b). The application of TOY restrictions should be based upon the geographic location, species and life history stages present, and the nature and scope of the dredging project. Because the employment of TOY restrictions may have some negative effects, such as extending the overall length of time required for dredging and disposal, increasing the impacts on less economically valuable or poorly studied species, and increasing the economic costs of a project, the benefits of TOY restrictions should be evaluated for each individual dredging project (Wilber et al. 2005; Nightingale and Simenstad 2001b).

### Contaminant release and source exposure

Contaminated sediments are a concern because of the risk of transport of the contaminants and the exposure to aquatic organism and humans through bioaccumulation and biomagnification (Nightingale and Simenstad 2001b). Navigation dredging can create deep channels where currents are reduced and fine sediments may be trapped. Nutrients and contaminants can bind to fine particles such as those that may settle in these deep channels (Newell et al. 1998; Messiah et al. 1991). Dredging and disposal causes resuspension of the sediments into the water column and the contaminants that may be associated with the sediment particles. The disturbance of bottom sediments during dredging can release metals (e.g., lead, zinc, mercury, cadmium, copper), hydrocarbons (e.g., PAH), hydrophobic organics (e.g., dioxins), pesticides, pathogens, and nutrients into the water column and allow these substances to become biologically available either in the water column or through trophic transfer (Wilbur and Pentony 1999; USEPA 2000; Nightingale and Simenstad 2001b). Generally, the resuspension of contaminated sediments can be reduced by avoiding dredging in areas containing fine sediments. In addition, the biological and/or chemical testing requirements under the Marine Protection, Research, and Sanctuaries Act and the Clean Water Act are designed to minimize adverse effects of dredge material disposal on the environment. For additional information regarding the affects of contaminants associated with resuspended sediments, refer to the chapters on Offshore Dredging and Disposal Activities and Chemical Affects: Water Discharge Facilities in this report.

### Release of nutrients/eutrophication

Dredging can degrade water quality through resuspension of sediments and the release of nutrients and other contaminants into the water column. Nutrients and contaminants may adhere to these fine particles (Newell et al. 1998; Messieh et al. 1991). The resuspension of this material creates turbid conditions and decreases photosynthesis. The combination of decreased photosynthesis and the release of organic material with high biological oxygen demand can result in short-term oxygen depletion to aquatic resources (Nightingale and Simenstad 2001b). Long-term anoxia can occur if highly organic sediments are dredged or discharged into estuaries, particularly in enclosed or confined bodies of water. The loss of SAV is linked to poor water quality from increased turbidity and nutrient loading (Deegan and Buchsbaum 2005; Wilber et al. 2005).

### Entrainment and impingement

Entrainment is the direct uptake of aquatic organisms by the suction field created by hydraulic dredges. Benthic infauna are particularly vulnerable to entrainment by dredging, although some mobile epibenthic and demersal species such as shrimp, crabs, and fish can be susceptible to entrainment as well (Nightingale and Simenstad 2001b). Elicit avoidance responses to suction dredge entrainment has been reported for some demersal and pelagic mobile species (Larson and Moehl 1990; McGraw and Armstrong 1990). The susceptibility to entrainment for some pelagic species may be related to the degree of waterway constriction in the area of the dredging, which makes it more difficult for fish to avoid the dredge operation (Larson and Moehl 1990; McGraw and Armstrong 1990).

## Altered tidal, current, and hydrologic regimes

Large channel deepening projects can potentially alter ecological relationships through a change in freshwater inflow, tidal circulation, estuarine flushing, and freshwater and saltwater mixing (Nightingale and Simenstad 2001b). Dredging may also modify longshore current patterns by altering the direction or velocity of water flow from adjacent estuaries. These changes in water circulation are often accompanied by changes in the transport of sediments and siltation rates resulting in alteration of local habitats used for spawning and feeding (Messieh et al. 1991).

Altered circulation patterns around dredged areas can also lead to changes in sediment composition and deposition and in the stability of the seabed. The deep channels created during navigational dredging may experience reduced current flow that allows the area to become a sink for fine particles as they settle out of the water column or slump from the channel walls (Newell et al. 1998). In some cases this may change the sediment composition from sand or shell substrate to a substrate consisting of fine particles which flocculate easily and are subject to resuspension by waves and currents (Messieh et al. 1991). This destabilization of the seabed can lead to changes in sedimentation rates and a reduction in benthic resources, such as shellfish beds and SAV (Wilber et al. 2005). In addition, changes in substrate type can smother demersal eggs, affect larval settlement, and increase predation on juveniles adapted to coarser bottom substrates (Messieh et al. 1991; Wilber et al. 2005).

Navigational dredging can remove natural benthic habitat features, such as shoals, sand bars, and other natural sediment deposits. The removal of such features can alter the water depth, change current direction or velocity, modify sedimentation patterns, alter wave action, and create bottom scour or shoreline erosion (Barr 1987). Channel dredging can alter the estuarine hydrology and the mixing zone between fresh and salt water, leading to accelerated upland run-off, lowered freshwater aquifers, and greater saltwater intrusion into aquifers, as well as reduce the buffering capabilities of wetlands and shallow water habitats (Barr 1987; Nightingale and Simenstad 2001b).

Navigational channels that are substantially deeper than surrounding areas can become anoxic or hypoxic as natural mixing is decreased and detrital material settles out of the water column and accumulates in the channels. This concentration of anoxic or hypoxic water can stress nearshore biota when mixing occurs from a storm event (Allen and Hardy 1980). The potential for anoxic conditions can be reduced in areas that experience strong currents or wave energy, and sediments are more mobile (Barr 1987; Newell et al. 1998).

## Altered temperature regimes

Channel and port dredging can alter bottom topography, increase water depths, and change circulation patterns in the dredged area, which may increase stratification of the water column and reduce vertical mixing. This thermal layering of water may create anoxic or hypoxic conditions for benthic habitats. Deepened or new navigation channels may create deep and poorly flushed areas that experience reduced light penetration and water temperatures. Temperature influences biochemical processes and deep channels may create zones of poor productivity that can serve as barriers to migration for benthic and demersal species and effectively fragment estuarine habitats.

## Conservation recommendations and best management practices for navigational dredging

1. Avoid new dredging to the maximum extent practicable. Activities that would likely require dredging (such as placement of piers, docks, marinas, etc.) should instead be located in deep water or designed to alleviate the need for maintenance dredging.
2. Reduce the area and volume of material to be dredged to the maximum extent practicable.

3. Ensure that the volumes of dredge material are appropriately considered and that the identified disposal sites are adequate in containing the material. For example, the volume of material removed for the allowable over-depth dredging (usually 2 feet below the authorized or target depth) should be included in the disposal volume calculations.
4. Ensure that areas proposed for dredging are necessary in order to maintain the necessary and authorized target depths of the channel. Recent bathymetric surveys should be reviewed to evaluate the existing depths of the area proposed for dredging. Areas within the proposed dredge area that are at or deeper than the target depths should be avoided, whenever practicable.
5. Identify sources of erosion in the watershed that may be contributing to excessive sedimentation and the need for regular maintenance dredging activities. Implement appropriate management techniques to ensure that actions are taken to curtail those causes.
6. Use settling basins to act as sediment traps to prevent accretion of sediments in the navigational channel, when appropriate. This reduces the need for frequent maintenance dredging of the entire channel.
7. Consider the effects of increased boat traffic to an area when assessing a new dredging project or expanding existing channels. Increases in the speed, size, and density of boat traffic in an area may require increased frequency of maintenance dredging and produce a number of secondary impacts, such as shoreline erosion, sedimentation, and turbidity.
8. Identify the user group during the planning process to ensure that the dredging project meets the basic needs of the target user without exceeding an appropriate size and scope, or encouraging inappropriate use.
9. Consider time-of-year dredging restrictions, which may reduce or avoid impacts to sensitive life history stages, such as migration, spawning, or egg and young-of-year development. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
10. Avoid projects that involve dredging intertidal and wetland habitat.
11. Avoid dredging in areas with SAV, areas which historically supported SAV, and areas which are potential habitat for recolonization by SAV.
12. Conduct both historic surveys of the area and predredge surveys because of the spatial and temporal dynamic nature of SAV beds.
13. Avoid dredging in areas supporting shellfish beds.
14. Consider beneficial uses for uncontaminated sediments when practicable and feasible. Priority should be given to beneficial uses of material that contributes to habitat restoration and enhancement, landscape ecology approach, and includes pre- and post-disposal surveys.
15. Avoid beneficial use projects that impose unnatural habitats and features and involve habitat trade-offs (substituting one habitat type for another).
16. Ensure that sediments are tested for contaminants and meet or exceed US EPA requirements and standards prior to dredging and disposal.
17. Assess cumulative impacts for current activities in the vicinity of a proposed dredging project, as well as for activities in the past and foreseeable future.
18. Ensure that bankward slopes of the dredged area are slanted to acceptable side slopes (e.g., 3:1 ratio) to ensure that sloughing of the channel side slopes does not occur.
19. Avoid placing pipelines and accessory equipment used in conjunction with dredging operations close to algae beds, eelgrass beds, estuarine/salt marshes, and other high value habitat areas.
20. Use silt curtains in some locations to reduce impacts of suspended sediments on adjacent benthic resources.
21. Avoid dredging in fine sediments when possible to reduce turbidity plumes and the release of nutrients and contaminants which tend to bind to fine particles.

22. Include information on control sites and predredging sampling for comparison and monitoring of impacts in environmental assessments for dredging projects.
23. Ensure that disposal sites are properly sited (i.e., avoid sensitive resources and habitats) and are appropriate for the type of dredge material proposed for disposal.
24. Ensure that disposal sites are being properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material.

# References for Marine Transportation

Able KW, Manderson JP, Studholme AL. 1999. Habitat quality for shallow water fishes in an urban estuary: the effects of man-made structures on growth. Marine Ecology Progress Series 187:227-35.

Allen KO, Hardy JW. 1980. Impacts of navigational dredging on fish and wildlife a literature review. Washington (DC): Biological Services Program, USFWS.

Amaral M, Lee V, Rhodes J. 2005. Environmental guide for marinas: controlling nonpoint source and storm water pollution in Rhode Island: best management practices for marinas. [Internet]. Narragansett (RI): University of Rhode Island, Coastal Resources Center, Rhode Island Sea Grant. [cited 2007 Dec 28]. Available from: http://seagrant.gso.uri.edu/BMP/BMP.html.

[ASMFC] Atlantic States Marine Fisheries Commission. 2004. NRC report outlines the impacts of oil on marine fish habitat. Habitat Hotline Atlantic 11(3):1-5.

Barr BW. 1987. The dredging handbook: a primer for dredging in the coastal zone of Massachusetts. Boston (MA): Massachusetts Coastal Zone Management. Publication No. 14, 870-181-500-6-87-CR.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Benfield MC, Minello TJ. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fishes 46:211-6.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. Ninth flatfish biology conference- poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Blaxter JHS. 1977. The effect of copper on the eggs and larvae of plaice and herring. Journal of the Marine Biological Association of the United Kingdom 57:849-59.

Burdick DM, Short FT. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23(2):231-40.

Caltrans. 2001. San Francisco-Oakland Bay Bridge East Span seismic safety project, pile installation demonstration project, fisheries impact assessment. Sacramento (CA): California Department of Transportation. 59 p.

Cardwell RD, Koons RR. 1981. Biological considerations for the siting and design of marinas and affiliated structures in Puget Sound. Olympia (WA): Washington Department of Fisheries. Technical Report No. 60. 31 p.

Cardwell RD, Olsen SJ, Carr MI, Sanborn EW. 1980. Biotic, water quality and hydrologic characteristics of skyline marina in 1978. Olympia (WA): Washington Department of Fisheries. Technical Report No. 54. 103 p.

Carlson TJ, Ploskey G, Johnson RL, Mueller RP, Weiland MA, Johnson PN. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Richland (WA): US Army Corps of Engineers, Portland District. 35 p + appendices.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Chapman MG. 2003. Paucity of mobile species on constructed seawalls: effects of urbanization on biodiversity. Marine Ecology Progress Series 264:21-9.

Cloern JE. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7(11-12):1367-81.

Costa JE, Howes BL, Giblin AE, Valiela I. 1992. Monitoring nitrogen and indicators of nitrogen loading to support management action in Buzzards Bay. In: McKenzie DH, Hyatt DE, McDonald VJ, editors. Ecological indicators. New York (NY): Elsevier Applied Science. p 499-531.

Cottingham D. 1988. Persistent marine debris: challenge and response: the federal perspective. Fairbanks (AK): Alaska Sea Grant. Report No. 88-1.

Dahl TE. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. [Internet]. Washington (DC): US Department of the Interior; Fish and Wildlife Service. [cited 2008 Jul 21]. 112 p. Available from: http://wetlandsfws.er.usgs.gov/status_trends/National_Reports/trends_2005_report.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dennison WC. 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany 27(1):15-26.

Dolat SW. 1997. Acoustic measurements during the Baldwin Bridge demolition. Waterford (CT): Prepared for White Oak Construction by Sonalysts. 34 p + appendices.

Eriksson BK, Sandstrom A, Iscus M, Schreiber H, Karas P. 2004. Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuarine, Coastal and Shelf Science 61(2):339-49.

Feist BE, Anderson JJ, Miyamoto R. 1996. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Seattle (WA): Fisheries Research Institute-University of Washington. FRI-UW-9603. 58 p.

Fresh KL, Williams B, Penttila D. 1995. Overwater structures and impacts on eelgrass (*Zostera marina*) in Puget Sound, Washington. In: Puget Sound Research '95 Proceedings; 1995 Jan 12-14; Bellevue, WA. Olympia (WA): Puget Sound Water Quality Authority. p 537-43.

Fresh KL, Williams BW, Wyllie-Echeverria S, Wyllie-Echeverria T. 2001. Mitigating impacts of overwater floats on eelgrass *Zostera marina* L. in Puget Sound, Washington. In: Proceedings of Puget Sound Research 2001-The fifth Puget Sound Research Conference; 2001 Feb 12-14; Bellevue, WA. Olympia (WA): Puget Sound Action Team.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. p 68 + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Haas MA, Simenstad CA Jr, Cordell JR, Beauchamp DA, Miller BS. 2002. Effects of large overwater structures on epibenthic juvenile salmon prey assemblages in Puget Sound, WA. [Internet]. Seattle (WA): Washington State Transportation Center (TRAC), University of Washington, and Washington State Department of Transportation. Final Research Report WA-RD 550.1. [cited 2008 Jul 9]. 114 p. Available from: http://depts.washington.edu/trac/bulkdisk/pdf/550.1.pdf.

Hall LW Jr, Anderson RD. 1999. A deterministic ecological risk assessment for copper in European saltwater environments. Marine Pollution Bulletin 38(3):207-18.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hastings K, Hesp P, Kendrick G. 1995. Seagrass loss associated with boat moorings at Rottnest Island, Western Australia. Ocean & Coastal Management 26:225-46.

Hawkins AD. 1986. Underwater sound and fish behaviour. In: Pitcher TJ, editor. The behavior of teleost fishes. Baltimore (MD): The Johns Hopkins University Press. p 114-51.

Heintz RA, Rice SD, Wertheimer AC, Bradshaw RF, Thrower FP, Joyce JE, Short JW. 2000. Delayed effects on growth and marine survival of pink salmon *Oncorhynchus gorbuscha* after exposure to crude oil during embryonic development. Marine Ecology Progress Series 208:205-16.

Helton D, Zelo I. 2003. Developing information and support necessary to prioritize and support removal of abandoned vessels impacting coral resources. In: Proceedings of the 13th

Biennial Coastal Zone Conference; 2003 Jul 13-17; Baltimore, MD. Charleston (SC): NOAA Coastal Services Center.

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hoagland P, Kite-Powell HL. 1997. Characterization and mitigation of marine debris in the Gulf of Maine. A report prepared for the U.S. Gulf of Maine Association under contract no. GM97-13. Gulf of Maine Council on the Marine Environment. 41 p.

Hofer T. 1998. Part II: Environmental and health effects resulting from marine bulk liquid transport. Environmental Science and Pollution Research 5(4):231-7.

[ICES] International Council for the Exploration of the Sea. 1992. Report of the ICES working group on the effects of extraction of marine sediments on fisheries. Copenhagen (Denmark): ICES Cooperative Research Report # 182.

Jasny M, Reynolds J, Horowitz C, Wetzler A. 1999. Sounding the depths: supertankers, sonar, and rise of undersea noise. Los Angeles (CA): Natural Resources Defense Council. Marine Mammal Protection Project. 38 p.

Kahler T, Grassley M, Beauchamp DA. 2000. A summary of the effects of bulkheads, piers, and other artificial structures and shorezone development on ESA listed salmonids in lakes. [Internet]. Bellevue (WA): Final Report to the City of Bellevue. [cited 2007 Dec 28]. 74 p. Available from: http://www.cityofbellevue.org/pdf/Utilities/dock_bulkhead.pdf.

Kalmijn AJ. 1988. Hydrodynamic and acoustic field detection. In: Atema J, Fay RR, Popper AN, Tavolga WN, editors. Sensory biology of aquatic animals. New York (NY): Springer-Verlag. p 83-130.

Karaki S, vanHoften J. 1975. Resuspension of bed material and wave effects on the Illinois and upper Mississippi Rivers caused by boat traffic. St. Louis (MO): US Army Engineer District. Cont. No. LMSSD 75-881.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C, and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Keevin TM. 1998. A review of natural resource agency recommendations for mitigating the impacts of underwater blasting. Reviews in Fisheries Science 6(4):281-313.

Keevin TM, Gaspin JB, Gitschlag GR, Hempen GL, Linton TL, Smith M, Wright DG. 1999. Underwater explosions: natural resource concerns, uncertainty of effects, and data needs. In: Proceedings of the twenty-fifth annual conference on explosives and blasting technique; 1999 Feb 7-10; Nashville, TN. Cleveland (OH): International Society of Explosive Engineers. p 105-16.

Keevin TM, Hempen GL, Schaeffer DJ. 1997. Use of a bubble curtain to reduce fish mortality during explosive demolition of Locks and Dam 26, Mississippi River. In: Proceedings of the twenty-third annual conference on explosives and blasting technique; 1997 Feb 2-5; Las Vegas, NV. Cleveland (OH): International Society of Explosive Engineers. p 197-206.

Kipple B, Gabriele C. 2004. Glacier Bay watercraft noise-noise characterization for tour, charter, private, and government vessels. Bermerton (WA): Naval Surface Warfare Center-Detachment Bermerton. Technical Report NSWCCD-71-TR-2004/545. 47 p.

Klein R. 1997. The effects of marinas and boating activities upon tidal waters. Owing Mills (MD): Community and Environmental Defense Services. 23 p.

Klein-MacPhee G, Macy WK, Berry W. 2004. *In situ* effects of suspended particulate loads produced by dredging on eggs of winter flounder (*Pseudopleuronectes americanus*). In: Ninth flatfish biology conference- oral presentation; 2004 Dec 1-2; Water's Edge Resort, Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Knudsen FR, Schreck CB, Knapp SM, Enger PS, Sand O. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology 51:824-9.

Krone CA, Brown DW, Burrows DG, Chan S-L, Varanasi U. 1989. Butyltins in sediment from marinas and waterways in Puget Sound, Washington State, USA. Marine Pollution Bulletin 20(10):528-31.

Larson K, Moehl CE. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): Washington Sea Grant, University of Washington. p 102-12.

Longmuir C, Lively T. 2001. Bubble curtain systems for use during marine pile driving. New Westminister (British Columbia): Fraser River Pile and Dredge LTD. 9 p.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

McGraw K, Armstrong D. 1990. Fish entrainment by dredges in Grays Harbor, Washington. In: Simenstad CA Jr, editor. Effects of dredging on anadromous Pacific coast fishes. Seattle (WA): University of Washington Sea Grant. p 113-31.

Messieh SN, El-Sabh MI. 1988. Man-made environmental changes in the southern Gulf of St. Lawrence, and their possible impact on inshore fisheries. In: El-Sabh MI, Murty TS, editors. Natural and man-made hazards. Boston (MA): D. Reidel Publishing Co. p 499-523.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Michel J, Helton D. 2003. Environmental considerations during wreck removal and scuttling. In: Abandoned Vessel Program (AVP) Conference Proceedings-National Maritime Salvage Conference; 2003 Sep 9-11; Crystal City, VA. Arlington (VA): American Salvage Association.

Milliken AS, Lee V. 1990. Pollution impacts from recreational boating: a bibliography and summary review. Narragansett (RI): Rhode Island Sea Grant. National Sea Grant Depository Publication # RIU-G-002.

Mills KE, Fonseca MS. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-34.

Moore M, Stolpe NE. 1995. Boating workshop raises tough questions. Commercial Fisheries News 22(7):6B-7B and 15B.

Mulvihill EL, Francisco CA, Glad JB, Kaster KB, Wilson RE. 1980. Biological impacts of minor shoreline structures in the coastal environment: state of the art review. Sidell (LA): US Fish and Wildlife. FWS/OBS-77/51. Vol. 1. 156 p.

Myrberg AA Jr. 1972. Using sound to influence the behavior of free-ranging marine mammals. In: Winn HE, Olla BL, editors. Behavior of marine animals. Vol. 2: Vertebrates. New York (NY): Plenum Press. p 435-68.

Myrberg AA Jr, Riggio RJ. 1985. Acoustically mediated individual recognition by a coral reef fish (*Pomacentrus partitus*). Animal Behaviour 33:411-6.

Neff JM. 1985. Polycyclic aromatic hydrocarbons. In: Rand GM, Petrocelli SR, editors. Fundamentals of aquatic toxicology. Washington (DC): Hemisphere Publishing. p 416-54.

Negri AP, Smith LD, Webster NS, Heyward AJ. 2002. Understanding ship-grounding impacts on a coral reef: potential effects of anti-foulant paint contamination on coral recruitment. Marine Pollution Bulletin 44:111-7.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Nightingale BJ, Simenstad CA Jr. 2001a. Overwater structures: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 9]. 133 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finalmar.pdf.

Nightingale B, Simenstad CA Jr. 2001b. Dredging activities: marine issues. [Internet]. Olympia (WA): Washington Department of Fish and Wildlife. White Paper. [cited 2008 Jul 17]. 119 p + appendices. Available from: http://wdfw.wa.gov/hab/ahg/finaldrg.pdf.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

Orth RJ, Batiuk RA, Moore KA. 2002. A perspective on two decades of policies and regulations influencing the protection and restoration of submerged aquatic vegetation in Chesapeake Bay, USA. Bulletin of Marine Science 71(3):1391-403.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, William SL. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Penttila D, Doty D. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Olympia (WA): Washington Department of Fisheries. Draft Progress Report. 41 p.

Pertola S, Faust MA, Kuosa H. 2006. Survey on germination and species composition of dinoflagellates from ballast tanks and recent sediments in ports on the South Coast of Finland, North-Eastern Baltic Sea. Marine Pollution Bulletin 52(8):900-11.

Poston T. 2001. Treated wood issues associated with overwater structures in freshwater and marine environments. [Internet]. Olympia (WA): Washington State Departments of Transportation, Fish and Wildlife, and Ecology. White Paper. [cited 2008 Jul 9]. 85 p. Available from: http://wdfw.wa.gov/hab/ahg/finaltw.pdf.

Precht WF, Aronson RB, Swanson DW. 2001. Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. Bulletin of Marine Science 69(2):1001-12.

Readman JW, Kwong LLW, Grondin D, Bartocci J, Villeneuve JP, Mee LD. 1993. Coastal water contamination from triazine herbicide used in antifouling paints. Environmental Science and Technology 27(9):1940-2.

Richard JD. 1968. Fish attraction with pulsed low-frequency sound. Journal of the Fisheries Research Board of Canada 25(7):1441-52.

Richardson WJ, Greene CR, Malme CI, Thomas DH. 1995. Marine mammals and noise. San Diego (CA): Academic Press. 576 p.

Sand O, Enger PS, Karlsen HE, Knudsen F, Kvernstuen T. 2000. Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. Environmental Biology of Fishes 57(3):327-36.

Scholik AR, Yan HY. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63:203-9.

Shafer DJ. 1999. The effects of dock shading on the seagrass *Halodule wrightii* in Perdido Bay, Alabama. Estuaries 22(4):936-43.

Smith KN, Mezich RR. 1999. Blending management and research for protection of manatee habitat in Florida: the seagrass dock effect. In: Poster presentation at the 15th Biennial International Estuarine Research Federation Conference; 1999 Sep 25-30; New Orleans, LA. Port Republic (MD): Coastal and Estuarine Research Federation.

Smith LD, Negri AP, Philipp E, Webster NS, Heyward AJ. 2003. The effects of antifoulant-paint-contaminated sediments on coral recruits and branchlets. Marine Biology 143:651-7.

Stocker M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America 112(5):2431.

Stolpe NE, Moore M. 1997. Boating workshop raises tough questions. [Internet]. New Jersey Fishing. Commercial Fisheries News 22(7); c2007 [cited 2007 Dec 28]. Available from: http://www.fishingnj.org/artobm2.htm.

Stotz T, Colby J. 2001. January 2001 dive report for Mukilteo wingwall replacement project. Washington State Ferries Memorandum. 5 p + appendices.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Sunda WG. 1994. Trace metal/phytoplankton interactions in the sea. In: Bidoglio G, Stumm W, editors. Chemistry of aquatic systems: local and global perspectives. Norwell (MA): Kluwer Academic Publishers Group. p 213-47.

Thayer WG, Fonseca MS, Kenworthy JW. 1997. Ecological value of seagrasses: a brief summary for the ASMFC habitat committee's SAV subcommittee. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. p 68 + appendices.

Thom RM, Shreffler DK. 1996. Eelgrass meadows near ferry terminals in Puget Sound: characterization of assemblages and mitigation impacts. Sequim (WA): Battelle Pacific Northwest Laboratories.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Tyrrell MC. 2005. Gulf of Maine marine habitat primer. [Internet]. Gulf of Maine Council on the Marine Environment. vi + 54 p. [cited 2008 Jul 2]. Available from: www.gulfofmaine.org/habitatprimer/.

Uhrin AV, Holmquist JG. 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Marine Ecology Progress Series 250:61-70.

[USEPA] US Environmental Protection Agency. 2000. Environmental screening checklist and workbook for the water transportation industry. Washington (DC): US EPA Office of Water. EPA-305-B-00-004.

[USEPA] US Environmental Protection Agency. 2001. National management measures guidance to control nonpoint source pollution from marinas and recreational boating. Washington (DC): US EPA Office of Water. EPA-841-B-01-005.

Waite ME, Waldock MJ, Thain JE, Smith DJ, Milton SM. 1991. Reductions in TBT concentrations in UK estuaries following legislation in 1986 and 1987. Marine Environmental Research 32:89-111.

Walker DI, Kendrick GA. 1998. Threats to macroalgal diversity: marine habitat destruction and fragmentation, pollution, and introduces species. Botanica Marina 41(1):105-12.

Walker DI, Lukatelich RJ, Bastyan G, McComb AJ. 1989. Effect of boat moorings on seagrass beds near Perth, Western Australia. Aquatic Botany 36(1):69-77.

Warnken J, Dunn RJK, Teasdale PR. 2004. Investigation of recreational boats as a source of copper at anchorage sites using time-integrated diffusive gradients in thin film and sediment measurements. Marine Pollution Bulletin 49(9-10):833-43.

Weis JS, Weis P. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-10.

Weis P, Wies JS, Coohill LM. 1991. Toxicity to estuarine organisms of leachates from chromated copper arsenate treated wood. Archives of Environmental Contamination and Toxicology 20:118-24.

Wertheimer AC, Heintz RA, Thedinga JF, Maselko JM, Rice SD. 2000. Straying of adult pink salmon from their natal stream following embryonic exposure to weathered *Exxon Valdez* crude oil. Transactions of the American Fisheries Society 129(4):989-1004.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White Paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. [cited 2008 Jul 9]. 99 p. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

Wright DG. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Winnipeg (Manitoba): Western Region, Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1052.

Yousef YA. 1974. Assessing effects on water quality by boating activity. Washington (DC): US Environmental Protection Agency. EPA-670/2-74-072. 60 p.

Zelo I, Helton D. 2005. Removal of grounded, derelict or abandoned vessels as site restoration. In: Abandoned Vessel Program (AVP) Conference Proceedings-International Oil Spill Conference; 2005 May 15-19; Miami Beach, FL. Seattle (WA): NOAA Ocean Service Office of Response and Restoration. 15 p.

# CHAPTER SIX: OFFSHORE DREDGING AND DISPOSAL ACTIVITIES

## Introduction

This chapter describes activities associated with offshore dredging and disposal and their potential effects on living marine resources and habitats in the northeast region of the United States. For purposes of this discussion, the "offshore" environment is defined as those waters and seabed areas considered to be "estuarine" environments and extending offshore to and occasionally beyond the edge of the continental shelf. For example, while the open waters of Chesapeake Bay, MD/VA, and Long Island Sound, NY/CT, are considered offshore for this discussion, the coves and embayments within those waters bodies are not. In addition, Raritan Bay, NY/NJ, (lower New York Harbor) and similar areas are considered offshore environments. Dredging and disposal activities within riverine habitats have been discussed in the Alteration of Freshwater Systems chapter of this report, and information on dredging within navigation channels can be reviewed in the Marine Transportation chapter of this report.

## Offshore Mineral Mining

### *Introduction*

There is an increasing demand for beach nourishment sand and a smaller, but growing, demand for construction and "stable fill" grade aggregates. As the historic landside sources of these materials have been reduced, there has been a corresponding move towards mining the continental shelf to meet this demand. It is expected that the shift to offshore mineral extraction will continue and escalate, particularly in areas where glacial movements have relocated the desired material to the continental shelf. Typically, these deposits are not contaminated because of their offshore location and isolation from anthropogenic pollution sources. Beginning in the mid-1970s, the US Geological Survey began mapping the nature and extent of the aggregate resources in coastal and nearshore continental shelf waters throughout the northeast beyond the 10-m isobath. Between 1995 and 2005, the Minerals Management Service (MMS), which oversees offshore mineral extractions, regulated the relocation of over 23 million cubic yards of sand from the Outer Continental Shelf (OCS) for beach nourishment projects (MMS 2005a). The OCS is defined as an area between the seaward extent of states' jurisdiction and the seaward extent of federal jurisdiction. Currently, the MMS, in partnership with 14 coastal states, is focusing on collecting and analyzing geologic and environmental information in the OCS in order to study sand deposits suitable for beach nourishment and wetlands protection projects and to assess the environmental impacts of OCS mining in general (Drucker et al. 2004). With the advances in marine mining and "at sea" processing, aggregate extraction can occur in waters in excess of 40 m **(**MMS 2005a**)**.

Mineral extraction is usually conducted with hydraulic dredges by vacuuming or, in some cases, by mechanical dredging with clamshell buckets in shallow water mining sites. Mechanical dredges can have a more severe but localized impact on the seabed and benthic biota, whereas hydraulic dredges may result in less intense but more widespread impact (Pearce 1994). The impacts of offshore mineral mining on living marine resources and their habitats include: (1) the removal of substrates that serve as habitat for fish and invertebrates; (2) creation of (or conversion to) less productive or uninhabitable sites such as anoxic depressions or highly hydrated clay/silt substrates; (3) release of harmful or toxic materials either in association with actual mining, or from incidental or accidental releases from machinery and materials used for mining; (4) burial of productive habitats during beach nourishment or other shoreline stabilization activities; (5) creation of harmful suspended sediment levels; and (6) modification of hydrologic conditions causing adverse impacts to desirable habitats (Pearce 1994; Wilber et al. 2003).

In addition, mineral extraction can potentially have secondary and indirect adverse effects on fishery habitat at the mining site and surrounding areas. These impacts may include accidental or intentional discharges of mining equipment and processing wastes and degradation or elimination of marine habitats from structures constructed to process or transport mined materials. These secondary effects can sometimes exceed the initial, direct consequences of the offshore mining.

### *Loss of benthic habitat types*

Offshore benthic habitats occurring on or over target aggregates may be adversely affected by mining. The mineral extraction process can disrupt or eliminate existing biological communities within the mining or borrow areas for several years following the excavation. Filling in of the borrow areas and reestablishment of a stable sediment structure is dependent upon the ability of bottom currents to transport similar sediments from surrounding areas to the mining site (ICES 1992). The principal concern noted by the International Council for the Exploration of the Sea (ICES) Working Group on the Effects of Extraction of Marine Sediments on Fisheries was dredging in spawning areas of commercial fish species (ICES 1992). Of particular concern to the ICES Working Group are fishery resources with demersal eggs (e.g., Atlantic herring [*Clupea harengus*] and sand lance [*Ammodytes marinus*]). They report that when aggregates are removed, Atlantic herring eggs are taken with them, resulting in lost production to the stock. Stewart and Arnold (1994) list the impacts on Atlantic herring from offshore mining to include the entrainment of eggs, larvae, and adults; burial of eggs; and effects of the turbidity plume on demersal egg masses. Gravel and coarse sand have been identified as preferred substrate for Atlantic herring eggs on Georges Bank and in coastal waters of the Gulf of Maine (Stevenson and Scott 2005).

### *Conversion of substrate/habitat and changes in community structure*

Disposal of residues ("tailings") of the mining process can alter the type, as well as the functions and values, of habitats which can then alter the survival and growth of marine organisms. The tailings are often fine-grained and highly hydrated, making them very dissimilar to the natural seafloor, particularly in depths where wave energy and currents are capable of winnowing or sorting sediments and relocating them to depositional areas. It has been found that wave forces are affecting habitats in the New York Bight at depths in excess of 22 m (USACE 2005a). In laboratory experiments, benthic dwelling flatfishes (Johnson et al. 1998a) and crabs (Johnson et al. 1998b) persistently avoided sediments comprised of mine tailings.

Additionally, there can be adverse impacts from aggregate and/or mineral mining on nearby habitats associated with the removal and disturbance of substrate (Scarrat 1987). Seabed alteration can fragment habitat, reduce habitat availability, and disrupt predator/prey interactions, resulting in negative impacts to fish and shellfish populations. Not all offshore aggregate mining results in adverse impacts on seabed resources. Hitchcock and Bell (2004) conducted a detailed study of the effects from a small-scale, aggregate mining operation off the south coast of the United Kingdom and found physical impacts on the seabed to be limited to a downtide zone approximately 300 m from the dredge area. Related studies at this mining operation reported no detectable impact on the surrounding benthic communities, despite a small change in seabed particle size distribution (Hitchcock and Bell 2004).

Long-term mining can alter the habitat to such a degree that recovery may be extremely protracted and create habitat of limited value to benthic communities during the entire recovery period (van Dalfsen et al. 2000). For example, construction grade aggregate removal in Long Island Sound, Raritan Bay (lower New York Harbor) and the New Jersey portion of the intercoastal waterway have left borrow pits that are more than twice the depth of the surrounding area. The pits have remained chemically, physically, and biologically unstable with limited diversity communities for more than five decades. These pits were used to provide fill material for interstate transportation projects and have been investigated to assess their environmental impact (Pacheco 1984). Borrow pits in Raritan Bay were found to possess depressed benthic communities and elevated levels of highly hydrated and organically enriched sediments (Pacheco 1984). In one example, aggregate mining operations from the 1950s through the 1970s created a 20 m deep borrow pit in an area of Raritan Bay that, although the mining company was required to refill the pit, remains today as a rapid deposition area filling with fine-grained sediment and organic material emanating from the Hudson River and adjacent continental shelf (Pacheco 1984**)**. The highly hydrated sediments filling the depressions are of limited utility to colonizing benthic organisms.

In offshore mining operation sites, the character of the sediment which is exposed or subsequently accumulates at the extraction site is important in predicting the composition of the colonizing benthic community (ICES 1992). If the composition and topography of the extraction site resembles that which originally existed, then colonization of it by the same benthic fauna is likely (ICES 1992).

### *Changes in sediment composition*

A review of studies conducted in Europe and Great Britain found that infilling and subsequent benthic recovery of borrow areas may take from 1-15 years, depending upon the tide and current strength, sediment characteristics, the stock of colonizing species and their immigration distance (ICES 1992). Typically the reestablishment of the community appears to follow a successional process similar to those on abandoned farmlands. Germano et al. (1994) described this process, reporting that pioneering species (i.e., Stage I colonizers) usually do not select any particular habitat but attempt to survive regardless of where they settle. These species are typically filter feeders relying on the availability of food in the overlying water rather than the seafloor on which they reside. Thus, their relationship to the substrate is somewhat tenuous, and their presence is often ephemeral. However, their presence tends to provide some stability to the seafloor, facilitating subsequent immigrations by other species that bioturbate the sediment seeking food and shelter. Their arrival induces further substrate consolidation and compaction. These colonizers are usually deemed to be Stage II community species. The habitat modification activities of Stage I and II species advance substrate stability and consolidation enough for it to support, both physically and nutritionally, the largest community members (i.e., Stage III). The benthic community instability caused by dredging gives rise to one of the principal justifications for retaining benthic disturbances: the disrupted site may become heavily populated by opportunistic (i.e., Stage I) colonizer species that flourish briefly and provide motile species with an abundance of food during late summer and fall periods (Kenny and Rees 1996). However, if environmental stresses are chronic, the expected climax community may never be attained (Germano et al. 1994).

If the borrow area fails to refill with sediment similar to that which was present prior to mining, the disturbed area may not possess the original physical and chemical conditions and recovery of the community structure may be restricted or fail to become reestablished. Dredge pits that have been excavated to depths much greater than the surrounding bottom often have very slow infill rates and can be a sink for sediments finer than those of the surrounding substrate (ICES 1992).

### Changes in bottom topography and hydrology

The combination of rapid deposition, anomalous sediment character, and an uneven topography, as compared to the surrounding seafloor, limit recolonization opportunities for harvesting purposes (Wilk and Barr 1994). By altering bottom topography, aggregate mining can reduce localized current strength, resulting in lowered dissolved oxygen concentrations and increased accumulation of fine sediments inside borrow pits (ICES 1992). One potential benefit of some borrow pits is that they appear to provide refugia for pelagic species such as alewife (*Alosa pseudoharengus*) and scup (*Stenotomus chrysops*), as well as demersal species such as tautog (*Tautoga onitis*) and black sea bass (*Centropristis striata*) during seasonally fluctuating water temperatures (Pacheco 1984). However, it is doubtful these benefits outweigh the persistent adverse affects associated with borrow pits (Palermo et al. 1998; Burlas et al. 2001). Other consequences of aggregate mining may include alteration of wave and tidal current patterns which could affect coastal erosion (ICES 1992).

### Siltation, sedimentation, and turbidity

Offshore mining can increase the suspended sediment load in the water column, increasing turbidity that can then adversely affect marine organisms, particularly less motile organisms such as shellfish, tunicates, and sponges. The duration of the turbidity plume in the water column depends upon the water temperature, salinity, current speed, and the size range of the suspended particles (ICES 1992). The distance the dredged material is transported from the excavation site will be dependent upon the current strength, storm resuspension, water salinity and temperature, and the grain size of the suspended material (ICES 1992).

The life stages of the affected taxa are an important factor affecting the type and extent of the adverse impacts (Wilber and Clarke 2001). As a general rule, the severity of sedimentation and turbidity effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996; Wilber and Clarke 2001). In particular, the eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Stewart and Arnold (1994) list the impacts on Atlantic herring from offshore mining to include the effects of the turbidity plume on demersal egg masses.

### Impacts to water quality

The release of material into the water column during offshore mining operations can degrade water quality if the excavated material is high in organic content or clay. The effects of mixing on the water column are likely to include increased consumption of oxygen by decomposing organic matter and the release of nutrients (ICES 1992). However, mined aggregate material is typically low in organic content and clay, and any increase in the biological oxygen demand is thought to be minor and of limited spatial extent (ICES 1992).

Deep borrow pits can become anaerobic during certain times of the year. The dissolved oxygen concentration within these pits can be depressed to a level that adversely affects the ability of fish and invertebrates to utilize the area for spawning, feeding, and development (Pacheco 1984).

### Release of contaminants

A number of factors (i.e., environmental, geochemical, and biological) influence the potential release and bioavailability of sediment contaminants. The toxicity of such releases, in general, is primarily dependent upon the contaminant involved, its concentration in the sediments and its chemical/geochemical state. Persistent organic pollutants (POPs), such as polyaromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyl (PCBs), are sequestered in the total organic carbon (TOC) fraction of sediments (USEPA 2003a; USEPA 2003b; USEPA 2003c). Similarly, heavy metals are sequestered by acid volatile sulfides (AVS) and the TOC fraction of marine sediments (USEPA 2005a). For POPs like PAHs, the ratio of the concentrations of these contaminants relative to those of the fractions govern bioavailability and hence toxicity (USEPA 2003a). In the case of metals, bioavailability is governed by an excess of AVS concentrations relative to the metal concentrations as normalized by TOC (USEPA 2005a). Sand and gravel sediments typically contain low TOC and AVS concentrations, and where there is a prominent source of POPs and metals, such as in highly industrialized riverways, these coarser sediments could in fact release such contaminants when disturbed or oxidized. However, the coarse-grained sediments typically targeted for aggregate mining tend to be found in high-energy environments which are not depositional areas that can be sinks for fine-grained material containing POPs and metals. Since most offshore sand and gravel deposits do not have prominent nearby sources of POPs and metals, these deposits are generally low in contaminants (ICES 1992; Pearce 1994). Thus, the mining of offshore sand and gravel material typically do not release high levels of contaminants. In addition, because of their relatively large particle size, low surface area relative to total bulk, and low surface activity (i.e., few clay or organic materials to interact chemically), there is usually little chemical interaction in the water column (Pearce 1994). However, extraction of material in estuaries or deep channels, where fine material accumulates and is subject to anthropogenic pollution deposition, may be more likely to release harmful chemicals during dredging and excavation (Pearce 1994). Refer to the chapters on Coastal Development, Marine Transportation, and Chemical Effects: Water Discharge Facilities for additional information on the release of contaminants during dredging and excavation.

### Sediment transport from site

Excavation at an offshore mining site that contains fine material can release suspended sediments into the water column during the excavation, as well as in the sorting or screening process. The distance the dredged material is transported from the excavation site will be dependent upon the current strength, storm resuspension, water salinity and temperature, and the grain size of the suspended material (ICES 1992). Some of the potential effects of redeposition of fines include smothering of demersal fish eggs on spawning grounds and the suffocation of filter-feeding benthos, such as shellfish and anemones (ICES 1992; Pearce 1994). Small-scale aggregate mining operations that are conducted in relatively shallow water and involving sandy, coarse-grained sediments often have relatively minimal physical and biological impacts on the surrounding seabed (Hitchcock and Bell 2004).

### Noise impacts

Anthropogenic sources of ocean noise appear to have increased over the past decades, and have been primarily attributed to commercial shipping, offshore gas and oil exploration and drilling, and naval and other uses of sonar (Hildebrand 2004). Offshore mineral mining likely contributes to the overall range of anthropogenic ocean noise, but little information exists regarding specific effects on marine organisms and their habitats or the importance of offshore mining relative to other sources of anthropogenic noise. The dredging equipment noise generated in offshore mining may be similar to navigation channel dredging in nearshore habitats; however, because of the greater water depths involved in offshore mining, the noise may be propagated for greater distances than in confined nearshore areas (Hildebrand 2004). Reductions in Atlantic herring catches on the Finnish coast were hypothesized to be due to disturbance to the herring movement patterns by noise and activity associated with sand and gravel mining activities (Stewart and Arnold 1994). Refer to the chapters on Global Affects and Other Impacts and Marine Transportation for additional information on noise impacts.

### *Conservation measures and best management practices for offshore mineral mining*

1. Avoid mining in areas containing sensitive or unique marine benthic habitats (e.g., spawning and feeding sites, surface deposits of cobble/gravel substrate).
2. Complete a comprehensive characterization of the borrow site and its resources prior to permit completion. Some of the components of a thorough assessment include:
    a. Determine the optimum dimensions of the borrow pit (i.e., small and deep areas or wide and shallow areas) in terms of minimizing the effects on resources.
    b. Prioritize the optimal locations of sand mining in terms of effects on resources.
    c. Assess the sand infill rates of borrow pits after completion.
    d. Assess the sediment migration patterns and rates as well as the side slope and adjacent natural seabed stability of the borrow pits after completion.
    e. Model and estimate the effect of massive and/or long-term sand mining on the surrounding seabed, shoreface (i.e., inner continental shelf), sand budgets, and resources.
    f. Assess the effect of removal (by dredging) of offshore sand banks/shoals on the surrounding natural seabed, adjacent shoreline, and the resources that use those habitats.
    g. Assess the effect of massive and/or long-term sand mining on the ecological structure of the seabed.
    h. Assess the effect of noise from mining operations on the feeding, reproduction, and migratory behavior of marine mammals and finfish.
3. Use site characterization and appropriate modeling to determine the areal extent and depth of extraction that affords expedited and/or complete recovery and recolonization times.
4. Employ sediment dispersion models to characterize sediment resuspension and dispersion during mining operations. Use model outputs to design mining operations, including "at sea" processing, to limit impacts of suspended sediment and turbidity on fishery resources and minimize the area affected.
5. Address the cumulative impacts of past, present, and foreseeable future development activities on aquatic habitats by considering them in offshore mining review processes.
6. Use seasonal restrictions when appropriate to avoid temporary impacts to habitat during species critical life history stages (e.g., spawning, and egg, embryo, and juvenile development). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. Resource managers should incorporate adequate time for habitat recovery of affected functions and values to levels required by managed species.

# Petroleum Extraction

## *Introduction*

After some intense but unsuccessful petroleum exploration on the northeastern US continental shelf, the attention for commercial quantities of oil and gas have been directed elsewhere. Georges Bank and the continental shelf off New Jersey were thought to contain significant reserves of natural gas and several exploratory wells were drilled to locate and characterize those reserves in the late 1980s and early 1990s. At that time, few commercially viable reserves were found and the focus of petroleum exploration shifted to other regions. However, this could change in the future considering the escalating market prices and dwindling supplies of petroleum. Should renewed interest in offshore petroleum exploration and extraction in the northeast region occur, existing regulatory guidance on petroleum exploration and extraction, as well any recent research and development efforts, should be employed to ensure that marine resource impacts can be avoided, minimized, and compensated for these types of activity.

Petroleum extraction has impacts similar to mineral mining but usually with significantly less of an impact footprint (excluding spills). However, there is more risk and occurrence of adverse impacts associated with equipment operation, process related wastes and handling of byproducts (e.g., drill cuttings and spent drilling mud) which can disrupt and destroy pelagic and benthic habitats (Malins 1977; Wilk and Barr 1994). Potential releases of oil and petroleum byproducts into the marine environment may also occur as a result of production well blow-outs and spills.

Drilling muds are used to provide pressure and lubrication for the drill bit and to carry drill cuttings (crushed rock produced by the drill bit) back to the surface. Drilling muds and their additives are complex and variable mixtures of fluids, fine-grained solids, and chemicals (MMS 2005b). Some of the possible impacts associated with petroleum extraction include the dispersion of soluble and colloidal pollutants, as well as the alteration of turbidity levels and benthic substrates. Many of these impacts can be mitigated by on-site reprocessing and by transferring substances deemed inappropriate for unrestricted openwater disposal to landside disposal.

For more information on petroleum-related impacts and conservation recommendations for petroleum exploration, production, and transportation refer to the Energy-related Activities chapter of this report.

# Offshore Dredged Material Disposal

## *Introduction*

The disposal of dredged material in offshore waters involves environmental effects beyond those associated with the actual dredging operations. The US Army Corps of Engineers (USACE) disposes approximately 65% of its dredged material in open water, as opposed to "upland," or land disposal (Kurland et al. 1994). Although some adverse environmental effects can be avoided with land disposal, there are a number of drawbacks including securing large tracts of land, material handling problems, overflow and runoff of polluted water, saltwater intrusion into groundwater, and costs of transporting material to land disposal sites (Kurland et al. 1994).

Disposal of dredged material is regulated under the Clean Water Act (CWA) and the Marine Protection, Research, and Sanctuaries Act (MPRSA), also known as the Ocean Dumping Ban Act (33 U.S.C. § 1251 and 1401 et seq.). The differences in the two Acts are found in the necessity and type(s) of sediment testing required by each. Generally, ocean dumping only requires biological testing if it is determined that the sediments do not meet the testing exclusion criteria as specified under the MPRSA (i.e., are contaminated). While the CWA provides for biological testing, it does not require such tests to determine whether the sediment meets the 404b testing guidelines unless specified by the USACE or the US Environmental Protection Agency (US EPA). The US EPA and the USACE are currently involved in discussions intended to combine the testing and evaluation protocols described in regulations, and in the "Greenbook" (Ocean Dumping Ban Act) and "Inland" (CWA) testing manuals. Currently, the US EPA and USACE use a tiered approach under both Acts, based upon empirical data gathered from each evaluated dredging project for determining the appropriate management options for dredge spoils (i.e., unconfined open water disposal, open water disposal with capping [CWA only], no open water disposal, or confined area disposal in harbors). Under the CWA, sediment quality guidelines or benchmarks can be used in the lower tiers to determine compliance with 404b guidelines or the need for futher testing. Although not required under the MPRSA, regulators in practice often use sediment chemistry to help determine the contaminant and sampling requirements for biological tests.

Offshore disposal sites are identified and designated by the US EPA using a combination of the MPRSA and National Environmental Policy Act (NEPA) criteria. However, the permitted use of designated disposal sites under these laws is not usually associated with the designation of the sites. To be eligible to use an offshore (i.e., federal waters) disposal site for dredged materials, project proponents must demonstrate: (1) that there are no reasonable and practical alternative disposal options available and; (2) that the sediments are compatible with natural sediments at the disposal site and are not likely to disrupt or degrade natural habitats and/or biotic communities (USEPA 2005b). Dredge material disposed at sites managed under the MPRSA must meet Ocean Dumping Ban Act criteria, which do not permit disposal of contaminated dredged material (USEPA 2005b).

### *Burial/disturbance of benthic habitat*

Studies using sidescan sonar and bottom video have been used to distinguish natural sediment character and evidence of past dumping of mud and boulders on sand bottom (Buchholtz ten Brink et al. 1996). These studies have indicated that not only have dumped materials disturbed and altered benthic habitats, but that in some cases (such as on Stellwagen Basin) the material dumped in the past was scattered far from the intended target areas (Buchholtz ten Brink et al. 1996). The discharge of dredged material disturbs benthic and pelagic communities during and after disposal. The duration and persistence of those impacts to the water column and seafloor are related to the grain size and specific gravity of the dredge spoil. Impacts to benthic communities are identified and assessed in the site designation documents (Battelle 2004; URI 2003), which may include benthic communities being buried and smothered and the physicochemical environment in which they reside being altered.

However, Rhoads and Germano (1982, 1986) and Germano et al. (1994) note that recolonization of benthic infauna at a disposal site following dumping often leads to increased occurrences of opportunistic species (Stage I), which are then heavily preyed upon by Stage II and III (e.g., target fisheries) species. According to these studies, this plethora of prey, resulting from the disturbance of the community structure, can at least temporarily increase the productivity at the disposal site. However, chronic disturbance from repeated disposal may prevent Stage III communities from establishing (Germano et al. 1994).

### *Conversion of substrate/habitat and changes in sediment composition*

Dumping dredged materials results in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. The discharges can adversely affect infauna, including benthic and epibenthic organisms at and adjacent to the disposal site by burying immobile organisms or forcing motile organisms to migrate from the area. Benthic infauna species that have greater burrowing capabilities may be better able to extricate themselves from the overburden of sediment. Seasonal constraints on dredging and disposal not withstanding, it is assumed that there is a cyclical and localized reduction in the populations of benthic organisms at a disposal site. Plants and benthic infauna present prior to a discharge are unlikely to recolonize if the composition of the deposited material is significantly different (NEFMC 1998). Altered sediment composition at the disposal site may reduce the availability of infaunal prey species, leading to reduced habitat quality (Wilber et al. 2005).

### *Siltation, sedimentation, and turbidity*

Increased suspended sediment released during the discharge process and the associated increase in turbidity may hinder or disrupt activities in the pelagic zone (i.e., predator–prey relationships and photosynthesis rates). It has been estimated that less than 5% of the material in each disposal vessel is unaccounted for during and after the disposal activity (Bohlen et al. 1996), but the specific volume is influenced by both mechanical and sediment characteristics.

The discharge of dredged material usually results in elevated levels of fine-grained mineral particles, usually smaller than sand (i.e., silt/clay), and organic particles being introduced into the water column (i.e., suspended sediment plumes). The suspended particulates reduce light penetration, which affects the rate of photosynthesis and the primary productivity of an aquatic area. Typically, the suspended materials are dispersed and diluted to levels approaching ambient within 1-4 hours of the release (Bohlen et al. 1996). However, the turbidity plume resulting from a discharge can last much longer, particularly near the bottom, if the dredge material is composed of fine-grain material. In the plume field, living marine resources may experience either reduced or enhanced feeding ability as a result of the disruption of water clarity, depending upon the predator-prey relationships and the type(s) of avoidance/feeding methodologies used by the species. For instance, summer flounder (*Paralichthys dentatus*) and bluefish (*Pomatomus saltatrix*) are sight feeders and avoid areas with reduced water clarity resulting from suspended sediment such as might be found at a dredging or disposal site (Packer et al. 1999). Conversely, recent deposits of sediment at dumpsites have been reported to act as an attractant for other species of fish and crustaceans such as winter flounder (*Pseudopleuronectes americanus*) and American lobster (*Homarus americanus*) even though winnowing of fine-grained material from the excavation site or deposit mound was ongoing at the site (USACE 2001).

Generally, the severity of the effects of suspended sediments on aquatic organisms increases as a function of the sediment concentration and the duration of exposure (Newcombe and Jensen 1996). Some of the effects of suspended sediments on marine organisms can include altered foraging patterns and success (Breitburg 1988), gill abrasion and reduced respiratory functions, and death (Wilber and Clark 2001). The sensitivity of species to suspended sediments is highly variable and dependent upon the nature of the sediment and the life history stage of the species. Mortality caused by suspended sediments for estuarine species have been reported from less than 1000 mg/L for 24 hours in highly sensitive species (e.g., Atlantic silversides [*Menidia menidia*], juvenile bluefish [*Pomatomus saltatrix*]) to greater than 10,000 mg/L for 24 hours in tolerant species (e.g., mummichog [*Fundulus heteroclitus*], striped killifish [*Fundulus majalis*], spot [*Leiostomus xanthurus*], oyster toadfish [*Opsanus tau*], hogchoker [*Trinectes maculates*]) (Wilber and Clark 2001). The egg and larval stages of marine and estuarine fish exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages studied (Wilber and Clark 2001). Impacts that have been identified for demersal eggs of fish from sedimentation and suspended sediments include delayed hatching and decreased hatching success (Wilber and Clark 2001; Berry et al. 2004). The development of larvae may be delayed or altered after exposure of elevated suspended sediments, and increased mortality rates in the larvae of some species, such as striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*), have been reported with exposure of suspended sediment concentrations less than or equal to 500 mg/L for 3 to 4 days (Wilber and Clark 2001).

The effects of sedimentation on benthic organisms can include smothering and decreased gas exchange, toxicity from exposure to anaerobic sediments, reduced light intensity, and physical abrasion (Wilber et al. 2005). Mobile benthic species that require coarse substrates, such as gravel or cobble (e.g., American lobster) may be forced to seek alternate habitat that is less optimal or compete with other species or individuals for suitable habitat (Wilber et al. 2005). Messieh et al. (1981) investigated sedimentation impacts on Atlantic herring in laboratory experiments and found increased mortality in herring eggs, early hatching and shorter hatching lengths, and reduced feeding success in herring larvae leading to stunted growth and increased mortality.

Although there is generally a consensus among scientists and resource managers that elevated suspended sediments and sedimentation on benthic habitat caused by dredging and disposal of dredge spoils result in adverse impacts to marine organisms, the specific effects on biological communities need to be better quantified. Additional research is needed to investigate dose-response models at scales appropriate for dredging and disposal and for appropriate species and life history stages (Wilber et al. 2005).

### *Release of contaminants*

Dredged material suspended in the water column can react with the dissolved oxygen in the water and result in localized depression of the oxygen level. However, research has indicated that reductions in dissolved oxygen levels during offshore sediment disposal is not appreciable or persistent in the general sediment classes found in the northeast region (USACE 1982; Fredette and French 2004; USEPA 2004).

In certain situations, trace levels of toxic metals and organics, pathogens, and viruses adsorbed or adhered to fine-grained particulates in the dredged material may become biologically available to organisms either in the water column or through food chain processes. Some of these pollutants and their concentrations are evaluated during project-specific sediment testing required under the MPRSA and CWA. Adverse chemical effects at the disposal site can be minimized through the sediment testing requirements under the MPRSA and CWA, since the discharge of potentially toxic materials are generally prohibited. Risk assessment approaches are used to further evaluate potential impacts using results from the MPRSA and CWA bioaccumulation and toxicity testing. In addition, monitoring is conducted to ensure that the biological and ecological functions and values are maintained within the site, notwithstanding the physical impacts associated with continued use of the site. However, some discharges of contaminated material may be permitted under CWA disposal regulations, if the sediments meet minimum testing criteria or the toxic affects can be managed by capping with clean material.

Fredette and French (2004) concluded that, after thirty-five years of monitoring and research, dredged material evaluated through preproject testing and deposited in properly located ocean disposal sites will remain where it is placed and have no unacceptable adverse effects on nearby marine resources. Furthermore, they concluded that the only discernible adverse impacts were near-field and short-term. These determinations were based on the magnitude of disposal activity relative to natural (e.g., storms) and other anthropogenic (e.g., outfalls) impacts (Rhoads

1994; Rhoads et al. 1995) and the low level of disposal-related impacts that have been documented (Fredette et al. 1993).

## *Changes in bottom topography, altered hydrological regimes, and altered current patterns*

A concern often raised is the stability of dredge spoil sediments placed on the seafloor. Because ocean disposal sites are typically located in low current areas with water depths in excess of the active erosion zone, the material is generally contained within the disposal site. However, before 1985, dredged material sites were occasionally located in water depths insufficient to retain materials placed there (USEPA 1986). For example, the Mud Dump Site, located in the New York Bight Apex slope area off New York Harbor, contains water depths as shallow as 15 m and the site experienced extensive erosion by a nor'easter storm in October 1992 (USEPA 1997). Reclassified as a remediation site in 1997, the site is now known as the Historic Area Remediation Site (HARS). Erosion was reported at depths of 26 m, and the winnowed sediment included grain sizes up to small cobble. Fortunately, much of the sediment was relocated into deeper portions of the site westward of the erosion field (USEPA 1997). More comprehensive evaluation protocols have been put into place since 1985 to prevent dredged or fill material discharged at authorized sites from modifying current patterns and water circulation by obstructing the flow, changing the direction or velocity of water flow and circulation, or otherwise significantly altering the dimensions of a water body.

The USACE utilizes more than twenty selected or designated offshore dredged material disposal sites in the northeast region of the United States. Several of these sites have been used because they are dispersive in nature. These sites are used, normally, to put littoral material back into the nearshore drift pattern. The containment sites have an average size of 1.15 square nautical miles in size (USACE 2005b). By law and regulation, the significant adverse effects of dredged material disposal activities must be contained within the designated or selected disposal site and even those impacts must not degrade the area's overall ecological health. There is some dispersion of fine-grained sediments and contaminants outside the sites. Each site is required to have and be managed under a dredged material monitoring and management plan that assesses the health and well-being of the site and surrounding environment. Monitoring of disposal sites is a part of these plans, which is designed to ensure that any degradation of resources or alteration in seafloor characteristics are identified and would illicit actions by permitting agencies (USEPA 2004).

## *Release of nutrients/eutrophication*

Nutrient overenrichment, or eutrophication, is one of the major causes of aquatic habitat decline associated with human activities (Deegan and Buchsbaum 2005). There are point sources of nutrients, such as sewage treatment outfalls, and nonpoint sources, such as urban storm water runoff, agricultural runoff, and atmospheric deposition, which have been discussed in other chapters of this report. Elevated levels of nutrients have undesirable effects, including: (1) increased incidence, extent, and persistence of blooms of noxious or toxic species of phytoplankton; (2) increased frequency, severity, spatial extent, and persistence of hypoxia; (3) alterations in the dominant phytoplankton species, which can reduce the nutritional and biochemical nature of primary productivity; and (4) increased turbidity levels of surface waters, leading to reductions in submerged aquatic vegetation (O'Reilly 1994).

Sediment particles can bind to some nutrients, and resuspension of sediments following dredge material disposal can cause a rapid release of nutrients to the water column (Lohrer and Wetz 2003). Ocean disposal of dredge material with high organic content can result in oxygen reduction (hypoxia) or even anaerobic conditions (anoxic) on the bottom and overlaying waters, particularly during periods when strong thermoclines are present (Kurland et al. 1994). Hypoxic and anoxic conditions can kill benthic organisms or even entire communities and lead to a proliferation of stress-tolerant species of reduced value to the ecosystem (Kurland et al. 1994). Generally, offshore waters are less sensitive to disposal of dredge material containing nutrients than inshore, enclosed water bodies.

Both the MPRSA and CWA regulations prohibit the discharge of dredge material containing high organic content and nutrient levels if the discharge results in adverse effects to the marine environment. However, prior to the stricter regulations instituted in the 1980s, the discharge of sewage sludge was permitted for decades in nearshore and offshore waters of many urbanized centers of the northeastern US coast (Barr and Wilk 1994).

### *Conservation measures and best management practices for dredge material disposal*

1. Ensure that all options for disposal of dredged materials at sea are comprehensively assessed. The consideration of upland alternatives for dredged material disposal sites must be evaluated before offshore sites are considered.
2. Ensure that adequate sediment characterizations are completed and available for making informed decisions.
3. Ensure that adequate resource assessments are completed and available during project evaluation.
4. Employ sediment dispersion models to characterize sediment resuspension and dispersion during operations. Use model outputs to design disposal operations, including measures to avoid and minimize impacts from suspended sediment and turbidity on living marine resources. Sediment dispersion models should be field-verified to various sediment and hydraulic conditions to ensure they have been calibrated appropriately to predict sediment transport and dispersion.
5. Consider "beneficial uses" of dredged material, as appropriate.
6. Ensure that the site evaluation criteria developed for selection or designation of dredged material disposal sites have been invoked and evaluated, as appropriate.
7. Avoid dredged material disposal activities in areas containing sensitive or unique marine benthic habitats (e.g., spawning and feeding sites, surface deposits of cobble/gravel substrate).
8. Employ all practicable methods for limiting the loss of sediment from the activity. Consider closed or "environmental" buckets, when appropriate.
9. Ensure that disposal sites are being properly managed (e.g., disposal site marking buoys, inspectors, the use of sediment capping and dredge sequencing) and monitored (e.g., chemical and toxicity testing, benthic recovery) to minimize impacts associated with dredge material.
10. Use sequential dredging to avoid dredging activity during specific time periods in particularly environmentally sensitive areas of large navigation channel dredging projects. This can avoid turbidity and sedimentation, bottom disruption, and noise in sensitive areas used by fishery resources during spawning, migration, and egg development.
11. Require appropriate monitoring to avoid and minimize individual and cumulative impacts of the disposal operations.
12. Use seasonal restrictions when appropriate to avoid temporary impacts to habitat during critical life history stages (e.g., spawning, egg and embryo development, and juvenile growth). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements. Resource managers should incorporate

adequate time for habitat recovery of affected functions and values to levels required by managed species.

# Fish Waste Disposal

## *Introduction*

Fish waste or material resulting from industrial fish processing operations from either wild stocks or aquaculture consists of particles of flesh, skin, bones, entrails, shells, or process water (i.e., liquid "stickwater" or "gurry"). The organic components of fish waste have a high biological oxygen demand and, if not managed properly, can pose environmental and health problems. Generally, the solid wastes make up 30-40% of total production, depending on the species processed (IMO 2005a). Most fish wastes degrade rapidly in warm weather and can cause aesthetic problems and strong odors as a result of bacterial decomposition if not stored properly or disposed of quickly. Because these waste streams are generally required to be pretreated and fully processed on-site, disposed at a suitable upland site, or sent through municipal sewage treatment, at sea disposal is no longer widely employed in the northeastern United States. However, these materials are sometimes discharged at sea, when appropriate.

Permitting of at sea disposal should be coordinated with appropriate federal and state agencies. Processors should contact the US EPA to determine whether federal permits are necessary for the activity. In order to determine if a federal permit applies, the US EPA must determine if the material constitutes an environmental risk or is a traditional and acceptable "fish waste" disposal defined under Section 102(d) of the Ocean Dumping Ban Act, 33 U.S.C. Part 1412(d) and the regulations promulgated at 40 C.F.R. Part 220. Generally, permits are not required for the transportation or the ocean disposal of fish waste unless: 1) disposal is proposed in harbors or other protected and enclosed waters, and the location is deemed by the EPA as potentially endangering human health, the marine environment or ecological systems; or 2) the waste contains additives or disinfectants from the processing or treatment. In these cases, National Pollutant Discharge Elimination System (NPDES) permits may be required if chlorine or other similar chemicals are used. If an environmental or human health risk is determined, the applicant may be required to submit an assessment of the disposal area and potential impacts to marine resources and follow disposal guidelines consistent with the provisions of the London Convention 1972 (IMO 2005a). Permits required for ocean disposal of fish wastes define the discharge rate of the fluids, residual tissue, and hard part pieces by using a dispersion model. Inputs to the model include discharge flow rate, tissue dimensions, mixing rates, local current patterns, and the specific gravity of the solids (USEPA 2005c). The US EPA may also consult with applicable federal and state regulatory and resource agencies and regional fisheries councils, to identify any areas of concern with respect to the disposal area and activity. Persons wishing to dispose of fish wastes in the ocean may be required to submit specific dilution modeling in support of the proposed disposal and participate in monitoring to verify the results of the modeling (USEPA 2005c).

Bivalve shells, when brought ashore and processed, are not allowed to be returned to the ocean for the purpose of waste disposal. Reuse of the shells as "cultch" in oyster farming operations is a standard, traditional fishing practice in the northeastern United States and does not require permitting, but prior to disposal the shells may be required to meet water quality criteria, principally regarding residual tissue volume.

The guidelines established by the London Convention 1972 place emphasis on progressively reducing the need to use the sea for dumping of wastes. Implementation of these guidelines and the regulations promulgated by US EPA for the disposal of fish wastes includes consideration of potential waste management options that reduce or avoid fish waste to the disposal stream. For example, applications for disposal should consider reprocessing to fishmeal, composting, production of silage (i.e., food for domestic animals/aquaculture), use in biochemical industry products, use as fertilizer in land farming, and reduction of liquid wastes by evaporation (IMO 2005a).

### *Introduction of pathogens*

Ocean disposal of fish wastes has the potential to introduce pathogens to the marine ecosystem that could infect fish and shellfish. In particular, aquaculture operations that raise nonnative species or those that provide food to animals derived from nonindigenous sources could introduce disease vectors to native species (IMO 2005a). However, the disposal guideline provisions implemented as part of the Ocean Dumping Ban Act is designed to ensure wide dispersion of the gurry and limited accumulation of soft parts waste on the sea floor. Models developed to predict the effects of authorized discharges of fish wastes were designed to avoid the accumulation of biodegradable materials on the seafloor and introduction of pathogens.

### *Release of nutrients/eutrophication*

The organic components of fish wastes have a high biological oxygen demand (BOD) and if not managed properly could result in nutrient over-enrichment and reductions in the dissolved oxygen. In ocean disposal, these affects may be seen with mounding of wastes, subsequent increases in BOD and contamination with bacteria associated with partly degraded organic wastes (IMO 2005a). However, disposal guidelines require that dumpsite selection criteria maximizes waste dispersion and consumption of the wastes by marine organisms.

### *Release of biosolids*

Generally, the solid wastes generated by fish waste disposal comprises approximately 30-40% of total production, depending upon the species processed (IMO 2005a). Biosolid waste at fish disposal sites could result in nutrient over-enrichment and reduced dissolved oxygen concentration. However, the disposal guideline provisions implemented as part of the Ocean Dumping Ban Act require wide dispersion of the gurry and limited accumulation of soft parts waste on the sea floor.

### *Alteration of benthic habitat*

Ocean disposal of fish wastes that fail to meet permit conditions and guidelines have the potential to degrade fishery habitat by adversely affecting the productivity and ecological functions of the benthic community. Concentration and mounding of wastes can increase the BOD and reduce dissolved oxygen concentration of an area resulting in reductions in the ability to support small consumer organisms such zooplankton and amphipods. This can then affect species at higher trophic levels that depend upon these consumers for food. However, disposal guidelines require dump-site selection criteria that maximize waste dispersion and consumption of the wastes by marine organisms and disposal monitoring that ensures permit conditions are met (USEPA 2005c). In addition, guidelines and permit review must consider chemical contamination of the marine environment from the waste disposal. For example, the potential presence of chemicals used in aquaculture and fish wastes subjected to chemical treatment must be assessed prior to disposal (IMO 2005a).

### Behavioral effects

The presence of biodegradable tissue in the water column has the potential to alter the behavior of organisms in various ways, such as causing an attractant source for scavengers. This could alter the diet of individuals and interfere with trophic-level energy dynamics and community structure. The discharge of process water and biosolid wastes should be monitored carefully to ensure conditions within state and federal permits are met.

### Conservation measures and best management practices for disposal of fish wastes

1. Consider the practical availability of alternative methods of disposal to reuse, recycle, or treat the waste as a comparative risk assessment involving both ocean dumping and alternatives.
2. Perform site assessments of the proposed ocean disposal location prior to dumping, including the water depths, average velocities of tidal and nontidal currents, prevailing winds throughout the year, sediment and benthic habitat types, and nature of the sea floor (depositional versus dispersive). Information collected in the site assessment will be used in predictive models developed for the waste disposal activities. Existing uses of the site should be assessed, such as commercial and recreational fishing and whale watching vessels.
3. Use predictive models for plume dispersion and waste settlement based upon physical dynamics of the disposal area, nature of the fish waste, and the method of disposal. The models should be used to assess the probability of the waste plume reaching nearshore coastal waters or other protected areas, such as marine sanctuary waters. The models should also estimate the mass flux of nitrogen and organic carbon associated with the proposed discharges on a daily and annual basis, and how this input may affect phytoplankton production and benthic communities.
4. Dispose material at a steady rate while the vessel maintains headway speed (e.g., 3 nautical miles per hour) as opposed to dumping the entire load at once in a fixed location in order to provide better dilution of fish waste.
5. Grind organic materials to appropriate sizes (e.g., 0.5 inch) prior to discharge where they will be consumed or degraded in the water column dispersion field during and subsequent to their discharge. The intent should be to avoid water quality degradation and tissue deposition and accumulation on the seafloor.
6. Ensure that the waste will be rendered biologically inert during its residence time in the water column and avoid adverse effects on water quality, including reductions in dissolved oxygen concentrations and nutrient over-enrichment.
7. Require monitoring of the waste plume during and after discharge to verify model outputs and advance the knowledge regarding the practice of at-sea disposal of fish processing wastes.

## Vessel Disposal

### Introduction

When vessels are no longer needed, there are several options for their disposition, including reuse of the vessel or parts of the vessel, recycling or scrapping, creating artificial reefs, and disposal on land or sea (USEPA 2006). This section discusses the potential habitat and marine fisheries impacts associated with disposal at sea.

The disposal of vessels in the open ocean is regulated by the US EPA under section 102(a) of the MPRSA (Ocean Dumping Ban Act) and under 40 CFR § 229.3 of the US EPA regulations. In part, these regulations require that (1) vessels sink to the bottom rapidly and permanently and that marine navigation is not otherwise impaired by the sunk vessel; (2) all vessels shall be disposed of in depths of at least 1,000 fathoms (6,000 feet) and at least 50 nautical miles from land; and (3) before sinking, appropriate measures shall be taken to remove to the maximum extent practicable all materials which may degrade the marine environment, including emptying of all fuel tanks and lines so that they are essentially free of petroleum and removing from the hulls other pollutants and all readily detachable material capable of creating debris or contributing to chemical pollution.

The US EPA and US Department of Transportation Maritime Administration have developed national guidance, including criteria and best management practices for the disposal of ships at sea when the vessels are intended for creation or addition to artificial reefs (USEPA 2006). Vessels disposed of to create artificial reefs have historically been designed and intended to enhance fishery resources for recreational fishermen. However, in recent years artificial reefs have been constructed for a number of nonextractive purposes such as: (1) recreational SCUBA diving opportunities; (2) socioeconomic benefits to local coastal communities; (3) increase habitat to reduce user pressure on nearby natural reefs; (4) reduce user conflicts (e.g., diving in heavily fished areas), and; (5) provide mitigation or restoration to habitat loss for commercial activities (e.g., beach nourishment, dredging, pipeline routes) (NOAA 2007). Some vessels may be sunk to provide a combination of these purposes. Vessels prepared for use as artificial reefs should: (1) be "environmentally sound" and free from hazardous and potentially polluting materials; (2) have had resource assessments for the disposal locations conducted to avoid adverse impacts to existing benthic habitats; and (3) have had stability analyses for the sinking and the ship's ultimate location conducted to ensure there is minimal expectation of adverse impacts on adjacent benthic habitats. Several guidance documents have been developed for the planning and preparation of vessels as artificial reef material, including the National Artificial Reef Plan (NOAA 2007), Coastal Artificial Reef Planning Guide (ASMFC and GSMFC 1998), the Guidelines for Marine Artificial Reef Materials (ASMFC and GSMFC 2004), and the National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs (USEPA 2006). These documents should be consulted to ensure that conflicts with existing uses of the potential disposal site/artificial reef site are addressed and that materials onboard the vessel do not adversely impact the marine environment. Section 203 of the National Fishing Enhancement Act of 1984 (Title II of P.L. 98-623, Appendix C) established that artificial reefs in waters covered under the Act shall "be sited and constructed, and subsequently monitored and managed in a manner which will: (1) enhance fishery resources to the maximum extent practicable; (2) facilitate access and utilization by US recreational and commercial fishermen; (3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters; (4) minimize environmental risks and risks to personal health and property; and (5) be consistent with generally accepted principles of international law and shall not create any unreasonable obstruction to navigation."

The appropriate siting is vital to the overall success of an artificial reef. Considerations and options for site placement and function in the environmental setting should be carefully weighed to ensure program success. Since placement of a reef involves displacement and disturbance of the existing habitat, and building the reef presumably accrues some benefits that could not exist in the absence of the reef, documentation of these effects should be brought out in the initial steps to justify artificial reef site selection. Placement of a vessel to create an artificial reef should: (1) enhance and conserve targeted fishery resources to the maximum extent practicable; (2) minimize conflicts among competing uses of water and water resources; (3) minimize the potential for environmental risks related to site location; (4) be consistent with international law and national fishing law and not create an obstruction to navigation; (5) be based on scientific information; and (6) conform to any federal, state, or local requirements or policies for artificial reefs (USEPA 2006).

The Coastal Artificial Reef Planning Guide (ASMFC and GSMFC 1998) state that when an artificial reef has been constructed, another important phase of reef management begins: monitoring and maintenance. Monitoring provides an assessment of the predicted performance of reefs and assures that reefs meet the general standards established in the Section 203 of the National Fishing Enhancement Act as listed above. It also ensures compliance with the conditions of any authorizing permits. Artificial reef monitoring should be linked with performance objectives, which ensures that NOAA National Marine Fisheries Service responsibilities to protect, restore, and manage living marine resources, and to avoid and minimize any adverse effects on these resources are fulfilled.

### *Release of contaminants*

Ships disposed of at sea, including those intended to create artificial reefs, are often military and commercial vessels which typically contain various materials that, if released into the marine environment, could have adverse effects on the marine environment. Some of the materials of concern include fuels and oil, asbestos, polychlorinated biphenyl (PCB), paint, debris (e.g., vessel debris, floatables, introduced material), and other materials of environmental concern (e.g., mercury, refrigerants) (USEPA 2006). Depending upon the nature of the contaminant and the concentration and duration of the release of contaminant(s) adverse effects to marine organisms may be acute or chronic and either lethal or sublethal. Some contaminants, such as PCB and mercury, can be persistent and bioaccumulate in the tissues of organisms resulting in more serious impacts in higher trophic level organisms. The Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels prohibit materials containing contaminants which may impact the marine environment. The guidance documents provide detailed best management practices regarding recommended measures to remove and abate contaminants contained within and as part of a vessel.

### *Release of debris*

Debris, including solids and floatables, are materials that could break free from a vessel during transportation to the disposal site, and during and after sinking. The release of debris can adversely affect the ecological and aesthetic value of the marine environment. Debris released from vessels is generally categorized into vessel debris (material that was once part of the vessel) and clean-up debris (material that was not part of the vessel but was brought on board the vessel during preparation for disposal).

Some debris released from vessels is not highly degradable and can be persistent in the marine environment for long periods of time, increasing the threat it poses to the environment. Some of the impacts associated with debris include: (1) entanglement and/or ingestion, leading to injury, infection, or death of marine animals that may be attracted to or fail perceive the debris in the water; (2) alteration of the benthic floral and faunal habitat structure, leading to injury or mortality or indirect impact to other species linked in the benthic food web and; (3) elevation of the risk of spills and other environmental impacts caused by impacts with other vessels (e.g., hull damage, damage to cooling or propulsion systems) (USEPA 2006). The Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels require all debris to be removed from vessels prior to sinking. The guidance documents provide detailed best management practices regarding recommended measures to remove vessel and clean-up debris.

### *Conversion of substrate/habitat and changes in community structure*

Vessels that are sunk for the purpose of discarding obsolete or decommissioned ships, as well as those sunk to create an artificial reef, can convert bottom habitat type and alter the ecological balance of marine communities inhabiting the area. For example, placement of vessels over sand bottom can change niche space and predator/prey interactions for species or life history stages utilizing that habitat type. Large structures such as ships tend to attract adult fish and larger predators, which may increase predation rates on smaller and juvenile fish or displace smaller fish and juveniles to other areas (USEPA 2006). Large, anthropogenic structures, such as oil and gas platforms in the Gulf of Mexico, have been shown to affect the distribution of larval and juvenile fish (Lindquist et al. 2005). In addition, large structures tend to provide proportionally less shelter for demersal fishes and invertebrates than smaller, lower profile structures, while the surfaces of steel hull vessels are less ideal for colonization by epibenthos than are natural surfaces like rock (ASMFC and GSMFC 2004). Certain types of habitat and areas may be more susceptible to physical and chemical impacts from the placement of vessels, particularly those vessels sunk as artificial reefs. Generally, vessels sunk for disposal only are located in deeper water (> 6,000 feet) and very far offshore (> 50 nautical miles from land) and may have less impacts on sensitive benthic habitats. However, vessels sunk as artificial reefs are usually located in nearshore coastal waters that also support or are frequented by marine resources that may be adversely impacted by the placement of the structure. Artificial reefs should not be sited in sensitive areas that contain coral reefs or other reef communities, submerged aquatic vegetation, or habitats known to be utilized by endangered or threatened species (USEPA 2006). The Ocean Dumping Ban Act prohibits vessel disposal in areas that may adversely effect the marine environment.

### *Changes in bathymetry and hydrodynamics*

The location of a vessel on the ocean bottom will change the bathymetry and can potentially alter the current flow of the disposal area. A proposed disposal site should be assessed as to the effects the vessel disposal and subsequent bathymetry change may have on the hydrodynamics and geomorphology of the immediate and adjacent habitats. For example, even small vessels placed on the bottom can alter currents and create turbulence around the vessel that may scour existing soft substrates and adversely affect adjacent habitats and communities. In addition, the high vertical profile may cause some vessels to be prone to movement and structural damage from ocean currents and wave surge during storm events. For example, during Hurricane Andrew, a category 5 storm, in south Florida during 1992, nearly all steel-hulled vessels sunk as artificial reefs in the area of the storm's path sustained structural damage, and a number moved 100-700 m because of the storm surge (ASMFC and GSMFC 2004). The movement of vessels after disposal can impact adjacent habitats and relocate the vessels to areas that could alter the ecological balance of marine communities in the area. In addition, reductions in navigational clearance, either as a result of the vessel being sunk in the wrong location and in an area too shallow or because later movement of the vessel from storm surge or currents may increase the potential danger to vessel navigation (e.g., hull damage, damage to cooling or propulsion systems) which may cause further damage from oil/fuel spills or groundings (ASMFC and GSMFC 2004). To minimize the risk of alterations to the bathymetry and hydrodynamics of the disposal area and vessel movement, the Ocean Dumping Ban Act and the various guidance documents available for offshore disposal of vessels require a number of evaluations prior to dumping activities, including: (1) stability analyses; (2) assessments of the seabed, including topography and geological characteristics and; (3) assessment of mean direction and velocity of currents and storm-wave induced bottom currents (ASMFC and GSMFC 2004; IMO 2005b).

### *Deployment impacts*

Some risks to the marine environment exist during the deployment (i.e., sinking) of vessels for disposal or as an artificial reef. Some potential impacts that may occur during deployment include the release of contaminants accidentally left onboard the vessel, damage to adjacent benthic habitats from anchors and cables used to maintain the vessel position as it sinks, impacts to benthic habitats from a vessel accidentally sinking in an unintended location while being towed or from movement of the ship after deployment (ASMFC and GSMFC 2004). However, careful planning during the assessment stages and adherence to operational protocols can avoid impacts during deployment.

### *Conservation measures and best management practices for disposal of vessels*

1. Require that a vessel disposal site assessment adequately characterize the physical and biological environment of the site. In addition to identifying the habitat types and species utilizing the area and targeted for enhancement, ecological investigations should include community settlement and recruitment and predator/prey dynamics and anticipated changes in competition and niche space as a result of the vessel disposal (USEPA 2006).
2. Identify the locations of any sensitive marine habitats in the area. Potential vessel disposal sites should generally not be located near any of the following marine resources: coral reefs; significant beds of aquatic vegetation or macroalgae; oyster reefs; scallop, mussel, or clam beds; existing live bottom (i.e., marine areas supporting sponges, sea fans, corals, or other sessile invertebrates generally associated with rock outcrops); and habitats of endangered or threatened species (federal and state listed) (USEPA 2006).
3. Conduct vessel stability analysis to ensure the vessel is retained in the intended location, including characterization of anticipated weather conditions, tidal dynamics, mean direction and velocity of surface and bottom drifts and storm-wave induced currents, and general wind and wave characteristics (IMO 2005b).
4. Ensure that a thorough inventory and assessment of all potential contaminants on the vessel are completed and that all preplacement cleaning and inspections are completed thoroughly and effectively.
5. Avoid the use of explosives to the extent possible in sinking vessels under 150 feet in length where alternate methods (e.g., opening seacocks, flooding with pumps, etc.) are feasible (ASMFC and GSMFC 2004).
6. Monitor the disposal operation and the placement site for adherence to permit compliance and performance objectives.
7. Ensure that physical and biological monitoring plans for vessels disposed of as artificial reefs are developed as appropriate and that monitoring and reporting requirements are met throughout the designed timeframe.

## References for Offshore Dredging and Disposal

[ASMFC], [GSMFC] Atlantic and Gulf States Marine Fisheries Commissions. 1998. Coastal artificial reef planning guide. Washington (DC): Joint Artificial Reef Technical Committee of the Atlantic and Gulf States Marine Fisheries Commissions. 45 p.

[ASMFC], [GSMFC] Atlantic and Gulf States Marine Fisheries Commissions. 2004. Guidelines for marine artificial reef materials, 2nd ed. Washington (DC): Subcommittees of the Atlantic and Gulf States Marine Fisheries Commissions. Number 121. 198 p.

Barr BW, Wilk SJ. 1994. Sewage sludge and industrial waste dumping. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 41-4.

Battelle. 2004. Designating an ocean disposal site for dredged material. [Internet]. Columbus (OH): Battelle Memorial Institute; [cited 2007 Dec 21]. Available from: http://www.battelle.org/Environment/publications/EnvUpdates/summer2004/article1.stm.

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth flatfish biology conference-poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Bohlen WF, Howard-Strobel MM, Cohen DR, Morton ET. 1996. An investigation of the dispersion of sediments resuspended by dredging operations in New Haven Harbor. Waltham (MA): New England Division, US Army Corps of Engineers. DAMOS Contribution #112. 12 p + appendices.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Burlas M, Ray GL, Clarke D. 2001. The New York District's biological monitoring program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section beach erosion control project. [Internet]. Final Report. Vicksburg (MS): US Army Corps of Engineers, New York and US Army Engineer Research and Development Center, Waterways Experiment Station. [cited 2007 Dec 21]. Available from: http://www.nan.usace.army.mil/business/prjlinks/coastal/asbury/index.htm.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New

England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Drucker BS, Waskes W, Byrnes MR. 2004. The US Minerals Management Service outer continental shelf sand and gravel program: environmental studies to assess the potential effects of offshore dredging operations in federal waters. Journal of Coastal Research 20(1):1-5.

Fredette TJ, French GT. 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Marine Pollution Bulletin 49(1-2):93-102.

Fredette TJ, Kullberg PG, Carey DA, Morton RW, Germano JD. 1993. Twenty-five years of dredged material disposal site monitoring in Long Island Sound: a long-term perspective. In: Van Patten MS, editor. Proceedings of the Long Island Sound Research Conference; 1992 Oct 23-24; New Haven, CT. Groton (CT): Connecticut Sea Grant Program, Publication No. CT-SG-93-03, p 153-61.

Germano JD, Rhoads DC, Lunz JD. 1994. An integrated, tiered approach to monitoring and management of dredged material sites in the New England region. Waltham (MA): US Army Corps of Engineers, New England Division. DAMOS Contribution No. 87, Report No. SAIC-90/7575&234. 55 p + appendices.

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hitchcock DR, Bell S. 2004. Physical impacts of marine aggregate dredging on seabed resources in coastal deposits. Journal of Coastal Research 20(1):101-114.

[ICES] International Council for the Exploration of the Sea. 1992. Report of the ICES working group on the effects of extraction of marine sediments on fisheries. Copenhagen (Denmark): ICES Cooperative Research Report # 182.

[IMO] International Maritime Organization. 2005a. Specific guidelines for assessment of fish wastes, or material resulting from industrial fish processing operations. [Internet]. London (England): IMO, Office for the London Convention 1972. [cited 2007 Dec 21]. 12 p. Available from: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D17022/3-FishWaste.pdf.

[IMO] International Maritime Organization. 2005b. Specific guidelines for assessment of vessels. [Internet]. London (England): IMO, Office for the London Convention 1972. [cited 2007 Dec 21]. 13 p. Available from: http://www.imo.org/includes/blastDataOnly.asp/data_id%3D17023/4-Vessels.pdf.

Johnson SW, Stanley DR, Moles DA. 1998a. Effects of submarine mine tailings disposal on juvenile yellowfin sole (*Pleuronectes asper*): a laboratory study. Marine Pollution Bulletin 36(4):278-87.

Johnson SW, Stone RP, Love DC. 1998b. Avoidance behavior of ovigerous Tanner crabs (*Chionoecetes bairdi*) exposed to mine tailings: a laboratory study. Alaska Fishery Research Bulletin 5:39-45.

Kenny AJ, Rees HL. 1996. The effects of marine gravel extraction on the macrobenthos: results 2 years post-dredging. Marine Pollution Bulletin 32(8-9):615-22.

Kurland JM, Ludwig FM, Gorski SW, Mantazaris C. 1994. Dredging and dredged-material disposal. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 44-7.

Lindquist DC, Shaw RF, Hernandez FJ Jr. 2005. Distribution patterns of larval and juvenile fishes at offshore petroleum platforms in the north-central Gulf of Mexico. Estuarine, Coastal and Shelf Science 62(4):655-65.

Lohrer AM, Wetz JJ. 2003. Dredging-induced nutrient release from sediments to the water column in a southeastern saltmarsh tidal creek. Marine Pollution Bulletin 46(9):1156-63.

Malins DC, editor. 1977. Effects of petroleum on arctic and subarctic marine environments and organisms. New York (NY): Academic Press.

Messieh SN, Wildish DJ, Peterson RH. 1981. Possible impact from dredging and spoil disposal on the Miramichi Bay herring fishery. St. Andrews (New Brunswick): Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1008. iv + 33 p.

[MMS] Minerals Management Service. 2005a. Marine Minerals Program, offshore energy and minerals management. [Internet]. Herndon (VA): MMS, [updated 2007 Jun 28; cited 2007 Dec 21]. Available from: http://www.mms.gov/sandandgravel/.

[MMS] Minerals Management Service. 2005b. Offshore discharges from oil and gas development operations – FAQ. Gulf of Mexico Region, Offshore Information. [Internet]. New Orleans (LA): MMS. [updated 2001 June 6; cited 2007 Dec 21]. Available from: http://www.gomr.mms.gov/homepg/offshore/egom/factshee.html.

[NOAA] National Oceanic and Atmospheric Administration. 2007. National Artificial Reef Plan (as amended): guidelines for siting, construction, development, and assessment of artificial reefs. Washington (DC): US Department of Commerce, National Oceanic and Atmospheric Administration. 51 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Pacheco A. 1984. Seasonal occurrence of finfish and larger invertebrates at three sites in Lower New York Harbor, 1981-1982. Final report. Sandy Hook (NJ): NOAA/NMFS. Special report for USACE, New York District. 53 p.

Packer DB, Griesbach SJ, Berrien PL, Zetlin CA, Johnson DL, Morse WW. 1999. Essential fish habitat source document: summer flounder, *Paralichthys dentatus*, life history and habitat characteristics. [Internet]. Woods Hole (MA): NOAA, NMFS NER, NEFSC. NOAA Technical Memorandum NMFS-NE-151. [cited 2008 Jul 22]. 88 p. Available from: http://www.nefsc.noaa.gov/nefsc/publications/tm/tm151/tm151.pdf.

Palermo MR, Clausner JE, Rollings MP, Williams GL, Myers TE, Fredette TJ, Randall RE. 1998. Guidance for subaqueous dredged material capping. Vicksburg (MS): US Army Corps of Engineers, WES, Dredging Operations and Environmental Research (DOER). Technical Report DOER-1. 302 p.

Pearce JB. 1994. Mining of seabed aggregates. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum. NMFS-NE-106. p 48-50.

Rhoads DC. 1994. Analysis of the contribution of dredged material to sediment and contaminant fluxes in Long Island Sound. Special Technical Report. Waltham (MA): US Army Corps of Engineers, New England Division, Regulatory Division. DAMOS Contribution No. 88. 32 p.

Rhoads DC, Germano JD. 1982. Characterization of organism-sediment relations using sediment profile imaging: an efficient method of remote ecological monitoring of the seafloor (REMOTS ™ System). Marine Ecology Progress Series 8:115-28.

Rhoads DC, Germano JD. 1986. Interpreting long-term changes in benthic community structure: a new protocol. Hydrobiologia 142(1):291-308.

Rhoads DC, Kullberg PG, Fredette TJ. 1995. Dredged material disposal within an estuary: is it a significant source of sediment and contaminant fluxes? The case of Long Island Sound. In:

Knott MA, editor. Proceedings of the Conference for Ports '95, Volume 1; 1995 Mar 13-15; Tampa, FL. Reston (VA): American Society of Civil Engineers. p 428-39.

Scarrat DJ. 1987. Fisheries' interests and ocean mining. Marine Mining 6:141-7.

Stevenson DK, Scott ML. 2005. Essential fish habitat source document: Atlantic herring, *Clupea harengus*, life history and habitat characteristics (2nd ed). [Internet]. Woods Hole (MA): NOAA, NMFS, Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-NE-192. [cited 2008 Jul 22]. 94 p. Available from: http://www.nefsc.noaa.gov/nefsc/habitat/efh.

Stewart PL, Arnold SH. 1994. Environmental requirements Atlantic herring (*Clupea harengus harengus*) in eastern Canada and its response to human impacts. Dartmouth (Nova Scotia): Canadian Technical Report of Fisheries and Aquatic Sciences 2003: ix + 37p.

[URI] University of Rhode Island Coastal Institute. 2003. Designation of a long-term offshore disposal site for dredged material. [Internet]. [cited 2007 Dec 21]. Available from: http://www.ci.uri.edu/Projects/DD/.

[USACE] US Army Corps of Engineers. 1982. Final Supplemental Environmental Impact Statement for the designation of a disposal site for dredged material in Western Long Island Sound WLIS III. Waltham (MA): USACE, New England Division.

[USACE] US Army Corps of Engineers. 2001. Monitoring at the New London Disposal Site 1992-1998 Vol. I. [Internet]. Concord (MA): USACE, New England District. DAMOS Contribution No. 128, SAIC No. 515. [cited 2008 Jul 22]. 157 p + appendices. Available from: http://www.nae.usace.army.mil/damos/pdf/128.pdf.

[USACE] US Army Corps of Engineers. 2005a. HARS – Historic Area Remediation Site. [Internet]. [cited 2007 Dec 21]. Available from: http://www.nan.usace.army.mil/business/prjlinks/dmmp/benefic/hars.htm.

[USACE] US Army Corps of Engineers. 2005b. Managed dredged material disposal sites in the North Atlantic Division. [Internet]. [updated 2007 Apr 12; cited 2007 Dec 21]. Available from: http://www.nae.usace.army.mil/damos/maps.asp.

[USEPA] US Environmental Protection Agency. 1986. Ocean dumping site designation delegation handbook for dredged material. Washington (DC): US EPA Office of Marine and Estuarine Protection.

[USEPA] US Environmental Protection Agency. 1997. Supplemental to the Environmental Impact Statement on the New York dredged material disposal site designation for the designation of the Historic Area Remediation Site (HARS) in the New York Bight. New York (NY): US EPA.

[USEPA] US Environmental Protection Agency. 2003a. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: PAH mixtures. [Internet]. Washington (DC): US EPA Office of Research and

Development. Report No. EPA-600-R-02-013. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/PAHESB.pdf.

[USEPA] US Environmental Protection Agency. 2003b. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: dieldrin. [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-010. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/dieldrin.pdf.

[USEPA] US Environmental Protection Agency. 2003c. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: endrin. [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-009. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/endrin.pdf.

[USEPA] US Environmental Protection Agency. 2004. Rhode Island region long-term dredged material disposal site evaluation project. Boston (MA): US EPA, New England Region.

[USEPA] US Environmental Protection Agency. 2005a. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms: metal mixtures (cadmium, copper, lead, nickel, silver, and zinc). [Internet]. Washington (DC): US EPA Office of Research and Development. Report No. EPA-600-R-02-011. [cited 2008 Jul 24]. Available from: http://www.epa.gov/nheerl/publications/files/metalsESB_022405.pdf.

[USEPA] US Environmental Protection Agency. 2005b. Ocean dumping in the Southeast. [Internet]. [updated 2007 Nov 21; cited 2007 Dec 21]. Atlanta (GA): US EPA, Region 4. Available from: http://www.epa.gov/region4/water/oceans/.

[USEPA] US Environmental Protection Agency. 2005c. Disposal of fish waste. [Internet]. [updated 2007 Nov 1; cited 2007 Dec 21]. New York (NY): US EPA, Region 2. Available from: http://www.epa.gov/region2/water/oceans/fwaste.htm.

[USEPA] US Environmental Protection Agency. 2006. National guidance: best management practices for preparing vessels intended to create artificial reefs. [Internet]. Washington (DC): US EPA Office of Wetlands, Oceans, and Watersheds. EPA Report 842-B-06-002. [cited 2008 Jul 24]. 77 p. Available from: http://www.epa.gov/owow/oceans/habitat/artificialreefs/documents/0605finalreefguidance.pdf.

van Dalfsen JA, Essink K, Toxvig Madsen H, Birklund J, Romero J, Manzanera M. 2000. Differential responses of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. Copenhagen (Denmark): ICES Journal of Marine Science 57:1439-45.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center.

ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilber DH, Clarke DG, Ray GL, Burlas M. 2003. Response of surf zone fish to beach nourishment operations on the northern coast of New Jersey, USA. Marine Ecology Progress Series 250:231-46.

Wilk SJ, Barr BW. 1994. Multiple-use issues in estuarine and coastal habitat loss. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 51-3.

# CHAPTER SEVEN: CHEMICAL EFFECTS—WATER DISCHARGE FACILITIES

## Introduction

Disposal of various waste materials into rivers, estuaries, and marine waters is not a modern phenomenon; this practice has been used as a preferred disposal option virtually since the beginning of human civilization (Ludwig and Gould 1988; Islam and Tanaka 2004). Nevertheless, when the full spectrum of emissions from land-based activities is taken into account, the use of coastal waters as a repository for anthropogenic waste has not previously been practiced on as large or intense a global scale as in recent decades (Williams 1996). In the United States, growing human population densities in coastal communities have manifested a demonstrably adverse effect on aquatic resources. The scientific literature is replete with evidence of inorganic and organic pollutant accumulation in coastal waters from anthropogenic effluents (e.g., Ragsdale and Thorhaug 1980; Tessier et al. 1984; Phelps et al. 1985; Long E et al. 1995; Pastor et al. 1996; Smith et al. 1996; Chapman and Wang 2001; Hare et al. 2001; O'Connor 2002; Robinet and Fenteun 2002; Wurl and Obbard 2004). The federal Clean Water Act (CWA), enacted in 1972 to address many of these issues, eliminated certain types of disposal activities and otherwise induced improvements to the nation's surface water quality. Nonetheless, "despite reductions in pollution from municipal and industrial point sources more than one-third of the river miles, lake acres, and estuary square miles suffer [*sic*] some degree of impairment" (Ribaudo et al. 1999). To the extent that it may alter natural processes and natural resource communities, unabated degradation of the aquatic environment caused by a wide spectrum of human activities poses consequences for fishery resources and their habitats.

Contaminants enter our waterways through two generic vectors: point and nonpoint sources. Pollutants of nonpoint source origins tend to enter aquatic systems as relatively diffuse contaminant streams primarily from atmospheric and terrestrial sources (see Coastal Development chapter of this report for discussions on nonpoint source pollution). In contrast, point source pollutants generally are introduced via some type of pipe, culvert, or similar outfall structure. These discharge facilities typically are associated with domestic or industrial activities, or in conjunction with collected runoff from roadways and other developed portions of the coastal landscape. Waste streams from sewage treatment facilities and watershed runoff in many urbanized portions of the northeastern United States are first intermingled and then subsequently released into aquatic habitats via combined sewer overflows (CSOs). Such point discharges collectively introduce a cocktail of inorganic and organic contaminants into aquatic habitats, where they may become bioavailable to living marine resources.

While all pollutants can become toxic at high enough levels, there are a number of compounds that are toxic even at relatively low levels. The US Environmental Protection Agency (US EPA) has identified and designated more than 126 analytes as "priority pollutants." According to the US EPA, "priority pollutants" of particular concern for aquatic systems include: (1) dichlorodiphenyl trichloroethane (DDT) and its metabolites; (2) chlorinated pesticides other than DDT (e.g., chlordane and dieldrin); (3) polychlorinated biphenyl (PCB) congeners; (4) metals (e.g., cadmium, copper, chromium, lead, mercury); (5) polycyclic aromatic hydrocarbons (PAHs); (6) dissolved gases (e.g., chlorine and ammonium); (7) anions (e.g., cyanides, fluorides, and sulfides); and (8) acids and alkalis (Kennish 1998; USEPA 2003a). While acute exposure to these substances produce adverse effects of aquatic biota and habitats, chronic exposure to low concentrations probably is a more significant issue for fish population structure and may result in multiple substances acting in "an additive, synergistic or antagonistic manner" that may render impacts relatively difficult to discern (Thurberg and Gould 2005).

Determining the eventual fate and effect of naturally occurring and synthetic contaminants in coastal environments and biota is a highly dynamic proposition that requires interdisciplinary evaluation. It is essential that all processes sensitive to pollutants be identified and that investigators realize that the resulting adverse effects may be manifested at the biochemical level in organisms (Luoma 1996) in a manner particular to the species or life stage exposed. Pollutant exposure can inhibit: (1) basic detoxification mechanisms, like production of metallothioneins or antioxidant enzymes; (2) the ability to resist diseases; (3) the ability of individuals or populations to counteract pollutant-induced metabolic stress; (4) reproductive processes including gamete development and embryonic viability; (5) growth and successful development through early life stages; (6) normal processes including feeding rate, respiration, osmoregulation; and (7) overall Darwinian fitness (Capuzzo and Sassner 1977; Widdows et al. 1990; Nelson et al. 1991; Stiles et al. 1991; Luoma 1996; Thurberg and Gould 2005).

The nature and extent of a pollutant's dispersal in our waterways are collectively dependent on a variety of factors including site-specific ecological conditions, the physical state in which the contaminant is introduced into the aquatic environment, and the inherent chemical properties of the substance in question. Soluble or miscible substances typically enter waterways in an aqueous phase and eventually become adsorbed onto organic and inorganic particles (Wu et al. 2005); however, contaminants may enter aquatic systems as either particle-borne suspensions or as solutes (Bishop 1984; Turner and Millward 2002). Dilution and settling out from such effluent streams initially are dictated by physical factors (e.g., the presence of significant currents or perhaps a strong thermocline or pycnocline) which predominantly influence the spatial extent of contaminant dispersal. In particular, turbulent mixing, or diffusion, disperses contaminant patches in coastal waters resulting in larger, comparatively diluted contaminant distributions further away from the initial point source (Bishop 1984). Biological activity and geochemical processes subsequently intercede and typically result in contaminant partitioning between the aqueous and particulate phases (Turner and Millward 2002).

While physical dispersion, biological activity, and other ecological factors clearly have important roles regarding the distribution of contaminants in aquatic habitats, contaminant partitioning is largely governed by certain ambient environmental conditions, notably salinity, pH, and the physical nature of local sediments (Turekian 1978; McElroy et al. 1989; Turner and Millward 2002; Leppard and Droppo 2003; Wu et al. 2005). Highly reactive suspended particles typically serve as important carriers of aquatic contaminants and largely are responsible for their bioavailability, transport, and ecological fate as they become dispersed in receiving waters (Turner and Millward 2002). In addition, hyporheic (i.e., the saturated zone under a river or stream, comprising substrate with the interstices filled with water) exchange between overlying water and groundwater can alter salinity, dissolved oxygen concentration, and other water chemistry aspects in ways that can influence the affinity of local sediment types for particular contaminants or otherwise affect contaminant behavior (Ren and Packman 2002).

Amendments to the CWA include important provisions to address acute or chronic water pollution emanating from discharge pipes and outfalls under the National Pollutant Discharge Elimination System (NPDES) program. Until the late 1980s, the NPDES program traditionally focused efforts on controlling industrial and municipal sewage discharges but has since expanded its purview to include storm water management (USEPA 1996). While the NPDES program has led to ecological improvements in waters of the United States, point sources continue to introduce pollutants into the aquatic environment, albeit at reduced levels. Nonetheless, studies demonstrate that particle-associated contaminants collected in coastal depositional areas are preserved in chronological strata or horizons (Huntley et al. 1995; Chillrud et al. 2003). Consequently, historically deposited contaminants may be encountered when installing new outfalls or coastal infrastructure, especially near urbanized areas. Regardless of whether these pollutants were deposited recently or decades ago, dredging incidental to construction and related activities that enhance their potential biological availability can have adverse ecological implications.

The environmental dynamics of point source wastes are complex and involve a variety of physical, chemical, and biological processes simultaneously acting on the introduced suite of contaminants and their surrounding habitat. Because of the many competing variables involved, it is difficult to predict the ultimate fate and effects of anthropogenic wastes with great precision; however, local habitat characteristics in combination with the relative solubility, degree of hydrophobicity (i.e., tending to repel and not absorb water), and chemical reactivity of the introduced substances are important determining factors at the most basic level of analysis.

To minimize redundancy, all recommended conservation measures and best management practices for sewage discharge facilities, industrial discharge facilities, and combined sewer overflows have been included at the end of this chapter.

## Sewage Discharge Facilities

### *Introduction*

Sewage treatment plants introduce a host of contaminants into our waterways primarily through discharge of fluid effluents comprising a mixture of processed “black water” (sewage) and “gray water” (all other domestic and industrial wastewater). Such municipal effluents begin as a complex mixture of human waste, suspended solids, debris, and a variety of chemicals collectively derived from domestic and industrial sources. These contaminants include an array of suspended and dissolved substances, representing both inorganic and organic chemical species (Grady et al. 1998; Epstein 2002). These substances potentially include the full spectrum of EPA priority pollutants mentioned previously and many other contaminants of anthropogenic origin. However, the five constituents that are usually the most important in determining the type of treatment that will be required are: (1) organic content (usually measured as volatile solids); (2) nutrients; (3) pathogens; (4) metals; and (5) toxic organic chemicals (USEPA 1984).

Coastal communities rely on municipal wastewater treatment to contend with potential human health issues related to sewage and also to protect surface and groundwater quality. Municipal processing facilities typically receive raw wastewater from both domestic and industrial sources, and are designed to produce a liquid effluent of suitable quality that can be returned to natural surface waters without endangering humans or producing adverse aquatic effects (Grady et al. 1998; Epstein 2002). As it is currently practiced in the United States, wastewater treatment entails subjecting domestic and industrial effluents to a series of physical, chemical, or even biological processes designed to address or manipulate different aspects of contaminant mitigation. For both logistical and economic reasons, not all municipalities expend the same level of effort removing contaminants from their wastewater before returning it to a receiving aquatic habitat. The following discussion summarizes the different levels that municipal wastewater treatment and resulting water quality benefits derived from them.

Primary treatment, also known as “screen and grit,” is only marginally effective at addressing sewage contaminants and simply entails bulk removal of “settleable” solids from the wastewater by sedimentation and filtration. Sometimes total suspended solids are further reduced in the initial effluent treatment phase by implementing another level of primary treatment, which entails using chemicals to induce coagulation and flocculation of smaller particles (Parnell 2003).

The resulting bio-solids must be disposed, and their final disposition could entail composting with subsequent use in agricultural applications, placement in a landfill, disposal at sea, or even incineration (Werther and Ogada 1999). Removal and appropriate disposal of sewage present in a solid phase are important steps, if elementary, in addressing human health and aesthetic issues surrounding sewage management because doing so removes visible substances that otherwise would accumulate in the aquatic environment at or near the discharge point. Unfortunately, primary treatment of municipal wastewater alone often fails to meet overall environmental goals of supporting important water-dependent uses like fishery resource production and recreational uses featuring primary contact with the water. As a consequence, coastal communities in the northeastern region process their wastewater through one or more additional treatment levels beyond bulk solids removal to address the environmental challenges of their sewage effluents more effectively.

Following bulk sludge removal, sewage treatment plants typically pass the highly organically-enriched water emerging from primary treatment through a second process that is intended to address biological oxygen demand (BOD), an indirect measure of the concentration of biologically degradable material present in organic wastes that reflects the amount of oxygen necessary to break down those substances in a set time interval. Such secondary treatment, which is required for all municipal wastewater treatment in the United States, involves removal of much of the remaining organic material by introducing aerobic microorganisms under oxygen-enriched conditions (Parnell 2003). The resulting microbial action breaks organic substrates into progressively simpler compounds, with the final waste components predominantly released as carbon dioxide. The bacteria subsequently are removed by chlorination before the secondarily-treated effluent is released into local surface waters or the secondarily treated wastewater is directed to another part of the sewage treatment plant for additional processing. Where practiced, such effluent-polishing or advanced treatment measures use any of several techniques to remove inorganic nitrogenous or phosphorous salts to reduce the final effluent's potential to cause excessive nutrient enrichment of the receiving waters (Epstein 2002; Parnell 2003).

Because of the large expense of tertiary sewage treatment, the public sector does not implement it as a uniform municipal wastewater treatment policy. Consequently, while secondary treatment is the standard operating procedure for municipal wastewater treatment in the northeastern United States, natural resource managers cannot assume that advanced, tertiary treatment is available to meet desired environmental goals. Recent point source management policy decisions by Boston, MA, area communities are a case in point. Rather than implementing more costly advanced treatment during system upgrades, these communities chose to address local municipal wastewater challenges by implementing primary and secondary treatment combined with source reduction of certain contaminants and offshore diversion of outfalls to encourage enhanced effluent dilution (Moore et al. 2005). Despite the added expense of implementing them, both secondary and advanced treatment processes are important potential habitat protection measures, particularly because they mitigate oxygen depletion events, eutrophication, and related phenomena that can result in adverse ecological conditions.

### *Release of nutrients and eutrophication*

Particularly under lesser levels of treatment, municipal sewage facilities discharge large volumes of nutrient-enriched effluent. While some level of readily available nutrients are essential to sustain healthy aquatic habitats and ecological productivity, excess concentrations result in eutrophication of coastal habitats. Elevated nitrogen and phosphorous concentrations in municipal wastewater effluents can cause pervasive ecological responses including: exaggeration of phytoplankton and macroalgal populations; initiation of harmful algal blooms (Anderson et al. 2002); adverse affects on the physiology, growth, and survival of certain ecologically important aquatic plants (Touchette and Burkholder 2000); reduction of water transparency with accompanying adverse effects to submerged and emergent vascular plants or other disruptions to the normal ecological balance among vascular plants and algae (Levinton 1982; Cloern 2001); hypoxic or anoxic events that may cause significant fish and invertebrate mortalities; disturbances to normal denitrification processes; and concomitant decrease in local populations of fishery resources and forage species (USEPA 1994). Sewage outfalls also may become an attraction nuisance in that they may at least initially attract fish around the point of discharge until hypoxia, toxin production, and algal bloom development render the aquatic area less productive (Islam and Tanaka 2004). Collectively, adverse chemical effects may be especially significant to aquatic resources in temperate regions because strong thermoclines and persistent ice cover restrict vertical mixing and exacerbate deteriorating habitat conditions at depth.

For additional information on the mechanisms involved in denitrification of organic and inorganic compounds, Korom's (1992) review of denitrification in natural aquifers is a concise and informative compilation of heterotrophic and autotrophic denitrifiers.

### *Release of contaminants*

Municipal treatment facilities discharge large volumes of effluent into the aquatic environment. The waste stream typically contains a complex mixture of domestic and industrial wastes that contain predominantly natural and synthetic organic substances, metals, and trace elements, as well as pathogens (Islam and Tanaka 2004). Similarly, introductions of certain pharmaceuticals via municipal wastewater discharges have become causes for concern because of their potential to act as endocrine disruptors in fish and other aquatic resources. Residence time of the different contaminant classes in aquatic environments is an important habitat management consideration. Some of these substances, such as volatile organic compounds, may have a relatively short residence time in the system and other, more persistent substances, such as synthetic organometallic compounds, may linger for decades after becoming associated with the substrate or concentrated in local biota. Such pollution has been associated with mortality, malformation, abnormal chromosome division, and higher frequencies of mitotic abnormality in adult fish from polluted areas compared with those from less polluted regions of the northwest Atlantic Ocean (Longwell et al. 1992).

Increased concentrations of the various contaminant classes associated with municipal wastewater can be highly ecologically significant. For instance, exposure to contaminants within these categories have been correlated with deleterious effects on aquatic life including larval deformities in haddock (*Melanogrammus aeglefinus*) (Bodammer 1981), reduced hatching success and increased larval mortality in winter flounder (*Pseudopleuronectes americanus*) (e.g., Klein-MacPhee et al. 1984; Nelson et al. 1991), skeletal deformities in Atlantic cod (*Gadus morhua*) (Lang and Dethlefsen 1987), inhibited gamete production and maturation in sea scallops (*Placopecten magellanicus*) (Gould et al. 1988), and reproductive impairment in Atlantic cod (Thurberg and Gould 2005).

Laboratory experiments with pesticides have shown a positive relationship between malformation and survival of embryos and larvae of Atlantic cod and concentration of DDT and its breakdown product dichlorodiphenyl dichloroethylene (DDE) (Dethlefsen 1976). The proportion of fin erosion in winter flounder collected on contaminated sediments was found to be greater in fish sampled with higher concentrations of PCB in muscle, liver, and brain tissues than in fish collected in reference sites (Sherwood 1982). Studies conducted in the harbor of New Haven, CT, found high occurrences of liver lesions, blood cell abnormalities, liver DNA damage, and liver neoplasms among winter flounder with high concentrations of organic compounds, metals, and PCB in their gonads (Gronlund et al. 1991). Such pollution also has been associated with mortality, malformation, abnormal chromosome division, and higher frequencies of mitotic abnormality in adult fish from polluted areas compared with those from less polluted regions of the northwest Atlantic Ocean (Longwell et al. 1992). Observed effects of fish exposed to PAH include decrease in growth, cardiac disfunction, lesions and tumors of the skin and liver, cataracts, damage to immune systems, estrogenic effects, bioaccumulation, bioconcentration, trophic transfer, and biochemical changes (Logan 2007).

For almost a century, sewage sludge (the solids extracted from raw wastewater during sewage treatment) was disposed of at sea. In the northeastern United States, a number of designated offshore sewage sludge dumpsites existed, including one in Boston Harbor, MA, and sites in the New York Bight and the Mid-Atlantic Bight (Barr and Wilk 1994). Not surprisingly, sediments sampled in the vicinity of sewage sludge dumpsites have contained higher levels of contaminants (e.g., PCB, PAH, chlorinated pesticides, and metals) than in control sites (Barr and Wilk 1994). Sewage sludge has been demonstrated to have adverse effects on aquatic organisms. For example, early life stages of Atlantic herring (*Clupea harengus*) have shown a series of developmental abnormalities, including premature hatching accompanied by reduced viability of emerging fry; poor larval survival; smothering or incapacitation of larvae by particle flocs; and fin damage (Urho 1989; Costello and Gamble 1992). The Ocean Dumping Ban Act of 1988 prohibited sewage sludge and industrial wastes from being dumped at sea after December 31, 1991. This law is an amendment to the Marine Protection, Research, and Sanctuaries Act of 1972, which regulates the dumping of wastes into ocean waters.

In addition to these diverse contaminant classes, wastewater facilities also discharge a host of synthetic hormones or other substances that could disrupt normal endocrine function in aquatic vertebrates, as well as introduce zoonotic viruses, bacteria, and fungi that may be present in raw human sewage. These chemicals act as "environmental hormones" that may mimic the function of the sex hormones (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Metals, PAHs, and other contaminants have been implicated in disrupting endocrine secretions of marine organisms (Brodeur et al. 1997; Thurberg and Gould 2005). However, the long-term effect of endocrine-disrupting substances on aquatic life is not well understood and demands serious attention by the scientific and resource policy communities. Refer to the Endocrine Disruptors subsection of this chapter for a broader discussion on this topic. Metals such as mercury are also capable of moving upward through trophic levels and can accumulate in fish (i.e., bioaccumulation) at levels which may cause health problems in human consumers.

While modern sewage treatment facilities undeniably reduce the noxious materials present in raw wastewater and some substances typical of processed effluents have their own inherent toxic effects, it also is important to recognize that secondary and advanced treatment can alter the chemistry of ordinarily benign materials in ways that initiate or enhance their toxicity. In particular, normally nonhazardous organic compounds present in wastewater potentially can be rendered toxic when raw municipal effluent is chlorinated in the sewage treatment process (NRC 1980; Epstein 2002). Other contaminants may become toxic to humans or many different aquatic resource taxa when these substances are methylated (addition of a $-CH_4$ group) or otherwise after having been chemically transformed into a harmful, biologically available molecular form.

The behavior and effects of trace chemicals in aquatic systems largely depend on the speciation and physical state of the pollutants in question. A detailed description concerning contaminant partitioning and bioavailability is beyond the scope of this technical discussion.

However, Gustafsson and Gschwend (1997) offer an excellent review of the matter in terms of how dissolved, colloidal and settling particle phases affect trace chemical fates and cycling in aquatic environments. While the observations provided by these Massachusetts Institute of Technology researchers pertain specifically to cycling of compounds in natural waters, the generic properties they discuss also would apply in the context of substances in treated wastewater since they are subject to the same physical and chemical forces. In addition, Tchobanoglous et al. (2002) may be consulted for an authoritative technical review of the environmental engineering aspects of wastewater treatment.

Exposure to potentially mutagenic or teratogenic pollutants and the resulting declines in viability at any life stage reduce the likelihood of maturation and eventual recruitment to adulthood or a targeted fishery. Literature on the aqueous and sedimentary geochemistry and physiological effects of contaminants on aquatic biota should be consulted to determine the fate of persistent compounds in local sediments and associated pore-water and the extent of acute or chronic toxic effects on affected aquatic biota (Varanasi 1989; Allen 1996; Langmuir 1996; Stumm and Morgan 1996; Tessier and Turner 1996; Paquin et al. 2003).

### *Alteration of water alkalinity*

Municipal sewage effluent that does not meet water quality standards can alter the alkalinity of riverine receiving waters. However, freshwater and low-salinity waters with low buffering capacity are more susceptible to acidification than are marine waters. Acidification of riverine habitats has been linked to the disruption of reproduction, development, and growth of anadromous fish (USFWS and NMFS 1999; Moring 2005). For example, osmoregulatory problems in Atlantic salmon (*Salmo salar*) smolts have been related to habitats with low pH (Staurnes et al. 1996). In estuarine waters, low pH has been shown to cause cellular changes in the muscle tissues of Atlantic herring which may lead to a reduction in swimming ability (Bahgat et al. 1989). However, all municipal sewage facilities are required to obtain water quality permits through the US EPA's NPDES program and must meet established pH standards for receiving waters. Acid precipitation from atmospheric sources is of concern in the northeastern United States. Refer to the Global Effects and Other Impacts chapter for more information regarding acid precipitation.

### *Impacts to submerged aquatic vegetation*

Submerged aquatic vegetation (SAV) requires relatively clear water in order to allow adequate light transmittance for metabolism and growth. Sewage effluent containing high concentrations of nutrients can lead to severely eutrophic conditions. The resulting depression of dissolved oxygen and diminished light transmittance through the water may result in local reduction or even extirpation of SAV beds that are present before habitat conditions become too degraded to support them (Goldsborough 1997). Examples of large scale SAV declines have been seen throughout the eastern coastal states, most notably in Chesapeake Bay, MD/VA, where overall abundance has been reduced by 90% during the 1960s and 1970s (Goldsborough 1997). Although a modest recovery of the historic SAV distribution has been seen in Chesapeake Bay over the past few decades, reduced light penetration in the water column from nutrient enrichment and sedimentation continues to impede substantial restoration. Primary sources of nutrients into Chesapeake Bay include fertilizers from farms, sewage treatment plant effluent, and acid rain (Goldsborough 1997). Short and Burdick (1996) correlated eelgrass losses in Waquoit Bay, MA, with anthropogenic nutrient loading primarily as a result of increased number of septic systems from housing developments in the watershed.

Eutrophication can alter the physical structure of SAV by decreasing the shoot density and blade stature, decreasing the size and depths of beds, and stimulating excessive growth of macroalgae (Short et al. 1993). An epidemic of an eelgrass wasting disease wiped out most eelgrass beds along the east coast during the 1930s, and although some of the historic distribution of eelgrass has recovered, eutrophication may increase the susceptibility of eelgrass to this disease (Deegan and Buchsbaum 2005).

### *Reduced dissolved oxygen*

The decline and loss of fish populations and habitats because of low dissolved oxygen concentrations is "one of the most severe problems associated with eutrophication in coastal waters" (Deegan and Buchsbaum 2005). The effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (Bejda et al. 1992). High nutrient loads into aquatic habitats can cause hypoxic or anoxic conditions, resulting in fish kills in rivers and estuaries (USEPA 2003b; Deegan and Buchsbaum 2005) and potentially altering long-term community dynamics (NRC 2000; Castro et al. 2003). Highly eutrophic conditions have been reported in a number of estuarine and coastal systems in the northeastern United States, including Boston Harbor, Long Island Sound, NY/CT, and Chesapeake Bay (Bricker et al. 1999). For the southern portions of the northeast coast (i.e., Narragansett Bay, RI, to Chesapeake Bay), O'Reilly (1994) described chronic hypoxia (low dissolved oxygen) as a result of coastal eutrophication in several systems. This author reported episodic, low dissolved oxygen conditions in some of the northern portions of the northeast coast, such as in Boston Bay/Charles River and the freshwater portion of the Merrimack River, MA/NH (O'Reilly 1994). Areas particularly vulnerable to hypoxia are those that have restricted water circulation, such as coastal ponds, subtidal basins, and salt marsh creeks (Deegan and Buchsbaum 2005). While any system can become overwhelmed by unabated nutrient inputs or nutrient enrichment, the effects of these generic types of pollution when experienced in temperate regions may be especially significant in the summer. This is primarily a result of stratification of the water column and higher water temperatures and metabolic rates during summer months (Deegan and Buchsbaum 2005).

### *Siltation, sedimentation, and turbidity*

Municipal sewage outfalls, especially those that release untreated effluent from storm drains, can release suspended sediments into the water column and the adjacent benthic habitat. Increased suspended particles within aquatic habitats can cause elevated turbidity levels, reduced light transmittance, and increased sedimentation of benthic habitat which may lead to the loss of SAV, shellfish beds, and other productive fishery habitats. Other affects from elevated suspended particles include respiration disruption of fishes, reduction in filtering efficiencies and respiration of invertebrates, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991; Barr 1993).

### *Introduction of pathogens*

Pathogens are generally a concern to human health because of consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). Microorganisms entering aquatic habitats in sewage effluents do pose some level of biological risk since they have been shown to infect marine mammals (Oliveri 1982; Bossart et al. 1990; Islam and Tanaka 2004). The degree to which anthropogenically-derived microbes may affect fish, shellfish, and other aquatic taxa remains an important research topic; however, some recently published observations concerning groundfish populations near the Boston sewage outfall into Massachusetts Bay are suggesting that appropriate management practices may address at least part of this risk (Moore et al. 2005). See also the chapters on Coastal Development and Introduced/Nuisance Species and Aquaculture for more information on the introduction of pathogens.

### *Introduction of harmful algal blooms*

Sewage treatment facilities releasing effluent with a high BOD that may enter estuarine and coastal habitats have been associated with harmful algal bloom events, which can deplete the oxygen in the water during bacterial degradation of algal tissue and result in hypoxic or anoxic "dead zones" and large-scale fish kills (Deegan and Buchsbaum 2005). There is evidence that nutrient overenrichment has led to increased incidence, extent, and persistence of nuisance and/or noxious or toxic species of phytoplankton; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from plankton algae (O'Reilly 1994).

Algal blooms may also contain species of phytoplankton such as dinoflagellates that produce toxins. Toxic algal blooms, such as red tides, can decimate large numbers of fish, contaminate shellfish beds, and cause health problems in humans. Shellfish sequester toxins from the algae and become dangerous to consume. Toxic algal blooms could increase in the future because many coastal and estuarine areas are currently moderately to severely eutrophic (Goldburg and Triplett 1997). Heavily developed watersheds tend to have reduced stormwater storage capacity, and the high flow velocity and pulse of contaminants from freshwater systems can have long-term, cumulative impacts to estuarine and marine ecosystems. Some naturally occurring microorganisms, such as bacteria from the genus, *Vibrio*, or the dinoflagellate, *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species will require additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997). See also the chapter on Introduced/Nuisance Species and Aquaculture for more information on harmful algal blooms.

### *Impacts to benthic habitat*

As discussed above, treated sewage effluent containing high concentrations of nutrients can lead to severely eutrophic conditions that can reduce or eliminate SAV beds (Goldsborough 1997). In addition, municipal sewage outfalls can release suspended sediments into the water column and the adjacent benthic habitat. Increased suspended particles within aquatic habitat can cause elevated turbidity levels, reduced light transmittance, which may lead to the reduction or loss of SAV, shellfish beds and other productive benthic habitats.

### *Changes in species composition*

Treated sewage effluent can contain, at various concentrations, nutrients, toxic chemicals, and pathogens that can affect the health, survival, and reproduction of aquatic organisms. These effects may lead to alterations in the composition of species inhabiting coastal aquatic habitats and can result in community and trophic level changes (Kennish 1998). For example, highly eutrophic water bodies have been found to contain exaggerated phytoplankton and macroalgal populations that can lead to harmful algal blooms (Anderson et al. 2002). Sewage treatment facilities may initially attract fish around the point of discharge until hypoxia, toxin production, and algal bloom development render the aquatic area less productive (Islam and Tanaka 2004). Reduced light penetration in the water column from nutrient enrichment and sedimentation has been shown to contribute to the loss of eelgrass beds in coastal estuaries in southern Massachusetts, Long Island Sound, and the Chesapeake Bay (Goldsborough 1997; Deegan and Buchsbaum 2005).

### *Contaminant bioaccumulation and biomagnification*

Sewage discharges can contain metals and other substances known to be toxic to marine organisms. Not surprisingly, the bays and estuaries of highly industrialized urban areas in northeastern US coastal areas, such as Boston Harbor, Portsmouth Harbor, NH/ME, Newark Bay,NJ, western Long Island Sound, and New York Harbor, have shown relatively high metal burdens in sampled sediments (Larsen 1992; Kennish 1998; USEPA 2004a). While industrial outfalls are responsible for metal contamination in some areas, sewage has been identified as one of the primary sources. For example, although lead contamination in coastal sediments can originate from a variety of sources, sewage is believed to be the primary source of silver contamination (Buchholtz ten Brink et al. 1996). Metals may move upward through trophic levels and accumulate in fish and some invertebrates (bioaccumulation) at levels which can eventually cause health problems in human consumers (Kennish 1998; NEFMC 1998). Other chemicals are known to bioaccumulate and biomagnify in the ecosystem, including pesticides (e.g., DDT) and PCB congeners (Kennish 1998). The National Coastal Condition Report (USEPA 2004a) reported that after metals, PCB congeners and DDT metabolites were responsible for most of the contaminant criteria exceedances in northeast coast samples. For example, sediment samples collected by NOAA's National Status and Trends (NS&T) Program found in some samples very high concentrations of chlorinated hydrocarbons such as PCBs, pesticides, and dioxins from the lower Passaic River, NJ, and Newark Bay in the Hudson-Raritan estuary (Long ER et al. 1995). Other locations in this estuary containing moderately to highly toxic samples in the NS&T Program included Arthur Kill, NY/NJ, and East River, NY.

### *Release of pharmaceuticals*

Concerns have been emerging over the past few years regarding the continual exposure of aquatic organisms to the complex spectrum of active ingredients in pharmaceuticals and personal care products (PPCP), which can persist in treated effluent from sewage facilities. PPCPs comprise thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, lotions, and cosmetics (Daughton and Ternes 1999; USEPA 2007). The concentrations of PPCP in the aquatic environment are generally detected in the range of parts per thousand to parts per billion and may not pose an acute risk. However, aquatic organisms may be adversely affected because they can have continual and multigenerational exposures, exposures at high concentrations from untreated water, and they may have low dose effects (Daughton and Ternes 1999; USEPA 2007). Some of these PPCPs include steroid compounds, which may act as endocrine disruptors by mimicking the functions of sex hormones (refer to the subsection below for more information on endocrine disruptors). The effects of antibiotics and antimicrobial drugs on aquatic organisms are also of concern. Although population level effects on aquatic organisms from PPCPs are inconclusive at this time, the growing evidence on this topic suggests further investigation is warranted.

### *Endocrine disruptors*

Another recent topic of concern involves a group of chemicals, called "endocrine disruptors," which interfere with the endocrine system of aquatic organisms. Growing concerns have mounted in response to the effects of endocrine-disrupting chemicals on humans, fish, and wildlife (Kavlock et al. 1996; Kavlock and Ankley 1996). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Adverse effects include reduced or altered reproductive functions, which could result in population-level impacts. Several studies have implicated endocrine-disrupting chemicals with the presence of elevated levels of vitellogellin in male fish, a yolk precursor protein that is normally only found in mature female fish (Thurberg and Gould 2005). Some of the chemicals shown to be estrogenic include PCB congeners, dieldrin, DDT, phthalates, and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture and may be present in irrigation water and storm water runoff. Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997).

In summary, the chemical implications of sewage treatment plant effluents vary as a function of the effort taken to remove organic and inorganic contaminants collected by the wastewater treatment plant. Further complicating matters, while secondary treatment is the minimal acceptable standard treatment process in the northeastern United States, inadequately treated or even raw wastewater containing human sewage and attendant debris routinely passes into the aquatic environment from municipal processing plant outfalls when the flow and/or storage demands exceed design specifications. Such releases are commonly experienced when older sewer systems are inundated, particularly in conjunction with storm events. Accordingly, the types of treatment processes implemented, how effectively the wastewater treatment infrastructure is operating, and the salinity of the receiving waters (to the extent that it influences contaminant chemistry) are critical variables when considering the chemical implications of releasing treated wastewater into the aquatic environment.

### *Maintenance activities associated with sewage discharge facilities*

Maintenance activities associated with sewage treatment plants typically involve periodic application of chemicals to treat piping for colonization of biofouling organisms. Efforts to control fouling communities can produce larger field or even chronic disturbances that could adversely affect the aquatic environment. Under some circumstances, chemical treatments are not necessary and fouling communities may be removed mechanically using hot water under pressure. When this type of procedure is implemented, most of the direct impacts are physical. Although the use of pressurized, hot freshwater to mechanically remove fouling organisms may temporarily alter salinity and solute loads, some localized indirect thermodynamic effects that alter ambient chemistry could also occur in the dispersal plume until ambient temperature is restored. In addition, differences in the chemical composition of the source and receiving waters would be expected to have at least a minimal effect, particularly when chlorinated water is used to facilitate the removal of fouling organisms and when there is a significant difference in salinity between cleaning and receiving waters. Perhaps more typically, colonization of fouling communities is controlled through periodic use of antifouling paints, coatings, or other treatments. When conducted inappropriately, periodic applications of these substances can have chronic and potentially harmful effects in the aquatic environment.

Fortunately, application of biocides in aquatic systems is regulated under the CWA, which includes provisions to protect fishes and many invertebrate species to the extent practicable. Since local salinity ranges and diffusion rates at the outfall are important considerations in terms of eventual dispersion and relative toxicity of outfall maintenance materials, these and similar site-specific considerations often dictate which products may be used safely at a given project site. It is vital that only products designed and federally approved for use in and near aquatic habitats are deliberately allowed to enter US waterways under any circumstances.

In general, the most deleterious effects of sewage outfall maintenance probably revolve around fouling community control measures. That is because the underlying intent of such practices is to remove a large variety of plant, animal, and even bacterial populations from inhabiting the area surrounding the outfall. Biocide applications control undesirable organisms by chemical or biological means (Knight and Cooke 2002). Whether removed chemically or mechanically, the loss of these organisms at least initially may result in other forms of local ecological disturbance, such as reduced productivity and diminished prey and cover (Meffe and Carroll 1997). While outfall maintenance events individually result in an acute chemical impact to the environment and biota, it is important also to consider the cumulative effects of repeated applications over a project's maintenance cycle. Especially when undertaken regularly, the maintenance of outfall structures can create a chronic cycle of disturbance on resident biota, particularly sessile organisms.

Individual biocides and other contaminants released during outfall maintenance operations may have direct effects on local aquatic biota or they may act in an additive, synergistic, or antagonistic manner in concert with ambient physical and chemical habitat conditions. Such exposure to organic and inorganic pollutants may result in a spectrum of lethal and sublethal effects that may be discerned at every level of biological organization (Thurberg and Gould 2005). Wide distribution of contaminants, such as biocides and related outfall maintenance substances, can be facilitated through bioaccumulation in motile aquatic organisms that are capable of dispersing between riverine, estuarine, and marine habitats (Mearns et al. 1991). The pollutant-induced effects these substances engender are not limited to biochemical or physiological responses, as they may also disrupt a variety of complex behaviors which may be essential for maintaining fitness and survival (Atchison et al. 1987; Blaxter and Hallers-Tjabbes 1992; Kasumyan 2001; Scott and Sloman 2004).

In addition to measures to control fouling organisms in wastewater treatment facilities, maintenance activities also involve repairs and enhancements of structures associated with the facilities' infrastructure. Because they typically are undertaken on a relatively small scale, physical repairs of existing infrastructure usually produce impacts of lesser intensity and on a more limited spatial scale than those created during initial installation. In contrast, application of antifouling coatings or related treatments not only discourages settlement by aquatic organisms on the treated surface, but also releases biocide into the aquatic environment (Richardson 1997; Terlizzi et al. 2001). Depending on the individual case, such releases can range from very limited to extensive plumes, as measured by the volume of material emitted, and the distance broadcast away from the point source the substance may be detected in the water column.

Collectively, such releases degrade local water quality. Fortunately, chemical effects of sewage outfall maintenance in lotic coastal systems generally would be expected to dissipate relatively quickly because of dispersion by river flow or tidal action. For health and aesthetic reasons, municipal sewage outfalls should not be sited in quiescent waters. In addition, government-established protocols for biological control agents approved for applications in subaqueous discharges generally are applied in isolation within a capped pipe and are subsequently released after sufficient time has passed for the biocide properties to have abated, or more rarely after the bulk of the treating solution is siphoned off and dealt with offsite. Typically, such biocide solutions are designed to decompose into relatively benign constituent forms within hours and, when used properly, are thought not to pose a significant risk to nontarget organisms (Diderich 2002).

As is the case for initial outfall installation impacts, a variety of chemical and biological factors determine the extent to which the polluting substance affects the water column, sediments, and biota and the distance it migrates from the point source. Among them, salinity and carbonate alkalinity (i.e., carbonic acid and bicarbonate ion content) are especially important because of their respective roles in mediating chemical reactions in solution and in conferring the buffering capacity provided by marine and estuarine waters. Carbonate alkalinity, or water hardness, is an especially important property in riverine systems because the ambient carbonate concentrations regulate acid-base chemistry and other water quality parameters, which are thought to be important factors in the recovery of depleted salmonid populations in Maine (Johnson and Kahl 2005). While salmonids are particularly sensitive to degraded water quality, poor water quality is known to affect a wide variety of aquatic organisms (Tessier et al. 1984; Scott and Sloman 2004; Moore et al. 2005; Thurberg and Gould 2005).

### *Construction impacts associated with sewage discharge facilities*

The construction of municipal wastewater outfalls can have chemical effects that result from a number of activities, including releasing suspended sediments and associated pore-water in the construction zone; releasing drill mud or cuttings from a directional drilling operation; discharging substances from mechanized equipment (e.g., incidental discharges of hydrocarbons or hydraulic fluid); and introducing leachate from fresh and curing concrete, antifouling paints, and other construction materials. Contaminants initially reside in aquatic systems in either a dissolved phase in the water column or in a particulate phase when they have adsorbed onto sediments or other solids. Pollutants present in biologically-available forms subsequently become assimilated by aquatic biota and become biomagnified as they are taken up in successive trophic strata (Levinton 1982; Sigel and Sigel 2001).

While plume and sedimentation effects incidental to outfall construction do not always result in a readily observable ecological response, they commonly produce a range of direct and indirect effects to living aquatic resources and their habitats. Not all of the ecological implications of sediment resuspension and transport result in adverse effects to aquatic organisms (Blaber and Blaber 1980). These effects vary a great deal depending on which life history stages are affected (Wilber and Clarke 2001). As a general rule, however, the severity of adverse chemical effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996). In particular, predictive models of dose-response relationships corroborate that the eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Mitigative measures that limit the nature and extent of chemical impacts arising from outfall installation typically can and should be undertaken to avoid and minimize adverse construction effects.

From the standpoint of water quality, most chemical effects associated with outfall construction should be relatively acute and transitory. Adverse water quality impacts arising from outfall installation generally arise as a consequence of: (1) substances that have adsorbed onto resuspended particles; (2) pollutants that have dissolved or leached into the water column; or (3) contaminants that have been released directly by construction equipment. These pollutants may include substances that lead to nutrient enrichment; they may be chemically reduced; they may exhibit acidic or caustic properties; they may contain organometallic complexes or a variety of other natural or synthetic compounds; they may be hydrophobic or hydrophilic; or they otherwise may exhibit a diverse spectrum of chemical properties that affect their relative toxicity and dispersal in the water column.

While various physical, chemical, and biological factors come into play, the area into which such water quality impacts extend is largely dependent upon the length of time particles and solutes are held in the water column and the distance they are transported from the construction site. Grain size and ambient sediment structure characteristics have an important bearing on dispersal. As benthic material is disturbed during outfall installation and site preparation, resuspended particulate matter would settle predominantly in the immediate project vicinity. Remaining waterborne fractions subsequently would be transported over a distance and direction that are related to the grain size of disturbed sediments, the velocity of local water currents, and local wave action (Neumann and Pierson 1966). Contaminants mobilized in and subsequently deposited by the dispersal plume generated by construction activities are subject to complex biogeochemical processes that ultimately dictate their fate and ecological effects. For example, hydrogen sulfide released with pore-water from disturbed sediments depletes dissolved oxygen and results in locally hypoxic or anoxic conditions in the water column until the area engulfed within the dispersal plume becomes reoxygenated.

While important, it is essential to recognize that local sediment characteristics alone do not determine contaminant introduction or resuspension during outfall installation. The type of construction equipment used to build an outfall structure also has an important influence on the dispersion of disturbed bottom material. For traditional clamshell dredging, Tavolaro (1984) estimates a 2% loss of material through sediment resuspension at the dredge site. It is reasonable to conclude that similar losses would accrue when clamshells are used to install outfall pipes for sewage treatment facilities. In the same way, dredging methods that purposely fluidize sediments to facilitate their removal (e.g., hydraulic dredges, water jets) could result in even greater dispersion of resuspended sediment, especially when local waters are not quiescent or in situations where unfiltered return flow to the waterway is permitted. Since fine depositional sediments tend to have greater contaminant loads than do coarser sediments typical of higher energy areas, the chemical consequences of resuspending fine sediments during outfall installation are potentially greater since they are more likely to be associated with pollutants.

Likewise, water quality implications of outfall construction are not limited to sediment resuspension or releasing pore-water that contains hydrogen sulfide. Secondary vectors of chemical contamination during outfall installation include substances introduced into aquatic habitats by construction equipment and materials. Mechanized construction equipment may inadvertently or incidentally release a broad spectrum of chemicals, fuels, and lubricants into the waterway. Similarly, until the building material has completely cured or has leached out soluble contaminant fractions, subaqueous applications of wet concrete or grout, treated timber products, paints, and other construction materials would all potentially introduce pollutants into the surrounding water.

The chemical implications of constructing municipal outfalls to local substrates ultimately depend on whether (and to what extent) contaminants are released, become associated with, and accumulate in, sediments and surrounding pore-water. While sediment particles naturally exhibit cycles of exchange between the water column and bottom substrate materials (Turner and Millward 2002), dredging or outfall installation can be expected to disturb much deeper sediment horizons in a short period of time than would be expected from storms or in all but the most highly erosion prone coastal areas. As construction equipment disrupts sediment horizons at the project site, some fraction of the benthic substrate becomes resuspended into the water column (Tavolaro 1984).

Outfall construction for sewage treatment facilities can create measurable adverse impacts within the disturbed footprint, including the disruption of ambient sediment stratigraphy, cohesiveness, and geochemistry. These effects have geochemical consequences that may be particularly significant when construction activities are located in depositional or nutrient-enriched areas and where local sediments tend to be fine-grained and contain at least moderate levels of pollution. Regardless of the nature and concentration of substances adsorbed onto the sediment or sequestered in the pore-water, salinity may significantly affect local aqueous conditions, sedimentary geochemistry, and resulting ecological effects.

While it is critical to consider the impacts of outfall construction on physical habitat features, implications for resident and transitory biota also should be taken into account. Excavation and relocation of sediments, which may be performed incidental to outfall installation, would produce a sediment plume and create sedimentation effects that could result in detrimental effects on aquatic resources present in the affected area (Newcombe and Jensen 1996; Wilber and Clarke 2001; Berry et al. 2003; Wilber et al. 2005). Direct and indirect impacts related to the removal of benthic material can elicit a variety of responses from aquatic biota (Wilber and Clarke 2001) which have been addressed elsewhere in this report.

While many potential construction impacts clearly are physical in nature, the chemical effects are complex and may have important implications for biota present in the affected area. In addition to the physicochemical considerations already discussed above, the life history and ecological strategies characteristic of different species also are important considerations in assessing the potential chemical impacts of outfall installation. For instance, while highly motile adult and fish in juvenile life stages of most species could flee when construction is ongoing, those in egg and larval stages and nonmotile benthic organisms could not escape contaminant exposure. While some species like the sessile life stages of eastern oyster (*Crassostrea virginica*) have adapted to withstand some acute habitat disturbances (Galtsoff 1964; Levinton 1982), most benthic and slow-moving species would not be able to escape contaminant exposure and instead would exhibit adaptive physiological and biochemical responses to counter any pollutants present.

Contaminants released during outfall installation activities may have direct effects on local aquatic biota or they may act in an additive, synergistic, or antagonistic manner in concert with ambient physical and chemical habitat conditions. Such exposure to organic and inorganic pollutants may result in a spectrum of lethal and sublethal effects that can be discerned at the organismal, tissue, cellular, and subcellular levels of biological organization (Thurberg and Gould 2005). Wide distribution of contaminants can be facilitated through bioaccumulation in motile aquatic organisms that are capable of dispersing between riverine, estuarine, and marine habitats (Mearns et al. 1991).

Importantly, pollutant-induced effects are not limited to biochemical or physiological responses. Environmental pollutants such as metals, pesticides, and other organic compounds also have been shown to disrupt a variety of complex fish behaviors, some of which may be essential for maintaining fitness and survival (Atchison et al. 1987; Blaxter and Hallers-Tjabbes 1992; Kasumyan 2001; Scott and Sloman 2004). In particular, Kasumyan (2001) provided an excellent review of how chemical pollutants interfere with normal fish foraging behavior and chemoreception physiology, while Scott and Sloman (2004) have focused on the ways metals and organic pollutants have been shown to induce behavioral and physiological effects on fresh water and marine fishes.

## Industrial Discharge Facilities

### *Introduction*

Industrial wastewater facilities face many of the same engineering and environmental challenges as municipal sewage treatment plants. Industrial discharge facilities produce a wide variety of trace elements and organic and inorganic compounds. In the industrialized portions of the northeastern United States, such facilities include a variety of chemical plants, refineries, paper mills, defense factories, energy generating facilities, electroplating firms, mining operations, and many other high intensity industrial uses that generate large volumes of wastewater. In many situations, the sanitary and industrial process streams are intermingled and processed at the industrial facility's own treatment plant, requiring that the eventual effluent is treated to address water quality concerns from a fairly broad spectrum of contaminants. While the procedures involved are similar to those implemented at municipal treatment facilities, the specific levels and methods of wastewater treatment at industrial treatment plants vary considerably. While a detailed description of industrial wastewater engineering is well beyond the scope of this report, readers interested in specific technical information may consult portions of Tchobanoglous et al. (2002) or Perry (1997) for more information.

Like sewage plant outfalls, industrial discharge structures are point sources for a variety of environmental contaminants, particularly metals and other trace elements; nutrients; and persistent organic compounds such as pesticides and organochlorines. These substances tend to adhere to solid particles within the waste stream, become adsorbed onto finer sediment fractions once dispersed into coastal waters, and subsequently accumulate in depositional areas. Together with microbial action, local salinity and other properties of the riverine, estuarine, or marine receiving waters may alter the chemistry of these contaminant-particle complexes in ways that render them more toxic than their parent compounds. Upon entering the food web, such contaminants tend to accumulate in benthic organisms at higher concentrations than in surrounding waters (Stein et al. 1995) and may result in various physiological, biochemical, or behavioral effects (Scott and Sloman 2004; Thurberg and Gould 2005).

## *Release of metals*

Industrial discharge structures can release large volumes of effluent containing a variety of potentially harmful substances into the aquatic environment. Metals and other trace elements are common byproducts of industrial processes and as a consequence are anticipated to be components of typical industrial waste streams that may enter the aquatic environment (Kennish 1998). Metals may be grouped into transitional metals and metalloids. Transitional metals, such as copper, cobalt, iron, and manganese, are essential for metabolic function of organisms at low concentrations but may be toxic at high concentrations. Metalloids, such as arsenic, cadmium, lead, mercury, and tin, are generally not required for metabolic function and may be toxic even at low concentrations (Kennish 1998). Metals are known to produce skeletal deformities and various developmental abnormalities in marine fish (Bodammer 1981; Klein-MacPhee et al. 1984; Lang and Dethlefsen 1987). The early life history stages of fish can be quite susceptible to the toxic impacts associated with metals (Gould et al. 1994).

## *Release of organic compounds*

A variety of synthetic organic compounds are released by industrial facilities, find their way into aquatic environments and can be taken up by resident biota. These compounds are some of the most persistent, ubiquitous, and toxic pollutants known to occur in marine ecosystems (Kennish 1998). Organochlorines, such as DDT, chlordane, and PCBs, are some of the most highly toxic, persistent, and well documented and studied synthetic organic compounds. Others include dioxins and dibenzofurans that are associated with pulp and paper mills and wood treatment plants and have been shown to be carcinogenic and capable of interfering with the development of early development stages of organisms (Kennish 1998). Longwell et al. (1992) determined that dozens of different organic contaminants were present in ripe winter flounder eggs. Such accumulation can reduce egg quality and disrupt ontogenic development in ways that significantly depress survival of young (Islam and Tanaka 2004). Organic contaminants, such as PCBs, have been shown to induce external lesions (Stork 1983) and fin erosion (Sherwood 1982) and reduce reproductive success (Nelson et al. 1991) in marine fishes. In addition, suspicion is mounting that exposure to even very low levels of such persistent xenobiotic (i.e., foreign) compounds may disrupt normal endocrine function and lead to reproductive dysfunction such as reduced fertility, hatch rate, and offspring viability in a variety of vertebrates.

### Release of petroleum products

Oil, characterized as petroleum and any derivatives, consists of thousands of chemical compounds and can be a major stressor on inshore fish habitats (Kennish 1998). Industrial wastewater, as well as combined wastewater from municipal and storm water drains, contributes to the release of oil into coastal waters. Petroleum hydrocarbons can adsorb readily to particulate matter in the water column and accumulate in bottom sediments, where they may be taken up by benthic organisms (Kennish 1998). Petroleum products consist of thousands of chemical compounds that can be toxic to marine life including PAHs and water-soluble compounds, such as benzene, toluene, and xylene, which can be particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). PAHs can be toxic to meroplankton, ichthyoplankton, and other pelagic life stages exposed to them in the water column (Kennish 1998). Short-term impacts include interference with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fishes, especially early life-history stages (Gould et al. 1994). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others. In general, the early life stages (eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Refer to the chapters on Coastal Development, Energy-related Activities, and Marine Transportation for additional information on impacts associated with petroleum products and PAH.

### Alteration of water alkalinity

A major point of departure when comparing municipal sanitary treatment outfall and industrial plant effluents concerns the ability of some industrial discharges to affect carbonate alkalinity, or buffering capacity, of receiving waters. Both riverine and estuarine strata are particularly susceptible to point source acidification because their low buffering capacity can be quickly overwhelmed by acid discharges; however, even marine habitats can be significantly and adversely affected when continual influx of acidified liquid wastewater outstrips the natural buffering capability of seawater. In riverine systems, it has been postulated that locally reduced pH may be linked to impaired Atlantic salmon recovery (Johnson and Kahl 2005) and osmoregulatory problems (NRC 2004). Oulasvirta (1990) reported periodic massive mortalities of Atlantic herring eggs from effluent containing sulfuric acid and various other metals released at a titanium-dioxide plant in the Gulf of Bothnia, Finland. Low pH in estuarine waters may lead to cellular changes in muscle tissues, which could reduce swimming ability in herring (Bahgat et al. 1989). A variety of industrial operations, ranging from mining and metal production to certain industrial manufacturing activities, is known to release acid effluents that may have adverse effects on fish, shellfish, and their habitat. Collectively, such detrimental impacts can hinder the survival and sustainability of fishery resources and their prey. Point source pollution from industrial sources is currently regulated by the states or the US EPA through the NPDES permit program, which generally does not allow discharges of low pH water into estuaries and coastal waters of the United States.

### Release of nutrients and other organic wastes

Industrial facilities that process animal or plant by-products can release effluent with high BOD which may have deleterious affects to receiving waters. Wood processing facilities, paper and pulp mills, and animal tissue rendering plants can release nutrients, reduced sulfur and organic compounds, and other contaminants through wastewater outfall pipes. For example, wood processing plants and pulp mills release effluents with tannins and lignin products containing high organic loads and BOD into aquatic habitats (USFWS and NMFS 1999). The release of these contaminants in mill effluent can reduce dissolved oxygen in the receiving waters. In addition, paper and pulp mills can release a number of toxic chemicals used in the process of bleaching pulp for printing and paper products. The bleaching process may use chlorine, sulfur derivatives, dioxins, furans, resin acids, and other chemicals that are known to be toxic to aquatic organisms (Mercer et al. 1997). These chemicals have been implicated in various abnormalities in fish, including skin and organ tissue lesions, fin necrosis, gill hyperplasia, elevated detoxifying enzymes, impaired liver functions, skeletal deformities, increased incidence of parasites, disruption of the immune system, presence of tumors, and impaired growth and reproduction (Barker et al. 1994; Mercer et al. 1997). Because of concern about the release of dioxins and other contaminants, considerable improvements in the bleaching process have reduced or eliminated the use of elemental chlorine. According to the US EPA, all pulp and nearly all paper mills in the United States have chemical recovery systems in place and primary and secondary wastewater treatment systems installed to remove particulates and BOD (USEPA 2002). Approximately 96% of all bleached pulp production uses chlorine-free bleaching technologies (USEPA 2002).

### *Construction impacts of industrial discharge facilities*

The chemical impacts associated with constructing an industrial discharge are similar to those described for sewage treatment outfalls. Generally, such discharges predominantly entail suspending sediments and releasing pore-water in the construction zone, releasing drill mud or cuttings from horizontal directional drilling equipment, incidental discharges of fuels, lubricants and other substances from mechanized construction equipment, and leachates from construction materials. Since the substances encountered and circumstances of exposure would be the same regardless of the type of outfall being installed, the Construction Impacts Associated with Sewage Discharge Facilities subsection of this chapter should be reviewed for details regarding the impacts to the water column, sediment, and aquatic biota from the construction of industrial discharge facilities.

### *Maintenance impacts of industrial discharge facilities*

The chemical impacts of maintaining industrial discharge facilities are similar to those described for sewage treatment facilities. Generally, the impacts of performing structural repairs are expected to be similar to those experienced during initial outfall installation, but on a lesser scope and magnitude. Impacts associated with the removal and treatment of fouling communities would be similar to those described for the maintenance activities of sewage treatment facilities. The reader should review the previous subsection on Maintenance Activities Associated with Sewage Discharge Facilities for details on the implications of outfall maintenance on the water column, sediment, and aquatic biota.

## Combined Sewer Overflow (CSO)

The discussion of point source discharges would be incomplete without mention of CSOs, which are ubiquitous in urban and even suburban areas in New England and the Mid-Atlantic region. For a variety of reasons, many of these municipalities operate wastewater collection systems composed of “separate” and “combined” sewers. “Separate” sewers tend to be newer or replacement installations that have distinct piping components for stormwater and sanitary sewers.

Under storm or other high runoff conditions, the separate sewer system allows excess volumes of storm water to bypass sewage treatment facilities and discharge directly into the receiving water body constraining all sanitary waste to processing at the wastewater treatment plant. This prevents the excess volume of watershed runoff from overwhelming the operating capacity of the treatment facilities. Older systems tend to be "combined" sewer systems that commingle watershed runoff and sanitary waste streams.

Typical CSOs do not discharge effluent under dry conditions but may permit unprocessed sewage under high runoff events to enter the receiving waters completely or partially untreated. This occurs when large volumes of storm water and sewage overwhelm the treatment plant and untreated sewage is discharged prematurely. Some CSO discharges violate state and/or federal water quality standards, and each municipality must develop a plan to control and eliminate these CSOs. There is no precise estimate on the number of CSOs that exist or on how much untreated sewage is discharged from them each year. However, 828 separate NPDES permits were issued by the US EPA in 2004. There were a total 9,348 authorized discharges from CSOs nationally in 2004, with approximately one half located in the northeastern United States and the remaining half in the Great Lakes region (USEPA 2002; USEPA 2004b).

The chemical implications of CSOs are that they are potential sources of very large amounts of untreated nutrients and contaminating chemicals that degrade both the aesthetic and ecological conditions of affected habitats. In addition to the adverse effects mentioned for the other outfall types, CSOs can be important point sources for pesticides, herbicides, fertilizers, and other substances commonly applied to terrestrial habitats, ranging from rural farmland and suburban yards or golf courses to highly urbanized centers. In addition, they are sources of terrestrial particulates and may be a secondary source of atmospherically-deposited pollutants that have settled anywhere in the local watershed. While impacts associated with nonpoint sources are discussed elsewhere in this report, the sanitary sewer component of CSO effluents can be construed as an extension of the preceding discussions for municipal and industrial outfalls. The net effect of permitting untreated domestic wastewater to enter the receiving waterway is to diminish the effectiveness of wastewater treatment elsewhere. In so doing, CSOs contribute to increased pollution levels and related natural resource impairments. It is not possible to measure the resulting habitat damage and accompanying aquatic resource degradation in isolation from nonpoint pollution. However, it is important that resource managers consider that CSO discharges can and will occur and account for the added pollutant loads they generate when setting permissible local effluent limits or establishing priorities for replacing outmoded urban infrastructure.

### *Construction and maintenance impacts of CSOs*

The chemical impacts associated with construction and maintenance activities in CSOs are similar to those described for sewage treatment and industrial discharge facilities. Generally, discharges associated with construction activities may include releasing contaminants associated with suspended sediments, releasing pore-water and drill mud or cuttings from directional drilling, discharges of fuels, lubricants, and other substances from construction equipment. Maintenance activities may include the removal and treatment of fouling communities and releases of contaminants similar to those described above. The reader should refer to the Construction Impacts Associated with Sewage Discharge Facilities and the Maintenance Activities Associated with Sewage Discharge Facilities subsections of this chapter for additional information on this topic.

### *Conservation measures and best management practices for sewage and industrial discharge facilities and CSOs (adapted from Hanson et al. 2003)*

1. Locate discharge points in coastal waters well away from shellfish beds, submerged aquatic vegetation, reefs, fish spawning grounds, and similar fragile and productive habitats.
2. Determine benthic productivity by sampling prior to any construction activity related to installation of new or modified facilities. Implement all appropriate best management practices to maintain habitat quality during construction including any seasonal restrictions, use of cofferdams, working in the dry at low tide, etc., as is necessary and practicable.
3. Use seasonal restrictions during construction and maintenance operations to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods), when appropriate. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
4. Develop appropriate modeling studies for plume effects and other parameters of concern in cooperation with the involved resource agencies before finalizing outfall design. Any appropriate recommendations that involve agencies and developed as a consequence of the study results should be incorporated in the construction plans and operation plan for these facilities as enforceable permit conditions.
5. Institute all appropriate source control measures and/or elevate the treatment level to reduce the polluting substances in all effluents to the extent practicable. Ensure that discharge facilities obtain and adhere to NPDES program permits, as appropriate.
6. Ensure that maximum permissible discharges are appropriate for the given project setting and specify any and all operation procedures, performance standards, or best management practices that must be observed to address all reasonably foreseeable contingencies over the life of the project. Consider implementing an adaptive management plan that includes representatives from appropriate agencies to participate in future consultations for administering the management plan. Management plans should include monitoring protocols designed to measure discharge and potential impacts to sensitive resources and habitats.
7. Use best available technologies to treat discharges to the maximal effective and practicable extent, including measures that reduce discharges of biocides and other toxic substances.
8. Take precautions to mitigate the ecological damage arising from outfall maintenance activities. Facility maintenance plans should include measures such as: (a) ensuring biocides selected for a particular application are specifically designed for their intended use; (b) applying no more than the minimal effective dose, and; (c) closely following instructions for use in aquatic applications and ultimate disposal.
9. Use land treatment and upland disposal or storage for any sludge or other remaining wastes after wastewater processing is concluded. Use of vegetated wetlands as biofilters and pollutant assimilators for large-scale discharges should be limited only to circumstances where other less damaging alternatives are not available and the overall environmental suitability of such an action has been demonstrated.
10. Avoid locating pipelines and treatment facilities in wetlands and streams. Discharges should not be sited near eroding waterfronts or where receiving waters cannot reasonably assimilate the amount of anticipated discharge.
11. Ensure that the design capacity for all facilities will address present and reasonably foreseeable needs and that the best available technologies are implemented.
12. Encourage communities to reduce the volume of pollutants entering CSOs and reduce the number of CSO overflows during storm water runoff producing events. The US EPA provides recommended best management practices for communities (USEPA 1999), including: (a) reduce

and manage solid wastes streams; (b) encourage waste reduction and recycling; (c) reduce commercial and industrial pollution; (d) implement regular program of street cleaning; (e) maintain catch basins; (f) conserve water; (g) reduce unnecessary fertilizer and pesticide applications and; (h) control sediment and erosion.

## References for Chemical Effects: Water Discharge Facilities


Allen H, editor. 1996. Metal contaminated aquatic sediments. Boca Raton (FL): CRC Press. 292 p.

Anderson DM, Glibert PM, Burkholder JM. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25(4b):704-26.

Atchison G, Henry M, Sandheinrich M. 1987. Effects of metals on fish behavior: a review. Environmental Biology of Fishes 18:11-25.

Bahgat FJ, King PE, Shackley SE. 1989. Ultrastructural changes in the muscle tissue of *Clupea harengus* L. larvae induced by acid pH. Journal of Fish Biology 34:25-30.

Barker DE, Khan RA, Hooper R. 1994. Bioindicators of stress in winter flounder, *Pleuronectes americanus*, captured adjacent to a pulp and paper mill in St. George's Bay, Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 51(10):2203-9.

Barr BW. 1993. Environmental impacts of small boat navigation: vessel/sediment interactions and management implications. In: Magoon OT, editor. Coastal Zone '93: proceedings of the eighth Symposium on Coastal and Ocean Management; 1993 Jul 19-23; New Orleans, LA. American Shore and Beach Preservation Association. p 1756-70.

Barr BW, Wilk SJ. 1994. Sewage sludge and industrial waste dumping. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 41-4.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Berry W, Rubenstein N, Melzian B, Hill B. 2003. The biological effects of suspended and bedded sediments (SABS) in aquatic systems: a review. Narragansett (RI): Internal report to US EPA, Office of Research and Development. 58 p.

Bishop JM. 1984. Applied oceanography. McCormick ME, Bhattacharyya R, editors. New York (NY): John Wiley & Sons. 252 p.

Blaber S, Blaber T. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143-62.

Blaxter J, Hallers-Tjabbes C. 1992. The effect of pollutants on sensory systems and behaviour of aquatic animals. Netherlands Journal of Aquatic Ecology 26(1):43-58.

Bodammer JE. 1981. The cytopathological effects of copper on the olfactory organs of larval fish (*Pseudopleuronectes americanus* and *Melanogrammus aeglefinus*). Copenhagen (Denmark): ICES CM-1981/ E: 46.

Bossart G, Brawner T, Cabal C, Kuhns M, Eimstad E, Caron J, Trimm M, Bradley P. 1990. Hepatitis B-like infection in a Pacific whitesided dolphin (*Lagenorhynchus obliquidens*).

American Veterinary Medical Association 196:127-30.

Bricker SB, Clement CG, Pirhalla DE, Orlando SP, Farrow DRG. 1999. National estuarine eutrophication assessment:  Effects of nutrient enrichment in the Nation's estuaries. Silver Spring (MD): NOAA, NOS, Special Projects Office and the National Centers for Coastal Ocean Science. 71 p.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Capuzzo JM, Sassner JJ Jr. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. In: Vernberg FJ, and others, editors. Physiological responses of marine biota to pollutants. San Diego (CA): Academic Press. p 225-37.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Chapman P, Wang F. 2001. Assessing sediment contamination in estuaries. Bulletin of Environmental Contamination and Toxicology 20:3-22.

Chillrud S, Hemming S, Shuster E, Simpson H, Bopp R, Ross J, Pederson D, Chaky D, Tolley L, Estabrooks F. 2003. Stable lead isotopes, contaminant metals and radionuclides in upper Hudson River sediment cores: implications for improved time stratigraphy and transport processes. Chemical Geology 199(1-2):53-70.

Cloern J. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210:223-52.

Costello MJ, Gamble JC. 1992. Effects of sewage sludge on marine fish embryos and larvae. Marine Environmental Research 33(1):49-74.

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? [Internet]. Environmental Health Perspectives 107(S6): 907-38. [cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/pdf/errata.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Dethlefsen V. 1976. The influence of DDT and DDE on the embryogenesis and the mortality of larvae of cod (*Gadus morhua* L.). Meereforshung 25(3-4):115-48.

Diderich R. 2002. Environmental safety and risk assessment. In: Knight D, Cooke M, editors. The biocides business. Wemheim (Federal Republic of Germany): Wiley-VCH. p 167-95.

Epstein E. 2002. Land applications of sewage sludge and biosolids. Boca Raton (FL): CRC Press. 216 p.

Galtsoff P. 1964. The American oyster *Crassostrea virginica* Gmelin. Fisheries Bulletin 64:1-480.

Goldburg R, Triplet T. 1997. Murky waters: environmental effects of aquaculture in the United States. Washington (DC): Environmental Defense Fund.

Goldsborough WJ. 1997. Human impacts on SAV-a Chesapeake Bay case study. In: Stephan CD, Bigford TE, editors. Atlantic coastal submerged aquatic vegetation: a review of its ecological role, anthropogenic impacts, state regulation, and value to Atlantic coastal fisheries. Washington (DC): ASMFC Habitat Management Series #1. 68 p + appendices.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Gould E, Thompson RJ, Buckley LJ, Rusanowsky D, Sennefelder GR. 1988. Uptake and effects of copper and cadmium in the gonad of the scallop *Placopecten magellanicus*: concurrent metal exposure. Marine Biology 97(2): 217-223.

Grady CPL, Daigger GT, Lim HC. 1998. Biological wastewater treatment. New York (NY): Marcel Dekker. 1076 p.

Gronlund W, Chan S, McCain B, Clark R, Myers M, Stein J, Brown D, Landahl J, Krahn M, Varanasi U. 1991. Multidisciplinary assessment of pollution at three sites in Long Island Sound. Estuaries 14(3):299-305.

Gustafsson Ö, Gschwend PM. 1997. Aquatic colloids: concepts, definitions, and current challenges. Limnology and Oceanography 42(3):519-28.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hare L, Tessier A, Warren L. 2001. Cadmium accumulation by invertebrates living at the sediment-water interface. Environmental Toxicology and Chemistry 20(4):880-9.

Huntley S, Wenning R, Bonnevie N, Paustenbach D. 1995. Geochronology and sedimentology of the lower Passaic River, New Jersey. Estuaries 18(2):351-61.

Islam MdS, Tanaka M. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin 48(7-8):624-49.

Johnson K, Kahl S. 2005. A systematic survey of water chemistry for Downeast area rivers (Final Report). [Internet]. Orono (ME): Senator George J. Mitchell Center for Environmental and Watershed Research, University of Maine. [cited 2007 Dec 21]. Available from: http://www.umaine.edu/waterresearch/research/nfwf_salmon_water_chemistry.htm.

Kasumyan A. 2001. Effects of chemical pollutants on foraging behavior and sensitivity of fish to food stimuli. Journal of Ichthyology 41(1):76-87.

Kavlock RJ, Ankley GT. 1996. A perspective on the risk assessment process for endocrine-disruptive effects on wildlife and human health. Risk Analysis 16(6):731-9.

Kavlock RJ, Daston GP, DeRosa C, Fenner-Crisp P, Gray LE, Kaattari S, Lucier G, Luster M, Mac MJ, Maczka C, and others. 1996. Research needs for the risk assessment of health and environmental effects of endocrine disruptors: a report of the US EPA-sponsored workshop. Environmental Health Perspectives 104 (Suppl 4):715-40.

Kennish MJ. 1998. Pollution impacts on marine biotic communities. Boca Raton (FL): CRC Press.

Klein-MacPhee G, Cardin JA, Berry WJ. 1984. Effects of silver on eggs and larvae of the winter flounder. Transactions of the American Fisheries Society 113(2):247-51.

Knight D, Cooke M, editors. 2002. The biocides business: regulation, safety and application. New York (NY): Wiley-Interscience. 404 p.

Korom S. 1992. Natural denitrification of the saturated zone: a review. Water Resources Research WRERAQ 28(6):1657-68.

Lang T, Dethlefsen V. 1987. Cadmium in skeletally deformed and normally developed Baltic cod (*Gadus morhua* L.). Copenhagen (Denmark): ICES CM-1987/ E: 30:18 p.

Langmuir D. 1996. Aqueous environmental geochemistry. New York (NY): Prentice-Hall. 600 p.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

Leppard GG, Droppo IG. 2003. The need and means to characterize sediment structure and behaviour prior to the selection and implementation of remediation plans. Hydrobiologia 494:313-7.

Levinton J. 1982. Marine ecology. New York (NY): Prentice-Hall. 526 p.

Lin Q, Mendelssohn IA. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish, and salt marshes. Marine Pollution Bulletin 32(2):202-9.

Logan DT. 2007. Perspective on ecotoxicology of PAHs to fish. Human and Ecological Risk Assessment 13(2):302-316.

Long E, MacDonald D, Smith S, Calder F. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1):81-97.

Long ER, Wolfe DA, Scott KJ, Thursby GB, Stern EA, Peven C, Schwartz T. 1995. Magnitude and extent of sediment toxicity in the Hudson-Raritan Estuary. Silver Spring (MD): US Department of Commerce. NOAA/National Ocean Service/Office of Ocean Resources Conservation and Assessment. NOAA Technical Memorandum NOS ORCA 88. 134 p + append.

Longwell AC, Chang S, Hebert A, Hughes J, Perry D. 1992. Pollution and development abnormalities of Atlantic fishes. Environmental Biology of Fishes 35:1-21.

Ludwig M, Gould E. 1988. Contaminant input, fate and biological effects. In: Pacheco AL, editor. Woods Hole (MA): US Department of Commerce. NOAA/NMFS/Northeast Fisheries Science Center. NOAA Technical Memorandum NMFS-F/NEC 56. p 305-322.

Luoma SN. 1996. The developing framework of marine ecotoxicology: pollutants as a variable in marine ecosystems. Journal of Experimental Marine Biology and Ecology 200:29-55.

McElroy A, Farrington J, Teal J. 1989. Bioavailability of polycyclic aromatic hydrocarbons in the aquatic environment. In: Varanasi U, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton (FL): CRC Press. p 2-39.

Mearns A, Matta M, Shigenaka G, MacDonald D, Buchman M, Harris H, Golas H, Laurenstein G. 1991. Contaminant trends in the southern California Bight: inventory and assessment. Silver Spring (MD): US Dept. Commerce, NOAA/NOS. NOAA Technical Memorandum NOS ORCA 62. 413 p.

Meffe G, Carroll C. 1997. Principles of conservation biology, 2nd ed. New York (NY): Sinauer Associates. 729 p.

Mercer IRG, Barker DE, Khan RA. 1997. Stress-related changes in cunner, *Tautogolabrus adspersus*, living near a paper mill. Bulletin of Environmental Contamination and Toxicology 58(3):442-7.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Moore M, Lefkovitz L, Hall M, Hillman R, Mitchell D, Burnett J. 2005. Reduction in organic contaminant exposure and resultant hepatic hydropic vacuolation in winter flounder (*Pseudopleuronectes americanus*) following improved effluent quality and relocation of the Boston sewage outfall into Massachusetts Bay, USA: 1987-2003. Marine Pollution Bulletin 50:156-66.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NRC] National Research Council. 1980. The chemistry of disinfectants in water: reactions and products. In: Drinking water and health, Vol. 2. Washington (DC): National Academy Press. p 139-250.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

[NRC] National Research Council. 2004. Atlantic salmon in Maine. Washington (DC): National Academy Press. 275 p.

Nelson D, Miller J, Rusanowsky D, Greig R, Sennefelder G, Mercaldo-Allen R, Kuropat C, Gould E, Thurberg F, Calabrese A. 1991. Comparative reproductive success of winter flounder in Long Island Sound: a three-year study (biology, biochemistry, and chemistry). Estuaries 14(3):318-31.

Neumann G, Pierson WJ Jr. 1966. Principles of physical oceanography. Englewood Cliffs (NJ): Prentice-Hall International. 545 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

O'Connor T. 2002. National distribution of chemical concentrations in mussels and oysters in the USA. Marine Environmental Research 53:117-43.

Olivieri V. 1982. Bacterial indicators of pollution. In: Pipes W, editor. Bacterial indicators of pollution. Boca Raton (FL): CRC Press. p 21-41.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Oulasvirta P. 1990. Effects of acid-iron effluent from a titanium dioxide factory on herring eggs in the Gulf of Bothnia. Finnish Fisheries Research 11:7-15.

Paquin P, Ditoro D, Farley K, Santore R, Wu K-B, editors. 2003. Metals in aquatic systems: a review of exposure, bioaccumulation, and toxicity models. Pensacola (FL): Society of Environmental Toxicology and Chemistry (SETAC). 160 p.

Parnell P. 2003. The effects of sewage discharge on water quality and phytoplankton of Hawaiin coastal waters. Marine Environmental Research 55:293-311.

Pastor D, Boix J, Fernandez V, Albaiges J. 1996. Bioaccumulation of organochlorinated contaminants in three estuarine fish species (*Mullus barbatus, Mugil cephalus* and *Dicentrarcus labrax*). Marine Pollution Bulletin 32(3):257-62.

Perry RDWG. 1997. Perry's chemical engineer's handbook. New York (NY): McGraw-Hill Professional. 2640 p.

Phelps H, Wright D, Mihursky J. 1985. Factors affecting trace metal accumulation by estuarine oysters *Crassostrea virginica*. Marine Ecology Progress Series 22:187-97.

Ragsdale H, Thorhaug A. 1980. Trace metal cycling in the U.S. coastal zone: a synthesis. American Journal of Botany 67(7):1102-12.

Ren J, Packman A. 2002. Effects of background water composition on stream-subsurface exchange of submicron colloids. Journal of Environmental Engineering 128(7):624-34.

Ribaudo M, Horan R, Smith M. 1999. Economics of water quality protection from non-point sources: theory and practice. Washington (DC): US Department of Agriculture, Resource Economics Division, Economic Research Service. Report NR 782. 113 p.

Rice SD, Short JW, Heintz RA, Carls MG, Moles A. 2000. Life-history consequences of oil pollution in fish natal habitat. In: Catania P, editor. Energy 2000: the beginning of a new millennium. Lancaster (PA): Technomic Publishers. p 1210-5.

Richardson H. 1997. Handbook of copper compounds and applications. New York (NY): Marcel Dekker. 432 p.

Robinet T, Feunteun E. 2002. Sublethal effects of exposure to chemical compounds: a cause for decline in Atlantic eels? Ecotoxicology 11:265-77.

Scott GR, Sloman KA. 2004. The effects of environmental pollutants on complex fish behaviour: integrating behavioural and physiological indicators of toxicity. Aquatic Toxicology 68:369-92.

Sherwood M. 1982. Fin erosion, liver condition, and trace contaminant exposure in fishes from three coastal regions. In: Mayer GG, editor. Ecological stress and the New York Bight: science and management. Columbia (SC): Estuarine Research Federation. p 359-77.

Short FT, Burdick DM. 1996. Quantifying, eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19(3):730-9.

Short FT, Burdick DM, Wolf JS, Jones GE. 1993. Eelgrass in estuarine research reserves along the East Coast, U.S.A. Part I: declines from pollution and disease and Part II: management of eelgrass meadows. Silver Spring (MD): NOAA-Coastal Ocean Program Publication. 107 p.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Sigel H, Sigel A, editors. 2001. Metal ions in biological systems: concepts on metal ion toxicity. New York (NY): Marcel Dekker. 416 p.

Smith S, MacDonald D, Keenleyside K, Ingersoll C, Field L. 1996. A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. Journal of Great Lakes Research 22(3):624-38.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Stein JE, Hom T, Collier T, Brown DR, Varanasi U. 1995. Contaminant exposure and biochemical effects in outmigrant juvenile chinook salmon from urban estuaries of Puget Sound, WA. Environmental Toxicology and Chemistry 14(6):1019-29.

Stiles S, Choromanski J, Nelson D, Miller J, Grieg R., Sennefelder G. 1991. Early reproductive success of the hard clam (*Mercenaria mercenaria*) from five sites in Long Island Sound. Estuaries 14(3):332-42.

Stork T. 1983. PCB levels correlated with the ulcus-syndromes in cod (*Gadus morhua* L.). Copenhagen (Denmark): International Council for the Exploration of the Sea. ICES CM-1983/ E: 50:11 p.

Stumm W, Morgan J. 1996. Aquatic chemistry: chemical equilibria and rates in natural waters. New York (NY): John Wiley & Sons. 1005 p.

Tavolaro J. 1984. A sediment budget study of clamshell dredging and ocean disposal activities in the New York Bight. Environmental Geology and Water Science 6(3):133-40.

Tchobanoglous G, Burton F, Stensel H. 2002. Wastewater engineering: treatment and reuse. New York (NY): McGraw-Hill Professional. 1848 p.

Terlizzi A, Fraschetti S, Gianguzza P, Faimali M, Boero F. 2001. Environmental impact of antifouling technologies: state of the art and perspectives. Aquatic Conservation: Marine and Freshwater Ecosystems 11:311-7.

Tessier A, Campbell P, Auclair J, Bisson M. 1984. Relationship between the partitioning of trace metals in sediments and their accumulation in the tissues of the freshwater mollusc *Elliptio complanata* in a mining area. Canadian Journal of Fisheries and Aquatic Sciences 41:1463-72.

Tessier A, Turner D, editors. 1996. Metal speciation and bioavailability in aquatic systems. New York (NY): John Wiley and Sons. 696 p.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Touchette BW, Burkholder JM. 2000. Review of nitrogen and phosphorus metabolism in seagrasses. Journal of Experimental Marine Biology and Ecology 250:133-67.

Turekian K. 1978. The fate of estuaries. Washington (DC): US Environmental Protection Agency. EPA-600/9-78-038. p 27-38.

Turner A, Millward GE. 2002. Suspended particles: their role in estuarine biogeochemical cycles. Estuarine, Coastal and Shelf Science 55:857-83.

Urho L. 1989. Fin damage in larval and adult fishes in a polluted inlet in the Baltic [abstract]. In: Blaxter JHS, Gamble JC, Westernhagen HV, editors. The early life history of fish. Third ICES Symposium; 1988 Oct 3-5; Bergen, Norway. Copenhagen (Denmark): Rapports et Proces-Verbaux Des Reunions 191. International Council for the Exploration of the Sea. p 493-4.

[USEPA] US Environmental Protection Agency. 1984. Use and disposal of municipal wastewater sludge. Washington (DC): US EPA. 625/10-84-003.

[USEPA] US Environmental Protection Agency. 1994. The Long Island Sound Study: the comprehensive conservation and management plan. Stony Brook (NY): University of New York; Long Island Sound Office of the US EPA. 168 p.

[USEPA] US Environmental Protection Agency. 1996. Overview of the storm water management program. Washington (DC): US EPA Office of Water. EPA 833-R-96-008. 42 p.

[USEPA] US Environmental Protection Agency. 1999. Combined sewer overflow management fact sheet: pollution prevention. Washington (DC): US EPA Office of Water. EPA 832-F-99-038. 9 p.

[USEPA] US Environmental Protection Agency. 2002. Profile of the pulp and paper industry, 2nd ed. [Internet]. Washington (DC): US EPA Office of Compliance Sector Notebook Project. EPA-310-R-02-002. [cited 2008 Jul 24]. 135 p. Available from: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp.html.

[USEPA] US Environmental Protection Agency. 2003a. Guide for industrial waste management. Washington (DC): US EPA Office of Solid Waste. EPA-530-R-03-001.

[USEPA] US Environmental Protection Agency. 2003b. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Wetlands, Oceans, and Watersheds. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2004a. National coastal condition report II. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2004b. Report to Congress on the impacts and control of CSOs and SSOs. Washington (DC): US EPA Office of Water. EPA 833-R-04-001.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USEPA] US Environmental Protection Agency. 2007. Pharmaceuticals and personal care products (PPCP): frequent questions. [Internet]. Washington (DC): US EPA Office of Research and Development. [updated 2007 Dec 14; cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/faq.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Varanasi U, editor. 1989. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. Boca Raton (FL): CRC Press. 341 p.

Werther J, Ogada T. 1999. Sewage sludge combustion. Progress in Energy and Combustion Science 25(1):55-116.

Widdows J, Burns KA, Menon NR, Page D, Soria S. 1990. Measurement of physiological energentics (scope for growth) and chemical contaminants in mussel (*Arca zebra*) transplanted along a contamination gradient in Bermuda. Journal of Experimental Marine Biology and Ecology 138:99-117.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Williams C. 1996. Combatting marine pollution from land-based activities: Australian initiatives. Ocean & Coastal Management 33(1-3):87-112.

Wu Y, Falconer R, Lin B. 2005. Modeling trace metal concentration distributions in estuarine waters. Estuarine, Coastal and Shelf Science 64:699-709.

Wurl O, Obbard J. 2004. A review of pollutants in the sea-surface microlayer (SML): a unique habitat for marine organisms. Marine Pollution Bulletin 48(11-12):1016-30.

# CHAPTER EIGHT: PHYSICAL EFFECTS—WATER INTAKE AND DISCHARGE FACILITIES

## Introduction

Water intake and discharge facilities are typically municipal or industrial operations that use water for some processing purpose and/or release effluent water into the aquatic environment. Increased water diversion is associated with human population growth and development (Gregory and Bisson 1997). Some examples of facilities that use and discharge water include fossil-fuel and nuclear power plants, sewage treatment facilities, industrial manufacturing facilities, and domestic and agricultural water supply facilities. The construction and operation of water intake and discharge facilities can have a wide range of physical effects on the aquatic environment including changes in the substrate and sediments, water quality and quantity, habitat quality, and hydrology. Most facilities that use water depend upon freshwater or water with very low salinity for their needs. Reductions in the quality and quantity of freshwater to bays and estuaries have led to serious damage to estuaries in the northeast US region and worldwide (Deegan and Buchsbaum 2005). This chapter discusses the physical impacts associated with water discharge and intake facilities. Refer to the chapter on Chemical Affects: Water Discharge Facilities for information on chemical impacts.

## Intake Facilities

### *Introduction*

Water intake facilities can be located in riverine, estuarine, and marine environments and can include domestic water supply facilities, irrigation systems for agriculture, power plants, and industrial process users. Nearly half of US water withdrawals are attributed to thermoelectric power facilities, and about one-third are used for agriculture irrigation (Markham 2006). In freshwater riverine systems, water withdrawal for commercial and domestic water use supports the needs of homes, farms, and industries that require a constant supply of water. Freshwater is diverted directly from lakes, streams, and rivers by means of pumping facilities or is stored in impoundments or reservoirs. Water withdrawn from estuarine and marine environments may be used to cool coastal power generating stations, as a source of water for agricultural purposes, and more recently, as a source of domestic water through desalinization facilities. In the case of power plants and desalinization plants, the subsequent discharge of water with temperatures higher than ambient levels can also occur.

Water intake structures can interfere or disrupt ecosystem functions in the source waters, as well as downstream water bodies such as estuaries and bays. The volume and the timing of freshwater delivery to estuaries have been substantially altered by the production of hydropower, domestic and industrial use, and agriculture (Deegan and Buchsbaum 2005). Long-term water withdrawal may adversely affect fish and shellfish populations by adding another source of mortality to the early life-stage, which affects recruitment and year-class strength (Travnichek et al. 1993). Water intake structures can result in adverse impacts to aquatic resources in a number of ways, including: (1) entrainment and impingement of fishes and invertebrates; (2) alteration of natural flow rates and hydroperiod; (3) degradation of shoreline and riparian habitats; and (4) alteration of aquatic community structure and diversity.

## *Entrainment and impingement*

Entrainment is the voluntary or involuntary movement of aquatic organisms from the parent water body into a surface diversion or through, under, or around screens and results in the loss of the organisms from the population. Impingement is the involuntary contact and entrapment of aquatic organisms on the surface of intake screens caused when the approach velocity exceeds the swimming capability of the organism (WDFW 1998). Most water-intake facilities have the potential to cause entrainment and impingement of some aquatic species when they are located in areas that support those organisms. Facilities that are known to entrain and impinge marine animals include power plants, domestic and agricultural water supplies, industrial manufacturing facilities, ballast water intakes, and hydraulic dredges. Some of these types of facilities need very large volumes and intake rates of water. For example, conventional 1,000-megawatt fossil fuel and nuclear power plants require cooling water rates of approximately 50 and 75 $m^3/s$, respectively (Hanson et al. 1977). Water diversion projects have been identified as a source of fish mortality and injury, and egg and larval stages of aquatic organisms tend to be the most susceptible (Moazzam and Rizvi 1980; NOAA 1994; Richkus and McLean 2000). Entrainment can subject these life stages to adverse conditions such as increased heat, antifouling chemicals, physical abrasion, rapid pressure changes, and other detrimental effects. Although some temperate species of fish are able to tolerate exposure to extreme temperatures for short durations (Brawn 1960; Barker et al. 1981), fish and invertebrates entrained into industrial and municipal water intake structures experience nearly 100% mortality from the combined stresses associated with altered temperatures, toxic effects of chemical exposure, and mechanical and pressure-related injuries (Enright 1977; Hanson et al. 1977; Moazzam and Rizvi 1980; Barker et al. 1981; Richkus and McLean 2000).

Both entrainment and impingement of fish and invertebrates in power plant and other water intake structures have immediate as well as future impacts to the riverine, estuarine, and marine ecosystems. Not only is fish and invertebrate biomass removed from the aquatic system, but the biomass that would have been produced in the future would not become available to predators (Rago 1984). Water intake structures, such as power plants and industrial facilities, are a source of mortality for managed-fishery species and play a role as one of the factors driving changes in species abundance over time (Richkus and McLean 2000).

Various physical impacts to fish traversing low-head, tidal turbines in the Bay of Fundy, Canada, were reported by Dadswell and Rulifson (1994) and included mechanical strikes with turbine blades, shear damage, and pressure- and cavitation-related injuries/mortality. They found 21-46% mortality rates for experimentally tagged American shad (*Alosa sapidissima*) passing through the turbine. NOAA (1994) reported fish diverted into power turbines experience up to 40% mortality, as well as injury, disorientation, and delay of migration. An entrainment and impingment study for a once-through cooling system of an 848-megawatt electric generating plant on the East River (NY) concluded the reduction in biomass of spawners from an unfished stock in the Long Island Sound and New York-New Jersey estuary to be extremely small (i.e., 0.01% for Atlantic menhaden [*Brevoortia tyrannus*] and 0.09% for winter flounder [*Pseudopleuronectes americanus*]) compared to fishing mortality (Heimbuch et al. 2007).

Organisms that are too large to pass through in-plant screening devices become stuck or impinged against the screening device or remain in the forebay sections of the system until they are removed by other means (Hanson et al. 1977; Langford et al. 1978; Helvey 1985; Helvey and Dorn 1987; Moazzam and Rizvi 1980). They are unable to escape because the water flow either pushes them against the screen or prevents them from exiting the intake tunnel. This can cause injuries such as bruising or descaling, as well as direct mortality. The extent of physical damage to organisms is directly related to the duration of impingement, techniques for handling impinged fish, and the intake water velocity (Hanson et al. 1977). Similar to entrainment, the withdrawal of water can entrap particular species, especially when visual acuity is reduced (Helvey 1985) or when the ambient water temperature and the metabolism of individuals are low (Grimes 1975). This condition reduces the suitability of the source waters to provide normal habitat functions necessary for subadult and adult life stages of managed living marine resources and their prey. Increased predation can also occur. Intakes can stress or disorient fish through nonlethal impingement or entrainment in the facility and by creating conditions favoring predators such as larger fish and birds (Hanson et al. 1977; NOAA 1994).

### *Ballast water and vessel operations intake*

Vessels take in and release water in order to maintain proper ballast and stability, which is affected by the variable weight of passengers and cargo and sea conditions. In addition, water is used for cooling engines and other systems. While the discharge of ballast water can cause significant impacts on the aquatic environment, particularly through the introduction of invasive species as discussed below, the intake of water for ballast and vessel cooling can also cause entrainment and impingement impacts on aquatic organisms.

Depending upon the size of the vessel, millions of gallons of water and its associated aquatic life, particularly eggs and larvae, can be transferred to the ballast tanks of a ship at a rate of tens of thousands of gallons per minute. For example, large ships, such as those constructed to transport liquefied natural gas (LNG), need to take on ballast water to stabilize the ship during offloading of the LNG. A 200,000-$m^3$ capacity LNG carrier would withdraw approximately 19.8 million gallons of water over a 10-hour period at an intake rate of 2 million gallons per hour (FERC 2005). The use of water for ballast and vessel cooling at these volumes and rates has the potential to entrain and impinge large numbers of fish eggs and larvae. For example, a proposed offshore LNG degasification facility using a closed-loop system near Gloucester, MA, would have estimated annual mortality of eggs and larvae from vessel ballast and cooling water for Atlantic mackerel (*Scomber scombrus*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), and Atlantic cod (*Gadus morhua*) of 8.5 million, 7.8 million, 411,000, and 569,000, respectively (USCG 2006). Refer to the chapters on Energy-related Activities and Marine Transportation for additional information on vessel entrainment and impingement impacts.

### *Alteration of hydrological regimes/flow restrictions*

Water withdrawals for industrial or municipal water needs can have a number of physical effects to riverine systems, including altering stream velocity, channel depth and width, turbidity, sediment and nutrient transport characteristics, dissolved oxygen concentrations, and seasonal and diel temperature patterns (Christie et al. 1993; Fajen and Layzer 1993). These physical changes can have ecological impacts, such as a reduction of riparian vegetation that affects the availability of fish habitat and prey (Christie et al. 1993; Fajen and Layzer 1993; Spence et al. 1996). Alteration of freshwater flows is one of the most prevalent problems facing coastal regions and has had profound effects on riverine, estuarine, and marine fisheries (Deegan and Buchsbaum 2005). For example, water in the Ipswich River in Massachusetts has been reduced to 10% of historic natural flows because of increased water withdrawals, such as irrigation water during the growing season, power plant cooling water, and potable water for a growing human population (Bowling and Mackin 2003). Approximately one-half of the 45-mile long Ipswich River was reported to have gone completely dry in 1995, 1997, 1999, and 2002, and nearly one-half of the native fish populations have either been extirpated or severely reduced in size (Bowling and Mackin 2003). Many estuarine and diadromous species, such as American eel (*Anguilla rostrata*), striped bass (*Morone* *saxatilis*), white perch (*Morone americana*), Atlantic herring (*Clupea harengus*), blue crab (*Callinectes sapidus*), American lobster (*Homarus americanus*), Atlantic menhaden (*Brevoortia tyrannus*), cunner (*Tautogolabrus adspersus*), Atlantic tomcod (*Microgadus tomcod*), and rainbow smelt (*Osmerus mordax*), depend upon the development of a counter current flow set up by freshwater discharge to enter estuaries as larvae or early juveniles; reductions in the timing and volume of freshwater entering estuaries can reduce this counter current flow and disrupt larval transport (Deegan and Buchsbaum 2005).

### *Increased need for dredging*

The alteration of the hydrological regimes and reductions in flow in riverine and estuarine systems caused by water intake structures can result in the build-up of sediments and increase the need to dredge around the intake facilities in order to prevent the sediments from negatively affecting the operations of the facility. Dredging can cause direct mortality of the benthic organisms within the area to be dredged, result in turbidity plumes of suspended particulates that can reduce light penetration, interfere with respiration and the ability of site-feeders to capture prey, impede the migration of anadromous fishes, and affect the growth and reproduction of filter feeding organisms. For more detailed discussion on the impacts of dredging, refer to the chapters on Marine Transportation and Offshore Dredging and Disposal Activities.

### *Habitat impacts*

The operation of water intake facilities can have a broad range of adverse effects on fishery habitats, including the conversion and loss of habitat and the alteration of the community structure resulting from changes in the hydrological regimes, salinities, and flow patterns. Large withdrawals of freshwater from riverine systems above the tidal water influence can cause an upstream "relocation" of the salt wedge, altering an area's suitability for some freshwater species and possibly altering benthic community structure. In addition, reductions in the volume of freshwater entering estuaries can alter vertical and longitudinal habitat structure and disrupt larval transport (Deegan and Buchsbaum 2005). Water withdrawals during certain times of the year, such as the use of irrigation water during the growing season of crops, power plant cooling water used during high energy-demand periods, or for domestic water usage during dry, summer months can severely impact the ecological health of riverine systems. For example, the water withdrawal from the Ipswich River in Massachusetts increases by two-fold or more during summer months when natural river flows are lowest (Bowling and Mackin 2003). This has led to one-half of the river going completely dry in some years and has caused fish kills and habitat degradation (Bowling and Mackin 2003).

### *Construction-related impacts*

Impacts to aquatic habitats can result from construction-related activities (e.g., dewatering, dredging) as well as routine operation and maintenance activities for water intake facilities. Generally, these impacts are similar in nature to both water intake and discharge structures and facilities. There is a broad range of impacts associated with these activities depending on the specific design and needs of the system. For example, dredging activities associated with construction of pipelines, bulkheads and seawalls, and buildings for a facility can cause turbidity and sedimentation in nearby waters, degraded water quality, noise, and substrate alterations. Filling of the aquatic habitat may also be needed for the construction of the facilities. Excavation of sediments in subtidal and intertidal habitats during construction may have at least short-term impacts, but the recovery of the aquatic habitat for spawning and egg deposition is uncertain

(Williams and Thom 2001). Many of these impacts can be reduced or eliminated through the use of various techniques, procedures, or technologies such as careful siting of the facility, timing restrictions on in-water work, and the use of directional drilling for the installation of pipelines. Some impacts may not be fully eliminated except by eliminating the activity itself.

Turbidity plume and sedimentation effects incidental to facility construction commonly produce a range of direct and indirect effects to living aquatic resources and their habitats. However, not all of the ecological implications of sediment resuspension and transport result in adverse effects to aquatic organisms (Blaber and Blaber 1980). The life history and ecological strategies characteristic of different species also are important considerations in assessing potential physical impacts from facility installation. For instance, while highly motile adult and juvenile life stages of most fishes could flee when construction is ongoing, egg and larval stages as well as nonmotile benthic organisms will likely not be able to avoid impacts. As a general rule, the severity of adverse effects tends to be greatest for early life stages and for adults of some highly sensitive species (Newcombe and Jensen 1996). The eggs and larvae of nonsalmonid estuarine fishes exhibit some of the most sensitive responses to suspended sediment exposures of all the taxa and life history stages for which data are available (Wilber and Clarke 2001). Reductions in the hatching success of white perch and striped bass eggs were reported at suspended sediment concentrations of 1,000 mg/L, and the survival of striped bass and yellow perch (*Perca flavescens*) larvae were reduced at concentrations greater than 500 mg/L and for American shad larvae at concentrations greater than 100 mg/L (Auld and Schubel 1978). Nelson and Wheeler (1997) found reduced hatching success for winter flounder eggs exposed to suspended sediment concentrations as low as 75 mg/L. While some species like the sessile life stages of eastern oyster (*Crassostrea virginica*) have adapted to withstand some acute habitat disturbances such as sedimentation and turbidity (Galtsoff 1964; Levinton 1982), most benthic and slow-moving species would not be able to escape exposure and instead would exhibit adaptive physiological and biochemical responses to counter adverse effects to water quality.

The area affected by water quality impacts from the construction of a water intake facility is largely dependent on the nature of the resuspended sediments, the duration the sediments are held in the water column, and the factors contributing to the transport of the sediments from the site. As benthic material is disturbed during facility installation and site preparation, resuspended particulate matter settles predominantly in the immediate vicinity of the project. Remaining waterborne fractions subsequently would be transported from the site and dispersed according to the grain size of disturbed sediments, the velocity of local water currents, and local wave action (Neumann and Pierson 1966).

The construction of water intake facilities can create adverse impacts within the immediate vicinity of the construction, including disrupting ambient sediment stratigraphy, cohesiveness, and geochemistry. These effects have geochemical consequences that may be particularly significant when construction activities are located in depositional or nutrient-enriched areas and where local sediments tend to be fine-grained. While important, it is essential to recognize that local sediment composition is not the only factor which affects resuspension during water intake facility installation. The type of construction equipment used to build an intake structure also has an important influence on the dispersion of dredge material. For traditional clamshell dredging, Tavolaro (1984) estimates a 2% loss of material through sediment resuspension at the dredge site. Dredge equipment that fluidizes sediments to facilitate their removal (e.g., hydraulic dredges or water jets) could result in a greater dispersion of resuspended sediment, especially when local waters are not quiescent or in situations where unfiltered return flow to the waterway is permitted. While sediment particles naturally exhibit cycles of exchange between the water column and materials composing the bottom substrate (Turner and Millward 2002), mechanized equipment used to remove sediments can reasonably be expected to disturb much deeper sediment horizons in a short period of time than would be expected from storms or in all but the most highly erosion prone coastal areas.

Additional discussions of the effects of dredging, dredged material disposal, and coastal development can be found in the Marine Transportation, Coastal Development, and Offshore Dredging and Disposal chapters.

### *Conservation measures and best management practices for water intake facilities (adapted from Hanson et al. 2003)*

1. Locate facilities that rely on surface waters for cooling or ballast in areas other than estuaries, inlets, heads of submarine canyons, rock reefs, or small coastal embayments where important fishery species or their prey concentrate for spawning and migration.
2. Design and operate facilities to create flow conditions that provide for passage, water quality, proper timing of life history stages, and properly functioning channel, floodplain, riparian, and estuarine conditions.
3. Establish adequate instream flow conditions for anadromous fish.
4. Design intake structures to minimize entrainment or impingement. Velocity caps that produce horizontal intake/discharge currents should be employed, and intake velocities across the intake screen should generally not exceed 0.5 ft/s.
5. Use closed-loop cooling systems in facilities requiring water whenever practicable, especially in areas that would impinge and entrain large numbers of fish and invertebrates.
6. Screen water diversions on fish-bearing streams, as needed. In general, 2 mm wedge wire screens are recommended on intake facilities in areas that support anadromous fishes.
7. Incorporate juvenile and adult fish passage facilities on all water diversion projects (e.g., fish bypass systems).
8. Assess existing and potential aquatic vegetation, the volume and depth of the water body, the amount and timing of freshwater inflow, the presence of upland rearing and spawning habitat, and the relative salinity of the water body.
9. Assess the hydrology of the regulated land's tolerance for increased water exchange. The assessment should account for active management of the water intake facility to allow increased water exchange during critical periods.
10. Install intake pipes and facilities during low flow periods and tidal stage; incorporate appropriate erosion and sediment control best management practices, and have an equipment spill and containment plan and appropriate materials onsite.
11. Monitor facility operations to assess impacts on water temperatures, dissolved oxygen, and other applicable parameters. Adaptive management should be designed to minimize impacts.

## Discharge Facilities

### *Introduction*

Although there are a number of potential impacts to aquatic resources from point-source discharges, it is important to be aware that not all point-source discharge results in adverse impacts to aquatic organisms or their habitats. Most point-source discharges are regulated by the US Environmental Protection Agency (US EPA) under the National Pollutant Discharge Elimination System (NPDES), and the effects on receiving waters are generally considered under this permitting program. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States.

Industrial, municipal, and other facilities must obtain permits if their discharges go directly into surface waters. In most cases, the NPDES permit program is administered by authorized state agencies.

Point source discharges may modify habitat by creating adverse impacts to sensitive areas such as freshwater, estuarine, and marine wetlands; emergent marshes; and submerged aquatic vegetation beds and shellfish beds. Extreme discharge velocities of effluent may also cause scouring at the discharge point as well as entrain particulates and thereby create turbidity plumes.

### Habitat conversion and exclusion

The discharge of effluent from point sources can cause numerous habitat impacts resulting from the changes in sediments, salinities, temperatures, and current patterns. These can include the conversion and loss of habitat as the salinities of estuarine areas decrease from the inflow of large quantities of freshwater or as areas become more saline through the discharge of effluent from desalinization plants. Temperature changes, increased turbidity, and the release of contaminants can also result in the reduced use of an area by marine and estuarine species and their prey and impede the migration of some diadromous fishes. Outfall pipes and their discharges may alter the structure of the habitats that serve as juvenile development habitat, such as eelgrass beds (Williams and Thom 2001). Power plants, for example, release large volumes of water at higher than ambient temperatures, and the area surrounding the discharge pipes may not support a healthy, productive community because of physical and chemical alterations of the habitat (Wilbur and Pentony 1999).

The accumulation of sediments at an outfall may alter the composition and abundance of infaunal or epibenthic invertebrate communities (Ferraro et al. 1991). These accumulated sediments can smother sessile organisms or force mobile animals to migrate from the area. If sediment characteristics are changed drastically at the discharge location, the benthic community composition may be altered permanently. This can lead to reductions in the biological productivity of the habitat at the discharge site for some aquatic resources as their prey species and important habitat types, such as aquatic vegetation, are no longer present. Outfall pipes can act as groins and interrupt sand transport, cause scour around the structures, and convert native sand habitat to larger course sediment or bedrock (Williams and Thom 2001). This can affect the spawning success of diadromous and estuarine species, many of which serve as prey species for other commercially or recreationally important species.

### Alteration of sediment composition

As discussed above, outfall pipes and their discharges may alter the composition of sediments that serve as juvenile development habitat through scouring or deposition of dissimilar sediments (Williams and Thom 2001). Outfalls that typically release water at high velocities may scour sediments in the vicinity of the outfall and convert the substrate to course sediments or bedrock. Conversely, outfalls that release water at lower velocities that contain fine grained, silt-laden sediments may accumulate sediments near the outfall and increase the need to dredge to remove sediment buildup (Williams and Thom 2001). This can lead to a change in the community composition because many benthic organisms are sensitive to grain size. The chronic accumulation of sediments can also bury benthic organisms that serve as prey and limit an area's suitability as forage habitat.

### Substrate and sediment scouring

The discharge of effluent from point sources can result in a variety of benthic habitat and water quality impacts relating to scouring of substrate and sediments at the discharge point.

Changes to the substrate from scouring may impact benthic invertebrate and shellfish community, as well as submerged aquatic vegetation, such as eelgrass (Williams and Thom 2001).

### *Turbidity and sedimentation effects*

Turbidity plumes of suspended particulates caused by the discharge of effluent, the scouring of the substrate at the discharge point, and even the repeated maintenance dredging of the discharge area can reduce light penetration and lower the rate of photosynthesis and the primary productivity of an aquatic area while elevated turbidity persists. Fish and invertebrates in the immediate area may suffer a wide range of adverse effects, including avoidance and abandonment of the area, reduced feeding ability and growth, impaired respiration, a reduction in egg hatching success, and resistance to disease if high levels of suspended particulates persist (Newcombe and MacDonald 1991; Newcombe and Jensen 1996; Wilber and Clarke 2001). Auld and Schubel (1978) reported reduced egg hatching success in white perch and striped bass at suspended sediment concentrations of 1,000 mg/L. They also found reduced survival of striped bass and yellow perch larvae at concentrations greater than 500 mg/L and for American shad at concentrations greater than 100 mg per liter (Auld and Schubel 1978). Short-term effects associated with an increase in suspended particles may include high turbidity, reduced light, and sedimentation, which may lead to the loss of benthic structure and disrupt overall productivity if elevated levels persist (USFWS and NMFS 1999; Newcombe and Jensen 1996). Other problems associated with suspended solids include reduced water transport rates and filtering efficiency of fishes and invertebrates and decreased foraging efficiency of sight feeders (Messieh et al. 1991; Wilber and Clarke 2001). Breitburg (1988) found the predation rates of striped bass larvae on copepods decreased by 40% when exposed to high turbidity conditions in the laboratory. In riverine habitats, Atlantic salmon (*Salmo salar*) fry and parr find refuge within interstitial spaces provided by gravel and cobble that can be potentially clogged by sediments, subsequently decreasing survivorship (USFWS and NMFS 1999).

### *Increased need for dredging*

The release of sediment from water discharge facilities, as well as increased turbidity and sedimentation resulting from high velocity outfall structures, can lead to a build-up of sediments. Over time this may increase the need to dredge around the discharge facility in order to prevent the sediments from negatively affecting the operations of the facility or interfering with vessel navigation. Dredging can cause direct mortality of the benthic organisms within the area to be dredged, as well as create turbidity plumes of suspended particulates that can reduce light penetration, interfere with respiration and the ability of site-feeders to capture prey, impede the migration of anadromous fishes, and affect the growth and reproduction of filter feeding organisms (Wilber and Clarke 2001). For more detailed discussion on the impacts of dredging, refer to the chapters on Marine Transportation and Offshore Dredging and Disposal Activities.

### *Reduced dissolved oxygen*

The contents of the suspended material can react with the dissolved oxygen in the water and result in oxygen depletion, which can impact submerged aquatic vegetation and benthos in the vicinity. Reduced dissolved oxygen (DO) can cause direct mortality of aquatic organisms or result in subacute effects such as reduced growth and reproductive success. Bejda et al. (1992) found that the growth of juvenile winter flounder was significantly reduced when DO levels were maintained at 2.2 mg/L or when DO varied diurnally between 2.5 and 6.4 mg/L for a period of 11 weeks.

## *Alteration of temperature regimes*

Sources of thermal pollution from water discharge facilities include industrial and power plants. Temperature changes resulting from the release of cooling water from power plants can cause unfavorable conditions for some species while attracting others. Altered temperature regimes have the ability to affect the distribution, growth rates, survival, migration patterns, egg maturation and incubation success, competitive ability, and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003). Increased water temperatures in the upper strata of the water column can result in water column stratification, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries (Kennedy et al. 2002). Because warmer water holds less oxygen than colder water does, increased water temperatures reduce the DO concentration in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. In addition, thermal stratification could also affect primary and secondary productivity by suppressing nutrient upwelling and mixing in the upper regions of the water column, potentially altering the composition of phytoplankton and zooplankton. Impacts to the base of the food chain would not only affect fisheries, but could impact entire ecosystems.

Elevated water temperature can alter the normal migration patterns of some species or result in thermal stress and mortality in individuals should the discharges cease during colder months of the year. Thermal effluents in inshore habitat can cause severe problems by directly altering the benthic community or killing marine organisms, especially larval fish. Temperature influences biochemical processes of the environment and the behavior (e.g., migration) and physiology (e.g., metabolism) of marine organisms (Blaxter 1969). Investigations to determine the thermal tolerances of larvae of Atlantic herring, smooth flounder (*Pleuronectes putnami*), and rainbow smelt suggests that these species can tolerate elevated temperatures for short durations which are near the upper limits of cooling systems of most normally operating nuclear power plants (Barker et al. 1981). However, a number of factors affected the survival of larvae, including the salinity the individuals were acclimated to and the age of the larvae.

Long-term thermal discharge may change natural community dynamics. For example, elevated water temperature has been identified as a potential factor contributing to harmful algae blooms (ICES 1991), which can lead to rapid growth of phytoplankton populations and subsequent oxygen depletion, sometimes resulting in fish kills. Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States caused by anthropogenic impacts may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005).

## *Alteration of salinity regimes*

The discharge of water with elevated salinity levels from desalination plants may be a potential source of impacts to fishery resources. Waste brine is either discharged directly to the ocean or passed through sewage treatment plants. Although some studies have found desalination plant effluent to not produce toxic effects in marine organisms (Bay and Greenstein 1994), there may be indirect effects of elevated salinity on estuarine and marine communities, such as forcing juvenile fish into areas that could increase their chances of being preyed upon by other species. Conversely, treated freshwater effluent from municipal wastewater plants can produce localized reductions in salinity and could subject juvenile fish to conditions of less than optimal salinity for growth and development (Hanson et al. 2003).

## *Changes in local current patterns*

In addition to changes in temperature and salinity, local current patterns can be altered by outfall discharges or by the structures themselves. These changes can be related to changes in the rate of sedimentation around the outfall, the volume of water discharged, and the size and location of the structures.

## *Release of radioactive wastes*

Both natural and anthropogenic sources of radionuclides exist in the environment (ICES 1991). Potential sources of anthropogenic radioactive wastes include nonpoint sources, such as storm water runoff and atmospheric sources (e.g., coal-burning power plants) and point sources, such as industrial facilities (e.g., uranium mining and milling fuel lubrication) and nuclear power plant discharges (ICES 1991; NEFMC 1998). Fish exposed to radioactive wastes can accumulate radioisotopes in tissues, causing toxicity to other marine organisms and consumers (ICES 1991). The identification of radioactive wastes from industrial and nuclear power plant discharges was a focus of concern during the 1980s (ICES 1991). However, most studies since then have found trends of decreasing releases of artificial radionuclides from industrial and nuclear power plant discharges and reduced tissue-burdens in sampled fish and shellfish to levels similar to naturally occurring radionuclides (ICES 1991).

## *Ballast water discharges*

Commercial cargo-carrying and recreational vessels are the primary type of vector that transports marine life around the world, some of which become exotic, invasive species that can alter the structure and function of aquatic ecosystems (Valiela 1995; Carlton 2001; Niimi 2004). Ballast water discharges, occurring when ships take on additional cargo while at a port, are one of the largest pathways for the introduction and spread of aquatic nuisance species (ANS). The introduction of ANS can have wide reaching impacts to the aquatic ecosystem, the economy, and human health. Many ANS species are transported and released in ballast in their larval stages, become bottom-dwelling as adults, and include sea anemones, marine worms, barnacles, crabs, snails, clams, mussels, bryozoans, sea squirts, and seaweeds (Carlton 2001). In addition, some species are transported and released as adults, including diatoms, dinoflagellates, copepods, and jellyfish (Carlton 2001). Invasive, exotic species can displace native species and increase competition with native species and can potentially alter nutrient cycling and energy flow leading to cascading and unpredictable ecological effects (Carlton 2001). Additional discussion of the effects of introduced species can be found in the chapters on Introduced/Nuisance Species and Aquaculture and Marine Transportation.

## *Behavioral effects*

Discharge facility effluents have the potential to alter the behavior of riverine, estuarine, and marine species by changing the chemical and physical attributes of the habitat and water column in the vicinity of the outfall. These include attractions to the increase in flow velocity and altered temperature regimes at the discharge point and changes in predator/prey interactions. Changes in temperature regimes can artificially attract species and alter their normal seasonal migration behavior, resulting in cold shock and mortality of fishes when ambient temperatures are colder and the flow of heated water is ceased during a facility shutdown (Pilati 1976). Shorelines physically altered with outfall structures may also disrupt the migratory patterns and pathways of fish and invertebrates (Williams and Thom 2001).

## *Physiological effects*

Point-source discharges can cause a wide range of physiological effects on aquatic resources including both lethal and sublethal effects. Alteration of temperature, salinity, and dissolved oxygen concentration regimes have been shown to effect the normal physiology of marine organisms and can retard or accelerate egg and larval development and time of hatching (Blaxter 1969). Fish subjected to abnormally cold or hot temperatures from water discharges will either leave the affected area or acclimate to the change if it is within the species' thermal tolerance zone (Pilati 1976). However, a sudden change in ambient temperature can cause thermal shock and result in death to the fish, or the thermal shock may debilitate a fish and make it susceptible to predation (Pilati 1976). Temperature plays an important role in determining the survival and fitness of coldwater species, such as Atlantic salmon, and can affect the normal growth and development of eggs and fry (Blaxter 1969; Spence et al. 1996).

Water intake and outfall facilities can also have widespread chemical effects on aquatic organisms. These effects are discussed in the Chemical Effects: Water Discharge Facilities chapter.

## *Construction-related impacts of water discharge facilities*

The physical effects of constructing water discharge facilities can result from a number of activities, including releasing suspended sediments and associated pore-water in the construction zone; removal of bottom sediments and subsequent suspended sediments; turbidity and alteration of benthic habitats from dredging; releasing drill mud or cuttings from a directional drilling operation; and the loss or conversion of the existing benthic habitat and water column from placement of fill pipelines, and shoreline stabilization structures (e.g., riprap, headwalls). The impacts associated with constructing water intake and discharge structures and facilities are similar in nature and have been discussed in more detail in the Intake Facilities section of this chapter.

## *Conservation measures and best management practices for discharge facilities (adapted from Hanson et al. 2003)*

1. Conduct a thorough environmental assessment of proposed site locations for water discharge facilities prior to granting any regulatory permits. The assessments should include detailed investigations on the utilization of the aquatic environment by resident and transient species, including the migratory pathways of marine and diadromous fishes. Physical and chemical parameters of the proposed site should be included, such as sediment and substrate characteristics, hydrological dynamics of tides and currents, and temperature and salinity regimes.
2. Develop outfall design (e.g., modeling concentrations within the predicted plume or likely extent of deposition within the zone of influence) by using site specific, hydrological data with input from appropriate resource agencies.
3. Select appropriate point-source discharge locations by using information on the concentrations of living marine resources based upon site-specific, biological assessments. Sensitive and highly productive areas and habitats, such as shellfish beds, sea grass beds, hardbottom reefs should be avoided. Reduce potentially high velocities by diffusing effluent to acceptable velocities.
4. Regulate discharge temperatures (both heated and cooled effluent) such that they do not appreciably alter ambient temperatures and cause a change in species assemblages and ecosystem function in the receiving waters. Strategies should be implemented to diffuse the heated effluent.

5. Use land-treatment and upland disposal/storage techniques where possible. Use of vegetated wetlands as natural filters and pollutant assimilators for large-scale discharges should be limited to those instances where other less damaging alternatives are not available and the overall environmental and ecological suitability of such an action has been demonstrated.
6. Avoid siting pipelines and treatment facilities in wetlands and streams. Since pipeline routes and treatment facilities should not necessarily be water-dependent with regard to positioning, the priority should be to avoid their placement in wetlands or other fragile coastal habitats. Avoiding placement of pipelines within streambeds and wetlands will also reduce inadvertent infiltration into conveyance systems and retain natural hydrology of local streams and wetlands.
7. Ensure that all discharge water from outfall structures meets state and federal water quality standards. Whenever feasible, discharge pipes should extend a substantial distance offshore and be buried deep enough to not affect shoreline processes. Buildings and associated structures should be set well back from the shoreline to preclude the need for bank armoring.

## References for Physical Effects: Water Intake and Discharge Facilities


Auld AH, Schubel JR. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine and Coastal Marine Science 6(2):153-64.

Barker SL, Townsend DW, Hacunda JS. 1981. Mortalities of Atlantic herring, *Clupea h. harengus*, smooth flounder, *Liopsetta putnami*, and rainbow smelt, *Osmerus mordax*, larvae exposed to acute thermal shock. Fisheries Bulletin 79(1):1981.

Bay S, Greenstein D. 1994. Toxic effects of elevated salinity and desalination waste brine. In: Cross J, editor. Southern California coastal water research project. Annual report 1992-1993. Westminister (CA): SCCWRP. p 149-53.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Blaber S, Blaber T. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143-62.

Blaxter JHS. 1969. Development: eggs and larvae. In: Hoar WS, Randall DJ, editors. Fish physiology-Vol. 3, reproduction and growth, bioluminescence, pigments, and poisons. New York (NY): Academic Press. p 177-252.

Bowling A, Mackin K. 2003. The state of the Ipswich River. Ipswich (MA): Ipswich River Watershed Association. 9 p.

Brawn VM. 1960. Temperature tolerance of unacclimated herring (*Clupea harengus* L.). Journal of the Fisheries Research Board of Canada 17(5):721-3.

Breitburg DL. 1988. Effects of turbidity on prey consumption by striped bass larvae. Transactions of the American Fisheries Society 117(1):72-7.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Christie RW, Allen DE, Jobsis GJ. 1993. Diversions. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 181-6.

Dadswell MJ, Rulifson RA. 1994. Macrotidal estuaries: a region of collision between marine animals and tidal power development. Biological Journal of the Linnean Society 51(1-2):93-113.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Enright JT. 1977. Power plants and plankton. Marine Pollution Bulletin 8(7):158-61.

Fajen OF, Layzer JB. 1993. Agricultural practices. In: Bryan CF, Rutherford DA, editors. Impacts on warmwater streams: guidelines for evaluation. Little Rock (AR): Southern Division, American Fisheries Society. p 257-67.

[FERC] Federal Energy Regulatory Commission. 2005. Draft environmental impact statement, Down Landing LNG and Logan Lateral projects. Washington (DC): FERC Office of Energy Projects.

Ferraro SP, Swartz C, Cole FA, Schults DW. 1991. Temporal changes in the benthos along a pollution gradient: discriminating the effects of natural phenomena from sewage-industrial wastewater effects. Estuarine, Coastal and Shelf Science 33:383-407.

Galtsoff P. 1964. The American oyster *Crassostrea virginica* Gmelin. Fisheries Bulletin 64:1-480.

Gregory SV, Bisson PA. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. In: Stouder DJ, Bisson PA, Naiman RJ, editors. Pacific salmon and their ecosystems: status and future options. New York (NY): Chapman and Hall. p 277-314.

Grimes CB. 1975. Entrapment of fishes on intake water screens at a stream electric generating station. Chesapeake Science 16(3):172-7.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Heimbuch DG, Dunning DJ, Ross QE, Blumberg AF. 2007. Assessing potential effects of entrainment and impingement on fish stocks of the New York-New Jersey Harbor estuary and Long Island Sound. Transactions of the American Fisheries Society 136:492-508.

Helvey M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Marine Fisheries Review 47:18-26.

Helvey M, Dorn PB. 1987. Selective removal of reef fish associated with an offshore cooling-water intake structure. Journal of Applied Ecology 24(1):1-12.

[ICES] International Council for the Exploration of the Sea. 1991. Report of the study group on ecosystem effects of fishing activities. 11-15 March 1991; Lowestoft, England. Copenhagen (Denmark): ICES C.M. 1991/G:7 Session Y.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Langford TE, Utting NJ, Holmes RHA. 1978. Factors affecting the impingement of fishes on power station cooling-water intake screens. In: McLusky DS, Berry AJ, editors. Physiology and behaviour of marine organisms. Oxford (England) and New York (NY): Pergamon Press. p 281-8.

Levinton J. 1982. Marine ecology. New York (NY): Prentice-Hall. 526 p.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

Messieh SN, Rowell TW, Peer DL, Cranford PJ. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-63.

Moazzam M, Rizvi SHN. 1980. Fish entrapment in the seawater intake of a power plant at Karachi coast. Environmental Biology of Fishes 5:49-57.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1994. Experimental fish guidance devices. Position statement. [Internet]. Long Beach (CA): National Marine Fisheries Service, Southwest Region. [cited 2008 Jul 24]. 7 p. Available from: http://swr.nmfs.noaa.gov/hcd/exprscrn.pdf.

Nelson DA, Wheeler JL. 1997. The influence of dredging-induced turbidity and associated contaminants upon hatching success and larval survival of winter flounder, *Pleuronectes americanus*, a laboratory study. Milford (CT): Connecticut Department of Environmental Protection. Final Report on Grant CWF #321-R. 57 p.

Neumann G, Pierson WJ Jr. 1966. Principles of physical oceanography. Englewood Cliffs (NJ): Prentice-Hall International. 545 p.

Newcombe CP, Jensen JO. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe CP, MacDonald DD. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11(1):72-82.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Pilati DA. 1976. Cold shock: biological implications and a method for approximating transient environmental temperatures in the near-field region of a thermal discharge. Science of the Total Environment 6(3):227-37.

Rago PJ. 1984. Production forgone: an alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. Ecological Modelling 24(1-2):79-111.

Richkus WA, McLean R. 2000. Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay. Environmental Science and Policy 3(Supplement 1):283-93.

Spence BC, Lomnicky GA, Hughes RM, Novitzki RP. 1996. An ecosystem approach to salmonid conservation. [Internet]. Corvallis (OR): ManTech Environmental Research Services Corp. TR-4501-96-6057. [cited 2008 Jul 9]. Available from: http://www.nwr.noaa.gov/Publications/Reference-Documents/ManTech-Report.cfm.

Tavolaro J. 1984. A sediment budget study of clamshell dredging and ocean disposal activities in the New York Bight. Environmental Geology and Water Science 6(3):133-40.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

Turner A, Millward GE. 2002. Suspended particles: their role in estuarine biogeochemical cycles. Estuarine, Coastal and Shelf Science 55:857-83.

[USCG] US Coast Guard. 2006. Environmental impact statement/environmental impact report for the Neptune LNG deepwater port license application. Washington (DC): USCG-2005-22611.

[USEPA] US Environmental Protection Agency. 2003. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Valiela I. 1995. Marine ecological processes, 2nd ed. New York (NY): Springer-Verlag.

[WDFW] Washington Department of Fish and Wildlife. 1998. Fish passage technical assistance: surface diversion and fish screen terminology. [Internet]. Olympia (WA): Washington

Department of Fish and Wildlife; c1998-1999; [cited 2007 Dec 28]. Available from: http://wdfw.wa.gov/hab/engineer/scrnterm.htm.

Wilber DH, Clarke DG. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-75.

Wilbur AR, Pentony MW. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. American Fisheries Society Symposium 22:299-321.

Williams GD, Thom RM. 2001. Marine and estuarine shoreline modification issues. [Internet]. White paper submitted to Washington Department of Fish and Wildlife, Washington Dept. of Ecology, Washington Dept. of Transportation. Sequim (WA): Battelle Memorial Institute. [cited 2008 Jul 9]. 99 p. Available from: http://wdfw.wa.gov/hab/ahg/marnrsrc.htm.

# CHAPTER NINE: AGRICULTURES AND SILVICULTURE

## Croplands, Rangelands, Livestock, and Nursery Operations

### *Introduction*

Substantial portions of croplands, rangelands, and commercial nursery operations are connected, either directly or indirectly, to coastal waters where point and nonpoint pollution can have an adverse effect on aquatic habitats. According to the US Environmental Protection Agency's (US EPA) 2000 National Water Quality Inventory, agriculture was the most widespread source of pollution for assessed rivers and lakes (USEPA 2002a). In that report, agriculture was responsible for 18% of all river-mile impacts and 14% of all lake-acre impacts in the United States. In addition, 48% of all impaired river miles and 41% of all impaired lake acres were attributed to agriculture (USEPA 2002a). Impacts to fishery habitat from agricultural and nursery operations can result from: (1) nutrient loading; (2) introduction of animal wastes; (3) erosion; (4) introduction of salts; (5) pesticides; (6) sedimentation; and (7) suspended silt in water column (USEPA 2002a).

### *Release of nutrients/eutrophication*

Nutrients in agricultural land are found in several different forms and originate from various sources, including: (1) commercial fertilizers containing nitrogen, phosphorus, potassium, secondary nutrients, and micronutrients; (2) manure from animal production facilities; (3) legumes and crop residues; and (4) irrigation water (USEPA 2002a). In addition, agriculturals land are characterized by poorly maintained dirt roads, ditches, and drains that transport sediments and nutrients directly into surface waters. In many instances, headwater streams have been replaced by a constructed system of roads, ditches, and drains that deliver nutrients directly to surface waters (Larimore and Smith 1963). Worldwide, the production of fertilizers is the largest source of anthropogenic nitrogen mobilization, although atmospheric deposition exceeds fertilizer production as the largest nonpoint source of nitrogen to surface waters in the northeastern United States (Howarth et al. 2002). Human activity is estimated to have increased nitrogen input to the coastal water of the northeastern United States, specifically to Chesapeake Bay, MD/VA, by 6- to 8-fold (Howarth et al. 2002). Castro et al. (2003) estimated that the mid-Atlantic and southeast regions contained between 24-37% agricultural lands, with fertilizers and manure applications representing the highest nitrogen sources for those watersheds. The Pamlico Sound-Pungo River, NC, and Chesapeake Bay estuaries contained the highest percent of nitrogen sources coming from agriculture from the mid-Atlantic region (Castro et al. 2003). The second leading cause of pollution in streams and rivers in Pennsylvania has been attributed to agriculture, primarily nutrient loading and siltation (Markham 2006).

Nitrogen and phosphorus are the two major nutrients from agriculture sources which degrade water quality. The main forces controlling nutrient movement from land to water are runoff, soil infiltration, and erosion. Introduction of these nutrients into aquatic systems can promote aquatic plant productivity and decay leading to cultural eutrophication (Waldichuk 1993). Eutrophication can adversely affect the quality and productivity of fishery habitats in rivers, lakes, estuaries, and near-shore, coastal waters. Eutrophication can cause a number of secondary effects, such as increased turbidity and water temperature, accumulation of dead organic material, decreased dissolved oxygen, and the proliferation of aquatic vegetation. Cultural eutrophication has resulted in widespread damage to the ecology of the Chesapeake Bay, causing nuisance algal blooms, loss of productive shellfish and blue crab (*Callinectes sapidus*) habitat, and destruction of submerged aquatic vegetation (SAV) beds (Duda 1985). Nearly 80% of the nutrient loads intothe Chesapeake

Bay can be attributed to nonpoint sources, and agriculture accounted for the majority of those (USEPA 2003b). Agriculture accounts for approximately 40% and 48% of nitrogen and phosphorus loads, respectively, to the Chesapeake Bay (USEPA 2003b). Chronic eutrophication has severely impacted the historically productive recreational and commercial fisheries of the Chesapeake Bay.

While eutrophication generally causes increased growth of aquatic vegetation, it has been shown to be responsible for wide spread losses of SAV in many urbanized estuaries (Deegan and Buchsbaum 2005). By stimulating the growth of macroalgae, such as sea lettuce (*Ulva lactuca*), eutrophication can alter the physical structure of seagrass meadows, such as eelgrass (*Zostera marina*), by decreasing shoot density and reducing the size and depth of beds (Short et al. 1993; MacKenzie 2005). These alterations can result in the destruction of habitat that is critical for developing juvenile fish and can severely impair biological food chains (Hanson et al. 2003).

Groundwater is also susceptible to nutrient contamination in agricultural lands composed of sandy or other coarse-textured soil (USGS 1999). Nitrate, a highly soluble and mobile form of nitrogen, can leach rapidly through the soil profile and accumulate in groundwater, especially in shallow zones (USEPA 2003a). In the eastern United States, nitrogen contamination of groundwater is generally higher in areas that receive excessive applications of agriculture fertilizers and manure, most notably in mid-Atlantic states like Delaware, Maryland, and Virginia (i.e., the Delmarva Peninsula) (USEPA 2003a). When discharged through seeps and drains, or by direct subsurface flow to water bodies, groundwater can be a significant source of nutrients to surface waters (Hanson et al. 2003). Phosphorus from agricultural sources, such as manure and fertilizer applications and tillage, can also be a significant contributor to eutrophication in freshwater and estuarine ecosystems. Cultivation of agricultural land greatly increases erosion and with it the export of particle-bound phosphorus.

Livestock waste (manure), including fecal and urinary wastes of livestock and poultry, processing water and the feed, bedding, litter, and soil with which they become intermixed, is reported to be the single largest source of phosphorus contamination in the United States (Howarth et al. 2002). Because cattle are often allowed to graze in riparian areas, nutrients that are consumed elsewhere are often excreted in riparian zones that can impact adjacent aquatic habitats (Hanson et al. 2003). Because grazing processes remove or disturb riparian vegetation and soils, runoff that carries additional organic wastes and nutrients into aquatic habitats is accelerated (Hanson et al. 2003). Pollutants contained and processed in rangelands, pastures, or confined animal facilities can be transported by storm water runoff into aquatic environments. These pollutants may include oxygen-demanding substances such as nitrogen and phosphorus; organic solids; salts; bacteria, viruses, and other microorganisms; metals; and sediments that increase organic decomposition (USEPA 2003a). Increased nutrient levels resulting from processed water or manure causes excessive aquatic plant growth and algae. The decomposition of aquatic plants depletes dissolved oxygen in the water, creating anoxic or hypoxic conditions that can lead to fish kills. For example, six individual spills from animal waste lagoons in North Carolina during 1995 totaled almost 30 million gallons; including one spill that involved 22 million gallons of swine waste that was responsible for a fish kill along a 19-mile stretch of the New River (USEPA 2003a). Animal wastes from farms in the United States produce nearly 1.5 billion tons of nitrogen and phosphate-laden wastes each year that contribute to nutrient contamination in approximately 27,999 miles of rivers and groundwater (Markham 2006). The release of animal wastes from livestock production facilities have led to reductions in productivity of riverine, estuarine, and marine habitats because of eutrophication.

## *Introduction of pathogens*

Stormwater runoff from agriculture, particularly livestock manure, typically contains elevated levels of pathogens, including bacteria, viruses, and protozoa (USEPA 2003a). Pathogens are generally a concern to human health because of consumption of contaminated shellfish and finfish and exposure at beaches and swimming areas (USEPA 2005). While many pathogens affecting marine organisms are associated with upland runoff of fecal contamination, there are also naturally occurring marine pathogens that affect fish and shellfish (Shumway and Kraeuter 2000). Some naturally occurring pathogens, such as bacteria from the genus, *Vibrio*, or the dinoflagellate, *Pfiesteria*, can produce blooms that release toxins capable of harming fish and possibly human health under certain conditions (Buck et al. 1997; Shumway and Kraeuter 2000). Although the factors leading to the formation of blooms for these species requires additional research, nutrient enrichment of coastal waters is suspected to play a role (Buck et al. 1997). See also the chapter on Introduced/Nuisance Species and Aquaculture for more information on pathogens.

## *Reduced dissolved oxygen*

Reduced (hypoxic) or depleted (anoxic) oxygen conditions within estuarine waters as a result of cultural eutrophication may be one of the most severe problems facing coastal waters in the United States (Deegan and Buchsbaum 2005), and agriculture is a major contributing source in some areas. In general, extensive hypoxia has been more chronic in river-estuarine systems in the southern portion of the northeast coast (i.e., Narragansett Bay, RI, to Chesapeake Bay) than in the northern portion (Whitledge 1985; O'Reilly 1994; NOAA 1997). In 2001 approximately 50% of the deeper waters of the Chesapeake Bay had reduced dissolved oxygen concentrations (USEPA 2003b).

Warm temperatures, high metabolic sediment demand, and water column stratification, conditions that can be common at night during summer months, may lead to low dissolved oxygen concentrations in bottom waters (Deegan and Buchsbaum 2005). Hypoxia in estuaries north of Cape Cod, MA, are uncommon because of strong mixing and flushing characteristics of their waters in the northern New England region. However, high nutrient loads into aquatic habitats from livestock and croplands can cause hypoxic or anoxic conditions that can result in fish kills in rivers and estuaries in other areas of the northeast coast (USEPA 2003a; Deegan and Buchsbaum 2005), and they can potentially alter long-term community dynamics (NRC 2000; Castro et al. 2003). Chronic low-dissolved oxygen conditions can lower the growth and survivorship of finfish and shellfish. For example, the effect of chronic, diurnally fluctuating levels of dissolved oxygen has been shown to reduce the growth of young-of-the-year winter flounder (*Pseudopleuronectes americanus*) (Bejda et al. 1992).

## *Altered temperature regimes*

Increased siltation in shallow aquatic habitats caused by erosion from croplands and livestock operations can result in increased water temperature (Duda 1985). In addition to accelerating bank erosion, loss of riparian vegetation resulting from livestock grazing can increase the amount of solar radiation reaching streams and rivers resulting in an increase in water temperatures (Moring 2005). Altered temperature regimes have the ability to affect the distribution, growth rates, survival, migration patterns, egg maturation and incubation success, competitive ability, and resistance to parasites, diseases, and pollutants of aquatic organisms (USEPA 2003a). The temperature regimes of cold-water fish, such as Atlantic salmon (*Salmo salar*) and rainbow smelt (*Osmerus mordax*), may be exceeded in some rivers and streams of the northeastern United States and lead to local extirpation of these species. The removal of riparian vegetation can also lower water temperatures during winter, which can increase the formation of ice and delay the development of incubating fish eggs and alevins (Hanson et al. 2003). Some evidence indicates that elevated water temperatures in freshwater streams and rivers in the northeastern United States may be responsible for increased algal growth, which has been suggested as a possible factor in the diminished stocks of rainbow smelt (Moring 2005). In the watersheds of eastern Maine, blueberry and cranberry processing plants discharge processing water into rivers important to Atlantic salmon spawning and migration. These facilities are permitted to discharge water at temperatures known to be lethal to both juvenile and adult Atlantic salmon (USFWS and NMFS 1999).

### *Siltation, sedimentation, and turbidity*

As discussed above, siltation, sedimentation, and turbidity impacts related to agricultural activities are generally a result of soil erosion. Agricultural lands are also characterized by poorly maintained dirt roads, ditches, and drains that transport sediments directly into surface waters. Suspended sediments in aquatic environments reduce the availability of sunlight to aquatic plants, cover fish spawning areas and food supply, interfere with filtering capacity of filter feeders, and can clog and harm the gills of fish, and when the sediments settle they can cover oysters and shells which prevents oyster larvae from settling on them (USEPA 2003a; MacKenzie 2007). The largest source of sediment into Chesapeake Bay, for example, is from agriculture. Approximately 63% of the over 5 million pounds of sediment delivered each year to tidal waters of the Chesapeake Bay comes from agricultural sources (MacKenzie 1983; USEPA 2003b) and results in devastating impacts to shellfish and SAV. Wide-spread agricultural deforestation during the $18^{th}$ and $19^{th}$ centuries contributed to large sediment loads in the James,VA; York, VA; Rappahannock,VA; Potomac, WV/VA/MD/DC; Patuxent, MD; Choptank, DE/MD; and Nanticoke, DE/MD, Rivers and which may have contributed to the decline of Atlantic sturgeon (*Acipenser oxyrinchus*) populations in the Chesapeake Bay watershed (USFWS and NMFS 1998).

In addition to the affects described in greater detail within the Bank and Soil Erosion subsection of this chapter, contaminants such as pesticides, phosphorus, and ammonium are transported with sediment in an adsorbed state, such that they may not be immediately available to aquatic organisms. However, alteration in water quality, such as decreased oxygen concentration or changes in water alkalinity, may cause these chemicals to be released from the sediment (USEPA 2003a). Consequently, the impacts to aquatic organisms associated with siltation and sedimentation may be combined with the affects of pollution originating from the agricultural lands.

### *Altered hydrological regimes*

There are both direct and indirect affects of agriculture activities on the hydrology of coastal watersheds. Direct alterations of hydrology can occur from water diversion projects used for crop irrigation and livestock operations. The volume and timing of freshwater delivery to estuaries can be altered by water diversions, such as for agriculture, which in turn can increase the salinity of coastal ecosystems and diminish the supply of sediments and nutrients to estuaries (Deegan and Buchsbaum 2005). Agriculture activities use large volumes of water for irrigation, accounting for one-third of all US water withdrawals in 2000 and the second largest source of total water use after thermoelectric energy (Markham 2006).

Water withdrawal for agriculture can have adverse affects on anadromous fish, particularly Atlantic salmon, which use rivers in the Gulf of Maine for spawning and migration. Water withdrawals pose a threat to life stages of Atlantic salmon and their habitat in the Machias, Pleasant, and Narraguagus Rivers in Maine (USFWS and NMFS 1999). Freshwater was diverted from eastern Maine watersheds in the late 1990s to irrigate approximately 6,000 acres of blueberry agricultural activities, and that acreage was expected to double by the year 2005 (USFWS and NMFS 1999). The withdrawal of water may also affect the productivity of oyster beds in the eastern United States, because the distribution of oysters is largely governed by water salinity. When water is withdrawn, oyster beds are forced to move upstream and into smaller areas and often closer to cities where pollution may affect commercial marketing of the oysters (MacKenzie 2007).

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and can increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002). Altered hydrodynamics can affect estuarine circulation, including short-term (diel) and longer term (seasonal or annual) changes (Deegan and Buchsbaum 2005). In addition, counter current flows set up by freshwater discharges into estuaries are important for larvae and juvenile fish entering those estuaries. The diurnal behavioral adaptations of marine and estuarine species allow larvae and early juveniles to concentrate in estuaries. Reductions in freshwater flows caused by increased freshwater withdrawals can disrupt counter current flows and larval transport into estuaries (Deegan and Buchsbaum 2005). The quality and quantity of freshwater flows into estuaries are important in maintaining suitable conditions for spawning, egg, larval, and juvenile development for many estuarine-dependent species.

Indirect affects occur when sediments are transported from agricultural lands via soil erosion and are deposited in roadside ditches, streams, rivers, and navigation channels, which decrease the capacity of watersheds to attenuate the affects of flooding. The morphology of streams and rivers can be altered by eroded soil from improper livestock grazing and croplands, changing the stream width and depth and the timing and magnitude of stream flow (USEPA 2003a). In addition, sediment deposited in lakes and navigation channels reduces the storage capacity of those systems and necessitates more frequent dredging (USEPA 2003a).

### *Impaired fish passage*

Sediments transported from agricultural lands via soil erosion can change the morphology of streams and rivers. As a result, alteration of stream width and depth and the timing and magnitude of stream flow can impair the ability of anadromous fish to reach upstream spawning habitats. Roads that are constructed to access agriculture lands and for livestock may impede or prohibit migrating fish. For example, culverts constructed under roads to allow for water flow can alter the velocity and volume of water in streams and inhibit the ability of fish to migrate through the structure (Furniss et al. 1991). Additional information on fish passage impairments can be reviewed in the Alteration of Freshwater Systems chapter of this report.

### *Change in community structure and species composition*

Cropland and livestock operations can result in community-level impacts to riverine and estuarine ecosystems. As mentioned above, fertilizers applied to agricultural lands enter streams, rivers, and estuaries through stormwater runoff and groundwater sources (e.g., seeps and subsurface flows) and may result in eutrophication. Eutrophication can cause a number of secondary effects, such as increased turbidity and water temperature, accumulation of dead organic material, decreased dissolved oxygen, and the proliferation of macroalgae, such as sea lettuce (MacKenzie 2005). These alterations can then result in the destruction of habitat for small or juvenile fish and severely impair biological food chains (Hanson et al. 2003). For example, eelgrass beds growing in deeper areas of estuaries tend to be impacted more than shallower areas because those beds are very sensitive to light attenuation as a result of eutrophication (Deegan and Buchsbaum 2005). Species that depend upon eelgrass beds may be forced into shallower, potentially less desirable habitats. Declines in commercially and recreationally important finfish in Waquoit Bay, MA, have followed a concomitant decline in eelgrass beds for that area (Deegan and Buchsbaum 2005). Similarly, eelgrass wasting disease was documented to be responsible for severe declines in bay scallop (*Argopectin irradians*) landings along the east coast in the 1930s (Buchsbaum 2005).

Other impacts from agricultural activities such as soil erosion and release of fine sediments can alter aquatic communities through siltation and alteration of benthic substrates. Waldichuk (1993) identified a number of impacts to Pacific salmon (*Oncorhynchus* spp.) caused by activities related to agriculture, such as siltation in spawning, egg incubation and feeding habitats, impaired respiration and abrasion of gills from suspended particles, and failure of egg hatching resulting from low dissolved oxygen. The cumulative effect from the degradation of riverine habitats can inhibit or preclude restoration efforts of salmon populations to historic ranges by altering the community. Release of nutrients from fertilizers applied to croplands, livestock manure, and erosion of soils can reduce the dissolved oxygen levels in aquatic habitats through storm water runoff. Reduced dissolved oxygen in the water or sediments can change community composition to coastal habitats, particularly in areas with restricted water circulation such as coastal ponds, subtidal basins, and salt marsh creeks (Deegan and Buchsbaum 2005). Chronic hypoxia caused by cultural eutrophication can permanently alter the species composition and productivity of these areas.

### *Entrainment and impingement*

Water diverted and extracted for agriculture use can entrain (i.e., draw into flow system) and impinge (i.e., capture onto filter screens) aquatic organisms. Entrainment and impingement generally affects eggs, larvae, and early juvenile fish and invertebrates that cannot actively avoid the currents created at the water intake opening (ASMFC 1992). Long-term water withdrawal may adversely affect fish and invertebrate populations as well as their prey by adding another source of mortality to the early life stage which often determines recruitment and year-class strength (Hanson et al. 2003). Refer to the Physical Affects: Water Intake and Discharge Facilities chapter in this report for additional information on entrainment and impingement.

### *Bank and soil erosion*

Soil erosion in US farmland is estimated to occur seven times as fast as soil formation (Markham 2006). Soil erosion can lead to the transport of fine sediment that may be associated with a wide variety of pollutants from agricultural land into the aquatic environment. The presence of livestock in the riparian zone accelerates sediment transport rates by increasing surface soil erosion (Hanson et al. 2003), loss of vegetation caused by trampling, and streambank erosion resulting from shearing or sloughing (Platts 1991). Increased sedimentation in aquatic systems can increase turbidity and the temperature of the water, reduce light penetration and dissolved oxygen, smother fish spawning areas and food supplies, decrease the growth of SAV, clog the filtering capacity of filter feeders, clog and harm the gills of fish, interfere with feeding behaviors of certain species, cover shells on oyster beds, and significantly lower overall biological productivity (MacKenzie 1983; Duda 1985; USEPA 2003a). Soil eroded and transported from cropland usually contains a higher percentage of finer and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides, herbicides, trace metals, and nutrients (Duda 1985; USEPA 2003a). One of the consequences of erosional runoff from agricultural land is that it necessitates more frequent dredging of navigational channels (USEPA 2003a), which may result in transportation to and disposal of contaminated sediments in areas important to fisheries production and other marine biota (Witman 1996). Deposition of sediments from erosional runoff can also decrease the storage capacity of roadside ditches, streams, rivers, and navigation channels, resulting in more frequent flooding (USEPA 2003a).

### *Loss and alteration of riparian-wetland areas*

Functioning riparian-wetland areas require stable interactions between geology, soil, water, and vegetation in order to maintain productive riverine ecosystems. When functioning properly, riparian-wetland areas can: (1) reduce erosion and improve water quality by dissipating stream energy; (2) filter sediment and runoff from floodplain development; (3) support denitrification of nitrate-contaminated groundwater; (4) improve floodwater retention and groundwater discharge; (5) develop root masses that stabilize banks from scouring and slumping; (6) develop ponding and channel characteristics necessary to provide habitat for fish, waterfowl, and invertebrates; and (7) support biodiversity (USEPA 2003a). Agriculture activities have the potential to degrade riparian habitats. In particular, improper livestock grazing along riparian corridors can eliminate or reduce vegetation by trampling and increase streambank erosion by shearing or sloughing (Platts 1991). These effects tend to increase the streambank angle, which increases stream width, decreases stream depth, and alters or eliminates fish habitat (USEPA 2003a). As discussed above, the transport of eroded soil from the streambank to streams and rivers impacts water quality and aquatic habitats. Removing riparian vegetation also increases the amount of solar radiation reaching the stream and can result in higher water temperatures.

### *Reduced soil infiltration and soil compaction*

Tillage of croplands aerates the upper soil but tends to compact fine textured soils just below the depth of tillage, thus altering infiltration. Use of farm machinery on cropland and adjacent roads causes further compaction, reducing infiltration and increasing surface runoff (Hanson et al. 2003).

Johnson (1992) and Platts (1991) reviewed studies related to livestock grazing and concluded that heavy grazing nearly always decreases infiltration, reduces vegetative biomass, and increases bare soil. Compaction of rangelands generally increases with grazing intensity, although site-specific soil and vegetative conditions are also important factors in determining the effects of soil compaction (Kauffman and Krueger 1984). Reduced soil infiltration and compaction caused by agriculture are two of the factors that accelerate erosion and release of sediments and contaminants in aquatic habitats.

Salts are present in varying amounts in all soils because of the natural weathering process, but agricultural lands that have poor subsurface drainage can lead to high salt concentrations. Likewise, irrigation water, whether from ground or surface water sources has a natural base load of dissolved mineral salts. Irrigation return flows convey the salt to the receiving streams or groundwater reservoirs. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that aquatic functions are impaired. However, if the process of water diversion and the return flow of saline drainage water is repeated many times along a stream or river, downstream habitat quality can become progressively degraded (USEPA 2003a). The accumulation of salts, particularly on irrigated croplands, tends to cause soil dispersion, structure breakdown, and decreased infiltration (USEPA 2003a). While salts are generally a greater pollutant for freshwater ecosystems than for estuarine systems, they may adversely affect anadromous fish that depend upon freshwater systems for crucial portions of their life cycles (USEPA 2003a).

### *Land-use change (post-agriculture)*

When demands for developable land are sufficiently high, the value of land in developed use will exceed its value in agricultural use. In general, conversion of land from agricultural to urban uses is largely irreversible according to the US Department of Agriculture. In the continental United States, census data from urban areas have shown more than a doubling of agricultural land conversion from 25.5 million acres to 55.9 million acres between 1960 and 1990 (USDA 2005). While impacts on aquatic ecosystems from agriculture may be problematic in some areas, conversion of croplands and rangelands to urban and industrial uses may be more harmful in the long-term. Between 1992 and 1997 the state of New York lost approximately 90,000 acres of prime farmland to residential and commercial development, which was 140% faster than in the previous five years (Markham 2006). Refer to the Coastal Development chapter in this report for more information on the impacts of land-use change.

### *Release of pesticides, herbicides, and fungicides*

The term "pesticide" is a collective description of hundreds of chemicals used to protect crops from damaging organisms with different sources and fates in the aquatic environment and that have varying toxic effects on fish and other aquatic organisms (USEPA 2003a). Pesticides can be divided into four categories according to the target pest: insecticides, herbicides, fungicides, and nematicides (USEPA 2003a). Agricultural activities are a major nonpoint source of pesticide pollution in coastal ecosystems (Hanson et al. 2003). Large quantities of pesticides, perhaps 18-20 pounds of pesticide active ingredient per acre, are applied to vegetable crops in coastal areas to control insect and plant pests (Scott et al. 1999). Soil eroded and transported from croplands and rangelands usually contains a higher percentage of finer and less dense particles, which tend to have a higher affinity for adsorbing pollutants such as insecticides and herbicides (Duda 1985; USEPA 2003a). In addition, agricultural lands are typically characterized by poorly maintained dirt roads, ditches and drains that transport sediments, nutrients, and pesticides directly into surface waters. In many instances, roads, ditches, and drains have replaced headwater streams, and these constructed systems deliver pollutants directly to surface waters (Larimore and Smith 1963). Pesticides are frequently detected in freshwater and estuarine systems that provide fishery habitat.

The most common pesticides include insecticides, herbicides, and fungicides. These are used for pest control on forested lands, agricultural crops, tree farms, and nurseries. Pesticides can enter the aquatic environment as single chemicals or complex mixtures. Direct applications, surface runoff, aerial drift, leaching, agricultural return flows, and groundwater intrusions are all examples of transport processes that deliver pesticides to aquatic ecosystems (Hanson et al. 2003).

Most studies evaluating pesticides in runoff and streams generally find that concentrations can be relatively high near the application site and soon after application but are significantly reduced further downstream and with time (USEPA 2003a). However, some pesticides used in the past, such as dichlorodiphenyl trichloroethane (DDT), are known to persist in the environment for years after application. Chlorinated pesticides, such as DDT, and some of the breakdown products are known to cause malformation and fatality in eggs and larvae, alter respiration, and disrupt central nervous system functions in fish (Gould et al. 1994). In addition, pesticides containing organochlorine compounds accumulate and persist in the fatty tissue and livers of fish and could be a threat to human health for those who consume contaminated fish (Gould et al. 1994).

Pesticides may bioaccumulate in organisms by first being adsorbed by sediments and detritus which are ingested by zooplankton and then eaten by planktivores, which in turn are eaten by fish (ASMFC 1992). For example, the livers of winter flounder from Boston and Salem Harbors, MA, contained the highest concentrations of DDT found on the east coast of the United

States and were ranked first and third, respectively, in the country in terms of total pesticides (Larsen 1992). In the Pocomoke River, MD/DE, a tributary of the Chesapeake Bay, agricultural runoff (primarily from poultry farms) was identified as one of the major sources of contaminants (Karuppiah and Gupta 1996). Blueberry and cranberry agriculture is an important land use in eastern Maine watersheds and involves the use of a number of pesticides, herbicides, and fungicides that may cause immediate mortalities to juvenile Atlantic salmon or can have indirect effects when chemicals enter rivers (USFWS and NMFS 1999). One study investigating the effects of two different classes of pesticides (organochlorines and organophosphates) in South Carolina estuaries found significant affects on populations of the dominant macrofauna species, daggerblade grass shrimp (*Palaemonetes pugio*), and mummichogs (*Fundulus heteroclitus*) (Scott et al. 1999). The study found impacts from pesticide runoff on daggerblade grass shrimp populations may cause community-level disruptions in estuaries; however, the authors concluded that implementation of integrated pest management, best management practices, and retention ponds could significantly reduce the levels of nonpoint source runoff from agriculture (Scott et al. 1999).

### *Endocrine disruptors*

Studies have recently focused on a group of chemicals, called "endocrine disruptors," that when present at extremely low concentrates can interfere with fish endocrine systems. Some of these chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Some of the chemicals shown to be estrogenic include some polychlorinated biphenyl (PCB) congeners, dieldrin, DDT, phthalates and alkylphenols (Thurberg and Gould 2005), which have had or still have applications in agriculture. Several studies have found vitellogenin, a yolk precursor protein, in male fish in the North Sea estuaries (Thurberg and Gould 2005). Metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic processes (Brodeur et al. 1997). However, the long-term effect of endocrine-disrupting substances on aquatic life is not well understood and demands serious attention by the scientific and resource policy communities.

### *Conservation measures and best management practices for croplands, rangelands, livestock, and nursery operations (adapted from Hanson et al. 2003)*

1. Recommend field and landscape buffers to provide cost-effective protection against the cumulative effects of multiple pollutant discharges associated with agricultural activities, including riparian forests, alley cropping, contour buffer strips, crosswind trap strips, field borders, filter strips, grassed waterways with vegetative filters, herbaceous wind barriers, vegetative barriers, and windbreak/shelterbelts.
2. Protect and restore soil quality with natural controls that affect permeability and water holding capacity, nutrient availability, organic matter content, and biological activity of the soil. Some examples of best management practices include cover cropping, crop sequence, sediment basins, contour farming, conservation tillage, crop residue management, grazing management, and the use of low-impact farming equipment.
3. Promote efficient use and appropriate applications of pesticides and irrigated water. Sound agricultural practices include use of integrated pest management, irrigation management, soil testing, and appropriate timing of nutrient applications.
4. Encourage protection and restoration of rangelands with practices such as rotational grazing systems or livestock distribution controls, exclusion of livestock from riparian and aquatic areas,

livestock-specific erosion controls, reestablishment of vegetation, or extensive brush management correction.
5. Avoid locating new confined animal facilities or expansion of existing facilities near riparian habitat, surface waters, and areas with high leaching potential to surface or groundwater. Ensure that adequate nutrient and wastewater collection facilities are in place.
6. Minimize water withdrawals for irrigation and promote water conservation measures, such as water reuse.
7. Site roads for agricultural lands to avoid sensitive areas such as streams, wetlands, and steep slopes.
8. Include best management practices (BMPs) for agricultural road construction plans, including erosion control, avoidance of side casting of road materials into streams, and using only native vegetation in stabilization plantings.
9. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

## Silviculture and Timber Harvest Activities

### *Introduction*

The growth and harvest of forestry products are major land-use types for watersheds along the east coast, particularly in New England, and can have short-term and long-term impacts to riverine habitat (USFWS and NMFS 1999). Forestry is the dominant land-use type in the watersheds of the Dennys, East Machias, Machias, Pleasant, and Narraguagus Rivers in Maine (USFWS and NMFS 1999). Forests that once covered up to 95% of the Chesapeake Bay watershed now cover only 58%, primarily because of land clearing for agriculture and timber (USEPA 2003b). Timber harvest generally removes the dominant vegetation; converts mature and old-growth upland and riparian forests to tree stands or forests of early seral stage; reduces the permeability of soils; increases sedimentation from surface runoff and mass wasting processes; alters hydrologic regimes; and impairs fish passage through inadequate design, construction, and maintenance of stream crossings (Hanson et al. 2003). Silviculture practices can also increase water temperatures in streams and rivers, increase impervious surfaces, and decrease water retention capacity in watersheds (USFWS and NMFS 1999). These watershed changes may result in inadequate river flows; increase stream bank and streambed erosion; sedimentation and siltation of riparian and stream habitat; increase the amount of woody debris; and increase of run-off and associated contaminants (e.g., from herbicides) (Sigman 1985; Hicks et al. 1991; Hanson et al. 2003). Debris (i.e., wood and silt) is released into the water as a result of timber harvest activities and can smother benthic habitat. Poorly placed or designed road construction can cause erosion, producing additional silt and sediment that can impact stream and riparian habitat. Deforestation can alter or impair natural habitat structures and dynamics of the ecosystem.

Four major categories of silviculture activities that can impact fishery habitat are: (1) construction of logging roads; (2) creation of barriers; (3) removal of streamside vegetation; and (4) input of pesticide and herbicide treatments to aquatic habitats.

### *Release of nutrients/eutrophication*

After logging activities, concentrations of plant nutrients in streams and rivers may increase for several years and up to a decade (Hicks et al. 1991). Excess nutrients, combined with increased light regimes caused by the removal of riparian vegetation, can stimulate algal growth; however, the effects of nutrient increases on salmonid populations are not well understood (Hicks et al. 1991). An estimated 41.5 million pounds of nitrogen per year from silviculture activities alone are released into the Chesapeake Bay watershed, contributing to phytoplankton blooms, chronic hypoxia (low dissolved oxygen concentrations), and die-off of SAV (USEPA 2003b).

### *Reduced dissolved oxygen*

Small wood debris and silt resulting from timber harvesting can smother benthic habitat and reduce dissolved oxygen levels in streams (Hicks et al. 1991; Hanson et al. 2003). Fine organic material introduced into streams following logging can result in increased oxygen demand and reduced exchange of surface and intergravel water (Hicks et al. 1991). While low oxygen conditions may not directly kill salmon embryos and alevins in streams after logging, emergent juveniles may have reduced viability (Hicks et al. 1991). Introduction of nutrients into aquatic systems can promote aquatic plant productivity and decay leading to cultural eutrophication (Waldichuk 1993). Anoxic (without oxygen) or hypoxic (low oxygen) conditions have caused widespread ecological problems for the Chesapeake Bay, resulting in a variety ecosystem impacts including the loss of shellfish beds and reductions of fish stocks in the Bay (USEPA 2003b). According to Chesapeake Bay Program modeling, approximately 15% of the nitrogen loads entering the Chesapeake Bay watershed each year are from forestry activities (USEPA 2003b).

### *Altered temperature regimes*

Removing streamside vegetation to construct logging access roads and logging adjacent to streams or rivers increase the amount of solar radiation reaching the water body and can increase water temperatures (Beschta et al. 1987; Hicks et al. 1991). In studies conducted in Alaska, researchers found that maximum temperatures in logged streams without riparian buffers exceeded that of unlogged streams by up to 5ºC, but did not reach lethal temperatures (Hanson et al. 2003). In cold climates, the removal of riparian vegetation can result in lower water temperatures during winter, increasing the formation of ice and damaging and delaying the development of incubating fish eggs and alevins (Hanson et al. 2003). In freshwater habitats of the northeastern United States, the temperature tolerances of cold-water fish such as Atlantic salmon and rainbow smelt may be exceeded leading to local extirpation of the species (USFWS and NMFS 1999). However, increased water temperatures can also increase primary and secondary production, which may lead to greater availability of food for fish (Hicks et al. 1991).

### *Siltation, sedimentation, and turbidity*

Sedimentation in streams resulting from timber harvesting activities can reduce benthic community production, cause mortality of incubating salmon eggs and alevins, reduce the amount of habitat available for juvenile salmon, and lower the productivity of oyster beds (MacKenzie 1983; Hicks et al. 1991; Hanson et al. 2003). Fine sediments deposited in salmon spawning gravel can reduce interstitial water flow, causing reduced dissolved oxygen concentrations, and they can physically trap emerging fry in the gravel (Hicks et al. 1991). Fine sediments on stream bottoms and in suspension can also reduce primary production and invertebrate abundance, reducing the availability of prey for fish (Hicks et al. 1991). Sedimentation in riparian habitat resulting from logging activities can reduce streamside vegetation that impacts bank stabilization, increasing solar radiation reaching the stream. In addition, suspended sediments can alter the behavior and feeding efficiencies of salmonids following timber harvesting (Hicks et al. 1991). Sawdust and pulp from sawmills and lumber companies can also enter streams and rivers and adversely affect benthic habitats of anadromous fish (Moring 2005).

Deforestation and silviculture activities have contributed to excessive amounts of sediments in Chesapeake Bay, which have led to adverse affects on benthic communities like SAV, oysters, and clams (USEPA 2003b). Nearly 1 million tons of sediments are estimated to enter the Chesapeake Bay each year from forestry activities alone, which accounts for approximately 20% of the total sediment loads into the Bay (USEPA 2003b).

### *Bank and soil erosion and altered hydrological regimes*

Timber harvesting may result in inadequate or excessive surface and stream flows, increased stream bank and streambed erosion, and the loss of complex instream habitats. Clear cutting large areas of forests can alter the hydrologic characteristics of watersheds, such as water temperature, and result in greater seasonal and daily variation in stream discharge and flows (Hicks et al. 1991; Hanson et al. 2003).

In addition, logging road construction can destabilize slopes and increase erosion and sedimentation. Mass wasting and surface erosion are the two major types of erosion that can occur from logging road construction. Mass movement of soils, commonly referred to as landslides or debris slides, is associated with timber harvesting and road building on high hazard soils and unstable slopes. The result is increased erosion and sediment deposition in down-slope waterways. Erosion from roadways is most severe when poor construction practices are employed that do not include properly located, designed, and installed culverts or when proper ditching is not utilized (Furniss et al. 1991).

Altered hydrology and flood plain storage patterns around estuaries can effect water residence time, temperature, and salinity and can increase vertical stratification of the water column which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations (Kennedy et al. 2002).

### *Alteration and loss of vegetation*

By removing vegetation, timber harvesting tends to decrease the absorptive capability of the groundcover vegetation. This, in turn, increases surface runoff during periods of high precipitation. These effects can destabilize slopes, increase erosion, and cause sedimentation and debris input to streams (Hanson et al. 2003). Reductions in the supply of large woody debris to streams can result when old-growth forests are removed, with resulting loss of habitat complexity that is important for successful salmonid spawning and rearing (Hicks et al. 1991; Hanson et al. 2003). Removing riparian vegetation increases the amount of solar radiation reaching the stream and can result in higher water temperatures during summer months. A loss of riparian vegetation can also reduce stream water temperatures during the winter months (Beschta et al. 1987; Hicks et al. 1991).

### *Impaired fish passage*

Poorly placed or ill-designed culverts placed as part of road construction can negatively affect access to riverine habitat by fish. Stream crossings (e.g., bridges and culverts) on forest roads are often inadequately designed, installed, and maintained, and they frequently result in full or partial barriers to both the upstream and downsteam migration of adult and juvenile fish (Hanson et al. 2003). Perched culverts, in which the culvert invert at the downstream end is above the water level of the downstream pool, create waterfalls that can be physical barriers to migrating fish. Undersized culverts can accelerate stream flows to the point that these structures become velocity barriers for migrating fish. Blocked culverts can result in displacement of the stream from the downstream channel to the roadway or roadside ditch (Hanson et al. 2003). Blocked culverts often result from installation of undersized culverts or inadequate maintenance to remove debris. In addition, culverts and bridges deteriorate structurally over time, and failure to replace or remove them at the end of their useful life may cause partial or total blockage of fish passage.

### *Release of pesticides, herbicides, and fungicides*

Riparian vegetation is an important component of rearing habitat for fish, providing shade for maintaining cool water temperatures, food supply, channel stability, and structure (Furniss et al. 1991). Herbicides that are used to suppress terrestrial vegetation can negatively impact these habitat functions (USFWS and NMFS 1999). In addition, insecticides applied to forests to control pests can interfere with the smoltification process of Atlantic salmon, preventing some fish from successfully making the transition from fresh to salt water. Matacil, one pesticide used in the Maine timber industry, is known to contain an endocrine disrupting chemical (USFWS and NMFS 1999). These chemicals act as "environmental hormones" that may mimic the function of the sex hormones androgen and estrogen (Thurberg and Gould 2005). Refer to the Chemical Effects: Water Discharge Facilities chapter for more information on endocrine disruptors. Other possible affects to Atlantic salmon from pesticides may include altered chemical perception of home stream odor and osmoregulatory ability (USFWS and NMFS 1999).

### *Conservation measures and best management practices for silviculture and timber harvest activities*

1. Encourage timber operations to be located as far from aquatic habitats as possible. Buffer zones of 100 ft for first- and second-order streams and greater than 600 feet for fourth- and fifth-order streams are recommended.
2. Ensure that all silviculture and timber operations incorporate conservation plans that include control of nonpoint source pollution, protecting important habitat through landowner agreements, maintaining riparian corridors, and monitoring and controlling pesticide use.
3. Incorporate watershed analysis into timber and silviculture projects. Attention should be given to the cumulative effects of past, present, and future timber sales within a watershed.
4. Logging roads should be sited to avoid sensitive areas such as streams, wetlands, and steep slopes.
5. Include BMPs for timber forest road construction plans, including erosion control, avoidance of side casting of road materials into streams, and using only native vegetation in stabilization plantings.
6. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

## Timber and Paper Mill Processing Activities

### *Introduction*

Timber and paper mill processing activities can affect riverine and estuarine habitats through both chemical and physical means. Timber and lumber processing can release sawdust and wood chips in riverine and estuarine environments where they may impact the water column and benthic habitat of fish and invertebrates. These facilities may also either directly or indirectly release contaminants, such as tannins and lignin products, into aquatic habitats (USFWS and NMFS 1999). Pulp manufacturing converts wood chips or recycled paper products into individual fibers by chemical and/or mechanical means, which are then used to produce various paper products. Paper and pulp mills use and can release a number of chemicals that are toxic to aquatic organisms, including chlorine, dioxins, and acids (Mercer et al. 1997), although a number of these chemicals have been reduced or eliminated from the effluent stream by increased regulations regarding their use.

### *Chemical contaminant releases*

Approximately 80% of all US pulp tonnage comes from kraft or sulfate pulping which uses sodium-based alkaline solutions, such as sodium sulfide and sodium hydroxide (USEPA 2002b). Kraft pulping reportedly involves less release of toxic chemicals, compared to other processes such as sulfite pulping (USEPA 2002b). Paper and pulp mills may also release a number of toxic chemicals used in the process of bleaching pulp for printing and wrapping paper products. The bleaching process may use chlorine, sulfur derivatives, dioxins, furans, resin acids, and other chemicals that are known to be toxic to aquatic organisms (Mercer et al. 1997). These chemicals have been implicated in various abnormalities in fish, including skin and organ tissue lesions, fin necrosis, gill hyperplasia, elevated detoxifying enzymes, impaired liver functions, skeletal deformities, increased incidence of parasites, disruption of the immune system, presence of tumors, and impaired growth and reproduction (Barker et al. 1994; Mercer et al. 1997). Because of concern about the release of dioxins and other contaminants, considerable improvements in the bleaching process have reduced or eliminated the use of elemental chlorine. Approximately 96% of all bleached pulp production uses chlorine-free bleaching technologies (USEPA 2002b).

An endocrine disrupting chemical, 4-nonylphenol, has been used in pulp and paper mill plants in Maine and has been shown to interfere with smoltification processes and the chemical perception of home range, and osmoregulatory ability in Atlantic salmon (USFWS and NMFS 1999). Other studies have implicated pulp and paper effluents in altered egg production, gonad development, sex steroids, secondary sexual characteristics, and vitellogenin concentration in male fish, which is considered to be an indicator of estrogenicity (Kovacs et al. 2005). A study investigating the prevalence of a microsporan parasite found in winter flounder in Newfoundland (Canada) waters observed infestations in the liver, kidney, spleen, heart, and gonads of fish collected downstream from pulp and paper mills, whereas fish collected from pristine sites harbored cysts of the parasite in only the digestive wall (Khan 2004). In addition, flounder with a high prevalence of parasite infections throughout multiple organs were found to have significant impairments to growth, organ mass, reproduction, and survival that were not observed in fish sampled from pristine locations, suggesting a link between those affects and effluent discharged by the pulp and paper mills (Khan 2004).

### *Entrainment and impingement*

Pulp and paper mills require large amounts of water and energy in the manufacturing process. For example, a bleached kraft pulp mill can utilize 4,000-12,000 gallons of water per ton of pulp produced (USEPA 2002b). Diverting water from streams, rivers, and estuaries for pulp and paper mills can entrain and impinge eggs, larvae, and juveniles and may impact local populations of fish and invertebrates. Information is not available on the potential magnitude of entrainment and impingement impacts from wood, pulp, and paper mills. Refer to Physical Effects: Water Intake and Discharge Facilities for more information on entrainment and impingement impacts.

### *Thermal discharge*

Pulp and paper production involves thermal and chemical processing to convert wood fibers to pulp or paper and may result in the release of effluent water with higher than ambient temperatures. There is a potential for cold-water fish such as Atlantic salmon and rainbow smelt to be adversely affected by these facilities. However, information is not available on the potential magnitude of thermal discharge impacts from wood, pulp, and paper mills.

### *Reduced dissolved oxygen*

Pulp and paper mill wastewaters generally contain sulfur compounds with a high biological oxygen demand (BOD), suspended solids, and tannins (USEPA 2002b). The release of these contaminants in mill effluent can reduce dissolved oxygen in the receiving waters. According to the US EPA, however, all kraft pulp mills and nearly all US paper mills have chemical recovery systems in place and primary and secondary wastewater treatment systems installed to remove particulates and BOD (USEPA 2002b).

### *Conversion of benthic substrate*

Sawdust and pulp from sawmills and lumber processing facilities can enter streams and rivers, adversely affecting benthic habitats for anadromous fish (Moring 2005). Pulp and paper mill effluent can contain solid particulates and a high BOD that can alter the benthic habitat of receiving water bodies. The impacts to benthic habitat from past practices of wood, pulp, and paper mills are evident today in some streams and rivers of Maine, including the Penobscot River from Winterport to Bucksport (USFWS and NMFS 1998). Most of the bottom substrate in this stretch of the Penobscot River is covered by bark and sawdust, which substantially reduces the diversity of benthic organisms (USFWS and NMFS 1998). However, chemical recovery systems and wastewater treatment systems should reduce or eliminate most solid wastes from the effluent stream.

### *Alteration of light regimes*

Lumber, pulp, and paper mills releasing effluent containing solids, a high BOD, and tannins can reduce water clarity and alter the light regimes in receiving waters. This can adversely affect primary production and SAV in riverine and estuarine habitat where these facilities are located. Information is not available on the potential magnitude of light regime impacts from wood, pulp, and paper mills.

### *Conservation measures and best management practices for timber and paper mill processing activities*

1. Ensure that lumber, pulp, and paper mills have adequate chemical recovery systems and wastewater treatment systems installed to reduce or eliminate most toxic chemicals and solid wastes from the effluent stream. Ensure that effluent streams do not elevate the ambient water temperatures of the receiving water bodies.
2. Discourage the construction of new lumber, pulp, and paper mills adjacent to riverine and estuarine waters that contain productive fisheries resources. New facilities should be sited so as to avoid the release of effluents in wetlands and open water habitats.
3. Use seasonal restrictions to avoid impacts to habitat during species' critical life history stages (e.g., spawning and egg development periods). Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.

4. Incorporate watershed analysis into new lumber, pulp, and paper mill facilities, with consideration for the cumulative effects of past, present, and future impacts within the watershed.

## References for Agriculture and Silviculture


[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

Barker DE, Khan RA, Hooper R. 1994. Bioindicators of stress in winter flounder, *Pleuronectes americanus*, captured adjacent to a pulp and paper mill in St. George's Bay, Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 51(10):2203-9.

Bejda AJ, Phelan BA, Studholme AL. 1992. The effects of dissolved oxygen on growth of young-of-the-year winter flounder. Environmental Biology of Fishes 34:321-7.

Beschta RL, Bilby RE, Brown GW, Holtby LB, Hofstra TD. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo EO, Cundy TW, editors. Streamside management: forestry and fishery interactions. Seattle (WA): University of Washington, College of Forest Resources. p 191-232.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54(12):2752-8.

Buchsbaum R. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Buck EH, Copeland C, Zinn JA, Vogt DU. 1997. *Pfiesteria* and related harmful blooms: natural resource and human health concerns. [Internet]. Washington (DC): National Council for Science and the Environment. Congressional Research Service Report for Congress 97-1047 ENR. [cited 2008 Jul 9]. Available from: http://www.cnie.org/NLE/CRSreports/marine/mar-23.cfm.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Duda AM. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Water Resources Bulletin 21(2):225-34.

Furniss MJ, Roelofs TD, Yee CS. 1991. Road construction and maintenance. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19 ed. Bethesda (MD): American Fisheries Society. p 297-323.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hicks BJ, Hall JD, Bisson PA, Sedell JR. 1991. Responses of salmonids to habitat changes. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitat. Special Publication 19 ed. Bethesda (MD): American Fisheries Society. p 483-518.

Howarth RW, Sharpley A, Walker D. 2002. Sources of nutrient pollution to coastal waters in the United States: implications for achieving coastal water quality goals. Estuaries 25(4b):656-76.

Johnson KL. 1992. Management for water quality on rangelands through best management practices: the Idaho approach. In: Naiman RJ, editor. Watershed management: balancing sustainability and environmental change. New York (NY): Springer-Verlag. p 415-41.

Karuppiah M, Gupta G. 1996. Impact of point and nonpoint source pollution on pore waters of two Chesapeake Bay tributaries. Ecotoxicology and Environmental Safety 35:81-5.

Kauffman JB, Krueger WC. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management 37(5):430-8.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Khan RA. 2004. Effect, distribution, and prevalence of *Glugea stephani* (Microspora) in winter flounder (*Pleuronectes americanus*) living near two pulp and paper mills in Newfoundland. Journal of Parasitology 90(2):229-33.

Kovacs T, Martel P, Ricci M, Michaud J, Voss R. 2005. Further insights into the potential of pulp and paper mill effluents to affect fish reproduction. Journal of Toxicology and Environmental Health 68(Part A):1621-41.

Larimore RW, Smith PW. 1963. The fishes of Champaign County, Illinois, as affected by 60 years of stream changes. Illinois Natural History Survey Bulletin 28:299-382.

Larsen PF. 1992. An overview of the environmental quality of the Gulf of Maine. In: The Gulf of Maine. Silver Spring (MD): NOAA Coastal Ocean Program Synthesis Series No. 1. p 71-95.

MacKenzie CL Jr. 1983. To increase oyster production in the northeastern United States. Marine Fisheries Review 45(3):1-22.

MacKenzie CL Jr. 2005. Removal of sea lettuce, *Ulva* sp., in estuaries to improve the environments for invertebrates, fish, wading birds, and eelgrass, *Zostera marina*. Marine Fisheries Review 67(4):1-8.

MacKenzie CL Jr. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-38.

Markham VD. 2006. U.S. national report on population and the environment. New Canaan (CT): Center for Environment and Population. 67 p.

Mercer IRG, Barker DE, Khan RA. 1997. Stress-related changes in cunner, *Tautogolabrus adspersus*, living near a paper mill. Bulletin of Environmental Contamination and Toxicology 58(3):442-7.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

[NOAA] National Oceanic and Atmospheric Administration. 1997. NOAA's estuarine eutrophication survey. Vol. 2: Mid-Atlantic Region. Silver Spring (MD): Office of Ocean Resources Conservation and Assessment. 51p.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Platts WS. 1991. Livestock grazing. In: Meehan WR, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Bethesda (MD): American Fisheries Society. Special Publication 19. p 389-423.

Scott GI, Fulton MH, Moore DW, Wirth EF, Chandler GT, Key PB, Daugomah JW, Strozier ED, Devane J, Clark JR, and others. 1999. Assessment of risk reduction strategies for the management of agricultural non-point source pesticide runoff in estuarine ecosystems. Toxicology and Industrial Health 15:200-13.

Short FT, Burdick DM, Wolf JS, Jones GE. 1993. Eelgrass in estuarine research reserves along the East Coast, U.S.A. Part I: declines from pollution and disease and Part II: management of eelgrass meadows. Silver Spring (MD): NOAA Coastal Ocean Program Publication. 107 p.

Shumway SE, Kraeuter JN, editors. 2000. Molluscan shellfish research and management: charting a course for the future. Final Proceedings from the Workshop; 2000 Jan; Charleston, SC. Washington (DC): Department of Commerce. 156 p.

Sigman M. 1985. Impacts of clearcut logging on the fish and wildlife resources of southeast Alaska. Juneau (AK): Alaska Dept. of Fish and Game, Habitat Division. Technical Report 85-3.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

[USDA] US Department of Agriculture. 2005. Land use, value, and management: urbanization and agricultural land. [Internet]. Washington (DC): Economic Research Service. [updated 2005 Jun 28; cited 2007 Dec 21]. Available from: http://www.ers.usda.gov/Briefing/LandUse/urbanchapter.htm.

[USEPA] US Environmental Protection Agency. 2002a. National water quality inventory: 2000 Report to Congress. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-R-02-001. [cited 2008 Jul 9]. Available from: http://www.epa.gov/305b/2000report/.

[USEPA] US Environmental Protection Agency. 2002b. Profile of the pulp and paper industry, 2nd ed. [Internet]. Washington (DC): US EPA Office of Compliance Sector Notebook Project. EPA-310-R-02-002. [cited 2008 Jul 24]. 135 p. Available from: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp.html.

[USEPA] US Environmental Protection Agency. 2003a. National management measures for the control of non-point pollution from agriculture. [Internet]. Washington (DC): US EPA Office of Water. EPA-841-B-03-004. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/nps/agmm/index.html.

[USEPA] US Environmental Protection Agency. 2003b. Technical support document for identification of Chesapeake Bay designated uses and attainability. [Internet]. Annapolis (MD): US EPA, Region III, Chesapeake Bay Program Office. EPA 903-R-03-004. [cited 2008 Jul 24]. 207 p. Available from: http://www.epa.gov/region03/chesapeake/uaasupport.htm.

[USEPA] US Environmental Protection Agency. 2005. National management measures to control nonpoint source pollution from urban areas. Washington (DC): US EPA Office of Water. EPA-841-B-05-004. 518 p.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). [Internet]. Hadley (MA): USFWS. [cited 2008 Jul 24]. 93 p. + appendices. Available from: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon.pdf.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

[USGS] US Geological Survey. 1999. The quality of our Nation's waters: nutrients and pesticides. [Internet]. Reston (VA): USGS Circular 1225. 82 p. [cited 2007 Dec 28]. Available from: http://pubs.usgs.gov/circ/circ1225/pdf/index.html.

Waldichuk M. 1993. Fish habitat and the impact of human activity with particular reference to Pacific salmon. In: Parsons LS, Lear WH, editors. Perspectives on Canadian marine fisheries management. Canadian Bulletin of Fisheries and Aquatic Sciences 226: 295-337.

Whitledge TE. 1985. Nationwide review of oxygen depletion and eutrophication in estuarine and coastal waters: Northeast region. Upton (NY): Brookhaven National Laboratory.

Witman JD. 1996. Dynamics of Gulf of Maine benthic communities. In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Darmouth College Regional Association for Research on the Gulf of Maine (RARGOM). Report 96-1. p 51-69.

# CHAPTER TEN: INTRODUCED/NUISANCE SPECIES AND AQUACULTURE

## Introduced/Nuisance Species

### *Introduction*

Introductions of nonnative invasive species into marine and estuarine waters are a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species can be released intentionally (i.e., fish stocking and pest control programs) or unintentionally during industrial shipping activities (e.g., ballast water releases), aquaculture operations, recreational boating, biotechnology, or from aquarium discharge (Hanson et al. 2003; Niimi 2004). Hundreds of species have been introduced into US waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001).

In New England and the mid-Atlantic region, a number of fish, crabs, bryozoans, mollusks, tunicates, and algae species have been introduced since colonial times (Deegan and Buchsbaum 2005). New introductions continue to occur, such as *Convoluta convoluta*, a small carnivorous flatworm from Europe that has invaded the Gulf of Maine (Carlton 2001; Byrnes and Witman 2003); *Didemnum* sp., an invasive species of tunicate that has invaded Georges Bank and many coastal areas in New England (Pederson et al. 2005); the Asian shore crab (*Hemigrapsus sanguineus*) that has invaded Long Island Sound, NY/CT, (Carlton 2001) and other coastal areas; and *Codium fragile* spp. *tomentosoides,* an invasive algal species from Japan that has invaded the Gulf of Maine (Pederson et al. 2005).

Introduced species may thrive best in areas where there has been some level of environmental disturbance (Vitousek et al. 1997; USFWS and NMFS 1999; Minchinton and Bertness 2003). For example, in riverine systems alteration in temperature and flow regimes can provide a niche for nonnative species to invade and dominate over native species such as salmon (USFWS and NMFS 1999). Invasive species introductions can result in negative impacts to the environment and to society, with millions of dollars being expended for research, control, and management efforts (Carlton 2001).

The impacts associated with introduced/nuisance species can involve habitat, species, and genetic-level effects. Introduced/nuisance species can impact the environment in a variety of ways, including: (1) habitat alterations; (2) trophic alterations; (3) gene pool alterations; (4) alterations to communities and competition with native species; (5) introduced diseases; (6) changes in species diversity; (7) alteration in the health of native species; and (8) impacts to water quality. The following is a review of the potential environmental impacts associated with the introduction of nonnative aquatic invasive/nuisance species into marine, estuarine, and freshwater ecosystems.

### *Habitat alterations*

Introduced species can have severe impacts on the quality of habitat (Deegan and Buchsbaum 2005). Nonnative aquatic plant species can infest water bodies, impair water quality, cause anoxic conditions when they die and decompose, and alter predator-prey relationships. Fish may be introduced into an area to graze and biologically control aquatic plant invasions. However, introduced fish may also destroy habitat, which can eliminate nursery areas for native juvenile fishes, accelerate eutrophication, and cause bank erosion (Kohler and Courtenay 1986).

Habitat has been altered by the introduction of invasive species in New England. For example, the green crab (*Carcinus maenus*) an exotic species from Europe, grazes on submerged aquatic vegeation and can interfere with eelgrass restoration efforts (Deegan and Buchsbaum 2005). *Didemnum* sp. is an invasive tunicate that has colonized the northern edge of Georges Bank, as well as many coastal areas in New England. This filter-feeding organism forms dense mats that encrust the seafloor, which can prevent the settlement of benthic organisms, reduce food availability for juvenile scallops and groundfish, and smother organisms attached to the substrate (e.g., Atlantic sea scallops [*Placopectin magellanicus*] in spat and juvenile stages) (Pederson et al. 2005; Valentine et al. 2007) and could have impacts to productive fishing grounds in New England and elsewhere. There is no evidence at this time that the spread of the tunicate on Georges Bank will be held in check by natural processes other than smothering by moving sediments; however, its offshore distribution may be limited by temperatures too low for reproduction (Valentine et al. 2007).

An invasive species of algae from Japan, *Codium fragiles* spp. *tomentosoides*, also referred to as deadman's fingers, has invaded subtidal and intertidal marine habitats in the Gulf of Maine and mid-Atlantic. Deadman's fingers can outcompete native kelp and eelgrass, thus destroying habitat for finfish and shellfish species (Pederson et al. 2005). The common reed (*Phragmites australis*) a nonnative marsh grass, has invaded coastal estuaries and can exclude native brackish and salt marsh plant species such as smooth cordgrass (*Spartina alterniflora*) from their historic habitat (Burdick et al. 2001; Minchinton and Bertness 2003; Deegan and Buchsbaum 2005). *Phragmites* invasions can increase the sedimentation rate in marshes and reduce intertidal habitat available for fish species in New England (Deegan and Buchsbaum 2005).

### *Trophic alterations and competition with native species*

Introduced species can alter the trophic structure of an ecosystem via increased competition for food and space between native and nonnative species (Kohler and Courtenay 1986; Caraco et al. 1997; Strayer et al. 2004; Deegan and Buchsbaum 2005) as well as through predation by introduced species on native species (Kohler and Courtenay 1986). Competition may result in the displacement of native species from their habitat or a decline in recruitment, which are factors that can collectively contribute to a decrease in population size (Kohler and Courtenay 1986). For example, introductions of the invasive zebra mussel (*Dreissena polymorpha*) in the Hudson River, NY/NJ, estuary coincided with a decline in the abundance, decreased growth rate, and a shift in the population distribution of commercially and recreationally important species (Strayer et al. 2004). Zebra mussels have altered trophic structure in the Hudson River estuary by withdrawing large quantities of phytoplankton and zooplankton from the water column, thus competing with planktivorous fish. Phytoplankton is the basis of the food web, and altering the trophic levels at the bottom of the food web could have a detrimental, cascading effect on the aquatic ecosystem. Increased competition for food between the zebra mussel and open-water commercial and recreational species such as the American shad (*Alosa sapidissima*) and black sea bass (*Centropristis striata*) has been associated with large, pervasive alterations in young-of-the-year fish, which can result in interspecies competition and alterations in trophic structure (Strayer et al. 2004; Deegan and Buchsbaum 2005).

Predation on native species by nonnative species may increase the mortality of a species and could also alter the trophic structure (Kohler and Courtenay 1986). Whether the predation is on the eggs, juveniles, or adults, a decline in native forage species can affect the entire food web (Kohler and Courtenay 1986). For example, the Asian shore crab invaded Long Island Sound and has an aggressive predatory behavior and voracious appetite for crustaceans, mussels, young clams, barnacles, periwinkles, polychaetes, macroalgae, and salt marsh grasses. The removal of the forage base by this invasive crab could have a ripple effect throughout the food web that could restructure communities along the Atlantic coast (Tyrrell and Harris 2000; Brousseau and Baglivo 2005).

### *Alterations to communities*

Introductions of nonnative species may result in alterations to communities and an increase in competition for food and habitat (Deegan and Buchsbaum 2005). For example, the green crab is an exotic species from Europe which preys on native soft-shelled clams and newly settled winter flounder (*Pseudopleuronectes americanus*) (Deegan and Buchsbaum 2005).

Nonnative marsh grass introductions can alter habitat conditions, resulting in changes in the fauna of salt marsh habitat. Alterations to communities have been noted in areas in which native marsh cordgrass habitat has been invaded by the invasive, exotic *Phragmites* (Posey et al. 2003). *Phragmites* has been implicated in alteration of the quality of intertidal habitats, including: lower abundance of nekton in *Phragmites* habitat; reduced utilization of this habitat by other species during certain life stages (Weinstein and Balletto 1999; Able and Hagan 2000); decreased density of gastropods, oligochaetes, and midges (Posey et al. 2003); decreased bird abundance and species richness (Benoit and Askins 1999); and avoidance of *Phragmites* by juvenile fishes (Weis and Weis 2000).

### *Gene pool alterations*

Native species may hybridize with introduced species that have a different genetic makeup (Kohler and Courtenay 1986), thus weakening the genetic integrity of wild populations and decreasing the fitness of wild species via breakup of gene combinations (Goldburg et al. 2001). Aquaculture operations have the potential to be a significant source of nonnative introductions into North American waters (Goldburg and Triplett 1997; USCOP 2004). Escaped aquaculture species can alter the genetic characteristics of wild populations when native species interbreed with escaped nonnative or native aquaculture species (USFWS and NMFS 1999).

In the Gulf of Maine, the wild Atlantic salmon (*Salmo salar*) population currently exhibits poor marine survival and low spawning stock and is in danger of becoming extinct, which makes the species particularly vulnerable to genetic modification via interbreeding with escaped aquaculture species. Any genetic modification combined with other threats such as reduced water levels, parasites and diseases, commercial and recreational fisheries, loss of habitat, poor water quality, and sedimentation may threaten or potentially extirpate the wild salmon stock in the Gulf of Maine (USFWS and NMFS 1999). Refer to the Aquaculture section of this chapter for a more detailed discussion on impacts from aquaculture operations.

### *Introduced diseases*

Introduced aquatic species are often vectors for disease transmittal that represent a significant threat to the integrity and health of native aquatic communities (Kohler and Courtenay 1986). Bacteria, viruses, and parasites may be introduced advertently or inadvertently and can reduce habitat quality (Hanson et al. 2003). The introduction of pathogens can have lethal or sublethal effects on aquatic organisms and has the potential to impair the health and fitness level of wild fish populations. Sources of introduced pathogens include industrial shipping, recreational boating, dredging activities, sediment disposal, municipal and agricultural runoff, wildlife feces, septic systems, biotechnology labs, aquariums, and transfer of oyster spat and other species to new areas for aquaculture or restoration purposes (ASMFC 1992; Boesch et al. 1997).

Parasite and disease introductions into wild fish and shellfish populations can be associated with aquaculture operations. These diseases have the potential to lower the fitness level of native species or contribute to the decline of native populations (USFWS and NMFS 1999). Examples include the MSX (multinucleated sphere unknown) oyster disease introduced through the Pacific oyster (*Crassostrea gigas*) which contributed to the decline of native oyster (*Crassostrea virginica*) populations in Delaware Bay, DE/NJ, and Chesapeake Bay, MD/VA, (Burreson et al. 2000; Rickards and Ticco 2002) and the Infectious Salmon Anemia (ISA) that has spread from salmon farms in New Brunswick, Canada, to salmon farms in Maine (USFWS and NMFS 1999). Refer to the Aquaculture section of this chapter for more information regarding diseases introduced through aquaculture operations.

### *Changes in species diversity*

Introduced species can rapidly dominate a new area and can cause changes within species communities to such an extent that native species are forced out of the invaded area or undergo a decline in abundance, leading to changes in species diversity (Omori et al. 1994). For example, changes in species distribution have been seen in the Hudson River, where the invasion of zebra mussels caused localized changes in phytoplankton levels and trophic structure that favored littoral zone species over open-water species. The zebra mussel invasion resulted in a decline in abundance of open-water fishes (e.g., American shad) and an increase in abundance for littoral zone species (e.g., sunfishes) (Strayer et al. 2004). Shifts in the distribution and abundance of species caused by introduced species can effect the diversity of species in an area.

Alterations in species diversity have been noted in areas in which native *Spartina alterniflora* habitat has been invaded by the exotic haplotype, *Phragmites australis* (Posey et al. 2003). *Phragmites* can rapidly colonize a marsh area, thus changing the species of marsh grass present at that site. In addition, *Phragmites* invasions have been shown to change species use patterns and abundance at invaded sites, potentially causing a cascading of effects to the species richness and diversity of a community.

Benthic species diversity can be altered by the introduction of shellfish for aquaculture purposes (Kaiser et al. 1998) and for habitat restoration projects. Cultivation of shellfish such as hard clams often requires the placement of gravel or crushed shell on the substrate. Changes in benthic structure can result in a shift in the community at that site (e.g., from a polychaete to a bivalve and nemertean dominated benthic community) which may have the effect of reduced diversity (Simenstad and Fresh 1995; Kaiser et al. 1998). However, community diversity may be enhanced by the introduction of aquaculture species and/or the modification of the substrate (Simenstad and Fresh 1995). In addition, changes in species diversity may occur as a result of oyster habitat restoration. Oyster reefs provide habitat for a variety of resident and transient species (Coen et al. 1999), so restoration activities that introduce oysters into an area may result in localized changes in species diversity, as reef-building organisms and fish are attracted to the restoration site. Refer to the section on Aquaculture of this chapter for more information regarding altered species diversity caused by aquaculture activities.

### *Alterations in the health of native species*

The health of native species can be impaired by the introduction of new species into an area. A number of factors may contribute to reduced health of native populations, including: (1) competition for food may result in a decrease in the growth rate and local abundance (Strayer et al. 2004) or the decline in the entire population (USFWS and NMFS 1999) of native species; (2) aggressive and fast growing nonnative predators can reduce the populations of native species (Pederson et al. 2005); (3) diseases represent a significant threat to the integrity and health of native aquatic communities and can decrease the sustainability of the native population (Kohler and

Courtenay 1986; USFWS and NMFS 1999; Rickards and Ticco 2002; Hanson et al. 2003); and (4) the genetic integrity of native species may be compromised through hybridization with introduced species (Kohler and Courtenay 1986), which can also decrease the fitness of wild species via breakup of gene combinations (Goldburg et al. 2001). The factors listed above, in combination with potential impact on the habitats of native species, can collectively result in long-term impacts to the health of native species (Burdick et al. 2001; Minchinton and Bertness 2003; Deegan and Buchsbaum 2005; Pederson et al. 2005).

### *Impacts to water quality*

Invasive species can affect water quality in marine, estuarine, and riverine environments because they have the potential to outcompete native species and dominate habitats. For example, nonnative aquatic plant species, which may not have natural predators in their new environments, can proliferate within water bodies, impair water quality, and cause anoxic conditions when they die and decompose. Fish species such as grass carp (*Ctenopharyngodon idella*) and tilapia (Cichlidae), introduced to control noxious weeds, can accelerate eutrophication through fecal decomposition of nutrients previously stored in the plants (Kohler and Courtenay 1986). In addition, fish introduced to control invasive plant species can increase turbidity in the water column from the grazing behavior itself (Kohler and Courtenay 1986).

Introduced nonnative algal species from anthropogenic sources such as ballast water and shellfish transfer (e.g., seeding) combined with nutrient overloading may increase the intensity and frequency of algal blooms. An overabundance of algae can degrade water quality when they die and decompose, which depletes oxygen levels in an ecosystem. Oxygen depletion can result in ecological “dead zones,” reduced light transmittance in the water column, seagrass and coral habitat degradation, and large-scale fish kills (Deegan and Buchsbaum 2005).

### *Conservation measures and best management practices for impacts on aquatic habitats from introduced/nuisance species*

1. Do not introduce exotic species for aquaculture purposes unless a thorough scientific evaluation and risk assessment is performed. Aquaculturist should be encouraged to only culture native species in open-water operations.
2. Prevent or discourage boaters, anglers, aquaculturists, traders, and other potential handlers of introduced species from accidental or purposeful introduction of species into ecosystems where these species are not native. In addition, measures should be taken to prevent the movement or transfer of exotic species into other waters.
3. Encourage vessels to perform a ballast water exchange in marine waters (in accordance with the US Coast Guard’s voluntary regulations) to minimize the possibility of introducing exotic species into estuarine habitats. Ballast water taken on in marine waters will contain fewer organisms, and these organisms will be less likely to become invasive in estuarine conditions than are species transported from other estuaries.
4. Discourage vessels that have not performed a ballast water exchange from discharging their ballast water into estuarine receiving waters.
5. Require vessels brought from other areas over land via trailering to clean any surfaces that may harbor nonnative plant or animal species (e.g., propellers, hulls, anchors, fenders). Bilges should be emptied and cleaned thoroughly with hot water or a mild bleach solution. These activities should be performed in an upland area to prevent introduction of nonnative species to aquatic environments during the cleaning process.

6. Encourage natural resource managers to provide outreach materials on the potential impacts resulting from releases of nonnative species into the natural environment.
7. Limit importation of ornamental fishes to licensed dealers.
8. Use only local, native fish for live seafood or bait.
9. Encourage natural resource managers to identify areas where invasive species have become established at an early time in the infestation and pursue efforts to remove them, either manually or by other methods.
10. Encourage natural resource managers to identify methods that eradicate or reduce the spread of invasive species (e.g., reducing *Phragmites* in coastal marshes by mitigating the effects of tidal restrictions).
11. Treat effluent from public aquaria displays, laboratories, and educational institutes that are using exotic species prior to discharge for the purpose of preventing the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.

# Aquaculture

## *Introduction*

Aquaculture is defined as the controlled cultivation and harvest of aquatic organisms, including finfish, shellfish, and aquatic plants (Goldburg et al. 2001, 2003). Aquaculture operations are conducted at both land and water facilities. Land-based aquaculture systems include ponds, tanks, raceways, and water flow-through and recirculating systems. Water-based aquaculture systems include netpens, cages, ocean ranching, longline culture, and bottom culture (Goldburg and Triplett 1997).

Aquaculture can provide a number of socio-economic benefits, including food provision, improved nutrition and health, generation of income and employment, diversification of primary products, and increased trade earnings through the export of high-value products (Barg 1992). Aquaculture can also provide environmental benefits by supporting stocking and release of hatchery-reared organisms, countering nutrient and organic enrichment in eutrophic waters from the culture of some mollusk and seaweed species, and because aquaculture operations relies on good water quality, the prevention and control of aquatic pollution (Barg 1992).

However, freshwater, estuarine, and marine aquaculture operations have the potential to adversely impact the habitat of native fish and shellfish species. The impact of aquaculture facilities varies according to the species cultured, the type and size of the operation, and the environmental characteristics of the site. Intensive cage and floating netpen systems typically have a greater impact because aquaculture effluent is released directly into the environment. Pond and tank systems are less harmful to the environment because waste products are released in pulses during cleaning and harvesting activities rather than continuously into the environment (Goldburg et al. 2001). The relative impact of finfish and shellfish aquaculture differs depending on the foraging behavior of the species. Finfish require the addition of a large amount of feed into the ecosystem, which can result in environmental impacts impacts from the introduction of the feed, but also from the depletion of species harvested to provide the feed. Bivalves are filter feeders and typically do not require food additives; however, fecal deposition can result in benthic and pelagic habitat impacts, changes in trophic structure (Kaspar et al. 1985; Grant et al. 1995), and nutrient and phytoplankton depletion (Dankers and Zuidema 1995).

Similar to the introduced/nuisance species section of this chapter, aquaculture activities can effect fisheries at both a habitat and species-level. Typical environmental impacts resulting from aquaculture production include: (1) impacts to the water quality from the discharge of organic wastes and contaminants; (2) seafloor impacts; (3) introductions of exotic invasive species; (4) food web impacts; (5) gene pool alterations; (6) changes in species diversity; (7) sediment deposition; (8) introduction of diseases; (9) habitat replacement or exclusion; and (10) habitat conversion. The following is a review of the known and potential environmental impacts associated with the cultivation and harvest of aquatic organisms in land- and water-based aquaculture facilities.

### *Discharge of organic wastes*

Aquaculture operations can degrade the quality of the water column and the benthic environment via the discharge of organic waste and other contaminants (Goldburg et al. 2001; USCOP 2004). Organic waste includes uneaten fish food, urine, feces, mucus, and byproducts of respiration, which can have an adverse effect on both benthic and pelagic organisms when released into marine, estuarine, and riverine environments.

Uneaten fish food can contribute a significant amount of nutrients to the ecosystem at aquaculture sites (Kelly 1992; Goldburg and Triplett 1997). Farmed fish are typically fed "forage fish" of low economic value, such as anchovies (Engraulidae) and menhaden (*Brevoortia* sp.), which are either fed directly to aquaculture species or processed into dry feed pellets. However, these "forage fish," while having low economic value, may be highly important to other species and the aquatic ecosystem. A large percentage of nutrients contained in farmed fish food are lost to the environment through organic waste. As much as 80% of total nitrogen and 70% of total phosphorus fed to farmed fish may be released into the water column through fish wastes (Goldburg et al. 2001).

In New England, the majority of aquaculture operations are located in Maine, with Cobscook Bay being the primary site of finfish aquaculture operations. Recent research in Cobscook Bay and in neighboring waters of New Brunswick, Canada, has shown the primary sources of nutrients in the area are finfish aquaculture operations and the open ocean (Goldburg et al. 2001). Research conducted at an aquaculture facility with 200,000 salmon has revealed that the amount of nitrogen, phosphorus, and feces discharged from the facility are equivalent to that released from untreated sewage produced by 20,000, 25,000, and 65,000 people, respectively (Goldburg et al. 2001).

The release of high concentrations of nutrients can negatively affect an aquatic system through eutrophication. Eutrophication of an aquatic system can occur when nutrients, such as nitrogen and phosphorus, are released in high concentrations and over long periods of time. Eutrophication can stimulate the growth of algae and other primary producers and, in some cases, may develop into "algal blooms" (Hopkins et al. 1995; Goldburg et al. 2001; Deegan and Buchsbaum 2005). Although the effects of eutrophication are not necessarily always adverse, they are often extremely undesirable and include: (1) increased incidence, extent, and persistence of noxious or toxic species of phytoplankton; (2) increased frequency, severity, spatial extent, and persistence of low oxygen conditions; (3) alteration in the dominant phytoplankton species and the nutritional-biochemical "quality" of the phytoplankton community; and (4) increased turbidity of the water column because of the presence of algae blooms (O'Reilly 1994).

Oxygen can be depleted in the water column during bacterial degradation of algal tissue or when algal respiration exceeds oxygen production and can result in hypoxic or anoxic "dead zones," reduced water clarity, seagrass habitat degradation, and large-scale fish kills (Deegan and Buchsbaum 2005). Algal blooms may contain species of phytoplankton such as dinoflagellates that can produce toxins, cause toxic blooms (e.g., red tides), kill large numbers of fish, contaminate shellfish beds, and cause health problems in humans. Coastal and estuarine ecosystems in the United States are already moderately to severely eutrophic (Goldburg et al. 2001; Goldburg and

Triplett 1997) and are expected to worsen in 70% of all coastal areas over the next two decades (USEPA 2001). Consequently, the frequency and severity of toxic algal blooms could increase in the future. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for more information on eutrophication and harmful algal blooms.

### *Discharge of contaminants*

In addition to organic waste, chemicals and other contaminants that are discharged as part of the aquaculture process can affect benthic and pelagic organisms (Hopkins et al. 1995; Goldburg and Triplett 1997). Chemicals are typically released directly into the water, including antibiotics that fight disease; pesticides that control parasites, algae, and weeds; hormones that initiate spawning; vitamins and minerals to promote fish growth; and anesthetics to ease handling of fish during transport. These chemical agents are readily dispersed into marine, estuarine, and freshwater systems and can be harmful to natural communities. Few chemicals have been approved for disease treatment in US aquaculture operations, although veterinarians can prescribe human and animal drugs use in food fish (Goldburg et al. 2001).

Antibiotics are given to fish and shrimp via injections, baths, and oral treatments (Hopkins et al. 1995; Goldburg and Triplett 1997). The most common method of oral administration is the incorporation of drugs into feed pellets, which results in a greater dispersion of antibiotics in the marine environment. Antibiotics, including those toxic to humans, typically bind to sediment particles, may remain in the environment for an extended period of time, can accumulate in farmed and wild fish and shellfish populations, and can harm humans when ingested.

Herbicides are chemicals used to control aquatic weeds in freshwater systems, and algicides are herbicides specifically formulated to kill algae; dissolved oxygen levels in ponds can be reduced when the algae die and decompose. A common ingredient in algicides is copper, which is toxic to aquatic organisms. Applications of herbicides or algicides must be carefully considered for their toxicity to aquaculture organisms and to humans, as well as their tendency to bioaccumulate in fish and shellfish tissues (Goldburg and Triplett 1997). While these chemicals may not be applied within riverine or estuarine systems, they may find their way there through stormwater runoff. Pesticides must also be carefully monitored for their effects on aquatic organisms and habitat. For example, antifouling compounds such as copper and organic tin compounds were historically used in the aquaculture industry to prevent fouling organisms from attaching to aquaculture structures. These chemicals accumulate in farmed and wild organisms, especially in shellfish species, and the use of organic tin compounds is now banned for use in both Washington and Maine. Aquaculturalists have used the insecticide, Sevin, for 35 years in Willapa Bay, WA, to control burrowing shrimp that destabilize sediment. Sevin kills other organisms such as the Dungeness crab (*Cancer magister*), and it should be used in moderation to minimize the impacts of the aquaculture industry on other important commercial fisheries (Goldburg and Triplett 1997). For additional information on the release of pesticides, refer to the Agriculture and Silviculture and Coastal Development chapters of this report.

### *Seafloor impacts*

Aquaculture operations not only can cause environmental impacts through the discharge of contaminants and organic wastes, but these operations can also affect the seafloor as a result of the deposition of waste products, the placement of aquaculture structures on the seafloor, and the harvesting of aquaculture species.

Aquaculture operations can have a wide range of biological, chemical, and physical impacts on seafloor habitat stemming from organic material deposition, shading effects, damage to habitat from aquaculture structures and operations, and harvesting with rakes and dredges (USFWS and NMFS 1999; Goldburg et al. 2001). Organic material deposition beneath netpens and cages can smother organisms, change the chemical and biological structure of sediment, alter species biomass and diversity, and reduce oxygen levels. The physical and chemical conditions present at the aquaculture site will influence the degree to which organic waste affects the benthic community. At aquaculture sites with slower currents and softer sediments, benthic community impacts will generally be localized; whereas sites with stronger currents and coarser sediments will generally have widely distributed but less intense benthic community effects downstream of the site.

At both land-based and water-based aquaculture facilities, accumulations of large amounts of carbon and nutrient-rich sediment may produce anaerobic conditions in sediments and cause the release of hydrogen sulfide and methane, two gases toxic to fish (Goldburg and Triplett 1997). In Maine, seafloor impacts resulting from sediment deposition at salmon farms include the growth of the bacterial mold *Beggiatoa* sp., which degrades water quality and subsequently lowers species diversity and biomass beneath the pens (Goldburg and Triplett 1997).

Suspended shellfish culture techniques may cause changes in benthic community structure similar to those conditions found under netpens. Filter-feeding shellfish "package" phytoplankton and other food particles into feces and pseudofeces, which are deposited on the seafloor and may cause local changes in benthic community structure (Grant et al. 1995; Goldburg and Triplett 1997). In Kenepuru Sound, New Zealand, a mussel aquaculture site consistently showed a higher organic nitrogen pool than at the reference site, indicating that organic nitrogen was accumulating in the sediments below the mussel farm (Kaspar et al. 1985). The benthic community at the mussel farm was composed of species adaptable to low-oxygen levels that live in fine-textured, organically rich sediments, while the reference site consisted of species that typically reside in highly oxygenated water (Kaspar et al. 1985).

Aquaculture structures can have direct impacts on seafloor habitat, including shading of seafloor habitat by netpens and cages (NEFMC 1998; USFWS and NMFS 1999). Shading can impede the growth of SAV that provides shelter and nursery habitat to fish and their prey species (Barnhardt et al. 1992; Griffin 1997; Deegan and Buchsbaum 2005). Seagrasses and other sensitive benthic habitats may also be impacted by the dumping of shells onto the seafloor for use in shellfish aquaculture operations (Simenstad and Fresh 1995). Shell substratum helps to stabilize the benthos and improve growth and survival of the cultured shellfish species. The placement of this material on the bottom not only causes a loss in seagrass and other habitat, but substrate modification also induces a localized change in benthic community composition (Simenstad and Fresh 1995).

Harvesting practices also have the potential to adversely affect seafloor habitat. Perhaps the most detrimental is the mechanical harvesting of shellfish (e.g., the use of dredges). Polychaete worms and crustaceans may be removed or buried during dredging activities (Newell et al. 1998). Mechanical harvesting of shellfish may also adversely affect benthic habitat through direct removal of seagrass and other reef-building organisms (Goldburg and Triplett 1997).

### *Introductions of exotic invasive species*

Aquaculture operations have the potential to be a significant source of nonnative introductions into North American waters (Goldburg and Triplett 1997; USCOP 2004). The cultivation of nonnative species becomes problematic when fish escape or are intentionally released into the marine environment. As discussed in the above section on introduced/nuisance species, introduced species can reduce biodiversity, alter species composition, compete with native species for food and habitat, prey on native species, inhibit reproduction, modify or destroy habitat, and introduce new parasites or diseases into an ecosystem (Goldburg and Triplett 1997; USFWS and

NMFS 1999). Impacts from introduced aquaculture species may result in the displacement or extinction of native species, which is believed to be a contributing factor in the decline of seven endangered or threatened fish species populations listed under the Endangered Species Act (Goldburg and Triplett 1997).

In Maine, escaped aquaculture salmon can disrupt redds (i.e., spawning nests) of wild salmon, transfer disease or parasites, compete for food and habitat, and interbreed with wild salmon (USFWS and NMFS 1999). Escaped aquaculture salmon represent a significant threat to wild salmon in Maine because even at low levels of escapement, aquaculture salmon can represent a large proportion of the salmon returns in some rivers. Escaped Atlantic salmon have been documented in the St. Croix, Penobscot, East Machias, Dennys, and Narraguagus rivers in Maine. Escapees represented 89% and 100% of the documented runs for the Dennys River in 1994 and 1997, respectively, and 22% of the documented run for the Narraguagus River in 1995 (USFWS and NMFS 1999). In 2000, only 22 wild Atlantic salmon in Maine were documented as returning to spawn in their native rivers; however, total adult returning spawners may have numbered approximately 150 fish (Goldburg et al. 2001).

Cultivating a reproductively viable European stock of Atlantic salmon in Maine waters poses a risk to native populations because of escapement and the subsequent interbreeding of genetically divergent populations (USFWS and NMFS 1999). The wild Atlantic salmon population in the Gulf of Maine currently exhibits poor marine survival and low spawning stock size, is particularly vulnerable to genetic modification, and is in danger of becoming extinct. Dilution of the gene pool, when combined with environmental threats such as reduced water levels, parasites and diseases, commercial and recreational fisheries, loss of habitat, poor water quality, and sedimentation could extirpate the wild salmon stock in the Gulf of Maine (USFWS and NMFS 1999). For additional discussions on this topic, refer to the subsection in this chapter on Gene Pool Alterations.

### *Food web impacts*

Aquaculture operations have the potential to impact food webs via localized nutrient loading from organic waste and by large-scale removals of oceanic fish for dry-pellet fish feed (Goldburg and Triplett 1997). As reviewed in previous sections of this chapter, nutrients in discharged organic waste may affect local populations by changing community structure and biodiversity. These localized changes may have broader implications to higher trophic level organisms. For example, biosedimentation at a mussel aquaculture site had a strong effect on benthic community structure both below and adjacent to mussels grown on rafts (Kaspar et al. 1985). Benthic species located beneath and adjacent to mussel rafts included sponges, tunicates, and calcareous polychaete worms, while benthic species at the reference site included bivalve mollusks, brittle stars, crustaceans, and polychaete worms. The shift in benthic community structure at the shellfish aquaculture site may have had implications in higher trophic levels in the ecosystem.

Large-scale removals of anchovy, herring, sardine, jack mackerel, and other pelagic fishes for the production of fish feed has an impact on the food web. Approximately 27% (31 million metric tons) of the world's fish harvest is now used to produce fish feeds, and about 15% of this is used in aquaculture production (Goldburg and Triplett 1997). Feeding fish to other fish on a commercial scale is highly energy-inefficient and may have environmental implications and impacts on other species. Higher trophic levels depend on small pelagic fishes for growth and survival, so the net removal of protein can have significant effects on sea birds, mammals, and commercially important fish species (Goldburg and Triplett 1997).

## *Gene pool alterations*

Escaped aquaculture species can alter the genetic characteristics of wild populations when native species interbreed with escaped nonnative or native aquaculture species or escaped genetically engineered aquaculture species (USFWS and NMFS 1999; Goldburg et al. 2001; USCOP 2004). Interbreeding of the wild population with escaped nonnative species is problematic, as discussed in the Introduced/Nuisance Species section of this chapter. Interbreeding of the wild population with escaped, native species may also be problematic because of the genetic differences between the escaped native and the wild native populations. Aquaculture operations often breed farmed fish for particular traits, such as smaller fins, aggressive feeding behavior, and larger bodies. Therefore, the genetic makeup of escaped native and wild native fish may be different, and interbreeding may decrease the fitness of wild populations through the breakup of gene combinations and the loss of genetic diversity (Goldburg et al. 2001).

Atlantic salmon aquaculture in New England has been established from Cape Cod, MA, north to Canada, although most of this activity is clustered at the Maine-New Brunswick border. In 1994, thousands of Atlantic salmon escaped from an aquaculture facility during a storm event; many of these fish spread into coastal rivers in eastern Maine (Moring 2005). In 2000, a similar storm event in Maine resulted in the escapement of 100,000 salmon from a single farm, which is more than 1,000 times the documented number of native adult Atlantic salmon. Canada is experiencing similar problems with aquaculture escapees and the interbreeding of wild and farmed salmon populations. In 1998, 82% of the young salmon leaving the Magaguadavic River in New Brunswick originated from aquaculture farms (Goldburg et al. 2001). Escapees can and do breed with wild populations of Atlantic salmon, which is a concern because interbreeding can alter the genetic makeup of native stocks (Moring 2005).

Escaped genetically engineered aquaculture species may exacerbate the problem of altering the gene pool of native fish stocks. Genetically engineered (i.e., transgenic) species are being developed by inserting genes from other species into the DNA of fish for the purpose of altering performance, improving flesh quality, and amplifying traits such as faster growth, resistance to diseases, and tolerance to freezing temperatures (Goldburg and Triplett 1997; Goldburg et al. 2001). For example, genetically engineered Atlantic salmon have an added hormone from chinook salmon that promotes faster growth, which may reduce costs for growers (Goldburg et al. 2001, 2003). Although no transgenic fish products are commercially available in the United States, at least one company has applied for permission through the Food and Drug Administration to market a genetically-engineered Atlantic salmon for human consumption (Goldburg et al. 2001, 2003). Transgenic aquaculture escapees could impair wild Atlantic salmon stocks via competition, predation, and expansion into new regions. Interbreeding could weaken the genetic integrity of wild salmon populations and have long-term, irreversible ecological effects (Goldburg et al. 2001).

## *Impacts to the water column and water quality*

Aquaculture may impact the water column via organic and contaminant discharge from land- and water-based aquaculture sites (NEFMC 1998). As discussed in other sections of this chapter, aquaculture discharges include nutrients, toxins, particulate matter, metabolic wastes, hormones, pigments, minerals, vitamins, antibiotics, herbicides, and pesticides. Water quality in the vicinity of finfish aquaculture operations may be impaired by the discharge of these compounds. The water column may become turbid as a result of this discharge, which can degrade overall habitat conditions for fish and shellfish in the area. Discharge may contribute to nutrient loading, which may lead to eutrophic conditions in the water column. Eutrophication often results in oxygen depletion, finfish and shellfish kills, habitat degradation, and harmful algal blooms that may impact human health.

Shellfish aquaculture operations have the potential to improve water quality by filtration of nutrients and suspended particles from the water column (Newell 1988). However, bivalves may contribute to the turbidity of the pelagic environment via their waste products (Kaspar et al. 1985; Grant et al. 1995). These waste products are expelled as feces and pseudofeces, which can be suspended into the water column, thus contributing to nutrient loads near aquaculture sites. Nutrient overenrichment often results in oxygen depletion, toxic gas generation, and harmful algal blooms, thus impairing the water quality near shellfish aquaculture sites. Therefore, both finfish and shellfish aquaculture operations have the potential to adversely affect water quality beneath aquaculture structures and in the surrounding environment. For additional information on discharge of nutrients and its subsequent effects on the water column via eutrophication and algal blooms, see the subsections on the Discharge of Organic Wastes and Discharge of Contaminants in this chapter, as well as the chapters on Agriculture and Silviculture, Coastal Development, and Alteration of Freshwater Systems of this report.

### *Changes in species diversity*

Species diversity and abundance may change in the vicinity of aquaculture farms as a result of effluent discharges or habitat modifications that alter environmental conditions. Changes in species diversity may occur through increased organic waste in pelagic and benthic environments, modification to bottom habitat, and the attraction of predators to the farmed species. Accumulated organic waste beneath aquaculture structures may change benthic community structure. In Maine, salmon netpen aquaculture can alter the benthos by shifting microbial and macrofaunal species to those adapted to enriched organic sediments. At one netpen site, epibenthic organisms were more numerous near the pen than at reference sites, suggesting that benthic community structure can be altered by salmon aquaculture in coastal Maine waters (Findlay et al. 1995).

Cultivated mussels can alter species diversity via biodeposition. Benthic habitat can shift from communities of bivalve mollusks, brittle stars, crustaceans, and polychaete worms to communities of sponges, tunicates, and calcareous polychaete worms beneath mussel aquaculture sites. The difference between the two sites represents a change in species diversity from those that typically reside in highly oxygenated water to those species adaptable to low-oxygen levels that can live in areas with fine-textured, organically rich sediments (Kaspar et al. 1985).

Benthic habitat modification at shellfish aquaculture sites can alter species diversity (Kaiser et al. 1998). Cultivation of shellfish such as hard clams requires the placement of gravel or crushed shell on the substrate. Seed clams are placed on the substrate in bags or directly on substrate covered with protective plastic netting. Benthic structure at shellfish aquaculture sites can therefore shift from polychaete-dominated communities to bivalve and nemertean-dominated communities, which could have repercussions for other trophic levels (Simenstad and Fresh 1995; Kaiser et al. 1998). However, community diversity may be enhanced by the introduction of aquaculture species and the modification of the substrate. For example, the placement of gravel in the intertidal area, the placement of substrates suitable for macroalgal attachment, or predator exclusion nets in some habitats may enhance epibenthos diversity and standing stock (Simenstad and Fresh 1995).

Open water netpens may alter species diversity by attracting wild fish or other predators to the aquaculture site (Vita et al. 2004). Wild benthic and pelagic species are attracted to uneaten pellet feed and other discharged effluent, which can result in impacts to the food web (Vita et al. 2004). Predators such as seals, sea lions, and river otters may also be attracted to aquaculture pens to feed on farmed species, which can alter communities in the vicinity of aquaculture sites (Goldburg et al. 2001).

### *Sediment deposition*

The effects of sediment deposition include eutrophication of the water column; toxic algal blooms; hypoxic or anoxic zones caused by microbial degradation; and the spread of contaminants such as antibiotics, herbicides, pesticides, hormones, pigments, minerals, and vitamins. The impacts of sediment deposition from discharged organic waste and contaminants on the water column and on the seafloor have been discussed in the Discharge of Organic Wastes, Discharge of Contaminants, Seaflood Impacts, Food Web Impacts, Changes in Species Diversity, and Habitat Exclusion and Replacement/Conversion subsections of this chapter.

### *Introduction of diseases*

Parasite and disease introductions into wild fish and shellfish populations are often associated with aquaculture operations and have the potential to lower the fitness level of native species or contribute to the decline of native populations. For example, in the 1940s and 1950s, scientists inadvertently introduced a new disease into eastern US waters when they attempted to restore declining populations of the eastern oyster (*Crassostrea virginica*) via the introduction of the Pacific oyster (*Crassostrea gigas*) (Burreson et al. 2000; Rickards and Ticco 2002). *Haplosporidium nelsoni* is a protistan parasite that causes MSX oyster disease and was present amongst the Pacific oysters introduced in east coast waters. MSX spread from Delaware Bay to the Chesapeake Bay and contributed to the decline in the native oyster population. MSX and another pathogenic disease, Dermo (*Perkinsus marinus*), have collectively decimated the native oyster population remaining along the much of the eastern US coast (Rickards and Ticco 2002).

In eastern Maine and New Brunswick, an outbreak of two diseases in both wild and cultured stocks of Atlantic salmon suggests that cultured stocks are acting as reservoirs of diseases and are now passing them on to wild stocks (Moring 2005). In addition to diseases, sea lice are a flesh-eating parasite that has been passed from farmed salmon to wild salmon when wild salmon migrate through coastal waters. Sea lice also can serve as a host for Infectious Salmon Anemia (ISA), which is a virus that has spread from salmon farms in New Brunswick to salmon farms in Maine (USFWS and NMFS 1999). The ISA virus causes fatalities in salmon at aquaculture facilities, and this virus has been detected in both escaped farmed salmon and wild salmon populations. ISA first appeared in New Brunswick in 1996, was detected in the United States in 2001, and represents a significant threat to wild salmon populations (Goldburg et al. 2001).

### *Habitat exclusion and replacement/conversion*

Aquaculture operations require the use of space, which results in the conversion of natural aquatic habitat that could have been used by native organisms for spawning, feeding, and growth. Approximately 321,000 acres of fresh water habitat and 64,000 acres of salt-water habitat have been converted for use in aquaculture operations in the United States (Goldburg et al. 2001). Aquaculture facilities may exclude aquatic organisms from their native habitat through the placement of physical barriers to entry or through changes in environmental conditions at aquaculture sites. Nets, cages, concrete, and other barriers exclude aquatic organisms from entering the space in which the aquaculture structures are placed. By effectively acting as physical barriers for wild populations, these formerly usable areas are no longer available as habitat for fish and shellfish species to carry out their life cycles. Aquaculture facilities may physically exclude wild stocks of fish, such as Atlantic salmon, from reaching critical spawning habitat upstream of the facilities (Goldburg et al. 2001).

Changes in environmental conditions at the aquaculture site may also exclude aquatic organisms from their native habitat. Discharge of organic waste and contaminants beneath aquaculture netpens and cages may render pelagic and benthic habitat unusable through nutrient loading and the subsequent effects of eutrophication. Low dissolved oxygen caused by eutrophication may force native species out of their habitat, while harmful algal blooms can cause widespread fish kills or exclude fish from areas affected by the outbreak (Goldburg and Triplett 1997). In the case of large shellfish aquaculture operations, filtering bivalves can also decrease the amount and type of nutrients and phytoplankton available to other species. This reduction in nutrients and phytoplankton can stimulate competition between populations of cultured and native species (Dankers and Zuidema 1995). Nutrient and phytoplankton removal could have a cascade effect on the trophic structure of the ecosystem (NEFMC 1998), which may eventually cause mobile species to relocate to other areas. Nonetheless, bivalves grown in open-water mariculture facilities can provide similarily beneficial filtering functions as native bivalves by contributing to the control nutrients, suspended sediments, and water column phytoplankton dynamics.

Aquaculture can result in the replacement or conversion of the natural benthic and pelagic community in the area surrounding the facility. For example, shellfish aquaculture can eliminate seagrass beds when shell material is dumped on the seafloor (Simenstad and Fresh 1995). Seagrass beds in the vicinity of shellfish culture operations may be eliminated during harvesting, which may temporarily reduce levels of biodiversity by reducing habitat for other marine species. Habitat conversion also takes place at netpen sites in which sediment deposition causes underlying habitat to become eutrophic. Sensitive benthic habitats beneath the netpens, such as seagrasses, may be eliminated or degraded by poor water quality conditions, thus converting viable habitat to unusable or less productive seafloor area (Goldburg and Triplett 1997).

Although the effects of replacement and exclusion of habitat by aquaculture facilities are often negative, there may be some positive effects of the structures. For example, cages, anchoring systems, and other devices can increase the structural complexity to the benthic and pelagic environment, which can provide shelter and foraging habitat for some native species. Open-water shellfish mariculture operations can provide some of the same habitat benefits as natural shellfish beds, such as refugia from predation and feeding habitat for juvenile and adult mobile species. Under some conditions, seafloor productivity may increase near aquaculture sites.

### *Conservation measures and best management practices for aquaculture*

1. Assess the aquatic resources in the area when siting new aquaculture facilities, including benthic communities, the proximity to wild stocks, migratory corridors, competing resource uses (e.g., commercial fishing, recreational uses, other aquaculture facilities), hydrographic conditions, and upstream habitat uses.
2. Avoid siting of aquaculture operations in or near sensitive benthic communities, such as submerged aquatic vegetation.
3. Avoid enclosing or impounding tidally influenced wetlands for mariculture purposes.
4. Ensure that aquaculture operations adequately address disease issues to minimize risks to wild stocks.
5. Employ methods to minimize escape from culture facilities to minimize potential genetic impacts and to prevent disruption of natural aquatic communities.
6. Design aquaculture facilities to meet applicable environmental standards for wastewater treatment and sludge control.

7. Locate aquaculture facilities to minimize discharge effects on habitat and locate water intakes to minimize entrainment of native fauna.
8. Evaluate and control the use of antibiotics, pesticides, and herbicides in aquaculture operations. Avoid direct application of carbaryl or other pesticides in water.
9. Consider biological controls to reduce pest populations, such as small, native species that feed on sea lice and fouling organisms.
10. Reduce the metabolic stress of aquaculture species in order to eliminate or reduce the need for using chemicals. Measures to reduce stress include improving water quality, lowering stock densities, and minimizing handling of fish.
11. Use aquaculture gear designed to minimize entanglement of native species attracted to the aquaculture operation (e.g., predators, such as marine mammals and birds).
12. Exclude exotic species from aquaculture operations until a thorough scientific evaluation and risk assessment is performed.
13. Locate aquaculture facilities rearing nonnative species upland and use closed-water circulation systems.
14. Treat effluent from public aquarium displays, laboratories, and educational institutes that are using exotic species prior to discharge for the purpose of preventing the introduction of viable animals, plants, reproductive material, pathogens, or parasites into the environment.
15. Consider growing several cultured species together, such as finfish, shellfish, algae, and hydroponic vegetables to reduce nutrient and sediment loads on the ecosystem.
16. Develop a monitoring program at the site to evaluate habitat and water quality impacts and the need for corrective measures through adaptive management.

## References for Introduced/Nuisance Species and Aquaculture

Able KW, Hagan SM. 2000. Effects of common reed (*Phragmites australis*) invasion on marsh surface macrofauna: response of fishes and decapod crustaceans. Estuaries 23:633-46.

[ASMFC] Atlantic States Marine Fisheries Commission. 1992. Fishery management plan for inshore stocks of winter flounder. Washington (DC): ASMFC. FMR No. 21. 138 p.

Barg UC. 1992. Guidelines for the promotion of environmental management of coastal aquaculture development. [Internet]. Rome (Italy): Food and Agriculture Organization of the United Nations (FAO). FAO Fisheries Technical Paper 328. [cited 2008 Jul 24]. 122 p. Available from: http://www.fao.org/docrep/T0697E/t0697e01.htm.

Barnhart RA, Boyd MJ, Pequegnat JE. 1992. The ecology of Humboldt Bay, California: an estuarine profile. Arcata (CA): US Fish and Wildlife Service. USFWS Biological Report 1. 121 p.

Benoit LK, Askins RA. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut marshes. Wetlands 19:194-208.

Boesch DF, Anderson DM, Horner RA, Shumway SE, Tester PA, Whitledge TE. 1997. Harmful algal blooms in coastal waters: options for prevention, control and mitigation. Silver Spring (MD): NOAA Coastal Ocean Office. NOAA Coastal Ocean Program Decision Analysis Series No. 10. 46 p + appendix.

Brousseau DJ, Baglivo JA. 2005. Laboratory investigations of food selection by the Asian shore crab, *Hemigrapsus sanguineus*: algal versus animal preference. Journal of Crustacean Biology 25(1):130-4.

Burdick DM, Buchsbaum R, Holt E. 2001. Variation in soil salinity associated with expansion of *Phragmites australis* in salt marshes. Environmental and Experimental Botany 46(3):247-61.

Burreson EM, Stokes NA, Friedman CS. 2000. Increased virulence in an introduced pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern oyster *Crassostrea virginica*. Journal of Aquatic Animal Health 12(1):1-8.

Byrnes J, Witman JD. 2003. Impact assessment of an invasive flatworm, *Convoluta convoluta*, in the southern Gulf of Maine. Journal of Experimental Marine Biology and Ecology 293(2):173-91.

Caraco NF, Cole JJ, Raymond PA, Strayer DL, Pace ML, Findlay SEG, Fischer DT. 1997. Zebra mussel invasion in a large, turbid river: phytoplankton response to increased grazing. Ecology 78(2):588-602.

Carlton JT. 2001. Introduced species in U.S. coastal waters: Environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Coen LD, Luckenback MW, Breitburg DL. 1999. The role of oyster reefs as essential fish habitat: A review of current knowledge and some new perspectives. In: Benaka LR, editor. Proceedings of the Sea Grant symposium on fish habitat and rehabilitation. Bethesda (MD): American Fisheries Society Symposium, No. 22. p 438-54.

Dankers N, Zuidema DR. 1995. The role of the mussel (*Mytilus edulis* L.) and mussel culture in the Dutch Wadden Sea. Estuaries 18(1A):71-80.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Drake LA, Jenkins PT, Dobbs FC. 2005. Domestic and international arrivals of NOBOB (no ballast on board) vessels to lower Chesapeake Bay. Marine Pollution Bulletin 50(5):560-5.

Findlay RH, Watling L, Mayer M. 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: a case study. Estuaries 18(1A):145-79.

Goldburg RJ, Elliott MS, Naylor RL. 2001. Marine aquaculture in the United States: environmental impacts and policy options. Arlington (VA): Pew Oceans Commission.

Goldburg RJ, Elliott MS, Naylor RL. 2003. Guiding sustainable marine aquaculture. In: Pew Ocean Commission. America's living oceans: charting a course for sea change. Arlington (VA): Pew Oceans Commission. p 73-79.

Goldburg R, Triplet T. 1997. Murky waters: environmental effects of aquaculture in the United States. Washington (DC): Environmental Defense Fund.

Grant J, Hatcher A, Scott DB, Pocklington P, Schafer CT, Winters GV. 1995. A multi-disciplinary approach to evaluating impacts of shellfish aquaculture on benthic communities. Estuaries 18(1A):124-44.

Griffin K. 1997. Commercial oyster cultivation and eelgrass ecology in Tillamook Bay, Oregon: a literature review and synthesis. Garibaldi (OR): Tillamook Bay National Estuary Project. 36 p.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hopkins JS, Sandifer PA, Devoe MR, Holland AF, Browdy CL, Stokes AD. 1995. Environmental impacts of shrimp farming with special reference to the situation in the continental United States. Estuaries 18(1A):25-42.

Kaiser MJ, Laing I, Utting SD, Burnell GM. 1998. Environmental impacts of bivalve mariculture. Journal of Shellfish Research 17(1):59-66.

Kaspar HF, Gillespie PA, Boyer IC, MacKenzie AL. 1985. Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. Marine Biology 85:127-36.

Kelly LA. 1992. Dissolved reactive phosphorus release from sediments beneath a freshwater cage aquaculture development in West Scotland. Hydrobiologia 235/236:569-72.

Kohler CC, Courtenay WR Jr. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries 11(2):39-42.

Minchinton TE, Bertness MD. 2003. Disturbance-mediated competition and the spread of *Phragmites australis* in a coastal marsh. Ecological Applications 13(5):1400-16.

Moring J. 2005. Recent trends in anadromous fishes. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 25-42.

Newell RC, Seiderer LJ, Hitchcock DR. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. In: Ansell AD, Gibson RN, Barnes M, editors. Oceanography and marine biology: an annual review. Vol. 36. Oban, Argyll (Scotland): UCL Press. p 127-78.

Newell RIE. 1988. Ecological changes in Chesapeake Bay: are they the result of overfishing the American Oyster, *Crassostrea virginica*? In: Understanding the estuary: advances in Chesapeake Bay research: proceedings of a conference; 1988 Mar 29-31; Baltimore, MD. Edgewater (MD): Chesapeake Research Consortium Publication 129. p 536-46.

[NEFMC] New England Fishery Management Council. 1998. Final Amendment #11 to the Northeast multispecies fishery management plan, Amendment #9 to the Atlantic sea scallop fishery management plan, Amendment #1 to the Monkfish fishery management plan, Amendment #1 to the Atlantic salmon fishery management plan, and components of the proposed Atlantic herring fishery management plan for essential fish habitat, incorporating the environmental assessment. Newburyport (MA): NEFMC Vol. 1.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Omori M, VanderSpoel S, Norman CP. 1994. Impact of human activities on pelagic biogeography. Progress in Oceanography 34(2-3):211-9.

O'Reilly JE. 1994. Nutrient loading and eutrophication. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 25-30.

Pederson J, Bullock R, Carlton J, Dijkstra J, Dobroski N, Dyrynda P, Fisher R, Harris L, Hobbs N, Lambert G, and others. 2005. Marine invaders in the Northeast: rapid assessment survey of non-native and native marine species of floating dock communities. Report of the August 3-9, 2003 Survey. Cambridge (MA): MIT Sea Grant College, Publication No. 05-3. 40 p.

Posey MH, Alphin TD, Meyer DL, Johnson JM. 2003. Benthic communities of common reed *Phragmites australis* and marsh cordgrass *Spartina alterniflora* marshes in Chesapeake Bay. Marine Ecology Progress Series 261:51-61.

Rickards WL, Ticco PC. 2002. The Suminoe oyster, *Crassostrea ariakensis*, in Chesapeake Bay: current status and near-term research activities. Charlottesville (VA): University of Virginia, Virginia Sea Grant.

Simenstad CA, Fresh KL. 1995. Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries: scales of disturbance. Estuaries 18(1A):43-70.

Strayer DL, Hattala KA, Kahnle AW. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-41.

Tyrrell MC, Harris LG. 2000. Potential impact of the introduced Asian shore crab, *Hemigrapsus sanguineus*, in northern New England: diet, feeding preferences, and overlap with the green crab, *Carcinus maenas*. In: Pederson J, editor. Marine bioinvasions: proceedings of the 1st National Conference; 1999 Jan 24-27; Cambridge (MA): MIT SeaGrant College Program. p 208-20.

[USCOP] US Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century. Final report. [Internet]. Washington (DC): USCOP. [cited 2008 Jul 24]. Available from: http://www.oceancommission.gov.

[USEPA] US Environmental Protection Agency. 2001. National coastal condition report. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-01/005. [cited 2008 Jul 24]. Available from: http://www.epa.gov/owow/oceans/nccr/downloads.html.

[USFWS], [NMFS] US Fish and Wildlife Service, National Marine Fisheries Service. 1999. Status review of anadromous Atlantic salmon in the United States. Hadley (MA): USFWS. 131 p.

Valentine PC, Collie JS, Reid RN, Asch RG, Guida VG, Blackwood DS. 2007. The occurrence of the colonial ascidian *Didemnum* sp. on Georges Bank gravel habitat–ecological implications and potential effects on groundfish and scallop fisheries. Journal of Experimental Marine Biology and Ecology 342(1):179-181.

Vita R, Marin A, Madrid JA, Jimenez-Brinquis B, Cesar A, Marin-Guirao L. 2004. Effects of wild fishes on waste exportation from a Mediterranean fish farm. Marine Ecology Progress Series 277:253-61.

Vitousek PM, D' Antonio CM, Loope LL, Rejmanek M, Westbrooks R. 1997. Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21(1):1-16.

Weinstein MP, Balletto JH. 1999. Does the common reed, *Phragmites australis*, affect essential fish habitat? Estuaries 22:793-802.

Weis JS, Weis P. 2000. Behavioral responses and interactions of estuarine animals with an invasive plant: a laboratory analysis. Biological Invasions 2:305-14.

# CHAPTER ELEVEN: GLOBAL EFFECTS AND OTHER IMPACTS

## Climate Change

### *Introduction*

The earth's climate has changed throughout geological history because of a number of natural factors that affect the radiation balance of the planet, such as changes in earth's orbit, the output of the sun, and volcanic activity (IPCC 2007a). These natural changes in the earth's climate have resulted in past ice ages and periods of warming that take place over several thousand years. An example of changes to earth's climate over recent geological timeframes caused by natural factors has been observed in slowly rising global temperatures and sea levels since the end of the Pleistocene epoch (about 10,000 years before present). However, the rate of warming observed over the past 50 years is unprecedented in at least the previous 1,300 years (IPCC 2007a). The Intergovernmental Panel on Climate Change (IPCC) concludes that recent human-induced increases in atmospheric concentrations of greenhouse gases are expected to cause much more rapid changes in the earth's climate than have previously been experienced (IPCC 2007a). The buildup of greenhouse gases (primarily carbon dioxide) is a result of burning fossil fuels and forests and from certain agricultural activities. Other greenhouse gases released by human activities include nitrous oxide, methane, and chlorofluorocarbons. The global atmospheric concentration of carbon dioxide has increased from about 280 ppm during preindustrial times to 379 ppm in 2005, which far exceeds the natural range over the last 650,000 years (180-300 ppm) as determined from ice cores (IPCC 2007a).

In the Fourth Assessment Report of the IPCC, the Contribution of Working Group I issued the following conclusions (IPCC 2007a):

> Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Most of the observed increase in globally averaged temperatures since the mid-20$^{th}$ century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.

In order to consider various possible futures for climate change effects, the IPCC developed a series of models, or scenarios, based upon different levels of greenhouse gas emissions. The higher-emissions scenario represented fossil fuel-intensive economic growth and global human population that peaks around 2050 and then declines. This model assumes atmospheric carbon dioxide concentrations to reach about 940 ppm by 2100, or about three times preindustrial levels (Frumhoff et al. 2007). The lower-emissions scenario also represents a global human population that peaks around 2050 but assumes a much faster shift to less fossil fuel-intensive industries and more resource-efficient technologies. This model assumes carbon dioxide concentrations to peak around 2050 and then to decline to about 550 ppm by 2100, which is about double preindustrial levels (Frumhoff et al. 2007).

Based on current global climate models for greenhouse gas emission scenarios, some of the 2007 IPCC report conclusions were:

1. By 2100 average global surface air temperatures will increase by 1.8°C (lower-emissions scenario) to 4.0°C (higher-emissions scenario) above 2000 levels. The most drastic warming will occur in northern latitudes in the winter.
2. Sea level rose 12-22 cm in the 20$^{th}$ century and may rise another 18-38 cm (lower-emissions scenario) and as high as 26-59 cm (higher-emissions scenario) by 2099. However, these projections were based upon contributions from increased ice flow from Greenland and Antarctica at rates observed for the 1993-2003 period. If this contribution were to grow linearly with global average temperature change, the upper ranges for sea level rise would increase by an additional 10-20 cm.
3. Global precipitation is likely to increase, with more precipitation and more intense storms in the mid to high latitudes in the northern hemisphere.
4. Increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100, adding to the present decrease of 0.1 units since preindustrial times.

The average annual atmospheric temperature across the northeastern United States has risen by approximately 0.8ºC since 1900, although this warming trend has increased to approximately 0.3ºC per decade since 1970 (Frumhoff et al. 2007). Most climate models indicate the region will experience continued increased warming over the next century (Frumhoff et al. 2007; IPCC 2007a). Climate change models predict increased warming under the lower-emissions scenario to be 2.2-4.2°C and 3.8-7.2°C under the higher-emissions scenario by 2100 in New England and eastern Canada (Frumhoff et al. 2007). Over the next several decades, the greatest temperature changes are expected to be in the wintertime and early spring with warm periods expected to increase in frequency and duration (Nedeau 2004). For example, the average winter temperature in over the next few decades are expected to increase 1.4-2.2°C under both emission scenarios, while average summer temperature increases are expected to be 0.8-1.9°C (Frumhoff et al. 2007). However, by the end of the century, the average winter temperature is expected to increase 4.4-6.7°C under the higher-emissions scenario, while summer temperature is expected to increase 3.3-7.8°C (Frumhoff et al. 2007). Long-term increases in average temperatures, the frequency and intensity of extreme temperature and climatic events, and the timing of seasonal temperature changes can have adverse effects on ecosystem function and health. Combined with extreme precipation and drought and rising sea levels, these effects have the potential to result in considerable adverse changes to the northeast region's ecosystems.

Primary impacts of global climate change that may threaten riverine, estuarine, and marine fishery resources include:

1. Increasing rates of sea-level rise and intensity and frequency of coastal storms and hurricanes will increase threats to shorelines, wetlands, and coastal ecosystems;
2. Marine and estuarine productivity will change in response to reductions in ocean pH and alterations in the timing and amount of freshwater, nutrients, and sediment delivery;
3. High water temperatures and changes in freshwater delivery will alter estuarine stratification, residence time, and eutrophication and;
4. Increased ocean temperatures are expected to cause poleward shifts in the ranges of many marine organisms, including commercial species, and these shifts may have secondary effects on their predators and prey.

These affects may be intensified by other ecosystem stresses (pollution, harvesting, habitat destruction, invasive species), leading to more significant environmental consequences. It should be noted that while the general consensus among climate scientists today indicates a current and future warming of the earth's climate caused by emissions of greenhouse gases from anthropogenic sources, the anticipated effects at regional and local levels are less understood. Consequently, there are degrees of uncertainty regarding the specific effects to marine organisms and communities and their habitats from climate change. For example, although most climate models predict an increase in extreme rainfall events in the northeast region of the United States, the regional projections for average annual precipitation and runoff vary considerably (Scavia et al. 2002).

This section attempts to address some of the possible effects of global climate change to fishery resources in the northeast region of the United States. The effects discussed in this report reflect the general topics identified by participants of the Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities. However, other possible effects and consequences of climate change have been suggested, some of which may be inconsistent with those described in this report. A complete and thorough discussion of this rapidly-developing area of science is beyond the scope of this report. For a more thorough assessment of impacts caused by climate change, we recommend the reader refer to the publications cited in this chapter, as well as new research that will emerge subsequent to this report.

### *Alteration of hydrological regimes*

The hydrologic cycle controls the strength, timing, and volume of freshwater input, as well as the chemical and sediment load to estuaries and coastal waters (Scavia et al. 2002). Precipitation across the continental United States has increased by about 10% in the past 100 years or so, primarily reflected in the heavy and extreme daily precipitation events (Karl and Knight 1998; USGS 2005). This trend is also evident in the northeastern US region, which has experienced an increase in annual average precipitation by about 5-10% since 1900 (Frumhoff et al. 2007). In addition, increased early spring streamflows have occurred over the past century in New England, possibly a result of earlier melting of winter snowpack caused by increased air temperatures and/or greater rainfall (Hodgkins and Dudley 2005).

The IPCC Working Group II Report on Climate Change Impacts, Adaptation, and Vulnerability (IPCC 2007b) concluded that by mid-century average annual river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics. For the northeastern United States, climate change models indicate an increase in precipitation over the next 100 years (Frumhoff et al. 2007; IPCC 2007b). By the end of the century, the average annual precipitation is expected to increase by about 10%; however, the average winter precipitation is expected to increase 20-30%, and a much greater proportion of the precipitation would be expected to fall as rain rather than snow (Frumhoff et al. 2007; IPCC 2007b). Climate models also predict more frequent, heavy-precipitation events, which are expected to increase the probability of high-flow events in Maine, New Hampshire, and Vermont streams and rivers by about 80% during late winter and spring (Frumhoff et al. 2007). These changes in the intensity and frequency of high-flow events have the potential to increase the export of nutrients, contaminants, and sediments to our estuaries. Climate-related changes in the northeast region may alter the timing and amount of water availability. For example, increased temperatures during summer months can increase evapotranspiration rates. Combined with reduced summer rainfall, these changes can cause reductions in soil moisture and streamflows that may lead to seasonal drought (Frumhoff et al. 2007).

Accelerated sea-level rise resulting from climate change threatens coastal wetlands through inundation, erosion, and saltwater intrusion (Kennedy et al. 2002; Scavia et al. 2002). The quantity of freshwater discharges affects salt marshes because river flow and runoff deliver sediments that are critical for marshes to maintain or increase its elevation. An increase in freshwater discharge could increase supply of sediment and allow coastal wetlands to cope with sea-level rise (Scavia et al. 2002). However, some coastal areas may experience a decrease in precipitation and freshwater runoff, causing salt marsh wetlands to become sediment-starved and ultimately lost as sea levels rise and marshes are drowned (Kennedy et al. 2002). Greater periods of drought leading to a decrease in freshwater discharge might also cause salinity stress in salt marshes. Rising sea levels will also allow storm surges to move further inland and expose freshwater wetlands to high salinity waters.

Estuaries may be affected by changes in precipation and freshwater discharge from rivers and runoff from land. Precipitation patterns and changes in freshwater inflow can influence water residence time, salinity, nutrient delivery, dilution, vertical stratification, and phytoplankton growth and abundance (Scavia et al. 2002). Patterns of more frequent heavy-precipitation events during winter and spring months and increased temperature and reduced rainfall during summer months may exacerbate existing nutrient over-enrichment and eutrophication conditions that already stress estuarine systems (Scavia et al. 2002; Frumhoff et al. 2007).

A decline in the atmospheric pressure at the sea surface in the central Arctic during the late 1980s led to increased delivery of warmer, higher-salinity Atlantic water into the Arctic Ocean, mainly via the Barents Sea (Greene and Pershing 2007). In addition, there has been an increase in continental melting of permafrost, snow, and ice which, combined with increased precipitation, has resulted in greater river discharge into the Arctic Ocean over the past three decades. This is believed to have led to accelerated sea ice melting and reductions in Arctic sea ice. Although the relative importance of human versus natural climate forces in driving the observed changes in atmospheric and ocean circulation patterns continues to be debated, it has led to an enhanced outflow of low-salinity waters from the Arctic and general freshening of shelf waters from the Labrador Sea to the Mid-Atlantic Bight beginning in the early 1990s (Greene and Pershing 2007). Increased freshwater input in the upper layers of the ocean results in increased stratification, which suppresses upwelling of nutrients into the upper regions of the ocean and generally reduces the productivity of phytoplankton (Kennedy et al. 2002). Conversely, increased freshwater flux and stratification could also lead to enhanced biological productivity in some systems by enabling organisms to remain longer in the photic zone (Scavia et al. 2002). Greene and Pershing (2007) reported enhanced ocean stratification caused by increased freshwater outflow from the Arctic during the 1990s. They attributed increased phytoplankton and zooplankton production and abundance during the autumn, a period when primary production would otherwise be expected to decline, with enhanced freshening of the Northwest Atlantic shelf (Greene and Pershing 2007). Although some climate models predict a net decrease in global phytoplankton productivity under doubled atmospheric carbon dioxide conditions caused by increased thermal stratification and reduced nutrient upwelling, simple extrapolation to particular northeast marine waters is difficult (Kennedy et al. 2002). The climatic variability associated with natural, large-scale phenomena such as the El Nino-Southern Oscillation and the North Atlantic Oscillation/Northen Hemisphere Annular Mode effects water column mixing and stratification on regional and global scales and has implications on the productivity of the oceans. These natural phenomena may act in tandem with, or in opposition to, anthropogenic climate change (Kennedy et al. 2002).

A number of computer climate models indicate a slowing of the “overturning” process of ocean waters, known as the thermohaline circulation (THC). This phenomenon appears to be driven by a reduction in the amount of cold and salty, and hence, more dense water sinking into the depths of the ocean. In fact, surface waters of the North Atlantic Ocean have been warming in recent decades and parts of the North Atlantic Ocean are also becoming less salty (Nedeau 2004).

In the North Atlantic, a weakening of the THC is related to wintertime warming and increased freshwater flow into the Arctic Ocean and the North Atlantic Ocean (Nedeau 2004). An increased weakening of the THC could lead to a complete shut down or southward shift of the warm Gulf Stream, as was experienced during the last glacial period (Nedeau 2004). However, the response of the THC to global climate change remains uncertain, and predictions are dependent upon future greenhouse gas emissions and temperature increases (Kennedy et al. 2002). On a regional level, changes in ocean current circulation patterns may alter temperature regimes, vertical mixing, salinity, dissolved oxygen, nutrient cycles, and larval dispersal of marine organisms in the northeast coastal region, ultimately leading to a net reduction in oceanic productivity (Nedeau 2004).

## *Alteration of temperature regimes*

Sea surface temperatures of the northeastern US coast have increased more than 0.6°C in the past 100 years, and are projected to increase by another 3.8-4.4°C under the high-emissions scenario and by 2.2-2.8°C under the lower-emissions scenario over the next 100 years (Frumhoff et al. 2007). The IPCC Working Group II Report (IPCC 2007b) concluded there is "high confidence" that observed changes in marine and freshwater biological systems are associated with rising water temperatures, including: (1) shifts in ranges and changes in algal, plankton, and fish abundance in high-latitude oceans; (2) increased algal and zooplankton abundance in high-latitude and high-altitude lakes; and (3) range changes and earlier migrations of fish in rivers.

Temperature affects nearly every aspect of marine environments, from cellular processes to ecosystem function. The distribution, abundance, metabolism, survival, growth, reproduction, productivity, and diversity of marine organisms will all be affected by temperature changes (Kennedy et al. 2002; Nedeau 2004). Most marine organisms are able tolerate a specific temperature range and will become physiologically stressed or die after exposure to temperatures above or below the normal range. At sublethal levels, temperature extremes can effect the growth and metabolism of organisms, as well as behavior and distribution patterns. Reproduction timing and the rates of egg and larval development are dependent upon water temperatures. The reproductive success of some cold water fish species may be reduced if water temperatures rise above the optimum for larval growth (Mountain 2002). For example, cold-adapted species, such as winter flounder (*Pseudopleuronectes americanus*), Atlantic cod (*Gadus morhua*), Atlantic salmon (*Salmo salar*), and ocean quahog (*Artica islandica*) may not be able to compete with warm-adapted species if coastal water temperatures increase, particularly for those populations that may be living near the southern distribution limit (Kennedy et al. 2002).

The predicted increase in water temperatures resulting from climate change, combined with other factors such as increased precipitation and runoff, may alter seasonal stratification in the northeast coastal waters. Stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton, thus affecting the growth and survival of fish larvae (Mountain 2002). In the northeast Atlantic, studies have found shifts in the timing and abundance of plankton populations with increasing ocean temperatures (Edwards and Richardson 2004; Richardson and Schoeman 2004). Edwards and Richardson (2004) found long term trends in the timing of seasonal peaks in plankton populations with increasing sea surface temperatures. However, the magnitude of the shifts in seasonal peaks were not equal among all trophic groups, suggesting alterations in the synchrony of timing between primary, secondary, and tertiary production. Richardson and Schoeman (2004) reported effects of increasing sea surface temperatures on phytoplankton abundances in the North Sea. Phytoplankton production tended to increase as cooler ocean areas warmed, probably because higher water temperatures boost phytoplankton metabolic rates. However, in warmer ocean areas phytoplankton became less abundant as sea surface temperatures increased further, possibly because warm water blocks nutrient-rich deep water from rising to the upper strata where phytoplankton exist (Richardson and Schoeman 2004). These effects have been implicated as a factor in the decline in North Sea cod stocks (Edwards and Richardson 2004; Richardson and Schoeman 2004). Impacts to the base of the food chain would not only affect fisheries but will impact entire ecosystems.

Mountain (2002) predicted a northward shift in the distributional patterns of many species of fish because of increasing water temperatures in the Mid-Atlantic region as a result of climate change. Nearly thirty years of standardized catch data on the northeast continental shelf revealed significant surface and bottom water temperature anomalies that resulted in changes to the distribution of 26 out of 30 fish species examined (Mountain and Murawski 1992). Increased water temperatures were correlated with fish moving northward or shallower to cooler water (Mountain and Murawski 1992). Perry et al. (2005) investigated the distributional patterns of demersal fish species in the North Sea and found two-thirds of all species examined shifted in latitude or depth or both in response to increasing water temperatures. This study reported that most of the species with shifting distributions had moved north or to greater depths in areas of cooler waters. Temperature induced shifts in the distribution of fish have implications for stock recruitment success and abundance. Based on the projected sea surface temperature increases under the higher-emission scenarios, Frumhoff et al. (2007) predicted bottom temperatures by the year 2100 on Georges Bank would approach the 30ºC threshold of thermally-suitable habitat and practical limit of Atlantic cod distribution. The 26ºC threshold for the growth and survival of young cod would be exceeded by the end of the century under both emission scenarios on Georges Bank (Frumhoff et al. 2007).

The frequency of diseases and pathogens may increase with warming ocean temperatures caused by climate change. For example, Dermo, a disease that affects commercially valuable oysters, exhibits higher infection rates with increased temperature and salinity. Warm, dry periods (e.g., summer drought) may make oysters more susceptible to this disease. Extremely warm waters in New England and the mid-Atlantic regions are suspected as playing a role causing disease and mortality events in American lobsters (*Homarus americanus*), including lobster-shell disease, parasitic paramoebiasis, and calcinosis (Frumhoff et al. 2007). The eelgrass wasting disease pathogen (*Labyrinthula zosterae*) has reduced eelgrass beds throughout the east coast in the past and may become more problematic because of its preference for higher salinity waters and warmer water (both of which are expected in some estuaries because of sea-level rise) (Nedeau 2004).

### *Changes in dissolved oxygen concentrations*

Dissolved oxygen concentrations are influenced by the temperature of the water. Because warmer water holds less oxygen than does colder water, increased water temperatures will reduce the dissolved oxygen in bodies of water that are not well mixed. This may exacerbate nutrient-enrichment and eutrophication conditions that already exist in many estuaries and marine waters in the northeastern United States. Increased precipitation and freshwater runoff into estuaries would effect water residence time, temperature and salinity, and increase vertical stratification of the water column, which inhibits the diffusion of oxygen into deeper water leading to reduced (hypoxic) or depleted (anoxic) dissolved oxygen concentrations in estuaries with excess nutrients (Kennedy et al. 2002; Scavia et al. 2002; Nedeau 2004). Increased vertical stratification of the water column occurs with increasing freshwater inflow and decreasing salinities, resulting from greater precipitation and storm water input. In addition, increased water temperatures in the upper strata of the water column also increase water column stratification.

Some species may be adversely affected by increasing surface water temperatures caused by climate change as they seek cooler and deeper waters. Deeper areas may be susceptible to hypoxic conditions near the bottom in stratified, poorly mixed estuarine and marine environments and would be unfavorable to many species. The habitats of aquatic species may be "squeezed" by warming surface waters and hypoxic bottom waters, resulting in greater physiologic stress and metabolic costs or death if the stress does not abate (Kennedy et al. 2002). However, an increase in coastal storm frequency and intensity, as predicted with some climate models, may contribute to some increase in vertical mixing of shallow habitats and reduce the effects of stratification.

Some phytoplankton populations may respond positively to increases in water temperatures and available carbon dioxide, which most climate models project are likely as a result of global warming (IPCC 2007a). Increased precipitation and runoff can increase the nutrient loads entering estuaries and marine waters that further exacerbate the proliferation of algae in nearshore waters. As algae die and begin to sink to the bottom, the decomposition of this increased organic material will consume more oxygen in the water, increasing the occurrence of hypoxic and anoxic conditions in coastal waters (Nedeau 2004).

### *Nutrient loading and eutrophication*

Nitrate driven eutrophication is one of the greatest threats to the integrity of many estuaries in the northeast region (NRC 2000; Cloern 2001; Howarth et al. 2002). Increases in the amount of precipitation are very likely in northern latitudes (IPCC 2007a), and excess nutrients exported from watersheds and delivered to estuarine and marine waters may increase if freshwater flow from rivers and stormwater discharges are greater. Higher nutrient loads may increase the incidence of eutrophication and harmful algal blooms, which can cause hypoxia or anoxia in nearshore coastal waters. These effects on water quality can also negatively impact benthic communities and submerged aquatic vegetation (SAV). The environmental effects of excess nutrients or sediments are the most common and significant causes of SAV decline worldwide (Orth et al. 2006).

### *Release of contaminants*

Increased precipitation and freshwater runoff may increase because of climate change and may lead to increased contaminant loading in coastal waters. Contaminants, such as hydrocarbons, metals, organic and inorganic chemicals, sewage, and wastewater materials, can be flushed from the watershed and exported to coastal waters, especially if the frequency and intensity of storms and floods are affected (Kennedy et al. 2002). These contaminants may be stored in coastal sediments or taken up directly by biota (e.g., bacteria, plankton, shellfish, or fish) and could ultimately affect fisheries and human health. Sea-level rise would inundate lowland sites near the coast, many of which contain hazardous substances that could leach contaminants into nearshore habitats (Bigford 1991).

### *Loss of wetlands and other fishery habitat*

Global warming is expected to accelerate the rate of sea-level rise by expanding ocean water and melting alpine glaciers over the next century (Schneider 1998; IPCC 2007a). Average global sea levels rose 12-22 cm between 1900 and 2000 and are expected to rise another 18-38 cm (lower-emissions scenario) and as high as 26-59 cm (higher-emissions scenario) by 2100 (IPCC 2007a). In the US Atlantic coast, relative sea levels over the last century have risen approximately 18 cm in Maine and as much as 44 cm in Virginia (Zervas 2001). Sea-level rise may affect diurnal tide ranges, causing coastal erosion, increasing salinity in estuaries, and changing the water content of shoreline soils. Accelerated sea-level rise threatens coastal habitats with inundation, erosion, and saltwater intrusion (Scavia et al. 2002; Frumhoff et al. 2007). Sea-level rise may indundate salt marshes and coastal wetlands, at which point shorelines will either need to build upward (accrete) to keep pace with rising sea levels or migrate inland to keep pace with drowning/erosion on the seaward edge. In cases where the upland edge is blocked by steep topography (e.g., bluffs) or human development (e.g., shoreline protection structures) coastal wetlands including salt marsh will be lost (Scavia et al. 2002; Frumhoff et al. 2007; IPCC 2007b). Conservative estimates of losses to saline and freshwater wetlands from sea-level rise range from 47-82% of the nation's coastal wetlands, or approximately 2.3-5.7 million acres (Bigford 1991). Shoreline protection structures can also prevent the shoreward migration of SAV necessitated by sea-level rise (Orth et al. 2006).

Worldwide distribution, productivity, and function of SAV may be effected by climate change. Perhaps most critical to SAV are impacts from increases in seawater temperature resulting from the greenhouse gas effect; secondary impacts of changing water depths and tidal range caused by sea-level rise, altered current circulation patterns and current velocities; changes in salinity regimes; and potential impacts on plant photosynthesis and productivity resulting from increased ultraviolet-B radiation and carbon dioxide concentrations (Short and Neckles 1999).

The distribution and productivity of coastal wetlands may be effected by rising sea levels, altered precipitation patterns, changes in the timing and delivery of freshwater and sediment, and increases in atmospheric carbon dioxide and temperature (Scavia et al. 2002). Increased atmospheric carbon dioxide could increase plant production for some coastal wetland species, assuming other factors such as nutrients and precipitation are not limiting. However, rising sea levels may inhibit the growth of some brackish and freshwater marshes and swamps.

### *Shoreline erosion*

Millions of cubic yards of sand are placed on northeast coastal beaches each year by state and federal governments to combat shoreline erosion. In addition, a variety of hard structures such as seawalls, revetments, groins, and jetties have been installed to protect eroding shorelines. Yet some areas of the northeast, such as Cape Cod, MA, Long Island, NY/CT, and coastal New Jersey, continue to experience a net loss of shoreline and have been identified by the US Geological Survey as being particularly at risk from sea-level rise (Frumhoff et al. 2007). It is uncertain how these engineering measures might affect the ability of natural processes to respond to future sea-level rise (Gutierrez et al. 2007). There exists a high degree of uncertainty in predicting long-term shoreline changes because of the uncertainty of the rate of future sea-level rise and the complex interactions of regional sediment budgets, coastal geomorphology, and anthropogenic influences, such as beach nourishment and seawall construction. However, Gutierrez et al. (2007) reported an increased likelihood for erosion and shoreline retreat for all types of mid-Atlantic coastal shorelines, including an increased likelihood for overwash and inlet breaching and the possibility of segmentation or disintegration of some barrier islands.

An increase in freshwater discharge, storm frequency and intensity, and sea-level rise can lead to increased erosion rates along coastal shorelines (Scavia et al. 2002). The loss of riparian and salt marsh vegetation because of climate change effects could serve as a feedback loop that reduces the ability of wetlands to withstand further increases in sea level and storm effects, which may exacerbate the effects of coastal erosion.

### *Alteration of salinity regimes*

Vertical mixing in coastal waters is influenced by several factors, including water temperatures and freshwater input, so warmer temperatures may affect the thermal stratification of estuaries (Nedeau 2004). Climate models project increased average temperatures and precipitation, particularly during the winter, in the northeastern US region (Frumhoff et al. 2007). Hotter and drier summers and warmer, wetter winters will alter the timing and volume of freshwater runoff and river flows. If freshwater flow from rivers is reduced or increased, salinities in rivers and estuaries will be altered which will have profound affects on the distribution and life history requirements of coastal fisheries. For example, increased freshwater input into estuaries would lower salinities in salt marsh habitat which could enhance conditions for invasive exotic plants that prefer low-salinity conditions, such as *Phragmites* or purple loosestrife (*Lythrum salicaria*). Increased freshwater runoff will increase vertical stratification of estuaries and coastal waters, which could have indirect effects on estuarine and coastal ecosystems (Kennedy et al. 2002). For example, upwelling of deep, nutrient-rich seawater could be reduced, leading to reductions in primary productivity in coastal waters. Rising sea levels could cause estuarine wetlands to be inundated with higher salinity seawater, altering the ecological balance of highly productive fishery habitat.

### *Alteration of weather patterns*

Numerous long-term changes in climate have already been observed at continental, regional, and ocean basin scales, including changes in Arctic temperatures, ice, ocean salinity, wind patterns; and increased occurrences of extreme weather events including droughts, heavy precipitation, heat waves, and intensity of tropical cyclones (IPCC 2007a).

There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since the 1970s, correlated with increased tropical sea-surface temperatures (IPCC 2007a). Increases in the amount of precipitation are very likely in high latitudes, and extra-tropical storms are projected to move poleward (Frumhoff et al. 2007; IPCC 2007a). Although there continues to be debate over the link between global warming and increased hurricane frequency, observed ocean warming is a key condition for the formation and strengthening of hurricanes (Frumhoff et al. 2007). The integrity of shorelines and wetlands would be threatened by increased intensity and frequency of coastal storms and hurricanes resulting from climate change. The loss of coastal wetland vegetation and increased erosion of shorelines and riparian habitats caused by storms would have an adverse effect on the integrity of aquatic habitats. Reductions in dissolved oxygen concentrations and salinity are phenomena associated with coastal storms and hurricanes, and most aquatic systems require weeks or months to recover following severe storms (Van Dolah and Anderson 1991). Increased frequency and intensity of storms could lead to chronic disturbances and have adverse consequences on the health and ecology of coastal rivers and estuaries.

### *Changes in water alkalinity*

Increasing atmospheric carbon dioxide concentrations can alter seawater carbonate chemistry by lowering seawater pH, carbonate ion concentration, and carbonate saturation state and by increasing dissolved carbon dioxide concentration (Riebesell 2004). According to the IPCC Working Group I Fouth Asssessment, increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100 (IPCC 2007a). The uptake of anthropogenic carbon since 1750 has led to an average decrease in pH of 0.1 units; however, the effects of observed ocean acidification on marine ecosystems are unclear at this time (IPCC 2007b).

Increased acidity in oceans is expected to effect calcium carbonate availability in seawater, which would lower the calcification rates in marine organisms (e.g., mollusks and crustaceans, some plankton, hard corals) (IPCC 2007b). Alteration of water alkalinity could have severe impacts on primary and secondary production, which have implications at the ecosystem level (Orr et al. 2005). Increasing atmospheric carbon dioxide concentrations and altered seawater carbonate chemistry could have a range of effects, including physiological changes to marine plankton on the organismal level, changes in ecosystem structure and regulation, and large scale shifts in biogeochemical cycling (Riebesell 2004). For example, increased carbon dioxide concentrations are predicted to decrease the carbonate saturation state and cause a reduction in biogenic calcification of corals and some plankton, including coccolithophorids and foraminifera; however, increasing carbon dioxide concentrations could increase the rates of photosynthetic carbon fixation of some calcifying phytoplankton (Riebesell 2004).

### *Changes in community and ecosystem structure*

The geographic distributions of species may expand, contract, or otherwise adjust to changing oceanic temperatures, creating new combinations of species that could interact in unpredictable ways. Fish communities are likely to change. For example, warming oceans may cause the southern range of northern species, such as Atlantic cod, American plaice (*Hippoglossoides platessoides*), haddock (*Melanogrammus aeglefinus*), and Atlantic halibut (*Hippoglossus hippoglossus*), to shift north as will the northern range limit of southern species, such as butterfish (*Peprilus triacanthus*) and menhaden (*Brevoortia tyrannus*) (Nedeau 2004; Frumhoff et al. 2007). Mountain and Murawski (1992) reported changes in the distribution of selected fish stocks in the northeast continental shelf that were attributed to changes in surface and bottom water temperatures. Distributional changes attributed to increased water temperatures were observed in 26 out of the 30 species examined and resulted in fish moving northward or shallower towards cooler water (Mountain and Murawski 1992). Temperature induced shifts in the distribution of fish have implications for stock recruitment success and abundance. Short-lived fish species may show the most rapid demographic responses to temperature changes, resulting in stronger distributional responses to warming (Perry et al. 2005). Range shifts could create new competitive interactions between species that had not evolved in sympatry, causing further losses of competitively inferior or poorly adapted species.

Because of changes in the atmospheric and oceanic circulation patterns in the Arctic Ocean, the Northwest Atlantic shelf waters became fresher during the 1990s relative to the 1980s (Greene and Pershing 2007). This freshening was believed to have enhanced stratification of shelf waters and led to greater phytoplankton and zooplankton production and abundance during the autumn, a period when primary production would otherwise be expected to decline (Greene and Pershing 2007). Although it is uncertain as to whether the increased abundances of plankton during the 1990s were solely attributed to enhanced stratification caused by greater inflow of freshwater (bottom-up control), overfishing of large predators, such as Atlantic cod (top-down control) or some combined effect, it is clear that changes in climate and oceanic circulation patterns can have profound effects on ecosystem functions and productivity (Greene and Pershing 2007). Mountain (2002) proposed several possible effects to fish stocks in the mid-Atlantic region in response to increased water temperatures, increased seasonal stratification of the water column, and changes in regional ocean circulation patterns. Direct effects included northward shift in stock distributions and reduced reproductive success for some cold water species because of increased water temperatures; indirect effects included changes in phytoplankton productivity and species composition that can impact the lower trophic levels affecting recruitment success of fish stocks (Mountain 2002).

Migratory and anadromous fish such as salmon and shad may be affected by climate change because they depend on the timing of seasonal temperature-related events as cues for migration. Ideal river and ocean temperatures may be out of synch as climate changes, making the saltwater-to-freshwater transition difficult for spawning adults or the freshwater-to-saltwater transition difficult for ocean-bound juveniles. Migration routes, timing of migration, and ocean growth and survival of fish may also be affected by altered sea-surface temperatures (Nedeau 2004).

Invasive species may flourish in a changing climate when shifting environmental conditions give certain species a foothold in a community and a competitive advantage over native species. Species inhabiting northern latitude islands may be particularly vulnerable as nonnative organisms adapted to warmer climates take advantage of changing climatic conditions (Scavia et al. 2002; IPCC 2007b).

Increases in the severity and frequency of coastal storms may result in cumulative losses of coastal marshes by eroding the seaward edge, causing flooding further inland, changing salinity regimes and marsh hydrology, and causing vegetation patterns to change. Healthy salt marshes can buffer upland areas (including human structures) from storm damage, and this ecosystem function will be impaired if marshes are destroyed or degraded. Increased sea-surface temperatures, sea-level rise, and intensity of storms and associated surge and swells, combined with more localized effects such as nutrients and increased loading of sediments, have had demonstrable impacts on SAV beds worldwide (Orth et al. 2006). The loss or degradation of freshwater, brackish, and salt marsh wetlands, SAV and shellfish beds, and other coastal habitats will affect critical habitat for many species of wildlife, which may ultimately affect biodiversity, coastal ecosystem productivity, fisheries, and water quality.

### *Changes in ocean/coastal uses*

Commercial fisheries could be impacted by the cumulative effects of climate change, including rising sea levels and water temperatures and habitat degradation in estuaries, rivers, and coastal wetlands. Approximately 32% of species important to fisheries in New England are dependent upon estuaries during some portion of their life histories (Nedeau 2004). Climate change could also affect human health and the use of ocean resources if the frequency and intensity of harmful algal blooms, fish and shellfish diseases, coastal storms, and impacts to coastal wetlands increase. These effects, combined with sea-level rise, may result in a loss or inability to utilize coastal resources. Climate-induced changes to marine ecosystems will require consideration of longer time-scale effects in fisheries and coastal management strategies.

The IPCC Working Group II Report (IPCC 2007b) concluded there is “high confidence” that climate change will cause regional changes in the distribution and production of particular fish species, with adverse effects projected for aquaculture and fisheries. Conservative predictions of impacts to fisheries resources from sea-level rise and habitat loss from climate change would likely dwarf those impacts now attributed to direct human activities, like water quality degradation, coastal development, and dredging (Bigford 1991). It is possible that nonclimate stresses will increase the vulnerability to climate change impacts by reducing resilience and adaptive capacity (IPCC 2007b). However, it is likely that sustainable development, along with implementing strategies of climate change mitigation and adaptation, technological development (to enhance adaptation and mitigation), and research (on climate science, impacts, adaptation, and mitigation) can minimize some of the risks associated with climate change (IPCC 2007b).

The development of strategic mitigation and adaptation measures to address global climate change are beyond the scope of this report. However, conservation measures and best management practices that are consistent with sound coastal management and sustainable development may help mitigate some of the effects of global warming.

### *Conservation measures and best management practices for climate change impacts to aquatic habitat*

1. Promote soft shore protection techniques, such as salt marsh restoration and creation and beach dune restoration, as alternatives to hard-armoring approaches.
2. Consider vertical structures such as concrete bulkheads for shoreline stabilization only as a last resort.
3. Establish setback lines for coastal development and rolling easements based on sea-level rise and subsidence projections that include local land movement.
4. Avoid development projects that involve wetland filling and increase impervious surfaces.
5. Improve land use practices, such as more efficient nutrient management and more extensive restoration and protection of riparian zones and wetlands.
6. Encourage the development and use of renewable, nongreenhouse gas emitting energy technologies, whenever practicable and feasible.
7. Encourage local, regional, and federal agencies to consider implications of climate change in their decision-support analysis and documents (e.g., National Environmental Policy Act) regarding permit decisions and funding programs.
8. Encourage the use of energy efficient technologies to be integrated into commercial and residential construction, including renewable energy and energy efficient heating and cooling systems and insulation.
9. Encourage the use of fuel-efficient vehicles and mass transportation systems.
10. Encourage communities and states to develop and implement strategies for sustainable development and greenhouse gas reduction initiatives, such as through the International Council for Local Environmental Initiatives (ICLEI).

## Ocean Noise

### *Introduction*

Sound is the result of energy created by a mechanical action dispersed from a source at a particular velocity and causes two types of actions: an oscillation of pressure in the surrounding environment and an oscillation of particles in the medium (Stocker 2002). Because water is 3500 times denser than air, sound travels five times faster in water (Stocker 2002). The openness of the ocean and relative density of the ocean medium allow for the transmission of sound energy over long distances. Factors that affect density include temperature, salinity, and pressure. These factors are relatively predictable in the open ocean but highly variable in coastal and estuarine waters. As a result of these factors along with water depth and variable nearshore bathymetry, sound attenuates more rapidly with distance in shallow compared to deep water (Rogers and Cox 1988).

Noise in the ocean environment can be categorized as natural and anthropogenic sources. Naturally generated sounds come from wind, waves, ice, seismic activity, tides and currents, and thunder, among other sources. Many sea animals use sound in a variety of ways; some use sound passively and others actively. Passive use of sound occurs when the animal does not create the sound that it senses but responds to environmental and ambient sounds. These uses include detection of predators, location and detection of prey, proximity perception of cospecies in schools or colonies, navigation, and perception of changing environmental conditions such as seismic movement, tides, and currents. Animals also create sounds to interact with their environment or other animals in it. Such active uses include sonic communication with cospecies for feeding and spawning (e.g., oyster toadfish [*Opsanus tau*]), territorial and social interactions, echolocation (e.g., marine mammals), stunning and apprehending prey, long distance navigation and mapping (e.g., sharks and marine mammals), and the use of sound as a defense against predators (e.g., croakers) (Stocker 2002).

The degree to which an individual fish exposed to noise will be affected is dependent upon a number of variables, including: (1) species of fish; (2) fish size; (3) presence of a swimbladder; (4) physical condition of the fish; (5) peak sound pressure and frequency; (6) shape of the sound wave (rise time); (7) depth of the water; (8) depth of the fish in the water column; (9) amount of air in the water; (10) size and number of waves on the water surface; (11) bottom substrate composition and texture; (12) tidal currents; and (13) presence of predators (Hanson et al. 2003).

Anthropogenic sources of noise include commercial shipping, seismic exploration, sonar, acoustic deterrent devices, and industrial activities and construction. The ambient noises in an average shipping channel are a combination of propeller, engine, hull, and navigation noises. In coastal areas the sounds of cargo and tanker traffic are multiplied by complex reflected paths – scattering and reverberating because of littoral geography. These cargo vessels are also accompanied by all other manner of vessels and watercraft: commercial and private fishing boats, pleasure craft, personal watercraft (e.g., jet skis) as well as coastal industrial vessels, public transport ferries, and shipping safety and security services such as tugs boats, pilot boats, US Coast Guard and coastal agency support craft, and of course all varieties of US Navy ships – from submarines to aircraft carriers. In large part, anthropogenic activities creating ocean noise are concentrated in coastal and nearshore areas. The most pervasive anthropogenic ocean noise is caused by transoceanic shipping traffic (Stocker 2002). The average shipping channel noise levels are 70-90 dB, which is as much as 45 dB over the natural ocean ambient noise in surface regions (Stocker 2002). Ships generate noise primarily by propeller action, propulsion machinery, and hydraulic flow over the hull (Hildebrand 2004). Considering all of these noises together, noise generated from a large container vessel can exceed 190 dB at the source (Jasny et al. 1999). Refer to the Marine Transportation chapter for additional information on ocean noises generated from vessels.

The loudest noises may be the sounds of marine extraction industries such as oil drilling and mineral mining (Stocker 2002). The most prevalent sources of these sounds are from "air guns" used to create and read seismic disturbances. Air guns are used in seismic exploration to create a sound pressure wave that aids in reflection profiling of underlying substrates for oil and gas. These devices generate and direct huge impact noises into the ocean substrate. Offshore oil and gas exploration generally occurs along the continental margins; however, a recent study indicated that air gun activity in these areas propagates into the deep ocean and is a significant component of low frequency noise (Hildebrand 2004). Peak source levels of air guns typically are 250-255 dB. Following the exploration stage, drilling, coring, and dredging are performed during extraction which also generates loud noises. Acoustic telemetry is also associated with positioning, locating, equipment steering, and remotely operated vessel control to support extraction operations (Stocker 2002).

Sonar systems are used for a wide variety of civilian and military operations. Active sonar systems send acoustic energy into the water column and receive reflected and scattered energy. Sonar systems can be classified into low (<1 kHz), mid (1-20 kHz), and high frequency (>20 kHz). Most vessels have sonar systems for navigation, depth sounding, and "fish finding." Some commercial fishing boats also deploy various acoustic aversion devices to keep dolphins, seals, and turtles from running afoul of the nets (Stocker 2002).

Because the ocean transfers sound over long distances so effectively, various technologies have been designed to make use of this feature (e.g., long distance communication, mapping, and surveillance). Since the early 1990s, it has been known that extremely loud sounds could be transmitted in the deep-ocean isotherm and could be coherently received throughout the seas. Early research in the use of deep-ocean noise was conducted to map and monitor deep-ocean water temperature regimes. Since the speed of sound in water is dependent on temperature, this characteristic was used to measure the temperature of the deep water throughout the sea. This technology has been used to study long-term trends in deep-ocean water temperature that could give a reliable confirmation of global warming. This program, Acoustic Thermometry of Ocean Climates (ATOC), uses receivers stationed throughout the Pacific Basin from the Aleutian Islands to Australia. ATOC is a long wavelength, low frequency sound in the 1-500 Hz band and is the first pervasive deep-water sound channel transmission, filling an acoustical niche previously only occupied by deep sounding whales and other deep water creatures (Stocker 2002). Concurrent with the development of ATOC, the US Navy and other North American Treaty Organization (NATO) navies have developed other low frequency communications and surveillance systems. Most notable of these is low frequency active sonar (LFAS) on a mobile platform, or towed array (Stocker 2002). Recently, the use of LFAS for military purposes has received considerable attention and controversy because of the concerns that this technology has resulted in injury and death to marine mammals, particularly threatened and endangered whales. Fernandez et al. (2005) found the occurrence of mass stranding events of beaked whales in the Canary Islands to have a temporal and spatial coincidence with military exercises using mid-frequency sonar. Beaked whales that died after stranding were found to have injuries to tissues consistent with acute decompression-like illness in humans and laboratory animals. Additional monitoring and research will need to be conducted to determine the degree of threat sonar has on marine organisms, particularly marine mammals. The effects of LFAS on bony fish and elasmobranches are unknown at this time.

Industrial and construction activities concentrated in nearshore areas contribute to ocean noise. Primary activities include pile driving, dredging, and resource extraction and production activities. Pile driving activities, which typically occur at frequencies below 1000 Hz, have led to mortality in fish (Hastings and Popper 2005). Intensity levels of pile driving have been measured up to 193 dB in certain studies (Hastings and Popper 2005). Refer to the chapter on Coastal Development for additional information on the affects of pile driving.

Underwater blasting with explosives is used for a number of development activities in coastal waters. Blasting is typically used for dredging new navigation channels in areas containing large boulders and ledges; decommissioning and removing bridge structures and dams; and construction of new in-water structures such as gas and oil pipelines, bridges, and dams. The potential for injury and mortality to fish from underwater explosives has been well-documented (Hubbs and Rechnitzer 1952; Teleki and Chamberlain 1978; Linton et al. 1985; and Keevin et al. 1999). Generally, aquatic organisms that possess air cavities (e.g., lungs, swim bladders) are more susceptible to underwater blasts than are those without. In addition, smaller fish are more likely to be impacted by the shock wave of underwater blasts than are larger fish, and the eggs and embryos tend to be particularly sensitive (Wright 1982). However, fish larvae tend to be less sensitive to blasts than are eggs or post-larval fish, probably because the larval stages do not yet possess air bladders (Wright 1982). Impacts to fishery habitat from underwater explosives may include sedimentation and turbidity in the water column and benthos and the release of contaminants (e.g., ammonia) in the water column with the use of certain types of explosives.

Noise generated from anthropogenic sources covers the full frequency of bandwidth used by marine animals (0.001-200 kHz), and most audiograms of fishes indicate a higher sensitivity to sound within the 0.100-2 kHz range (Stocker 2002). Evidence indicates that fish as a group have very complex and diverse relationships with sound and how they perceive it. It should be noted that relatively little direct research has been conducted on the impacts of noise to marine fish. However, some studies and formal observations have been conducted that elucidate general categories of impacts to fish species. Noise impacts to fish can generally be divided into four categories: (1) physiological; (2) acoustic; (3) behavioral; and (4) cumulative.

### *Physiological impacts to fish*

Increased pressure from high noise levels may have impacts on other nonauditory biological structures such as swim bladders, the brain, eyes, and vascular systems (Hastings and Popper 2005). Any organ that reflects a pressure differential between internal and external conditions may be susceptible to pressure-related impacts. Some of the resulting affects on fish include a rupturing of organs and mortality (Hastings and Popper 2005). Sounds within autonomic response ranges of various organisms may trigger physiological responses that are not environmentally adapted in healthful ways (Stocker 2002).

The lethality of underwater blasts on fish is dependent upon the detonation velocity of the explosion; however, a number of other variables may play an important role, including the size, shape, species, and orientation of the organism to the shock wave, and the amount, type of explosive, detonation depth, water depth, and bottom type (Linton et al. 1985). Fish with swimbladders are the most susceptible to underwater blasts, owing to the effects of rapid changes in hydrostatic pressures on this gas-filled organ. The kidney, liver, spleen, and sinus venosus are other organs that are typically injured after underwater blasts (Linton et al. 1985).

### *Acoustic impacts to fish*

Acoustic impacts include damage to auditory tissue that can lead to hearing loss or threshold shifts in hearing (Jasny et al. 1999; Heathershaw et al. 2001; Hastings and Popper 2005). Temporary threshold shifts and permanent threshold shifts may result from exposure to low levels of sound for a relatively long period of time or exposure to high levels of sound for shorter periods. Threshold shifts can impact a fish's ability to carry out its life functions.

### *Behavioral impacts to fish*

While tissue damage would be a significant factor in compromising the health of fish, other effects of anthropogenic noise are more pervasive and potentially more damaging. For example, masking biologically significant sounds by anthropogenic interference could compromise acoustical interactions from feeding to breeding, to community bonding, to schooling synchronization, and all of the more subtle communications between these behaviors. Anthropogenic sounds that falsely trigger these responses may have animals expend energy without benefits (Stocker 2002). With respect to behavioral impacts on fish, studies in this area have been limited. Clupeid fish, including Atlantic herring (*Clupea harengus*) are extremely sensitive to noise, and schools have been shown to disperse when approached by fishing gear, such as trawls and seines (NOAA Fisheries 2005). Several studies indicate that catch rates of fish have decreased in areas exposed to seismic air gun blasts (Engås et al. 1996; Hastings and Popper 2005). These results imply that fish relocate to areas beyond the impact zone. One study indicated that catch rates increased 30-50 km away from the noise source (Hastings and Popper 2005). Several studies have indicated that increased background noise and sudden increases in sound pressure can lead to elevated levels of stress in many fish species (Hastings and Popper 2005). Elevated stress levels can increase a fish's vulnerability to predation and other environmental impacts. New studies are addressing the masking effects by background noise on the ability of fish to understand their surroundings. Because fish apparently rely so heavily on auditory cues to develop an "auditory scene," an increase in ambient background noise can potentially reduce a fish's ability to receive those cues and respond appropriately (Jasny et al. 1999; Scholik and Yan 2002; Hastings and Popper 2005). Furthermore, the auditory threshold shifts of fish exposed to noise may not recover even after termination of the noise exposure (Scholik and Yan 2002).

### Cumulative impacts to fish

Few research efforts have focused on the cumulative effects of anthropogenic ocean noise on fish. Subtle and long-term effects on behavior or physiology could result from persistent exposure to certain noise levels leading to an impact on the survival of fish populations (Jasny et al. 1999; Hastings and Popper 2005).

### Conservation measures and best management practices for ocean noise

1. Develop mitigation strategies for noise impacts to consider the frequency, intensity, and duration of exposure and evaluate possible reductions of each of these three factors. Mitigation strategies for ocean noise are challenged by the fact that a sound source may move in addition to the movement of affected fish in and out of the insonified region.
2. Assess the "acoustic footprint" of a given sound source and develop standoff ranges for various impact levels. Standoff ranges can be calculated by using damage risk criteria for species exposure, source levels, sound propagation conditions, and acoustic attenuation models. Development of standoff ranges implies that sound sources be relocated or reduced since the sound receptors (fish) are more difficult to control. Because the potential number of species affected and their location is most likely unknown, development of a generic approach for mitigation by using the species with the most sensitive hearing would produce a precautionary approach to reducing impacts on all animals (Heathershaw et al. 2001).
3. Recommend an assessment and designation of "acoustic hotspots" that are particularly susceptible to acoustic impacts and reducing sound sources around them. These hotspots may include seasonal areas for particularly susceptible life history activities like spawning or breeding (Jasny et al. 1999).
4. Recognize that reducing noise intensity at the source primarily relies on technological solutions. These options include the use of "quiet" technology in marine engines and using bubble curtains for activities such as pile driving.
5. Encourage the use of sound dampening technologies for vessels and port/marine infrastructure to reduce ocean noise impacts to aquatic organisms.
6. Manage the duration of sound when the source level of a sound cannot be reduced in order to reduce impacts. Underwater sounds should be avoided during sensitive times of year (e.g., upstream and downstream river migrations, spawning, and egg and larvae development).
7. Avoid using underwater explosives in areas supporting productive fishery habitats. The use of less destructive methods should be encouraged, whenever possible. In some cases, the use of mechanical devices (e.g., ram hoe, clamshell dredge) may reduce impacts associated with rock and ledge removal.
8. Investigate options to mitigate the impacts associated with underwater explosives. Avoiding use during sensitive periods (e.g., upstream and downstream river migrations, spawning, and egg and larvae development) may be one of the most effective means of minimizing impacts to fishery resources. Other methods may include the use of bubble curtains; stemming (back-filling charge holes with gravel); delayed charges (explosive charges broken down into a series of smaller charges); and the use of repelling charges (small explosive charges used to frighten and drive fish away from the blasting zone) (Keevin 1998).

# Atmospheric Deposition

## *Introduction*

Pollutants travel through the atmosphere for distances of up to thousands of miles, often times to be deposited into rivers, estuaries, and nearshore and offshore marine environments. Substances such as sulfur dioxide, nitrogen oxide, carbon monoxide, lead, volatile organic compounds, particulate matter, and other pollutants are returned to the earth through either wet or dry atmospheric deposition. Wet deposition removes gases and particles in the atmosphere and deposits them to the earth's surface by means of rain, sleet, snow, and fog. Dry deposition is the process through which particles and gases are deposited in the absence of precipitation. Deposition of nutrients (i.e., nitrogen and phosphorous) and contaminants (e.g., polychlorinated biphenyl [PCB] and mercury) into the aquatic system are of particular concern because of the resulting impacts to fisheries and health-risks to humans.

Atmospheric inputs of nutrients and contaminants differ from riverine inputs in the following ways: (1) riverine inputs are delivered to the coastal seas at their margins, whereas atmospheric inputs can be delivered directly to the surface of the central areas of coastal seas and hence exert an impact in regions less directly affected by riverine inputs; (2) atmospheric delivery occurs at all times, whereas riverine inputs are dominated by seasonal high-flows and coastal phytoplankton activity; (3) atmospheric inputs are capable of episodic, high deposition events associated with natural or manmade phenomena (e.g., volcanic eruptions, forest fires); and (4) atmospheric inputs of nitrogen are chemically different from river inputs in that rivers are dominated by nitrous oxides, phosphorus, and silica, while atmospheric inputs include reduced and oxidized nitrogen, but no significant phosphorus or silica (Jickells 1998). While there is little information on the direct effects of atmospheric deposition on marine ecosystems, management strategies must attempt to address these variations in inputs from terrestrial and atmospheric pathways.

## *Nutrient loading and eutrophication*

Nutrient pollution is currently the largest pollution problem in the coastal rivers and bays of the United States (NRC 2000). Nitrogen inputs to estuaries on the Atlantic and Gulf Coasts of the United States are now 2-20 times greater than during preindustrialized times (Castro et al. 2003). Sources of nitrogen include emissions from automobiles, as well as urban, industrial, and agricultural sources. Atmospheric deposition is one means of nitrogen input into aquatic systems, with atmospheric inputs delivering 20 to greater than 50% of the total input of nitrogen oxide to coastal waters (Paerl 1995). One of the most rapidly increasing means of nutrient loading to both freshwater systems and the coastal zone is via atmospheric pathways (Anderson et al. 2002).

Precipitation readily removes most reactive nitrogen compounds, such as ammonia and nitrogen oxides, from the atmosphere. These compounds are subsequently available as nutrients to aquatic and terrestrial ecosystems. Because nitrogen is commonly a growth-limiting nutrient in streams, lakes, and coastal waters, increased concentrations can lead to eutrophication, a process involving excess algae production, followed by depletion of oxygen in bottom waters. Hypoxic and anoxic conditions are created as algae die off and decompose. Harmful algal blooms associated with unnatural nutrient levels have been known to stimulate fish disease and kills. In addition, phytoplankton production increases the turbidity of waters and may result in a reduced photic zone and subsequent loss of submerged aquatic vegetation. Anoxic conditions, increased turbidity, and fish mortality may result from increased nitrogen inputs into the aquatic system, potentially altering long-term community dynamics (NRC 2000; Castro et al. 2003). Refer to the chapters on

Agriculture and Silviculture, Coastal Development, Alteration of Freshwater Systems, and Chemical Effects: Water Discharge Facilities for further discussion on impacts to fisheries from eutrophication.

The atmospheric component of nitrogen flux into estuaries has often been underestimated, particularly with respect to deposition on the terrestrial landscape with subsequent export downstream to estuaries and coastal waters (Howarth et al. 2002). The deposition of nitrogen on land via atmospheric pathways impacts aquatic systems when terrestrial ecosystems become nitrogen saturated. Nitrogen saturation means that the inputs of nitrogen into the soil exceed the uptake ability by plants and soil microorganisms. Under conditions of nitrogen saturation, excess nitrogen leaches into soil water and subsequently into ground and surface waters. This leaching of excess nitrogen from the soils degrades water quality. Such conditions have been known to occur in some forested watersheds in the northeastern United States, and streams that drain these watersheds have shown increased levels of nitrogen from runoff (Williams et al. 1996).

In one study, quantifying nitrogen inputs for 34 estuaries on the Atlantic and Gulf Coasts of the United States, atmospheric deposition was the dominant nitrogen source for three estuaries, and six estuaries had atmospheric contributions greater than 30% of the total nitrogen inputs (Castro et al. 2003). In the northeastern United States, atmospheric deposition of oxidized nitrogen from fossil-fuel combustion may be the major source of nonpoint input. Evidence suggests a significant movement of nitrogen in the atmosphere from the eastern United States to coastal and offshore waters of the North Atlantic Ocean where it is deposited (Holland et al. 1999). Nitrogen fluxes in many rivers in the northeastern United States have increased 2- to 3-fold or more since 1960, with much of this increase occurring between 1965 and 1988. Most of this increase in nitrogen was attributed to increased atmospheric deposition originating from fossil-fuel combustion onto the landscape (Jaworski et al. 1997).

### *Mercury loading/bioaccumulation*

Mercury is a hazardous environmental contaminant. Mercury bioaccumulates in the environment, which means it can collect in the tissues of a plant or animal over its lifetime and biomagnify (i.e., increases in concentration within organisms between successive trophic levels) within the food chain. Fish near the top of the food chain often contain high levels of mercury, prompting the United States and Canada to issue health advisories against consumption of certain fish species. The US Food and Drug Administration reports certain species, including sharks, swordfish (*Xiphias gladius*), king mackerel (*Scombermorus cavalla*), and tilefish (*Lopholatilus chamaeleonticeps*), to have typically high concentrations of mercury (USFDA 2004).

One of the most important anthropogenic sources of mercury pollution in aquatic systems is atmospheric deposition (Wang et al. 2004). The amount of mercury emitted into the atmosphere through natural and reemitted sources was estimated to be between 1500-2500 metric tons/year in the late 20$^{th}$ century (Nriagu 1990). Industrial activities have increased atmospheric mercury levels, with modern deposition flux estimated to be 3-24 times higher than preindustrial flux (Bindler 2003). More than half of the total global mercury emissions are from incineration of solid waste, municipal and medical wastes, and combustion of coal and oil (Pirrone et al. 1996).

Studies strongly support the theory that atmospheric deposition is an important (sometimes even the predominant) source of mercury contamination in aquatic systems (Wang et al. 2004). Mercury exists in the atmosphere predominately in the gaseous form, although particulate and aqueous forms also exist (Schroeder et al. 1991). Gaseous mercury is highly volatile, remaining in the atmosphere for more than one year, making long-range atmospheric transport a major environmental concern (Wang et al. 2004).

Concentrations of mercury in the atmosphere and flux of mercury deposition vary with the seasons, and studies suggest that atmospheric mercury deposition is greatest in summer and least in winter (Mason et al. 2000). Different, site-specific factors may influence the transport and transformation of mercury in the atmosphere. Wind influences the direction and distance of deposition from the source, while high moisture content may increase the oxidation of mercury, resulting in the rapid settlement of mercury into terrestrial or aquatic systems. Mercury that is deposited on land can be absorbed by plants through their foliage and ultimately be passed into watersheds by litterfall (Wang et al. 2004).

Mercury and other metal contaminants are found in the water column and persist in sediments (Buchholtz ten Brink et al. 1996). Mercury is toxic in any form according to some scientists, but when absorbed by certain bacteria such as those in marine sediments, it is converted to its most toxic form, methyl mercury. Methyl mercury can cause nerve and developmental damage in humans and animals. Mercury inhibits reproduction and development of aquatic organisms, with the early life-history stages of fish being the most susceptible to the toxic impacts associated with metals (Gould et al. 1994). Metals have also been implicated in disrupting endocrine secretions of aquatic organisms, potentially disrupting natural biotic properties (Brodeur et al. 1997). Direct mortality of fish and invertebrates by lethal concentrations of metals may occur in some instances. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for more information on impacts from mercury contamination.

### *PCB and other contaminants*

PCB congeners are a group of organic chemicals which can be odorless or mildly aromatic and exist in solid or oily-liquid form. They were formerly used in the United States as hydraulic fluids, plasticizers, adhesives, fire retardants, way extenders, dedusting agents, pesticide extenders, inks, lubricants, cutting oils, manufacturing of heat transfer systems, and carbonless reproducing paper. Most uses of PCB were banned by the US Environmental Protection Agency in 1979; however this persistent contaminant continues to enter the atmosphere mainly by cycling from soil to air to soil again. PCB is also currently released from landfills, incineration of municipal refuse and sewage sludge, and improper (or illegal) disposal of PCB-contaminated materials, such as waste transformer fluid, to open areas (USEPA 2005a).

PCB compounds are a mixture of different congeners of chlorobiphenyl. In general, the persistence of PCB increases with an increase in the degree of chlorination. Mono-, di- and trichlorinated biphenyls biodegrade relatively rapidly, tetrachlorinated biphenyls biodegrade slowly, and higher chlorinated biphenyls are resistant to biodegradation. If released to the atmosphere, PCB will primarily exist in the vapor-phase and have a tendency to become associated with the particulate-phase as the degree of chlorination of the PCB increases. Physical removal of PCB from the atmosphere is accomplished by wet and dry deposition (USEPA 2005b).

Although restrictions were first placed on the use of PCBs in the United States during the 1970s, lipid-rich finfish and shellfish tissues have continued to accumulate PCBs, dichlorodiphenyl trichloroethane (DDT), and chlordane from the environment (Kennish 1998). PCB congeners are strongly lipophilic and accumulate in fatty tissues including egg masses, affecting the development of fish as well as posing a threat to human health through the consumption of contaminated seafood. Refer to the chapters on Coastal Development and Chemical Effects: Water Discharge Facilities for more additional information on PCB contamination.

### *Alteration of ocean alkalinity*

The influx of acid to the aquatic environment occurs through the atmospheric precipitation of two predominant acids, sulfuric acid and nitric acid, making up acid rain (i.e., pH less than 5.0). Sulfur dioxide is produced naturally by volcanoes and decomposition of plants, while the main anthropogenic source is combustion, especially from coal-burning power plants. In eastern North America, acid rain is ubiquitous because of the presence of coal-burning power plants (Baird 1995). Other sources of sulfuric acid in the atmosphere include oil refinement, cleaning of natural gas, and nonferrous smelting. Affects on biological life depend strongly on soil composition. Granite and quartz have little capacity to neutralize acid, while limestone or chalk can efficiently neutralize acids. Under acidic conditions, aluminum is leached from rocks. Both acidity and high concentrations of dissolved aluminum are responsible for decreases in fish populations observed in many acidified water systems (Baird 1995).

The freshwater environment does not have the buffering capacity of marine ecosystems, so acidification has serious implications on riverine habitat. Low pH (below 5.0) has been implicated with osmoregulation problems (Staurnes et al. 1996), pathological changes in eggs (Peterson et al. 1980; Haines 1981), and reproduction failure in Atlantic salmon (Watt et al. 1983). Cumulative, long-term deposition of acid into the aquatic environment can hinder the survival and sustainability of fisheries by disrupting and degrading important fish and shellfish habitat. Refer to the Coastal Development and Chemical Effects: Water Discharge Facilities chapters for additional information on the affects of acidification of aquatic habitats.

### *Conservation measures and best management practices for atmospheric deposition*

1. Install scrubbers for flue-gas desulfurization in electricity generating powerplants, oil refineries, nonferrous smelters, and other point sources of sulfur dioxide emissions.
2. Use integrated, gas-scrubbing systems on municipal waste combustion units.
3. Reduce sulfur dioxide emissions by substituting natural gas or low-sulfur coal for high-sulfur coal at power plants.
4. Encourage renewable energy generation using wind, solar, and geothermal technologies.
5. Encourage the use of fuel-efficient vehicles and mass transportation systems.
6. Encourage the separation of batteries from the waste stream to reduce the release of mercury vapors through waste incineration.
7. Lower volatization and/or erosion and resuspension of persistent compounds through remediation at waste sites.

## Military/Security Activities

The operations of the US military span the globe and are carried out in coastal, estuarine, and marine habitats. Military operations have the potential to adversely impact fish habitat through training activities conducted on land bases as well as in coastal rivers and the open ocean. Military operations also impact fish habitat and larger ecological communities during wars (Literathy 1993).

Because many military bases and training activities are located in coastal areas and oftentimes directly on shorelines, they can cause impacts similar to those mentioned in other parts of this document (e.g., coastal development, dredging, sewage discharge, road construction, shoreline protection, over-water structures, pile driving, port and marina operations, and vessel operations). In addition to these conventional activities, the military often stockpiles and disposes of toxic chemicals on base grounds. Toxic dumping on base grounds has led to the contamination of groundwater at Otis Air National Guard Base on Cape Cod, MA, (NRDC 2003) and in Vieques, Puerto Rico.

The United States Navy also uses sonar systems that create large amounts of noise in ocean waters. The Surveillance Towed Array Sensor System (SURTASS) low frequency active sonar produces extremely loud low frequency sound that can be heard at 140 dB from 300 miles away from the source (NRDC 2004). Sixty percent of the US Navy's 294 ships are equipped with mid-frequency sonar devices that can produce noise above 215 dB (NRDC 2002). The intensity of these noises in the water column can cause a variety of impacts to fish, marine mammals, and other marine life such as behavior alterations, temporary and permanent impairments to hearing, and mortality. Other sources of underwater noise from military activities may include explosive devices and ordnances during training exercises and during wartime. Refer to the Ocean Noise section in this chapter for more information on impacts associated with sonar, as well as the Marine Transportation and Coastal Development chapters for information related to blasting impacts.

## Natural Disasters and Events

### *Introduction*

Natural events and natural disasters of greatest concern for the northeastern United States include hurricanes, floods, and drought. These events may impact water quality, alter or destroy habitat, alter hydrological regimes, and result in changes to biological communities. Natural disasters have the potential to impact fishery resources, such as displacing plankton and fish from preferred habitat and altering freshwater inputs and sediment patterns. While these effects may not themselves pose a threat to coastal ecosystems, they may have additive and synergistic effects when combined with anthropogenic influences such as the release of agricultural and industrial pollutants in storm water.

### *Water quality impacts*

Water quality degradation by hurricanes can be exacerbated by human activities. Hurricanes and posthurricane flooding have been known to result in large freshwater inputs and high concentrations of nutrients into river and estuarine waters, causing reductions in water quality and massive fish kills (Mallin et al. 1999). For example, when Hurricane Fran struck North Carolina in the Cape Fear River area in 1996, the following impacts were reported as a result of the hurricane: (1) power failures caused the diversion of millions of liters of raw and partially treated human waste into rivers when sewage treatment plants and pump stations were unable to operate; (2) dissolved oxygen concentrations decreased in parts of the Cape Fear River for more than three weeks following the hurricane; (3) ammonium and total phosphorous concentrations were the highest recorded in 27 years of monitoring in Northeast Cape Fear River following the hurricane and; (4) sediment-laden waters flowing into Cape Fear River increased turbidity levels (Mallin et al. 1999).

Generally, high rates of flushing and reduced water residence times will inhibit the formation of algal blooms in bays and estuaries. However, the input of large amounts of human and animal waste can greatly increase the biological oxygen demand and lead to hypoxic conditions in aquatic systems. In addition to the diversion of untreated waste from sewage treatment plants during Hurricane Fran, several swine waste lagoons were breached, overtopped, or inundated, discharging large quantities of concentrated organic waste into the aquatic environment (Mallin et al. 1999). Other sources of nutrient releases during storms and subsequent flooding events include septic systems on private residences built on river and coastal floodplains.

Natural disasters, such as hurricanes, may also put vessels (e.g., oil tankers) and coastal industrial facilities (e.g., liquefied natural gas [LNG] facilities, nuclear power plants) at risk of damage and contaminant spills. Tanker ship groundings generally occur during severe storms, when moorings are more susceptible to being broken and the control of a vessel may be lost or compromised. The release of toxic chemicals from damaged tanks, pipelines, and vessels threaten aquatic organisms and habitats.

### *Changes to community composition*

Major storm events may impact benthic communities through a variety of mechanisms, including increased sedimentation, introduction of contaminants, reduction in dissolved oxygen, short-term changes in salinity, and disturbance from increased flow. Monitoring of environmental impacts following Hurricane Fran in 1996 indicated that significant declines in benthic organism abundance were observed up to three months after the storm. However, significant declines in benthic abundance generally did not occur in areas where levels of dissolved oxygen recovered quickly after the storm (Mallin et al. 1999). Poorly flushed bays and inland river floodplains are areas that typically exhibit greater magnitude and duration of storm-related impacts.

### *Loss/alteration of habitat*

The rate of accretion and erosion of coastal areas is influenced by wave energy impacting the shoreline, and natural events such as hurricanes will accelerate this process. Erosion may occur as a function of hydraulic scour produced by hurricane overwash and offshore-directed wave energy. Accretion of materials resulting from overwash deposition may result in subsequent flood tidal delta development. Extreme climatic events, such as hurricanes and tsunamis, can have large-scale impacts on submerged aquatic vegetation communities (Orth et al. 2006). Loss or alteration of coastal habitat as a result of storms may be exacerbated by the effects of shoreline development and erosion control measures. For example, the creation of hardened shoreline structures (e.g., seawalls, jetties) and storm-water control systems can focus storm energy and redirect storm water to wetlands, resulting in increased erosion and habitat loss in productive fishery habitat.

### *Alteration of hydrological regimes*

Hurricane and flood events result in large volumes of water delivered to the watershed in a relatively short period of time. These events can alter the hydrology of wetlands, streams, and rivers by increasing erosion and overwhelming flood control structures. Freshwater flows into rivers draining into Charleston Harbor in South Carolina increased as much as four times the historical average after Hurricane Hugo in 1989 (Van Dolah and Anderson 1991). Reduced dissolved oxygen concentrations were observed in all portions of the Charleston Harbor estuary following Hurricane Hugo, with hypoxic conditions in some of the rivers in the watershed. The decomposition of vegetation and the failure of septic and sewer systems overflowing into the watershed as a result of this hurricane was identified as the primary cause of the high organic loads (Van Dolah and Anderson 1991). At the other extreme, drought will result in reduced run-off and low flows in streams and rivers that drain into estuaries and bays. Low freshwater input resulted in dramatic reductions in phytoplankton and zooplankton in San Francisco Bay, CA, reducing pelagic food for fish populations (Bennett et al. 1995). Larval starvation may limit recruitment. During low-flow years, toxins from agricultural and urban runoff are less diluted which can also harm fish.

### *Conservation measures and best management practices for natural disasters and events*

1. Require backup generating systems for publicly owned waste treatment facilities.
2. Prohibit development of high-risk facilities, such as animal waste lagoons, storage of hazardous chemicals within the 100-year floodplain.
3. Ensure that all industrial and municipal facilities involving potentially hazardous chemicals and materials have appropriate emergency spill response plans, including emergency notification systems and spill cleanup procedures, training, and equipment.
4. Encourage the protection and restoration of coastal wetlands and barrier islands, which buffer the affects of storm events by dissipating wave energy and retaining floodwaters.
5. Discourage new construction and development in or near coastal and riparian wetlands.
6. Discourage the use of "hard" shoreline stabilization, such as seawalls and bulkheads.
7. Limit emergency authorizations (e.g., federal Clean Water Act permits) for reconstruction projects to replacing structures that were in-place and functional at the time of the natural disaster/event and do not include the expansion of structures and facilities.

## Electromagnetic Fields

Anthropogenic activities are responsible for the majority of the overall electromagnetic fields (EMF) emitted into the environment, with natural sources making up the remainder. Levels of EMF from anthropogenic sources have increased steadily over the past 50-100 years (WHO 2005). Anthropogenic sources of EMF include undersea power cables, high voltage power lines, radar, FM radio and TV transmitters, cell phones, high frequency transmitters for atmospheric research, and solar power satellites. The EMF created by undersea power cables may have some adverse affect on marine organisms. Undersea power cables transfer electric power across water, usually conducting very large direct currents (DC) of up to a thousand amperes or more. It has been inferred that undersea cables can interfere with the prey sensing or navigational abilities of animals in the immediate vicinity of the sea cables (See also the Cables and Pipelines section of the Energy-related Activities chapter). Few published, peer reviewed scientific articles on the environmental effects of electromagnetic fields on aquatic organisms exist. However, the World Health Organization cosponsored an international seminar in October 1999 entitled "Effect of Electromagnetic Fields on the Living Environment" to focus attention on this subject. A review of the information presented at the seminar was prepared by Foster and Repacholi (2000).

Electromagnetic fields are the product of both natural and artificial sources. Natural sources of EMF include radiation from the sun, the earth's magnetic fields, the atmosphere (e.g., lightning discharges), and geological processes (WHO 2005). Marine animals are also exposed to natural electric fields caused by sea currents moving through the geomagnetic field. Examples of anthropogenic sources of EMF include undersea power cables and US Navy submarine communication systems (Foster and Repacholi 2000). Mild electroreception by teleost (bony) fishes occurs through external pit organs that interpret minute electrical currents in the water (Moyle and Cech 1988). However, elasmobranches (i.e., sharks, skates, and rays) are unique in that they possess well-developed electroreceptive organs, called Ampullae of Lorenzini, that enable them to detect weak electric fields in the surrounding seawater as low as 0.01 $\mu$V/m (Kalmijn 1971). Elasmobranchs are able to receive information about the positions of their prey, the drift of ocean currents, and their magnetic compass headings from electric fields in their surrounding environment.

Most aquatic organisms emanate low-frequency electric fields that can be detected by fish, such as skates and rays, through a process known as "passive electrolocation" or "passive electroreception." Passive electroreception allows animals to sense electric fields generated in the environment, thereby allowing predators to detect prey by the electric fields that individual fauna emanate. Elasmobranchs have demonstrated during controlled experiments the ability to detect artificially created electric fields (1-5 μA) that are similar to those produced by prey (Kalmijn 1971). The other form of electroreception is "active electroreception" and occurs when an animal detects changes in their own electric field caused by the electric field produced by prey in the vicinity. This ability to detect disturbances to an individual's own electric field is rare, occurring only in a few families of weakly electric fish, none of which are found in the Northwest Atlantic Ocean.

There is evidence that elasmobranches also use their ability to detect electric fields for the purpose of navigation. For example, blue sharks (*Prionace glauca*) have been observed migrating in the North Atlantic Ocean maintaining straight courses for hundreds of kilometers over many days (Paulin 1995). The two modes of detection used for navigation are: (1) passive detection (when an animal estimates its drift from the electrical fields produced by interactions of tidal and wind-driven currents and the vertical component of the earth's magnetic field); or (2) active detection (when the animal derives its magnetic compass heading from the electrical field it generates by its interaction with the horizontal component of the earth's magnetic field) (Gill and Taylor 2001).

### *Changes in migration of marine organisms*

Anthropogenic sources of EMFs may affect social behavior, communications, navigation, and orientation of those animals that rely on the earth's magnetic field. Certain fish rely on the natural (geomagnetic) static magnetic field as one of a number of parameters believed to be used as orientation and navigational cues. For example, stingrays have demonstrated their ability during training experiments to orient relative to uniform electric fields similar to those produced by ocean currents (Kalmijn 1982). In addition, the small-spotted catshark (*Scyliorhinus canicula*) and the thornback skate (*Raja clavata*) have shown a remarkable sensitivity to electric fields (Kalmijn 1982). However, studies demonstrating an impact on the ability of marine organisms to migrate because of anthropogenic sources of EMFs have not been found. Foster and Repacholi (2000) noted the sensitivity of sharks to low frequency electric fields and a potential mechanism for adverse effects from DC fields but made no mention of adverse effects from EMFs.

### *Changes to feeding behavior*

Electric or magnetic fields near sea cables may affect prey sensing of electrically or magnetically sensitive species. Submarine cables may attract species when the field intensity approximates that of their natural prey. Smooth dogfish (*Mustelus canis*) and the blue shark have been observed to execute apparent feeding responses to dipole electric fields designed to mimic prey (Kalmijn 1982). Less is known about how elasmobranches respond in the presence of stronger EMFs that exist closer to the cable. Depending on the presence and strength of electric fields, the feeding behavior of elasmobranches could be altered by submarine cables.

The possible affects of exposure to EMF depend on a coupling between the external field and the body of the animal and the biological response mechanisms. The size of the animal, frequency of the field, and whether the pathway of exposure is via air or water will determine effects to the animal. It has been suggested that monopolar power links are more likely to affect aquatic animals than bipolar links do because they produce perceptible levels of fields over larger distances from the cables (Kalmijn 2000). Sea cables are isolated from the surrounding water by layers of insulation and metal sheathing, yet electric fields that can exceed natural ambient levels remain detectable (Foster and Repacholi 2000). The flow of seawater past the cables can create electric fields by magnetic induction. The resulting field strength in the seawater can exceed naturally occurring levels and depends on the flow velocity, whether or not the observer is moving with respect to the water, and on the electrical conductivity of nearby surfaces (Foster and Repacholi 2000).

Further directed research should be conducted to examine the effect of EMFs from underwater transmission lines on marine organisms. Increased understanding is needed about the effects of cable burial within different substrata and the range of frequencies and sensitivities of electric fields that marine species are capable of detecting.

### *Conservation recommendations and best management practices for electromagnetic fields*

1. Map proposed submarine cable routes with marine resource utilization in a geographic information system database to provide information on potential interference with elasmobranch fishes and other organisms. Particular attention should be paid to known nursery and pupping grounds of coastal shark species.
2. Bury submarine cables below the seafloor to potentially reduce possible interference with the electroreception of fishes. However, the benefits of cable burial to minimize potential impacts to elasmobranchs should be weighed with the adverse effects associated with trenching on the seafloor.
3. Place new submarine electric transmission lines within existing transmission corridors to minimize the cumulative effect of transmission lines across the ocean bottom to the extent practicable.

## References for Global Effects and Other Impacts


Anderson DM, Glibert PM, Burkholder JM. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25(4b):704-26.

Baird C. 1995. Ground-level air chemistry and air pollution. In: Environmental Chemistry. New York (NY): W. H. Freeman and Company. p 90-9.

Bennett WA, Ostrach DJ, Hinton DE. 1995. Larval striped bass condition in a drought-stricken estuary: evaluating pelagic food-web limitation. Ecological Applications 5(3):680-92.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Bindler R. 2003. Estimating the natural background atmospheric deposition rate of mercury utilizing ombrotrophic bogs in southern Sweden. Environmental Science and Technology 37:40-6.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchholtz ten Brink MR, Manheim FT, Bothner MH. 1996. Contaminants in the Gulf of Maine: what's there and should we worry? In: Dow D, Braasch E, editors. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Hanover (NH): Dartmouth College, Regional Association for Research on the Gulf of Maine (RARGOM) Report 96-1. p 91-5.

Castro MS, Driscoll CT, Jorden TE, Reay WG, Boynton WR. 2003. Sources of nitrogen to estuaries in the United States. Estuaries 26(3):803-14.

Cloern J. 2001. Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 210:223-52.

Edwards M, Richardson A. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430(7002):881-4.

Engås A, Lokkeborg S, Ona E, Soldal AV. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Sciences 53:2238-49.

Fernandez A, Edwards JF, Rodriguez F, Espinosa De Los Monteros A, Herraez P, Castro P, Jaber JR, Martin V, Arbelo M. 2005. ‘‘Gas and fat embolic syndrome’’ involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. Veterinary Pathology 42:446-57.

Foster KR, Repacholi MH. 2000. Environmental impacts of electromagnetic fields from major electrical technologies. In: Matthes R, Bernhardt JH, Repacholi MH, editors. Proceedings of the international seminar on effects of electromagnetic fields on the living environment; 1999 Oct. 4-5; Ismaning, Germany. Munich (Germany): International Commission on Non-Ionizing Radiation Protection. World Health Organization (WHO). 17 p.

Frumhoff PC, McCarthy JJ, Melillo, SC, Moser SC, Wuebbles DJ. 2007. Confronting climate change in the U.S. Northeast: science, impacts, and solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge (MA): Union of Concerned Scientists (UCS). 146 p.

Gill AB, Taylor H. 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. University of Liverpool: Research project for Countryside Council of Wales. CCW Science report No. 488. 73 p.

Gould E, Clark PE, Thurberg FP. 1994. Pollutant effects on dermersal fishes. In: Langton RW, Pearce JB, Gibson JA, editors. Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum NMFS-NE-106. p 30-41.

Greene CH, Pershing AJ. 2007. Oceans: climate drives sea change. Science 315:1084-5.

Gutierrez BT, Williams SJ, Thieler ER. 2007. Potential for shoreline changes due to sea-level rise along the U.S. mid-Atlantic region. [Internet]. Reston (VA): US Geological Survey Open-File Report 2007-1278. [cited 2008 July 28]. 26 p. Available from: http://pubs.er.usgs.gov/usgspubs/ofr/ofr20071278.

Haines TA. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Transactions of the American Fisheries Society 110(6):669-707.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Hastings MC, Popper AN. 2005. Effects of sound on fish. Sacramento (CA): Jones & Stokes. CADOT Contract No. 43A0139, Task Order 1. 82 p.

Heathershaw AD, Ward PD, David AM. 2001. The environmental impact of underwater sound. Proceedings of the Institute of Acoustics 23(4).

Hildebrand J. 2004. Sources of anthropogenic sound in the marine environment. [Internet]. In: Vos E, Reeves RR, editors. Report of an international workshop: policy on sound and marine mammals; 2004 Sep 28-30; London, England. Bethesda (MD): Marine Mammal Commission. [cited 2008 Jul 21]. 129 p. Available from: http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hodgkins GA, Dudley RW. 2005. Changes in the magnitude of annual and monthly streamflows in New England, 1902-2002. Denver (CO): US Department of the Interior, US Geological Survey. Scientific Investigations Report 2005-5135. 23 p. plus appendices.

Holland TA, Dentener FJ, Braswell BH, Sulzman JM. 1999. Contemporary and pre-industrial global reactive nitrogen budgets. Biogeochemistry 46:7-43.

Howarth RW, Sharpley A, Walker D. 2002. Sources of nutrient pollution to coastal waters in the United States: implications for achieving coastal water quality goals. Estuaries 25(4b):656-76.

Hubbs CL, Rechnitzer AB. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38:333-66.

[IPCC] Intergovernmental Panel on Climate Change. 2007a. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 996 p. Available from: http://www.ipcc.ch.

[IPCC] Intergovernmental Panel on Climate Change (IPCC). 2007b. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Internet]. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. New York (NY): Cambridge University Press. [cited 2008 Jul 9]. 976 p. Available from: http://www.ipcc.ch.

Jasny M, Reynolds J, Horowitz C, Wetzler A. 1999. Sounding the depths: supertankers, sonar, and rise of undersea noise. Los Angeles (CA): Natural Resources Defense Council. Marine Mammal Protection Project. 38 p.

Jaworski NA, Howarth RW, Hetling LJ. 1997. Atmospheric deposition of nitrogen oxides onto the landscape contributes to coastal eutrophication in the northeast United States. Environmental Science and Technology 31:1995-2004.

Jickells TD. 1998. Nutrient biogeochemistry of the coastal zone. Science 281(5374):217-22.

Kalmijn AJ. 1971. The electric sense of sharks and rays. Journal of Experimental Biology 55:371-83.

Kalmijn AJ. 1982. The electric and magnetic field detection in elasmobranch fishes. Science 218(4575):916-18.

Kalmijn AJ. 2000. Detection and processing of electromagnetic and near-field acoustic signals in elasmobranch fishes. Biological Sciences 335(1401):1135-41.

Karl TR, Knight RW. 1998. Secular trends in precipitation amount, frequency, and intensity in the United States. Bulletin of the American Meteorological Society 79(2):231-41.

Keevin TM. 1998. A review of natural resource agency recommendations for mitigating the impacts of underwater blasting. Reviews in Fisheries Science 6(4):281-313.

Keevin TM, Gaspin JB, Gitschlag GR, Hempen GL, Linton TL, Smith M, Wright DG. 1999. Underwater explosions: natural resource concerns, uncertainty of effects, and data needs. In: Proceedings of the twenty-fifth annual conference on explosives and blasting technique; 1999 Feb 7-10; Nashville, TN. Cleveland (OH): International Society of Explosive Engineers. p 105-16.

Kennedy VS, Twilley RR, Kleypas JA, Cowan JH, Hare SR. 2002. Coastal and marine ecosystems and global climate change: potential effects on U.S. resources. Arlington (VA): Pew Center on Global Climate Change. 51 p.

Kennish MJ, Ruppel BE. 1998. Organochlorine contamination in selected estuarine and coastal marine finfish and shellfish of New Jersey. Water, Air, and Soil Pollution 101(1-4):123-36.

Linton TL, Landry AM Jr, Buckner JE Jr, Berry RL. 1985. Effects upon selected marine organisms of explosives used for sound production in geophysical exploration. The Texas Journal of Science 37(4):341-53.

Literathy P. 1993. Considerations for the assessement of environmental consequences of the 1991 Gulf War. Marine Pollution Bulletin 27:349-56.

Mallin MA, Posey MH, Shank GC, McIver MR, Ensign SH, Alphin TD. 1999. Hurricane effects on water quality and benthos in the Cape Fear watershed: natural and anthropogenic impacts. Ecological Applications 9(1):350-62.

Mason RP, Lawson NM, Sheu GR. 2000. Annual and seasonal trends in mercury deposition in Maryland. Atmospheric Environment 34:1691-701.

Mountain DG. 2002. Potential consequences of climate change for the fish resources in the Mid-Atlantic region. In: McGinn NA, editor. Fisheries in a changing climate. Bethesda (MD): American Fisheries Society, Symposium 32.

Mountain DG, Murawski SA. 1992. Variation in the distribution of fish stocks on the northeast continental shelf in relation to their environment, 1980-1989. ICES Marine Science Symposia 195:424-432.

Moyle P, Cech J. 1988. Fishes: an introduction to ichthyology. Englewood Cliffs (NJ): Prentice-Hall. 559 p.

[NOAA] National Oceanic and Atmospheric Administration. 2005. Final environmental impact statement for minimizing impacts of the Atlantic herring fishery on essential fish habitat. Gloucester (MA): National Marine Fisheries Service, Northeast Regional Office. 274 p.

[NRC] National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington (DC): National Academy Press. 405 p.

[NRDC] Natural Resource Defense Council. 2002. Federal court blocks full deployment of navy low frequency active sonar system. [Internet]. NRDC Press Archive, October 31, 2002. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/021031.asp.

[NRDC] Natural Resource Defense Council. 2003. Above the law? The Pentagon is taking aim at America's public health and environmental protections. [Internet]. NRDC Backgrounder, March 12, 2003. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/030312.asp.

[NRDC] Natural Resources Defense Council. 2004. Coalition warns navy over destructive use of mid-frequency sonar. [Internet]. NRDC Press Archive, July 15, 2004. [cited 2007 Dec 21]. Available from: http://www.nrdc.org/media/pressreleases/040715.asp.

Nedeau E. 2004. Effects of climate change on the Gulf of Maine region. [Internet]. Gulf of Maine Council on the Marine Environment. [cited 2008 Jul 9]. 12 p. Available from: http://www.gulfofmaine.org/summit/ClimateChangeKbase.pdf.

Nriagu JO. 1990. Global metal pollution. Poisoning the biosphere? Environment 32:7-33.

Orr JC, Fabry VJ, Aumont O, Bopp L, Doney SC, Feely RA, Gnanadesikan A, Gruber N, Ishida A, Joos F, and others. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-6.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL Jr, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, and others. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-96.

Paerl HW. 1995. Coastal eutrophication in relation to atmospheric nitrogen deposition: current perspectives. Ophelia 41:237-59.

Paulin MG. 1995. Electroreception and the compass sense of sharks. Journal of Theoretical Biology 174(3):325-39.

Perry AL, Low PJ, Ellis JR, Reynolds JD. 2005. Climate change and distribution shifts in marine fisheries. Science 308:1912-5.

Peterson RH, Daye PG, Metcalfe JL. 1980. Inhibition of Atlantic salmon (*Salmo salar*) hatching at low pH. Canadian Journal of Fisheries and Aquatic Sciences 37:770-4.

Pirrone N, Keeler GJ, Nriagu JO. 1996. Regional differences in worldwide emissions of mercury to the atmosphere. Atmospheric Environment 30:2981-7.

Richardson A, Schoeman D. 2004. Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305(5690):1609-12.

Riebesell U. 2004. Effects of $CO_2$ enrichment on marine phytoplankton. Journal of Oceanography 60:719-29.

Rogers PH, Cox M. 1988. Underwater sound as a biological stimulus. In: Atema J, Fay RR, Popper AN, Tavolga WN, editors. Sensory biology of aquatic animals. New York (NY): Springer-Verlag. p 131-49.

Scavia D, Field JC, Boesch DF, Buddemeier RW, Burkett V, Cayan DR, Fogarty M, Harwell MA, Howart RW, Mason C, and others. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25(2):149-64.

Schneider D. 1998. The rising seas. Oceans; Scientific American Quarterly 9(3):28-35.

Scholik AR, Yan HY. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63:203-9.

Schroeder WH, Yarwood G, Niki H. 1991. Transformation processes involving mercury species in the atmosphere-results from a literature survey. Water, Air, and Soil Pollution 56:653-66.

Short FT, Neckles HA. 1999. The effects of global climate change on seagrasses. Aquatic Botany 63 (3-4): 169-96.

Staurnes M, Hansen LP, Fugelli K, Haraldstad O. 1996. Short-term exposure to acid water impairs osmoregulation, seawater tolerance, and subsequent marine survival of smolts of Atlantic salmon (*Salmo salar* L.). Canadian Journal of Fisheries and Aquatic Sciences 53(8):1695-704.

Stocker M. 2002. Fish, mollusks and other sea animals' use of sound, and the impact of anthropogenic noise in the marine acoustic environment. Journal of Acoustical Society of America 112(5):2431.

Teleki GC, Chamberlain AJ. 1978. Acute effects of underwater construction blasting on fishes in Long Point Bay, Lake Erie. Journal of the Fisheries Research Board of Canada 35:1191-8.

[USEPA] US Environmental Protection Agency. 2005a. Technical factsheet on polychlorinated biphenyls (PCBs). [Internet]. Washington (DC): US EPA. [updated 2006 Nov 28; cited 2007 Dec 21]. Available from: http://www.epa.gov/safewater/dwh/t-soc/pcbs.html.

[USEPA] US Environmental Protection Agency (USEPA). 2005b. Consumer factsheet on polychlorinated biphenyls (PCBs). [Internet]. Washington (DC): US EPA Office of Groundwater and Drinking Water. [updated 2006 Nov 28; cited 2007 Dec 21]. Available from: http://www.epa.gov/OGWDW/dwh/c-soc/pcbs.html.

[USFDA] US Food and Drug Adminstration. 2004. What you need to know about mercury in fish and shellfish. [Internet]. Washington (DC): US Department of Health and Human Services and US Environmental Protection Agency. EPA-823-R-04-005. [cited 2008 Jul 28]. Available from: http://www.cfsan.fda.gov/~dms/admehg3.html.

[USGS] US Geological Survey. 2005. Streamflow trends in the United States. Reston (VA): US Department of the Interior, US Geological Survey. USGS Fact Sheet 2005-3017. 3 p.

Van Dolah RF, Anderson GS. 1991. Effects of Hurricane Hugo on salinity and dissolved oxygen conditions in the Charleston Harbor estuary. Journal of Coastal Research Special Issue 8:83-94.

Wang Q, Kim D, Doinysiou DD, Sorial GA, Timberlake D. 2004. Sources and remediation for mercury contamination in aquatic systems-a literature review. Environmental Pollution 131(2004):323-36.

Watt WD, Scott CD, White WJ. 1983. Evidence of acidification of some Nova Scotia rivers and its impact on Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences 40:462-73.

Williams MW, Baron JS, Caine N, Sommerfield R, Sanford RJ. 1996. Nitrogen saturation in the Rocky Mountains. Environmental Science and Technology 30:640-6.

[WHO] World Health Organization. 2005. Electromagnetic fields and public health: Effects of EMF on the environment. [Internet]. Munich (Germany): WHO. Fact sheet No. 296. 2005 Dec. [cited 2008 Jul 28]. Available from: http://www.who.int/mediacentre/factsheets/fs296/en/.

Wright DG. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Winnipeg (Manitoba): Western Region, Department of Fisheries and Oceans. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1052. 16 p.

Zervas C. 2001. Sea level variations of the United States 1854-1999. [Internet]. Silver Spring (MD): National Ocean Service. NOAA Technical Report NOS CO-OPS 36. [cited 2008 Aug 12]. 66 p. Available from: http://tidesandcurrents.noaa.gov/publications/techrpt36doc.pdf.

# CHAPTER TWELVE: COMPENSATORY MITIGATION

## Introduction

The purpose of this chapter is to describe the need for and use of compensatory mitigation within the context of regulatory review of proposed coastal development activities. This topic has purposefully been included in a separate chapter of this report to reflect NOAA National Marine Fisheries Services' view that compensatory mitigation is a process that is distinct and separate from impact avoidance and minimization. Only a cursory discussion of compensatory mitigation has been attempted in this report because of the complexity and depth that would be required to cover this topic. We have provided a list of websites and publications that the reader may want to refer to for more detailed discussion of compensatory mitigation.

Compensatory mitigation is a means of offsetting unavoidable impacts to natural resources. It cannot be stressed strongly enough that compensatory mitigation should not be considered until a thorough and exhaustive assessment of project alternatives that may be less environmentally damaging and options for avoiding and minimizing impacts has been completed, and all remaining impacts are "unavoidable." The term "unavoidable impacts" is used ubiquitously in environmental impact assessments developed to meet various requirements of the National Environmental Policy Act (NEPA), Clean Water Act (CWA), Magnuson-Stevens Fishery Conservation and Management Act (MSA), Fish and Wildlife Coordination Act, and other laws and regulations.

The MSA identified the continuing loss of marine, estuarine, and other aquatic habitats to be one of the greatest long-term threats to the viability of commercial and recreational fisheries. The consultation requirements of §305(b)(4)(A) of the MSA require that NOAA National Marine Fisheries Service provide recommendations, which may include measures to avoid, minimize, mitigate, or otherwise offset adverse effects on essential fish habitat (EFH), to federal or state agencies for activities that would adversely effect EFH.

According to NEPA regulations, environmental assessments and environmental impact statements must include a discussion of the means to mitigate adverse environmental impacts. However, according to NEPA guidance, the term "mitigation" includes avoidance and minimization in addition to compensatory mitigation, and NEPA does not strictly require agencies to first avoid and minimize before utilizing compensatory mitigation to offset adverse effects. NEPA regulations do, however, require agencies to assess and discuss the environmental effects of all reasonable alternatives, including the means to mitigate any adverse effects.

The Federal CWA 404(b)(1) guidelines prohibit the discharge of dredge or fill material in waters of the United States if there is a practicable alternative. The 404(b)(1) guidelines also require that all waters of the United States will be accorded the full measure of protection under the CWA, including the requirements for appropriate and practicable mitigation. "Appropriate" is based on the values and functions of the aquatic resource that will be impacted, and "practicable" is defined as that which is available and capable of being done after taking into consideration the cost, existing technology, and logistics in light of overall project purposes. The Memorandum of Agreement (MOA) between the US Environmental Protection Agency and the Department of the Army Concerning the Determination of Mitigation under the Clean Water Act Section 404(b)(1) Guidelines states, "Appropriate and practicable compensatory mitigation is required for unavoidable adverse impacts which remain after all appropriate and practicable minimization has been required." This MOA established a three-part sequential process to help guide mitigation decisions, which includes: (1) avoidance – adverse impacts are to be avoided and no discharge shall be permitted if there is a practicable alternative with less adverse impact; (2) minimization – if impacts cannot be avoided, appropriate and practicable steps to minimize adverse impacts must be taken; and (3) compensation – appropriate and practicable compensatory mitigation is required for unavoidable adverse impacts which remain (USDOA and USEPA 1989).

The need for exhausting all practicable alternatives to avoid and minimize adverse impacts prior to consideration of compensatory mitigation is necessary because of the inherent risks associated with compensatory mitigation. Establishing (creating), reestablishing (restoring), and rehabilitating (enhancing) degraded wetlands and/or aquatic habitats have inherent risks. Replicating or restoring the physical and chemical characteristics of fishery habitat, including soil/sediment hydrology and chemistry, hydrologic connections, and water quality are complex undertakings and can require years to achieve desired results. Replicating and restoring the full ecological functions and values of fishery habitat may not occur without additional effort and cost, and there are no assurances of success. In addition, evaluating mitigation performance and success can require considerable pre- and postconstruction monitoring and assessment, which can be time consuming and costly. For these and other reasons, compensatory mitigation should be viewed as a "last resort" option to achieve effective mitigation, with avoidance and minimization of impacts being the initial focus during the impact assessment process.

Once all practicable alternatives have been considered satisfactorily and a least damaging practicable alternative has been selected that effectively avoids and minimizes adverse effects to the maximum extent practicable, measures to offset unavoidable impacts should be assessed and utilized. Compensatory mitigation can be accomplished on-site or off-site (i.e., in relation to the area being impacted) and can either be in-kind or out-of-kind (i.e., compensation with the same or different ecological functions and values). Generally, in order to achieve the functional replacement of the same or similar ecological resources, in-kind should be considered over out-of-kind compensatory mitigation. However, compensatory mitigation decisions are often made in the context of landscape and watershed implications, as well as logistical and technological limitations. Out-of-kind mitigation, should it be considered, should provide services of equal or greater ecological value and should only be employed if in-kind mitigation is deemed impracticable, unfeasible, or less desirable in the watershed context. However, replacing lost or degraded tidal wetlands or other intertidal/subtidal habitats with nontidal (e.g., freshwater) wetlands should not occur.

Compensatory mitigation can be broadly categorized as restoration, creation, enhancement, and preservation (USACE 2002). Restoration includes reestablishment of a wetland or other aquatic resource with the goal of returning natural or historic functions and characteristics to a former or degraded habitat. Restoration may result in a net gain in ecological function and area. Creation or establishment consists of the development of a wetland or other aquatic resource through manipulation of the physical, chemical, or biological characteristics where a wetland did not previously exist. Creation results in a net gain in ecological function and area. Enhancement or rehabilitation includes activities within existing wetlands that heighten, intensify, or improve one or more ecological functions. Enhancement may result in improved ecological function(s), but does not result in a gain in area. Preservation is designed to protect important wetland or other aquatic resources into perpetuity through implementation of appropriate legal and physical mechanisms (i.e., conservation easements, title transfers). Preservation may include protection of upland areas adjacent to wetlands or other aquatic resources. Preservation does not result in a net gain of wetland acres or other aquatic habitats and should only be used in exceptional circumstances. Preservation is best applied in conjunction with restoration and/or enhancement of ecological functions and values and rarely as the sole means of compensation.

Compensatory mitigation can be provided in the form of project-specific mitigation, mitigation banking, or in-lieu fee mitigation (USEPA 2003). Project-specific mitigation is generally undertaken by a permittee or agency in order to compensate for resource impacts resulting from a specific action or permit. The permittee or agency performs the mitigation and is ultimately responsible for implementation and success of the mitigation. Mitigation banking is a wetland area that has been restored, created, or enhanced, which is then set aside ("banked") to compensate for future impacts to wetlands or other aquatic resources. The value of a bank is determined by quantifying the resource functions restored or created in terms of "credits," which can be acquired, upon the approval of regulatory agencies, to meet a project's requirements for compensatory mitigation. The bank sponsor is ultimately responsible for the success of the project. In-lieu fee mitigation involves a program where funds are paid to a natural resource management entity by a permittee or agency to meet their requirements of compensatory mitigation. The fees are used to fund the implementation of either specific or general wetland or other aquatic resource conservation projects. The management entity may be a third party (e.g., nongovernmental organizations, land trusts) or a public agency that specializes in resource conservation, restoration, and enhancement programs.

Below are some general topics and recommendations regarding the assessment and implementation of compensatory mitigation for actions that may adversely affect fishery resources. It may be necessary to include some of these measures as permit conditions or in decision documents in order to ensure that compensatory mitigation is completed satisfactorily and within the agreed upon timeframes.

### Baseline information

The primary purpose of providing effective compensatory mitigation should be to restore or replace the ecological functions and values of resources. In order to assess the effectiveness of compensatory mitigation, the baseline or existing functions and values of the project impact site must be known, as well as the target functions and values for the completed compensatory mitigation site. This can only be accomplished through site-specific monitoring and resource assessments. There are a number of assessment methodologies available to accomplish this, and it is important to determine the method(s) that should be used in advance because it will be necessary for the performance evaluation of the completed mitigation site.

Generally, compensatory mitigation should be provided for direct and indirect impacts, as well as short-term, long-term, and cumulative impacts to fishery resources. Indirect, long-term, and cumulative impacts of a development project may be more difficult to identify and quantify than short-term impacts, but they are no less important. In some cases, the adverse effects on aquatic resources from indirect, long-term, and cumulative impacts may be greater than the direct, short-term construction-related impacts. For example, the direct construction-related impacts of deepening a navigation channel for the purpose of expanding a commercial marina may only involve the removal of bottom sediments in the existing channel. Even so, the dredging project may also result in other short-term impacts to benthic resources from sedimentation and turbidity and anchor damage from vessels. Expansion of a marina operation may result in long-term and cumulative impacts to seagrass and riparian vegetation from vessel wakes and prop scour and in chronic turbidity and sedimentation from larger and more frequent vessel activity. Long-term and cumulative impacts from a development project may also determine whether compensatory mitigation is more appropriately located on-site or off-site.

### Compensatory mitigation plan

A clear and concise description of the specific habitats and the functions and values that are intended to be restored should be provided in the mitigation plan. Wetlands and other aquatic habitats provide numerous functions and values within an ecosystem, so it is important to identify the specific functions and values that the compensatory mitigation is intended to restore or replace. Performance criteria should be established (e.g., 80% vegetation cover by target species by the end of the second growing season), and specific monitoring and analytical methods to assess the success of the mitigation should be stipulated in advance.

Adaptive management should be incorporated into mitigation plans, when appropriate. While clear and concise performance criteria are important in all compensatory mitigation plans, monitoring data and predetermined ecological indicators should be used to guide the progress of the mitigation and ensure mitigation objectives are met. Effective compensatory mitigation plans should recognize the importance of adaptive management and allow for corrective action when performance measures are not being met.

A compensatory mitigation plan should include requirements for monitoring and performance reporting, including the content and frequency of reports and who should receive the reports. Generally, the reports should be provided concurrently with the completion of performance monitoring to allow for corrective actions to be taken should success criteria not be met. Other features of a mitigation plan may include measures to ensure mitigation site protection, financial assurances, and a description of long-term maintenance requirements, if necessary, and the party or parties responsible for completing the mitigation requirements.

### *Contingency plans*

Contingency plans for the mitigation plan may be necessary to ensure that adequate compensation is provided, particularly for mitigation that is considered a high-risk endeavor, such as restoration of eelgrass beds. The contingency plan may be necessary to extend the completion of the mitigation plan, and it may require supplemental effort (e.g., planting) or call for alternative mitigations (e.g., out-of-kind). If it is determined that mitigation contingencies are necessary, they should be specified in the permit or decision documents.

### *Mitigation timing*

To minimize the time lag between the loss of wetlands or other aquatic resources and the completion of the compensatory mitigation project, implementation of mitigation construction should begin as soon as possible. For example, if mitigation construction must begin during a specific time of year or the ecological functions and values at the mitigation site require multiple years before being realized, it may be desirable for the compensatory mitigation project to begin before the resource impacts occur.

### *Interim losses*

In situations where there will be delays in implementation of compensatory mitigation or a compensatory mitigation project requires several years to complete, interim or temporal losses of ecological functions and values may be substantial. In these cases, compensation of the interim losses of ecological functions and values should be included in the compensatory mitigation plan. There are a number of ways in which compensation of interim losses can be assessed, such as increasing the ratio of acreage lost to acreage replaced. However, “loss of services” analyses, such as the Habitat Equivalency Analysis (HEA), have been used successfully in a number of restoration projects (NOAA 2006). The HEA assumes there is a one-to-one tradeoff between the resource services at the compensatory restoration site and the resource impact site. In other words, it assumes that the resources can be compensated for past losses through habitat replacement projects providing the replacement resources are the same type as the lost or damaged resources (i.e., in-kind mitigation).

For more information and a more detailed discussion about compensatory mitigation, the reader may refer to the following resources.

### *General compensatory mitigation guidelines*

http://www.epa.gov/wetlandsmitigation
http://www.epa.gov/owow/wetlands/guidance
http://www.nap.usace.army.mil/cenap-op/regulatory/draft_mit_guidelines.pdf
http://www.mitigationactionplan.gov/Preservation_8-27-04.htm

### *Mitigation banking and in-lieu fee programs*

http://www2.eli.org/wmb/backgroundb.htm
http://www.gao.gov/new.items/d01325.pdf

### *Habitat equivalency analysis*

http://www.csc.noaa.gov/coastal/economics/habitatequ.htm
http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

## References for Compensatory Mitigation


[NOAA] National Oceanic and Atmospheric Administration. 2006. Habitat equivalency analysis: an overview. [Internet]. Washington (DC): US Department of Commerce, NOAA, Damage Assessment and Restoration Program.[cited 2008 Jul 28]. 24 pp. Available from: http://www.darrp.noaa.gov/library/pdf/heaoverv.pdf

[USACE] US Army Corps of Engineers. 2002. Guidance on compensatory mitigation projects for aquatic resource impacts under the Corps regulatory program pursuant to Section 404(a) of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. [Internet]. Washington DC): USACE. Regulatory Guidance Letter No. 02-2, 2002 Dec 24. [cited 2008 Jul 28]. Available from: http://www.usace.army.mil/cw/cecwo/reg/rgls/RGL2-02.pdf.

[US Army], [USEPA] US Department of the Army, US Environmental Protection Agency. 1989. Memorandum of agreement between the Department of the Army and the Environmental Protection Agency concerning the determination of the Section 404 Program and the application of the exemptions under Section 404(F) of the Clean Water Act. [Internet]. Washington (DC): US Army and US EPA. [cited 2008 Jul 28]. Available from: http://www.usace.army.mil/cw/cecwo/reg/mou/404f.htm.

[USEPA] US Environmental Protection Agency. 2003. Wetlands compensatory mitigation. [Internet]. Washington (DC): US EPA, Office of Wetlands, Oceans, and Watersheds. EPA Report EPA-843-F-03-002. [cited 2008 Jul 28]. Available from: http://www.epa.gov/owow/wetlands/pdf/CMitigation.pdf.

# CONCLUSIONS AND RECOMMENDATIONS

The purpose of this chapter is to synthesize the information discussed in the previous chapters of this report and to identify topics for future research and focus. In addition, the participants of the technical workshop on nonfishing impacts identified activities that are known or suspected to have adverse impacts on fisheries habitat, and we have attempted to draw some conclusions (based upon the effects scores) concerning those activities and effects that deserve further scrutiny and discussion. While many of these activities clearly have known direct, adverse impacts on the quantity and quality of fisheries habitat, their effects at the population and ecosystem level are not well known or understood. For example, there are a number of ports and harbors in the northeast region that have been identified as the most contaminated sites in US coastal waters for polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, and trace metals (USEPA 2004; Buchsbaum 2005). Although many of the effects of these pollutants at the cellular, physiological, and whole organism level are known, information on the effects at the population and ecosystem level is less understood.

There were some noteworthy results from the technical workshop, particularly regarding the geographic areas that scored high for some of the activity types and effects. As one might expect, the workshop participants considered impacts on fisheries habitats to be generally focused in nearshore coastal areas. These results are not particularly surprising considering the proximity of riverine and nearshore habitats to industrial facilities, shipping, and other coastal development. Rivers, estuaries, and coastal embayments are essential for fisheries because they serve as nurseries for the juvenile stages of species harvested offshore or as habitats for the prey of commercially important species (Deegan and Buchsbaum 2005). Estuarine and wetland dependent fish and shellfish species account for about 75% of the total annual seafood harvest of the United States (Dahl 2006). In the workshop session on alteration of freshwater systems, several effects scored high in the estuarine/nearshore ecosystem in addition to the riverine ecosystem. For example, impaired fish passage and altered temperature regimes scored high for the riverine and estuarine/nearshore ecosystems in the dam construction/operation and water withdrawal activity types, suggesting that the participants viewed these activities to have broad ecosystem impacts.

Most effects in both the chemical and physical effects workshop sessions scored high in the riverine and estuarine/nearshore ecosystems. In addition, a few of these effects also scored high in the marine/offshore ecosystem. For the chemical effects session, the release of nutrients/eutrophication, release of contaminants, development of harmful algal blooms, contaminant bioaccumulation/biomagnification, and all effects under the combined sewer overflows impact type scored high in all ecosystem types. The concern of the workshop participants regarding these impacts seems to reflect recently published assessments on threats to coastal habitats (USEPA 2004; Deegan and Buchsbaum 2005; Lotze et al. 2006). For example, the 2004 National Coastal Condition Report (USEPA 2004) assessed the condition of estuaries in the northeast to be poor, with 27% of estuarine area as impaired for aquatic life, 31% impaired for human use, and an additional 49% as threatened for aquatic life use. One of the primary factors contributing to poor estuarine conditions in the northeast region is poor water quality, which is typically caused by high total nitrogen loading, low dissolved oxygen concentrations, and poor water clarity. In the northeast region, the contributing factors associated with nutrient enrichment are principally high human population density and, in the mid-Atlantic states, agriculture (USEPA 2004). In addition, harmful algal blooms (HABs) have been associated with eutrophication of coastal waters, which can deplete oxygen in the water, result in hypoxia or anoxia, and lead to large-scale fish kills (Deegan and Buchsbaum 2005). HABs may also contain species of algae that produce toxins, such as red tides, that can kill or otherwise negatively affect large numbers of fish and shellfish, contaminate shellfish beds, and cause health problems in humans. The extent and severity of coastal eutrophication and HABs will likely continue and may worsen as coastal human population density increases. Considerable attention should be focused on the effects of eutrophication on habitat and water quality, the populations of fish and shellfish, and the role of natural versus anthropogenic sources of nutrients in the occurrence of HABs.

For the workshop session on physical effects, entrainment and impingement effects scored high in all ecosystem types. Entrainment and impingement of eggs, larvae, and juvenile fish and shellfish are increasingly being identified as potential threats to fishery populations from a wide variety of activities, including industrial and municipal water intake facilities, electric power generating facilities, shipping, and liquefied natural gas facilities (Hanson et al. 1977; Travnichek et al. 1993; Richkus and McLean 2000; Deegan and Buchsbaum 2005). Future research is needed to assess the long-term and cumulative effects that entrainment and impingement from these activities have on fish stocks, their prey, and higher trophic levels of the marine ecosystem.

The participants of the workshop session on global effects and other impacts scored most effects in the estuarine/nearshore ecosystem as high. However, several effects of climate change scored high for all ecosystems, including alteration of temperature and hydrological regimes, alteration of weather patterns, and changes in community structure. The effects of climate change related to commercial and recreational fisheries have not as of yet been the focus of extensive research. However, greater emphasis on this topic will likely be necessary as the effects of global warming become more pronounced (Bigford 1991; Frumhoff et al. 2007).

A number of activities and effects were identified during the workshop and in the preparation of this report that may pose substantial threats to fisheries habitat, but the extent of the problems they represent and their implications to aquatic ecosystems are not well understood. Some of these activities and effects have only recently been recognized as potential threats, such as the effects of endocrine disrupting chemicals on aquatic organisms and the threats to fisheries from global warming and will require additional research to have a clearer understanding of the mechanism and scope of these problems. However, other effects such as sedimentation on benthic habitats and biota have been the focus of considerable research and attention, but questions remain as to the lethal and sublethal thresholds of sedimentation effects on individual species and its effects on populations. For example, although sedimentation caused by navigation channel dredging is known to adversely affect the demersal eggs of winter flounder (*Pseudopleuronectes americanus*) (Berry et al. 2004; Klein-MacPhee et al. 2004; Wilber et al. 2005) a better understanding of how the intensity and duration of egg burial effects mortality is needed (i.e., lower lethal thresholds). In addition, how do grain size, the type and amount of contamination, and background suspended sediment concentrations affect egg and larvae survival rates, and what are the implications at the population level?

A number of energy-related activities were assessed for adverse effects on fisheries habitat in the technical workshop and in the corresponding report chapter, including offshore liquefied natural gas platforms, wind turbines, and wave and tidal energy facilities. Although various impacts were discussed, there have not been any facilities of this type constructed in the northeast region of the United States at the time of this report. Although we believe the resource assessments for these types of facilities have been based upon the best available information, further monitoring and assessments will be necessary once they are constructed.

The workshop participants identified a number of chemical effects in several sessions that may have a high degree of impact on fisheries, such as endocrine disrupting chemicals and pharmaceuticals in treated wastewater. Pharmaceuticals and personal care products (PPCP) can persist in treated wastewater and have been found in natural surface waters at concentrations of parts per thousand to parts per billion (Daughton and Ternes 1999). Although the range of concentrations of PPCPs may not pose an acute risk, because aquatic organisms may be exposed continually and for multi-generations, the effects on coastal aquatic communities are a major concern (USEPA 2007). Some of these PPCPs include steroid compounds, which may also be endocrine disruptors. Endocrine disruptors can mimic the functions of sex hormones, androgen and estrogen, and can interfere with reproductive functions and potentially result in population-level impacts. Some chemicals shown to be estrogenic include polychlorinated biphenyl (PCB) congeners, pesticides (e.g., dieldrin, dichlorodiphenyl trichloroethane [DDT]), and compounds used in some industrial manufacturing (e.g., phthalates, alkylphenols) (Thurberg and Gould 2005). In addition, some metal compounds have also been implicated in disrupting endocrine secretions of marine organisms (Brodeur et al. 1997). Additional investigation into the effects of PPCPs and endocrine disruptors on aquatic organisms and their potential impacts at the population and ecosystem level is needed.

In addition, the workshop participants identified a number of adverse effects on aquatic ecosystems from introduced/nuisance species, particularly in the estuarine/nearshore ecosystem. Introduction of nonnative invasive species into marine and estuarine waters poses a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species introductions occur through a wide range of activities, including hull fouling and ballast water releases from ships, aquaculture operations, fish stocking and pest control programs, and aquarium discharges (Hanson et al. 2003; Niimi 2004). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001). Increased research focused towards reducing the rate of nonnative species introductions is needed, in addition to a better understanding of the effects of nonnative species on fisheries in the United States.

Overfishing, including fishing effects on habitat, is likely the greatest factor in the decline of groundfish species in New England (Buchsbaum 2005) and is responsible for the majority of fish and shellfish species depletions and extinctions worldwide (Lotze et al. 2006). However, habitat loss and degradation through nonfishing activities (including pollution, eutrophication, and sedimentation) closely follow exploitation as a causative agent in fishery declines and may be equally or more important for some species such as Atlantic salmon (*Salmo salar*) (Buchsbaum 2005; Lotze et al. 2006). Cumulative effects likely play a role in a large majority of historic changes in fish stocks. Worldwide, nearly half of all marine and estuarine species depletions and extinctions involve multiple human impacts, most notably exploitation and habitat loss (Lotze et al. 2006). It is imperative that management measures intended to reduce exploitation, increase habitat protection, and improve water quality be applied holistically and that the cumulative effects of multiple human interactions be considered in both management and conservation strategies (Lotze et al. 2006). The challenges of quantifying the cumulative effects of nonfishing impacts are vast and complex. Nonetheless, the importance of nonfishing impacts on the coastal ecosystem will likely become greater in the future, and we believe fishery managers would be well served by beginning to collaborate with coastal resource managers and integrate signals from nonfishing effects and stresses on the ecosystem with traditional stock assessment models.

## References for Conclusions and Recommendations

Berry WJ, Hinchey EK, Rubinstein NI, Klein-MacPhee G. 2004. Winter flounder, *Pseudopleuronectes americanus*, hatching success as a function of burial depth in the laboratory. In: Ninth f latfish biology conference-poster presentation; 2004 Dec 1-2; Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Bigford TE. 1991. Sea-level rise, nearshore fisheries, and the fishing industry. Coastal Management 19:417-37.

Brodeur JC, Sherwood G, Rasmussen JB, Hontela A. 1997. Impaired cortisol secretion in yellow perch (*Perca flavescens*) from lakes contaminated by heavy metals: *in vivo* and *in vitro* assessment. Canadian Journal of Fisheries and Aquatic Sciences 54 (12):2752-8.

Buchsbaum RN. 2005. The role of overfishing, pollution, and habitat degradation on marine fish and shellfish populations of New England: summary and conclusions. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. 175 p.

Carlton JT. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Arlington (VA): Pew Oceans Commission. 28 p.

Dahl TE. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. [Internet]. Washington (DC): US Department of the Interior; Fish and Wildlife Service. [cited 2008 Jul 21]. 112 p. Available from: http://wetlandsfws.er.usgs.gov/status_trends/National_Reports/trends_2005_report.pdf.

Daughton CG, Ternes TA. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? [Internet]. Environmental Health Perspectives 107(S6): 907-38. [cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/pdf/errata.pdf.

Deegan LA, Buchsbaum RN. 2005. The effect of habitat loss and degradation on fisheries. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline on fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 67-96.

Frumhoff PC, McCarthy JJ, Melillo, SC, Moser SC, Wuebbles DJ. 2007. Confronting climate change in the U.S. Northeast: science, impacts, and solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge (MA): Union of Concerned Scientists (UCS). 146 p.

Hanson CH, White JR, Li HW. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fisheries Review 39:7-17.

Hanson J, Helvey M, Strach R. editors. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. Long Beach (CA): National Marine Fisheries Service (NOAA Fisheries) Southwest Region. Version 1. 75 p.

Klein-MacPhee G, Macy WK, Berry W. 2004. *In situ* effects of suspended particulate loads produced by dredging on eggs of winter flounder (*Pseudopleuronectes americanus*). In: Ninth flatfish biology conference-oral presentation; 2004 Dec 1-2; Water's Edge Resort, Westbrook, CT. Woods Hole (MA): Northeast Fisheries Science Center Reference Document 04-13.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806-9.

Niimi AJ. 2004. Role of container vessels in the introduction of exotic species. Marine Pollution Bulletin 49(9-10):778-82.

Richkus WA, McLean R. 2000. Historical overview of the efficacy of two decades of power plant fisheries impact assessment activities in Chesapeake Bay. Environmental Science and Policy 3(Supplement 1):283-93.

Thurberg FP, Gould E. 2005. Pollutant effects upon cod, haddock, pollock, and flounder of the inshore fisheries of Massachusetts and Cape Cod Bays. In: Buchsbaum R, Pederson J, Robinson WE, editors. The decline of fisheries resources in New England: evaluating the impact of overfishing, contamination, and habitat degradation. Cambridge (MA): MIT Sea Grant College Program; Publication No. MITSG 05-5. p 43-66.

Travnichek VH, Zale AV, Fisher WL. 1993. Entrainment of ichthyoplankton by a warmwater hydroelectric facility. Transactions of the American Fisheries Society 122(5):709-16.

[USEPA] US Environmental Protection Agency. 2004. National coastal condition report II. [Internet]. Washington (DC): US EPA Office of Research and Development/Office of Water. EPA-620/R-03/002. [cited 2008 Jul 9]. Available from: http://www.epa.gov/owow/oceans/nccr2.

[USEPA] US Environmental Protection Agency. 2007. Pharmaceuticals and personal care products (PPCP): frequent questions. [Internet]. Washington (DC): US EPA Office of Research and Development. [updated 2007 Dec 14; cited 2008 Aug 5]. Available from: http://www.epa.gov/ppcp/faq.html.

Wilber D, Brostoff W, Clarke D, Ray G. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. [Internet]. DOER Technical Notes Collection. Vicksburg (MS): US Army Engineer Research and Development Center. ERDC TN-DOER-E20. [cited 2008 Jul 22]. 14 p. Available from: http://el.erdc.usace.army.mil/dots/doer/pdf/doere20.pdf.

# APPENDIX

## Technical Workshop on Impacts to Coastal Fishery Habitat from Nonfishing Activities, January 10-12, 2005 in Mystic, CT

*Attendee List*

| Name | Organization/Affiliation | City and State |
|---|---|---|
| Michael Johnson | National Marine Fisheries Service | Gloucester, MA |
| Sean McDermott | National Marine Fisheries Service | Gloucester, MA |
| Chris Boelke | National Marine Fisheries Service | Gloucester, MA |
| Marcy Scott | National Marine Fisheries Service | Gloucester, MA |
| Lou Chiarella | National Marine Fisheries Service | Gloucester, MA |
| David Tomey | National Marine Fisheries Service | Gloucester, MA |
| Jennifer Anderson | National Marine Fisheries Service | Gloucester, MA |
| Mike Ludwig | National Marine Fisheries Service | Milford, CT |
| Diane Rusanowsky | National Marine Fisheries Service | Milford, CT |
| Anita Riportella | National Marine Fisheries Service | Highlands, NJ |
| Stan Gorski | National Marine Fisheries Service | Highlands, NJ |
| Andy Draxler | National Marine Fisheries Service | Highlands, NJ |
| Ric Ruebsamen | National Marine Fisheries Service | St. Petersburg, FL |
| Jeanne Hanson | National Marine Fisheries Service | Anchorage, AK |
| Heather Ludemann | National Marine Fisheries Service | Silver Spring, MD |
| Kimberly Lellis | National Marine Fisheries Service | Silver Spring, MD |
| David Wiley | Stellwagen Bank National Marine Sanctuary | Situate, MA |
| Leslie-Ann McGee | New England Fishery Management Council | Woods Hole, MA |
| Sally McGee | New England Fishery Management Council | Mystic, CT |
| Eric Nelson | US Environmental Protection Agency | Boston, MA |
| Phil Colarusso | US Environmental Protection Agency | Boston, MA |
| Cathy Rogers | US Army Corps of Engineers | Concord, MA |
| Michael Hayduk | US Army Corps of Engineers | Philadelphia, PA |
| Brenda Schrecengost | US Army Corps of Engineers | Philadelphia, PA |
| Steven Mars | US Fish and Wildlife Service | Trenton, NJ |
| Michelle Dione | Wells National Estuarine Research Reserve | Wells, ME |
| John Sowles | Maine Dept. of Marine Resources | W. Boothbay Harbor, ME |
| Brian Swan | Maine Dept. of Marine Resources | Augusta, ME |
| Ray Grizzle | University of New Hampshire | Durham, NH |
| Mashkoor Malik | University of New Hampshire | Durham, NH |
| Vincent Malkoski | Massachusetts Division of Marine Fisheries | Boston, MA |
| Stephanie Cunningham | Massachusetts Division of Marine Fisheries | Gloucester, MA |
| Tony Wilbur | Massachusetts Office of Coastal Zone Management | Boston, MA |
| Joe Pelczarski | Massachusetts Office of Coastal Zone Management | Boston, MA |
| Chris Powell | Rhode Island Division of Fish & Wildlife | Jamestown, RI |
| Mark Johnson | Connecticut Dept. of Environmental Protection | Hartford, CT |
| Karen Chytalo | New York State Dept. of Environmental Conservation | East Setauket, NY |
| Drew Carey | Coastal Vision | Newport, RI |
| Donna Bilkovic | Virginia Institute of Marine Science | Gloucester Point, VA |
| Robert Van Dolah | South Carolina Dept. of Natural Resources | Charleston, SC |
| Trevor Kenchington | Gadus Associates/Fisheries Survival Fund | Nova Scotia, Canada |
| Phil Ruhle | New England Fishery Management Council/ F/V Sea Breeze | Newport, RI |
| Gib Brogan | Oceana | Mystic, CT |

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

**Refer to NMFS No:**
**2008/03298**

August 13, 2008

Cayla Morgan
Seattle Airports District Office
Federal Aviation Administration
1601 Lind Avenue SW, Suite 250
Renton, Washington 98055-4056

Re: Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Coos Bay Airport Expansion in North Bend (HUC: 171003040303), Coos County, Oregon

Dear Ms. Morgan:

The enclosed document contains a biological opinion (Opinion) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of the Federal Aviation Administration's (FAA) proposal to fund the Coos Bay Airport Expansion in North Bend (HUC: 171003040303), in Coos County, Oregon. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), or result in the destruction or adverse modification of designated critical habitat for OC coho salmon. This Opinion also concludes the proposed action is not likely to jeopardize the continued existence of the southern distinct population segment of North American green sturgeon (*Acipenser medirostris*).

As required by section 7 of the ESA, NMFS is providing an incidental take statement (ITS) for OC coho salmon with the Opinion. The ITS describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The ITS sets forth nondiscretionary terms and conditions, including reporting requirements, that the FAA and their applicant must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of ESA-listed species.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes two conservation recommendations to avoid, minimize or otherwise offset potential adverse effects on EFH. These conservation recommendations are a subset of the terms and conditions found in the ITS. Section 305(b)(4)(B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations.

If the response is inconsistent with the EFH conservation recommendations, the FAA must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, in your statutory reply to the EFH portion of this consultation, please clearly identify the number of conservation recommendations accepted.

If you have questions regarding this consultation, please contact Ken Phippen, Branch Chief of the Southwest Oregon Habitat Branch of the Oregon State Habitat Office, at 541.957.3385.

Sincerely,

Michael Tehan

for D. Robert Lohn
Regional Administrator

cc: Teena Monical, Corps.
Casey Storey, W & H Pacific
Southwest Oregon Regional Airport

# Endangered Species Act Section 7 Consultation
# Biological Opinion

# and

# Magnuson-Stevens Fishery Conservation and Management Act
# Essential Fish Habitat Consultation

Coos Bay Airport Expansion in North Bend (HUC: 171003040303)
Coos County, Oregon

| | |
|---|---|
| Lead Action Agency: | Federal Aviation Administration |
| Consultation Conducted By: | National Marine Fisheries Service<br>Northwest Region |
| Date Issued: | August 13, 2008 |
| Issued by: | for D. Robert Lohn<br>Regional Administrator |
| **NMFS No.:** | **2008/03298** |

## TABLE OF CONTENTS

## INTRODUCTION

This document contains a biological opinion (Opinion) and incidental take statement (ITS) prepared in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, *et seq.*), and implementing regulations at 50 C.F.R. 402. The National Marine Fisheries Service (NMFS) also completed an essential fish habitat (EFH) consultation, prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq.*) and implementing regulations at 50 CFR 600.

The docket for this consultation is on file at the Southwest Oregon Habitat Branch in Roseburg, Oregon.

### Background and Consultation History

On December 1, 2006, NMFS received a letter and biological assessment (BA) from the Seattle Airports District Office of the Federal Aviation Administration (FAA), requesting consultation on the effects of funding a construction project at the Southwest Oregon Regional Airport in North Bend, Oregon. The request for consultation was made pursuant to section 305(b)(2) of the MSA. The funding would allow the Southwest Oregon Regional Airport to improve airport safety and meet FAA design requirements by expanding an existing taxiway and adding a new air traffic control tower. The proposed changes will require that a 1,000-foot long by 65-foot wide section of Coos Bay be filled to accommodate the expansion.

The Southwest Oregon Regional Airport (formerly known as the North Bend Municipal Airport) began in 1936 as a local Work Project Administration (WPA) project. The airfield became an Auxiliary Air Facility in 1942. In 1947, the airfield was deeded to the City of North Bend. The most recent airport expansion occurred in 1988, and extended Runway 4-22. The airport is currently owned and operated by the Coos County Airport District (CCAD). It is the only commercial airport on the Oregon Coast.

A field trip was held on November 1, 2006, to visit the construction site and nearby mitigation site. Representatives from W&H Pacific (consultant), the U.S. Army Corps of Engineers, the Ocean and Coastal Program of the Oregon Land Conservation and Development Commission, Oregon Department of Fish and Wildlife (ODFW), and the Southwest Oregon Regional Airport attended the field trip.

On July 16, 2007, the Southwest Oregon Habitat Branch of the NMFS received the final Environmental Assessment (EA) for the project. This final assessment provided key information that outlined the proposed activities at the Mangan mitigation site on Haynes Inlet.

On October 5, 2007, NMFS issued an EFH consultation (refer to NMFS No.: 2006/06108) completing MSA consultation to the Federal Aviation Administration (FAA) for their proposed funding of the Coos Bay Airport Expansion and provided two conservation recommendations to avoid, minimize or otherwise offset potential adverse effects to EFH. Some upland work has occurred to prepare the site, but project area work previously permitted and with the potential to impact EFH has not been completed. Deployment of temporary coffer-dams was attempted before the lapse of the in-water work period, but was discontinued due to delays encountered while deploying the coffer dam, as described below. Wetland and estuarine habitat mitigation construction has taken place at the Mangan mitigation site, but elements including the breech of the dike and installation of work area isolation structures associated with this activity, have not taken place.

The relocation of taxiway C at the Southwest Oregon Regional Airport requires the placement of fill material into the Coos Bay estuary. The erosion control plan called for the installation of a temporary cofferdam with a minimum 10 feet of clearance between the toe of slope and the back of the cofferdam. Removal of existing riprap along the old embankment, compaction of the proposed fill area, and filling/completion of the proposed taxiway and new embankment were to be completed only after this structure had been installed.

Due to the nature of substrate in the project area and the isolation structure, a standard cofferdam was deemed to be inappropriate for the project area by cofferdam suppliers and the contractor. In response, the contractor selected a water-filled temporary dam for work area isolation. Such a structure typically produces fewer impacts, requires less installation time, and does not require stable foundation substrate-as was the case with other cofferdams.

The water-filled dam was received at the project site in early January, 2008. Deployment of the dam began soon after its arrival at the site. Delays and problems with the deployment of the water dam began almost immediately. Tidal timing, rupture of internal bladders, and long delays in receiving replacement parts and technical staff from the suppliers added to multiple delays. Finally, after additional deployment attempts and structure failures, the water filled dams were abandoned as viable options for work area isolation. At this time, the in-water work period at the project site had lapsed and plan changes were deemed necessary.

Multiple conference calls were conducted between personnel from W&H Pacific, ODFW, and NMFS personnel to discuss the project status and consultation strategy. On May 27, 2008, the FAA transmitted a letter to the NMFS requesting reinitiation of the MSA consultation due to changes in the proposed work. The FAA also requested initiation of formal consultation under the ESA for the newly-listed Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) and its designated critical habitat, and for the newly-listed Southern distinct population segment (DPS) of the North American green sturgeon (*Acipenser medirostris*). Southern DPS green sturgeon individuals were recently determined to inhabit Coos Bay, therefore the FAA chose to initiate ESA consultation on this ESA-listed species.

The FAA concluded that funding the proposed action may adversely affect OC coho salmon, critical habitat for OC coho salmon, southern DPS green sturgeon and EFH designated for Pacific salmon and groundfish.

**Description of the Proposed Action**

The proposed action is to fund the remaining elements of an expansion of a runway and taxiway at the Southwest Oregon Regional Airport in North Bend, Coos County, Oregon. The expansion will improve airport safety but will not increase the operational capacity of the airport, nor will it allow larger aircraft to use the airport.

The following descriptions summarize the proposed project changes that remain to be completed at the Airport and the Mangan mitigation site that are pertinent to review and consultation by NMFS. The summary includes the proposed changes to timing and staging.

**Taxiway C Relocation – Southwest Oregon Regional Airport.** In response to a need for plan changes, an alternative isolation method for the site has been devised. This method involves the construction of a coarse gravel pier extending eastward to westward from the existing embankment near the current stormwater discharge and then north to the existing taxiway C embankment as depicted in the Embankment Plan – Sheet C-15A. The pier will match the toe of slope of the final grade proposed for the fill area in the original plan. The pier will be constructed in the following order:

1. Work will commence from east to west, and then north.
2. Geotextile fabric will be placed on the bay bottom.
3. Aggregate will be placed on the geotextile fabric to a height of 6.62 feet, the elevation of highest measured tide.
4. Geotextile fabric will be wrapped around the aggregate and secured.
5. The closure of the pier will be completed at low tide to avoid fish entrapment within the structure.

Dewatering of the fill area will pump water into the existing stormwater containment pond for sediment control. Fill activities will be conducted during low and low slack tides to reduce the generation of local turbidity. The pier construction process and general work conditions during filling will be monitored for sediment and fish entrapment. In the event of fish salvage behind the pier structure, beach seines and dip nets will be utilized to remove fish to bay waters. Fish salvage is expected to be conducted by a W&H Pacific biologist.

Following completion of compaction and filling in the internal fill area, the pier will be capped with additional fill materials to the proposed final elevation of the new taxiway alignment and previously specified riprap will be installed on the bay-side face of the pier. See Sheet C-22A for a detail of the sequence of fill and pier (embankment) construction.

Construction of the pier work containment structure constitutes in-water work, but does not constitute a difference in fill volumes or the final development footprint. The estimated time for construction of the pier is expected to be no more than 2 weeks. Following recommendations and considering environmental conditions, construction of the structure will not commence until after June 30, 2008. This timing is out of the in-water work period for the watershed, but is during the driest time of the year for the region and is out of the expected peak outmigration time for OC coho salmon smolts.

**Mangan Mitigation Site – Taxiway C Wetland Impacts Mitigation Site.** The creation of the Mangan mitigation site involves the restoration of mud flats and salt marsh from diked agricultural lands. The primary element of the mitigation site is the removal of an existing levee to introduce tidal action to the site. As specified in the original demolition plan, the levee removal work was to be isolated by a temporary coffer dam as designed for the taxiway. Following failure of the water-dam at the Airport site, the device was rejected for work area isolation at the Mangan site as well.

In lieu of utilizing the water-dam, the levee removal work will be isolated from the Haynes Inlet by the deployment of two 5-foot tall silt fences spaced 5 feet apart. These silt fences would be installed as close to the toe of the existing levee as practical. See Existing Conditions Demolition Plan Sheets WL-02 and WL-03 for details. All excavation at elevations within tidal influence will be conducted when tidal waters are not in the project area.

Upon complete removal of the existing levee, both silt fences will be removed from the project area. The site will be monitored for fish stranding and turbidity while the silt fences are deployed. In the event that fish are stranded behind the silt fences and in the work area, W&H Pacific biologists will coordinate salvage efforts with ODFW. Stranded fish will be removed from the work area with beach seines and dip nets and returned to Haynes Inlet.

Demolition of the levee (in-water work) is expected to take no more than 5 days – with excavated materials being used to add to the new levee elevation. All other work besides installation of salt marsh plantings is completed to date and does not require in-water work. The proposed in-water work at the site is expected to be conducted after June 30, 2008, for the same reasons specified for the pier construction at the airport. The site will be monitored for sedimentation and fish entrapment while the sediment barriers are deployed.

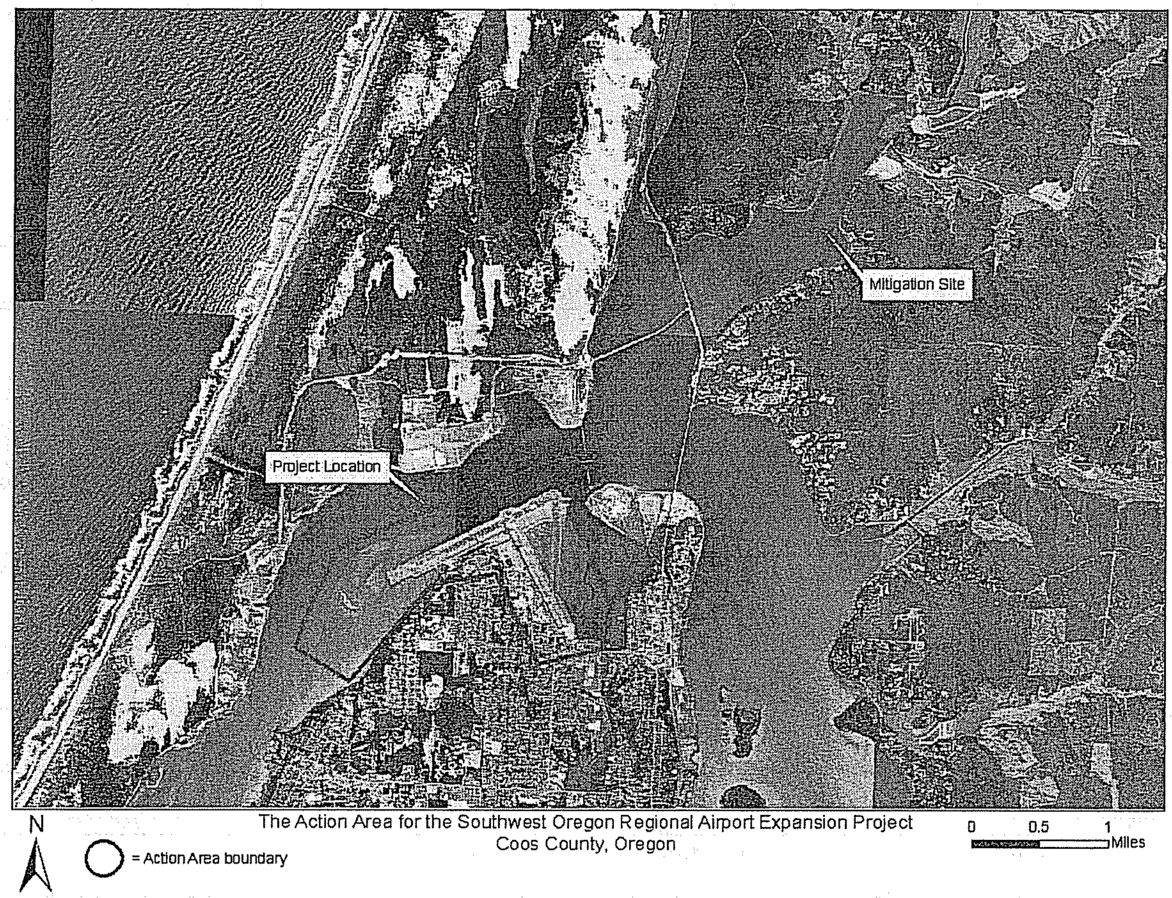
The impact reduction measures, described here as part of the proposed action, are intended to reduce adverse effects on ESA-listed species and their habitats. The NMFS regards these impact reduction measures as integral components of the proposed action and expects that all proposed project activities will be completed consistent with those measures. We have completed our effects analysis accordingly. Any project activity that deviates from these impact reduction measures will be beyond the scope of this consultation and will not be exempted from the prohibition against take as described in the attached ITS. Further consultation will be required to determine what effect the modified action may have on listed species or critical habitats.

The NMFS relied on the foregoing description of the proposed action, including all stated impact reduction measures, to complete this consultation. To ensure that this consultation remains valid, NMFS requests that the action agency or applicant keep NMFS informed of any changes to the proposed action.

**Action Area**

'Action area' means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area is defined as the footprint of the existing airport and adjacent bank, substrate, and aquatic areas of the Coos Bay Estuary and Pony Slough. The action area extends 500 feet upstream from the project site and 1,500 feet downstream from the downstream end of the project site in Coos Bay due to potential impacts from stormwater discharge, turbidity and contaminant dispersion, and habitat loss. The action area also incorporates the mitigation site which includes the immediate footprint of the site and the waters of Haynes Inlet surrounding the site out to a distance of approximately 300 feet. The airport is on Coos Bay in North Bend, Coos County, Oregon. The site is in Township 25 South, Range 13 West, Sections 8, 9, and 10.

**Figure 1.** Location of the two construction areas within Coos Bay for the Southwest Oregon Regional Airport Expansion Project.




The Pacific Fishery Management Council (PFMC) designated EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon (*O. tshawytscha*), coho salmon, and Puget Sound pink salmon (PFMC 1999). The action area includes areas designated as EFH for various life-history stages of groundfish, coastal pelagics, and Chinook salmon and coho salmon (Table 1).

The action area is used by adult and juvenile OC coho salmon for migration and making the transition between the marine and freshwater environments. The OC coho salmon were listed under the ESA, protective regulations were issued and critical habitat was designated on February 4, 2008 (70 FR 7816).

**Table 1.** Species with designated EFH found in waters of Oregon and Washington

| **Groundfish Species** | Blue rockfish (*S. mystinus*) | Rougheye rockfish (*S. aleutianus*) | Flathead sole (*Hippoglossoides elassodon*) |
|---|---|---|---|
| Leopard shark (*Triakis semifasciata*) | Bocaccio (*S. paucispinis*) | Sharpchin rockfish (*S. zacentrus*) | Pacific sanddab (*Citharichthys sordidus*) |
| Soupfin shark (*Galeorhinus zyopterus*) | Brown rockfish (*S. auriculatus*) | Shortbelly rockfish (*S. jordani*) | Petrale sole (*Eopsetta jordani*) |
| Spiny dogfish (*Squalus acanthias*) | Canary rockfish (*S. pinniger*) | Shortraker rockfish (*S. borealis*) | Rex sole (*Glyptocephalus zachirus*) |
| Big skate (*Raja binoculata*) | Chilipepper (*S. goodei*) | Silvergray rockfish (*S. brevispinus*) | Rock sole (*Lepidopsetta bilineata*) |
| California skate (*R. inornata*) | China rockfish (*S. nebulosus*) | Speckled rockfish (*S. ovalis*) | Sand sole (*Psettichthys melanostictus*) |
| Longnose skate (*R. rhina*) | Copper rockfish (*S. caurinus*) | Splitnose rockfish (*S. diploproa*) | Starry flounder (*Platyichthys stellatus*) |
| Ratfish (*Hydrolagus colliei*) | Darkblotched rockfish (*S. crameri*) | Stripetail rockfish (*S. saxicola*) | |
| Pacific rattail (*Coryphaenoides acrolepsis*) | Grass rockfish (*S. rastrelliger*) | Tiger rockfish (*S. nigrocinctus*) | **Coastal Pelagic Species** |
| Lingcod (*Ophiodon elongatus*) | Greenspotted rockfish (*S. chlorostictus*) | Vermillion rockfish (*S. miniatus*) | Northern anchovy (*Engraulis mordax*) |
| Cabezon (*Scorpaenichthys marmoratus*) | Greenstriped rockfish (*S. elongatus*) | Widow Rockfish (*S. entomelas*) | Pacific sardine (*Sardinops sagax*) |
| Kelp greenling (*Hexagrammos decagrammus*) | Longspine thornyhead (*Sebastolobus altivelis*) | Yelloweye rockfish (*S. ruberrimus*) | Pacific mackerel (*Scomber japonicus*) |
| Pacific cod (*Gadus macrocephalus*) | Shortspine thornyhead (*Sebastolobus alascanus*) | Yellowmouth rockfish (*S. reedi*) | Jack mackerel (*Trachurus symmetricus*) |
| Pacific whiting (Hake) (*Merluccius productus*) | Pacific Ocean perch (*S. alutus*) | Yellowtail rockfish (*S. flavidus*) | Market squid (*Loligo opalescens*) |
| Sablefish (*Anoplopoma fimbria*) | Quillback rockfish (*S. maliger*) | Arrowtooth flounder (*Atheresthes stomias*) | |
| Aurora rockfish (*Sebastes aurora*) | Redbanded rockfish (*S. babcocki*) | Butter sole (*Isopsetta isolepsis*) | **Salmon** |
| Bank Rockfish (*S. rufus*) | Redstripe rockfish (*S. proriger*) | Curlfin sole (*Pleuronichthys decurrens*) | Coho salmon (*Oncorhynchus kisutch*) |
| Black rockfish (*S. melanops*) | Rosethorn rockfish (*S . helvomaculatus*) | Dover sole (*Microstomus pacificus*) | Chinook salmon (*O. tshawytscha*) |
| Blackgill rockfish (*S. melanostomus*) | Rosy rockfish (*S. rosaceus*) | English sole (*Parophrys vetulus*) | Pink salmon (*O. gorbuscha*) |

The NMFS listed southern DPS green sturgeon as threatened under the ESA on April 7, 2006 (71 FR 17757). Southern DPS green sturgeon use the action area as habitat for growth and development to adulthood and for adult feeding. The NMFS has not designated critical habitat for southern DPS green sturgeon, or issued protective regulations under section 4(d) of the ESA.

## ENDANGERED SPECIES ACT

Section 7(a)(2) of the ESA requires Federal agencies to consult with NMFS to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The Opinion that follows records the results of the interagency consultation for this proposed action. An ITS is provided after the Opinion that specifies the impact of any taking of OC coho salmon that will be incidental to the proposed action, reasonable and prudent measures that NMFS considers necessary and appropriate to minimize such impact, and nondiscretionary terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agencies, applicants, or both, to carry out the reasonable and prudent measures.

### Biological Opinion

To complete the jeopardy analysis presented in this Opinion, NMFS reviewed the status of each listed species considered in this consultation, the environmental baseline in the action area, the effects of the action, and cumulative effects (50 CFR 402.14(g)). From this analysis, NMFS determined whether effects of the action were likely, in view of existing risks, to appreciably reduce the likelihood of both the survival and recovery of the affected listed species.

For the critical habitat adverse modification analysis, NMFS considered the status of the entire designated area of the critical habitat considered in this consultation, the environmental baseline in the action area, the likely effects of the action on the function and conservation role of the affected critical habitat, and cumulative effects. The NMFS used this assessment to determine whether, with implementation of the proposed action, critical habitat would remain functional, or retain the current ability for the primary constituent elements (PCEs) to become functionally established, to serve the intended conservation role for the species (Hogarth 2005).

#### Status of the Species and Critical Habitat

This section defines the biological requirements of the species, and reviews the status of the species and affected critical habitat relative to those requirements. The present risk of extinction faced by the listed species informs NMFS' determination of whether additional risk will 'appreciably reduce' the likelihood that they will survive or recover in the wild. The greater the present risk, the more likely it is that any additional risk resulting from the proposed action's effects on the population size, productivity (growth rate), distribution, or genetic diversity of the species (McElhany *et al.* 2000), or on the conservation value of critical habitat, will be an appreciable reduction.

**<u>OC Coho Salmon</u>**. This species includes all naturally-spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco, and progeny of five artificial propagation programs. The Oregon Coast Technical Recovery Team (OC-TRT) identified 56 historical populations, grouped into five major "biogeographic strata," based in consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Lawson *et al.* 2007).

The OC-TRT concluded that, if recent past conditions continue into the future, OC coho salmon are moderately likely to persist over a 100-year period without artificial support, and have a low to moderate likelihood of being able to sustain their genetic legacy and long-term adaptive potential for the foreseeable future (Wainwright *et al.* 2007).

The following factors were identified by NMFS (2007) as limiting the recovery of OC coho salmon: Degraded floodplain connectivity and function, degraded channel structure and complexity, degraded riparian areas and large wood debris recruitment, degraded stream substrate, degraded water quality, predation, competition, and disease.

***Coos River population***. OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population (Lawson *et al.* 2007). An independent population is defined as having minimal demographic influence from adjacent populations and is viable-in-isolation. An independent population is any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations (McElhany *et al.* 2000). The Coos River Population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU (Lawson *et al.* 2007).

Annual spawning surveys document the Coos River population's annual abundance varies considerably from year to year (Tables 2 and 3). The recent negative trend in abundance demonstrated at the ESU level is reflected at the population level as well (Table 3). Preliminary conclusions for the 2007 spawner abundance places last year's spawner abundance at a very low level.

The number of OC coho salmon juvenile outmigrants from the Coos River population has not been studied enough to provide a reliable estimate. However, it can be back-calculated by dividing the number of returning adults by marine survival. Marine survival predictions averaged 4%, with a range of 0.5% and 11.7%, between 1970 and 1999 (PMFC 2000). In the years of overlapping data (1990-1999), the average number of outmigrants estimated by this back-calculation is 123,625, with a range of 72,067 to 1,686,360.

**Table 2.** Annual estimates of wild OC coho salmon spawner abundance in the Coos Bay system based on monitoring data collected by ODFW.

| Year | Coos Bay & Big Creek |
|---|---|
| 1990 | 2,273 |
| 1991 | 3,813 |
| 1992 | 16,545 |
| 1993 | 15,284 |
| 1994 | 14,685 |
| 1995 | 10,351 |
| 1996 | 12,128 |
| 1997 | 1,127 |
| 1998 | 3,167 |
| 1999 | 4,945 |
| 2000 | 5,386 |
| 2001 | 43,301 |
| 2002 | 35,429 |
| 2003 | 29,559 |
| 2004 | 24,116 |

**Table 3.** Estimated wild OC coho salmon abundance estimates and 95% confidence interval (CI) from the 2002 through 2007 spawning survey seasons for Coos River. Included are the number of surveys and miles surveyed.

| Year | Number Surveys | Miles | Estimate | 95% CI |
|---|---|---|---|---|
| 2002 | 32 | 29.4 | 35,688 | 13,258 |
| 2003 | 33 | 30.9 | 29,559 | 11,486 |
| 2004 | 34 | 31.8 | 24,116 | 7,446 |
| 2005 | 9 | 7.3 | 17,048 | 9,170 |
| 2006 | 23 | 20.0 | 11,266 | 4,243 |
| 2007 | 31 | 30.1 | 1,414 | 459 |

**Southern DPS Green Sturgeon.** Green sturgeon are a widely-distributed and marine-oriented species found in nearshore waters from Baja California to Canada (NMFS 2008). There are two distinct population segments defined for green sturgeon – a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River (NMFS 2008). The southern DPS includes all spawning populations of green sturgeon south of the Eel River in California, of which only the Sacramento River currently contains a spawning population. McLain (2006) noted that southern DPS green sturgeon were first determined to occur in Oregon and Washington waters in the late 1950s when tagged San Pablo Bay green sturgeon were recovered in the Columbia River estuary (CDFG 2002).

The green sturgeon biological review team (BRT) convened a status review update in November 2004 (BRT 2005). The majority of the BRT concluded that southern DPS green sturgeon is likely to become endangered in the foreseeable future and only one member concluded that the southern DPS is not in danger of extinction or likely to become endangered in the foreseeable future. Weighing heavily in this decision was the fact that this species only spawns in one area, the Sacramento River. The BRT felt that the blockage of green sturgeon spawning from what were certainly historic spawning areas above Shasta Dam and the accompanying decrease in spawning area with the loss of the Feather River spawning area make green sturgeon in the southern DPS at risk of extinction in the foreseeable future.

The distribution of green sturgeon is not well known, although southern DPS green sturgeon are reported to congregate in coastal waters and estuaries, including non-natal estuaries, such as Coos Bay. Beamis and Kynard (1997) suggested that green sturgeon move into estuaries of non-natal rivers to feed. Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States. Green sturgeon are known to enter Washington estuaries during summer (Moser and Lindley 2007). Commercial catches of green sturgeon peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are likely to be present in these estuaries from June until October (Moser and Lindley 2007).

***Coos Bay.*** Total population estimates are not available for abundance of either DPS of green sturgeon in Coos Bay; southern DPS individuals were documented to occur by sampling in a 2006 study (Israel and May 2006). Because Coos Bay is not their natal stream, southern DPS green sturgeon are likely to be present from June through October. While in the Coos Bay estuary, they are likely feeding and seeking out the deepest habitats.

**Status of OC Coho Salmon Critical Habitat.** The NMFS reviews the status of critical habitat affected by the proposed action by examining the condition and trends of PCEs of critical habitat throughout the designated area. Within the action area, critical habitat has been designated for OC coho salmon. The PCEs consist of the physical and biological elements identified as essential to the conservation of the species in the documents identifying critical habitat (Table 4).

**Table 4.** Sites (types of habitats), essential physical and biological features named as PCEs, and affected life history events in all salmon critical habitat designations.

| Site | Essential Physical and Biological Features | Affected Life History Event |
|---|---|---|
| Estuarine | Free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover[a]; and forage[b]. | Juvenile and adult mobility and survival |

[a] Natural cover includes submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.

Critical habitat was designated for OC coho salmon, and the action area contains one or more PCEs within the acceptable range of values required to support the biological processes for which the species use that habitat. The specific unit of OC coho salmon critical habitat that will be affected by the proposed action is the Coos Bay 5th field hydraulic unit code (HUC5

#1710030403). This watershed contains PCEs necessary for spawning, rearing and migration. The action area is identified as estuarine habitat and contains the PCEs necessary for juvenile and adult mobility and survival (Table 4). The NMFS Critical Habitat Analytical Review Team (CHART) identified the key management activities with the potential to affect the PCEs as forestry and urbanization. The CHART rated the conservation values of the HUC5 and the migratory corridor as high.

OC coho salmon adult and smolts considered in this Opinion migrate through the action area and use the area to make the physiological transition between marine and freshwater environments. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile coho salmon for migration and to make the transition between these two environments (Table 4). Loss of estuarine wetlands caused by diking and filling to make those areas suitable for agricultural use, urbanization, and industrialization is the most important factor limiting salmon habitat value in the Coos Bay estuary.

### Environmental Baseline for the Action Area

The NMFS describes the environmental baseline in terms of the biological requirements for habitat features and processes necessary to support all life stages of ESA-listed species within the action area. When the environmental baseline departs from those biological requirements, the adverse effects of a proposed action on the species or its habitat are more likely to jeopardize the listed species or result in destruction or adverse modification of a critical habitat (NMFS 1999).

The Coos Bay estuary is the second largest estuary in Oregon. It is approximately 13,300 acres in size, averaging nearly 0.6 mile wide by 15 miles long. The bay has approximately 30 tributaries. The major tributary flowing into Coos Bay is the Coos River. The Coos Bay estuary is classified as a drowned river mouth-type estuary, where winter flows discharge high volumes of sediment through the estuary. In summer, when discharge is lower, seawater inflow dominates this type of estuary. Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary. Approximately 90% of Coos Bay marshes have been lost to dikes and landfills (Proctor *et al.*1980). Approximately 72,000 tons of sediment, mainly silts and clays, pour into the Coos Bay estuary every year (Schultz 1990).

The waters surrounding the airport site consist of mostly shallow tidal mudflats that are exposed during most low tide occurrences. Habitat typing and mapping identified the area around the airport as: (1) Intertidal with sand and mud flats; (2) undifferentiated aquatic bed; and (3) seagrass aquatic bed. These three habitat types comprise 57.3% of the total 8,582 acres of intertidal zone within Coos Bay.

### Effects of the Action

'Effects of the action' means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). The effects analysis presented in this section is based on information developed with the FAA and the applicants during the consultation process and provided by the applicants BA and supplemental information.

Based on information provided in the BA, NMFS concludes that the proposed action will have adverse effects on the aquatic environment in the action area. Two distinct areas exist in the action area. The taxiway C relocation and the Mangan mitigation site are the two areas with very distinct actions and effects on the environment. The NMFS believes the action, as proposed, is reasonably likely to have the following direct and indirect effects on the ESA-listed species and their aquatic environment: (1) Increased turbidity; (2) chemical contamination from materials staging and construction activities; (3) loss of benthic and shoreline habitat; (4) restoration of estuary functions; and (5) injury due to fish salvage.

Changes in stormwater generation and management are not expected to result in adverse effects to the local aquatic environment. Increased impervious surface and resulting stormwater management will result in discharged stormwater to Coos Bay and Pony Slough, but the proposed level of treatment and water management results in a negligible probability of an adverse effect on OC coho salmon and southern DPS green sturgeon. Approximately 76,595 square feet of increased impervious surface will result from the proposed action. The development of grassy swales, retention ponds, and an infiltration collection system will treat the 6-month, 24-hour storm; that is 90 to 95% of the annual runoff volume. Discharge will occur into Coos Bay and Pony Slough, which will have some low-intensity but insignificant effects on flow and potential contaminants.

**<u>Effects on the Aquatic Environment</u>.**

***Turbidity.*** Elevated turbidity levels will result from actions taken in both areas of the project. Actions associated with the taxiway C relocation that will cause elevated turbidity include the construction of the gravel pier. Dike removal at the Mangan mitigation site will also result in elevated turbidity.

Dry season construction of the pier will equate to less opportunity for precipitation-generated turbidity from the structure and fill area and will reduce the chances of smolts entering the work area. Construction of the pier within the early portion of the in-water work period would present a more significant delay from that already incurred by the project and would increase the likelihood of fall and winter storms affecting the work area and potentially increasing local turbidity.

During the gravel pier construction that will be used to isolate the work area, geotextile fabric will be placed during low tide and filled with unwashed aggregate. Each day the fabric will be folded up and closed around the aggregate to prevent tidal action from washing dirt off of the aggregate. It is expected that some turbidity will be generated through this process. Elevated turbidity levels will occur along the outside of the geotextile fabric from two causes: primarily due to wave action at the base of the structure, and secondarily from fine sediments escaping the geotextile fabric.

This elevated turbidity is expected to be localized, but to develop cumulatively along the face of the pier. Elevated turbidity levels will accumulate fine material and travel along the face of the pier in the direction of the water current. Turbidity plume directional movement and disbursement will be dependent on current flow. The outgoing tidal flows, combined with outgoing river flows, will carry the turbidity approximately 1,500 feet downstream from the end of the gravel pier. The gravel pier is inside a cove, therefore incoming tides will carry along the face of the pier into the back end of the cove. Most turbidity movement will be parallel to the gravel pier and then dispersed out from the pier to settle at the end of the cove. The cove area where elevated turbidity is expected to be observed is approximately 3.8 acres (185 feet wide and 900 feet long). During the incoming tide, the NMFS expects any increase in turbidity to not be detectable beyond this area. Tidal fluctuations and wind will drive the currents and disperse the suspended sediments away from the pier. Elevated turbidity levels will occur over a short time, lasting a few hours immediately after the work area is inundated by the incoming high tide. The elevated turbidity levels will occur over the 2 weeks of in-water work, twice each day in relation to the high tide cycle.

The dike removal process will create elevated turbidity in the immediate vicinity of the work. Although the removal work will occur at low tide, inundation of the work area during the high tide cycle will suspend sediments and create elevated turbidity. The placement of two silt fences will aid in controlling the suspended sediment spread, but not eliminate elevated turbidity. It is expected that the elevated turbidity levels will be observed up to 300 feet from the dike removal area. The elevated turbidity levels will occur over the 5 days of in-water work, twice each day in relation to the high-tide cycle.

**Chemical Contamination.** As with all construction activities, accidental release of fuel, oil, and other contaminants may occur as the presence of construction equipment near sensitive habitats, such as the estuary and wetlands, creates the potential for introduction of toxic materials from accidental spills, improper storage of petrochemicals, or mechanical failure. Operation of back-hoes, excavators, and other equipment requires the use of fuel, lubricants, *etc*., which, if spilled into the channel of a waterbody or into the adjacent riparian zone, can injure or kill aquatic organisms.

Based on experience with construction activities, the probability of a fuel spill, equipment malfunction, or accident is more than negligible. However, this is likely to be a short-term effect. Short-term effects of a spill could be extremely detrimental to aquatic habitat within the action area. Petroleum-based contaminants, such as fuel, oil, and some hydraulic fluids, contain poly-cyclic aromatic hydrocarbons (PAHs) which can be acutely toxic to the aquatic environment for fishes and can also cause lethal and chronic sublethal effects to aquatic organisms (Neff 1985).

Accidental spills may occur, allowing chemicals to reach Coos Bay, resulting in impacted water quality and reduced feeding opportunities for aquatic species within the action area. The large volume of water in the bay, the strong water currents and wind action, and the conservation measures proposed to minimize the amount and distance of a toxicant material spread will result in the dilution of any spill to undetectable levels in a few hours. Potential water contamination from construction activities will be controlled by the implementation of a spill containment plan. However, depending on the timing, weather conditions, and response and clean-up efficiency, adverse impacts may still occur due to the proximity to aquatic habitat.

**Loss of Benthic and Shoreline Habitat.** The fill will permanently destroy 1.23 acres of tidal estuarine habitat in Coos Bay. Habitat typing and mapping identified the area around the airport as: (1) Intertidal with sand and mud flats; (2) undifferentiated aquatic bed; and (3) seagrass aquatic bed. This proposed action will fill 1.23 acres of the total 8,582 acres of these three habitat types in the intertidal zone of Coos Bay. This loss will result in reduced abundance and diversity of prey for species inhabiting the immediate surrounding area of the Coos Bay estuary. The loss of shallow-water and benthic habitat from construction operations will eliminate the physical habitat space and the biotic community living in the 1.23 acres. Macroinvertebrates move, rest, find shelter, and feed on the substrate and organic material, as well as live within the substrate. The proposed project will physically disturb channel bottoms, eliminate the aquatic habitat, eliminate or displace established benthic communities and reduce prey availability in the vicinity of the fill placement.

**Restoration of Estuary Functions.** The applicant proposes to provide approximately 10 acres of estuarine compensatory mitigation at the Mangan mitigation site on Haynes Inlet, in the town of North Bend in Coos County, Oregon. This mitigation area is currently a 35-acre diked freshwater wetland and has been used to graze livestock since the 1940s. The mitigation action will restore portions of the area and provide similar estuarine habitat function to those that will be lost due to the filling of 1.23 acres of intertidal estuarine habitat; the conversion of 1.39 acres of freshwater wetland to intertidal wetland; and the 1.13 acres of freshwater wetland lost from the new dike construction. Approximately 8.6 acres of the total 10-acre intertidal mitigation site will function as a tidal mud flat, supporting mats of green and brown algae and provide support for a mud flat biotic community. Establishing approximately 1.44 acres of salt marsh in the mitigation area will be accomplished by planting plugs of Lyngbye's sedge (*Carex lygbyei*) and seeding of redtop (*Agrostis alba*), which are both salt marsh species. This salt marsh complex provides productive nutrient cycling and forage production in the estuarine ecosystem. Full conversion of this area will likely take several years for the salt tolerant plants to establish and mature. This is also the likely time line for most of the other estuarine biotic community.

**Effects on Species.**

***Fish salvage.*** Project activities will create fish entrapment conditions. This activity is proposed for July, but may occur in August, depending on action approval. During July and August, very few OC coho salmon smolts are expected to inhabit the action area. Adult coho salmon are not expected to be in the action area at that time. Adult southern DPS green sturgeon occurring in the action area are not likely to occur in the areas immediately adjacent to the project where fish salvage will occur, and are not likely to be entrapped or require capture.

Fish salvage is proposed to occur in the taxiway relocation area and in the Mangan mitigation area. In the taxiway C relocation area, proposed activities include constructing a gravel pier to serve as an in-water work enclosure. An area of approximately 1.23 acres will be enclosed and require fish salvage. In the process of isolating the work area, fish entrapment conditions are created and the proposed action includes seining the entrapment area to recover fish. Enclosure of the isolation area will occur at low tide and this should result in fewer trapped fish than if the entire area was enclosed at a higher tide. Some juvenile coho salmon will likely evacuate the areas to be isolated in response to disturbance of the areas and as the tide recedes, but it is reasonably certain that some smolts will be stranded or trapped and will require handling. All captured fish will be released in the open bay. Approximately 0.25 acre of intertidal area will be enclosed with the two silt curtains at the Mangan mitigation site. As stated, few coho salmon smolts are expected to be in the area during the proposed in-water work period. Seining and dip-netting are proposed methods of capture for any fish entrapped within the silt curtain deployment.

The NMFS assumes that any coho salmon smolts salvaged would experience high stress with the possibility of up to a 5% direct or delayed mortality due to injury and stress experienced in the fish salvage process. Although work area isolation is a conservation measure intended to reduce adverse effects from in-water work activities, some OC coho salmon smolts are likely to be subjected to incidental harassment, injury or death.

Based on an average of 4% survival from smolts to returning adults, back-calculated estimates from recent (last 6 years, Table 3) return numbers would suggest 35,000 to 875,000 smolts pass through the action area. It is expected almost all smolts from the Coos River OC coho salmon population will move through the estuary and into the ocean prior to this work area isolation activity (July and August); therefore, only a very small proportion of the number of individuals in the Coos population will be exposed to adverse effects. Based on experience with smolt outmigration timing and the proposed in-water work timing in July and August, the NMFS expects 0.5 % of the total smolts to still be in Coos Bay; therefore 175 to 4,375 smolts could inhabit the bay at the time work area isolation will occur. Of these smolts, few are expected to occur in the action area and the NMFS expects a smaller number to actually be trapped in the isolation areas.

The two isolation areas will have different probabilities of entrapping coho salmon smolts. At the airport site, the NMFS expects 450 smolts (10% of the highest estimate) to be entrapped with up to 23 (approximately 5%) of these dying from stress and injury due harassment from being captured and handled. At the Mangan site, the NMFS expects 219 smolts (5% of the highest estimate) to be entrapped with up to 11 (approximately 5%) of these dying from stress and injury due harassment from being captured and handled.

***Turbidity.*** Elevated turbidity levels will be the result of in-water work. The two regions of the action area will have differing causes and patterns of generating elevated turbidity. Increases in suspended sediment at a concentration of 53.5 milligrams per liter (mg/L) for a 12-hour period caused physiological stress and changes in behavior in coho salmon (Berg 1983). The NMFS expects the OC coho salmon smolts would react quicker with higher concentrations.

At the taxiway relocation area, the initial installation of the gravel pier will result in disturbance of the substrate from installation of the geotextile fabric and then placement of the coarse gravel and the resulting increased suspended sediment will reach concentrations that are likely to cause physiological stress to smolt coho salmon residing in the area. Most work will occur at low tide and the step-wise procedures described in the proposed action are intended to minimize turbidity by covering the unwashed gravel with the geotextile. Some turbidity creation will occur during this process, but NMFS expects the turbidity to be localized. Disturbed substrate at the outside base of the gravel pier will be suspended by wave action created from tidal influence, wind action, and ship wakes. This elevated turbidity will move directionally with the current and wave action.

During the outgoing tide, elevated turbidity levels are expected to be observed up to 1,500 feet from the downstream end of the gravel pier where it will disperse to an undetectable level. At the downstream end of the gravel pier and for the first 300 feet of this 1,500 feet turbidity plume, turbidity concentrations may approach and likely exceed the 53.5 mg/L levels that could cause gill irritation and behavioral response.

During the incoming tide, the highest concentrations will occur along the base of the gravel pier and as the suspended sediment is carried back into the cove, thereby limiting its dispersal. The NMFS expects the elevated turbidity concentrations within the cove will reach levels that are likely to cause gill irritation and behavioral response over approximately 3.8 acres. Turbidity will be highest at the back of the cove and dissipate as the currents flow back outwards

Any coho salmon smolts exposed to these high turbidity levels are likely to display behavioral effects, such as reduced feeding and gill-flaring, in response to pulses of suspended sediment (Berg and Northcote 1985). Gill irritation can result in increased disease exposure resulting in higher mortality rates. OC coho salmon smolts exposed to these elevated concentrations will likely move out of the area, thus forced to seek other suitable habitat. This may make them more vulnerable to predators, although the lower water visibility will assist their avoidance of predators. Adult southern DPS green sturgeon are most likely to inhabit deeper waters where project caused elevated turbidity levels are not expected to reach concentrations that would adversely affect this species.

At the Mangan mitigation site, turbidity generation will occur from the removal of the existing dike. Equipment operation and actual fill removal will occur at low tide intervals, but the work site will be inundated during each high tide event. This inundation will mobilize disturbed and exposed fine sediments during the fill removal process. Deploying two silt screens, set five feet apart, will filter some of the fine sediments. This control measure will maintain some control of the turbidity distribution, but turbidity concentrations are expected to reach gill irritation levels inside the silt screened area and the first 200 feet outside of the last screen. Any OC coho salmon smolts within this area exposed to these high levels will experience gill irritation and make a behavioral avoidance response. These smolts will likely move out to the outer edge of the turbidity line to avoid the irritation. This may make them more vulnerable to predators, although the lower water visibility will assist their avoidance of predators. Adult southern DPS green sturgeon are most likely to inhabit deeper waters where project caused elevated turbidity levels are not expected to reach concentrations that would adversely affect this species.

In July and August, when the turbidity causing project activities will occur, few (175 to 4,375) OC coho salmon smolts will occur in the bay, with even fewer in the action area. Some smolts that are late in leaving the Coos Estuary could be exposed to higher turbidity concentrations, therefore the potential for exposure and subsequent adverse effects that may lead to increased mortality due to vulnerability to predation and disease cannot be discounted. In conclusion, only a very small portion (0.5%) of the total smolts from the Coos River population of OC coho salmon will be exposed to elevated turbidity levels cause by the project. Therefore, it is reasonably certain that these effects are not likely to be significant at the population level.

***Chemical contamination.*** The potential extent of a chemical spill from the proposed project is limited because of work area isolation for construction activities and proposed conservation measures. Additionally, all work is proposed to occur during the late summer when the fewest amount of coho salmon will be present due to their limited use of the estuary at that time. Nonetheless, any exposure to these toxic chemicals could be extremely detrimental to juvenile coho salmon within the action area.

Petroleum-based contaminants, such as fuel, oil, and some hydraulic fluids, contain PAHs which can kill salmonids at high levels of exposure and can also cause lethal and sublethal adverse effects to aquatic organisms (Neff 1985). The action area is a large open bay with sufficient open space for the fish to quickly move from the toxicants. Each compound has its own specific characteristics related to mobility, toxicity, and density, therefore some compounds that may move through the water column more rapidly will expose more fish to toxic chemicals.

Mortality, harm and harassment, including reduced or less aggressive feeding, reduced growth, increased disease susceptibility and reduced survival of OC coho salmon smolts is reasonably certain to occur from chemical contamination from accidental spills, but the extent of this exposure will be limited to the few individuals in the immediate area of the spill. It is expected that the conservation measures employed to contain any spill and the large volume of water of Coos Bay will result in limiting adverse concentrations of these chemicals to 300 feet around the gravel pier. Potential dispersal patterns are expected to those described in the turbidity section. A large fuel spill is unlikely, but would degrade water quality from the spill location up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Based on the few OC coho salmon smolts that potentially could be exposed to the contaminants, only a very small proportion of the Coos River population's total smolts will be exposed to chemical contamination. Therefore it is reasonably certain that these effects are not likely to be significant at the population level.

***Loss of benthic and shoreline habitat.*** Adult, smolt, and juvenile coho salmon from the Coos River population of OC coho salmon will be exposed to the loss of estuarine habitat resulting in impacts to available forage and decreased cover from predators. Juvenile salmonids feed on a range of invertebrates. In winter, aquatic larval forms of organisms dominate the food source (Brown 2002) while the benthic invertebrates most commonly consumed by rearing and migrating coho juvenile salmonids in an estuary are *Corophium salmonis* and *Corophium spinicorne* (amphipods) and adult *Diptera* (Bottom *et al.* 2001). Areas with rooted vegetation provide a greater density of food sources than bare mud (Brown 2002). The fill will permanently destroy approximately 1.23 acres of tidal estuarine habitat in Coos Bay and will result in reduced abundance and diversity of prey for juvenile coho salmon inhabiting the Coos Bay estuary. Habitat typing and mapping identified the area around the airport as intertidal with sand and mud flats; undifferentiated aquatic bed; and seagrass aquatic bed. Aquatic seagrass provides natural cover for coho salmon smolts. Coho salmon smolts will be more vulnerable to predation with the loss of cover.

Increased predation is also likely with the change to a riprapped shoreline that favors some predatory fish species. All Coos River population individuals whose natal streams are upstream of the project site will have some exposure to this component of the proposed action resulting in lost estuarine habitat and reduced forage. With the exception of South Slough and a few other smaller tributaries, the majority of OC coho salmon in this population are from upstream of this action area. Based on estimates from the last 6 years, the estimated number of adult OC coho salmon exposed to the lost habitat is from 1,400 to 35,000 individuals per year. OC coho salmon outmigrant numbers vary significantly depending on the year and the environmental conditions determining the survival rates. Based on an average of 4% survival from smolts to returning adults, back-calculated estimates from these return numbers would suggest 35,000 to 875,000 smolts would be exposed to this lost habitat per year.

Little is known about green sturgeon feeding other than general information. The 2002 status review (Adam *et al.* 2002) described benthic invertebrates, mollusks, and small fish as potential forage for green sturgeon. All of these prey species are likely to inhabit the habitat to be filled. Specific information about southern DPS green sturgeon use of this habitat is not known, but permanently lost habitat will result in some level of reduced forage available for green sturgeon in the airport area.

***Restoration of estuary functions.*** Proposed compensatory mitigation is expected to result in long-term beneficial habitat restoration for OC coho salmon and southern DPS green sturgeon. Full conversion of this area will likely take several years for the salt tolerant plants to establish and mature and the ecological functioning of the area to reach full potential. Forage production, nutrient cycling, water quality maintenance, natural cover through submerged plant growth; and other biotic and abiotic components of the estuarine ecosystem will be improved by re-introducing this diked pasture to tidal flushing. When this tidal flat and salt marsh reach their full ecological potential, the result for OC coho salmon and southern DPS green sturgeon is an increase in forage production, water quality, and coho salmon natural cover. This mitigation site is located in Haynes Inlet, which is approximately 2.7 miles upstream from the taxiway relocation, and in an arm of Coos Bay that is not necessarily directly benefiting all upstream segments of the Coos River coho salmon population. The resulting habitat increase from the mitigation site will provide benefits to the population overall by increasing natural cover and forage production in Haynes Inlet. Fewer individuals of the Coos River population will be exposed to this habitat, but it is likely the increased quantity of habitat will offset the losses from the airport site.

Distribution of green sturgeon in Coos Bay is likely independent of the Coos Bay tributaries. The NMFS assumes any green sturgeon inhabiting Coos Bay that would be impacted by the loss of the intertidal zone at the airport will also be benefitted by the benefits from the Mangan mitigation site due to the overall increase in forage production within this area of the bay.

***Summary of effects to OC coho salmon and southern DPS green sturgeon.*** Project-caused effects on OC coho salmon and southern DPS green sturgeon will reach adverse levels. Direct and indirect effects from project actions will adversely affect OC coho salmon due to fish salvage efforts, turbidity, chemical contamination, and habitat loss. The proposal to complete in-water work between July 1 and August 31 results in fewer OC coho salmon exposed to the activities and serves to minimize, but not eliminate, exposure to direct adverse conditions. Salvage will occur in two separate areas that will have differing probabilities of entrapping coho salmon smolts. A total of 669 OC coho salmon smolts are expected to be harassed and captured during fish salvage operations. Up to 34 of these smolts are expected to die due to injury and stress related factors. Southern DPS green sturgeon occurring in the action area are expected to inhabit the deeper waters of the bay, depending on the time of day, tidal cycle, and activity. Adverse effects from project caused elevated turbidity or chemical contamination are discountable due to green sturgeon spatial distribution. Southern DPS green sturgeon in the area are adult fish residing and feeding in the estuary. It is unlikely and considered discountable that any individuals will be captured during the fish salvage effort. Both OC coho salmon and southern DPS green sturgeon will lose habitat at the airport taxiway expansion resulting in adverse effects to both species due to permanent loss of forage at the airport site. Beneficial actions are proposed to compensate for the loss of forage and ecological functions by re-introducing approximately 10 acres of intertidal habitat to tidal flushing, but a delay of several years before the area reaches full ecological potential is expected.

**Effects on OC Coho Salmon Critical Habitat.** The action area in Coos Bay, which is designated as critical habitat for OC coho salmon, provides habitat to support successful estuarine life history requirements. OC coho salmon adults and smolts use the action area for migration and to make the physiological transition between marine and freshwater environments. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile coho salmon for migration and to make this transition between these two environments. These PCEs include water quality, salinity conditions, natural cover, and forage which support juvenile and adult physiological transitions between fresh- and saltwater. The likely effects of the project on these essential features are described below.

1. Water Quality. Suspended sediment levels will be increased over background due to fine sediment mobilized by construction activities. While the impact on habitat is great enough to adversely affect some OC coho salmon smolts, it will not occur on a large enough spatial or temporal scale to significantly disrupt their normal behavioral patterns. Few smolts will occur in the action area at the time elevated turbidity levels will occur and the elevated turbidity levels will be short-term, lasting a few hours at a time during the two weeks of in-water work. A large fuel spill is unlikely, but would degrade water quality from the spill location up to 300 feet for up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Because these impacts are short term and temporary or are unlikely, the water quality PCE will not be functionally changed.

2. Salinity Conditions. Salinity conditions will be improved within the Haynes Inlet portion of the Coos Bay 5th field due to the Mangan mitigation site development. This area is not accessible to OC coho salmon unless this proposed action occurs. The mitigation site

is located in Haynes Inlet where reintroduction of river flows and tidal currents to approximately 10 acres of previously inaccessible intertidal habitat will provide a complex and varying salinity gradient, which is necessary to aid adult and smolt OC coho salmon making the transition between the marine and freshwater environments.

3. Natural Cover. 1.23 acres of natural cover will be permanently lost due to the filling of intertidal habitat. An additional area (10 acres) will be restored at the Mangan mitigation site. The additional acres of habitat reintroduced to tidal influence is likely a reasonable offset to the acres lost at the airport site.

4. Forage. Food resources will be permanently lost in the 1.23 acres of the airport fill site. Additional forage production will be available in the Mangan mitigation site once the area reaches functioning condition, perhaps in 1 to 2 years. While the impact on habitat is great enough to result in some OC coho salmon smolts being adversely affected, it will not disrupt normal behavior patterns. Because the mitigation site will provide additional benthic habitat in the Coos Bay 5$^{th}$ field watershed, the food resources PCE will not be functionally changed.

***Summary of effects to OC coho salmon critical habitat.*** Information presented in the status and baseline sections of this opinion show that the Coos Bay estuary has been altered, but conditions still support successful migration and transition from freshwater to saltwater environments. Four PCEs will be affected, but will not be functionally changed because effects will be small-scale, short-term, unlikely, or sufficiently offset by the proposed mitigation. Potential short-term effects to the water quality PCE include increased turbidity concentrations and toxic material contamination from PAHs due to spill, equipment failure, or accident. These are expected to be short-term and localized. Salinity conditions will be improved in the action area at the Mangan mitigation site where tidal flow and fluctuation will be reintroduced to 10 acres of intertidal habitat. Forage production and natural cover will be lost from the filling of 1.23 acres and this will be replaced with the 10 acre mitigation site within the same watershed. Since the effects will not adversely change the habitat functions at the site scale, the effects from the proposed project will not adversely change functions at the 5$^{th}$ field watershed scale either.

**Cumulative Effects**

Between 2000 and 2006, the population of Coos County increased by 3.2%.[1] Thus, NMFS assumes that future private and state actions will continue within the action area, increasing as population density rises. As the human population in the action area continues to grow, demand for agricultural, commercial, or residential development is also likely to grow. The effects of new development caused by that demand are likely to reduce the conservation value of the habitat within the action area. However, NMFS is not aware of any specific future non-Federal activities within the action area that would cause greater effects to a listed species or a designated critical habitat than presently occurs.

[1] U.S. Census Bureau, State and County Quickfacts, Curry County. Available at: http://quickfacts.census.gov/qfd/

### Conclusion

After reviewing the status of OC coho salmon and designated critical habitat, the environmental baseline for the action area, the effects of the proposed action, and cumulative effects, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of southern DPS green sturgeon or OC coho salmon, and is not likely to destroy or adversely modify OC coho salmon designated critical habitat. These conclusions are based on the following considerations.

The suspended sediment and contaminant spill threats from the proposed action will expose OC coho salmon smolts to adverse water quality conditions that may reduce survival due to increased susceptibility to disease, predation, and physiological response to toxicants. However, only a very small percentage of Coos River coho salmon smolts will still be in the estuary during July and August. These two threats to southern DPS green sturgeon are discountable because of their deep-water habitat use.

The proposed action will result in harassment of up to 669 smolt OC coho salmon due to capture and handling. Effects on abundance and productivity at the population scale will be insignificant because such a small proportion of the total Coos River population's smolt population will be affected (approximately 0.07 to 1.9%, based on 6-year high and low population estimates). No specific future non-Federal activities have been identified within the action area that would cause greater effects to a listed species or a designated critical habitat than presently occurs.

The limiting factor to OC coho salmon that will be affected from this project is the loss of intertidal estuarine habitat including sand and mud flats, undifferentiated aquatic bed, and seagrass aquatic bed. As proposed, 1.23 acres of intertidal habitat will be permanently filled and approximately 10 acres of intertidal habitat will be restored for fish use by relocating a dike. Within these 10 acres of intertidal habitat, the potential exists for all three habitat types to develop after several years of tidal flow exposure. As part of the proposed action, this habitat replacement is expected to offset the habitat loss at the taxiway relocation site; therefore, the proposed action will not result in a net decrease in intertidal habitat. The lag time between the mitigation site reaching its full ecological potential and the immediate habitat loss will cause adverse impacts to OC coho salmon and southern DPS green sturgeon due to loss of available cover for OC coho salmon and reduced forage available to both species.

Four critical habitat PCEs will be affected, but will not be functionally changed because effects will be localized and short-term, beneficial, or replaced by compensatory mitigation in the same watershed. The actions will not adversely affect the estuary habitat functions within the 5$^{th}$ field watershed. The critical habitat would remain functional and retain its current ability for the PCEs to become functionally established.

### Reinitiation of Consultation

Reinitiation of formal consultation is required and shall be requested by the Federal agency or by NMFS where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) If the amount or extent of taking specified in the ITS is exceeded;

(b) if new information reveals effects of the action that may affect listed species or designated critical habitat in a manner or to an extent not previously considered; (c) if the identified action is subsequently modified in a manner that has an effect to the listed species or designated critical habitat that was not considered in the biological opinion; or (d) if a new species is listed or critical habitat is designated that may be affected by the identified action (50 CFR 402.16).

To reinitiate consultation, contact the Oregon State Habitat Office of NMFS and refer to the NMFS Number assigned to this consultation (2008/03298).

**Incidental Take Statement**

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering. Harass is defined by Fish and Wildlife Service as an intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA, provided that such taking is in compliance with the terms and conditions of this ITS.

**Amount or Extent of Take**

The NMFS has not prohibited take of southern DPS green sturgeon. However, the effects of the proposed action will overlap in time and space with the presence of adult and smolt OC coho salmon, and are reasonably likely to result in take of some juveniles. The action area is used as a migration corridor and as an area that both life stages use to acclimate while making the physiological transition between freshwater and saltwater. The action area is defined as the footprint of the existing airport and adjacent bank, substrate, and aquatic areas of the Coos Bay Estuary and Pony Slough. The action area extends 500 feet upstream from the project site and 1,500 feet downstream from the downstream end of the project site in Coos Bay due to potential impacts from turbidity, contaminant dispersion, and habitat loss. The mitigation site includes the immediate footprint of the site and the waters of Haynes Inlet surrounding the site out to a distance of approximately 300 feet. The Coos Bay estuary plays a critical role in the survival and recovery of ESA-listed OC coho salmon by providing refuge, nutrients and conditions in which juvenile and adult salmon change physiologically.

While adults will not be present in the bay during construction and very few smolts are expected, both life-stages will be exposed to the long-term, continuing adverse effects of the project. The action area provides migration and vital estuarine habitat in fair condition. Incidental take caused by the adverse short- and long-term effects will include the following: (1) Death or injury of smolts from work area isolation and fish salvage; (2) increased vulnerability to predation of juvenile coho salmon displaced from the action area during construction, changed habitat characteristics favoring predators, and lost natural cover; (3) death or significant impairment of essential behaviors from increased turbidity and exposure to PAHs; and (4) reduced growth and survival from reduced feeding opportunities due to lost forage production in the area until the mitigation site's ecological potential is reached in 2 years. Outmigrating OC coho salmon smolts from most of the Coos River population use the action area for migration and to acclimate to saltwater conditions. Within this action area, the area that incidental take may occur includes an area 300 feet downstream from the gravel pier construction, approximately 3.8 acres inside the cove adjacent to the gravel pier, and approximately 200 feet outside the silt screen placement surrounding the Mangan mitigation site. Incidental take within that area that meets the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

Some coho salmon smolts will likely evacuate the action area in response to work area isolation activities, but it is reasonably certain that some individuals will be trapped within the work isolation area. These trapped individuals will be stranded during dewatering. Death and injury of captured smolts is reasonably certain to occur. However, only a small number of individuals are likely to be exposed to or displaced by work area isolation due to the July and August implementation. The process of work area isolation for the proposed action is reasonably certain to cause incidental take (capture) of 669 individual OC coho salmon smolts, up to 34 of which may die.

The distribution and abundance of fish that occur within an action area are affected by habitat quality, competition, predation and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, the distribution and abundance of fish within the action area cannot be attributed entirely to habitat conditions, nor can NMFS precisely predict the number of fish that are reasonably certain to be injured or killed if their habitat is modified or degraded by the proposed action.

Here, the best available indicators for the extent of take is the 1.23 acres of intertidal aquatic habitat that is to be permanently modified by the action, and increased turbidity measured within the 3.8 acres of the cove at 300 feet downstream from the end of the gravel pier and 200 feet outside the last silt screen at the Mangan site. These are the best indicators of the likely take pathways associated with this action, are proportional to the anticipated amount of harm and harassment, and are the most practical and feasible indicators to measure.

In the accompanying Opinion, NMFS determined that this level of incidental take is not likely to jeopardize OC coho salmon. The area of intertidal habitat modified, extent of suspended sediment, and the number of juveniles captured or killed by work area isolation (up to 669 smolts captured or 34 smolts killed) are the thresholds for reinitiating consultation. Exceeding any of these limits will trigger the reinitiation provisions of this Opinion.

### Reasonable and Prudent Measures

The following measures are necessary and appropriate to minimize the impact of incidental take of listed species from the proposed action:

The FAA shall:

1. Minimize incidental take from construction by applying permit conditions to avoid or minimize disturbance to aquatic habitats.

2. Avoid or minimize the likelihood of incidental take caused by work area isolation.

3. Avoid or minimize long-term take from the loss of eel grass by planting eel grass in the mitigation area.

4. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this incidental take statement are effective in minimizing incidental take.

### Terms and Conditions

The measures described below are non-discretionary, and must be undertaken by the FAA or, if an applicant is involved, must become binding conditions of any permit or grant issued to the applicant, for the exemption in section 7(o)(2) to apply. The FAA has a continuing duty to regulate the activity covered by this incidental take statement. If the FAA (1) fails to assume and implement the terms and conditions or (2) fails to require an applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, the FAA or applicant must report the progress of the action and its impact on the species to the NMFS as specified in the incidental take statement.

1. To implement reasonable and prudent measure number 1 (construction), the FAA shall ensure that:

    a. Timing of In-water Work. Work below the oridinary high tide will be completed during the period of July 1 through August 31. All in-water work must be completed within these dates unless otherwise approved in writing by NMFS.
    b. Minimum Area. Construction impacts are confined to the minimum area necessary to complete the project.
    c. Cessation of Work. Project operations will cease under high flow conditions that may inundate the project area, except for efforts to avoid or minimize resource damage.

d. Fish Screens. All water intakes used, including pumps used to isolate any in-water work area, will have a fish screen installed, operated and maintained according to NMFS' fish screen criteria.[2]

e. Pollution and Erosion Control Plan. A pollution and erosion control plan will be prepared and carried out to prevent pollution related to construction operations. The plan must be available for inspection upon request by the FAA or NMFS.

   i. Plan contents. The pollution and erosion control plan must contain the pertinent elements listed below, and meet requirements of all applicable laws and regulations.

      1. Practices to prevent erosion and sedimentation associated with access roads, stream crossings, construction sites, haul roads, equipment and material storage sites, fueling operations and staging areas.
      2. A description of any hazardous products or materials that will be used, including procedures for inventory, storage, handling, and monitoring.
      3. A spill containment and control plan with notification procedures, specific clean up and disposal instructions for different products, quick response containment and clean up measures that will be available on the site, proposed methods for disposal of spilled materials, and provisions for employee training on spill containment.
      4. Practices to prevent construction debris from dropping into any stream or waterbody, and to remove any material that does drop with a minimum disturbance to the streambed and water quality.

   ii. Inspection of erosion controls. During construction, all erosion controls must be inspected daily to ensure they are working adequately.[3] If inspection shows that the erosion controls are ineffective, work crews must be mobilized immediately to make repairs, install replacements, or install additional controls as necessary.

   iii. Sediment must be removed from each erosion control once it has reached 1/3 of the exposed height of the control.

f. Pre-construction Activity. Before significant[4] alteration of the project area, the following actions must be completed:

   i. Marking. Flag the boundaries of clearing limits associated with site access and construction to prevent ground disturbance of riparian vegetation, wetlands, and other sensitive features beyond the flagged boundary.

   ii. Emergency erosion controls. Ensure that the following materials for emergency erosion control are on site:

---

[2] National Marine Fisheries Service, *Juvenile Fish Screen Criteria* (revised February 16, 1995) and *Addendum: Juvenile Fish Screen Criteria for Pump Intakes* (May 9, 1996) (guidelines and criteria for migrant fish passage facilities, and new pump intakes and existing inadequate pump intake screens) *(http://www.nwr.noaa.gov/1hydrop/hydroweb/ferc.htm).*

[3] 'Working adequately' means no turbidity plumes are evident during any part of the year.

[4] 'Significant' means an effect can be meaningfully measured, detected or evaluated.

1. A supply of sediment control materials (*e.g.*, silt fence, straw bales).[5]
2. An oil-absorbing floating boom whenever surface water is present.

g. Heavy Equipment. Use of heavy equipment will be restricted as follows:
   i. Select equipment that will have the least adverse effects on the environment (*e.g.*, minimally-sized, low ground pressure equipment).
   ii. Ensure that only enough supplies and equipment to complete a specific job will be stored on site.
   iii. Complete vehicle cleaning, maintenance, refueling and fuel storage in the vehicle staging area placed 150 feet or more from any stream, waterbody or wetland.
   iv. Inspect all vehicles operated within 150 feet of any stream or wetland daily for fluid leaks before leaving the vehicle staging area. Repair any leaks detected in the vehicle staging area before the vehicle resumes operation. Document inspections in a record that is available for review on request by FAA or NMFS.
   v. Before operations begin, and as often as necessary during operation, steam clean all equipment that will be used below ordinary high water until all visible external oil, grease, mud, and other visible contaminants are removed. Complete all cleaning in the vehicle staging area.

h. Vehicle staging. Vehicle staging, cleaning, maintenance, refueling, and fuel storage must take place in a vehicle staging area placed 150 feet or more from any stream, waterbody or wetland.

i. Stationary power equipment. Stationary power equipment (*e.g.*, generators, cranes) operated within 150 feet of any stream, waterbody or wetland must be diapered to prevent leaks, unless otherwise approved in writing by NMFS.

j. Site Preparation. Native materials will be conserved for site restoration. If possible, native materials must be left where they are found. Materials that are moved, damaged or destroyed must be replaced with a functional equivalent during site restoration.

k. Earthwork. Earthwork (including excavation, filling and compacting) will be completed as quickly as possible.

l. Site Stabilization. Stabilize all disturbed areas, including obliteration of temporary roads, following any break in work unless construction will resume within 4 days.

m. Source of Materials. Boulders, rock, woody materials, and other natural construction materials used must be obtained outside riparian areas.

---

[5] When available, certified weed-free straw or hay bales must be used to prevent introduction of noxious weeds.

2. To implement reasonable and prudent measure number 2 (work area isolation), the FAA shall ensure that:

   a. Fish Salvage. Before, and intermittently during, isolation of in-water work areas, fish trapped in the area must be captured using a hand-net, seine, or other methods as are prudent to minimize risk of injury, then released at a safe release site under the supervision of a qualified fishery biologist.
      i. If an isolated pool is affected by work area isolation the entire pool must be salvaged for fish prior to isolation.
      ii. Handle ESA-listed fish with extreme care, keeping fish in water to the maximum extent possible during seining or hand-netting and transfer procedures to prevent the added stress of out-of-water handling.
      iii. Ensure water quality conditions are adequate in buckets or tanks used to transport fish by providing circulation of clean, cold water, using aerators to provide dissolved oxygen, and minimizing holding times.
      iv. Release fish into a safe release site as quickly as possible, and as near as possible to capture sites.
      v. Do not transfer ESA-listed fish to anyone except NMFS personnel, unless otherwise approved in writing by NMFS.
      vi. Obtain all other Federal, state, and local permits necessary to conduct the capture and release activity.
   b. Salvage Notice. The following notice is included as a permit condition and shall be provided to the applicant and the contractor and posted at the work site:

      NOTICE: If a sick, injured or dead specimen of a threatened or endangered species is found in the project area, the finder must notify NMFS through the contact person identified in the transmittal letter for this Opinion, or through the NMFS Office of Law Enforcement at 1-800-853-1964, and follow any instructions. If the proposed action may worsen the fish's condition before NMFS can be contacted, the finder should attempt to move the fish to a suitable location near the capture site while keeping the fish in the water and reducing its stress as much as possible. Do not disturb the fish after it has been moved. If the fish is dead, or dies while being captured or moved, report the following information: (1) NMFS consultation number; (2) the date, time, and location of discovery; (3) a brief description of circumstances and any information that may show the cause of death; and (4) photographs of the fish and where it was found. The NMFS also suggests that the finder coordinate with local biologists to recover any tags or other relevant research information. If the specimen is not needed by local biologists for tag recovery or by NMFS for analysis, the specimen should be returned to the water in which it was found, or otherwise discarded.

3. To implement reasonable and prudent measure number 3 (eel grass planting), the FAA shall ensure that:

    a. Identify areas within the Mangan mitigation site that are suitable for eel grass production.
    b. Plant eel grass in the identified suitable habitat.

4. To implement reasonable and prudent measure number 4 (monitoring and reporting) the FAA shall:

    a. Turbidity Monitoring. Complete turbidity monitoring as follows.
        i. Equipment. Use an appropriate and regularly calibrated turbidometer to quantify change as nephelometic turbidity units (NTU), or use a visual observation based on any detectable change.
        ii. Interval. A turbidometer reading, or visual observation, must be taken as often as necessary to ensure that each work area is not contributing excessive sediment to the stream.
            1. Whenever in-water work is in progress, or when precipitation has occurred within seven days, a sample must be taken at least twice each day, at approximately 10:00 a.m. and again at 2:00 p.m.
            2. When in-water work is not in progress and no precipitation has occurred within the previous seven days, a sample may be taken once each day, at approximately 2:00 p.m.
            3. Sites. Each sample consists of a turbidometer reading, or a visual observation, made at a baseline site upstream of each work area, and a corresponding reading or observation made within the 3.8 acres of the cove, within 300 feet downstream from the end of the gravel pier and 200 feet outside the last silt screen at the Mangan site.
        iii. Compliance.
            1. Compare results from the baseline and compliance sites for each sample to determine whether turbidity increased below the work area.
            2. If turbidity increased by 5 NTUs, or to any visible extent, take corrective action to reduce turbidity, including any work necessary to repair, replace or reinforce sediment controls, and continue to monitor every 4 hours.
            3. If the turbidity does not return to baseline level within 24 hours, contact NMFS and cease work until turbidity returns to baseline.
        iv. Reporting. Prepare and submit a summary of the turbidity monitoring, including a photograph of the baseline and compliance sites; a copy of turbidity measurements or observations with the date and time that each was taken; other relevant sampling conditions; and description of any sediment control failure, sediment release, and correction efforts.
    b. Implementation Monitoring Report. Complete implementation monitoring and submit a monitoring report to NMFS describing the FAA' progress and success in

meeting the terms and conditions contained in this Opinion by March 1 of the year following construction. The content of the monitoring report will include:

i. Project name
ii. Project location by $6^{th}$ field HUC
iii. FAA contact person(s)
iv. Starting and ending dates for work completed
v. Photos, within construction areas, of the riparian vegetation and the stream channel before, during, and after project completion.
    1. Include general views and close-ups showing details of the project and project area, including pre- and post-construction.
    2. Label each photo with date, time, project name, and a comment about the subject.
vi. Other data as follows:
    1. A summary of pollution and erosion control inspection results, including a description of any erosion control failure, contaminant release, and efforts to correct such incidences.
    2. Dates work ceased due to high flows.
    3. Status of compliance with NMFS' fish screen criteria.
    4. Isolation of in-water work area and fish capture and release.
        a. Supervisory fish biologist – name and contact information.
        b. Methods of work area isolation and take minimization.
        c. Habitat conditions before, during and within 1 week after completion of work area isolation.
        d. Means of fish capture.
        e. Number of OC coho salmon captured.
        f. Location and condition of OC coho salmon released.
        g. Any incidence of observed injury or mortality.

c. Site Restoration.
    i. Post-construction report showing as-built conditions, including photo points, construction and any variation from the approved plan, to be submitted within 60 days of the completion of construction.
    ii. Final area reintroduced to tidal flow at the Mangan mitigation site.
    iii. Final linear distance breached in the dike.
    iv. Planting composition and density.
    v. Copy of the legal agreement conveying mitigation site responsibilities.

d. Extent of Take. At project completion, report the total acres of intertidal habitat filled, the total acres of estuary restored, all turbidity measurements and the results of fish salvage operations.

e. Reporting. On an annual basis for 5 years after completing the proposed action, the FAA shall ensure submittal of a monitoring report to NMFS describing the applicant's success in meeting their habitat restoration goals of intertidal habitat restoration. This report will include the following information:
    i. Project identification.
        (1). Project name.
        (2) Starting and ending dates of work completed for this project.
        (3) The FAA contact person.

ii. <u>Intertidal and freshwater habitat development at the Mangan site</u>. Documentation of the following conditions:

(1) Any changes in survival and coverage of the willow plantings.

(2) A plan to inspect and, if necessary, replace failed plantings.

(3) Intertidal habitat rehabilitation will be documented by mapping habitats established for 5 years.

(4) Monitoring report of survival and spread of Lyngbye's sedge and redtop.

(5) Report the identified potential eel grass habitat in #ii(3) and monitoring survival and spread of eel grass.

(6) Benthic invertebrate monitoring to document colonization of the mitigation area with marine/estuarine species.

(7) Tidal influence area achieved based on the highest measured tide.

iii. A plan to inspect and, if necessary, replace failed plantings to achieve 100% survival at the end of the first year, and 80% survival or 80% coverage after 5 years (including both plantings and natural recruitment) of native species in the salt marsh area; control invasive non-native vegetation; and protect plantings from wildlife damage and other harm.

f. Monitoring reports shall be submitted to:

Oregon State Habitat Office
National Marine Fisheries Service
Attn: 2008/03298
1201 NE Lloyd Blvd., Ste. 1100
Portland, OR 97232-2182

## MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions, or proposed actions that may adversely affect EFH. Adverse effects include the direct or indirect physical, chemical or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that may be taken by the action agency to conserve EFH.

The Pacific Fishery Management Council (PFMC) designated EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon, coho salmon, and Puget Sound pink salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999).

Based on information provided in the BA and the analysis of effects presented in the ESA portion of this document, NMFS concludes that proposed action will have the following adverse effects on EFH designated for groundfish, coastal pelagic species, and Chinook salmon and coho salmon:

1. Water Quality. Suspended sediment levels will be increased over background due to fine sediment mobilized by construction activities. While the impact on habitat is great enough to adversely affect some MSA-managed species, it will not occur on a large enough spatial or temporal scale to significantly disrupt their normal behavioral patterns. The elevated turbidity levels will be short-term, lasting a few hours at a time during the 2 weeks of in-water work. A large fuel spill is unlikely, but would degrade water quality from the spill location up to 300 feet for up to a couple of hours until it is diluted. Directional movement will depend on tidal currents, river flow, and wind/wave direction. Because these impacts are short term and temporary or are unlikely, the water quality of the action area will not be functionally changed.

2. Salinity Conditions. Salinity conditions will be improved within the Haynes Inlet portion of the Coos Bay 5th field due to the Mangan mitigation site development. This area is not accessible to MSA-managed species unless this proposed action occurs. The mitigation site is located in Haynes Inlet where reintroduction of river flows and tidal currents to approximately 10 acres of previously inaccessible intertidal habitat will provide a complex and varying salinity gradient, which is necessary to aid adult and smolt salmon making the transition between the marine and freshwater environments. Other MSA-managed species will have access to this intertidal habitat.

3. Natural Cover. An unknown area of eelgrass beds, which is natural cover for MSA-managed species, will be permanently lost due to the filling of intertidal habitat. This could be up to 1.23 acres of natural cover. An additional area, possibly up to 10 acres, will be developed at the Mangan mitigation site. Although neither maximum is likely, the additional acres of habitat reintroduced to tidal influence is likely a reasonable offset to the acres lost at the airport site.

4. Forage. Food resources will be permanently lost in the 1.23 acres of airport relocation fill site. Additional forage production will be available in the Mangan mitigation site once the area reaches functioning condition, perhaps in 1 to 2 years. While the impact on habitat is great enough to result in some MSA-managed species being adversely affected, it will not disrupt normal behavior patterns. Because the mitigation site will provide additional benthic habitat in the Coos Bay 5th field watershed, the food resources for MSA-managed species will not be functionally changed.

**EFH Conservation Recommendations**

The following two conservation measures are necessary to avoid, mitigate or offset the impact of the proposed action on EFH. These conservation recommendations are a subset of the ESA terms and conditions.

1. Minimize adverse effects from construction by applying permit conditions to avoid or minimize disturbance to aquatic habitats as described in Term and Condition 1 in the accompanying Opinion.
2. Ensure completion of a monitoring and reporting program as described in Term and Condition 3, except for 3.b.vi.4 (isolation of in-water work area and fish capture and release), in the accompanying Opinion to confirm the action is meeting its objective of minimizing habitat modification from permitted activities. Recommended EFH monitoring and reporting components are pollution and erosion control, final area of intertidal habitat filled; area of intertidal habitat reintroduced to tidal influence, success of plant establishment, and species composition and abundance of invertebrates in the intertidal mitigation site.

**Statutory Response Requirement**

Federal agencies are required to provide a detailed written response to NMFS' EFH conservation recommendations within 30 days of receipt of these recommendations [50 CFR 600.920(j) (1)]. The response must include a description of measures proposed to avoid, mitigate or offset the adverse affects of the activity on EFH. If the response is inconsistent with the EFH conservation recommendations, the response must explain the reasons for not following the recommendations. The reasons must include the scientific justification for any disagreements over the anticipated effects of the proposed action and the measures needed to avoid, minimize, mitigate or offset such effects.

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, in your statutory reply to the EFH portion of this consultation, we ask that you clearly identify the number of conservation recommendations accepted.

**Supplemental Consultation**

The FAA must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations [50 CFR 600.920(k)].

## DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity and objectivity. This section of the Opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this EFH consultation has undergone pre-dissemination review.

**Utility:** Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable and beneficial to the intended users.

This consultation concludes that the Coos Bay airport expansion will adversely affect EFH, and includes conservation recommendations to the action agency to avoid, minimize or otherwise offset those adverse modifications. The FAA may authorize and fund this action in accordance with its authority to oversee aviation guidelines. The intended users are the FAA and the Southwest Oregon Regional Airport.

Individual copies were provided to the above-listed entities. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

**Integrity:** This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

**Objectivity:**

***Information Product Category:*** Natural Resource Plan.

***Standards:*** This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq.*, and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

***Best Available Information:*** This consultation and supporting documents use the best available information, as referenced in the Literature Cited section. The analyses in this Opinion/EFH consultation contain more background on information sources and quality.

***Referencing:*** All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

***Review Process:*** This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

## LITERATURE CITED


Adams, P.B., C.B. Grimes, S.T. Lindley, and M.L. Moser. 2002. Status Review for North American Green Sturgeon, *Acipenser medirostris*. National Marine Fisheries Service. Santa Cruz, CA. June 2002.

BRT (Biological Review Team). 2005. Green Sturgeon (*Acipenser medirostris*) Status Review Update. Santa Cruz, CA. December 2004.

Beamis, W.E. and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. *Environmental Biology of Fishes* 48:167-183.

Berg, L. 1983. Effects of short-term exposure to suspended sediments on the behavior of juvenile coho salmon. Master's Thesis. University of British Columbia, Vancouver, B.C. Canada.

Berg, L. and T.G. Northcote. 1985. Changes In Territorial, Gill-Flaring, and Feeding Behavior in Juvenile Coho Salmon (*Oncorhynchus kisutch*) Following Short-Term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Bottom, D.L., C.A. Simenstad, A.M. Baptista, D.A. Jay, J. Burke, K.K. Jones, E. Casillas and M.H. Schiewe. 2001. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. January 2001.

Brown, T.G. 2002. Floodplains, flooding, and salmon rearing habitats in British Columbia: A review. Canadian Science Advisory Secretariat Research Document 2002/007. 155 p.

CDFG (California Department of Fish and Game). 2002. California Department of Fish and Game comments to NMFS regarding green sturgeon listing.

Good, T.P., R.S. Waples and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

Hogarth, W.T. 2005. Memorandum from William T. Hogarth, to Regional Administrators, Office of Protected Resources, NMFS, Regarding Application of the "Destruction or Adverse Modification" Standard Under Section 7(a)(2) of the Endangered Species Act, 3p. November 7.

Israel, J.A. and B. May. 2006. Mixed stock analysis of green sturgeon from Washington State coastal aggregations. Final Report. Genomic Variation Laboratory Department of Animal Science, University of California at Davis.

Lawson, P.W., E. Bjorkstedt, M. Chilcote, C. Huntington, J. Mills, K. Moore, T. Nickelson, G.H. Reeves, H.A. Stout and T.C. Wainwright. 2007. Identification of historical populations of coho salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit. U. S. Department of Commerce, Technical Report of the Oregon Coast Workgroup, Oregon and Northern California Coasts. Technical Recovery Team, NOAA-NMFS-NWFSC.

McElhany, P., M. Ruckleshaus, M.J. Ford, T. Wainwright and E. Bjorkstedt. 2000. Viable Salmon Populations and the Recovery of Evolutionarily Significant Units. U. S. Department of Commerce, National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memorandum NMFS-NWFSC-42. 156 p.

McLain, J. December 18, 2006. Memorandum: The likely distribution of the Southern Distinct Population Segment of North American green sturgeon in SWR waters. National Marine Fisheries Service, Sacramento CA.

Moser, M. and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/sl0641-006-9028-1.

NMFS (National Marine Fisheries Service). 1999. The Habitat Approach. Implementation of Section 7 of the Endangered Species Act for Actions Affecting the Habitat of Pacific Anadromous Salmonids. Northwest Region, Habitat Conservation and Protected Resources Divisions, Portland, Oregon (August 26).

NMFS (National Marine Fisheries Service). 2007. Pacific coastal salmon recovery fund, fiscal year 2000-2006.

NMFS (National Marine Fisheries Service). 2008. Species of Concern - Green Sturgeon (*Acipenser medirostris*) Northern DPS.

Neff, J.M. 1985. Polycyclic aromatic hydrocarbons. *In*: Fundamentals of aquatic toxicology, G.M. Rand and S.R. Petrocelli, p. 416-454. Hemisphere Publishing, Washington, D.C.

PFMC (Pacific Fishery Management Council). 1998. The coastal pelagic species fishery management plan: Amendment 8. Portland, Oregon.

PFMC (Pacific Fishery Management Council). 1999. Amendment 14 to the Pacific Coast Salmon Plan. Appendix A: Description and Identification of Essential Fish Habitat, Adverse Impacts and Recommended Conservation Measures for Salmon. Pacific Fishery Management Council, Portland, Oregon (March).

PFMC (Pacific Fishery Management Council). 2000. 2000 Review of Amendment 13 to the Pacific Coast Salmon Plan. Pacific Fishery Management Council, Portland, Oregon (October).

PFMC (Pacific Fishery Management Council). 2005. Amendment 19 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon (November).

Proctor, C.M., C. Garcia, D.V. Galvin, G.B. Lewis and L.C. Loehr. 1980. An ecological characterization of the Pacific Northwest coastal region. U.S. Fish and Wildlife Service. FWS/OBS-79/15.

Schultz, S.T. 1990. The northwest coast: A natural history. Timber Press, Inc. Portland, Oregon.

Wainwright T.C., M.C. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout and L.A. Weitkamp. 2007. Biological recovery criteria for the Oregon coast coho salmon evolutionarily significant unit, public review draft.

NOAA Technical Memorandum NMFS-NWFSC-105

# Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

March 2010

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service

**NOAA Technical Memorandum NMFS-NWFSC Series**

The Northwest Fisheries Science Center of the National Marine Fisheries Service, NOAA, uses the NOAA Technical Memorandum NMFS-NWFSC series to issue scientific and technical publications. Manuscripts have been peer reviewed and edited. Documents published in this series may be cited in the scientific and technical literature.

The NMFS-NWFSC Technical Memorandum series of the Northwest Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest & Alaska Fisheries Science Center, which has since been split into the Northwest Fisheries Science Center and the Alaska Fisheries Science Center. The NMFS-AFSC Technical Memorandum series is now being used by the Alaska Fisheries Science Center.



**This document should be referenced as follows:**

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 p.

NOAA Technical Memorandum NMFS-NWFSC-105

# Status Review of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California

Richard G. Gustafson, Michael J. Ford,
David Teel*, and Jonathan S. Drake

Northwest Fisheries Science Center
Conservation Biology Division
2725 Montlake Boulevard East
Seattle, Washington 98112

* Northwest Fisheries Science Center
Conservation Biology Division
Manchester Research Station
7305 East Beach Drive
Port Orchard, Washington 98366

March 2010

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service

**Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov)**

Copies are also available from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone orders (1-800-553-6847)
e-mail orders (orders@ntis.fedworld.gov)

# Table of Contents

# List of Figures

# List of Tables

# Executive Summary

On 27 November 2007, the National Marine Fisheries Service (NMFS) received a petition seeking to list southern eulachon (*Thaleichthys pacificus*), as a threatened or endangered species under the Endangered Species Act (ESA) of 1973. NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated an updated status review of eulachon in Washington, Oregon, and California.

The Eulachon Biological Review Team (BRT)—consisting of scientists from the Northwest Fisheries Science Center, Alaska Fisheries Science Center, Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted from state agencies and other interested parties were also considered. The BRT also reviewed additional information submitted to the ESA Administrative Record.

The BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.
2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is: at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or

chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.

5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the species to which it belongs and significant to the species to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

After consideration of the all available scientific data, the eulachon BRT has determined that the petitioned unit of eulachon that spawn in rivers in Washington, Oregon, and California is not a species under the ESA, as it does not meet all the biological criteria to be considered a DPS as defined by the joint USFWS-NMFS 1996 policy on vertebrate populations. However, the BRT has determined that eulachon spawning in Washington, Oregon, and California rivers are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT found it difficult to establish a clear northern terrestrial or river boundary for this DPS in light of the fact that the BRT believes the northern boundary is essentially determined by oceanographic processes. However, it was the majority opinion of the BRT that the northern boundary of the DPS is south of the Nass River on the north coast of British Columbia. The BRT proposes that this DPS be termed the southern DPS of eulachon. The BRT also concluded that the eulachon spawning in the Nass River and further north consist of at least one additional (northern) DPS.

The BRT qualitatively ranked threats to the southern DPS of eulachon subpopulations that spawn in the Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. In each case, the BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon. Climate change impacts on freshwater habitat and eulachon bycatch were scored as moderate to high risk in all subareas of the DPS, and dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers were also ranked within the top four threats in their respective regions.

The BRT was concerned that although eulachon are a relatively poorly monitored species, the weight of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. Considering this large decline, in addition to other risk factors, the BRT determined that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range.

# Acknowledgments

The status review of eulachon (*Thaleichthys pacificus*) was conducted by a team of scientists. NMFS gratefully acknowledges the commitment and efforts of the Eulachon Biological Review Team (BRT) members and thanks them for generously contributing their time and expertise to the development of this status review.

The Eulachon BRT relied on comments and informational reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), California Department of Fish and Game, and Department of Fisheries and Oceans Canada (DFO).

Numerous individual fishery scientists and managers provided information that aided in preparation of this document and deserve special thanks. We particularly thank Dr. Doug Hay, Nearshore Consulting, Nanaimo, British Columbia (Scientist Emeritus, Pacific Biological Station, DFO); Brad James, WDFW; Olaf Langness, WDFW; and Tom Rien, ODFW; for information, data, opinions, and advice.

We also thank Megan Moody, Nuxalk Nation, Bella Coola, British Columbia; Andy Lecuyer, Environmental Advisor, Rio Tinto Alcan Inc., Kemano, British Columbia; Michael R. Gordon, M. R. Gordon & Associates Ltd., North Vancouver, British Columbia; and Irene Martin, Skamokawa, Washington, for providing documents or steering us toward those who could.

We also thank five anonymous scientists whose peer review of an earlier version of this document provided added clarity.

# Introduction: Summary of Information Presented by the Petitioner

In 1999 the National Marine Fisheries Service (NMFS) received a petition (Wright 1999) to list eulachon (*Thaleichthys pacificus*) in the Columbia River and its tributaries as a threatened or endangered species under the U.S. Endangered Species Act (ESA) of 1973. NMFS determined that the 1999 eulachon petition failed to present substantial scientific and commercial information indicating that the petitioned action may be warranted (NMFS 1999).

On 27 November 2007, NMFS received a new petition seeking to list eulachon in Washington, Oregon, and California as a threatened or endangered species under the ESA (Cowlitz Indian Tribe 2007). NMFS evaluated the petition to determine whether the petitioner provided substantial information to list a species as required by the ESA. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the 27 November 2007 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated a status review of eulachon in Washington, Oregon, and California (NMFS 2008).

A Eulachon Biological Review Team (BRT)[1]—consisting of scientists from the Northwest Fisheries Science Center (NWFSC), Alaska Fisheries Science Center (AFSC), Southwest Fisheries Science Center, U.S. Fish and Wildlife Service (USFWS), and U.S. Forest Service—was formed by NMFS, and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. Information presented at a public meeting in June 2008 in Seattle, Washington, and data submitted to the ESA Administrative Record from state agencies and other interested parties were also considered.

The BRT proceeded on the directives included in the Draft BRT Eulachon Instructions Memo that was received from the NMFS Northwest Region on 19 May 2008. In the memo the BRT was charged with consideration of the following questions:

1. Consider, consistent with the criteria defined by the joint USFWS-NMFS DPS policy (61 FR 4722; 7 February 1996), whether eulachon warrant delineation into one or more DPSs.

[1] The Eulachon BRT consisted of: Jonathan Drake, Robert Emmett, Kurt Fresh, Richard Gustafson, Mindy Rowse, and David Teel, NWFSC; Matthew Wilson, AFSC; Peter Adams, SWFSC; Elizabeth A. K. Spangler, USFWS; and Robert Spangler, U. S. Forest Service.

2. Once the DPS structure for eulachon has been delineated, assess the level of extinction risk facing the species (including any DPS in the United States) throughout all of its range.
3. In articulating the assessed level of extinction risk, describe the BRT's confidence that the species or DPS is at high risk of extinction, at moderate risk, or neither.
4. In the BRT's evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document the BRT's consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species.
5. If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range.

The Eulachon BRT submitted a summary status review document (BRT 2008) to the NMFS Northwest Region in December 2008. In April 2009 we asked a number of scientists with expertise in eulachon biology or viability analysis to review that document (BRT 2008). Substantial scientific comments received from five peer reviewers and our responses to these comments can be found in Appendix E. Numerous changes have been incorporated into the present document in response to suggestions made by the peer reviewers.

## The DPS Question: Evidence for Discreteness and Significance

The petitioner noted that early mitochondrial DNA (mtDNA) genetic information (McLean et al. 1999) suggested that eulachon did not exhibit genetic discreteness and gave little support for subdivision of population structure throughout the species' range. However, other biological data including the number of vertebrae, size-at-maturity, fecundity, river-specific spawning times, and population dynamics indicated that there is substantial local stock structure (Hart and McHugh 1944, Hay and McCarter 2000). The petitioner described these latter observations as consistent with the hypothesis that there is local adaptation and genetic differentiation among populations. Recent microsatellite genetic work (Beacham et al. 2005) appears to confirm the existence of significant differentiation among populations. The petitioner summarized these findings as indicating that although the Fraser River, mainstem Columbia River, and Cowlitz River spawning populations are genetically distinct from each other, they are more closely related to one another than either population is to the more northerly British Columbia populations (Beacham et al. 2005). Although the petitioner felt that the available information is inconclusive, the petitioner noted that eulachon may be composed of several DPSs separated by differences in run timing, spawn timing, meristics, and genetic characteristics.

The petitioner concluded that the available genetic, meristic, and life history information is inconclusive regarding the discreteness of eulachon populations. However, the petitioner argued that under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively discrete from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. The petitioner noted that the United States and Canada differ in their regulatory control of commercial, recreational, and tribal or First Nations eulachon harvest, and also differ in their management of eulachon habitat. The petitioner concluded that there is no assurance that the United States and Canada will coordinate management and regulatory efforts sufficiently to conserve eulachon and their habitat, and thus the DPS should be delineated at the border between Washington and British Columbia.

The petitioner argued that the southern eulachon population segment is significant under the DPS policy because the loss of the discrete population segment would cause a significant gap in the taxon's range. The petitioner stated that eulachon have largely disappeared in rivers throughout the southern portion of their range, and that eulachon in the Columbia River probably represent the southernmost extant population for the species. The petitioner argued that the loss of the Columbia River eulachon population and any dependent coastal spawning populations could represent the loss of the species throughout its range in the United States, as well as the loss of a substantial proportion of its historical range.

## Summary of Abundance and Population Trends

The petitioner stated that although eulachon abundance exhibits considerable year-to-year variability, nearly all spawning runs from California to southeastern Alaska have declined in the past 20 years, especially since the mid-1990s (Hay and McCarter 2000). Historically, the Columbia River has exhibited the largest returns of any spawning population throughout the species' range. The petitioner noted that from 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 1.9 million pounds (lb). From 1993 to 2006, the median catch had declined to approximately 43,000 lb, representing a 97.7% reduction in catch from the prior period. Although there was an increasing trend in Columbia River eulachon catch from 2000 to 2003, recent catches have been extremely low. The petitioner also presented catch per unit effort (CPUE) and larval survey data (JCRMS 2006) for the Columbia River and tributaries in Oregon and Washington that similarly reflect the depressed status of Columbia River eulachon during the 1990s, a relative increase during 2001 to 2003, and a decline back to low levels in recent years.

The petitioner also noted that eulachon returns in the Fraser River showed a similar pattern to those in the Columbia River; a rapid decline in the mid-1990s, increased returns during 2001 to 2003, and a recent decline to low levels. The petitioner stated that egg and larval surveys conducted in the Fraser River since 1995 also demonstrate that, despite the implementation of fishing restrictions in British Columbia, the stock has not recovered from its mid-1990s collapse and remains at a precariously low level. An offshore index of Fraser and

Columbia rivers eulachon biomass, calculated from eulachon bycatch in an annual trawl survey of shrimp biomass off the west coast of Vancouver Island, illustrates highly variable biomass over the time series since 1973, but also reflects stock declines in the mid-1990s and in recent years, according to the petitioner. With respect to eulachon populations further south in the species' range, the petitioner noted that populations in the Klamath River, Mad River, Redwood Creek, and Sacramento River are likely extirpated or nearly so.

## Summary of Risk Factors

The petitioner described a number of threats facing eulachon range-wide and facing populations in U.S. rivers in particular. The petitioner expressed concern that habitat loss and degradation threaten eulachon, particularly in the Columbia River basin. The petitioner argued that hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation.

The petitioner expressed strong concern regarding the siltation of spawning substrates in the Cowlitz River due to altered flow management and the accumulation of fine sediments from the Toutle River. The petitioner believes that efforts to retain and stabilize fine sediments generated by the 1980 eruption of Mount St. Helens are inadequate. The petitioner noted that the release of fine sediments from behind a U.S. Army Corps of Engineers (USACE) sediment retention structure (SRS) on the Toutle River has been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later. The petitioner also expressed concern that dredging activities in the Cowlitz and Columbia rivers during the eulachon spawning run may entrain and kill fish, or otherwise result in decreased spawning success.

The petitioner also noted that eulachon have been shown to carry high levels of chemical pollutants (EPA 2002), and although it has not been demonstrated that high contaminant loads in eulachon result in increased mortality or reduced reproductive success, such effects have been shown in other fish species (Kime 1995). The petitioner concluded that no evidence suggests that disease currently poses a threat to eulachon, but noted that information presented in the 1999 petition (Wright 1999) to list eulachon suggested that predation by pinnipeds may be substantial.

The petitioner expressed concern that depressed eulachon populations are particularly susceptible to overharvest in fisheries where they are targeted or taken as bycatch. The petitioner acknowledged that eulachon harvest has been curtailed significantly in response to population declines, and that were it not for continued low levels of harvest, there would be little or no status information available for some populations. However, the petitioner concluded that existing regulatory mechanisms have proven inadequate in recovering eulachon stocks, and that directed harvest and bycatch may be important factors limiting the recovery of impacted stocks. The petitioner emphasized the need for further fishery-independent monitoring and research.

Finally, the petitioner concluded that global climate change is one of the greatest threats facing eulachon, particularly in the southern portion of its range where ocean warming trends may be the most pronounced. The petitioner felt that the risks facing southerly eulachon populations in Washington, Oregon, and California will be exacerbated by such a deterioration of marine conditions. According to the petitioner, these southerly populations, already exhibiting dramatic declines and impacted by other threats (e.g., habitat loss and degradation), might be at risk of extirpation if unfavorable marine conditions predominate in the future.

# The Species Question

As amended in 1978, the ESA allows listing of DPSs of vertebrates as well as named species and subspecies. Guidance on what constitutes a DPS is provided by the joint USFWS-NMFS (1996) policy on vertebrate populations. To be considered distinct, a population, or group of populations, must be discrete from the remainder of the taxon to which it belongs and significant to the taxon to which it belongs as a whole. Discreteness and significance are further defined by the services in the following policy language (USFWS-NMFS 1996, p. 4,725):

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
>
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
> 2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the [Endangered Species] Act.
>
> Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, the services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:
>
> 1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,
> 2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,
> 3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or
> 4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

The interagency policy states that international boundaries within the geographical range of the species may be used to delimit a distinct population segment in the United States. This criterion is applicable if differences in the control of exploitation of the species, the management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment in the United States. However, in past assessments of DPSs of marine fish, NMFS has placed the emphasis on biological information in defining DPSs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological information in identifying whether DPSs of eulachon could be delineated.

# Eulachon Life History and Ecology

## Taxonomy and Species Description

### Scientific Nomenclature

Eulachon are an anadromous smelt in the family Osmeridae and are distinguished from other osmerids by having 4–6 gill rakers on the upper half of the arch (others have 8–14 gill rakers), distinct concentric striae on the operculum and suboperculum (other osmerids lack these concentric striae), and 8–11 pyloric caeca (others have 0–8 pyloric caeca) (McAllister 1963, Hart 1973, Mecklenburg et al. 2002). McAllister (1963) provides a taxonomic synonymy for the species, which was originally described from the Columbia River as *Salmo (Mallotus) pacificus* by Richardson (1836). The genus *Thaleichthys* has only one species and valid subspecies have not been described (McAllister 1963). The binomial species name is derived from Greek roots; *thaleia* meaning rich, *ichthys* meaning fish, and *pacificus* meaning of the Pacific (Hart 1973).

### Common Names

#### Native, Indian, and First Nations languages

The common name officially recognized by the American Fisheries Society (Nelson et al. 2004) for *Thaleichthys pacificus* is eulachon (pronounced you-la-kon in the United States), which is originally derived from the Chinook Indian trade language of the lower Columbia River (Hart and McHugh 1944, Moody 2008). Numerous variations include hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon, oulacon, ulchen, ulichan, uthlecan, yshuh (Hart and McHugh 1944), ooligan, olachen, and olachon (Moody 2008). The Yurok Tribe of the lower Klamath River call eulachon quat-ra (Larson and Belchik 1998) and the Quinault Tribe named the fish páagwáls (Olson 1936). Each First Nations group in British Columbia has a unique name for eulachon (Hay and McCarter 2000, Moody 2008). The First Nations of the lower Fraser River called eulachon swavie or chucka (Hart and McHugh 1944); and the Haisla and Tlingit of Alaska call it juk'wan or za'xwen and ssag or saak, respectively (Krause 1885, Betts 1994, Willson et al. 2006).

#### English

Besides eulachon, *Thaleichthys pacificus* is known by numerous local common English names including candlefish, small fish, savior fish, salvation fish, little fish, fathom fish (because it was sold by the fathom) (Hart and McHugh 1944), and Columbia River smelt.

# Eulachon and Human Cultural History

Eulachon were, and still are, highly important ceremonially, nutritionally, medicinally, and economically to First Nations people in British Columbia and Native American tribes in northern California and the Pacific Northwest. Many ethnographers and historians have stressed the cultural and nutritional importance of eulachon to the Tlingit of Southeast Alaska (Mills 1982, Olson and Hubbard 1984, Krause 1885, Betts 1994), Tsimshians of the north coast of British Columbia (Stewart 1975, Halpin and Seguin 1990, Martindale 2003), Haisla of Douglas Channel and Gardner Canal of British Columbia (Hawthorn et al. 1960, Hamori-Torok 1990), Haihais and Oowekeeno of Rivers Inlet in British Columbia (Hilton 1990), Nuxalk (formerly known as the Bella Coola) of the central coast of British Columbia (Kuhnlein et al. 1982, Kennedy and Bouchard 1990), Kwakwaka'wakw (formerly known as the Kwakiutl) of the north and central coast of British Columbia (Curtis 1915, Rohner 1967, Macnair 1971, Mitchell 1983, Codere 1990), Stó:lō of the Fraser River (Duff 1952), Quinault of the Washington coast (Willoughby 1889, Olson 1936), Chinook and Cowlitz on the lower Columbia River (Boyd and Hajda 1987, Byram and Lewis 2001), and Yurok on the Klamath River (Pilling 1978, Byram and Lewis 2001). In many areas, eulachon returned in the late winter and early spring when other food supplies were scarce and were known, for this reason, as savior or salvation fish (Boyd and Hajda 1987, Byram and Lewis 2001).

Major aboriginal subsistence fisheries for eulachon reportedly occurred on the Stikine, Nass, Skeena, Kitimat, Bella Coola, Kingcome, Klinaklini, Fraser (Macnair 1971, Kuhnlein et al. 1982, Mitchell 1983), and Columbia rivers (Boyd and Hajda 1987). Eulachon were eaten fresh, smoked, dried, and salted, and rendered as oil or grease. Especially to the north of the Fraser River, the fat of the eulachon was rendered into oil, or what is commonly called grease, which is solid at room temperature and was a common traditional year-round condiment with many foods, as well as a medicine for skin rashes and internal ailments among First Nations people on the central and north coasts of British Columbia and in some parts of Alaska (Kuhnlein et al. 1982). Kuhnlein et al. (1982, p. 155) stated that:

> The cultural significance of ooligan grease cannot be underestimated, as it was (and continues to be) a prominent food and gift during feasts and potlatch ceremonies. Early ethnographers among the Nuxalk and Kwakiutl people noted that it was a sign of poverty for a family to be without ooligan grease.

Eulachon grease was widely traded to First Nations such as the Haida and Nootka of Vancouver Island and First Nations in the interior of British Columbia that had no rivers with eulachon runs (Krause 1885, Green 1891, Martindale 2003). Sutherland (2001, p. 8) has stated that "by trading the grease [First Nations people] obtained wealth, prestige, and power." Ancient trade routes up the Nass and Bella Coola river valleys, in particular, and through the mountains, became known as "grease trails" after the traffic in eulachon grease, packed in wooden boxes (Collison 1941, Hart and McHugh 1944, Stewart 1977, Byram and Lewis 2001, Hirch 2003). Numerous sources describe the methods, which varied slightly from area to area, of extracting the oil by boiling the fish bodies (MacFie 1865, Lord 1866, Swan 1881, Krause 1885, Green 1891, Macnair 1971, Stewart 1977).

The largest and most important eulachon fisheries for grease production were on the Nass and Klinaklini rivers of British Columbia (Stacey 1995), although grease was produced by all the First Nations with fishing rights on eulachon rivers north of the Fraser River (Swan 1881, Macnair 1971). As many as 2,000 people annually migrated to the eulachon fishing grounds (Tsawatti) on the Klinaklini River at the head of Knight Inlet (Macnair 1971, Mitchell 1983, Stacey 1995), some traveling from as far as 402 km (250 miles) away by canoe (Codere 1990). The assemblage on the Klinaklini River included nine winter village groups of the Southern Kwakwaka'wakw (formerly known as the Southern Kwakiutl) (Mitchell 1983). A comparable assemblage of five other Southern Kwakwaka'wakw winter village groups and the bulk of the Nimpkish First Nation people from Vancouver Island congregated at Quaee at the head of Kingcome Inlet on the Kingcome River to harvest the spring run of eulachon (Mitchell 1983). Kennedy and Bouchard (1990, p. 325) in an ethnographic summary of the Bella Coola First Nation noted that "Because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola."

# Historical and Current Distribution

### Freshwater Spawning Distribution

Eulachon spawn in the lower portions of certain rivers draining into the northeastern Pacific Ocean ranging from northern California to the southeastern Bering Sea in Bristol Bay, Alaska (Hubbs 1925, Schultz and DeLacy 1935, McAllister 1963, Scott and Crossman 1973, Willson et al. 2006) (Table A-1 in Appendix A, Figures 1 through 3). This distribution coincides closely with the distribution of the coastal temperate rain forest ecosystem on the west coast of North America (Figure 1). Both Willson et al. (2006) and Moody (2008) have recently reviewed the coast-wide spawning distribution of eulachon in North America.

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of fishes in U.S. West Coast estuaries (see Table A-2) and based on the references cited therein described adult eulachon as common in Grays Harbor and Willapa Bay on the Washington coast, abundant in the Columbia River, common in Oregon's Umpqua River, and abundant in the Klamath River in northern California. In addition, a number of estuaries where eulachon were thought to occur in rare relative abundance included Puget Sound and Skagit Bay in Washington; Siuslaw River, Coos Bay, and Rogue River in Oregon; and Humboldt Bay in California (Monaco et al. 1990, Emmett et al. 1991). Hay and McCarter (2000) and Hay (2002) identified 33 eulachon spawning rivers in British Columbia and 14 of these were classified as supporting regular yearly spawning runs. Willson et al. (2006) and Moody (2008) list numerous rivers that support eulachon runs in Southeast and Southcentral Alaska and on the coastline of Alaska in the southeastern Bering Sea (Table A-1). McPhail and Lindsey (1970, p. 198) suggested that eulachon "apparently survived glaciation south of the ice sheet along the Pacific coast of North America" and likely "entered the Bering Sea from the south" following the Wisconsian glaciation.

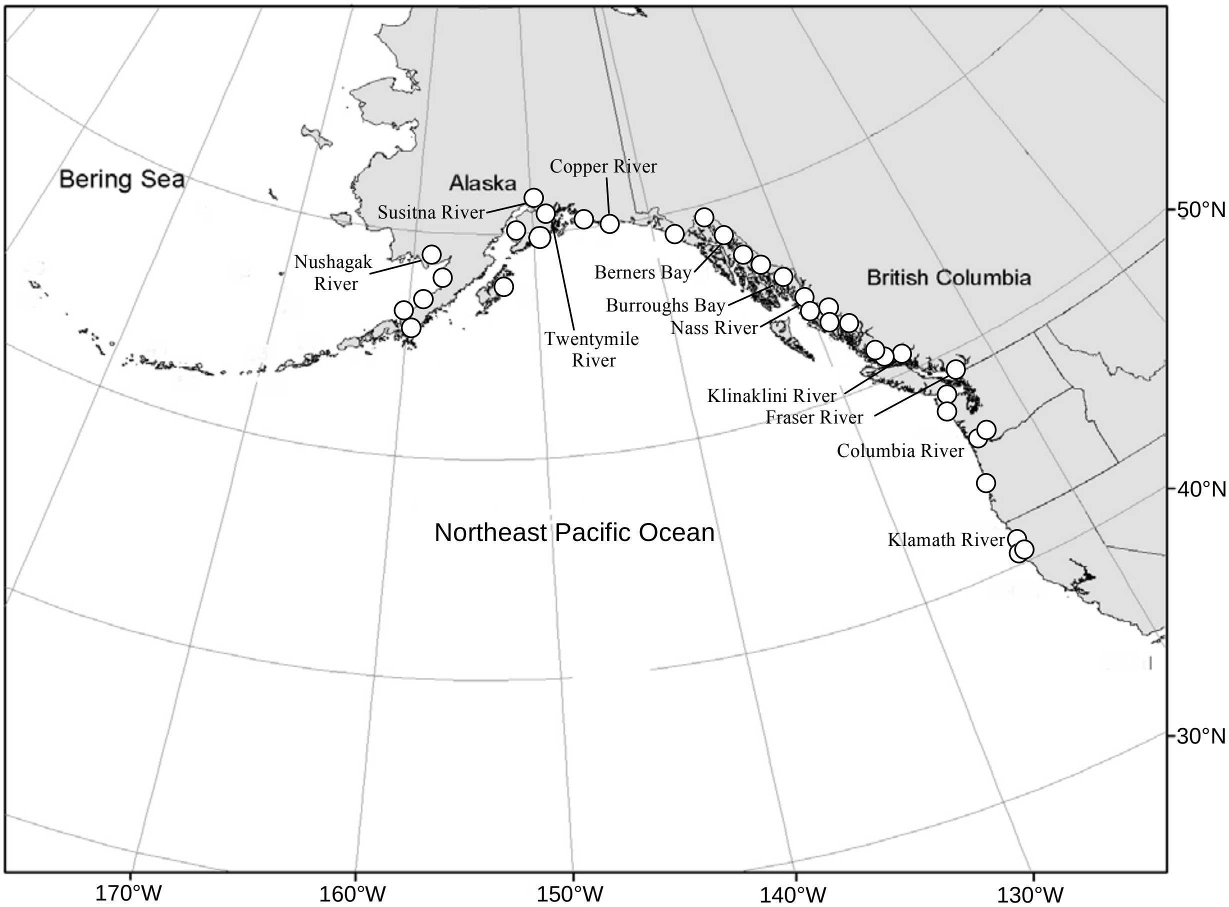



Figure 1. Distribution of eulachon spawning rivers (open circles) in the Northeast Pacific Ocean.

## California

Hubbs (1925) and Schultz and DeLacy (1935), leading ichthyologists of their day, described the Klamath River in northern California as the southern limit of the range of eulachon. Miller and Lea (1972, p. 62) in the California Department of Fish and Game's (CDFG) Guide to the Coastal Marine Fishes of California reported that the eulachon "spawns in rivers from Mad River north." More recent compilations state that large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Ridenhour and Hofstra 1994, Moyle et al. 1995) (Table A-1, Figure 2).

In addition, Moyle et al. (1995) and Moyle (2002) state that small numbers of eulachon have been reported from the Smith River (Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) states that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries. The California

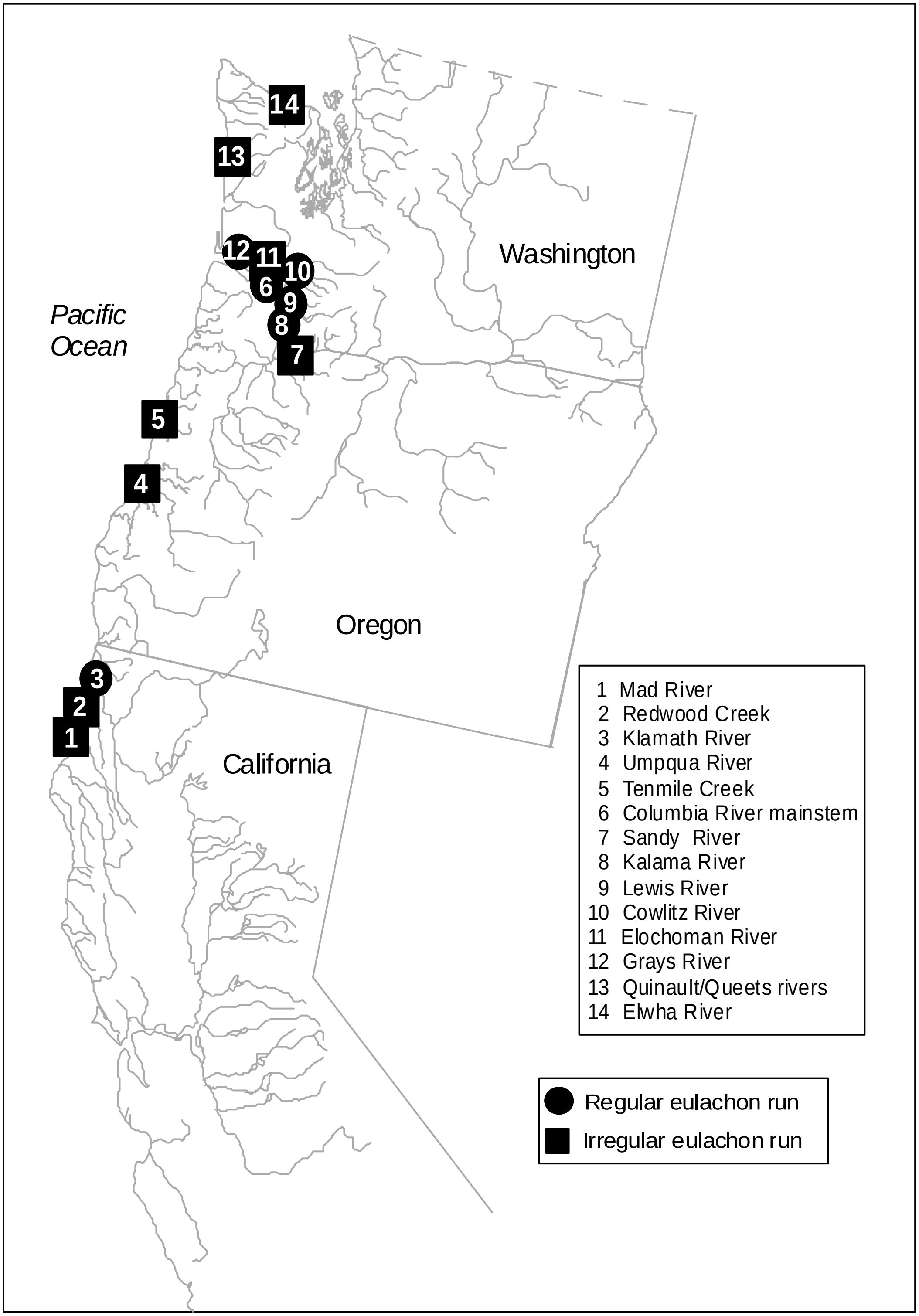



Figure 2. Eulachon spawning areas mentioned in the text in the conterminous United States.

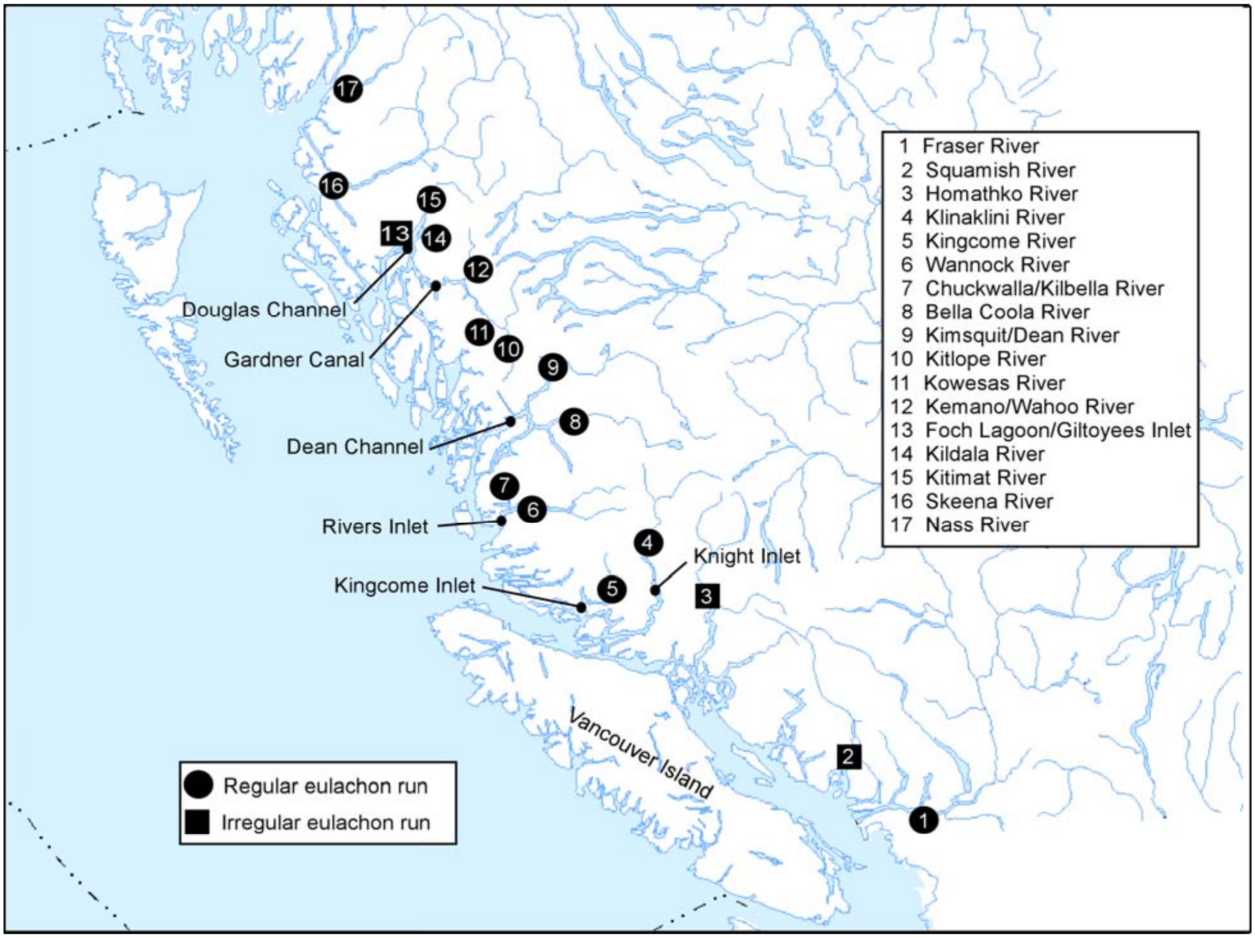



Figure 3. Major known eulachon spawning rivers in British Columbia (based on Hay and McCarter 2000 and Hay 2002).

Academy of Sciences (CAS) ichthyology collection database (online at http://research .calacademy.org/research/Ichthyology/collection/index.asp) lists eulachon specimens collected from the Klamath River in February 1916, March 1947, and March 1963, and in Redwood Creek in February 1955.

A search of available online digital newspaper resources (listed in Table B-1) revealed an early account of eulachon (aka candlefish in northern California) in the Klamath River in a newspaper article in 1879 (Appendix B). Runs large enough to be noted in available local newspaper articles occurred in the Klamath River in February 1919, March 1968, April 1963, and April 1969, in Redwood Creek in April 1963 and April 1967, and in the Mad River in April 1963 (Table A-3 and Appendix B). An early memoir by a traveler surveying timber resources on the Klamath River reported eulachon being harvested (15–20 lb in a single dip net haul) by Yurok tribal members in the early 1890s (Pearsall 1928) (Appendix C). Petersen (2006) reported on interviews with Yurok and Karuk tribal fishers on the lower Klamath River that indicated eulachon were abundant in the river in the 1960s. Petersen (2006, p. 88) stated that "one fisher remembered picking up 75 pounds of fish in one dip" and that another remembered "filling the back of a pickup truck in one hour" with eulachon in 1966.

Young (1984) collected eulachon in Redwood Creek in April 1978 and in the Klamath River in April 1978, March and April of 1979, and 1980. Bowlby (1981) documented eulachon in the diet of California sea lions (*Zalophus californianus*) through gastrointestinal content analysis and in harbor seals (*Phoca vitulina*) through scat analysis and gastrointestinal content analysis in the Klamath River during spring 1978 and 1979. One California sea lion contained 186 eulachon in its gut on 10 April 1978 when the carcass was recovered 1 km upriver from the river mouth, and sea lions "were observed at Klamath Glenn, 9.6 km upriver, while fishermen dipnetted these congregating fish from shore" (Bowlby 1981, p. 59). Eulachon have been reported to spawn at least as far as 40 km upstream on the Klamath River (Fry 1979, Hamilton et al. 2005). Larson and Belchik (1998, p. 5) noted that "In the Klamath, adults generally migrate as high as Pecwan Creek …, have been witnessed as high as Weitchpec …, but specific spawning areas are unknown."

Eulachon have been occasionally reported from other freshwater streams of California. Fry (1979, p. 90) reported that the largest eulachon run in California occurred in the Klamath River, and that eulachon occurred in "fresh water from the Gualala River, California, northward." Although Odemar (1964) has been cited as evidence that eulachon occurred in the Russian River, Odemar (1964) actually stated that "No runs of *T. pacificus* have been reported in the Russian River, or in any river south of the Mad River, and it does not appear that the fish examined off the Russian River in May 1963 were destined to spawn there."

Eulachon were not observed by Eldridge and Bryan (1972) in a larval fish survey of Humboldt Bay, California, and Barnhart et al. (1992, p. 101) stated that eulachon are "not reported in Humboldt Bay tributaries," although they are occasionally recorded in Humboldt Bay itself. Monaco et al. (1990) described eulachon as rare in Humboldt Bay and, in addition to several personal communications, cited Gotshall et al. (1980) and Young (1984) as supporting references (Table A-2). Gotshall et al. (1980, p. 229) recorded eulachon as an "occasional visitor" in winter to Humboldt Bay, California. Young (1984) stated that:

> Specimens [of eulachon] have occasionally been taken, during the spawning season, in Jolly Giant and Jacoby creeks (George Allen, pers. comm., 1980). Both of these streams empty into Humboldt Bay.

Jennings (1996) reported on observations of adult eulachon in creeks tributary to Humboldt Bay, California, in May 1977. A single spawned-out adult male eulachon was collected in a downstream migrant trap on Jolly Giant Creek, approximately 7 km south of Mad River, and a total of seven adult eulachon were observed in another downstream migrant trap in Jacoby Creek, located 8.5 km south of Mad River (Jennings 1996).

Although Minckley et al. (1986, their Table 15.1, p. 541) indicate that eulachon were native to the Sacramento River and drainages within the south California Coastal to Baja California region, no verifying references for these assertions were given. Recently, Vincik and Titus (2007) reported on the capture of a single mature male eulachon in a screw trap at RKM 228 (RM 142) on the Sacramento River.

## Coastal Oregon

Monaco et al. (1990) and Emmett et al. (1991) summarized distribution and abundance of eulachon in major Oregon estuaries and listed the Rogue River, Coos Bay, Siuslaw River, and Umpqua River as possessing records of eulachon presence. More recently, Willson et al. (2006, p. 36–37) listed the following drainages on the coast of Oregon as supporting eulachon spawning runs (based on Emmett et al. [1991] and personal communications with fish biologists of ODFW): Winchuck, Chetco, Pistol, Rogue, Elk, Sixes, Coquille, Coos, Siuslaw, Umpqua, and Yaquina rivers; and Hunter, Euchre, Tenmile (draining Tenmile Lake), and Tenmile (near Yachats, Oregon) creeks (Table A-1).

Monaco et al. (1990) described eulachon as rare in the Rogue River and, in addition to a personal communication, cited Ratti (1979b) as a supporting reference (Table A-2). Although smelt and surf smelt (*Hypomesus pretiosus*) were reported from the Rogue River estuary by Ratti (1979b), no specific mention of eulachon occurs in this report. Roffe and Mate (1984) reported the presence of otoliths representing at least 120 eulachon from harbor seal scat collected in April 1978 on the Rogue River, which represented 16.7% of the identified harbor seal prey.

Reimers and Baxter (1976) reported that adult eulachon were caught in a downstream migrant trap in the lower portion of the Sixes River in Oregon between 1964 and 1972, although dates of occurrence or numbers caught were not provided. Reimers and Baxter (1976) suggested that these adults had possibly been spawning and were headed downstream at the time of capture.

Gaumer et al. (1973) recorded the taking of 28 eulachon in June 1971 by recreational fishers at the city docks of Bandon, Oregon, in the Coquille River estuary. Kreag (1979) also lists eulachon as occurring in the marine portion of the Coquille River estuary.

Monaco et al. (1990) described eulachon as rare in Coos Bay, Oregon, and, in addition to a personal communication, cited Cummings and Schwartz (1971), Hostick (1975), Roye (1979), and Wagoner et al. (1988) as supporting references (Table A-2). Cummings and Schwartz (1971) included eulachon in their list of fishes occurring in Coos Bay and indicated that eulachon were found up to 11 km (6.8 miles) upstream of the mouth of the bay. Although whitebait smelt (*Allosmerus elongatus)* and surf smelt were reported from Coos Bay by Hostick (1975), no specific mention of eulachon occurs in this report. Roye (1979, p. 36) referenced Cummings and Schwartz (1971) in describing eulachon as occurring in the lower 14.5 km (9 miles) of the Coos Bay estuary. The final version of the draft report, cited by Monaco et al. (1990) as Wagoner et al. (1988), stated that "eulachon may have occurred in large numbers in past years [in the Coos Bay estuary], but they have apparently not been abundant enough in recent years to attract an active dipnet fishery" (Wagoner et al. 1990, p. 100). More recently, Miller and Shanks (2005) surveyed the distribution of 28 identified larval and juvenile fish species in Coos Bay for more than three years between 1998 and 2001, but did not encounter eulachon.

Two reports (Gestring 1991, ODFW 1991) were found that list eulachon as a native fish species occurring in Tenmile and North Tenmile lakes, although no further information on frequency of occurrence or abundance were provided in these reports.

OFC (1970) reported that from 4,000 to 5,000 lb of eulachon were landed by two commercial fishermen in the Umpqua River during 31 days of drift gill net fishing from late December 1966 to mid-March 1967. OFC (1970, p. 34) stated that "The fishing area extended from the Highway 101 bridge at Reedsport upstream about 4 miles." A sport fishery for eulachon also operated over this period in the Umpqua River (OFC 1970). Monaco et al. (1990) described eulachon as common in the Umpqua River estuary and, in addition to a personal communication, cited Mullen (1977), Ratti (1979a), and Johnson et al. (1986) as supporting references (Table A-2). Neither Mullen (1977) nor Ratti (1979a) mention eulachon and Johnson et al. (1986, their Table 1) list eulachon as occurring in trace amounts in their trawl and beach-seine samples from April 1977 to January 1986.

Williams (2009, p. 2) reported that the Oregon Department of Fish and Wildlife (ODFW) has "no direct observations of eulachon spawning in the Umpqua" River, but provided additional information "on eulachon observations and captures during inventories." Williams (2009, p. 2) noted that:

> two random observations of eulachon [were reported] from Little Mill Creek [a tributary of the lower Umpqua River] on December 8, 1954 and January 26, 1955. The fish found in 1954 measured 6 inches in total length.

Williams (2009, p. 3) also reported on the results of seine collections conducted during March to November from 1995 to 2003 in Winchester Bay estuary on the Lower Umpqua River, which documented the

> presence … [of eulachon] in 4 of the last 14 years. Forty-four fish were found in May 1995, 80 fish during April and July 1998, 54 fish during March and May 1999, and 2 fish during June 2003. Seining was also conducted in the lower Smith River estuary [a tributary of the Lower Umpqua] at three sites during 1999 during February and March, but no eulachon were captured.

A search of available online digital newspaper resources (listed in Appendix B) revealed anecdotal evidence that an extensive recreational fishery for eulachon occurred in the lower Umpqua River at least from 1969 to 1982 during January to April. The last reference to eulachon in the Umpqua River in these digital newspaper resources occurred in 1989 (Appendix B).

Monaco et al. (1990) described eulachon as rare in the Siuslaw River estuary and, in addition to a personal communication, cited Hutchinson (1979) as a supporting reference (Table A-2); however, we have been unable to locate a copy of this document.

WDFW and ODFW (2008) describe the occasional occurrence of small numbers of eulachon in Tenmile Creek (not be confused with the Tenmile Lakes Basin), just south of Yachats, Oregon. Between 1992 and 2008, a total of 75 eulachon were caught in traps designed to catch outmigrating salmonid smolts located 0.8 km upstream from the ocean. Eulachon were caught in 1992 (24), 1993 (6), 1994 (1), 1995 (1), 1996 (1), 2001 (26), 2003 (3), 2005 (10), 2007 (1), and 2008 (2). As reported in WDFW and ODFW (2008):

> Eulachon were seen in February (3 years), March (6 years), April (7 years) and May (1 year). The earliest observed arrival was the week of February 3 in 1992.

> The latest observed presence was the week of May 21 in 2001. Fish lengths (annual averages) ranged from 155 to 208 mm FL. Local biologists suspect the eulachon spawn in the creek based on the trapping location, fish size, and that some fish appear to be spawned out.

Although Monaco et al. (1990) describe eulachon as not found in the Yaquina River (based on several personal communications) (Table A-2), Borgerson et al. (1991) list eulachon as occurring in the Yaquina River basin, but do not elaborate further on the evidence for this opinion.

**Columbia River**

Large spawning runs of eulachon occur in the mainstem lower Columbia River and the tributary Cowlitz, Lewis, Sandy (Craig and Hacker 1940), Grays (Smith and Saalfeld 1955), Kalama, and Elochoman (DeLacy and Batts 1963) rivers and Skamokawa Creek (WDFW and ODFW 2001, 2008). Smith and Saalfeld (1955) stated that eulachon were occasionally reported to spawn up to the Hood River on the Oregon side of the Columbia River prior to the construction of Bonneville Dam in the 1930s. In times of great abundance (e.g., 1945, 1953), eulachon have been known to migrate as far upstream as Bonneville Dam (Smith and Saalfeld 1955, WDFW and ODFW 2008) and may extend above Bonneville Dam by passing through the ship locks (Smith and Saalfeld 1955). Eulachon likely reached the Klickitat River on the Washington side of the Columbia River in 1945 via this route (Smith and Saalfeld 1955).

On average, the highest incidence of spawning occurs in the Cowlitz River (Smith and Saalfeld 1955, Wydoski and Whitney 2003), although on occasion eulachon may avoid the Cowlitz entirely, due to unfavorable environmental conditions (Wydoski and Whitney 2003). Sporadic spawning runs occur in the Grays, Elochoman, Kalama, Lewis, and Sandy rivers (JCRMS 2007, 2008, 2009). Stockley (1981, p. 1) stated that "occasionally, with very large runs, smelt ascend and enter the Washougal" River on the Washington side of the Columbia River at RKM 195. Stockley and Ellis (1970) suggested that in years of low abundance eulachon may not enter the Columbia River tributaries but remain within the mainstem Columbia River. In 2001 eulachon migrated upstream to Bonneville Dam at RKM 234 and spawned in all the major tributaries of the lower Columbia River, including the Sandy River (Howell et al. 2001). In 1953 eulachon were observed spawning in Tanner Creek on the Oregon side of the Columbia River near the base of Bonneville Dam (OFC 1953, WDFW and ODFW 2008).

Craig and Suomela (1940, p. 11) stated that "smelt are reported to confine their spawning activities to the lower 5 miles of the [Sandy] river" and that "this section is characterized, especially near the mouth, by moderate riffles and an abundance of glacial silt and sand." Anderson (2009) noted that eulachon have been observed on the Sandy River, Oregon, as far upstream as Gordon Creek at RKM 20.9 (RM 13). In addition, ODFW (Williams 2009, p. 1) stated that:

> The Sandy River in Oregon is the only Oregon tributary known to support a run of eulachon. However, it is sporadic and none have been seen in the last 6 to 8 years. … Based on observed sport fishing activity in the Sandy, we believe that spawning took place from the mouth up to RM 2.5.

Williams (2009) also reported on the onetime observation by an ODFW stream surveyor in February 1991 of eulachon in Conyers Creek, a tributary of the Clatskanie River, which is in turn a tributary of the lower Columbia River on the Oregon side of the river. The stream surveyor reported that eulachon were seen holding in pools within the lower 0.8 km (0.5 mile) of Conyers Creek during a daytime flood tide, but none were observed in the main stem of the Clatskanie River.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [Grays River] more frequently than commercial landings would suggest." Furthermore, Anderson (2009, his Table 1, p. 2) stated that the normal extent of eulachon spawning on the Grays River extended to the "covered bridge (RKM 17.4)."

Smith and Saalfeld (1955, p. 22) reported that:

> The lowest suitable spawning ground on the Cowlitz is located just below Kelso and the upper limit of spawning was noted in 1946, when smelt eggs were found in river bottom samples taken upstream almost to the mouth of the Toutle River, 20 river miles [32.2 km] from the Columbia.

In describing the principle spawning reaches of eulachon in the Cowlitz River, WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 16 miles [25.7 km] (Castle Rock/Toutle River mouth area), often up to 34 miles [54.7 km] (Toledo area), and on occasion up to 50 miles [80.5 km] upstream (Cowlitz Salmon Hatchery barrier dam). … Upstream movement during the past 15 years or so has apparently been limited to the Castle Rock/Toutle River mouth area.

Stockley (1981, p. 1) indicated that eulachon "have been known to ascend the Toutle River [tributary of the Cowlitz River] occasionally," particularly before the 1980 eruption of Mount St. Helens (WDFW and ODFW 2008). Anderson (2009, p. 3) stated that:

> Adult eulachon were observed to enter the Toutle River prior to the eruption of Mount St. Helens. … Though the Washington Department of Fish and Wildlife (WDFW) has no reports of eulachon using the Toutle River since the eruption … WDFW considers the Toutle River as potential primary habitat due to its past use and vicinity to primary Cowlitz River spawning grounds.

WDFW and ODFW (2008, p. 4) indicated that eulachon "used [the Kalama River] more frequently than commercial landings would suggest." In addition, Anderson (2009, his Table 1, p. 2) said that the normal extent of eulachon spawning on the Kalama River extended "downstream of Modrow Bridge (RKM 4.5)."

Anderson (2009, his Table 1, p. 2) indicated that the normal extent of eulachon spawning on the Lewis River extended to the "upper end of Eagle Island (RKM 18.8)." WDFW and ODFW (2008, p. 4) stated that eulachon:

> typically move upstream about 10 miles [on the Lewis River] but on occasion upstream 19.5 miles [31.4 km] to Ariel [aka Merwin] Dam. … Biologists believed that a natural sediment blockage prevented upstream movement past river mile 7

> [11.3 km] for a number of years, from 1977 until the mid-1980s. Spawning eulachon have since been observed upstream of river mile 7 [11.3 km].

Anderson (2009, p. 2) noted that “eulachon spawn within the main stem of the Columbia River, but spawning ground locations are not well known.” Smith and Saalfeld (1955) reported that spawned out and partially spawned out eulachon captured near Eagle Cliff on the main stem of the Columbia River identified this area as a eulachon spawning ground. Howell et al. (2001, p. 12) also noted that Eagle Cliff at RKM 82 “on the Washington shore [is] historically recognized as a major mainstem eulachon spawning area” and that “spawning in the main stem of the Columbia River has never been recorded upstream of Martin’s Bluff” at RKM 117. Romano et el. (2002) collected eulachon eggs between RKM 56 and RKM 118 on the Washington side of the main stem of the Columbia River; however, mapping the extent of spawning on the main stem will require much additional sampling (Anderson 2009). Anderson (2009, p. 3) noted that:

> In years of very high eulachon abundance, spawning has been observed in the main stem of the Columbia River upstream of RKM 137 as eulachon travel to the Lewis and Sandy rivers and as far as Bonneville Dam on rare occasion. Primary spawning habitat could, therefore, extend from the estuary upstream to at least as far as the Sandy River (RKM 193).

The earliest mention of eulachon in the Columbia River occurs in the journals of members of the Lewis and Clark Expedition during February and March 1806 (Gass 1807, Moulton 1990, Moring 1996) (Appendix C). Throughout the 1810s–1820s, the journals of several fur trappers and explorers (e.g., Gabriel Franchère [Franchère 1967, 1968, 1969], Robert Stuart [Rollins (ed.) 1995], Wilson Price Hunt [Rollins (ed.) 1995], Alexander Henry [Gough (ed.) 1992], and Alexander Ross [Ross 1849]) describe the appearance of large eulachon runs in the lower Columbia River and their importance to the local Native American tribes (Appendix C).

Subsequently, several contemporary references (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963) (Appendix C) indicate a major decline in Columbia River eulachon abundance occurred between the mid to late 1830s and mid to late 1860s. Similarly, several secondary references (Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008, 2009) cite additional sources that indicate eulachon were at low levels of abundance prior to about 1867, when eulachon were once again seen in large numbers. Anderson (1872, footnote on p. 30–31) (Appendix C) stated that eulachon:

> were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence-forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

Subsequently, Anderson (1877, p. 345) (Appendix C) said:

> Formerly resorting in enormous shoals to the estuary of the Columbia River, [eulachon] disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore.

Similarly, Lord (1866, p. 96) (see Appendix C) observed that:

> Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together.

An early settler on the Cowlitz River, Edwin Huntington (Huntington 1963, p. 5) (Appendix C), recalled that:

> Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. … After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife) having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

Summers (1982, p. 31) in a local history of the town of Kelso, Washington, at the confluence of the Cowlitz and Columbia rivers, related that:

> The earliest record of a smelt run was found in a 1867 diary written by W. A. L. McCorkle, a settler at Lexington. He tells of small silvery fish coming into the Cowlitz during that year and that no smelt had been observed by Americans earlier than that. Settlers came beginning 1850. Of course, the Cowlitz Indians and other tribes had caught smelt in the Cowlitz many years before the Americans came.

However, a memoir written by Peter W. Crawford (Crawford 1878, p. 369) indicates that early settlers were aware of “small numbers” of eulachon on the Cowlitz River, and that large runs were noted, after an absence of 17 years, in the spring of 1865. Crawford (1878, p. 369) (Appendix C) stated that:

> In Feby and March 1865 there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. … The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

Hinrichsen (1998, p. 16) reported that “According to historian Duncan Stacey, Hudson’s Bay Company documents describe very low returns in the Columbia River from about 1835 to 1865.” However, examination of microfilmed records from the Hudson’s Bay Company Archives (Fort Vancouver Report 1826–1845 [reel #1M783] and Fort Vancouver Post Journal

1825–1836 [reel # 1M148]) did not reveal any reference to eulachon or smelt in these records. Fort Vancouver was a Hudson's Bay Company post from 1825 to 1860 near the present location of Vancouver, Washington, on the lower Columbia River. Another early reference (Swan 1881, p. 258) mentions that "eulachon are found in limited numbers at certain seasons in the Columbia River."

A search of available online digital newspaper resources (listed in Appendix B) revealed mention of eulachon in the Columbia River or "smelt" as items for sale in local fish markets in the spring of 1867. A two sentence article in the Vancouver Register (Vancouver, Washington Territory) for 6 April 1867 (Appendix B) indicates that large numbers of "smelt" were present in the Columbia River off the city of Vancouver (at about RKM 170) at that time. This newspaper article said that previously "this … fish ... [had] never before been known to come up higher than Lewis River," which indicates that eulachon were known to occur in some numbers prior to 1867 in the Lewis River or in the Columbia River, downstream of the Lewis River.

Two advertisements of "smelt" for sale in Portland, Oregon, fish markets appeared in early newspapers, one in April 1867 and another in April 1868. Since April is near the tail end of the traditional period for eulachon run timing in the Columbia River, and other species of smelt are available at that time, it is uncertain whether these advertisements (Appendix B) refer to eulachon or some other species of smelt. An advertisement of eulachon for sale (referred to as Oak Point smelt) in a local fish market appeared on 15 January 1869 in the Daily Oregonian (Portland) (Appendix B). In later years the eulachon commercial fishery commonly operated in the vicinity of Oak Point on the Lower Columbia River indicating that this advertisement of "Oak Point smelt" likely refers to eulachon and not some other smelt species.

A newspaper article published in the Daily Oregonian on 13 March 1885 (Appendix B) reported that:

> a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years.

## Coastal Washington

Outside of the Columbia River Basin, eulachon have been occasionally reported from other coastal Washington rivers. Swan (1881, p. 258) noted that "eulachon are found in limited numbers at certain seasons in … Shoalwater bay [Willapa Bay], Gray's Harbor, and at the mouth of various small streams of the coast." WDFW and ODFW (2001) stated that "Washington rivers outside the Columbia Basin where eulachon have been known to spawn include the Bear, Naselle, Nemah, Wynoochee, Quinault, [and] Queets … rivers." Willson et al. (2006) listed Willapa Bay (North, Naselle, Nemah, Bear, and Willapa rivers), Grays Harbor (Humptulips, Chehalis, Aberdeen, and Wynoochee rivers), and the Copalis, Moclips, Quinault, Queets, and Bogachiel rivers as supporting eulachon spawning runs.

Monaco et al. (1990) described eulachon as common in Willapa Bay based on a personal communication (Table A-2). Smith (1941) noted that:

> A small smelt run was noted in the north fork of the Nemah River on 7 February 1941. The fish ascended the Nemah River as far as the mouth of Williams Creek, which stream they entered for a distance of about 100 yards. … An old resident of the community reported that this was the first smelt run that had occurred during his 48 years in the section.

According to WDFHMD (1992), adult eulachon "were found in the Naselle and Bear rivers, tributaries of Willapa Bay (B. Dumbauld, WDF, pers. comm.)" in 1992. WDFW and ODFW (2001, p. 12) reported "that in 1993, when the eulachon run into the Columbia River was delayed (presumably due to cold water conditions), they were noted in large abundance in the Quinault and Wynoochee rivers, outside the Columbia Basin."

Monaco et al. (1990) described eulachon as "common" in Grays Harbor and, in addition to a personal communication, cited Deschamps et al. (1970) as a supporting reference (Table A-2). Deschamps et al. (1970, p. 16) reported the capture of a single adult eulachon in a seine catch in March 1966 and stated that "It is unlikely that the Chehalis system [which drains into Grays Harbor] has a run of any consequence, although strays or feeding fish from other areas probably visit the upper harbor at times." WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the … Wynoochee" River, a tributary of the Chehalis River, in 1993. Simenstad et al. (2001) recorded eulachon as of "rare" occurrence in sloughs of the Chehalis River estuary in 1990 and 1995.

Willoughby (1889) and Olson (1936) record the Quinault Indian Tribe as taking eulachon in the lower Quinault River with dip nets. Olson (1936, p. 36) stated that:

> The people of the lower villages often came down to the river mouth to catch smelt (komólnil) and candlefish (páagwáls). Both were taken in the surf of the beach, though the candlefish often ascend the river for several miles. There was usually a big run every three or four years, when the water was literally filled with fish. The time of the run varied, usually occurring between January and April.

The Washington Department of Fisheries annual report for 1960 (Starlund 1960) and statistical report for 1970 (Ward et al. 1971) listed commercial eulachon landings in the Quinault River in 1936 (36,315 lb [16,507 kg]), 1940 (6,917 lb [3,144 kg]), 1953 (93,387 lb [42,449 kg]), 1958 (34,387 lb [15,630 kg]), 1960 (135 lb [61 kg]), and 1961 (1,051 lb [ 477 kg]). Fiedler (1939, p. 213) also records 36,300 lb (16,500 kg) of eulachon taken by dip net in the coastal district of Washington State in 1936. WDFW and ODFW (2001, p. 12) reported that eulachon "were noted in large abundance in the Quinault" River in 1993. Quotations from unattributed sources were presented in Workman (1997) that described eulachon occurring in and about the Quinault River in January 1936 and February 1993. NWIFC (1998, p. 11) reported that "candlefish, or Columbia River smelt, were caught in significant numbers at the mouth of the Queets River for the second time in 5 years in late January [1998]." A noticeable number of eulachon make an appearance in the Queets, Quinault, and occasionally, the Moclips rivers at 5–6 year intervals and were last observed in the Quinault River in the winter of 2004–2005.[2]

Shaffer et al. (2007) reported on the capture of 58 adult eulachon in the Elwha River on Washington's Olympic Peninsula (Figure 2) between March 18 and June 28, 2005. This was the first formal documentation of eulachon in the Elwha River, although anecdotal observations suggest that eulachon "were a regular, predictable feature in the Elwha until the mid 1970s" (Shaffer et al. 2007, p. 80). Other Olympic Peninsula rivers draining into the Strait of Juan de Fuca have been extensively surveyed over many years for salmonid migrations; however, eulachon have not been observed in any of these other systems (Shaffer et al. 2007).

## Puget Sound

Girard (1858) based his description of a new species *Thaleichthys stevensi* (later synonymized with *Salmo* [*Mallotus*] *pacificus* Richardson, 1836 as *T. pacificus* [Richardson, 1836] [McAllister, 1963]) on a single specimen collected in Puget Sound by George Suckley. The published figure (Girard 1858, his Plate LXXV, his Figure 1 through Figure 4) of this single specimen is detailed enough to be identifiable as a eulachon. Later, Suckley (1860, p. 348–349) in his Report Upon the Fishes Collected on the Survey (text republished in Suckley and Cooper 1860) stated that eulachon were "a very delicious fish, in some years coming in great shoals in the bays in the lower part of Puget Sound, and along the coast near the mouth of Frazer's River." Suckley (1860, p. 348–349) also stated that eulachon were "abundant in Puget Sound" and that "several eulachon in the recent state [dried] were obtained by me from different portions of the lower end of Puget Sound;" however, these specimens were lost when in transit to "Washington city" and their identification cannot be verified. Similarly, Lord (1866, p. 96), in his The Naturalist in Vancouver Island and British Columbia, stated that "the eulachon has also disappeared from Puget's Sound."

Curiously, although these early authorities (Girard 1858, Suckley 1860, Lord 1866) describe Pacific herring (*Clupea pallasii*) and eulachon as occurring in Puget Sound, they make no mention of surf smelt, longfin smelt (*Spirinchus thaleichthys*), or Pacific sand lance (*Ammodytes hexapterus*) in Puget Sound. Swan (1881, p. 258) also stated that eulachon were found "in limited numbers at certain seasons … in the waters of Puget Sound" and they are "found on Puget Sound occasionally with the sand-smelt *Hypomesus olidus*." Since *H. olidus*, or pond smelt, is a freshwater species, Swan may have meant to refer to the abundant surf smelt.

Jordan and Starks (1895, p. 793) also listed eulachon as "abundant in spring" in Puget Sound, although they did not obtain specimens themselves. They cite a local fisherman as reporting "that this species buries itself in the sand of the beach," which indicates that the fish referred to by the local fisherman were not eulachon, but were possibly either surf smelt or Pacific sand lance. Both surf smelt and Pacific sand lance are currently common in Puget Sound and spawn on Puget Sound beaches, and Pacific sand lance are locally known as "candlefish" (Penttila 2007). Therefore, there is substantial reason to believe that mention of abundant eulachon in Puget Sound in some nineteenth century references (Suckley 1860, Lord 1866,

[2] L. Gilbertson, Quinault Indian Nation, Taholah, WA. Pers. commun., 27 June 2008.

Jordan and Starks 1895) results from misidentification with either the common longfin smelt or surf smelt, neither of which were mentioned in Suckley (1860) or Lord (1866).

DeLacy et al. (1972) gathered available fish collection records for Puget Sound from academic and fisheries agencies sources and indicated that between 10 and 49 reports of eulachon exist in these records for the San Juan Islands. However, no more than 10 reports of eulachon specimens exist for each of the Juan de Fuca Strait, Everett, Seattle, central Puget Sound, and south Puget Sound regions (DeLacy et al. 1972). Monaco et al. (1990) described eulachon as rare in Puget Sound and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference. Miller and Borton (1980) list five eulachon specimens collected in Puget Sound (one each in Port Susan, off Everett, and in Carr Sound, and two at Carkeek Park), which are deposited in the University of Washington Fish Collection, and seven eulachon specimens reported in the University of Washington Boat Log (one each at Golden Gardens, Port Madison, Herron Island, Penn Cove, and three in or near Carr Inlet). Currently, 12 specimens of eulachon collected in Puget Sound are deposited in the University of Washington Fish Collection (searchable database at http://www.washington.edu/burkemuseum/collections/ichthyology/index.php).

Miller and Borton (1980) also reported a personal communication dated 22 April 1976 from a biologist with the Puyallup Tribe indicating that eulachon "spawn in Wapato Creek, 1 mile upstream from the mouth of the Puyallup River." Fiedler (1941, p. 463) recorded 10,200 lb (4,636 kg) of eulachon landed in Puget Sound in 1938 in a commercial fishery using drag bag net gear. The precise location of this fish catch is not recorded (Fiedler 1941).

There are some records of transplant efforts to Puget Sound rivers from Columbia River source populations. An article in a Centralia, Washington, newspaper in 1932 (Centralia Daily Chronicle, 1 February 1932, p. 2, col. 8) (Appendix B) reported that:

> Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama river and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful.

Similarly, Wendler and Nye (1962, p. 9) stated that:

> A smelt transplant was initiated in 1959 from the Lewis River to the Puyallup River.... Approximately 4,500 fish were transplanted with an estimated egg potential of 40 million. This was considered a minimal number to plant for a species which requires mass spawning for successful reproduction. However, a measure of success may be seen if Columbia River smelt are present in the Puyallup during the spring of 1962.

A recent WDFW technical report entitled Marine Forage Fishes in Puget Sound (Penttila 2007, p. 19) presents detailed data on the biology, status, and trends of surf smelt and longfin smelt in Puget Sound, but states that "there is virtually no life history information within the

Puget Sound basin" available for eulachon. Similarly, detailed notes provided by WDFW and ODFW (2008) as part of this review, do not provide evidence of spawning stocks of eulachon in Puget Sound rivers. Interestingly, a newspaper account in The Daily Oregonian of Portland for 4 March 1876, cautions the public "against buying Puget Sound smelt [a likely reference to surf smelt] for Columbia River smelt [eulachon]" (Appendix B).

Monaco et al. (1990) described eulachon as rare in Skagit Bay and, in addition to a personal communication, cited Miller and Borton (1980) as a supporting reference (Table A-2). Miller and Borton (1980) report on a total of 20 eulachon specimens collected in the San Juan Islands, southern Strait of Georgia, and Strait of Juan de Fuca and recorded in boat logs and museum collection records; however, samples from Skagit Bay were not included in this list.

The Nooksack River has been frequently listed as supporting a run of eulachon (WDFW and ODFW 2001, Wydoski and Whitney 2003, Willson et al. 2006, Moody 2008); however, Anchor Environmental (2003, p. 27) stated that:

> Longfin smelt [*Spirinchus thaleichthys*] are also called "hooligans" and are sometimes mistaken for eulachon. Eulachon occurrence and spawning has not [been] documented in the Nooksack River.

The run of hooligans into the Nooksack River commonly occurs in November, which is outside of the normal spawn timing period for eulachon, and these fish have recently been positively identified as longfin smelt.[3]

## British Columbia

Hay and McCarter (2000, their Table 1) listed a total of 33 eulachon spawning rivers in British Columbia; however, only about 14 of these river systems were thought to have regular yearly eulachon returns (Table A-1). These 14 river systems and the estuaries or inlets they are associated with from south to north are the Fraser River (Strait of Georgia), Klinaklini River (Knight Inlet), Kingcome River (Kingcome Inlet), Wannock River (Rivers Inlet), Chuckwalla/Kilbella rivers (Rivers Inlet), Kimsquit and Dean rivers (Dean Channel), Bella Coola River (Dean Channel), Kemano/Wahoo rivers (Gardner Canal), Kowesas River (Gardner Canal), Kitlope River (Gardner Canal), Kildala River (Douglas Channel), Kitimat River (Douglas Channel), Skeena River (Chatham Sound), and Nass River (Portland Inlet) (Hay and McCarter 2000, Hay 2002).

Many of these distributions were discovered or verified during a series of ichthyoplankton surveys of eulachon larvae on the mainland coast of British Columbia (McCarter and Hay 1999). These surveys "suggested the occurrence of eulachon spawning in … rivers not previously known to support eulachon spawning" (McCarter and Hay 1999, p. 8). In particular, small spawning runs of eulachon may be detected through ichthyoplankton surveys "that might be missed by conventional fishing techniques (gill nets or seine nets) on adults" (McCarter and Hay 2003, p. 17). Willson et al. (2006) and Moody (2008) recently listed numerous rivers in British Columbia thought to support eulachon runs and these distribution data, essentially the same as in Hay and McCarter (2000), are provided in Table A-1.

[3] G. Bargmann, WDFW, Olympia, WA. Pers. commun., June 2008.

**Fraser River**—Early reference to eulachon being caught by First Nations groups on the Fraser River in 1827–1830 appear in the journals of the Hudson's Bay Company post Fort Langley, located on the south bank of the lower Fraser River near the Salmon River (MacLachlan 1998) (Appendix C). According to Swan (1881, p. 258) eulachon "taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized."

Recent surveys of the Fraser River indicate that eulachon primarily spawn in the lower 50 km (Hay et al. 2002), although earlier studies reported spawning occurred at least up to RKM 100 (McHugh 1940), and perhaps as far upstream as Hope, more than 150 km from Vancouver, British Columbia (Moody 2008). McHugh (1940) surveyed eulachon egg distribution in the Fraser River using a bottom dredge and determined that spawning in 1940 occurred mainly between the towns of Mission and Chilliwack, over a distance of about 13 km. Samis (1977, p. 1) stated that "localized areas of spawning may occur in the north and south arms of the Fraser River, in the Pitt and Alouette rivers, and in other tributaries." However, similar to the findings of Hart and McHugh (1944), Samis (1977) found the highest concentration of eulachon eggs in the Fraser River in May 1976 to occur upstream of Mission, adjacent to Nicomen Island. Higgins et al. (1987, p. 2) noted that "potential [eulachon] spawning sites exist in the lower Fraser River adjacent to Barnston, McMillan, and Matsqui islands (Samis 1977), which are approximately 100 km, 130 km, and 175 km from the Fraser River mouth, respectively." Interannual variation in spawning locations in the Fraser River occur (Hay and McCarter 2000, Hay et al. 2002), with most spawning being above New Westminster in 1995, below New Westminster in 1996, and in the tributary Pitt River in 1999 (Hay and McCarter 2000).

**Other British Columbia rivers**—Outside of the Fraser River, only limited aspects of the biology of eulachon have been studied in other spawning rivers in British Columbia, including: the Kingcome (Berry and Jacob 1998), Wannock (Berry and Jacob 1998, Moody 2008), Bella Coola (Moody 2008), Kemano (Lewis et al. 2002, Ecometrix 2006), Kitimat (Pedersen et al. 1995, Kelson 1997, Ecometrix 2006), Skeena (Lewis, 1997, Stoffels 2001), and Nass (Langer et al. 1977) rivers.

Eulachon were normally located no further upstream in the Kemano River, British Columbia, than RKM 2.7, about 1.5 km above saltwater, although they have been rarely observed up to RKM 4.3 (Lewis et al. 2002). Eulachon spawning is limited to the lower 1.6 km of the nearby Wahoo River (Lewis et al. 2002). Stoffels (2001, p. 4) described areas of the lower mainstem Skeena River and several tributaries (Table A-1) and stated that:

> The eulachon spawn in the main stem Skeena, with high value spawning grounds around the lower Skeena River Islands and around the mouth of the Kwinitsa River (D. De Leeuw, WLAP, pers. comm.). Eulachon also spawn throughout the Ecstall River system, almost up to Johnston Lake and in the Khyex, the Scotia, the Khtada, Kasiks, Gitnadoix and other tributaries in the vicinity (Don Roberts, Terrace, pers. comm.).

Eulachon reportedly spawn upriver in the Nass River to about RM 32 (RKM 51.5), which is the near the limit of tidal influence (Langer et al. 1977).

Although eulachon are not thought to maintain populations in island rivers (Hay and McCarter 2000), anomalous spawning events have reportedly occurred in the Somass, Nimpkish (Hay and McCarter 2000), and Kokish rivers (Willson et al. 2006) on Vancouver Island, as well as in "unnamed rivers on Haida G'waii [Queen Charlotte Islands]" (Willson et al. 2006, p. 35).

### Alaska

Moffitt et al. (2002) indicated that at least 35 rivers in Alaska have spawning runs of eulachon, including one in a glacial stream on Unimak Island, the first island in the Aleutian Island chain off the western end of the Alaska Peninsula. According to Moffitt et al. (2002, p. 3), "this is probably the only island in Alaska with a glacial river of the type similar to mainland systems used for spawning." Armstrong and Hermans (2007, p. 2) stated that "no eulachon runs in island rivers have been reported in Southeast [Alaska]." Aspects of the biology of eulachon have been studied in the following Alaska rivers: the Stikine (Franzel and Nelson 1981), Taku (Flory 2008b), Chilkoot (Betts 1994), Chilkat (Mills 1982, Betts 1994), Copper (Moffitt et al. 2002), Eyak, Alaganik (Moffitt et al. 2002, Joyce et al. 2004), Twentymile (Kubik and Wadman 1977, 1978, Spangler 2002, Spangler et al. 2003), and Susitna (Barrett et al. 1984, Vincent-Lang and Queral 1984).

Both Willson et al. (2006) and Moody (2008) listed numerous other Alaska rivers thought to support eulachon runs and these distribution data are provided in Table A-1. In some years, commercial harvests have occurred on eulachon in the Copper, Stikine, Unuk, Chickamin, and Bradfield rivers (Moffitt et al. 2002, Armstrong and Hermans 2007). Jordan and Gilbert (1899, p. 439) indicated that eulachon occurred in the "Nushagah [Nushagak] River" that flows into Alaska's Bristol Bay in the southeastern Bering Sea. Other more recent compilations also list the Nushagak River as supporting a run of eulachon (Mecklenburg et al. 2002, Willson et al. 2006). The Nushagak River is the northern most system reported to support a run of eulachon.

Larval plankton surveys suggest that the upstream limit of eulachon distribution in the Taku River occurs at about RKM 44 (Flory 2008b). During exceptionally large runs, eulachon have reportedly been seen "at Bull Slough, near the Tulsequah River in Canada" (Flory 2008b, p. 16). Tidal influence affects the Taku River up to about RKM 35 (Flory 2008b). Eulachon were observed from the mouth of the Susitna River up to about RKM 80 in 1982 and 1983, although the greatest concentration of spawning occurred within the lower 46.6 km of the main channel of the Susitna River (Barrett et al. 1984).

### Physical characteristics of spawning rivers

Hay and McCarter (2000, p. 12) noted that some eulachon rivers are "large or turbid, with high sediment loads; others are small and clear." Despite these apparent differences, they recognized that "virtually all [eulachon rivers] have spring freshets, which are characteristic of rivers draining large snow packs or glaciers." Although this is true of most rivers supporting eulachon in British Columbia and Alaska (Hay et al. 2002), many eulachon rivers in the lower Columbia River basin and on the coasts of California, Oregon, and Washington are not fed by extensive snowmelt or glacial runoff. However, most systems that support eulachon and are not fed by snowmelt still possess extensive spring freshets. Hay and McCarter (2000, p. 12) suggested that the apparent requirement for snow pack or glacier-fed spring freshets may be the reason why "there are no known eulachon spawning rivers found on any large coastal islands, including Vancouver Island, Queen Charlotte Islands, Kodiak, or any of the small coastal islands in northern British Columbia or southeastern Alaska."

The lack of eulachon larvae in waters examined during ichthyoplankton surveys off Vancouver Island and the Queen Charlotte Islands in April and May (Hay and McCarter 1997) "reinforce the conclusion that eulachon spawning is mainly confined to coastal rivers that have a distinct spring freshet and drain major glaciers or snowpacks" (McCarter and Hay 2003, p. 16). Typically, eulachon spawn well before the spring freshet, near the seasonal flow minimum, especially on the mainland coast of British Columbia (Lewis et al. 2002); however, Fraser River eulachon appear to spawn during the height of the freshet (Stables et al. 2005). In many rivers, eulachon spawning appears to be timed so that egg hatching will coincide with peak spring river discharge (Flory 2008b).

## Marine Distribution

Although they spend 95–98% of their lives at sea (Hay and McCarter 2000), little is known concerning the saltwater existence of eulachon. They are reported to be present in the "food rich" and "echo scattering layer" of coastal waters (Barraclough 1964, p. 1,337), and "in near-benthic habitats in open marine waters" of the continental shelf between 20 and 150 m depth (Hay and McCarter 2000, p. 14). Hay and McCarter (2000, their Figure 5) illustrated the offshore distribution of eulachon in British Columbia as determined in research trawl surveys, which indicate that most eulachon were taken at around 100 m depth, although some were taken as deep as 500 m and some at less than 10 m. Schweigert et al. (2007, p. 11) stated that "the marine distribution of adults in British Columbia includes the deeper portions of the continental shelf around Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island, generally at depths of 80–200 m." Mueter and Norcross (2002) reported eulachon were present in 32% of triennial bottom trawl surveys on the upper slope and continental slope in the Gulf of Alaska between 1984 and 1996 and were caught at depths down to 500 m in the Kodiak, Yakutat, and southeast areas of Alaska. Armstrong and Hermans (2007) indicated that eulachon are commonly caught in trawls in the coastal fjords of Southeast Alaska. Further information on eulachon distribution in research bottom trawl surveys is below and in Table A-4 and Table A-5.

Smith and Saalfeld (1955, p. 12) reported the occasional capture of eulachon in the offshore "otter trawl fishery," particularly in November to January near the mouth of the Columbia River "as the mature smelt approach the Columbia River." Emmett et al. (2001) reported the capture of small numbers of eulachon by nighttime surface trawls targeted on pelagic fishes off the Columbia River in April to July of 1998 and 1999. About 10% of hauls in 1999 contained from one to a maximum of eight eulachon (Emmett et al. 2001). Eulachon also occur as bycatch in some U.S.-based groundfish fisheries (Bellman et al. 2008) off the U.S. West Coast and more commonly in the California and Oregon ocean shrimp (*Pandalus jordani*) fisheries (NWFSC 2008). The Pacific Fishery Management Council has prohibited at-sea directed harvest of eulachon in U.S. West Coast waters and eulachon are not an actively managed or monitored species (PFMC 2008); therefore there is a paucity of data on at-sea distribution of eulachon off the U.S. West Coast.

## U.S. West Coast groundfish trawl surveys

Fishery-independent surveys conducted off the U.S. West Coast that provide data on distribution or abundance of eulachon in the ocean are very limited (Table A-4). The Northwest and Alaska Fisheries Center (NWAFC, before it split into NWFSC and AFSC) and AFSC conducted groundfish trawl surveys on the continental slope (at depths of 184–1,280 m) periodically from 1984 to 1987, and annually beginning in 1988. Continental shelf (at depths of 55–183 m) surveys were conducted triennially from 1977 to 2001 by the NWAFC and AFSC. The NWFSC assumed responsibility for the slope portion of the groundfish survey starting in 1998 and expanded the depth coverage to include the continental shelf as well as the continental slope in 2003. Many of these groundfish surveys report catch as occurring in one of five International North Pacific Fisheries Commission (INPFC) statistical areas. These INPFC areas from north to south are: 1) Vancouver (U.S.-Canada border to lat 47°30′N), 2) Columbia (lat 47°30′ to 43°00′N), 3) Eureka (lat 43°00′ to 40°30′N), 4) Monterey (lat 40°30′ to 36°00′N), and 5) Conception (lat 36°00′N to the U.S.-Mexico border) (Figure 4).

Eulachon were reported in the triennial groundfish bottom trawl surveys on the U.S. West Coast continental shelf in 1977 (Gabriel and Tyler 1980), 1980 (Coleman 1986), 1983 (Weinberg et al. 1984), 1986 (Coleman 1988), 1989 (Weinberg et al. 1994a, 1994b), 1992 (Zimmermann 1994, Zimmermann et al. 1994), 1995 (Wilkins 1998, Wilkins et al. 1998), 1998 (Shaw et al. 2000, Wilkins and Shaw 2000), and 2001 (Weinberg et al. 2002, Wilkins and Weinberg 2002) (Table A-4). These surveys targeted rockfish from 1977 to 1986, and were subsequently designed to estimate Pacific hake (*Merluccius productus*) and juvenile sablefish (*Anoplopoma fimbria*) abundance, as well as other commercially important groundfish (Weinberg et al. 1994a). However, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

The 1977 shelf groundfish survey recorded eulachon in six of nine assemblages off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m) off Oregon (Gabriel and Tyler 1980). Trawl surveys in 1980–1986 occurred between Monterey Bay, California, and either Northern Vancouver Island (1980), Estevan Point, Vancouver Island (1983), or the U.S.-Canada border (1986) at depths of 55–366 m (Coleman 1986, 1988, Weinberg et al. 1984). From 1989 to 2001 triennial groundfish bottom trawl surveys covered all West Coast INPFC areas from Vancouver to Monterey, inclusive. In 1980 eulachon were recorded as the fifteenth most common fish encountered at depths of 55–183 m in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986).

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in the triennial surveys from 1989 to 2001 are provided in Table A-4. Eulachon were found into the far south Monterey INPFC area in the 1989 survey but were not recorded in either the Monterey or Eureka INPFC areas in surveys conducted between 1992 and 2001. Mean depth of occurrence of eulachon in these surveys varied between 137 and 147 m, with minimum depths of 59–79 m and maximum depths of 322–466 m (Table A-4).

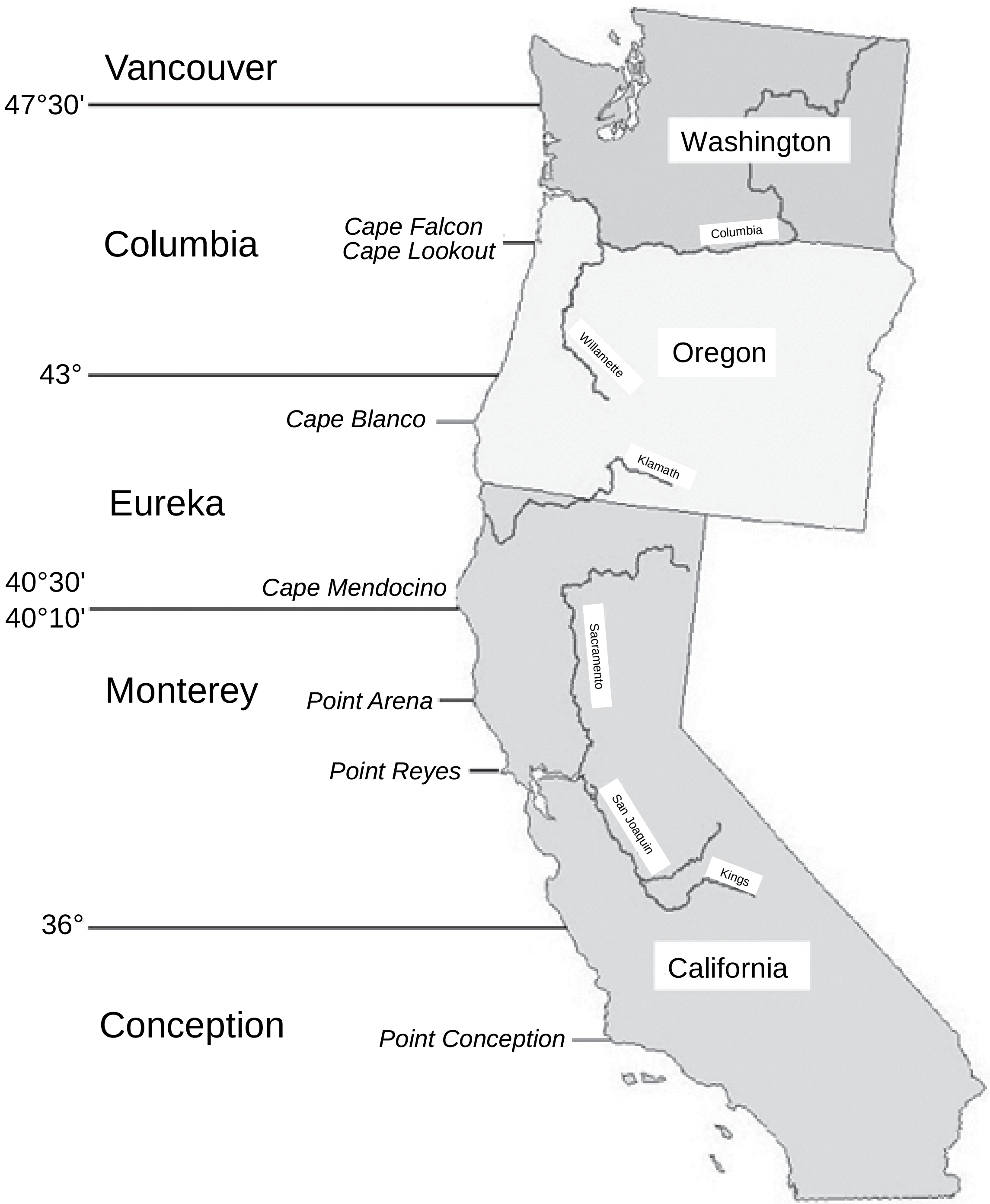



Figure 4. INPFC statistical areas off the U.S. West Coast. Modified from Pacific Fishery Management Council Web site at http://www.pcouncil.org/wp-content/uploads/georock.pdf.

Eulachon were occasionally sampled in West Coast upper continental slope groundfish trawl surveys conducted between 1984 and 1999 by the NWAFC and AFSC (Raymore and Weinberg 1990, Parks et al. 1993, Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000) and between 1999 and 2002 by the NWFSC (Builder Ramsey et al. 2002, Keller et al. 2005, 2006a, 2006b). These surveys covered habitat between 183 and 1,280 m from the U.S.-Canada border to lat 30°30′N (Lauth et al. 1997, Lauth 1997a, 1997b, 1999, 2000, Keller et al. 2005, 2006a, 2006b), although annual surveys prior to 1997 covered only a portion of the area each year (Table A-4). This depth range is deeper than is preferred by eulachon (Hay and McCarter 2000), so these surveys likely missed the vast majority of eulachon, which occur on the continental shelf and not the slope.

Minimum, maximum, and mean depths of eulachon captured during the 1989–2002 survey years are given in Table A-4; however, eulachon were seldom encountered at these depths (below 183 m) and their reported occurrence in trawl hauls ranged from 6% of trawls conducted between 1989 and 1993 to fewer than 1% of all trawls in 2001. Presumably, eulachon were not encountered during the NWFSC 1999 bottom survey of the U.S. West Coast continental slope, as this species is not included in the comprehensive list of species encountered (Builder Ramsey et al. 2002). Eulachon were captured as deep as 608 m during the 2001 survey (Keller et al. 2005).

Starting in 2003, the NWFSC conducted combined slope and shelf surveys for groundfish between depths of 55 and 1,280 m (Keller et al. 2007a, 2007b, 2008) off the U.S. West Coast (Table A-4). Sampling in these slope and shelf surveys, in contrast to the NWAFC and AFSC triennial bottom trawl surveys (discussed above), did not extend into the Canadian portion of the Vancouver INPFC area where the triennial surveys had encountered the majority of eulachon. Currently, eulachon abundance in the Canadian portion of the Vancouver INPFC is tracked by the Department of Fisheries and Oceans Canada (DFO) during the annual surveys of shrimp biomass off the west coast of Vancouver Island (DFO 2008a). Eulachon were found at depth extremes of 51 to 237 m in the NWFSC surveys, with mean depths of 119 to 130 m during the three survey years (Table A-4) (Keller et al. 2007a, 2007b, 2008); however, eulachon biomass estimates were not presented in these survey documents. Some eulachon were found as far south as 34°N in the INPFC Conception area in 2003 and 2004 (Keller et al. 2007a, 2007b), a southern distribution that had not been recorded in groundfish surveys since 1989 (Weinberg et al. 1994a) (Table A-4). Pacific hake trawl surveys in U.S. and Canadian waters off the Pacific Coast have also reported incidental catch of eulachon (Fleischer et al. 2005, 2008), although details on catch location were not provided.

### Alaska trawl surveys

Latitudinal and longitudinal range and minimum, maximum, and mean depth distribution of eulachon captured in AFSC bottom trawl surveys in the Gulf of Alaska (triennially from 1984 to 1996, biennially from 1999 to 2007), Eastern Bering Sea (annually from 1982 to 2008), and Aleutian Islands (triennially from 1983 to 1997, biennially from 2000 to 2006) regions of Alaska are summarized in Table A-5. Eulachon are a common species in the Gulf of Alaska trawl surveys (Stark and Clausen 1995, Martin and Clausen 1995, von Szalay et al. 2008) and are particularly abundant in the Chirikof and Kodiak INPFC areas (von Szalay et al. 2008). In the

2007 trawl survey, eulachon were present in about 31% of the hauls under 300 m deep and 9% of hauls below that depth, although none were seen deeper than 700 m (von Szalay et al. 2008).

Eulachon distribution and abundance were also incidentally reported in two summer echo integration-trawl (EIT) surveys of prespawning walleye pollock (*Theragra chalcogramma*) on the Gulf of Alaska continental shelf in 2003 (Shumagin Islands to Prince William Sound) and 2005 (Islands of Four Mountains to south Prince William Sound) (Guttormsen and Yasenak 2007). Eulachon were the fourth and third most abundant species by numbers of fish caught in midwater trawls in the Gulf of Alaska in 2003 (10% of total) and 2005 (18% of total), respectively. Eulachon constituted 6.6% of the fish caught during EIT bottom trawls in 2003 in the Gulf of Alaska, but were not recorded in bottom trawls in 2005 (Guttormsen and Yasenak 2007).

Marine distribution maps of eulachon captured in AFSC research bottom trawl surveys of the Eastern Bering Sea continental shelf between 2001 and 2007 are provided in Nebenzahl (2001), Acuna et al. (2003), Acuna and Kotwicki (2004, 2006), Lauth and Acuna (2007a, 2007b), and Acuna and Lauth (2008). Abundance estimates for eulachon are not generally provided in these documents as they are "not adequately represented in the samples," which is "due to the bottom sampling nature of the survey" (Nebenzahl 2001, p. 27).

### Ichthyoplankton surveys

Ichthyoplankton surveys in the northeastern Pacific Ocean commonly report the capture of osmerid larvae, but few studies have identified smelt larvae to the species level (Waldron 1972, Richardson and Pearcy 1977, Doyle et al. 2002, Auth and Brodeur 2006, Parnell et al. 2008). It is also possible that by the time eulachon reach the open ocean where these ichthyoplankton surveys occur, they may have grown sufficiently to be able to avoid capture in slowly towed, fine-mesh ichthyoplankton nets.

### Mixed stock genetic analysis

Beacham et al. (2005) used variation at 14 microsatellite DNA loci to examine the stock composition of trawl and research surveys in marine areas off British Columbia. Using a genetic baseline data set of eulachon populations in eight rivers in Washington and British Columbia, they estimated the proportional composition of three marine-caught samples. A sample of 184 eulachon was collected during a shrimp research survey near Nootka Sound off the west coast of Vancouver Island in May of 2000. The largest proportions of fish were estimated to be from the Columbia River (56.6%, SD = 10.4) and Fraser River (37.5%, SD = 10.1). Populations in other rivers were estimated to contribute less than 6% to the sample. A sample of 100 eulachon sampled as bycatch in a shrimp trawl fishery near Chatham Sound (off British Columbia's north coast) in March 2001 was estimated to be largely fish from the British Columbia central mainland (51.6%, SD = 13.8) and from the Nass River (37.4%, SD = 10.9). Columbia (1.7%, SD = 2.4) and Fraser (2.1%, SD = 3.6) rivers contributed a small fraction to the sample. A third sample of 200 fish taken in research shrimp surveys in Queen Charlotte Sound in March 2001 was comprised of substantial proportions of Columbia, Fraser, British Columbia central mainland, and Skeena rivers, all contributing between 22.1% (SD = 5.9) and 27.1% (SD = 6.9).

Beacham et al. (2005) concluded that although eulachon marine migrations are largely unknown, there is spatial structure to the distributions of fish from different rivers. Their data indicate that Queen Charlotte Sound is an area inhabited by eulachon from very diverse origins including fish from nearby rivers as well as from more northern and southern sources. Analysis of samples in the south (off Vancouver Island) were dominated by Columbia River and Fraser River fish, whereas eulachon in the most northern marine region sampled, Chatham Sound, were largely from British Columbia coastal rivers north of the Fraser River.

# Life History Stages

## Eggs

Eulachon eggs from the Columbia River are reported to be approximately 1 mm in diameter (Parente and Snyder 1970, WDFW and ODFW 2001). In the Fraser River, eggs have been variously reported to "have an average diameter between 0.03 and 0.04 inches [0.76–1.02 mm] after preservation in formalin" (Hart and McHugh 1944, p. 9), to measure " less than 1.0 mm diameter" (Hay and McCarter 2000, p. 18), or to be "small (≈0.8 mm)" (Hay et al. 2002, p. 20). According to Garrison and Miller (1982, p. 119), "the eggs show considerable irregularity in shape and have numerous oil globules in the yolk." This irregularity in shape likely refers to unfertilized eggs.

Mature eggs are reported to have an outer sticky membrane that turns inside out after the broadcast spawned eggs are fertilized and remains attached to the egg by a short stalk, which serves to adhere the egg to particles of sand or other substrates (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Hay and McCarter 2000). Hay et al. (2002, p. 18) speculated that as eulachon eggs may attach to small sediment particles and appear to develop while being actively carried downstream by river currents that "the mobile incubation (or 'tumble' incubation) may even have a selective advantage because it may spread the eggs over a broad space, thereby reducing predation and optimizing environmental conditions."

Pedersen et al. (1995) found no significant relationship between egg weight and female body length in the Kitimat River, British Columbia. Eggs weighed 0.26–0.58 mg with a mean and standard error of 0.43 ± 0.01 mg (n = 58) (Pedersen et al. 1995). Similarly, Hay and McCarter (2000) reported eggs from the Fraser River to weigh 0.36–0.68 mg (0.51 ± 0.01 mg, n = 106) in 1995 and 0.30–0.68 mg (0.44 ± 0.01 mg, n = 100) in 1996 in the Fraser River. Mean eulachon egg weight in the Kemano River, British Columbia, was estimated at 0.43 mg (± 0.16 SD, n = 429) (Lewis et al. 2002).

Smith and Saalfeld (1955) reported that eulachon eggs from the Columbia River required 388, 378, and 370 daily cumulative degree Fahrenheit days (equivalent to 198, 192, and 188 degree Celsius days) to hatch in the Naselle River Hatchery, Kalama River Hatchery, and the University of Washington School of Fisheries hatchery, respectively. In hatchery conditions, Smith and Saalfeld (1955) reported eggs taken from the Cowlitz River hatched in 19 days at temperatures that varied from 9.4 to 12.7ºC. These data led Smith and Saalfeld (1955) to estimate that eulachon eggs would hatch in 30–40 days, given the usual water temperatures in February and March in the Cowlitz River. Assuming similar thermal requirements for incubation, Langer et al. (1977) estimated that it would take 30–40 days for eulachon eggs to hatch in the Nass River, British Columbia. Artificially spawned and incubated eulachon eggs from the Cowlitz River hatched in 21–25 days when reared at 6.5–9.0ºC (Parente and Snyder 1970). Berry and Jacob (1998 p. 4) reported the incubation period in the Kingcome River in Kingcome Inlet, British Columbia "to be approximately 21 days." Flory (2008b, p. 3) cited a personal communication indicating that the incubation period for eulachon in Southeast Alaska ranges from four to six weeks, longer than the typical three to five weeks common in more southern regions.

Lewis et al. (2002) estimated that the number of accumulated thermal units (ATUs, one ATU equal to one degree Celsius for one day) between the peak of adult spawning and larval migration for eulachon in the Kemano River, British Columbia, in 1990 to be 204 degree-days based on daily recorded temperatures. In 1997 the number of ATUs to reach 50% larval hatch were estimated to be 340 in the Kemano River and 235 in the nearby Wahoo River (Lewis et al. 2002). Duration of egg incubation in the Kemano River was calculated at 50 days (Lewis et al. 2002). Similarly, 51% of eulachon larvae hatched in the Kitimat River, British Columbia, in 1993 after accumulating 258 ATUs and 87% of hatch occurred at an estimated 307 ATUs (Pedersen et al. 1995). The shortest duration of incubation of eulachon eggs from deposition to hatch was 35–39 days, the earlier time period equating to approximately 168 ATUs (Pedersen et al. 1995).

In the Twentymile River in Southcentral Alaska, incubation was estimated during three time periods at 47–50 days, which equated to between 294 and 321 ATUs, based on calculations using mean daily water temperatures (Spangler 2002, Spangler et al. 2003). Moody (2008, p. 3) reported that earlier studies had found eulachon eggs from the Bella Coola River hatched in 54 days at about 6ºC, equivalent to about 340 ATUs. Howell (2001) reported that 400ºC ATUs (752ºF ATUs) were accumulated prior to hatching, after a minimum of 47 days, by eulachon eggs stripped from Cowlitz River broodstock and incubated at a constant temperature of 48ºC under artificial hatchery conditions. The anomalously high number of ATUs required for hatching in this experiment may have been an artifact of the experimental conditions (Howell 2001).

Pedersen et al. (1995) postulated that incubation requirements may vary with latitude, and Spangler (2002) and Spangler et al. (2003) noted that, in general, the number of ATUs required for eulachon egg incubation appears to increase with increasing latitude.

Parente and Snyder (1970) provide the only published observations on eulachon embryonic development, which is typical of teleost fishes. In laboratory conditions at temperatures ranging from 6.5°C to 9°C; a blastodisc appears at 3 hours after fertilization, cleavage is occurring by 30 hours, invagination of the gastrula is in process at 60 hours, and the head and auditory capsule are apparent at 120 hours. At 300 hours (12–13 days) a weak heart beat is present, which is stronger by 400 hours. By this time the yolk sac is about one-half its original size. The active embryo begins hatching at about 500 hours (20–21 days) and all eggs under observation hatched within 5 days of each other (Parente and Snyder 1970).

## Larvae

Newly hatched larvae are transparent, slender, and about 4–8 mm in length in the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001), 4.0–6.5 mm in the Fraser River (Hay et al. 2002), and 4–6 mm in the Kemano River (Lewis et al. 2002). Eulachon larvae are reported to be feeble swimmers and are rapidly carried downstream to estuarine portions of rivers and inlets within hours or days of hatching (McHugh 1940, Hart and McHugh 1944, Smith and Saalfeld 1955, Parente and Snyder 1970, Samis 1977, Howell 2001). In the Columbia River, larval eulachon are usually located near the bottom during their downstream migration (Smith and Saalfeld 1955, Howell et al. 2001). Larval nutrition is provided by the yolk sac prior to first feeding (WDFW and ODFW 2001). Spangler et al. (2003) detected higher levels of downstream drifting larval eulachon during low light intensity periods at night than during the day in the Twentymile River, Alaska. Care must be taken in many parts of the range that larval eulachon in rivers are not confused with superficially similar cottid (sculpin) larvae (Kelson 1997, Flory 2008b).

Ichthyoplankton surveys indicate that larval eulachon may be retained for weeks or months in estuaries (McCarter and Hay 1999, 2003), especially in inlets or fjords on the British Columbia mainland coast (McCarter and Hay 2003). These surveys also indicate that eulachon larvae are mostly present in the top 15 m of the water column, with few larvae occurring below 20 m (McCarter and Hay 1999, Hay and McCarter 2000). Hay and McCarter (2000, p. 19) showed that newly hatched larvae were about 3.6–8 mm in length and that in mainland inlets on the British Columbia coast “mean eulachon larval size (mm) generally increased at each sampling station in a seaward direction away from eulachon spawning rivers.” Although larvae disperse seaward from their spawning rivers, they also “appear to be retained in inlets” and fjords to some degree on the British Columbia coast (Hay and McCarter 2000, p. 21). Ichthyoplankton surveys also showed that larvae were smaller in shallow water than those captured in deeper depths (McCarter and Hay 1999, Hay and McCarter 2000). During the period from April to August, larval eulachon on the central British Columbia coast were estimated to grow from an initial size of 3–4 mm to 30–35 mm in length (McCarter and Hay 1999, 2003).

Robinson et al. (1968b, their Table I) determined that almost all eulachon larvae in the Strait of Georgia, off the Fraser River during daylight on 6 June 1967, were distributed in the top 6.5 m of the water column, with the greatest density (50–150 larvae/$m^3$) occurring between 1.7 and 3.5 m depth. McCarter and Hay (1999) found that eulachon larvae (mostly ≤15 mm in length) in mainland inlets on the central coast of British Columbia were mainly found within the top 15 m of the water column during springtime plankton tows and suggested that larval densities were greater near the surface at night than during daytime tows.

## Juveniles

Information on the distribution and ecology of juvenile eulachon is scanty, owing to these fish being too small to occur in most fisheries and too large to occur in ichthyoplankton surveys (Hay and McCarter 2000). Eulachon that range 30–100 mm in length, exhibit schooling behavior, and have developed pigmentation and lateral scales are generally classified as juveniles (Hay and McCarter 2000). Barraclough (1964) sampled juvenile eulachon in the Strait of Georgia in winter and spring with midwater trawls and shrimp trawls and indicated that Fraser

River eulachon may spend their first year of life in the Strait of Georgia; however, observer data indicate that virtually no eulachon were caught as bycatch in the late 1990s in the Strait of Georgia shrimp fishery (Hay et al. 1999a). A larger mesh size is used in commercial shrimp trawls, compared to the mesh size used in Barraclough's (1964) studies (Hay and McCarter 2000), suggesting that juvenile eulachon may be present in coastal waters but are difficult to detect without a directed effort. Hay and McCarter (2000, p. 22) reported that "it seems that … [juveniles] disperse to open, marine waters within the first year of life and perhaps within the first few months."

## Adults and Spawners

### Age composition

The two common methods of estimating age in eulachon, either through counting rings on scales or on otoliths, have not been validated for any population of eulachon (Ricker et al. 1954, DeLacy and Batts 1963, Higgins et al. 1987, Hay and McCarter 2000, Moffitt et al. 2002, Clarke et al. 2007). Age as determined from scales is typically one to three years less than age determined from otolith increments (Ricker et al. 1954, Langer et al. 1977, Higgins et al. 1987). Several early studies expressed doubt as to the reliability of using otolith rings to determine eulachon age (Smith and Saalfeld 1955, DeLacy and Batts 1963). Consequently, the determination of age from scales and otoliths are not considered reliable methods by many researchers (Ricker et al. 1954, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007). Clarke et al. (2007, p. 1,480) noted that many dark bands or pseudo-annuli are present in whole and polished otoliths "that have been interpreted as winter growth zones in past ageing attempts" and that "sectioned otoliths viewed under transmitted light can reveal fewer zones," indicating some of the problems with this ageing methodology.

In some cases "there is no corresponding increase in size (length or weight) with putative [increase in] age" (Hay and McCarter 2000, p. 15). Higgins et al. (1987) also reported overlap in fork lengths (FL) between putative age classes of eulachon. However, in the Twentymile River, Alaska, eulachon body length has been shown to increase with age in both males and females, as expected (Spangler 2002). Beamish and McFarlane (1983) highlighted the importance of proving that a technique for ageing a species is accurate (age validation). Age validation "requires either a mark-recapture study or the identification of known-age fish in the population" (Beamish and McFarlane 1983, p. 741). It is important to point out that age validation is different than determining the precision of an ageing technique by assessing the level of agreement among several age readers. Despite the acknowledged problems with age determination in eulachon, numerous studies have reported age composition of spawning populations of eulachon based on examination of growth increments on either scales or otoliths and these data are presented in Table A-6.

Although age determination of eulachon is admittedly difficult and uncertain, adult spawners are variously reported to be 3–4 years old (Smith and Saalfeld 1955) or 3–5 years old (WDFW and ODFW 2001) in the Columbia River; 2–3 years old (McHugh 1939, Ricker et al. 1954) or mostly 3 years old, with some 2-, 4-, and 5-year-olds in the Fraser River (Hay et al. 2005); and mostly age 3 (Hay and McCarter 2000, Hay 2002) or 2–5 years old (Schweigert et al. 2007) in British Columbia. The majority of adult eulachon on the Columbia River are reported to return at age 3, although some are purported to be up to 9 years old (WDFW and ODFW 2001). Wydoski and Whitney (2003, p. 106) also stated that some eulachon "may live for 9 years;" however, these age estimates are based on the unvalidated otolith methodology.

Clarke et al. (2007) examined seasonal changes in trace elements incorporated into otoliths to estimate age structure of eulachon populations in the Columbia, Fraser, Kemano, Skeena, and Copper rivers. It has been shown that barium (Ba) and calcium (Ca) are incorporated into the aragonitic matrix of fish otoliths in proportion to their concentration in the environment (Bath et al. 2000). Barium concentrations are normally about three times greater in deep ocean waters than in surface waters; however, for about 3 months during the summer, wind-driven upwelling of deep barium-rich waters occurs off the west coast of North America and "these upwelling events should therefore impart a seasonal barium peak … in … [eulachon] otoliths" (Clarke et al. 2007, p. 1,481). As expected, Clarke et al. (2007) found that eulachon otoliths had low Ba:Ca levels in the outer region of the otolith in February and March and high levels in the summer. Clarke et al. (2007, p. 1,488) used laser-ablation inductively coupled plasma mass spectrometry to reconstruct the Ba:Ca profile of eulachon otoliths and stated that:

> a single age class of fish was observed to spawn in the systems examined in this study. Only 3-year-old eulachon were observed from the spawning populations in the Fraser and Kemano rivers, and the majority of fish for the Columbia, Skeena, and Copper rivers were also composed of a single age class; 2-, 3- and 4-year-olds from the Columbia, Skeena, and Copper rivers, respectively.

These data suggest that populations to the south spawn at an earlier age than more northern populations. Clarke et al. (2007, p. 1,489) concluded that "seasonal fluctuations in Ba:Ca observed in this study suggests that, to date, many eulachon have been aged incorrectly" and that "Ba:Ca variations appear to match expected annual shifts in ambient chemistry and so offer a more reliable annual marker for ageing."

Analyses of size frequencies have also been used to estimate age of at-sea (Ricker et al. 1954, Barraclough 1964, Hay and McCarter 2000, Hay et al. 2003, Clarke et al. 2007) and in-river (McHugh 1939) eulachon. These methods have identified age 1+ and age 2+ eulachon in the ocean (Barraclough 1964, Hay et al. 2003) and indicate that "the largest size mode [in the ocean] corresponds to the size modes observed in spawning rivers" (Hay et al. 2003, p. 5). Size frequency analysis indicates that most eulachon in British Columbia are spawning at age 3 (Hay and McCarter 2000).

**Body size**

Eulachon are reportedly the largest species of smelt in the family Osmeridae on the west coast of North America (Scott and Crossman 1973). Published reports of maximum eulachon body length of 305 mm (Clemens and Wilby 1967, Miller and Lea 1972) are likely in error (Miller and Lea 1976, Mecklenburg et al. 2002). Specimens of 254 mm (Miller and Lea 1976, Mecklenburg et al. 2002) from the Bering Sea represent the maximum known length for eulachon. Mean lengths of male and female eulachon in the Twentymile and Susitna rivers of Southcentral Alaska are greater than 200 mm FL (Table A-7), much larger than mean lengths in rivers further south (Spangler 2002, Spangler et al. 2003). These authors also noted that the mean weight of eulachon in the Susitna and Twentymile rivers was greater than in eulachon spawning in more southern rivers (Spangler 2002, Spangler et al. 2003) (Table A-8).

Moffitt et al. (2002) found mean length of male eulachon on the Copper River to be significantly longer than females in all years analyzed from 1998 to 2002. There were also significant differences in length among years for both male and female eulachon from the Copper River. Male eulachon were also found to be significantly longer and heavier than female eulachon in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Male eulachon were significantly larger than females in the Kemano River, British Columbia, and both sexes were significantly longer than eulachon in the nearby Wahoo River (Lewis et al. 2002).

Length of pelvic and pectoral fins of female eulachon from the Fraser River were both 14.3% of the standard body length, compared to 17.6% for pelvic fins and 15.8% for pectoral fins in male eulachon (McHugh 1939, Hart and McHugh 1944). By comparison, Langer et al. (1977) found that lengths of pelvic and pectoral fins of female eulachon in the Nass River were 11.1% and 11.8% of the standard body length, compared to 13.4% for pelvic fins and 12.7% for pectoral fins in male eulachon. Both sexes of eulachon in the Nass River apparently possess "relatively smaller fins than do Fraser fish" (Langer et al. 1977, p. 33). Craig (1947, p. 3) stated that among Columbia River tributaries:

> fishermen consistently claim to find larger smelt in the runs comprising the Lewis and Sandy river populations than those in the Cowlitz River stocks. Such size variation has been statistically proven sound in 1946 when large samples of fish were measured from both the Cowlitz and Sandy rivers.

Clarke et al. (2007, p. 1,484) found significant differences in length and weight of eulachon from five river systems (Columbia, Fraser, Kemano, Skeena, and Copper) and found a trend towards larger fish in more northerly populations "and the largest fish were from Alaska and northern British Columbia." Clarke et al. (2007) suggested that eulachon likely spawn after reaching a minimum fork length of 160 mm and a body weight greater than 30 g and that these size thresholds are obtained at an earlier age in southern latitudes and later in the far north. Available data on eulachon body length and weight from throughout the species' range are compiled in Table A-7 and Table A-8, respectively.

### Vertebrae meristics

Hart and McHugh (1944) and DeLacy and Batts (1963) attempted to identify stocks of eulachon based on differences in the number of vertebrae present in adult fish on the spawning grounds. Hart and McHugh (1944, p. 6) counted vertebrae, which varied from 65 to 72 per fish, in eulachon samples from the Nass River, Rivers Inlet, Knight and Kingcome inlets, and Fraser River and found:

> the Fraser river run to differ in average vertebral number from the runs to the more northern parts of the province.… This indicates that mixing between the runs to the Fraser and more northerly rivers cannot be extensive because, if it were, any differences in vertebral count would soon be eliminated.

Similarly, DeLacy and Batts (1963, p. 33) counted vertebrae, which also varied from 65 to 72 per fish, in eulachon samples taken between 1953 and 1962 in the lower Columbia River and its tributaries and reported that "an indication of heterogeneity was found among eight collections of smelt made in 1956 from the Cowlitz, Kalama, and Sandy rivers." Based on these data, DeLacy and Batts (1963, p. 33) stated that their study found "scant evidence of heterogeneity in the total Columbia River smelt population;" however, "there is enough suggestion of heterogeneity to justify further exploration of the possibility that smelt do move to the spawning grounds in some nonrandom fashion."

### Sexual dimorphism

There are a number of morphological differences between male and female eulachon at maturity. Mean length is in general longer in males than in females (McHugh 1939, Higgins et al. 1987, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003, Cambria Gordon 2006). Although age-2 males were statistically greater in length than the same age females on the Nass River in 1971, length of age-3 through age-5 fish did not vary between the sexes (Langer et al. 1977). Mean weight of males was statistically greater than that of females in the Twentymile River, Alaska, in 2000 and 2001 (Spangler 2002, Spangler et al. 2003) and in the Kemano River, British Columbia, from 1988 to 1998 (Lewis et al. 2002). However, mean lengths and weights of male and female eulachon in the Fraser River from 1995 to 2001 as reported by Hay et al. (2002, their Table 3) did not show consistent differences between the sexes. McHugh (1939) was also unable to detect significant difference in size between males and female eulachon from the Fraser River.

Males differ from females in having numerous tubercles on the body, head, and fins, and particularly along the lateral line (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003). In males, "the muscles of the body wall have undergone considerable development, so that the body wall is considerably thicker, and the whole fish is more firm and rigid than the female" (McHugh 1939, p. 21). Females are smoother in appearance with far fewer tubercles and do not possess the mass of muscle along the lateral line (McAllister 1963, Spangler et al. 2003). The pelvic fins are also larger at the base and longer in male compared to female eulachon; the ends of the pelvic fins often reach as far posterior as the level of the anus in males, but are much shorter in females (McHugh 1939, Hart and McHugh 1944, McAllister 1963, McPhail and Lindsey 1970, Spangler et al. 2003, Cambria Gordon 2006). Hart and McHugh (1944, p. 4) reported that female eulachon have a more tapered form than male eulachon. Spangler (2002) found females retained teeth to a greater degree (84.0–96.9%) than did males (3.4–32.4%) in the Twentymile River, Alaska.

### Proximate analysis

The very high fat content of eulachon led many Native American tribal groups in Southeast Alaska and First Nations in British Columbia, especially to the north of the Fraser River, to render the fat of the eulachon into oil or "grease" (Kuhnlein et al. 1982, Hay and McCarter 2000). Several early studies investigated the chemical characteristics of eulachon oil with regard to its nutritional qualities (Brocklesby and Denstedt 1933, Brocklesby 1941, Bailey et al. 1952). However, Clark and Clough (1926, p. 505) were the first to publish on the proximate composition of eulachon flesh and they reported that a single sample of the edible portion of fresh eulachon from the Columbia River contained 11.2% fat, 13.2% protein, and 1.4% ash. Although Clark and Clough (1926) studied the composition of Columbia River eulachon, these results were subsequently republished in Babcock (1927) as typical for British Columbia. Stansby (1976) found the mean (and range) of percent moisture, oil, protein, and ash in the raw muscle of 16 eulachon specimens from the Columbia River to be 79.6% (76.5–81.3), 6.3% (4.6–9.0), 14.6% (13.2–15.3), and 1.3% (1.1–1.4), respectively. Stansby's (1976) data were also reported in Sidwell (1981).

Whole unprocessed eulachon sampled in Knights Inlet on the British Columbia coast contained 16.7% fat and 72.3% moisture (Kuhnlein et al. 1996). Mean percent values for eulachon caught at sea in the Gulf of Alaska were 18.8% oil (as total lipid), 11.9% protein, 1.6% ash, and 68.1% moisture (Payne et al. 1999). Similar mean values for sea-caught eulachon in the eastern Bering Sea were 19.9% oil (as total lipid), 12.5% protein, 1.5% ash, and 66.7% moisture (Payne et al. 1999). Of 14 species of forage fish in the Gulf of Alaska and Bering Sea, eulachon had the highest oil content (16.8–21.4%) and the lowest moisture content (64.6–70.8%) (Payne et al. 1997, 1999). No significant differences in composition of eulachon were seen between the Gulf of Alaska and the Bering Sea when fish of a common size range collected in the same season of the year were compared (Payne et al. 1999).

In the Gulf of Alaska, eulachon were found to have the lowest mean moisture content (64%), lowest mean ash content as a percentage of dry mass (4%), highest dry mass energy value (7.7 kcal/g), and highest wet mass energy value (2.6 kcal/g) among 18 fish and 5 squid species analyzed (Perez 1994). These energetic values were obtained using bomb calorimetry (Perez 1994). Payne et al. (1999) derived a mean value for eulachon wet mass energy of 2.47 kcal/g derived from calculations of caloric content using energy coefficients for protein and oil from Gulf of Alaska eulachon. These eulachon energy values were the highest in relation to moisture content of the 13 forage fish analyzed (Payne et al. 1999). Similarly, Anthony et al. (2000) reported that eulachon had the highest mean lipid content (50% of dry mass) among 39 forage fish species analyzed in the Gulf of Alaska. Eulachon also had a much higher water content as a percent of wet mass (71%) than would be expected given its high lipid content (Anthony et al. 2000). A sample of 34 eulachon (141–202 mm standard length [SL]) also had the second highest mean energy density, after northern lampfish (*Stenobrachius leucopsarus*): 6.5 kcal/g (27.2 kJ/g) dry mass or 1.8 kcal/g (7.49 kJ/g) wet mass (Anthony et al. 2000).

Iverson et al. (2002) examined fat content and fatty acid composition in 26 species of fish and invertebrates in Prince William Sound, Alaska. Fat content of 20 eulachon samples taken in spring were uniformly the highest in fat content and ranged 15–25% fat with a mean value of 19% fat (Iverson et al. 2002). The next highest fat content was found in adult herring, which ranged 7–20% fat with a mean value of 14% fat (Iverson et al. 2002). Eulachon possessed unique fatty acid signatures that "differed most from all other finfish, cephalopod, or crustacean species studied" (Iverson et al. 2002, p. 177). Eulachon in Prince William Sound had "extremely high levels of 18:1n-9, moderately high levels of 14:0 and 16:1n-7, and extremely low levels of polyunsaturated fatty acids such as 20:5n-3 and 22:6n-3" (Iverson et al. 2002, p. 177). The dietary source of this unique fatty acid signature in eulachon is currently unknown (Iverson et al. 2002).

The apparent differences in fat content between eulachon samples in the Columbia River (6.3% fat; Stansby 1976), Knight Inlet on the British Columbia coast (16.7% fat, Kuhnlein et al. 1996), and in the Gulf of Alaska (19% fat, Payne et al. 1999, Iverson et al. 2002) likely had a significant impact on American Indian and First Nations uses for these fish. MacLachlan (1998, p. 183) stated that:

> On the northern coast, eulachon were a major source of oil, but on the Fraser, as on the Columbia, they were eaten fresh or smoked whole. A difference in oil content may have been the basis of this difference in use.

# Reproduction and Development

### Sex Ratio

Many studies have reported that sex ratios in eulachon are either biased in favor of males (Smith and Saalfeld 1955, Kubik and Wadman 1977, 1978, Franzel and Nelson 1981, Higgins et al. 1987, Lewis 1997, Lewis et al. 2002, Moffitt et al. 2002, Spangler 2002, Spangler et al. 2003) or are highly variable depending on time and location of sampling (McHugh 1939, Hart and McHugh 1944, Langer et al. 1977, Pedersen et al. 1995). On the other hand, Hay and McCarter (2000) and Hay et al. (2002) report that the ratio of spawning male to female eulachon in their gill net samples from the Fraser River in 1995–2002 was approximately 1 to 1, with the exception of 1998 when the sex ratio was 1.7 to 1.

All reports of eulachon sex ratio should be viewed with caution, as proportions of male to female eulachon have been reported to vary with fishing gear type, distance upriver, distance from the river shoreline, time of the day, and migration time (McHugh 1939, Langer et al. 1977, Moffit et al. 2002, Lewis et al. 2002, Spangler 2002, Spangler et al. 2003). Langer et al. (1977, p. 33) reported that “sex ratios varied with location, within the duration of the run, and between years in the Nass River.” Lewis (1997) suggested that sex ratios skewed in favor of males may be due to longer residence time of male eulachon in freshwater compared to females. Moffit et al. (2002) postulated that as spawning commences, females may avoid the riverbank and disperse to the center of the river, thus skewing sex ratios calculated from dip net sampling along riverbanks. Spangler (2002) and Spangler et al. (2003) reported that sampling with different gear types (gill nets versus dip nets) resulted in different sex ratios in the Twentymile River, Alaska. However, Franzel and Nelson (1981) reported that fishing gear did not significantly change the sex ratio of eulachon captured in the Stikine River, Alaska.

Mc Hugh (1939) and Hart and McHugh (1944) reported that the sex ratio varied during the fishing season in 1939 and 1941 in the Fraser River; males predominated in the early part of the eulachon run, but in the latter part females came to predominate. A similar situation may obtain in the Columbia River basin, where WDFW and ODFW (2001, p. 15) stated that analysis of sex ratios indicated that “female return timing is skewed later than that of males,” although females never appear to dominate. Pedersen et al. (1995, p. 16) reported that earlier studies in the Nass River had found “a changing sex ratio during the spawning season,” whereas another study based on daily monitoring had found 55% males and 45% females. Lewis et al. (2002) also reported changing sex ratios over the duration of the eulachon run in the Kemano River, British Columbia; however, there appeared to be two pulses of female returns, and males rather than females appeared to dominate the later part of the run. The proportion of males was also found to increase as the run progressed in 1971 on the Nass River (Langer et al. 1977) and at Flag Point Channel on the Copper River in 1998 and 2000–2002 (Moffit et al. 2002).

The overall sex ratio reported by Smith and Saalfeld (1955) for the Columbia River basin was 4.5 males to 1 female. Similarly, Higgins et al. (1987) and Rogers et al. (1990) found a sex ratio of 3.4 males to 1 female in Fraser River samples collected in April 1986 and Rogers et al. (1990) reported the ratio to be 5.9 to 1 in 1988. Sex ratios in the early 1930s in Cowlitz River dip net, Lewis River dip net, and Columbia River gill net samples were 3.2 to 1, 12.3 to 1, and 6.8 to 1, respectively (Smith and Saalfeld 1955). In 1946 sex ratios in commercial fisheries were 10.5 to 1 in the Cowlitz River and 2.8 to 1 in the Sandy River, which may reflect the bias in the fishery for the more marketable male eulachon (Smith and Saalfeld 1955). Since males dominate the early part of the run in the Columbia River, they are more prevalent in both the sport and commercial fisheries, which preferentially target the first fish to return (WDFW and ODFW 2001).

Sex ratio of male to female eulachon in the Kemano River, British Columbia, ranged from 1.1 to 1 to 10.7 to 1 with a mean of 4.4 to 1 between 1989 and 1997; however, when weighted by fish abundance over the duration of the run, the true sex ratio was estimated at 1.6 to 1 (Lewis et al. 2002, p. 72). Males predominated in upriver locations in both 1970 and 1971 in the Nass River (Langer et al. 1977). However, in the Fraser River the proportion of male to female eulachon was independent of the distance of upriver capture (along a 31 km gradient) among April 1986 (Higgins et al. 1987, Rogers et al. 1990) and April/May 1988 (Rogers et al. 1990) samples.

Franzel and Nelson (1981) found that gill net–sampled eulachon in the Stikine River, Alaska, over two years had a sex ratio of males to females of 17.5 to 1. Eulachon sex ratios on the Copper River, Alaska, and nearby systems were also dominated by males in all samples (Moffitt et al. 2002). The percentages of males at Flag Point Channel on the Copper River in 1998, 2000, 2001, and 2002 were 78%, 60%, 72%, and 69%, respectively. At 60-km Channel on the Copper River in 2002, males represented 61%–85% of the captured eulachon (Moffit et al. 2002). On the Copper River delta, the percentages of males in 1998 and 2000 were 91% and 66%, respectively, in Alaganik Slough and ranged from 82% to 98% in January to February 2001 in Ibeck Creek (Moffit et al. 2002). Eulachon collected in Twentymile River, Alaska, from May 15 to June 2, 1976, and from April 29 to June 5, 1977, had a cumulative sex ratio of 5 males to 1 female (n = 204) (Kubik and Wadman 1977) and 7.4 males to 1 female (n = 408) (Kubik and Wadman 1978), respectively. Sampling by dip net in the Twentymile River resulted in male to female ratios of 6.7 to 1 in 2000 (n = 394) and 2.1 to 1 in 2001 (n = 2,711) (Spangler 2002, Spangler et al. 2003). Barrett et al. (1984) reported average male to female sex ratios of prespawning eulachon of 1.6 to 1 in late May 1982, 1.3 to 1 in early June 1982, 1.2 to 1 in mid-May 1983, and 0.6 to 1 in mid-May and early June 1983. Spawning and postspawning ratios were higher due to the shorter stream residence time of female eulachon (Barrett et al. 1984).

Smith and Saalfeld (1955, p. 22) first hypothesized "that the type of spawning of smelt may necessitate an excess of males." Moffitt et al. (2002, p. 26) postulated that in the case of eulachon, which broadcast-spawn eggs and sperm in fast moving rivers, "a large number of males upstream may increase the probability of egg fertilization." Spangler et al. (2003, p. 46) also postulated that a sex ratio skewed in favor of males "may be a key element to successful spawning" and that "fertilization would increase with more available milt in the water increasing the probability of eggs being fertilized." Hay and McCarter (2000, p. 23) stated that spawning involves groups of fish and eulachons must closely synchronize the timing of spawning between sexes, because the duration of sperm viability in freshwater is short, perhaps only minutes. Interestingly, Langer et al. (1977, p. 32) reported on a second-hand observation of spawning in eulachon, suggesting that a group of males simultaneously released milt upstream of a group of females that laid their eggs as the milt drifted over the downstream female eulachon. Lewis et al. (2002, p. 83) observed spawning eulachon in the Kemano River, British Columbia and reported that:

> At night in the riffles, males lay next the females, beside them and on top of them. We observed small puffs of milt and eggs drifting in the water. We interpret this behaviour as egg laying behaviour because we had not seen it during the day and because we examined rocks at the site during daylight hours … and discovered eggs adhering to the rocks.

## Fecundity

Hart and McHugh (1944) noted that fecundity in the Fraser River ranged about 17,300–39,600 eggs in female eulachon measuring 145–188 mm SL. Average fecundity was about 25,000 eggs per female (Hart and McHugh 1944, Hart 1973). Smith and Saalfeld (1955, p. 22) report a fecundity of 20,000–60,000 for female eulachon ranging 140–195 mm length from the Columbia River. Both Clemens and Wilby (1967) and McPhail and Lindsey (1970) report fecundity to be about 25,000 eggs in an average size female. Hay and McCarter (2000) reported total fecundity range of 20,000–40,000 eggs, the number generally increasing with fish size. Depending on fish size, fecundity can range 7,000–31,000 eggs on the Columbia River (Parente and Snyder 1970, WDFW and ODFW 2001).

Mean total fecundity in Fraser River eulachon ranged from a low of about 31,200 to a high of about 34,100 when estimated between 1995 and 1998 (Hay et al. 2002). Mean relative fecundity (total fecundity divided by female body weight) of Fraser River eulachon ranged from a low of 683 eggs/g in 1995 to a high of 898 eggs/g in 1997 (Hay et al. 2002). There are significant differences in fecundity among years in Fraser River eulachon, which are likely related to "significant interannual differences in mean size (length and weight)" (Hay et al. 2002, p. 11).

Mean fecundity of 58 eulachon from the Kitimat River, British Columbia, in 1993 was about 22,900 eggs with a range of 3,242 to 47,798 (Pedersen et al. 1995). Relative fecundity in the Kitimat River was calculated at 504 eggs/g female body weight (Pedersen et al. 1995). Based on 5 years of data, mean eulachon fecundity in Kemano River, British Columbia, was about 27,000 and ranged 6,744–57,260 eggs. Mean relative fecundity of Kemano River eulachon over this 5-year data set was 544 eggs/g female body weight (Lewis et al. 2002).

Mean fecundity of eulachon in the Copper River, Alaska, was estimated at about 35,520 (range: 12,202–52,722) in 2000 and 36,200 (range: 18,645–62,855) in 2001 (Moffitt et al. 2002). From these data, Moffitt et al. (2002) estimated relative fecundity of eulachon from the Copper River in 2000 and 2001 as 790 and 792 eggs/g female body weight, respectively. Fecundity in the Twentymile River, Alaska, ranged from as low as 8,530 to as high as 67,510 and reportedly increased with increasing length, weight, and age (as determined by otolith increment analysis) (Spangler 2002, Spangler et al. 2003).

## Homing

Smith and Saalfeld (1955, p. 12) examined migration behavior of eulachon in the Columbia River and its tributaries and stated that:

> The so-called "homing instinct," influencing fish to return as adults to the stream in which they were hatched, has not been established for smelt. … The irregularity of the runs into the various tributaries virtually precludes the existence of a home tributary influence.

McCarter and Hay (1999) and Hay and McCarter (2000) argue that both the short time eulachon larvae spend in the natal freshwater environment and their small size would preclude their ability to imprint on a spawning river. Eulachon larvae are very small, 4–6 mm in length, weigh only a few mg at hatching, and are flushed into the estuarine environment almost as soon as they rise into the water column. Hay and McCarter (2000, p. 13) noted that eulachon larvae are so small that they "may lack the necessary physiological tissue (i.e., olfactory rosette and associated nervous system memory capacity)" to imprint on the freshwater natal spawning river. However, eulachon larvae may spend weeks to months in nearby estuarine environments where they grow significantly in size and may develop the capacity to imprint on large estuaries and eventually home to these areas as adults (McCarter and Hay 1999, Hay and McCarter 2000). These considerations would suggest that large river estuaries, inlets, and fjords may serve as the smallest stock structure unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005).

## Spawn Timing

McCarter and Hay (1999, p. 12) emphasized that:

> Based on concepts developed from observation of spawning of Pacific salmon, the timing of [eulachon] spawning runs should be biologically adapted to each river. If so, and if the same model is applied to eulachons, then each population would be adapted to each river.

However, several authors emphasize that there is no clear latitudinal (Hay and McCarter 2000, Cambria Gordon 2006) or other pattern (Hay et al. 2002) apparent in eulachon spawn timing (Table A-9, Figure 5). Over the whole range of eulachon from northern California to the southeastern Bering Sea, Hay and McCarter (2000, p. 17) noted that:

> the most southern runs (i.e., the California and the Columbia River runs) are early, beginning in late January, whereas some of the Alaska runs are much later (May), although not too dissimilar to [eulachon in] the Fraser [River, which run in April through May].

However, eulachon have been known to spawn as early as January in rivers on the Copper River delta of Alaska (Moffitt et al. 2002), as late as May in northern California, and from January to April in various subbasins of the Columbia River (Table A-9, Figure 5, and Figure 6). Analysis

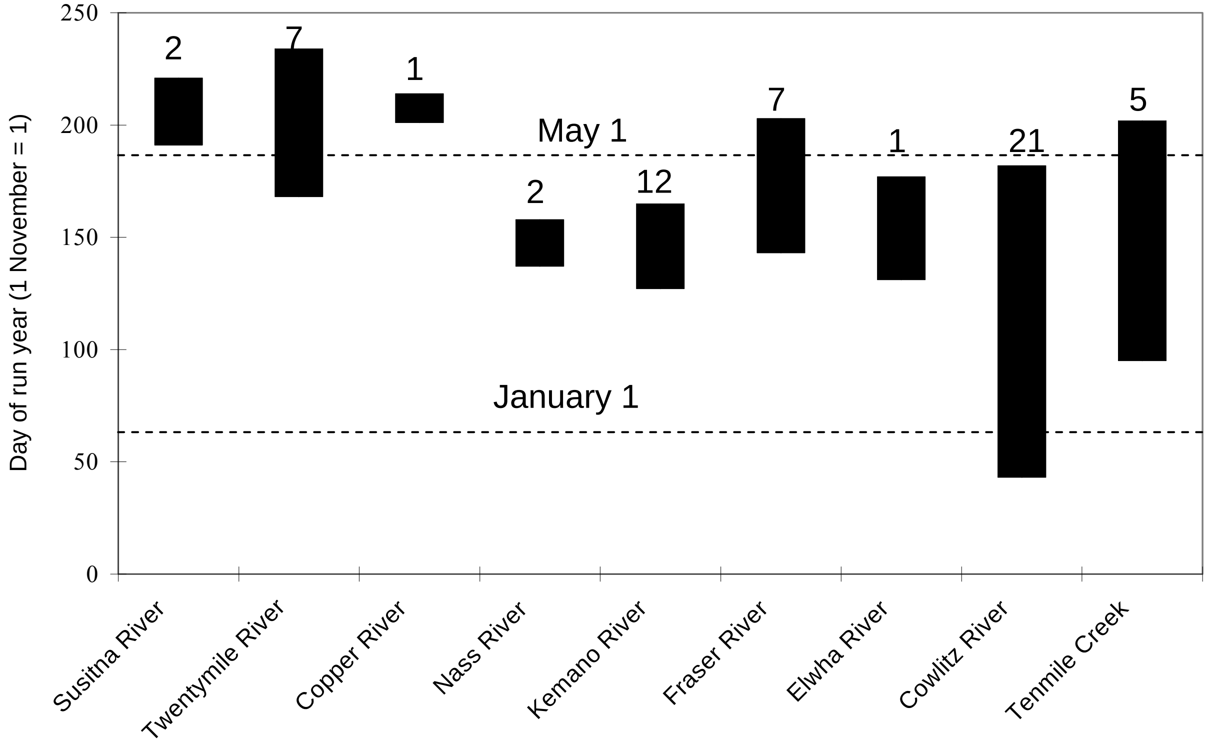



Figure 5. Duration of reported eulachon spawn timing in various river systems arranged north to south from left to right on the x-axis. Dates of spawn timing have been converted relative to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each system. Data from Barrett et al. (1984, reported in Spangler et al. 2003), ADFG (1972, 1973, 1974, reported in Spangler et al. 2003), Kubik and Waldman (1977, 1978), Spangler (2002), Spangler et al. (2003), Morstad (1998, reported in Spangler et al. 2003), Langer et al. (1977), Lewis et al. (2002), Hay et al. (2003), Shaffer et al. (2007), B. James,[4] and WDFW and ODFW (2008).

of spawn timing as a stock identifier in eulachon is also complicated by observed variation in the duration of spawn timing from year to year, the presence of multiple spawning runs in some rivers, and observations of eulachon returning earlier in recent years in some systems relative to historical data (Moody 2008).

## California

Historically, eulachon runs in northern California were said to start as early as December and January and peak in abundance during March and April (Table A-9). Larson and Belchik (1998, p. 5) reported that:

> The timing of the Klamath, Redwood Creek, and Mad River spawning migrations were similar to the Columbia's runs, which usually begin in December and January (S. King, ODFW, pers. comm.). The Klamath run continued until around May with peak occurrence between March and April.

[4] B. James, WDFW, Vancouver, WA. Pers. commun., 12 May 2008.

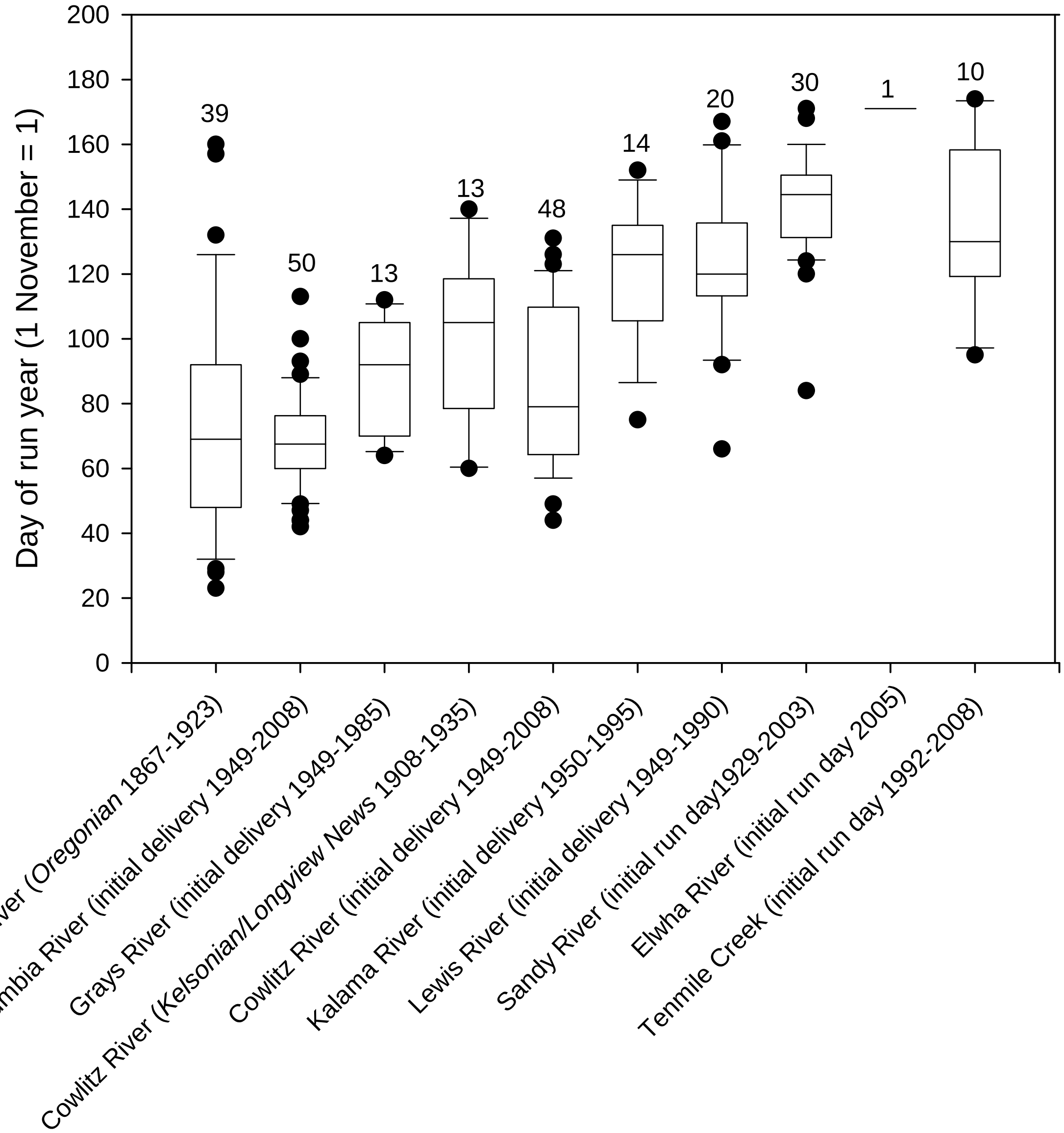



Figure 6. Box plots of the initial day of river entry in various river systems as reported in local newspapers (Appendix B and Smith et al. 1953), commercial fishery deliveries (B. James[5]), Shaffer et al. (2007), and WDFW and ODFW (2008). Dates of initial river entry or fishery delivery have been converted to the day of the run year beginning on November 1. Numbers above plots indicate the total years of data available for each data set.

Similarly, Young (1984) reported on the collection or observation of adult eulachon in the Klamath River and Redwood Creek in April 1978 and in the Klamath River in March and April in both 1979 and 1980. Young (1984, p. 62) further stated that eulachon begin their migration in the Klamath River "in January in small numbers well before the main spawning runs (more than one may occur) in March and April, and then continuing on a smaller scale."

[5] See footnote 4.

## Columbia River and tributaries

Smith and Saalfeld (1955, p. 24) noted that eulachon "may be found in the Columbia River between late December and mid-May." Howell and Uusitalo (2000, p. 3) documented that historically eulachon migration into the Columbia River "begins in December, peaks in February, and continues through May." Bargmann et al. (2005, p. 22) stated that "peak [eulachon] abundance [in the Columbia River] is usually in February, but may be as late as April."

Initial arrival of eulachon in the Columbia River and its tributaries can be estimated from historical landings data in the commercial fishery (WDFW,[6] Howell and Uusitalo 2000) (Figure 6). Documented eulachon landings in the Columbia River have occurred as early as December 13 and as late as February 21 with an average date of around January 8 for the years 1949 to 2008, based on data supplied by WDFW.[7] Based on newspaper accounts of eulachon in the fish markets of Portland, Oregon, from 1867 to 1923 (Appendix B), the earliest date of appearance of eulachon in the Portland markets was November 23 and the mean date of initial appearance was February 12 (Figure 6).

Similarly, documented eulachon landings in the Cowlitz River have occurred as early as December 13 and as late as March 11 with an average date of around January 25 for the years 1949 to 2008, based on data supplied by WDFW.[8] Newspaper accounts of initial appearance of eulachon in the Cowlitz River between 1908 and 1935 were summarized in Smith et al. (1953) and give the earliest date of January 30. In the Grays River between 1949 and 1985, initial eulachon landings occurred as early as January 3 with an average initial date of February 20, based on data supplied by WDFW.[9] In the Kalama River between 1950 and 1995, initial eulachon landings occurred as early as January 14 with an average initial date of April 1, based on data supplied by WDFW.[10] In the Lewis River between 1949 and 1990, initial eulachon landings occurred as early as January 5 with an average initial date of April 16, based on data supplied by WDFW.[11]

WDFW and ODFW (2008) provided the initial arrival dates of eulachon in the Sandy River, Oregon, for the years 1929 to 2008, although no run was recorded in 48 of the 79 years. The earliest appearance of eulachon on the Sandy River occurred on January 23 (the next earliest being February 28) and the latest on April 21, with an average data of initial appearance of about March 21 (Figure 6). Craig (1947, p. 3) stated that eulachon "runs into the Sandy and Lewis rivers normally occur later than those in the Cowlitz." Smith and Saalfeld (1955, p. 13) also noted that "the Cowlitz fish [appear] in the early part of the season, and the Sandy fish nearly two months later." Comparison of average dates of initial landings in the commercial fishery in the Cowlitz River (January 25) and in the Sandy River (March 21) confirm that a nearly two-month period separates the average run timing in these two tributaries (Figure 6).

[6] Statewide eulachon landings database, B. James, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.
[7] See Footnote 6.
[8] See Footnote 6.
[9] See Footnote 6.
[10] See Footnote 6.
[11] See Footnote 6.

## British Columbia

On the mainland coast of British Columbia, earliest eulachon spawning occurs in the far north in February to early March in the Nass River, and the latest spawning occurs in April and May in the Fraser River in the far south (Table A-9, Figure 5). This pattern of spawn timing is reversed from the apparent overall range-wide pattern of eulachon spawning earlier in the south and later in the north (Hay and McCarter 2000). Early researchers variously stated that eulachon enter and spawn in rivers in British Columbia "from the middle of March to the middle of May" (Hart and McHugh 1944, p. 7) or "during March, April, and May" (Clemens and Wilby 1967, p. 123). Hart and McHugh (1944, p. 7) also affirmed that "The time of appearance is fairly constant from year to year in each locality and the runs are apparently of progressively shorter duration from south to north." Similarly, McCarter and Hay (2003, p. 16) noted that:

> In some rivers, such as the Kitimat or Kemano, the time of spawning is relatively early, beginning in early March and in others, such as the Fraser or Klinaklini, the timing is later, beginning in April or May.

**Fraser River**—The early journals of Fort Langley, a Hudson's Bay Company post on the lower Fraser River, indicate that eulachon were observed in the Fraser River on 28–29 April 1828, 14 April 1829, and 4 May 1830 (MacLachlan 1998) (Appendix C). McHugh (1939) suggested that the presence of spent fish in the catch indicated that spawning may occur throughout the two-month period from early April until late May in the Fraser River. Hart and McHugh (1944) sampled eulachon on the Fraser River 12 April–19 May 1939 and 4 April–8 May 1940. Ricker et al. (1954, p. 1) noted that historically the eulachon fishery operated in the Fraser River "between the middle of March and the middle of May, from the mouth of the river up to Mission and Matsqui." More recently, Hay et al. (2002, p. 20) stated that eulachon enter the Fraser River "in late March and April to spawn" and Stables et al. (2005) recorded the capture of eulachon by trawl net in late April and early May of both 2001 and 2002.

**Kitimat River**—In 1993 eulachon spawned in the lower 4 km of the Kitimat River March 20–30 (Pedersen et al. 1995). Peak spawning in 1997 occurred March 7–19 (Kelson 1997).

**Kemano River**—Lewis et al. (2002) reported that eulachon run timing in the Kemano River extended from late March to early April in 1980 and typically lasted from March 22 to April 10 between the years 1988 and 1998. Females entered the Kemano River in two distinct pulses separated in time by from several days up to 10 days (Lewis et al. 2002). Typically the run duration was about 15 days in the Kemano River, "ranging from 4 to 20 days" and "over the 11 year study [1988–1998] there was a trend for the eulachon run to begin and end earlier" perhaps in "response to changing sea temperatures" (Lewis et al. 2002, p. 68).

**Skeena River**—Adult eulachon were present in the Skeena River March 10–20, 1997 (Lewis 1997). Historically, the Skeena River eulachon run was reported to occur between early February and late March (Lewis 1997).

**Nass River**—Swan (1881) noted that two spawning runs of eulachon appear in the Nass River, one that normally begins between March 16 and 22, but sometimes occurs as late as March 28 to April 4, and a second run that enter the river towards the end of June. Langer et al.

(1977, p. 45) verified that eulachon typically enter the Nass River in mid-March, peaking in late March, and the run may extend into mid-April and may consist of "two overlapping spawning waves."

### Alaska

Moffitt et al. (2002, p. 3) stated that "eulachon enter river systems from January through early July" in Alaska. Eulachon typically spawn in early April in the Taku River in Southeast Alaska and may migrate beneath river ice to reach the spawning grounds (Flory 2008b). Franzel and Nelson (1981) reported that the eulachon run in the Stikine River, Alaska, in 1979 and 1980 occurred in early April soon after spring breakup and lasted for up to 3 to 4 weeks. Marston et al. (2002, p. 231) reported that eulachon spawning runs in 1995–1997 in the Antler and Berners rivers in Berners Bay in Southeast Alaska began between May 3–6 and lasted 10–12 days, "although spent fish or a few late spawners remained in the rivers until the end of May." More recently, eulachon have spawned in mid to late April in Berners Bay rivers (Flory 2008a), spawning 26 April–14 May 2004 in the Antler River in particular (Eller and Hillgruber 2005).

**Chilkat and Chilkoot rivers**—Krause (1885) indicated that two runs of eulachon occurred in the Chilkat River region of Southeast Alaska, a February run and a separate run in late April to mid-May. The later run was characterized as larger in both numbers and individual fish size (Krause 1885). Mills (1992, p. 8) stated that the main eulachon run occurred "between mid and late May" on the Chilkat River. Betts (1994, p. 19) reported that both the Chilkat and Chilkoot rivers supported two runs of eulachon, "a small run in February, and en masse most commonly in mid-May." Eulachon harvest on the Chilkat River occurred 1–7 May 1990 and 6–16 May 1991 (Betts 1994). On the nearby Chilkoot River, harvest occurred 6–9 May 1990 and 9–16 May 1991 (Betts 1994). Betts (1994) also reported that salmon fishwheels on the Chilkat River caught eulachon 7 May–17 June 1991. Eulachon reportedly spawn in several rivers in the Yakutat region of Alaska in March to early June (Rogers et al. 1980).

**Copper River delta**—Eulachon run timing in the Copper River, Alaska, and in nearby rivers of the Copper River delta is variable, and in many cases two runs separated by weeks to months have been observed in the same rivers (Moffitt et al. 2002, Joyce et al. 2004) (Table A-9). Eulachon were observed in the Eyak River on the western Copper River delta 16–23 June 2002, but did not appear in Ibeck Creek in 2002, a tributary of the Eyak (Joyce et al. 2004). In 2003 there were two separate eulachon runs observed in the Eyak River, February 15–22 and June 9–13. Eulachon were observed in the tributary Ibeck Creek 28 January–17 March 2001 (Moffitt et al. 2002) and 15 February–1 March 2003 (Joyce et al. 2004). On the central Copper River delta, eulachon were present in Alaganik Slough as early as 9 February 2001 (Moffitt et al. 2002), 9–16 June 2002, and during two periods in 2003, February 23–26 and May 29 to June 15 (Joyce et al. 2004). In the Copper River itself, eulachon were present as early as May 19 and as late as May 24 at Flag Point Channel between 1998 and 2002, and the duration of the run lasted 8–14 days (Moffitt et al. 2002). Eulachon were present at Flag Point 20 May–2 June 1998, 19–28 May 2000, 19–30 May 2001, 24 May–6 June and 16–24 June in 2002, and 1–5 March and 17–19 April 2003 (Joyce et al. 2004). Eulachon were also present at 37-mile Bridge on the Copper River 16–23 June 2003 (Joyce et al. 2004).

**Twentymile River**—The eulachon run in the Twentymile River "spanned a period of 25 days between May 13 and June 6" in 1976 (Kubik and Wadman 1977, p. 37) and "44 days from April 23 to June 5" in 1977 (Kubik and Wadman 1978, p. 54) (Table A-9). Spangler (2002) and Spangler et al. (2003) cited an additional 7 years of observations in the Twentymile River where the spawn period ranged 18–54 days. Eulachon were captured in the Twentymile River by dip nets 4 May–21 June and 17 April–9 June in 2000 and 2001 (Spangler 2002, Spangler et al. 2003). Spangler (2002, p. 27) stated that "the eulachon run lasts over a longer period of time in the Twentymile River than in any other river for which data are available." In contrast, other researchers have stated that the duration of eulachon spawning migrations decreases from south to north (Hart and McHugh 1944, Scott and Crossman 1973).

**Susitna River**—Based on the presence of adults, two runs of eulachon were observed on the Susitna River in Southcentral Alaska in 1982 (May 16–30 and June 1–8) and 1983 (May 10–17 and May 19 to June 8) (Barrett et al. 1984, Vincent-Lang and Queral 1984). Initial eulachon run timing likely precedes these early dates for the first run, as fish were present as soon as sampling was possible following ice breakup in both years (Vincent-Lang and Queral 1984). Actual spawning occurred on the Susitna River May 21–31 and June 4–9 in 1982, and May 15–22 and May 23 to June 5 in 1983 (Barrett et al. 1984).

### Multiple spawning runs

A number of rivers are reported to have two or even more separate spawning runs of eulachon, including the Chilkat River (Krause 1885, Betts 1994), Chilkoot River (Betts 1994), Copper River (Moffitt et al. 2002, Joyce et al. 2004), and Susitna River (Vincent-Lang and Queral 1984) in Alaska, and the Nass River (Swan 1881, Langer et al. 1977) and Kingcome River (Berry and Jacob 1998) in British Columbia. Based on adult run timing, Langer et al. (1977) suggested there could be up to three waves of spawning on the Nass River. Berry and Jacob (1998, p. 4) reported that there appeared to be four waves of eulachon spawning activity in the Kingcome River, British Columbia, in 1997, "with peaks on April 2, April 15, April 21, and May 2." There may also have been an earlier eulachon spawning event in March and a later one in early June in the Kingcome River (Berry and Jacob 1998), based on the presence of eggs and larvae; however, experience in other river systems raises the possibility that some of these eggs and larvae may have been confused with those of sculpins (cottids) (Kelson 1997). Indications of eulachon spawning in May and June, based on egg and larval presence, in the Kitimat (Pedersen et al. 1995), Skeena (Lewis 1997), and other rivers on the central and north coast of British Columbia are suspect, due to the presence of sculpin larvae in these rivers that may have been misidentified as eulachon larvae (Kelson 1997).

## Semelparity versus Iteroparity

Numerous references (McPhail and Lindsey 1970, Hart 1973, Scott and Crossman 1973, Samis 1977, Garrison and Miller 1982, Lewis et al. 2002) cite Barraclough (1964) as evidence that eulachon may be iteroparous. In fact, Barraclough (1964, p. 1,337) noted that the presence of dead eulachon found in the Columbia and Fraser rivers indicates many die after spawning. The evidence in Barraclough (1964, p. 1,337) that eulachon may be iteroparous occurs in the statement that: "spent eulachon in good condition caught by trawlers in the Strait of Georgia off the mouth of the Fraser River suggest that some eulachon recover after spawning, and may spawn a second time." However, it is uncertain whether the spent eulachon observed at the mouth of the Fraser River, as reported by Barraclough (1964), recovered and lived long enough to spawn in a subsequent season. Some additional secondary sources indicate that some eulachon are iteroparous (WDFW and ODFW 2001, Mecklenburg et al. 2002, LCFRB 2004b). According to WDFW and ODFW (2001, p. 4), "although adults can repeatedly spawn, most die after spawning." Mecklenburg et al. (2002, p. 175) stated that "most [eulachon] die after spawning, but some survive to spawn once more."

Earlier authorities (McHugh 1939, Hart and McHugh 1944, Clemens and Wilby 1946, Ricker et al. 1954, Smith and Saalfeld 1955) reported that eulachon were semelparous (spawn once in their lifetime and die soon after spawning). McHugh (1939) and Hart and McHugh (1944) noted that the outer edge of the scales in spawning eulachon in the Fraser River were resorbed and showed a characteristic clear margin. This region of the scale is commonly called a spawning mark or spawning check. However, these authors found no eulachon with a previous year's spawning check and "concluded that none of the fish examined had spawned in a previous year" (McHugh 1939, p. 21). Similarly, Langer et al. (1977, p. 39) stated that "since no spawning checks were noted on any scales from the Nass River, repeat spawning is probably minor or nonexistent on the Nass." Eulachon in the Kemano River also showed no evidence of spawning checks on the otoliths (Lewis et al. 2002). Smith and Saalfeld (1955, p. 25) reported that:

> All available evidence indicates that smelt die after one spawning. In all spawning studies where live smelt were allowed to spawn in the confines of [a] hatchery trough, death followed extrusion of the spawn. In addition, commercial fisherman, who fish in the Columbia River after the smelt run, report the tremendous abundance of dead smelt on the river bottom.

The evidence is strong that most, if not all, eulachon in the southern portion of the range (south of about 54°N latitude) are semelparous (Hay and McCarter 2000, Hay 2002, Hay et al. 2002, 2003), "although there may be some iteroparity (survive spawning) at higher latitudes, in Alaska" (Hay et al. 2003, p. 2). Hay et al. (2002, 2003) presented three lines of evidence for semelparity in eulachon from British Columbia: 1) direct observation of postspawning mortality in the form of beached and floating carcasses in many rivers, 2) only eulachon with well developed teeth are found at sea, whereas all spawning eulachon observed in the Fraser River have undergone substantial tooth loss and resorption, and 3) the largest size class of eulachon in British Columbia are found in rivers during the spawning runs and are much larger than any eulachon caught anywhere in the nearby ocean. However, retention of teeth in significant numbers of spawning eulachon in the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003), indicates that some of these fish may survive spawning, return to the sea, and begin feeding again. Teeth retention rates in spawning eulachon in the Twentymile River were 84% and 97% for females, and 3% and 32% for males in 2000 and 2001, respectively (Spangler 2002, Spangler et al. 2003).

Although age determination in eulachon has not been validated (see above discussion in the Age Composition subsection, p. 35), Lewis et al. (2002) examined age composition as estimated from otolith increments of prespawning eulachon captured in a fishery and postspawning carcasses on the Kemano River and reported that the carcass sample had:

> a greater proportion of fish age 5 years [than did the prespawning sample] (31% versus 21%) and a lower proportion age 3 (18% versus 41%) and 4 years (51% versus 38%). Based on these data, we reject the null hypothesis that Kemano River eulachon are semelparous.

However, Clarke et al. (2007) reported that the pattern of seasonal oscillations in barium and calcium deposited in eulachon otoliths (see discussion in Age Composition subsection on page 36) and the lack of a freshwater strontium signal in otoliths of spawners indicate that eulachon are semelparous. Comparison of length frequencies of eulachon at sea and in the Kemano River also indicate that Kemano River eulachon are semelparous, and are estimated to spawn at age 3 (Clarke et al. 2007). Otoliths of eulachon that had spawned in freshwater in a previous season would be expected to show a corresponding decrease in the strontium to calcium ratio representative of this time spent in freshwater; however, this was not evident in otolith samples from any of five river systems (Clarke et al. 2007). Strontium to calcium ratios are much higher in bony structures of fish secreted while in the marine compared to freshwater environment, have been used to detect migration of fish between these two environments in many studies, and can detect exposure to freshwater conditions of as little as 6 hours. This study "supports the hypothesis that [eulachon] are semelparous" (Clarke et al. 2007, p. 1,490).

## Spawn Behavior

### Selection of spawn substrate

Eulachon eggs were reportedly preferentially laid on sand in both the Fraser (McHugh 1940, Hay et al. 2002) and Nass rivers (Langer et al. 1977). Eggs were primarily found attached to pea-sized gravel and only secondarily on sand in the Columbia River (Smith and Saalfeld 1955). Eggs laid in areas of silt or organic debris reportedly suffer much higher mortality than those laid over sand or gravel (Langer et al. 1977). Although eulachon eggs are most commonly laid on a sand substrate, eggs have been found on silt, gravel to cobble–sized rock, and organic detritus (Smith and Saalfeld 1955, Langer et al. 1977, Vincent-Lang and Queral 1984, Lewis et al. 2002).

### Estuary spawning

Based on movements of adult eulachon tracked with gastrically implanted radio tags in the Twentymile River, Spangler (2002) and Spangler et al. (2003) speculated that a portion of the eulachon population in this river may have spawned in the estuary. Some tagged fish moved in and out of the lower river and did not move upstream of the tagging site. Spangler et al. (2003, p. 52) stated that "if fish are capable of spawning in the estuary, larval sampling [and thus abundance estimation methodology] could be missing a segment of the population leading to erroneous results." However, Armstrong and Hermans (2007, p. 4) cite an unpublished study indicating that eulachon egg survival is reduced on exposure to salinities of 16 ppt and greater, and thus successful spawning in estuarine salinities greater than this is unlikely.

### Spawn migration

According to Spangler et al. (2003, p. 2), "There are no consistently reported environmental factors known to influence spawning run timing of adult eulachon throughout their range." These factors include water temperature, tide height, and river discharge rates (Spangler 2002, Spangler et al. 2003). However, both water temperature and river discharge rate are cited as factors that may initiate upriver migration of eulachon in local river basins (Ricker et al. 1954, Smith and Saalfeld 1955, Langer et al. 1977).

**Spawn temperature**

It is apparent that "the temperature at which eulachon spawning runs commence varies by geographic area" (Spangler 2002, p. 71); however, a clear pattern is not readily discernible. Columbia River eulachon are reported to spawn at temperatures between 4ºC and 10ºC and that the spawning migration is inhibited at temperatures less than 4ºC (WDFW and ODFW 2001). In 2001, most eulachon avoided the Columbia River until mid-February when the temperature rose above 4ºC (Howell et al. 2001). Spawning in the Fraser River reportedly occurs "at temperatures exceeding 6 or 7ºC whereas temperatures in northern rivers, which sometimes are ice covered during spawning, are much lower" (Hay et al. 2003, p. 2). Mean, minimum, and maximum water temperatures during spawning in the Kemano River in March-April between 1992 and 1998 were 3.1ºC, 1.1ºC, and 6.5ºC, respectively (Lewis et al. 2002). Langer et al. (1977, p. 18) reported that "1971 temperature records from the Nass [River] indicated that peak [eulachon] migration was occurring at temperatures as low as 0–1°C." During the 8-day peak eulachon migration in the Nass River in 1971, the mean daily water temperature ranged from 0.3 to 2.0°C (Langer et al. 1977, their Table 6). Temperature at the onset of the eulachon run in the Twentymile River, Alaska, ranged 2.8–6.0°C (Spangler 2002, Spangler et al. 2003); however, over the entire spawning run temperatures varied "from 1.6°C to 12.7°C in 2000 and from 0.5°C to 10.7°C in 2001" (Spangler et al. 2003, p. 28). Eulachon spawned in the Susitna River, Alaska, in 1982 and 1983 when temperatures ranged about 6–11°C (Barrett et al. 1984, Vincent-Lang and Queral 1984).

**Spawning under ice**

Swan (1881, p. 260) stated that eulachon arrive in the Nass River "about the time the ice begins to break up" and that in "some years the ice remains solid until after the fish are caught, in which case holes have to be cut in the ice to put down the nets." Langer et al. (1977, p. 43) documented this under-ice eulachon fishery on the Nass River in 1969 and stated that "adult migration occurs at colder river temperatures than previously recorded." Hay and McCarter (2000) also noted that spawning may occur under the ice in some northern British Columbia rivers. Eulachon reportedly migrate, and presumably spawn, under the ice on the Unuk River in Southeast Alaska, and this under-ice migratory behavior may have also occurred in the past on the Twentymile River in Southcentral Alaska (Spangler 2002, Spangler et al. 2003). Flory (2008b) reported that in April 2006 on the Taku River in Southeast Alaska, "eulachon schools were observed up river [before ice break up], indicating the fish moved underneath the ice [to] access spawning grounds (E. Jones, pers. comm.)."

**Spawning at night or under low light levels**

Several authors indicate that eulachon mainly spawn at night (Smith and Saalfeld 1955, Parente and Snyder 1970, Lewis 1997) or under low light conditions (Spangler 2002), and this has been suggested as possible predator avoidance behavior (Spangler et al. 2003). Smith and

Saalfeld (1955) reported that captive eulachon always deposited eggs at night, and when partially spent eulachon were captured at night in the Cowlitz River, freshly deposited eggs were sampled on the river bottom the next morning. Lewis et al. (2002, p. 74) reported that "female eulachon migrated into the [Kemano] river to spawn in darkness on high tides, retreating by day to the lower river" and that egg drift was greatest at night in the Kemano River.

### Tidal level during spawning

Periods of low river discharge and high tides are associated with peak adult eulachon migration in both the Nass River, British Columbia (Langer et al. 1977), and the Twentymile River, Alaska (Spangler 2002, Spangler et al. 2003). Higgins et al. (1987, p. 6) were unable to discriminate between interacting effects of light and tide on eulachon migration in the Fraser River but did note that fishing success was best "at dusk on the high slack tide." Lewis et al. (2002) also suggested that eulachon spawning may be tied to nighttime high tides, and noted that "higher tides reduced water velocity, allowing eulachon to swim further upstream."

### Flow velocity and depth during spawning

In the Kemano River, British Columbia, eulachon preferred water velocities from 0.1 to 0.7 m/s (Lewis et al. 2002). Earlier studies on Kemano eulachon indicated that many eulachon are unable to maintain long-term position in the stream at flow velocities greater than 0.3 m/s (Lewis et al. 2002). In the Susitna River, Alaska, "water velocities ranging from 0.5 to 2.5 feet/s [0.2–0.8 m/s] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

McHugh (1940) found the heaviest concentration of eulachon eggs in the Fraser River at a depth of 25 feet (7.6 m). Likewise, Langer et al. (1977) reported eggs to be more abundant at depths greater than 4 m than in shallower waters in the Nass River, British Columbia. In the Columbia River, larval eulachon were recovered in waters from 3 inches (0.1 m) to more than 20 feet (6.1 m) in depth and spent adults have been caught as deep as 75 feet (22.9 m) (Smith and Saalfeld 1955). However, eulachon may live long enough after spawning to be swept far downstream from the spawning grounds, so the presence of spent eulachon may not indicate that spawning occurred in the vicinity. In the Kemano River, British Columbia, eulachon preferred depths between 0.5 and 2.3 m, but used available habitat from 0.2 to more than 4 m in depth (Lewis et al. 2002). In the Susitna River, Alaska, "depths ranging from 0.5 to 3.0 feet [0.2–0.9 m] are most commonly utilized for spawning" (Vincent-Lang and Queral 1984, p. 5).

# Trophic Interactions

## Diet

Larval and juvenile eulachon are planktivorous (WDFW and ODFW 2001). Barraclough (1967) and Robinson et al. (1968b) examined stomach contents of larval (5–15 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June of 1966 and 1967, respectively. Although 5–8 mm FL larvae still possessed a yolk sac, larvae as small as 6 mm FL had fed on copepod nauplii. Other stomach contents of larval (≤15 mm FL) eulachon in the Strait of Georgia included phytoplankton, centric diatoms, copepod metanauplii, copepod eggs, barnacle eggs, rotifers, cladocerans (*Podon* sp.), ostracods, and polychaete larvae (Barraclough 1967, Robinson et al. 1968b).

Barraclough (1967), Barraclough and Fulton (1967), and Robinson et al. (1968a, 1968b) examined stomach contents of postlarval and juvenile (20–69 mm FL) eulachon caught in surface trawls in the Strait of Georgia in early June 1966, July 1966, May 1967, and June 1967. Stomach contents of eulachon in the Strait of Georgia included phytoplankton, barnacle eggs, barnacle nauplii, copepod eggs, copepod nauplii, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Acartia* sp., *Microcalanus pygmaeus*, *Calanus* sp.), cladocerans, ostracods, mysiids, larvaceans (*Oikopleura* sp.), and in one case a larval eulachon (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968a, 1968b). Larger specimens of eulachon (91–157 mm FL) collected in the Strait of Georgia had consumed barnacle eggs, copepods (*Pseudocalanus* sp., *Acartia longiremis*, *Calanus* sp.), cladocerans, and gammaridean amphipods (Robinson et al. 1968a, 1968b).

Smith and Saalfeld (1955, p. 12) stated that the only recognizable prey found in stomachs of adult eulachon captured off Washington in 1948 were abundant "remains of the cumacean, *Cumacea dawsoni*." Other authorities have reported that juvenile and adult eulachon eat primarily "euphausiids and copepods" (Hart 1973, p. 149) or "euphausiids, crustaceans, and cumaceans" (Scott and Crossman 1973, p. 323). Hay (2002, p. 100) stated that "eulachon stomachs from offshore waters indicate that [they] mainly consume the euphausiid *Thysanoessa spinifera*." Yang et al. (2006) examined the stomach contents of 39 eulachon from a single haul in the Gulf of Alaska in 2001 that ranged in size from 160 to 210 mm FL. Food items and their percent of total stomach content weight included mysids (2.7%), cumaceans (2.1%), hyperiid amphipods (5.9%), the euphausiid *T. inermis* (25.8%), other euphausiids (40.8%), larvaceans (1.7%), teleost fish (13.8%), undetermined fish remains (2.6%), and unidentified material (4.6%) (Yang et al. 2006).

## Predators

### Marine mammals

Numerous pinnipeds prey on eulachon both at sea and during eulachon spawning runs, including: 1) Stellar sea lions (*Eumetopias jubatus*) (Beach et al. 1981, 1985, Jeffries 1984, Bigg 1988, Marston et al. 2002, Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009), 2) California sea lions (Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984), 3) northern fur seals (*Callorhinus ursinus*) (Clemens et al. 1936, Spalding 1964, Antonelis and Fiscus 1980, Antonelis and Perez 1984), and 4) harbor seals (Fisher 1947, 1952, Spalding 1964, Pitcher 1980, Beach et al. 1981, 1985, Bowlby 1981, Jeffries 1984, Roffe and Mate 1984, Olesiuk 1993, Marston et al. 2002). Other nonpinniped marine mammal predators on eulachon include baleen whales, beluga whales (*Delphinapterus leucas*) (Moore et al. 2000, Rugh et al. 2000, Speckman and Piatt 2000), humpback whales (*Megaptera novaeangliae*) (Marston et al. 2002, Witteveen et al. 2004), killer whales (*Orcinus orca*), harbor porpoises (*Phocoena phocoena*) (Jeffries 1984), Dall's porpoises (*Phocoenoides dalli*) (Kajimura et al. 1980, Stroud et al. 1981, Jeffries 1984), and white-sided dolphins (*Lagenorhyncus obliquidens*) (Morton 2000).

## Birds

Numerous authors (WDFW and ODFW 2001, Spangler 2002, Willson and Marston 2002, Marston et al. 2002, Maggiulli et al. 2006) report large numbers of gulls (*Larus* spp.), terns (*Sterna* spp.), ducks (Anatidae), bald eagles (*Haliaeetus leucocephalus*), shorebirds (Scolopacidae), corvids, and other birds feeding on live and dead eulachon during spawning events. Documented bird predators on spawning aggregations of eulachon in various river systems are summarized in Table A-10.

Ormseth et al. (2008, their Table 2) listed the estimates of eulachon contribution to seabird diets (percent weight of eulachon in the predator's diet) based on a mass-balance ecosystem model derived from predator diet data in the Gulf of Alaska for the following birds: kittiwakes (*Rissa* spp.) (4.3%), murres (*Uria* spp.) (3.0%), puffins (*Fratercula* spp.) (6.1%), cormorants (*Phalacrocorax* spp.) (3.0%), gulls (*Larus* spp.) (8.2%), shearwaters (*Puffinus* spp.) (5.0%), and albatross/jaeger (3.5%).

## Fish

Numerous fish species have been recorded as consuming eulachon, including spiny dogfish (*Squalus acanthias*) (Chatwin and Forrester 1953, Jones and Geen 1977), green sturgeon (*Acipenser medirostris*) (Fry 1979), Pacific cod (*Gadus macrocephalus*) (Hart 1949, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), walleye pollock (Yang 1993, Yang and Nelson 2000, Yang et al. 2006), Pacific halibut (*Hippoglossus stenolepis*) (Scott and Crossman 1973, Yang 1993, Yang and Nelson 2000, Yang et al. 2006), sablefish (Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006), Pacific hake (Alton and Nelson 1970, Outram and Haegele 1972, Livingston 1983, McFarlane and Beamish 1985, Rexstad and Pikitch 1986, Buckley and Livingston 1997, Buckley et al. 1999), rougheye rockfish (*Sebastes aleutianus*) (Yang and Nelson 2000), and arrowtooth flounder (*Atheresthes stomias*) (Kabata and Forrester 1974, Yang 1993, Buckley et al. 1999, Yang and Nelson 2000, Yang et al. 2006).

Larval and juvenile eulachon have also been reported to be the occasional prey of Pacific herring, surf smelt, Pacific sand lance, kelp greenling (*Hexagrammos decagrammus*), threespine stickleback (*Gasterosteus aculeatus*), steelhead (*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*) salmon in the Strait of Georgia (Barraclough 1967, Barraclough and Fulton 1967, Robinson et al. 1968b). Juvenile white sturgeon (*Acipenser transmontanus*) in the Columbia River are known to consume large quantities of eulachon eggs during spawning events (McCabe et al. 1993). Marston et al. (2002) reported that coho salmon and Dolly Varden (*Salvelinus malma*) may also feed on eulachon eggs and larvae. In addition, juvenile eulachon may occasionally consume larval eulachon (Barraclough 1967, p. 26).

## Other predators

Marston et al. (2002) noted that terrestrial mammals such as bears (*Ursus* spp.), wolves (*Canis lupus*), river otters (*Lontra canadensis*), and mink (*Mustela vison*) likely prey on eulachon either during or after spawning events.

### Parasites

Compilations of parasites and fish hosts in British Columbia (Margolis and Arthur 1979, Kabata 1988, McDonald and Margolis 1995, Gibson 1996) listed two trematodes (*Pronoprymna petrowi* and *Lecithaster gibbosus*), a cestode (*Phyllobothrium* sp.), a nematode (*Contracaecum* sp.), and a parasitic pennellid copepod (*Haemobaphes disphaerocephalus*) as known parasites on eulachon. The trematode *L. gibbosus* was found in stomachs of juvenile eulachon collected in the Strait of Georgia with 29–59 mm FL (Robinson et al. 1968a, 1968b, Barraclough 1967). Similarly, the trematode *P. petrowi* was found in the stomachs of juvenile eulachon collected in the Strait of Georgia with 32–38 mm FL (Barraclough 1967). Arai (1967, 1969) reported the trematode *L. gibbosus*, a larval cestode *Phyllobothrium* sp, and a larval nematode *Contracaecum* sp. in eulachon from Burke Channel, an inlet on the south mainland coast of British Columbia. Hoskins et al. (1976) reported the occurrence of the parasitic copepod *Haemobaphes diceraus* on a eulachon host, from Port Hardy on Vancouver Island, British Columbia. Kabata (1988) and McDonald and Margolis (1995) described another pennellid copepod (*H. disphaerocephalus*) as parasitic on eulachon from British Columbia. Kabata (1988) noted that the report of *H. diceraus* infecting eulachon by Hoskins et al. (1976) occurred before *H. disphaerocephalus* was described as a separate species. The pennellid copepods in the genus *Haemobaphes* attach themselves headfirst to the bulbous arteriosus of the host fish with the body protruding from the gill arch (McDonald and Margolis 1995).

# Information Relating to the Species Question

### Approaches to Addressing Discreteness and Significance

The BRT considered several kinds of information to delineate potential DPS structure in eulachon. To address the discreteness criteria, the BRT primarily considered patterns of genetic variation among eulachon sampled from various locations along the coast, patterns of variation in life history and morphology, and ecological and environmental differences between eulachon populations. Comparison of spawning distribution, spawn timing, meristic variation in vertebral counts, elemental analysis of otoliths, and genetic variation have also been cited as evidence for stock discrimination in eulachon (Hay and McCarter 2000, Beacham et al. 2005, Hay and Beacham 2005). For the significance criteria, the BRT focused primarily on ecological differences among populations and on whether loss of such populations would create a significant gap in the range of the species.

#### Life history and morphology

Isolation between populations may be reflected in several variables, including differences in life history variables (e.g., spawning timing, seasonal migrations), spawning location, parasite incidence, growth rates, morphological variability (e.g., morphometric and meristic traits), and demography (e.g., fecundity, age structure, length and age at maturity, mortality rates), among others. Although some of these traits may have a genetic basis, they are usually also strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and can sometimes be used to infer the degree of independence among populations or subpopulations. Begg et al. (1999) have emphasized the necessity to examine the temporal stability of life history characteristics in order to determine whether differences between populations persist across generations.

**Persistence of spawn location and spawn timing**

Eulachon generally spawn in rivers that are glacier fed or have peak spring freshets. It has been argued that the rapid movement of eggs and larvae by these freshets to estuaries makes it likely that eulachon imprint and home to an estuary into which several rivers drain rather than to individual spawning rivers (McCarter and Hay 1999, Hay and McCarter 2000). Thus the estuary has been invoked as the likely geographic stock unit for eulachon (McCarter and Hay 1999, 2003, Hay and McCarter 2000, Hay 2002, Hay and Beacham 2005) (Table A-1).

Variation in spawn timing among rivers has been cited as indicative of local adaptation in eulachon (Hay and McCarter 2000), although the wide overlap in spawn timing and river entry timing among rivers makes it difficult to discern distinctive geographic patterns in this trait. In general, eulachon spawn earlier in southern portions of their range than in rivers to the north. River entry and spawning begins as early as December and January in the Columbia River system and as late as June in Southcentral Alaska (Table A-9, Figure 5, and Figure 6). However, they have been known to spawn as early as January in rivers on the Copper River delta of Alaska and as late as May in northern California. The general spawn timing pattern is reversed along the coast of British Columbia, where the earliest spawning occurs in the Nass River in the far north in February to early March and the latest spawning occurs in the Fraser River in April and May in the far south (Table A-9, Figure 5). There is also some evidence that different waves or runs of eulachon may occur in some basins, based on run-time separation (Table A-9).

These differences in spawn timing result in some populations spawning when water temperatures are as low as 0–2°C, and sometimes under ice (Nass River, Langer et al. 1977), whereas other populations experience spawning temperatures of 4–7°C (Cowlitz River, Smith and Saalfeld 1955) (Table A-11).

**Morphology**

Differences in the mean number of vertebrae in eulachon from northern and southern rivers in British Columbia have been cited as indicative of population separation (Hart and McHugh 1944, Hay and McCarter 2000), although no differences were evident in population means between the Fraser and Columbia rivers (Hay and McCarter 2000) (Figure 7). However, meristic differences such as these can vary with environmental conditions and it is impossible to determine the underlying causes of these differences from the available data. It has often been shown that the number of vertebrae formed during early development is subject to modification by temperature such that the average vertebral number in fish populations is greater in the northern versus the southern portion of the range and the mean vertebral number in a population may also vary from year to year within a population (McHugh 1954, Waldman 2005). In addition, morphometric and meristic differences between groups of fish are often subtle and relating such differences to a specific degree of isolation among populations can be difficult.

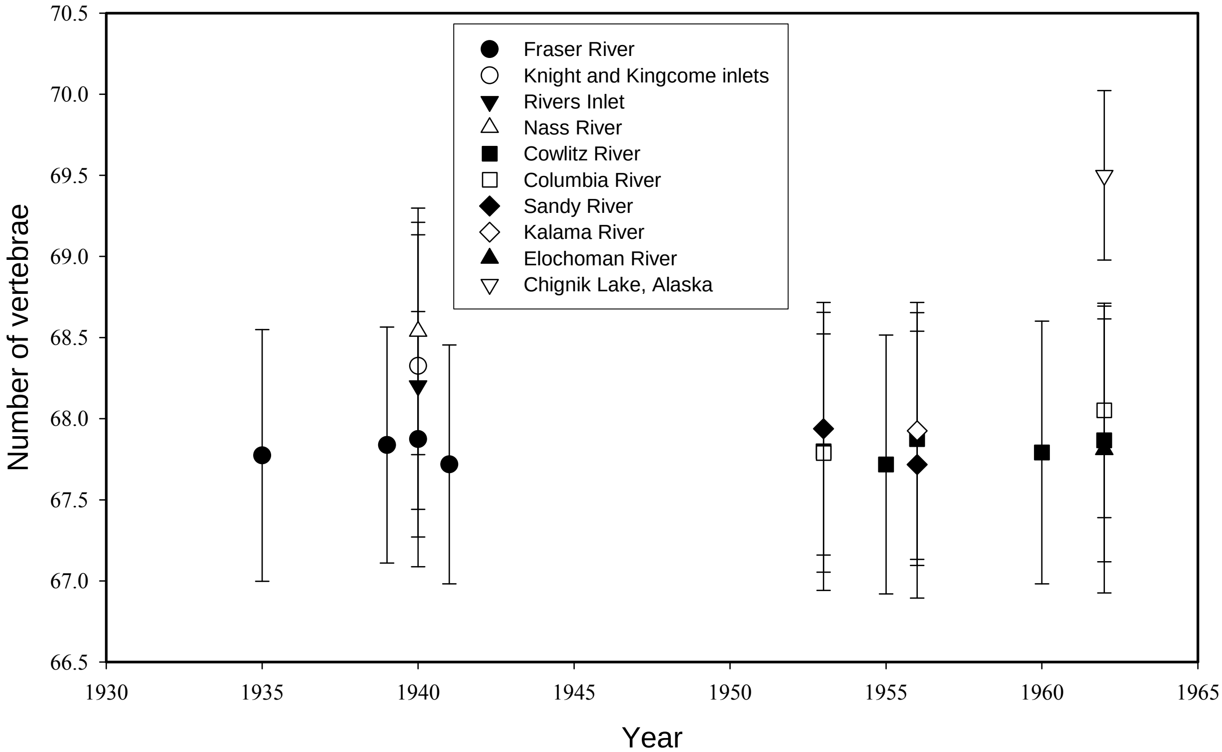



Figure 7. Comparison of mean and standard deviations of eulachon vertebral counts in various rivers. Data from DeLacy and Batts (1963) for the Columbia River, its tributaries, and Chignik Lake. Data from Hart and McHugh (1944) for rivers in British Columbia.

Coastwide, there appears to be an increase in both mean length and weight of eulachon at maturity with an increase in latitude (Table A-7, Table A-8, and Figure 8). Mean eulachon fork length and weight at maturity range from upwards of 215 mm and 70 g in the Twentymile River in Alaska to 175 mm and 37 g in the Columbia River. Although eulachon obtain a larger body size in the northern portion of their range compared to populations in the south, this relationship may be somewhat obscured by problems associated with the ageing of this species (Hay and McCarter 2000). Most Pacific herring also exhibit a latitudinal cline in mean size-at-age, such that Pacific herring in southern locations (e.g., California) exhibit small size and Pacific herring in the north (e.g., Bering Sea) obtain a far larger size at a similar age (Stout et al. 2001a, Gustafson et al. 2006). This pattern is typical of many vertebrate ectotherms where higher rearing temperatures result in reduced size at a given stage of development (Lindsey 1966, Atkinson 1994).

**Otolith chemistry**

Hay and McCarter (2000) and Hay and Beacham (2005) reported on attempts to use differences in the elemental makeup of eulachon otoliths (earbones) to detect stock structure among various rivers on the coast of British Columbia. Significant variation occurred in the elemental analysis associated with the date of the laboratory elemental analysis. Despite these sources of potential error, the results indicated that there were differences in the elemental

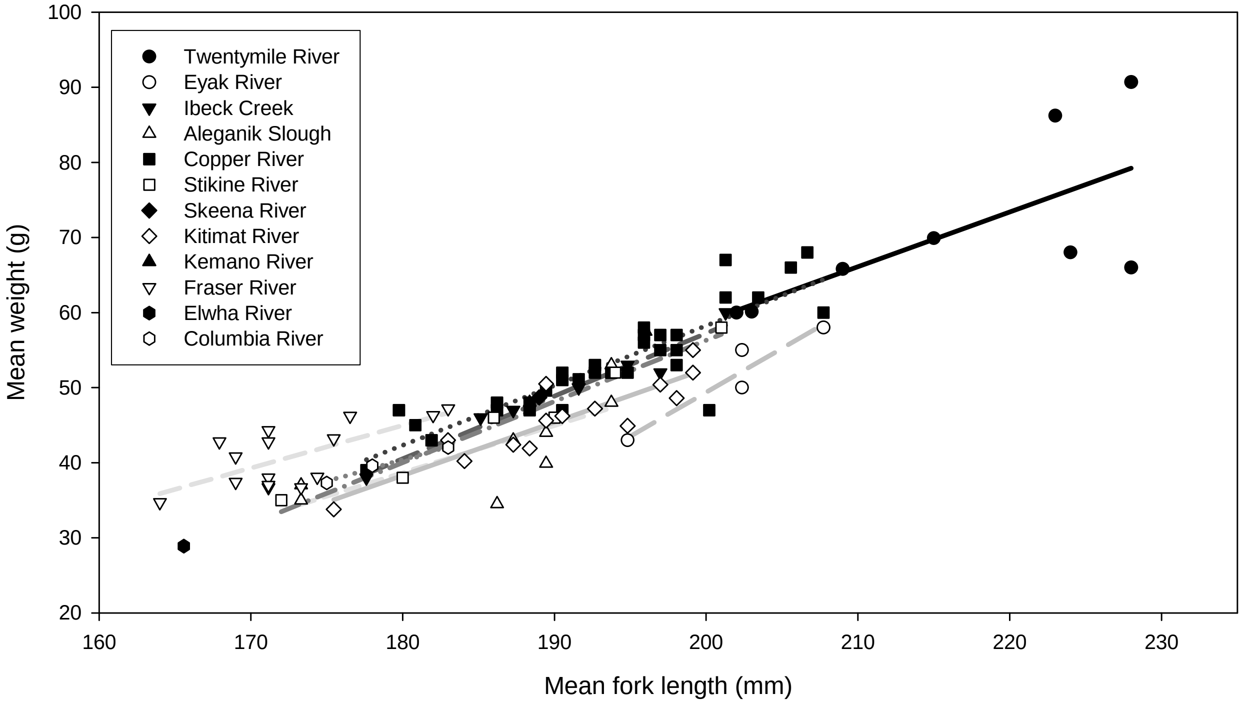



Figure 8. Length-weight relationship of eulachon from various rivers. Standard linear regressions fit the data to lines for each population that has multiple observations. Standard lengths and total lengths have been converted to fork length using equations published in Buchheister and Wilson (2005).

composition of eulachon otoliths over a broad geographic range, but that "elemental analysis was not useful to distinguish between closely adjacent stocks" (Hay and Beacham 2005, p. 10).

## Age composition

Age determination of eulachon has been difficult to validate and estimates of age based on otolith or scale increments may not be accurate (Ricker et al. 1954, Hay and McCarter 2000). However, in general, studies using otolith aging techniques have concluded that some eulachon spawn at age 2 or age 5, but most are age 2 or age 3 at spawning (Willson et al. 2006). Recently, Clarke et al. (2007) pioneered a method to estimate eulachon age at spawning from analysis of variations in barium and calcium in the otoliths. This study indicated that age structure of spawners in the southern areas may be limited to one, or at most, two year classes (Clarke et al. 2007). According to Clarke et al. (2007):

> The number of Ba:Ca peaks measured in the eulachon populations varied; eulachon captured in Barkley Sound, located off the west coast of Vancouver Island (ocean), had 1.5 and 2.5 peaks, Fraser River eulachon were all characterized by 3 peaks, and Columbia River eulachon exhibited 2 or 3 peaks. All of the fish in the Kemano and Skeena rivers examined were characterized by 3 peaks in Ba:Ca with the exception of two Skeena River fish that had 4 peaks. Fish collected from the Copper River in Alaska had 3 or 4 peaks. The number of

peaks in Ba:Ca observed in eulachon otoliths increased with increasing latitude, suggesting that the age at maturity is older for northern populations.

### Genetic differentiation

The analysis of the geographical distribution of genetic variation is a powerful method of identifying discrete populations. In addition, such analysis can sometimes be used to estimate historical dispersals, equilibrium levels of migration (gene flow), and past isolation. Commonly used molecular genetic markers include protein variants (allozymes), microsatellite loci (variable numbers of short tandem DNA repeats), and mtDNA.

One widely used method of population analysis is sequence or restriction fragment length polymorphism (RFLP) analysis of mtDNA, which codes for several genes that are not found in the cell nucleus. mtDNA differs from nuclear DNA (nDNA) in two ways. One way is that recombination is lacking in mtDNA, so that gene combinations (haplotypes) are passed unaltered from one generation to the next, except for new mutations. A second way is that mtDNA is inherited from only the maternal parent in most fishes, so that gene phylogenies correspond to female lineages. These characteristics permit phylogeographical analyses of mtDNA haplotypes, which can potentially indicate dispersal pathways for females and the extent of gene flow between populations (Avise et al. 1987). Although the lack of recombination allows for some types of analysis that are difficult to conduct with other markers (e.g., microsatellites), inferences of population structure (or lack thereof) from mtDNA are limited by the fact that the entire mitochondrial genome is inherited genetically as a single locus. Mitochondrial studies are therefore most useful for detecting deep patterns of population structure, and may not be very powerful for detecting structure among closely related populations.

Microsatellite DNA markers can potentially detect stock structure on finer spatial and temporal scales than can other DNA or protein markers, because of higher levels of polymorphism found in microsatellite DNA (reflecting a high mutation rate). Relatively high levels of variation can increase the statistical power to detect stock structure, particularly among closely related populations. In addition, microsatellite studies usually involve analysis of multiple genetic loci, which increases the power to detect differentiation among populations.

The BRT reviewed four published genetic studies of genetic population structure in eulachon. One of these studies (McLean et al. 1999) used RFLP analysis to examine variation in mtDNA. The other studies (McLean and Taylor 2001, Kaukinen et al. 2004, Beacham et al. 2005) analyzed microsatellite loci. Additional detail on two of these studies can be found in McLean (1999).

McLean et al. (1999) examined mtDNA variation in two fragments (each containing two genes NADH-5/NADH-6 and 12S/16S rRNA) in 285 eulachon samples collected at 11 freshwater sites ranging from the Columbia River to Cook Inlet, Alaska, and also in 29 ocean-caught fish captured in the Bering Sea. Samples were taken at two sites (Columbia and Cowlitz rivers) in two years and all other locations were sampled in single years. Overall, 37 mtDNA composite haplotypes were observed in the study. Two haplotypes were found in all sampling locations and together accounted for approximately 67% of the samples in the study. Eight additional haplotypes were present at multiple sites and the remaining 27 haplotypes were "private" (found only in one location).

An analysis of the nucleotide substitutions separating the 37 haplotypes revealed that the haplotypes were all closely related, with the number of substitutions ranging between 1 and 13. The mtDNA haplotypes clustered into two major groups and the frequencies of the two haplotype groups differed among sampling sites, particularly in the Alaska and Bering Sea collections compared to samples from further south, although these differences were not statistically significant. Approximately 97% of mtDNA variation occurs within populations and about 2% is found among regions ($F_{ST}$ = 0.023). McLean et al. (1999) also found that genetic distance among sampling locations was correlated with geographic distance ($r^2$ = 0.22, $P$ = 0.0001). Based on these results, McLean et al. (1999) concluded that there was little genetic differentiation among distinct freshwater locations throughout the eulachon range. However, McLean et al. (1999) noted that association of geographic distance and genetic differentiation among eulachon populations suggested an emerging population subdivision throughout the range of the species.

In a later study, McLean and Taylor (2001) used five microsatellite loci to examine variation in the same set of populations as McLean et al. (1999). The populations in the Columbia and Cowlitz rivers were represented by 2 years of samples with a total sample size of 60 fish from each river. However, several populations were represented by very few samples including just 5 fish from the 3 rivers in Gardner Canal and just 10 fish from the Fraser River. Results from a hierarchical analysis of molecular variance test were similar to that of the McLean et al. (1999) mtDNA study, with 0.85% of variation occurring among large regions and 3.75% among populations within regions.

Tests of differentiation were significant among several pairs of populations in the microsatellite study (27% of tests after correction for multiple comparisons), particularly comparisons that included populations in the Columbia and Cowlitz rivers and those with the Nass River sample and samples taken further south. $F_{ST}$ (a commonly used metric to evaluate population subdivision) was estimated as 0.047 when sample sites were considered separately, and was significantly different from zero. In contrast to the mtDNA analysis, genetic distances among populations using these five microsatellite loci were not correlated with geographic distances. Overall, however, McLean and Taylor (2001) concluded that their microsatellite results were mostly consistent with the mtDNA findings of McLean et al. (1999) and that both studies indicated that eulachon have some degree of population structure.

The most extensive study of eulachon, in terms of sample size and number of loci examined, is that of Beacham et al. (2005). Beacham et al. (2005) examined microsatellite DNA variation in eulachon collected at 9 sites ranging from the Columbia River to Cook Inlet, Alaska, using the 14 loci developed by Kaukinen et al. (2004). Sample sizes per site ranged from 74 fish in the Columbia River to 421 from the Fraser River. Samples collected in multiple years were analyzed from populations in the Bella Coola and Kemano rivers (2 years of sampling) and also in the Nass River (3 years of sampling).

Beacham et al. (2005) observed much greater microsatellite diversity within populations than that reported by McLean and Taylor (2001) and all loci were highly polymorphic in all of the sampled populations. Significant genetic differentiation was observed among all comparisons of the nine populations in the study and $F_{ST}$ values for pairs of populations ranged from 0.0014 to 0.0130. A cluster analysis of genetic distances showed genetic affinities among the populations in the Fraser, Columbia, and Cowlitz rivers and also among the Kemano, Klinaklini, and Bella Coola rivers along the central British Columbia coast. In particular, there was evidence of a genetic discontinuity north of the Fraser River, with Fraser and Columbia/Cowlitz samples being approximately 3–6 times more divergent from samples further to the north than they were to each other (Figure 9). Similar to the mtDNA study of McLean et al. (1999), Beacham et al. (2005) also found that genetic differentiation among populations ($F_{ST}$) was correlated with geographic distances ($r = 0.34$, $P < 0.05$).

Beacham et al. (2005) found stronger evidence of population structure than the earlier genetic studies, and concluded that their results indicated that management of eulachon would be appropriately based at the level of the river drainage. In particular, the microsatellite analysis showed that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels. The authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish, but less than that observed in most salmon species.

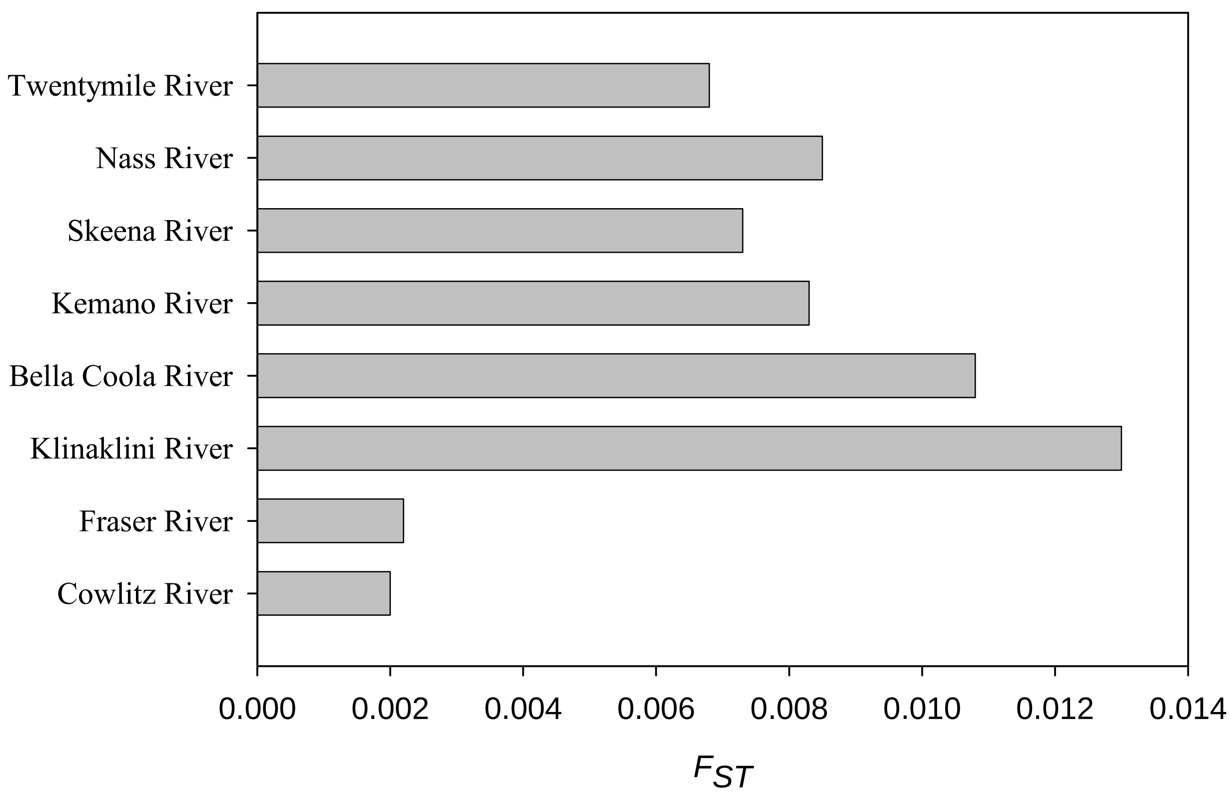



Figure 9. Comparison of $F_{ST}$ (a measure of genetic distance) values of the Columbia River eulachon sample to other samples. Data are from Beacham et al. (2005, their Table 4). See Beacham et al. (2005, their Figure 1) for sampling locations.

Although Beacham et al. (2005) found clear evidence of genetic structure among eulachon populations, the authors also noted that important questions remained unresolved. The most important one in terms of identifying a DPS or DPSs for eulachon is the relationship between temporal and geographic patterns of genetic variation. In particular, Beacham et al. (2005) found that year-to-year genetic variation within three British Columbia coastal river systems was similar to the level of variation among the rivers, which suggests that patterns among rivers may not be temporally stable. However, in the comparisons involving the Columbia River samples, the variation between the Columbia samples and one north-of-Fraser sample from the same year was approximately five times greater than a comparison within the Columbia from two different years. Taken together, there appears to be little doubt that there is some genetic structure within eulachon and that the most obvious genetic break appears to occur in southern British Columbia north of the Fraser River. To fully characterize genetic relationships among eulachon populations, additional research will be needed to identify appropriate sampling and data collection strategies.

### Ecological features

The analysis of ecological features or habitat characteristics may be informative in identifying population segments that occupy unusual or distinctive habitats, relative to the biological species as a whole. One of the criteria that may be useful for evaluating discreteness as articulated in the joint DPS policy (USFWS-NMFS 1996) relates to the population being "markedly separated from other populations of the same taxon as a consequence of … ecological … factors." In addition, the persistence of a discrete population segment in an ecological setting unusual or unique for the taxon is also a factor identified in the joint DPS policy that may provide evidence of the population's significance. Oceanographic and other ecological features may also contribute to demographic isolation between marine populations.

**Freshwater (spawning) environment**—The presumed fidelity with which eulachon return to their natal river, estuary, inlet, or area implies a close association between a specific stock and its freshwater or estuarine environment. Differences in life history strategies among eulachon populations or stocks may have arisen, in part, in response to selective pressures of different freshwater and estuarine environments. If the boundaries of distinct freshwater or estuarine habitats coincide with substantial differences in life histories, it would suggest a certain degree of local adaptation. Therefore, identifying distinct freshwater, terrestrial, and climatic regions may be useful in identifying eulachon DPSs.

The Environmental Protection Agency has established a system of ecoregion designations based on soil content, topography, climate, potential vegetation, and land use for the conterminous United States (Omernik 1987) and Alaska (Gallant et al. 1995). Historically, the distribution of eulachon in Washington, Oregon, and California corresponds closely with the Coastal Range Level III Ecoregions as defined in Omernik and Gallant (1986) and Omernik (1987). Similarly, Environment Canada (2008) has established a system of ecozones and ecoregions in Canada. Ecozones in Canada have been described as "areas of the earth's surface representative of large and very generalized ecological units characterized by interactive and adjusting abiotic and biotic factors." Each ecozone consists of numerous ecoregions that are described as "a part of a province characterized by distinctive regional ecological factors, including climatic, physiography, vegetation, soil, water, fauna, and land use" (Environment Canada 2008).

**Coastal range ecoregions of the United States**—Extending from the Olympic Peninsula through the Coast Range proper and down to the Klamath Mountains and the San Francisco Bay area, this region is influenced by medium to high rainfall levels due to the interaction between marine weather systems and the mountainous nature of the region. Topographically, the region averages about 500 m in elevation, with mountain tops under 1,200 m. These mountains are generally rugged with steep canyons. Between the ocean and the mountains lies a narrow coastal plain composed of sand, silt, and gravel. Tributary streams are short and have a steep gradient; therefore, surface runoff is rapid and water storage is relatively short term during periods of no recharge.

These rivers are especially prone to low flows during times of drought. Regional rainfall averages 200–240 cm per year, with generally lower levels along the southern Oregon coast. Average annual river flows for most rivers in this region are among the highest found on the West Coast when adjusted for watershed area. Peak flow of coastal rivers occurs during winter rain storms common in December and January. Snow melt adds to the surface runoff in the spring, providing a second flow peak (spring freshet), and there are long periods when the river flows are maintained at a level of at least 50% of peak flow. During July or August there is usually little or no precipitation; this period may expand to 2 or 3 months every few years. River flows are correspondingly at their lowest and temperatures at their highest during August and September, with the exception of glacier fed systems. The region is heavily forested primarily with Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Forest undergrowth is composed of numerous types of shrubs and herbaceous plants.

**Terrestrial ecozones and ecoregions of Canada**—All rivers that support regular runs of eulachon in British Columbia are within the Pacific Maritime Ecozone, which consists of 14 ecoregions (Figure 10). The Lower Mainland, Pacific Ranges, and Coastal Gap ecoregions contain rivers supporting regular runs of eulachon as defined in Hay and McCarter (2000) and Hay (2002), and two rivers, the Nass and the Skeena, drain out of the Nass Basin Ecoregion (Environment Canada 2008).

The Lower Mainland Ecoregion (196 in Figure 10) is dominated by the Fraser River and occupies the Fraser River valley from Chilliwack and the Cascade Range foothills downstream to the Fraser River delta and northward from there to incorporate the Sunshine Coast. Mean summer and winter air temperatures in this region are 15°C and 3.5°C, respectively. At sea level, less than 10% of winter precipitation falls as snow, although maximum precipitation occurs in the winter. Mean annual precipitation in the Fraser River valley ranges from 200 cm in the Cascade foothills to 85 cm at the river's mouth. Douglas fir *(Pseudotsuga menziesii*) dominates native forest stands with an understory typically containing hollyleaved barberry, aka tall Oregon grape (*Mahonia aquifolium*), salal (*Gaultheria shallon*), and mosses. Disturbed sites are commonly dominated by stands of red alder (*Alnus rubra*). Drier natural sites consist of mixed stands of Pacific madrone (*Arbutus menziesii*), Douglas fir, western hemlock, and occasionally, Pacific dogwood (*Cornus nuttallii*). Wetter areas contain mixtures of western red cedar, Douglas fir, and western hemlock. Soils consist of unconsolidated clay-like and silty

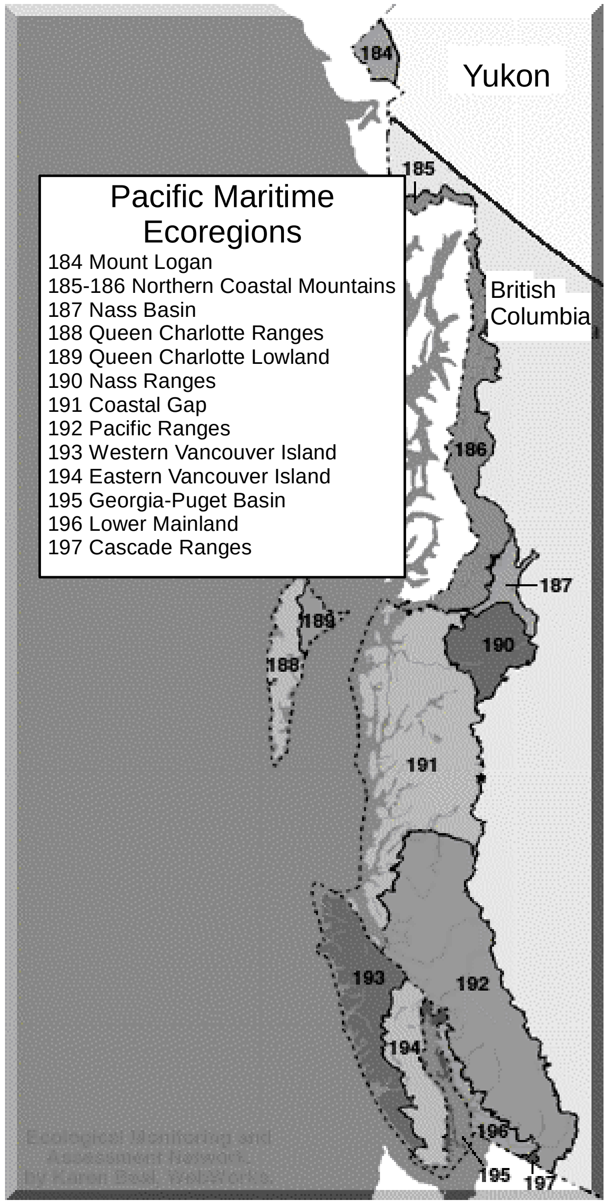



Figure 10. Ecoregions in the Pacific Maritime Ecozone of British Columbia. Map modified from online source: http://ecozones.ca/english/zone/PacificMaritime/ecoregions.html.

marine deposits, silty alluvium, glacial till, and glaciofluvial deposits. Eastern hills in the ecoregion up to 310 m in height are formed from bedrock outcrops of Mesozoic and Paleozoic age.

The Pacific Ranges Ecoregion (192 in Figure 10) extends from the southern extent of the steeply sloping irregular Coast Mountains at the U.S.-Canada border to Bella Coola in the north. These mountains range from sea level to as high as 4,000 m and are made up of granite and crystalline gneisses. Many rivers in this region originate in expansive ice fields, and numerous glaciers extend into the lowlands. Many steep-sided, transverse valleys bisect these mountains and terminate in inlets or fjords. Mean summer and winter air temperatures in this region are

13.5°C and –1°C, respectively. Mean annual precipitation in this ecoregion ranges from 340 cm at high elevations to 150 cm at sea level. This ecoregion consists of three main regions distinguished by altitude: an alpine zone above 1,800 m, a subalpine zone between 900 and 1,800 m, and a coastal forest zone below 900 m. The coastal forest zone is dominated by stands of western red cedar, western hemlock, and Pacific silver fir (*Abies amabilis*) and in drier sites by Douglas fir and western hemlock.

The Coastal Gap Ecoregion (191 in Figure 10) extends from Dean Channel north to the border between British Columbia and Alaska and is bounded by the taller Pacific Ranges to the south and the Boundary Ranges to the north. The low-relief mountains in this ecoregion consist of the Kitimat Ranges, which rarely reach higher than 2,400 m and are made up of granitic rocks and crystalline gneisses. Although many inlets and fjords bisect this mountainous coastline and terminate in steep-sided, transverse valleys, glaciers are less common and smaller than in areas to the south and north of this ecoregion. Mean summer and winter air temperatures are 13°C and –0.5°C, respectively. This ecoregion has the highest mean annual precipitation in British Columbia, ranging from 200 cm on the coast to more than 450 cm at high elevations. At sea level, the forests are dominated by western red cedar, yellow cedar (*Chamaecyparis nootkatensis*), and western hemlock. Some Sitka spruce and shore pine (*Pinus contorta* var. *contorta*) are also present with red alder being common on disturbed sites. Low-lying bogs and stream fens are common types of wetlands. Forests in upland areas are dominated by western red cedar and western hemlock, whereas Pacific silver fir and western hemlock are found in areas with poorer drainage.

The Nass Basin Ecoregion (187 in Figure 10) lies between the interior and coastal portions of the Coast Mountains in west-central British Columbia and is an area of low relief composed of folded Jurassic and Cretaceous sediments that is almost encircled by mountains. The Nass Basin is drained by the Nass and Skeena rivers to the ocean through large gaps in the Coast Mountains and consists of a gently rolling landscape generally below 750 m in altitude. Mean summer and winter air temperatures in this region are 11.5°C and –9.5°C, respectively. Mean annual precipitation ranges up to 250 cm at higher elevations to 150 cm in the lowlands. The moist montane zone is dominated by western red cedar and western hemlock, whereas forests in the subalpine zone contain subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta* var. *latifolia*), and Engelmann spruce (*Picea engelmannii*).

**Oceanic environment**—Ware and McFarlane (1989) built on previous descriptions of oceanic domains in the northeast Pacific Ocean by Dodimead et al. (1963) and Thomson (1981) to identify three principal fish production domains: 1) a southern Coastal Upwelling Domain, 2) a northern Coastal Downwelling Domain, and 3) a central Subarctic Domain (aka the Alaskan Gyre) (Figure 11). The boundary between the Coastal Upwelling Domain and Coastal Downwelling Domain occurs where the eastward flowing Subarctic Current (aka the North Pacific Current) bifurcates to form the north-flowing Alaska Current and the south-flowing California Current in the vicinity of a transitional zone between the northern tip of Vancouver Island and the northern extent of the Queen Charlotte Islands (Figure 11). Similarly, Longhurst (2006) identifies an Alaska Downwelling Coastal Province and a California Current Province within the Pacific Coastal Biome.

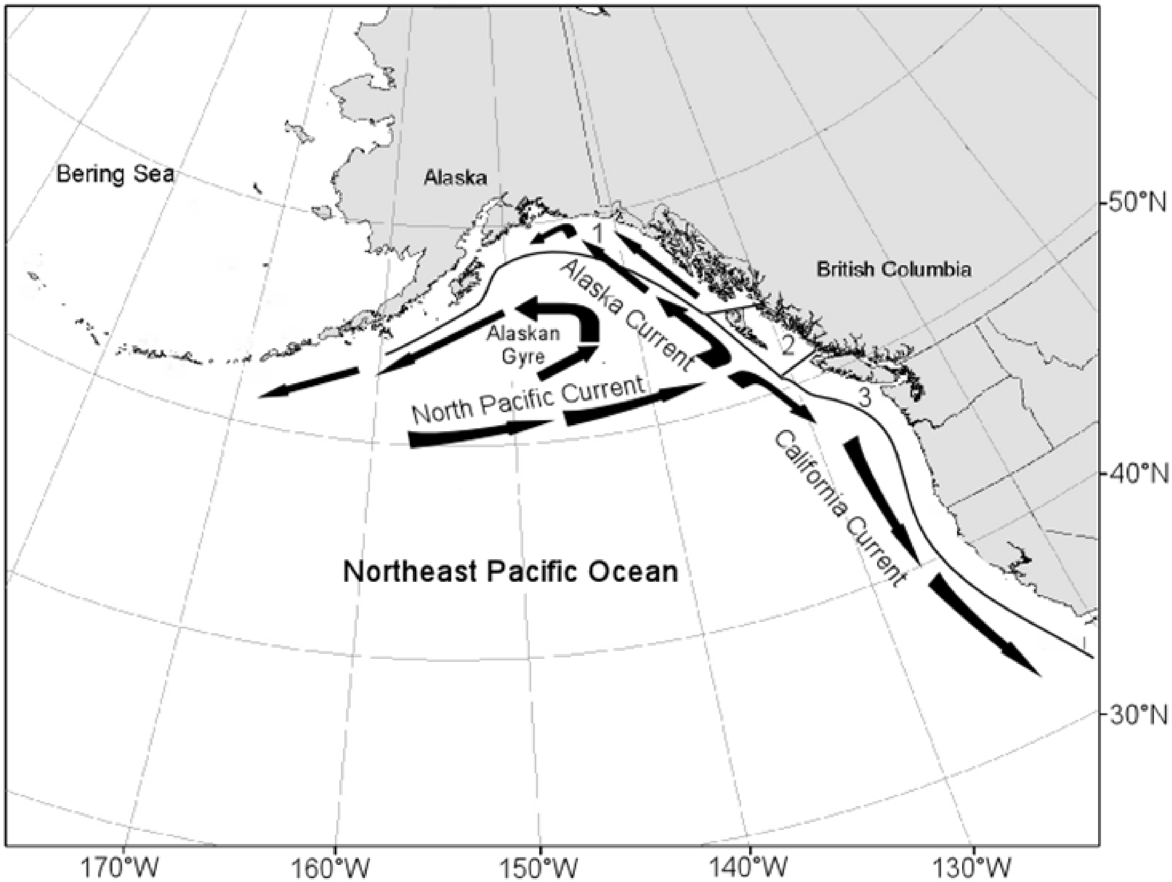



Figure 11. Approximate locations of oceanographic currents, oceanic domains (Ware and McFarlane 1989), and coastal provinces (Longhurst 2006) in the Northeast Pacific Ocean. 1–Alaska Coastal Downwelling Province (aka Coastal Downwelling Domain), 2–Transition Zone, and 3–California Current Province (aka Coastal Upwelling Domain).

Longhurst's (2006) work provides a worldwide ecological geography of the sea that identifies 4 primary oceanic biomes and 51 biogeochemical provinces based mainly on differences in regional physical processes that act on regional patterns of phytoplankton growth that are partially defined by "the interaction between light, nutrients, mixing, and stability in the upper part of the water column." This scheme to partition the ocean into provinces differs from previous attempts by relying on oceanographic features that drive phytoplankton ecology rather than on biogeography of species or water current patterns alone (Longhurst 2006). The steps taken and data analyzed to define biogeochemical provinces in the ocean are detailed in Longhurst (2006).

Within Longhurst's (2006) Pacific Coastal Biome, ocean distribution of eulachon spans the Alaska Downwelling Coastal Province and the northern portion of the California Current Province (Figure 11). Longhurst (2006) places the boundary between the Alaska Coastal Downwelling Province and the California Current Province between the Queen Charlotte Islands at 53°N latitude and the northern end of Vancouver Island at 47–48°N latitude, where the eastward flowing North Pacific Current encounters the North American continent and bifurcates to form the north-flowing Alaska Current and south-flowing California Current. Different modes of physical forcing and nutrient enrichment characterize these provinces.

The Alaska Coastal Downwelling Province spans the coastal boundary region from the Aleutian Islands east and south to the Queen Charlotte Islands (Haida Gwai'i) at about 53°N latitude and extends seaward to the Alaska Current velocity maximum (Longhurst 2006). The continental shelf in this region is dominated by nearly year-round onshore downwelling winds. Large amounts of precipitation and runoff from melting glaciers along the mountainous Alaska coast is another feature of this province. In summer and fall, when runoff is at maximum, waters in the fjord-like coastline and in the Alaska Coastal Current are usually highly stratified in both temperature and salinity. Following the spring phytoplankton bloom, stratification in the top layers of the water column limits nutrient availability and leads to subsequent nutrient depletion. Occasional wind events lead to temporary local upwelling of nutrients and subsequent phytoplankton blooms.

The northern extent of the California Current Province (aka California Upwelling Coastal Province) begins where the eastward flowing North Pacific Current splits near Vancouver Island near 47–48°N latitude, creating the southward flowing California Current and northward flowing Alaska Coastal Current (Longhurst 2006). The southern boundary of this province occurs off the southwest tip of Baja California, where the North Equatorial Current begins. Seasonal wind-driven upwelling is a dominate feature of this province, especially in the northern portion of the province. This process carries nutrients onshore where they are upwelled along the coast, leading to high primary production that lasts through much of the spring and summer. Nearshore upwelling also results in higher salinities and lower temperatures compared to offshore locations.

A widely recognized Transition Pacific Zone (Ware and McFarlane 1989, BC Ministry of Sustainable Resource Management 2002) occurs between the Alaska Coastal Downwelling and California Current provinces whose "northern boundary is indistinct and approximately coincident with the southern limit of the Alaskan Current" (BC Ministry of Sustainable Resource Management 2002, p. 35). This zone is characterized as a mixing area between boreal plankton communities to the north and temperate plankton communities to the south, and incorporates the waters of Queen Charlotte Sound and Hecate Strait (i.e., north of Vancouver Island and inshore of the Queen Charlotte Islands). In the summer, the California Current may affect the southern portion of this transition zone with the inshore Davidson Current flowing south in the summer and north in the winter (BC Ministry of Sustainable Resource Management 2002).

### Marine zoogeographic provinces

Marine zoogeography attempts to identify regional geographic patterns in marine species' distribution and delineate faunal provinces or regions based largely on the occurrence of endemic species and of unique species' assemblages (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988). These province boundaries are usually coincident with changes in the physical environment such as temperature and major oceanographic currents. Similar to the above ecological features category, boundaries between zoogeographic provinces may indicate changes in the physical environment that are shared with the species under review.

Ekman (1953), Hedgpeth (1957), and Briggs (1974) summarized the distribution patterns of coastal marine fishes and invertebrates and defined major worldwide marine zoogeographic zones or provinces. Along the coastline of the boreal eastern Pacific, which extends roughly from Point Conception, California, to the eastern Bering Sea, numerous schemes have been proposed for grouping the faunas into zones or provinces. A number of authors (Ekman 1953, Hedgpeth 1957, Briggs 1974, Allen and Smith 1988) have recognized a zoogeographic zone within the lower boreal eastern Pacific that has been termed the Oregonian Province.

Another zone in the upper boreal eastern Pacific has been termed the Aleutian Province (Briggs 1974). However, exact boundaries of zoogeographic provinces in the eastern boreal Pacific are in dispute (Allen and Smith 1988). Briggs (1974) and Allen and Smith (1988) reviewed previous literature from a variety of taxa and from fishes, respectively, and found the coastal region from Puget Sound to Sitka, Alaska, to be a gray zone or transition zone that could be classified as part of either of two provinces: Aleutian or Oregonian (Figure 12). The southern boundary of the Oregonian Province is generally recognized as Point Conception, California, and the northern boundary of the Aleutian Province is similarly recognized as Nunivak in the Bering Sea or perhaps the Aleutian Islands (Allen and Smith 1988).

Briggs (1974) placed the boundary between the Oregonian and Aleutian provinces at Dixon Entrance, based on the well-studied distribution of mollusks, but indicated that distributions of fishes, echinoderms, and marine algae gave evidence for placement of this

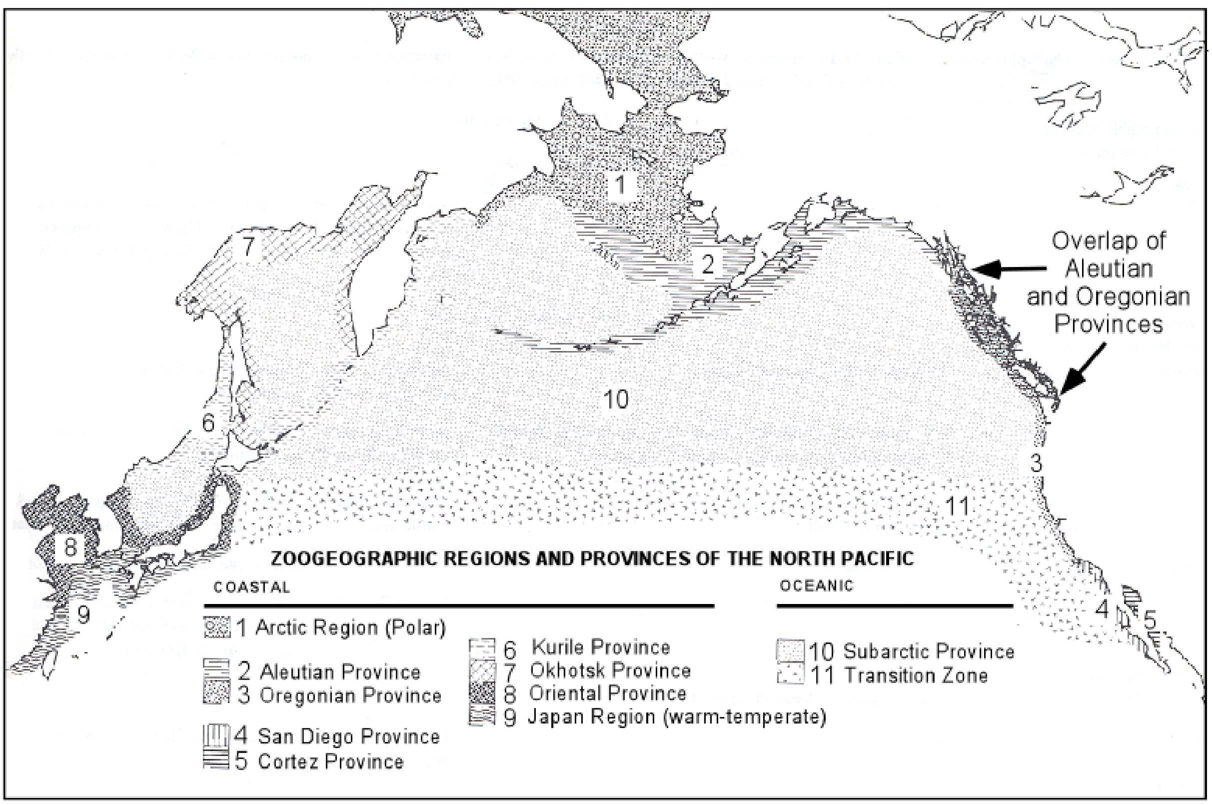



Figure 12. Marine zoogeographic provinces of the North Pacific Ocean. Modified after Allen and Smith (1988).

boundary in the vicinity of Sitka, Alaska. Briggs (1974) placed strong emphasis on the distribution of littoral mollusks (due to the more thorough treatment this group has received) in placing a major faunal break at Dixon Entrance. The authoritative work by Valentine (1966) on distribution of marine mollusks of the northeastern Pacific shelf showed that the Oregonian molluscan assemblage extended to Dixon Entrance with the Aleutian fauna extending northward from that area. Valentine (1966) erected the term Columbian Subprovince to define the zone from Puget Sound to Dixon Entrance.

Several lines of evidence suggest that an important zoogeographic break for marine fishes occurs in the vicinity of Southeast Alaska. Peden and Wilson (1976) investigated the distributions of inshore fishes in British Columbia and found Dixon Entrance to be of minor importance as a barrier to fish distribution. A more likely boundary between these fish faunas was variously suggested to occur near Sitka, Alaska, off northern Vancouver Island, or off Cape Flattery, Washington (Peden and Wilson 1976, Allen and Smith 1988). Chen (1971) found that of the more than 50 or more rockfish species belonging to the genus Sebastes occurring in northern California, more than two-thirds do not extend north of British Columbia or Southeast Alaska. Briggs (1974, p. 278) stated that "about 50 percent of the entire shore fish fauna of western Canada does not extend north of the Alaskan Panhandle." In addition, many marine fish species common to the Bering Sea extend southward into the Gulf of Alaska, but apparently occur no further south (Briggs 1974). Allen and Smith (1988, p. 144) noted that "the relative abundance of some geographically displacing [marine fish] species suggest that the boundary between these provinces [Aleutian and Oregonian] occurs off northern Vancouver Island."

Blaylock et al. (1998) examined the distribution of more than 25 species of parasites in 432 juvenile and adult Pacific halibut sampled over much of its North American range and found evidence of three zoogeographic zones as determined by parasite clustering; northern, central, and southern. Similar to studies with other invertebrates, Blaylock et al. (1998, p. 2,269) found a breakpoint between zoogeographic zones in the vicinity of the Queen Charlotte Islands.

**Other marine fish DPS designations**

It is also useful to briefly review the size and complexity of other designated DPSs of marine fish that have undergone the status review process and have thus been considered both discrete and significant to their respective biological species. DPSs have been designated for portions of the range of Pacific herring (NMFS 2000, 2005, 2008b), Pacific hake, Pacific cod, walleye pollock (NMFS 2000), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*), brown rockfish (*S. auriculatus*) (NMFS 2001), bocaccio (*S. paucispinis*) (NMFS 2002), and smalltooth sawfish (*Pristis pectinata*) (NMFS 2003).

Several marine fish DPSs cover large geographic areas (e.g., Pacific cod and walleye pollock DPSs extend from Puget Sound to Southeast Alaska, two West Coast DPSs of bocaccio rockfish were designated off Washington and Oregon [the northern DPS] and off California and Mexico [the southern DPS], and all smalltooth sawfish in U.S. waters were designated a separate DPS). At slightly smaller geographic scales, a Southeast Alaska Pacific herring DPS (Carls et al. 2008) and DPSs of Pacific hake and Pacific herring in Georgia Basin (Puget Sound and the straits of Georgia and Juan de Fuca) were established as separate from coastal hake and herring (Gustafson et al. 2000, Stout et al. 2001a) (Figure 13). Three DPSs each of copper and quillback rockfish (Puget Sound Proper DPS, Northern Puget Sound DPS, and Coastal DPS) and two of brown rockfish (Puget Sound Proper DPS and Coastal DPS) have also been delineated (Stout et al. 2001b). Many of these marine fish DPSs include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008).

## Evaluation of Discreteness and Significance for Eulachon

In past evaluations of distinct population boundaries for marine fish (Gustafson et al. 2000, 2006, Stout et al. 2001a), spawn timing, spawning distribution, tagging, biogeography, ecological factors, seasonal migration patterns, parasite incidence, genetic population structure, morphometrics, meristics, and demographic data (growth rate, fecundity, etc.) have been evaluated for evidence of DPS discreteness and significance. The BRT examined similar evidence for eulachon and found evidence that was informative included genetic data, differences in spawning temperatures and length-at-maturity and weight-at-maturity of eulachon between northern and southern rivers, ecological features of both the oceanic and terrestrial environments occupied by eulachon, and biogeography.

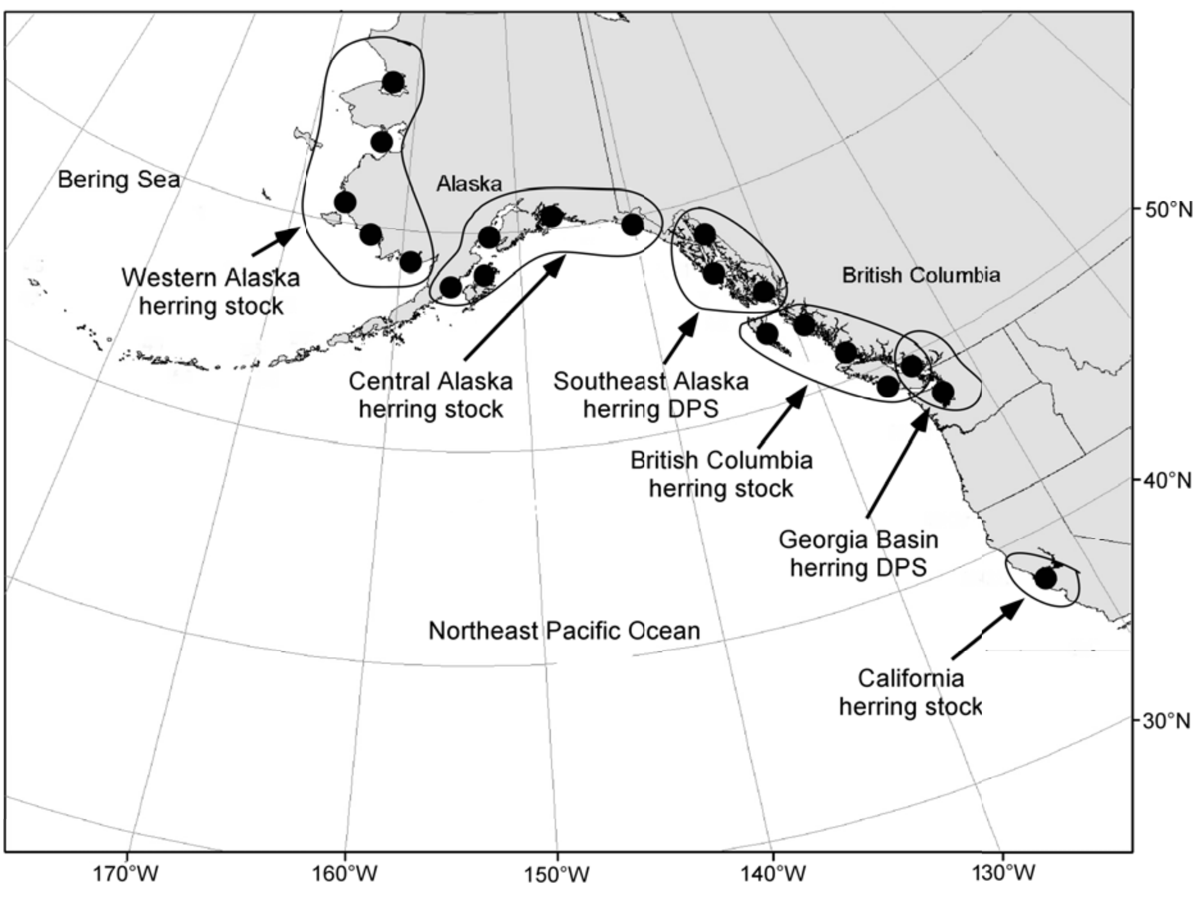



Figure 13. Major stocks of Pacific herring in the Northeast Pacific in relation to the Georgia Basin Pacific herring DPS (Stout et al. 2001a, Gustafson et al. 2006) and the Southeast Alaska Pacific herring DPS (Carls et al. 2008).

To allow for expressions of the level of uncertainty in identifying the boundaries of a discrete and significant eulachon population, the BRT adopted a likelihood point method, often referred to as the FEMAT method, because it is a variation of a method used by scientific teams evaluating options under the Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT) (FEMAT 1993). This method was previously used in the DPS decisions for Southern Resident killer whales (Krahn et al. 2004) and Pacific herring (Gustafson et al. 2006). In this approach, each BRT member distributes 10 "likelihood" points among a number of proposed DPSs, reflecting their opinion of how likely that proposal correctly reflects the true DPS boundary. Thus if a member were certain that the DPS that contains eulachon from California, Oregon, and Washington included all spawning aggregations from the Fraser to the south, he or she could assign all 10 points to that proposal. A member with less certainty about DPS boundaries could split the points among two, three, or even more DPS proposals (Table 1).

The BRT ultimately considered six possible DPS configurations or scenarios that might conceivably incorporate eulachon that spawn in Washington, Oregon, and California rivers. Each BRT member distributed his or her 10 likelihood points amongst these six scenarios. Other possible geographic configurations that incorporated the petitioned unit were contemplated but not seriously considered by the BRT. The BRT did not attempt to divide the entire species into DPSs, but rather focused on evaluating whether a DPS could be identified that contains eulachon that spawn in Washington, Oregon, and California. The geographic boundaries (Figure 14) of possible DPSs considered in this evaluation were:

1. The entire biological species is the ESA species (i.e., there is no apparent DPS structure)
2. One DPS inclusive of eulachon in Southeast Alaska to northern California
3. One DPS south of the Nass River/Dixon Entrance
4. One DPS inclusive of eulachon in the Fraser River to California
5. One DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California)
6. Multiple DPSs of eulachon in Washington, Oregon, and California

The distribution of likelihood points among these six scenarios is presented in Table 1. Scenario 1 (no DPS structure) received about 12% of the total likelihood points. Scenarios 2 (one DPS inclusive of eulachon in Southeast Alaska to northern California) and 5 (one DPS south of the Fraser River) received no support on the BRT. There was also very little support on the BRT for multiple DPSs of eulachon in the conterminous United States; only about 4% of the likelihood points were placed in scenario 6 (multiple DPSs of eulachon in Washington, Oregon, and California).

All remaining likelihood points (84%) were distributed among scenarios supporting a DPS at a level larger than the petitioned unit of Washington, Oregon, and California. Scenario 3 (one DPS south of the Nass River/Dixon Entrance) received about 57% of the total likelihood points and all but one BRT member placed between 5 and 10 points in this DPS scenario. Scenario 4 (one DPS inclusive of eulachon in the Fraser River to California) received significant

Table 1. Worksheet for evaluating potential of DPS or DPSs of eulachon (*Thaleichthys pacificus*) that incorporate spawning populations in California, Oregon, and Washington using the "likelihood point" method (FEMAT 1993).

| | Likelihood points | |
|---|---|---|
| **Scenario** | **Number**[a] | **Percentage**[b] |
| 1) Entire species (no DPS structure) | 11 | 12.2 |
| 2) One DPS south of Yakutat Forelands | — | — |
| 3) One DPS south of Nass River and Dixon Entrance | 51 | 56.7 |
| 4) One DPS, Fraser River and south | 24 | 26.7 |
| 5) One DPS south of Fraser River | — | — |
| 6) Multiple DPSs in Washington, Oregon, and California | 4 | 4.4 |

[a]Each BRT member distributes 10 likelihood points among the 6 DPS scenarios. Placement of all 10 points in a given scenario reflects 100% certainty that this is the DPS configuration that incorporates eulachon from Washington, Oregon, and California. Distributing points between scenarios reflects uncertainty in whether a given scenario reflects the true DPS delineation.
[b]Nine of 10 BRT members in attendance.

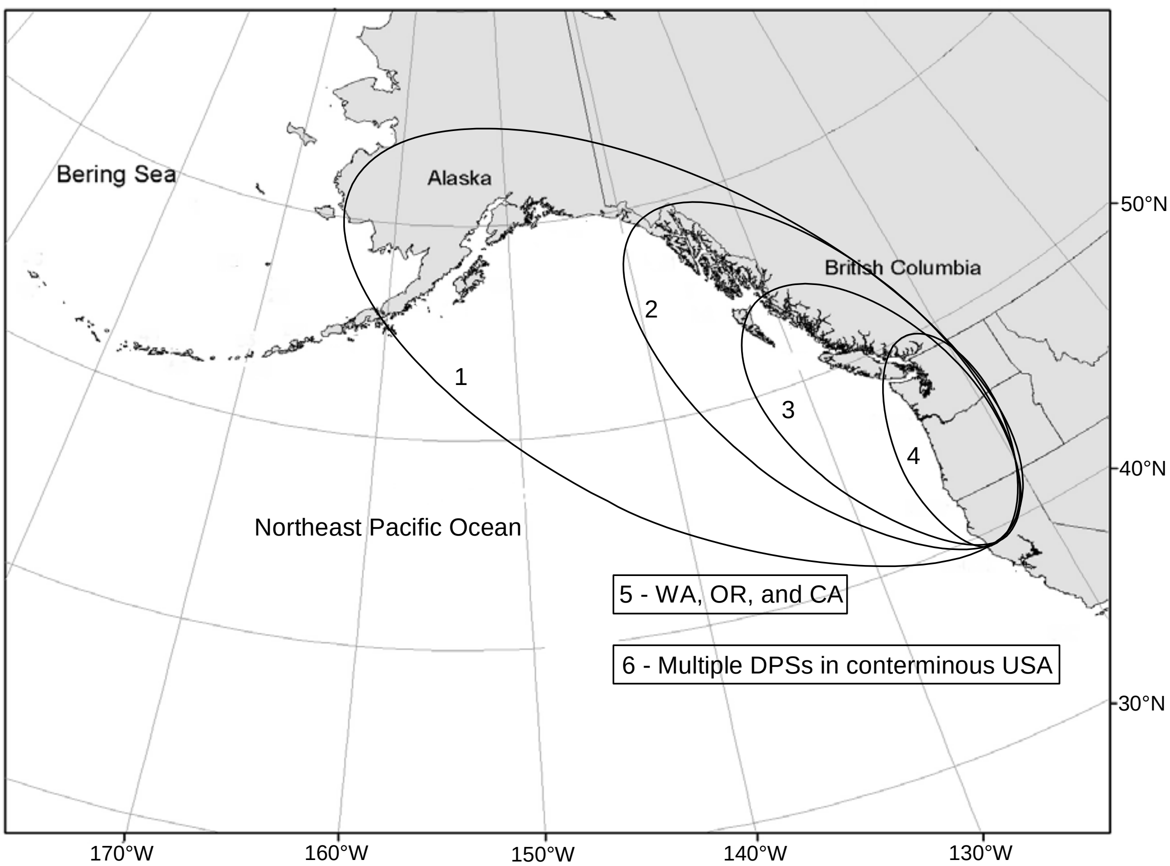



Figure 14. Geographic boundaries of possible eulachon DPSs considered by the BRT: 1) the entire biological species is one DPS, 2) one DPS south of the Yakutat Forelands (Southeast Alaska to northern California), 3) one DPS south of the Nass River (i.e., south of Dixon Entrance), 4) one DPS that includes the Fraser River and south, 5) one DPS south of the Fraser River (i.e., one DPS in Washington, Oregon, and California), and 6) multiple DPSs of eulachon in Washington, Oregon, and California.

support with about 27% of all points placed in this scenario and all but two members placed from 2 to 5 of their likelihood points in this DPS scenario. In discussing the evidence for these alternative scenarios, the BRT focused on the following factors.

In considering the discreteness and significance criteria (USFWS-NMFS 1996), the BRT concluded that the weight of the available evidence indicated that there are multiple discrete populations of eulachon. In particular, the most comprehensive genetic study of eulachon that has been published to date (Beacham et al. 2005) found reasonably strong evidence of a genetic break between eulachon spawning in the Fraser and Columbia rivers compared to those spawning in rivers further north in British Columbia and Alaska, and also found that nearly all sampled populations were differentiated statistically from each other. Earlier genetic studies (McLean et al. 1999, McLean and Taylor 2001) also found some evidence of population structure, although the evidence was less compelling than that reported by Beacham et al. (2005). However, these earlier studies were characterized by fewer loci and smaller sample sizes than the later study and therefore likely had less power to detect population structure. Overall, the BRT believed the results to be largely consistent among the studies, when differences in sample size and power are taken into account. The BRT did note, however, that there was some uncertainty about the genetic population structure due to the small number of temporally replicated samples in all of the studies, and this uncertainty is reflected in the proportion of the likelihood points that were placed in the no DPS structure category (Table 1).

In addition to the genetic data, the BRT considered the strong ecological and environmental break that occurs between the California Current and Alaska Current oceanic domains as contributing evidence for discreteness, a factor that was also important for identifying DPS structure in Pacific cod (Gustafson et al. 2000), killer whales (Krahn et al. 2004), and Southeast Alaska Pacific herring (Carls et al. 2008). The BRT also considered, but did not weigh heavily, the latitudinal differences in spawn timing, body size, and vertebral counts among samples from different rivers. Similar latitudinal patterns in life history characters were considered but did not weigh heavily in DPS decisions for Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a). Overall, the BRT believed the genetic and ecological data provided strong evidence that eulachon south of the Nass River were discrete from those in the Nass River and northward, but that there was also evidence (from the genetic data) suggesting that Fraser and Columbia River groups may be discrete from more northern groups.

In evaluating the significance criteria, the BRT focused primarily on criteria 1 (ecological setting), criteria 2 (evidence that loss would result in a significant gap in the range of the species), and criteria 4 (markedly differs in genetic characteristics). After carefully discussing all of the available data, the BRT concluded that there was evidence supporting the significance criteria under either scenario 3 (one DPS south of the Nass River/Dixon Entrance) or scenario 4 (one DPS inclusive of eulachon in the Fraser River to California). In particular, there is evidence under either scenario for a significant break in ecological setting, and loss of a putative DPS defined by either boundary would without question result in a significant gap (or reduction) in the range of the overall species. The BRT also considered whether the available genetic data provided any evidence for "markedly different" populations, but concluded that although the genetic data provides evidence for discreteness (lack of gene flow) there was little evidence to support the existence of deep intraspecific phylogenetic breaks that the BRT believed were necessary to be considered "marked."

In summary, the BRT believed the evidence most strongly supported scenario 3, but that there was also some evidence for scenarios 4 and 1. The factors supporting each of the top three scenarios are summarized below.

### Scenario 3

This scenario designated one DPS south of the Nass River/Dixon Entrance (57% support). Supporting factors were:

1. Beacham et al. (2005) found strong evidence that populations of eulachon in different rivers are genetically differentiated from each other at statistically significant levels and the authors suggested that the pattern of eulachon differentiation was similar to that typically found in studies of marine fish but less than that observed in most Pacific salmon species.
2. A major ecological break occurs in the coastal ocean biome between the Coastal Downwelling Province (Ware and McFarlane 1989, Longhurst 2006) to the north and the California Current Province (Ware and McFarlane 1989, Longhurst 2006) to the south. The northern boundary of the transition zone that separates these provinces occurs in the vicinity of the Dixon Entrance at the northern end of the Queen Charlotte Islands. The coastal distribution of eulachon south of the Dixon Entrance occupies an ecologically discrete area that is a combination of this transition zone and the northern California Current Province (Longhurst 2006).
3. Dixon Entrance is also the approximate northern boundary that separates two major marine zoogeographic provinces (Oregonian and Aleutian Provinces) (Briggs 1974), further supporting the ecological discreteness of marine waters south of Dixon Entrance.
4. Stocks of eulachon from the Columbia River to the Klinaklini River in British Columbia experienced a nearly simultaneous collapse in 1994 (Hay and McCarter 2000, Hay 2002), stayed at low levels throughout the 1990s, experienced a rebound in 2001–2003, and subsequently declined to near record low levels of abundance (Hay 2002, JCRMS 2007). The nearly synchronous demographic responses of all eulachon stocks south of the Nass River to what are likely coast-wide changes in ocean condition, strongly suggest that these stocks occupy a common ocean rearing environment. Stocks of eulachon from the Nass River and north remained relatively healthy throughout this period of decline of more southern stocks. Not until 2003 did eulachon stocks in southern Southeast Alaska begin to show serious declines. These demographic patterns are similar to those seen in Pacific salmon stock abundance that fluctuates in opposite directions in the Alaska and California Current domains (Hare et al. 1999), which has been correlated with the Pacific Decadal Oscillation (PDO) (Mantua and Hare 2002).
5. A major break in terrestrial ecoregions also occurs along the north coast of British Columbia in the vicinity of the Nass River, with both the Nass and Skeena rivers draining the interior Nass Basin Ecoregion (Environment Canada 2008). Evidence of a natural biological boundary coinciding with the international boundary separating Southeast Alaska and British Columbia (Dixon Entrance/Nass River) also supported delineation of

- Different biological zones are apparent along the coast, probably a result of both thermal (north-south) and salinity (east-west) gradients.
- A thermal gradient is clearly evident through British Columbia and Southeast Alaska.
  - o Temperatures in Southeast Alaska are colder than in British Columbia.
  - o Southeast Alaska has tidewater glaciers, British Columbia does not, chilling the water and increasing turbidity and possibly nutrients.
  - o Southeast Alaska mainland topography is heavily influenced by snowfields and glaciers; this is less prevalent in British Columbia.

6. Eulachon spawning in rivers on the north coast of British Columbia (e.g., Nass River) experience significantly colder temperatures at spawning (often spawning under ice) than eulachon spawning to the south, particularly in the Klinaklini, Fraser, and Columbia rivers (Hay and McCarter 2000) (Table A-11). Hochachka and Somero (2002, p. 292, 317) emphasized that habitat temperature plays a "strong and frequently dominant role … in governing the distribution patterns of organisms" and that "temperature differences of a few degrees Celsius have sufficient effects on proteins to favor adaptive change." The dominant role that temperature plays on ectothermic organisms, affecting "essentially every aspect of an organism's physiology" (Hochachka and Somero 2002, p. 290), suggests that these 2–4°C temperature differences experienced by adult eulachon and their gametes during spawning (Table A-11) are a strong indicator of potential physiological differences between eulachon south of the Nass River and those in the Nass River and northward.

Items 2–5 above support a discrete and significant eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of ecological features" and Item 6 supports a discrete eulachon population south of the Nass River/Dixon Entrance on the basis of being "markedly separated on the basis of physiological features."

**Scenario 4**

This scenario designated one DPS inclusive of eulachon in the Fraser River to California (27% support). Supporting factors were:

1. The available genetic data indicate that a substantial genetic break occurs between eulachon populations from the Fraser River and those from rivers further to the north (see Genetic Differentiation subsection, p. 61). In particular, the largest genetic discontinuity appears to be in southern British Columbia rather than northern British Columbia.

2. In contrast to systems to the north of the Fraser River, the Columbia, Fraser, and Klamath rivers have many physiographic and habitat features in common; all three are large rivers with wide valleys, drain extensive interior basins, are fed by spring snow melt, and do not drain off extensive ice sheets.

Average length-at-maturity and weight-at-maturity in eulachon from the Columbia and Fraser rivers and southern rivers in general are smaller than eulachon from more northern rivers (Figure 8). However, this pattern is typical in many vertebrate poikilotherms (ectotherms), where higher temperatures lead to reduced size at a given stage of development (Atkinson 1994, Lindsey 1966), so the BRT did not weight this evidence very heavily.

### Scenario 1

This scenario designated no DPS structure (12% support). Supporting factors were:

1. There was a lack of apparent discrete differences in many eulachon life history traits (Hay and McCarter 2000, Hay and Beacham 2005); however, similar uniformity in life history characters over large geographic distances was evident in previous marine fish reviews of Pacific cod, walleye pollock (Gustafson et al. 2000), and Pacific herring (Stout et al. 2001a).
2. Another reason BRT members put some support in this scenario was uncertainty about how strongly to weight the genetic study of Beacham et al. (2005). In particular, although the BRT concluded that the study as a whole clearly supported the existence of discrete genetic populations of eulachon, the BRT was also somewhat concerned about the limited temporal replication in the study.

Given the previous DPS structure established for marine fishes, such as Pacific herring, Pacific cod, Pacific hake, and walleye pollock (Gustafson et al. 2000, 2006, Stout et al. 2001a), it seems unlikely that there would be an absence of DPS structure across the more than 2,800 km range of eulachon, an anadromous species with similar among-population genetic differentiation, as these purely marine fishes. Pacific herring, which exhibit genetic variation similar to eulachon when compared over the same geographic range (Beacham et al. 2002, 2005, Small et al. 2005), have had DPSs delineated at the geographic level of the Georgia Basin (Stout et al. 2001a) and Southeast Alaska (Carls et al. 2008), based to a large degree on marked differences in ecological features of their habitats. For example, the estimated mean $F_{ST}$ value for Pacific herring over 13 microsatellite DNA loci and 83 sampling sites ranging from California to Southeast Alaska was 0.0032 (Beacham et al. 2002), whereas a similar estimated mean $F_{ST}$ value over 14 loci and 9 eulachon sampling sites ranging from the Columbia River to Southcentral Alaska was 0.0046 (Beacham et al. 2005).

Although nowhere near the same quantity or quality of data exists for eulachon as for the economically more valuable Pacific herring, it is likely that if data comparable to that for Pacific herring were available, an even finer DPS structure for the anadromous eulachon might become apparent. In addition, the biological heterogeneity of eulachon as seen in “the geographical discontinuity of different spawning runs, different spawning times, and the apparent homing of each run to individual rivers” (Hay and McCarter 2000, p. 36) strongly argues against the lack of DPS structure.

## BRT DPS Determination

In conclusion, it was the majority opinion of the BRT that eulachon from Washington, Oregon, and California are part of a DPS that extends beyond the conterminous United States and that the northern boundary of the DPS occurs in northern British Columbia south of the Nass River (most likely) or in southern British Columbia north of the Fraser River (less likely). The BRT proposes that this DPS be termed the southern DPS of eulachon. Although it was not the

BRT's objective to subdivide the entire biological species of eulachon into DPSs throughout their range, the identification of a southern DPS of eulachon indicates that at least one, and possibly more than one, additional DPS or DPSs of eulachon occur north of the Skeena River on the north coast of British Columbia and in Alaska.

Although the BRT could not with any certainty identify multiple populations or DPSs of eulachon within the region south of Dixon Entrance/Nass River, it acknowledged the possibility that significant stock structuring does exist within this region and that a finer DPS structure might be revealed by further information on the behavior, ecology, and genetic population structure of eulachon. The BRT also recognized that the DPS that includes eulachon from California, Oregon, and Washington may represent fish that are uniquely adapted to survive at the southern end of the species' range.

# The Extinction Risk Question

Information considered in evaluating the status of a DPS can generally be grouped into two categories: 1) demographic information reflecting the past and present condition of subpopulations (e.g., data on population abundance or density, population trends and growth rates, number and distribution of populations, exchange rates of individuals among populations, and ecological, life history, or genetic diversity among populations) and 2) information on past factors for decline as well as threats faced by the DPS (e.g., habitat loss and degradation, overutilization, disease, climate change). The demographic risk data reviewed by the BRT are summarized in this document. This document also contains a narrative summary of threats faced by the DPS.

Evaluating extinction risk of a species includes considering the available information concerning the abundance, growth rate and productivity, spatial structure and connectivity, and diversity of a species and assessing whether these demographic criteria indicate that it is at high risk of extinction, at moderate risk, or neither. A species at very low levels of abundance and with few populations will be less tolerant to environmental variation, catastrophic events, genetic processes, demographic stochasticity, ecological interactions, and other processes (e.g., Gilpin and Soulé 1986, Meffe and Carroll 1994, Caughley and Gunn 1996). A rate of productivity that is unstable or declining over a long period of time may reflect a variety of causes, but indicates poor resiliency to future environmental variability or change (e.g., Lande 1993, Foley 1997, Middleton and Nisbet 1997).

For species at low levels of abundance, in particular, declining or highly variable productivity confers a high level of extinction risk. A species that is not widely distributed across a variety of well-connected habitats will have a diminished capacity for recolonizing locally extirpated populations and is at increased risk of extinction due to environmental perturbations and catastrophic events (Schlosser and Angermeier 1995, Hanski and Gilpin 1997, Tilman and Lehman 1997, Cooper and Mangel 1999). A species that has lost locally adapted genetic and life history diversity may lack the characteristics necessary to endure short-term and long-term environmental changes (e.g., Hilborn et al. 2003, Wood et al. 2008).

The demographic risk criteria described above are evaluated based on the present species status in the context of historical information, if available. However, there may be threats or other relevant biological factors that might alter the determination of the species' overall level of extinction risk. These threats or other risk factors are not yet reflected in the available demographic data because of the time lags involved, but are nonetheless critical considerations in evaluating a species' extinction risk (Wainwright and Kope 1999).

Forecasting the effects of threats and other risk factors into the foreseeable future is rarely straightforward, and usually necessitates qualitative evaluations and the application of informed professional judgment. This evaluation highlights those factors that may exacerbate or ameliorate demographic risks so that all relevant information may be integrated into the determination of overall extinction risk for the species. Examples of such threats or other relevant factors may include climatic regime shifts that portend favorable temperature and marine productivity conditions, an El Niño event that is anticipated to result in reduced food quantity or quality, or recent or anticipated increases in the range or abundance of predator populations.

In considering the status of eulachon, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments of the status of eulachon populations by agencies, reviewed below. Additional information presented by the petitioners was considered, as discussed under the Introduction: Summary of Information Presented by the Petitioner section above.

# Abundance and Carrying Capacity

### Absolute Numbers

The absolute number of individuals in a population is important in assessing two aspects of extinction risk. For small populations that are stable or increasing, population size can be an indicator of whether the population can sustain itself into the future in the face of environmental fluctuations and small-population stochasticity; this aspect is related to the concept of minimum viable populations (MVP) (Gilpin and Soulé 1986, Thompson 1991). For a declining population, present abundance is an indicator of the expected time until the population reaches critically low numbers; this aspect is related to the concept of "driven extinction" (Caughley 1994). In addition to total numbers, the spatial and temporal distribution of adults is important in assessing risk to a species or DPS.

Several aspects of eulachon biology indicate that large aggregations of adult eulachon are necessary for maintenance of normal reproductive output. Eulachon are a short-lived, high-fecundity, high-mortality forage fish, and such species typically have extremely large population sizes. Research from other marine fishes (Sadovy 2001) suggests that there is likely a biological requirement for a critical threshold density of eulachon during spawning to ensure adequate synchronization of spawning, mate choice, gonadal sterol levels, and fertilization success. Since eulachon sperm may remain viable for only a short time, perhaps only minutes, sexes must synchronize spawning activities closely, unlike other fish such as Pacific herring (Hay and McCarter 2000, Willson et al. 2006).

In most samples of spawning eulachon, males greatly outnumber females (although many factors may contribute to these observations) (Willson et al. 2006), and in some instances congregations of males have been observed simultaneously spawning upstream of females that laid eggs as milt drifted downstream (Langer et al. 1977). Sadovy (2001, p. 100) noted that "the idea that, if a population drops below some critical density, the intrinsic rate of population increase may not be realized because breeding activity may cease, cannot be readily dismissed and a number of possible Allee effects have been noted" in marine fishes. Sadovy (2001, p. 101) further noted that "aggregating behaviour presumably reflects some biological imperative for sociality during the reproductive season."

In addition, the genetically effective population size of eulachon may be much lower than the census size. Although eulachon exhibit high fecundity (7,000–60,000 eggs; mean ≈30,000), survival from egg to larva may vary widely (3–5% in the Kemano River to approximately 1% in the Wahoo River [Willson et al. 2006]) and may be less than 1% in large egg masses. Larvae are small (4–8 mm long), are rapidly carried by currents to the sea, and rear in the pelagic zone similarly to many marine pelagic fish larvae where the extent of mortality during the transition phase from larva to juvenile is high. In marine species, under conditions of high fecundity and high mortality associated with pelagic larval development, local environmental conditions may lead to random "sweepstake recruitment" events where only a small minority of spawning individuals contribute to subsequent generations (Hedgecock 1994). Hauser and Carvalho (2008) report that "data available so far suggest that the scope for sweepstake recruitment may be higher in larger populations, as the $N_e/N$ [ratio of effective size to census size] is lower in larger populations."

Large spawning aggregations of adult eulachon may also be necessary to withstand predation pressure associated with large congregations of predators that target returning adults, and to produce enough eggs and pelagic larvae to swamp out predation in the ocean (Bailey and Houde 1989). Multiple species of predators (sea lions, harbor seals, gulls, bald eagles, ducks, sturgeon, porpoises, killer whales, etc.) commonly congregate at eulachon spawning runs and "local observers often judge arrival of fish by the conspicuous arrival of many predators" (Willson et al. 2006).

### Historical Abundance and Carrying Capacity

Knowing the relationship of present abundance to present carrying capacity is important for evaluating the health of populations, but the fact that a population is near its current capacity does not necessarily signify full health. A population near capacity implies that short-term management may not be able to increase fish abundance.

The relationship of current abundance and habitat capacity to historical levels is an important consideration in evaluating risk. Knowledge of historical population conditions provides a perspective for understanding the conditions under which present populations evolved. Historical abundance also provides the basis for scaling long-term trends in populations. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation. For eulachon, current and historical abundance data and information was available in the form of spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish), offshore juvenile eulachon biomass estimates (metric tons), mean eulachon larval density, CPUE, commercial-recreational-subsistence fisheries landings, ethnographic studies, and anecdotal qualitative information.

### Trends in Abundance

Short-term and long-term trends in abundance are primary indicators of risk. Trends may be calculated from a variety of quantitative data, which are discussed in detail in specific subsections below. Interpretation of trends in terms of population sustainability is difficult for several reasons. First, eulachon are harvested in fisheries and shifting harvest goals or market conditions directly affect trends in spawning abundance and catch. Second, environmental fluctuations on short timescales affect trend estimates, especially for shorter trends.

## Recent Events

A variety of factors, both natural and human-induced, affect the degree of risk facing eulachon populations. Because of time lags in these effects and variability in populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus consideration of these effects must go beyond examination of recent abundance and trends, but forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgment. Events affecting populations may include natural changes in the environment or human-induced changes, either beneficial or detrimental. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis, but we have considered documented changes in the natural environment. A key question regarding the role of recent events is: Given our uncertainty regarding the future, how do we evaluate the risk that a population may not persist?

It is generally accepted that important shifts in ocean-atmosphere conditions occurred about 1977 and again in 1998 that affected North Pacific marine ecosystems. Several studies have described decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua and Hare 2002). These changes have been associated with recruitment patterns of several groundfish species and Pacific herring (McFarlane et al. 2000). As discussed in this report, increases in eulachon in the Columbia, Fraser, and Klinaklini rivers in 2001–2002 may be largely a result of the more favorable ocean conditions for eulachon survival during the transition from larvae to juvenile when these broods entered the ocean in 1998–2000.

One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index; Figure 15 shows that from fall 2007 to mid-summer 2009 (time period E on the graph) monthly PDO values were negative, whereas PDO values were mostly positive in time period D from 2002 to fall of 2007 and during most of the previous two decades (time period B). One exception is time period C, which corresponds with 1998–2000 when good ocean conditions for survival of larval eulachon led to the increased run strength noted in 2001–2002. PDO values were generally negative for a long period from the 1950s to the late 1980s (time period A). Recently negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest and positive values are associated with warmer, less productive conditions (Mantua and Hare 2002).

Coupled changes in climate and ocean conditions have occurred on several different time scales and have influenced the geographical distributions, and hence local abundance, of marine fishes. On time scales of hundreds of millennia, periodic cooling produced several glaciations in the Pleistocene Epoch (Imbrie et al. 1984, Bond et al. 1993). Since the end of this major period of cooling, several population oscillations of pelagic fishes, such as anchovies (*Engraulis mordax*) and sardines (*Sardinops sagax*), have been noted on the west coast of North America (Baumgartner et al. 1992). These oscillations, with periods of about 100 years, have presumably occurred in response to climatic variability. On decadal time scales, climatic variability in the North Pacific and North Atlantic oceans has influenced the abundances and distributions of widespread species, including several species of Pacific salmon (*Oncorhynchus* spp.) (Francis et

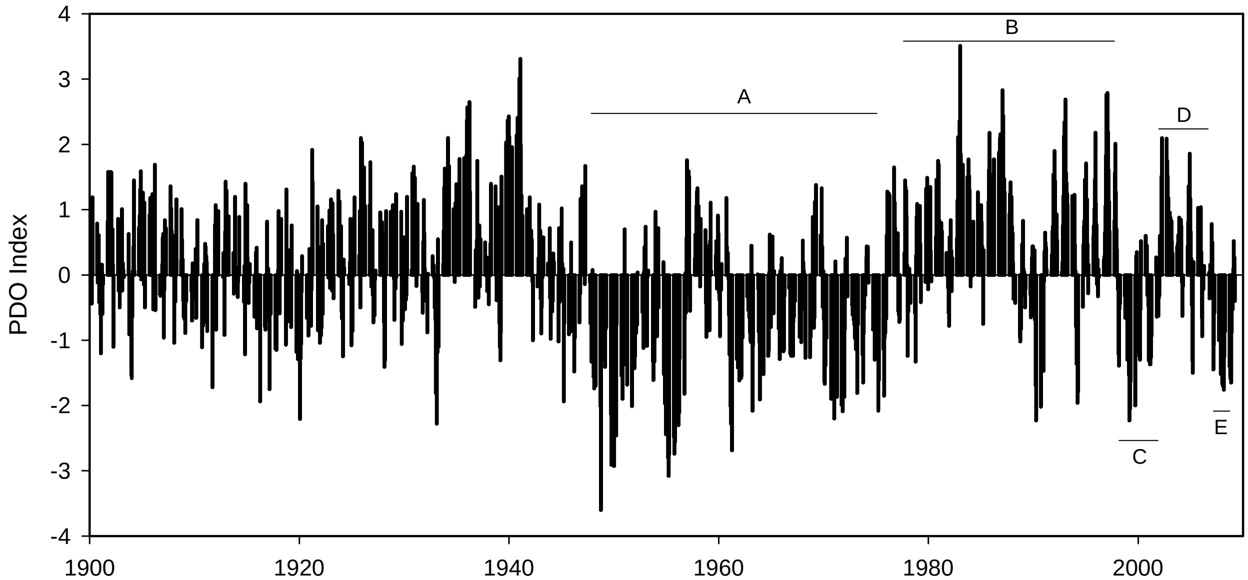



Figure 15. Monthly values for the PDO index, which is based on sea surface temperatures in the North Pacific Ocean, poleward of 20º N. A through E are time periods discussed in the text. Data source: online at http://jisao.washington.edu/pdo/PDO.latest.

al. 1998, Mantua et al. 1997) in the North Pacific, and Atlantic herring (*Clupea harengus*) (Alheit and Hagen 1997) and Atlantic cod (*Gadus morhua*) (Swain 1999) in the North Atlantic. At this time, we do not know whether recent shifts in climate and ocean conditions represent a long-term shift in conditions that will continue affecting stocks into the future or short-term environmental fluctuations that can be expected to be reversed in the near future. Although recent conditions appear to be within the range of historic conditions under which eulachon populations have evolved, the risks associated with poor climate conditions may be exacerbated by human influence on these populations (Lawson 1993).

None of the elements of risk outlined above are easy to evaluate, particularly in light of the great variety in quantity and quality of information available for various populations. Two major types of information were considered: previous assessments that provided integrated reviews of the status of eulachon in our region and data regarding individual elements of population status, such as abundance, trend, and habitat conditions.

A major problem in evaluations of risk for eulachon is combining information on a variety of risk factors into a single overall assessment of risk facing a population. Conducting an overall assessment of extinction risk involves the consideration of a wide variety of qualitative and quantitative information concerning the threats and demographic risks affecting a species' persistence. Moreover, the type and spatial-temporal coverage of the information available often varies within and among populations. This presents a substantial challenge of integrating disparate types of information into an assessment of a species' overall level of extinction risk. Usually such assessments necessitate qualitative evaluations based on informed professional judgment. In this review, we have used a risk-matrix approach through which the BRT members applied their best scientific judgment to combine qualitative and quantitative evidence regarding multiple risks into an overall assessment.

# Status Assessments

### Official Status in California, Oregon, and Washington

In California eulachon are classified on the Fish Species of Special Concern List as a Class 3 Watch List species (see http://www.dfg.ca.gov/wildlife/nongame/ssc/fish.html). This list was most recently updated in 1995. Class 3 Watch List species are defined as:

> taxa occupying much of their native range, but were formerly more widespread or abundant within that range. … The populations of such species need to be assessed periodically (i.e., every 5 years) and included in long-term plans for protected waterways (e.g., ADMAs [aquatic diversity management areas]).

In Oregon, eulachon are not listed as a state threatened, endangered, or candidate species, nor are they on the state sensitive species list. However, eulachon are on the list of Strategy Species in Oregon's Nearshore Strategy (ODFW 2006, p. 26). These species are defined in the following manner:

> Strategy species are nearshore species that were identified by the Nearshore Team to be in greatest need of management attention. Identification as a strategy species does not necessarily mean the species is in trouble. Rather, those identified as a strategy species have some significant nearshore management/conservation issue connected to that species that is of interest to managers.

ODFW (2006, p. 28) further refers to eulachon under the category of Notes on Conservation Needs as:

> Forage fish. Vulnerable freshwater spawning and nursery grounds. Columbia River population has declined. Other distinct population segments (DPS) may have experienced similar declines.

In Washington, eulachon are classified by the WDFW (online at http://wdfw.wa.gov/wlm/diversty/soc/candidat.htm) as a State Candidate Species, which are defined as:

> fish and wildlife species that the department will review for possible listing as State Endangered, Threatened, or Sensitive. A species will be considered for designation as a State Candidate if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened, or Sensitive.

### Status in Canada

The Province of British Columbia examined the conservation status of eulachon in 2000 and again in 2004 and in both instances assigned eulachon to its blue list. According to the British Columbia Conservation Data Centre (2008, online at http://www.env.gov.bc.ca/atrisk/red-blue.html) the blue list:

> Includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered, or Threatened.

Eulachon are also considered a Group 1 high priority candidate species for review in British Columbia by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). According to the COSEWIC Web site (http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm), "Group 1 contains species of highest priority for COSEWIC assessment. Wildlife species suspected to be extirpated from Canada would also be included in this group." A recent bid to conduct a COSEWIC review has been awarded in Canada and a final product is due in November 2010 (see information online at http://www.cosewic.gc.ca/eng/sct2/sct2_4_e.cfm).

Pickard and Marmorek (2007) reported out the results of a DFO workshop whose purpose was to determine research priorities and recovery strategies for eulachon in the wake of the recent coastwide decline. They stated that:

> Recent information indicates that eulachon are declining in many parts of the west coast of North America, though the reasons for this decline and possible remedies are not well understood. In 1994 the Columbia, Fraser, and Klinaklini rivers suffered sudden drastic declines (Hay 1996). Since then First Nations have reported that fish are absent or at very low levels in many other British Columbia eulachon spawning rivers including: the Kemano, Kitimat, Wannock, Bella Coola, Nass, Skeena, Chilcoot, Unuk, Kitlope, and Stikine (Moody 2007, Hay 2007).

According to Schweigert et al. (2007, p. 13):

> In recent years, particularly since 1994, eulachon abundance has declined synchronously in many rivers and virtually disappeared in California. This decrease has been noticeable in the PNCIMA [Pacific North Coast Integrated Management Area] region, with very poor runs in Douglas Channel, Gardner Canal, Dean/Burke channels, and Rivers Inlet areas in the past 5 years. It is suspected that these declines may be related to large-scale climate change. Recent studies suggest rivers that normally experience spring freshet events may gradually be changing to summer and fall freshets that may impair eulachon spawning runs.

### Other Status Assessments

Musick et al. (2000, p. 11) assessed the status of eulachon following American Fisheries Society criteria to define extinction risk in marine fishes (Musick 1999), and classified eulachon in the Columbia River as threatened based on "commercial landings [that] have declined from average of 2.1 million lb annually from 1938 to 1989 to 5,000 lb in 1999, a decline > 0.99." In addition, Musick et al. (2000, p. 11) stated that "other DPSs from British Columbia to northern California may have declines similar to that observed in the Columbia River."

Hay and McCarter (2000) conducted a review of the status of eulachon for the Canadian Stock Assessment Secretariat of Fisheries and Oceans Canada and concluded at that time that "the widespread decline in the southern part of the range warrants a COSEWIC classification of 'threatened' in Canadian waters." This conclusion was based on:

> Available evidence [which] suggests that several rivers in the central coast of British Columbia may be extirpated, while others have declined severely. Only the Nass maintains normal or near-normal runs, although the Fraser, while markedly lower in recent decades and especially since 1994, still has regular, but diminished runs. The Columbia River, with the world's largest eulachon run, declined sharply in 1993, and has remained low since. Apparently all runs in California have declined and several runs that once were large have not been seen in more than 20 years.

## General Demographic Indicators

Within the range of the DPS, the BRT examined abundance related information in the published literature; data provided by DFO, WDFW, and ODFW; analyses of available abundance data both past and present summarized in Moody (2008); and information and presentations provided by eulachon experts from DFO, WDFW, ODFW, the Cowlitz Indian Tribe, and the Yurok Indian Tribe assembled during a scientific technical meeting at the NWFSC in June 2008. Information on eulachon abundance fell into the general categories of 1) fisheries-independent scientific surveys of adults, offshore juveniles, and outmigrant larvae; 2) commercial fisheries-dependent landings; 3) recreational fisheries-dependent landings; 4) First Nations subsistence fisheries landings; 5) ethnographic studies; 6) anecdotal qualitative information; and 7) traditional ecological knowledge.

In addition, the BRT reviewed the results of a fuzzy logic expert system developed by Moody (2008) to estimate a past and present relative abundance status index for eulachon in several areas of the southern DPS of eulachon. Moody's (2008) expert system uses catch data to determine the exploitation status of a fishery and combines this with other data sources such as spawning stock biomass estimates, CPUE data, test fishery catches, larval survey data, or anecdotal comments on run size to estimate the relative abundance status index. This index was produced using designed heuristic rules and by adjusting weighting parameters (Moody 2008).

Although humans have exploited eulachon populations for centuries, the perceived abundance of the resource and its low commercial value has resulted in limited regulation of past commercial and recreational fisheries, limited recording of past catches, and until recently a lack of assessment surveys of spawning abundance. The BRT recognized that the lack of direct estimates of eulachon abundance based on fishery-independent surveys (spawning stock biomass estimates or escapement counts) prior to 1993 makes it very difficult to quantify trends in eulachon abundance. Since the mid-1990s, monitoring of this resource has improved and a handful of data sets are now available that track eulachon spawning stock abundance and offshore juvenile abundance or provide an indication of run strength in several subareas of the DPS.

## Data Availability

### Fisheries-independent scientific surveys

There are few direct estimates of spawning biomass of eulachon from rivers within the DPS, although all of these data sets began to be collected after the perceived decline in run sizes occurred in the early 1990s. Spawner biomass (pounds or metric tons) or total spawner counts (numbers of adult fish) are available for the Fraser River (1996–2009), Klinaklini River (1995), Kingcome River (1997), Wannock/Kilbella rivers (2005–2006), Bella Coola River (2001–2004), Kitimat River (1993–1996, 1998–2005), and Skeena River (1997). Even though the results of most of these studies are only available in gray literature reports, they were regarded by the BRT as constituting the best scientific and commercial data available for recent eulachon abundance in the DPS and were heavily weighted in the BRT's risk analysis. The BRT was cognizant of the fact that abundance estimates always contain observational error. These factors were taken into account when evaluating the data sets.

Offshore juvenile eulachon biomass estimates were available for Queen Charlotte Sound (1998–2009), West Coast Vancouver Island (1973, 1975–1983, 1985, 1987–2009), and the U.S. West Coast (1995, 1998, 2001). Data for Queen Charlotte Sound and West Coast Vancouver Island were collected by DFO as part of offshore shrimp biomass assessments. Eulachon juvenile biomass data for the U.S. West Coast were available from AFSC triennial groundfish bottom trawl surveys on the continental shelf (55–500 m) in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

CPUE data for eulachon were also available off the U.S. West Coast in AFSC triennial groundfish bottom trawl surveys over the continental shelf in depths of 55–366 m (1989, 1992) or 55–500 m (1995, 1998, 2001) and in certain INPFC statistical areas in AFSC groundfish bottom trawl surveys over the continental slope in depths of 183–1,280 m (1989–1999). However, as mentioned previously, these groundfish surveys were designed to sample bottom dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon.

Mean eulachon larval density data were available in the mainstem Columbia River (1996–2009), Cowlitz River (1986, 1994–2004, 2006–2009), Grays River (1998–2001, 2004–2006, 2008, 2009), Elochoman River (1997–2001, 2003, 2008), Kalama River (1995–2002), Lewis River (1997–2003, 2007–2009), and Sandy River (1998–2000, 2003).

Data from a Fraser River test fishery were available for the years 1995–1998 and 2000–2005 and are reported as number of fish caught. CPUE data were available from the Columbia River (1988–2008), Kemano River (1988–2006), and Kitimat River (1994–2006).

### Commercial fisheries–dependent landings

Commercial fisheries landings in pounds or metric tons of eulachon were available for the Klamath River (1963), Umpqua River (1967), Columbia River (1888–1892, 1894–1913, 1915–2009), Fraser River (1881–1996), Kitimat River (1969–1971), and Skeena River (1900–1916, 1919, 1924, 1926–1927, 1929–1932, 1935, 1941).

In some areas of the southern DPS of eulachon where escapement counts or estimates of spawning stock biomass are unavailable, catch statistics provide the only available quantitative data source that defines the relative abundance of eulachon occurrence that may be otherwise evident only by simple run-strength observation. However, inferring population status or even trends from yearly changes in catch statistics requires assumptions that are seldom met, including similar fishing effort and efficiency, assumptions about the relationship of the harvested portion to the total portion of the stock, and statistical assumptions such as random sampling.

**First Nations and Indian tribal subsistence fisheries landings**

First Nations subsistence fisheries landings in pounds or metric tons of eulachon were available for a number of rivers in British Columbia including the Fraser River (1975–1987, 1991), Klinaklini River (1947, 1949, 1950, 1952, 1959–1973, 1977), Kingcome River (1950, 1957, 1960, 1961, 1963, 1966), Wannock River (1967, 1968, 1971), Bella Coola River (1945, 1946, 1948–1989, 1995, 1998), Kemano River (1969–1973, 1988–2006), and Kitimat River (1969–1972).

**Recreational fisheries–dependent landings**

Recreational fisheries for eulachon are even more poorly documented that those for commercial and subsistence purposes. A popular recreational dip net fishery for eulachon has a long history on the Columbia River, particularly in tributary rivers such as the Cowlitz and on occasion the Sandy River. Catch records are not maintained for this fishery, although it has been estimated at times to equal the commercial catch (WDFW and ODFW 2001). A similar recreational dip net fishery occurred in the past on the Fraser River, and landings data exist for a portion of this fishery in the vicinity of Mission, British Columbia, for the years 1956, 1963–1967, and 1970–1980 (Moody 2008, p. 49, her Figure 2.22).

**Ethnographic studies**

Numerous ethnographic studies emphasize the nutritional and cultural importance of eulachon to coastal mainland Indian tribes and First Nations. The BRT examined ethnographic sources that describe historical distributions and relative abundance of eulachon fisheries within the boundaries of the DPS. Many of the statements in these sources as to the historical distribution and abundance of eulachon consisted of traditional ecological knowledge or were anecdotal in nature.

**Anecdotal qualitative information**

Anecdotal information is defined in the present context as information based on personal observation, case study reports, or random investigations rather than systematic scientific evaluation. This category includes memoirs of pioneers, fur trappers, and explorers; newspaper articles; and interviews with local fishers.

The BRT examined a variety of primary sources (e.g., accounts of early explorers, surveyors, fur trappers, and settlers and newspaper articles) and secondary sourced (e.g., agency fisheries reports and journal articles that cite personal communications) that describe historical distributions and relative abundance of eulachon within the boundaries of the DPS. The BRT also examined documents (e.g., Larson and Belchik 1998, Hay and McCarter 2000, Moody 2008) that cited interviews with local fishers or personal communications from local fisheries managers in their attempt to qualitatively characterize eulachon run strength. Many statements in these sources as to the historical distribution of eulachon were largely anecdotal in nature.

### Traditional ecological knowledge

Although there is a largely untapped store of knowledge on eulachon residing in the culture and traditions of Native American Indian Tribes and First Nations in Canada, the BRT did not separately consider traditional ecological knowledge sources in its deliberations; however, the BRT did examine secondary sources that presented information on eulachon presence and run size that was gathered from interviews with traditional local fishers.

## Summary of Regional Demographic Data

To facilitate evaluation of eulachon distribution and abundance, the BRT analyzed the available demographic information on a subpopulation basis, arranged geographically into separate major estuaries, which have been postulated to be the smallest area that likely supports a biological stock (McCarter and Hay 1999, Hay and McCarter 2000, Hay 2002). These major areas are 1) Klamath River, 2) Columbia River (Cowlitz, Grays, Lewis, Kalama, Sandy rivers, etc.) in the United States, 3) Fraser River, 4) Knight Inlet (Klinaklini River), 5) Kingcome Inlet (Kingcome River), 6) Rivers Inlet (Wannock and Kilbella/Chuckwalla rivers), 7) Dean Channel (Bella Coola and Kimsquit rivers), 8) Gardner Canal (Kemano, Kowesas, and Kitlope rivers), 9) Douglas Channel (Kitimat and Kildala rivers), and 10) Skeena River in British Columbia.

Eulachon are periodically noted in small numbers in several rivers and creeks on the Washington and Oregon coast. Documentation of these irregular occurrences of eulachon is usually anecdotal and it is uncertain how these fish are related demographically to eulachon in rivers such as the Fraser and Columbia where consistent annual runs occur. Occasionally large runs are noticed, usually by the abundance of predatory birds and marine mammals that accompany these runs, in coastal rivers such as the Queets and Quinault. Usually these large run events are separated in time by periods greater than the generation time of eulachon. We do not know enough about the biology of eulachon to know if these eulachon run events represent self-sustaining populations or are simply stray individuals from larger eulachon systems. It is possible that these populations may exist at levels of abundance that would not be detected by the casual observer, only to become noticed in years of high abundance. Further research on the source and sustainability of eulachon that occasionally appear in these coastal creeks and rivers is needed to fully assess the status of these eulachon aggregations.

### Offshore juvenile abundance estimates

Four fisheries-independent indices of juvenile offshore biomass are available that indicate status of stock mixtures: 1) a West Coast Vancouver Island eulachon biomass index (Figure 16); 2) a Queen Charlotte Sound eulachon biomass index (Figure 17); 3) estimates of CPUE, biomass, or number of eulachon reported in a series of groundfish bottom trawl surveys conducted on the continental shelf and slope of the U.S. West Coast by NMFS's NWAFC and

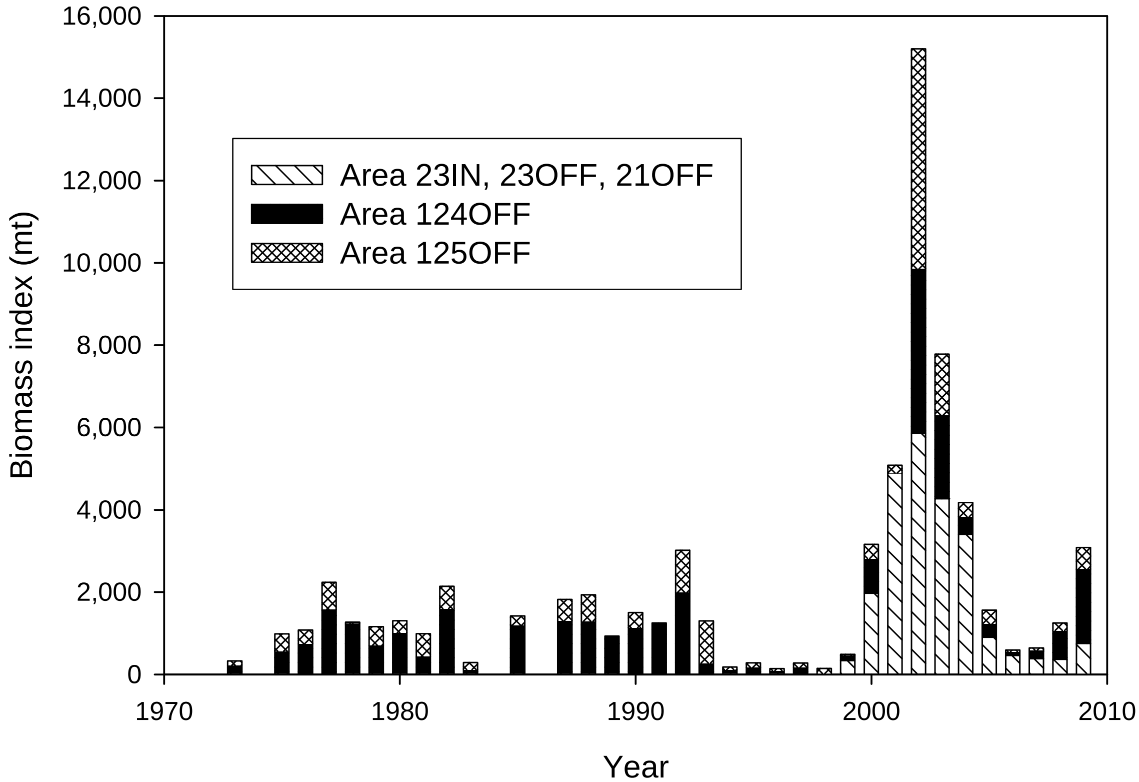



Figure 16. West coast Vancouver Island offshore eulachon biomass index. See Figure 21 for geographic locations of DFO shrimp management areas 23IN, 23OFF, 21OFF, 124OFF, and 125OFF. Data from Hay et al. (2003) and DFO west coast Vancouver Island shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

AFSC and more recently by NWFSC (Table 2 through Table 5, Figure 18, and Figure 19); and 4) the AFSC Gulf of Alaska bottom trawl biomass estimates for eulachon (Figure 20). The latter two groundfish surveys were designed to sample bottom-dwelling species and capture only a small and erratic portion of the pelagic distribution of eulachon. In addition, none of these four indices provides information on spawning stock biomass and each incorporates juvenile biomass derived from 2 to 4 broodyears; however, these indices are useful predictors for potential future run sizes.

DFO (2008a, p. 11) describes the west coast Vancouver Island eulachon biomass index as follows (Figure 16):

> The offshore biomass index is based on an annual trawl survey conducted in late April or early May by Fisheries and Oceans Canada, Science Branch. The survey initially was designed to index shrimp abundance but since eulachon also are caught by this survey, a eulachon index is possible. It is important to note that this is a biomass index and not a biomass estimate and that eulachon caught in this survey include stocks from both the Fraser River, and the Columbia River, and possibly other areas. This survey has been conducted since 1973 and provides an annual index of offshore abundance for the lower west coast Vancouver Island (areas 121, 23, 123, 124, and 125) [Figure 21].

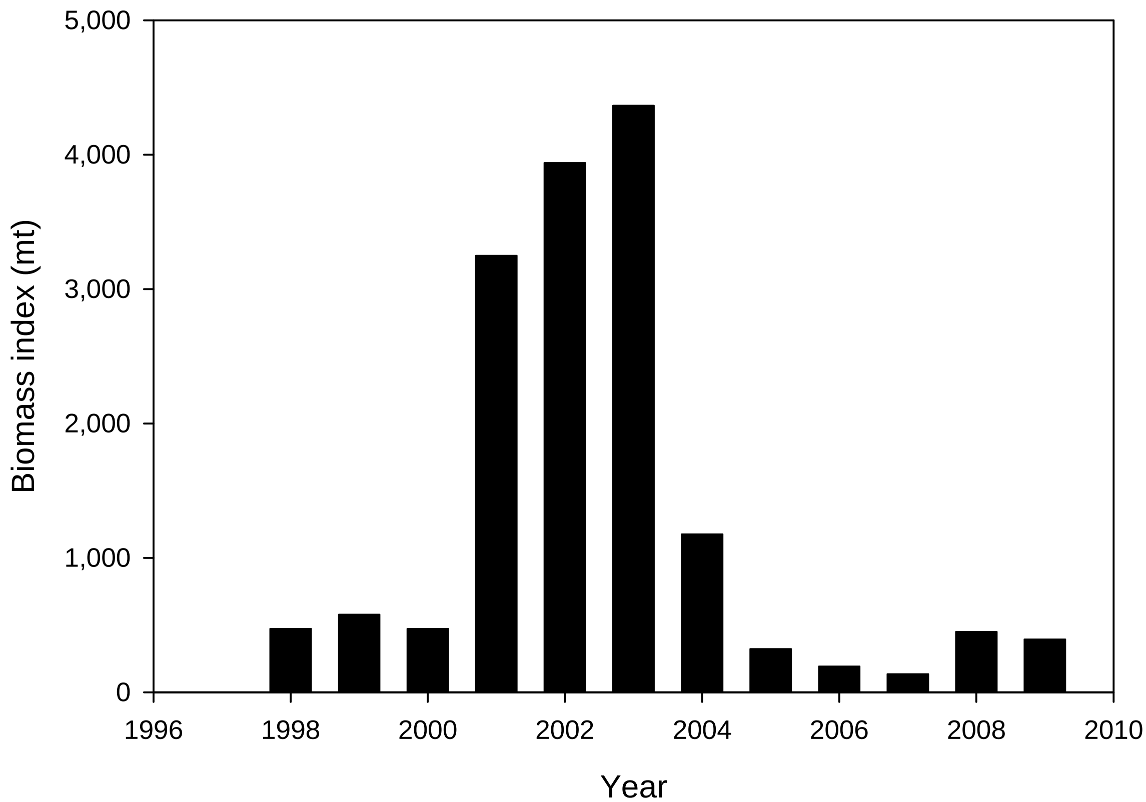



Figure 17. Queen Charlotte Sound offshore eulachon biomass index. Data from DFO Queen Charlotte Sound shrimp survey bulletins (2000–2009), online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/Shellfish/shrimp/surveys/surveys.htm?

DFO (2009a, p. 3) stated that "the eulachon biomass indices for 2009 increased in all SMAs [shrimp management areas] surveyed [off west coast Vancouver Island] compared to 2008 indices" (Figure 16). Biomass increased "from 353.7 t in 2008 to 720.8 t in 2009" in SMAs 23OFF+21OFF, "from 697.8 t in 2008 to 1810.1 t in 2009" in SMA 124OFF, and "from 184.9 t in 2008 to 520.0 t in 2009" in SMA 125OFF (DFO 2009a, p. 3) (Figure 21).

In a similar manner, a Queen Charlotte Sound eulachon biomass index (Figure 17) is derived from eulachon caught in the fishery-independent shrimp survey that is conducted in May of each year in SMA Queen Charlotte Sound. Data indicate that "the 2008 estimate of 451.5 t is a significant increase from the record low 137.1 t in 2007" (DFO 2008b, p. 2); however, "eulachon biomass on the shrimp grounds decreased slightly to 394.8 t in 2009 from 451.5 t in 2008" (DFO 2009b, p. 2). As reported in DFO (2009b, p. 3) "the shrimp trawl fishery in SMA Queen Charlotte Sound will remain closed due to eulachon conservation concerns in central British Columbia rivers" (Figure 21).

The history and location of groundfish trawl surveys conducted by the NWAFC, AFSC, and NWFSC in Alaska and off the U.S. West Coast were described in the above Marine Distribution subsection. Mean CPUE (kg/ha) data for eulachon in select INPFC statistical areas (Table 2) were published in various AFSC groundfish bottom trawl surveys conducted between

Table 2. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC groundfish bottom trawl surveys on the continental slope in depths of 183 to 1,280 m. ND (for no data) indicates that no survey occurred in a certain area and a dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1989[a] | ND | ND | ND | 2.296 | ND | ND | ND | ND | ND |
| 1990[a] | ND | ND | ND | ND | 0.487 | ND | ND | ND | ND |
| 1991[a] | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 1992[a] (183–366 m) | ND | 0.003 | ND | 0.032 | ND | ND | ND | ND | ND |
| 1992[a] (367–549) | ND | 0.004 | ND | 0.002 | ND | ND | ND | ND | ND |
| 1993[a] (183–366 m) | ND | ND | ND | 0.001 | ND | ND | ND | ND | ND |
| 1993[a] (367–549 m) | ND | ND | ND | 0.001 | ND | ND | ND | ND | ND |
| 1996[b] (183–366 m) | ND | — | ND | — | ND | ND | ND | ND | ND |
| 1996[b] (367–549 m) | ND | — | ND | 0.002 | ND | ND | ND | ND | ND |
| 1997[c] (183–366 m) | ND | — | ND | 0.002 | — | — | — | 0.001 | ND |
| 1997[c] (367–549 m) | ND | — | ND | 0.003 | — | — | — | 0.001 | ND |
| 1999[d] (183–366 m) | ND | — | ND | 0.006 | 0.007 | — | — | 0.003 | ND |

[a] Lauth et al. 1997
[b] Lauth 1997b
[c] Lauth 1999
[d] Lauth 2000

Table 3. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 366 m (1989 and 1992) or 55 to 500 m (1995–2001). A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1989[a] | 0.723 | 0.259 | 0.557 | 0.438 | 0.458 | 0.014 | 0.169 | 0.295 | 0.368 |
| 1992[b] | 3.115 | 0.010 | 1.933 | 0.188 | 0.226 | — | — | 0.114 | 0.604 |
| 1995[c] | 1.118 | 0.094 | 0.761 | 0.027 | 0.001 | — | — | 0.019 | 0.169 |
| 1998[d] | 0.127 | 0.007 | 0.077 | 0.009 | Trace | — | — | 0.004 | 0.018 |
| 2001[e] | 13.251 | 0.362 | 6.888 | 0.253 | 0.013 | — | — | 0.135 | 1.172 |

[a] Weinberg et al. 1994, [b] Zimmerman 1994, [c] Wilkins 1998, [d] Wilkins and Shaw 2000, [e] Wilkins and Weinberg 2002

Table 4. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1995[a] | 1,137 | 85 | 1,221 | 59 | 1 | — | — | 145 | 1,281 |
| 1998[b] | 123 | 9 | 132 | 20 | — | — | — | 30 | 153 |
| 2001[c] | 12,186 | 717 | 12,903 | 558 | 9 | — | — | 1,284 | 13,470 |

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

Table 5. Estimated number of eulachon in INPFC statistical areas (Figure 4) as reported in AFSC triennial groundfish bottom trawl surveys on the continental slope in depths of 55 to 500 m. A dash indicates a survey occurred but no eulachon were reported.

| Year | Canadian Vancouver | U.S. Vancouver | Total Vancouver | Columbia | Eureka | Monterey | Conception | U.S. total | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1995[a] | 39,912,489 | 2,475,680 | 42,579,382 | 1,552,718 | 16,787 | — | — | 4,045,185 | 44,148,887 |
| 1998[b] | 7,811,913 | 595,554 | 8,407,466 | 1,150,452 | 5,297 | — | — | 1,751,303 | 9,653,216 |
| 2001[c] | 340,794,386 | 22,481,691 | 363,276,077 | 22,146,832 | 808,073 | — | — | 45,436,595 | 386,230,981 |

[a] Wilkins 1998, [b] Wilkins and Shaw 2000, [c] Wilkins and Weinberg 2002

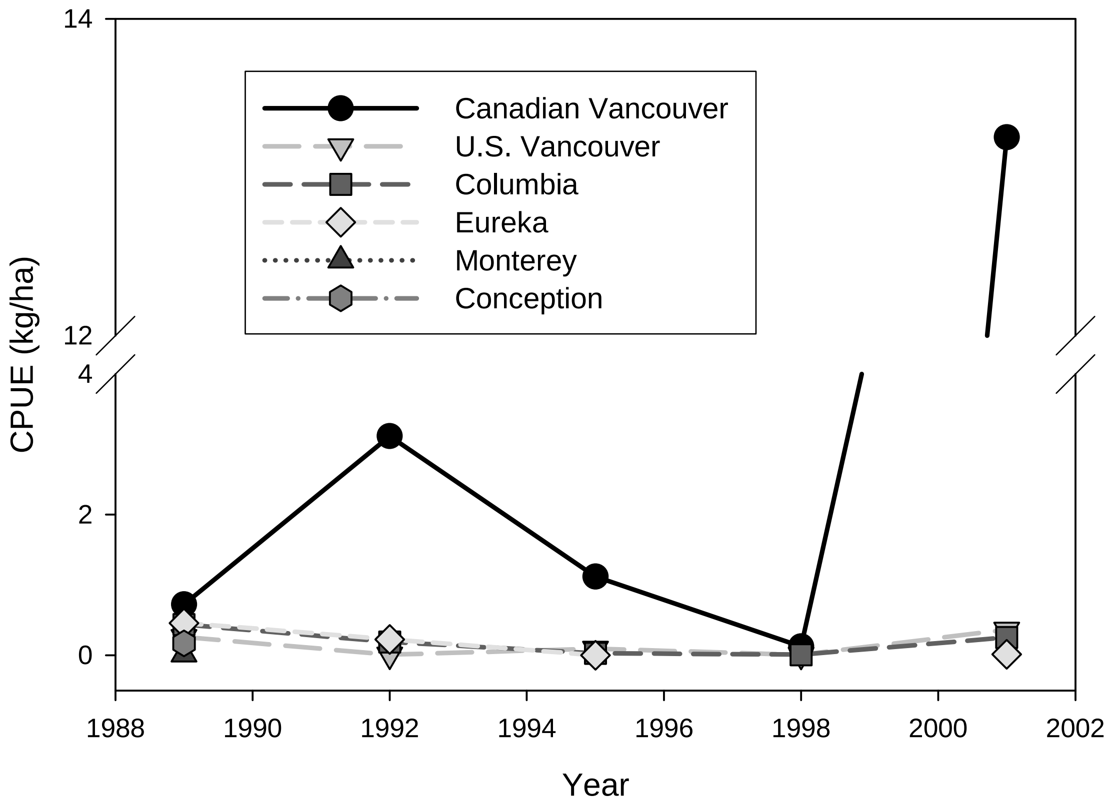



Figure 18. Mean CPUE (kg/ha) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast, as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–366 m (1989 and 1992) or 55–500 m (1995–2001) in 1989 (Weinberg et al. 1994), 1992 (Zimmermann 1994), 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

1989 and 1999 on the U.S. West Coast continental slope between depths of 183 and 1,280 m (Lauth et al. 1997, Lauth 1997b, 1999, 2000).

As mentioned previously, this depth range is deeper than preferred by eulachon and it is likely that these continental slope surveys missed the vast majority of eulachon in the area. The 1977 triennial groundfish survey recorded eulachon in six of nine assemblages on the continental shelf off the Washington and Oregon coasts, being most abundant within the Nestucca Intermediate Assemblage (90–145 m), where they constituted 3.5% of the total biomass and had a mean CPUE of 28.6 lb/haul (13 kg/haul) (Gabriel and Tyler 1980). In 1980 eulachon were recorded as the 15th most common fish encountered (0.69 kg/ km trawled) in the shallow stratum (55–183 m) in the INPFC Eureka area, but were not recorded within the top 20 species encountered in the INPFC Vancouver, Columbia, or Monterey areas (Coleman 1986). Triennial surveys conducted in 1989–2001 provided mean CPUE (kg/ha) data for eulachon (Table 3, Figure 18) in INPFC statistical areas off the U.S. West Coast (Weinberg et al. 1994b, Zimmermann 1994, Wilkins 1998, Wilkins and Shaw 2000, Wilkins and Weinberg 2002).

Biomass and total number of fish (Table 5) estimates for eulachon were published for surveys conducted in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins

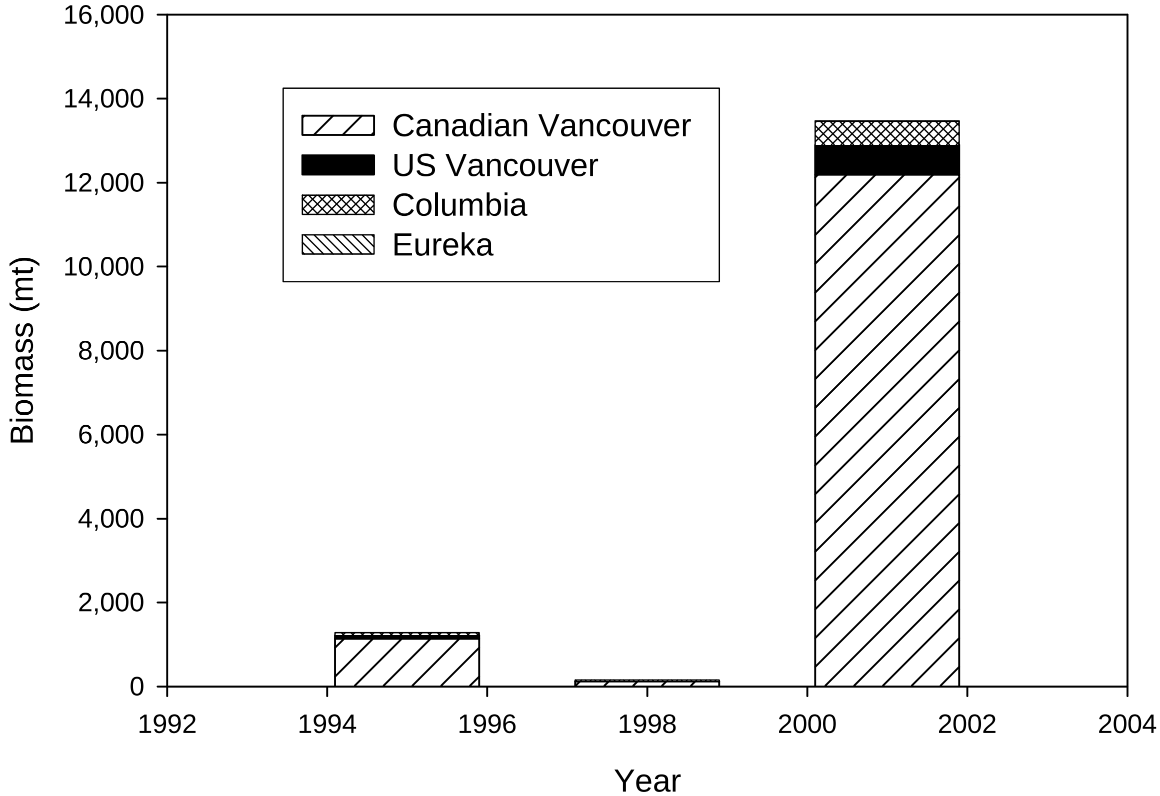



Figure 19. Estimated biomass (mt) of eulachon in INPFC statistical areas (Figure 4) off the U.S. West Coast as reported in AFSC triennial groundfish bottom trawl surveys on the continental shelf in depths of 55–500 m in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002).

and Weinberg 2002). Between 80% and 90% of the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 19). As stated previously, these groundfish surveys were designed to sample bottom-dwelling species and only capture a small and erratic portion of the pelagic distribution of eulachon.

Although unlikely to include eulachon from the southern DPS, the AFSC Gulf of Alaska bottom trawl estimates for eulachon (Figure 20) are a useful indicator of fluctuations in abundance in the Alaska Current for comparison with conditions in the California Current.

**Oregon marine recreational fisheries survey data**

ODFW (Williams 2009) (Table 6) provided a:

> summary for catches of eulachon in the marine sport fishery. The Oregon Recreational Boat Survey (ORBS) is our ocean boat sampling project. The survey is responsible for sampling sport catches from boats, focusing on ocean catches. Estimates of harvest are produced based on this sampling and are used for in-season management of quota species. Sampling takes place at a lesser extent in estuaries and that information is catalogued, but not used routinely. The

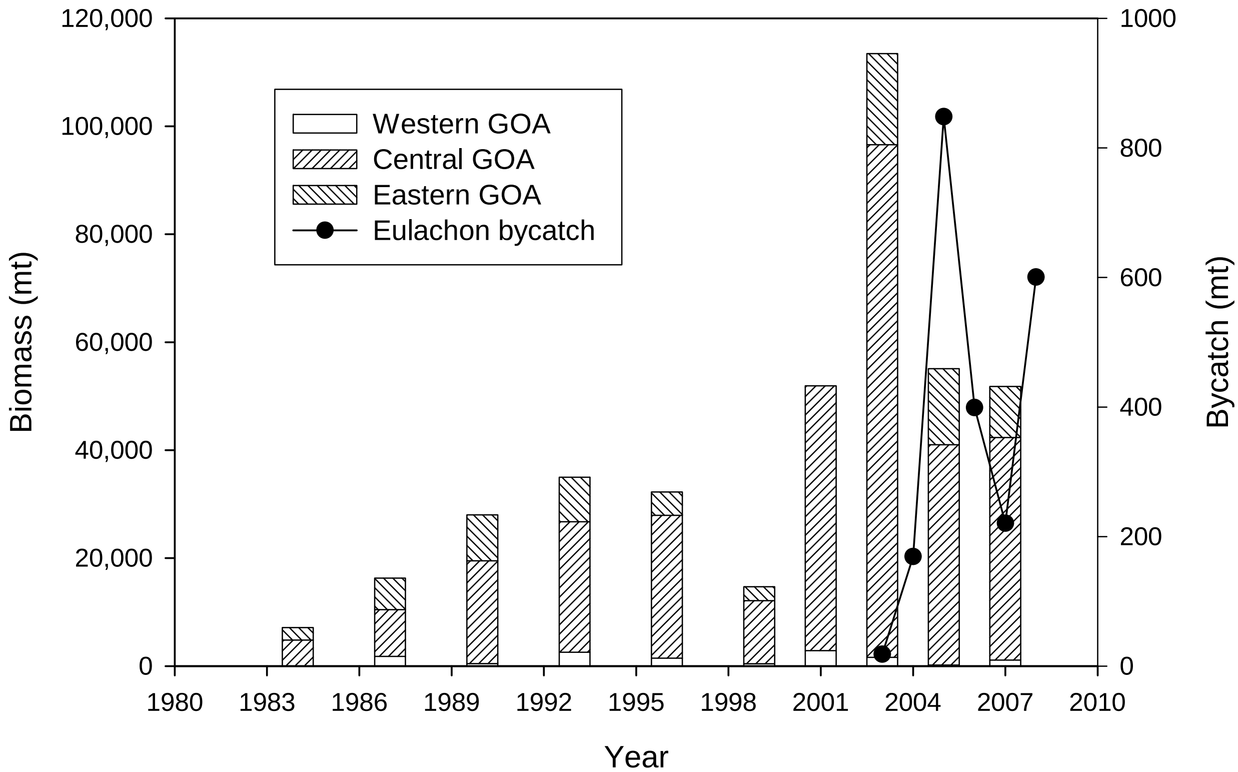



Figure 20. AFSC bottom trawl survey biomass estimates for eulachon and fishery incidental catch (bycatch) of eulachon in the Gulf of Alaska. Data from Ormseth and Vollenweider (2007) and Ormseth et al. (2008).

> Marine Recreational Finfish Statistical Survey (MRFSS) was formed by NMFS and operated by the Pacific States Marine Fisheries Commission. This survey was conducted at all saltwater access points including beaches, estuaries, man-made structures (e.g., jetties), and docks. It was a comprehensive survey that was intended to produce harvest trends over a number of years. … Beginning in 1994, ORBS estimates for ocean boats superseded those generated by the old MRFSS program because ORBS methodology generates more accurate estimates. In particular, MRFSS is weak in capturing pulse, or short-term, fisheries like smelt (the PSE [proportional statistical error] for the annual eulachon estimates range from 73 to 100). Hence, the summary is best regarded as an indicator of eulachon presence in the sport fishery, not absolute numbers.

**Northern California**

There has been no long-term monitoring program for eulachon in California, making the assessment of historical abundance and abundance trends difficult. Within California, large spawning aggregations of eulachon were reported to have once regularly occurred in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005) and on occasion in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek (Moyle et al. 1995) (Table A-1, Figure 2). In addition, Moyle et al. (1995) and Moyle (2002) stated that small numbers of eulachon have been reported from the Smith River

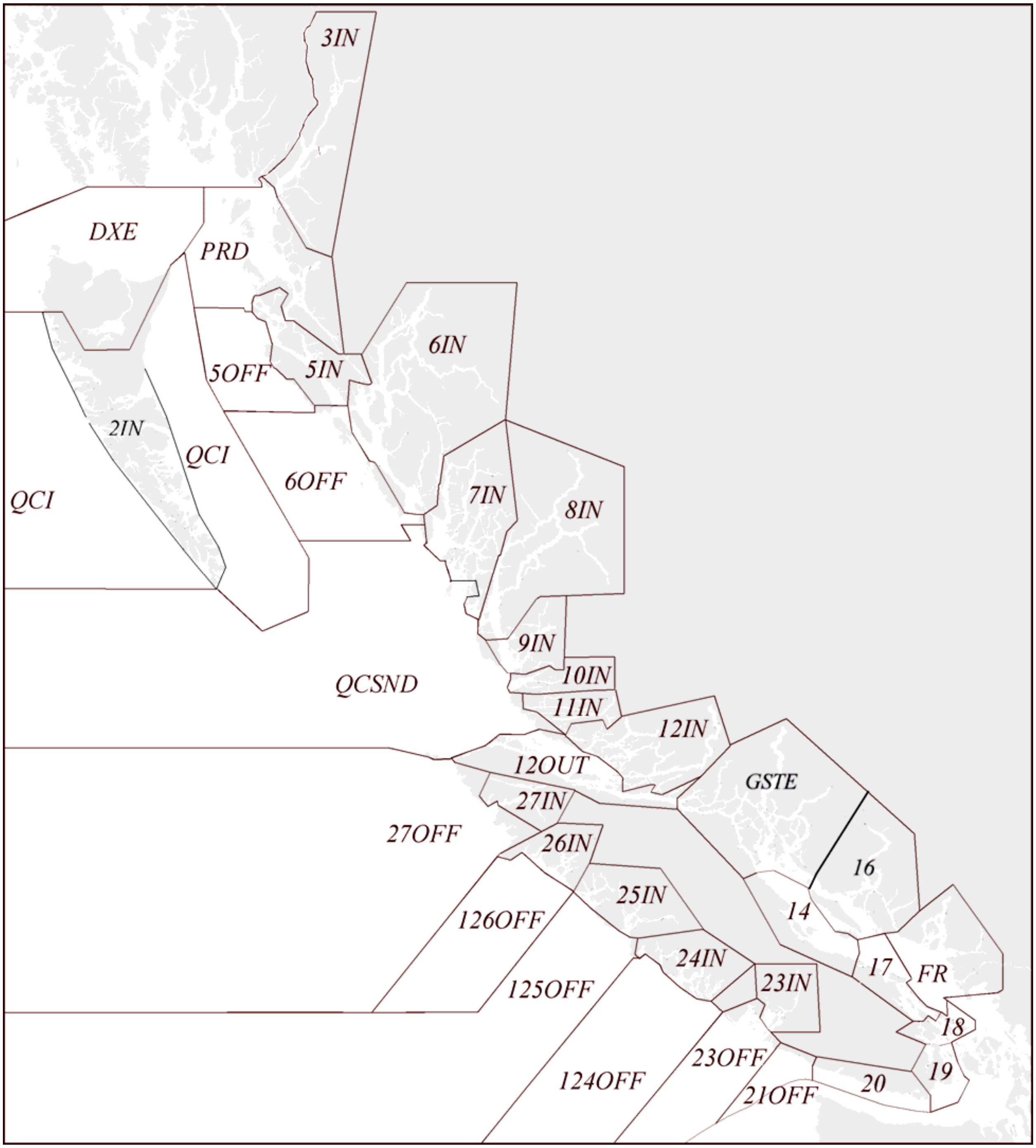



Figure 21. Map of major shrimp management areas on the coast of British Columbia. Map modified from DFO (2009c).

Table 6. Marine Recreational Finfish Statistical Survey (MRFSS) and Shore and Estuary Boat Survey (SEBS) eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

| | South Beach | | | Winchester Bay | | | Bandon | | |
|---|---|---|---|---|---|---|---|---|---|
| | **No. fish** | **No. fishers** | **CPUE** | **No. fish** | **No. fishers** | **CPUE** | **No. fish** | **No. fishers** | **CPUE** |
| 1983 | | | | | | | | | |
| 1987 | | | | | | | | | |
| 1993 | 53 | 11 | 4.8 | 8 | 4 | 2.0 | | | |
| 1994 | | | | | | | | | |
| 1995 | | | | 18 | 1 | 18.0 | | | |
| 1999 | | | | | | | 66 | 6 | 11.0 |
| Total | 53 | 11 | 4.8 | 26 | 5 | 5.2 | 66 | 6 | 11.0 |

Table 6 continued horizontally. MRFSS and SEBS eulachon catch data provided by Williams (2009) for Oregon between 1980 and June 2005. All eulachon were caught from piers or docks in bays. CPUE is fish caught per fisher interviewed.

| | Charleston | | | Brookings | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | **No. fish** | **No. fishers** | **CPUE** | **No. fish** | **No. fishers** | **CPUE** | **No. fish** | **No. fishers** | **CPUE** |
| 1983 | 1 | 2 | 0.5 | | | | 1 | 2 | 0.5 |
| 1987 | 2 | 3 | 0.7 | | | | 2 | 3 | 0.7 |
| 1993 | | | | | | | 61 | 15 | 4.1 |
| 1994 | | | | 4 | 2 | 2.0 | 4 | 2 | 2.0 |
| 1995 | | | | | | | 18 | 1 | 18.0 |
| 1999 | | | | | | | 66 | 6 | 11.0 |
| Total | 3 | 5 | 0.6 | 4 | 2 | 2.0 | 152 | 29 | 5.5 |

(Table A-1). CDFG's Status Report on Living Marine Resources (Sweetnam et al. 2001, p. 477–478) stated that "The principal spawning run [of eulachon] in California is in the Klamath River, but runs have also been recorded in the Mad and Smith rivers and Redwood Creek." Allen et al. (2006) indicated that eulachon usually spawn no further south than the lower Klamath River and Humboldt Bay tributaries.

Eulachon were of great cultural and subsistence importance to the Yurok Tribe on the lower Klamath River (Trihey and Associates 1996) and the Yurok people consider eulachon to be a Tribal Trust Species along with spring and fall Chinook salmon, coho salmon, steelhead, Pacific lamprey (*Lampetra tridentata*) , and green sturgeon (*Acipenser medirostris*) (Trihey and Associates 1996, Larson and Belchik 1998). Eulachon once supported popular recreational fisheries in northern California rivers, but were never commercially important in California. The only reported commercial catch of eulachon in northern California occurred in 1963 when a combined total of 56,000 lb (25 mt) was landed from the Klamath River, the Mad River, and Redwood Creek. According to Larson and Belchik (1998, p. 4):

> Literature regarding … [eulachon] specific to the Klamath River Basin is limited to accounts of mere presence and qualitative descriptions of the species. Though integral components of Yurok culture, eulachon … have not been of commercial importance in the Klamath and are … totally unstudied as to their run strengths.

Larson and Belchik (1998, p. 6) also reported that according to accounts of Yurok tribal elders:

> The last noticeable runs of eulachon were observed [in the Klamath River] in 1988 and 1989 by tribal fishers. Most fishers interviewed perceived a decline in the mid to late 1970s, while about a fifth thought it was in the 1980s. A minority of those interviewed noticed declines in the 1950s and 1960s.

Larson and Belchik (1998, p. 7) further stated that:

> In December 1988 and May 1989, a total of 44 eulachon were identified in outmigrant salmonid seining operations in and above the Klamath River estuary (CDFG unpublished seining data). Though only selected sites are seined and salmonids are the targeted species, no eulachon have been positively identified since at least 1991 (M. Wallace, CDFG, pers. commun.).

As detailed in Larson and Belchik (1998), the Yurok Tribal Fisheries Program spent more than 119 hours of staff time from February 5 to May 6, 1996, sampling for eulachon in the lower Klamath River at 5 different sites where eulachon had been noted in the past without encountering a single eulachon. However, one eulachon was captured by a Yurok tribal member near the mouth of the Klamath River in 1996 (Larson and Belchik 1998). Sweetnam et al. (2001, p. 478), in the CDFG Status Report on Living Marine Resources, stated that "In recent years, eulachon numbers seem to have declined drastically, so they are now rare or absent from the Mad River and Redwood Creek and scarce in the Klamath River." CDFG (Sweetnam et al. 2001, p. 478) also stated that "the eulachon and its fishery have been largely ignored in the past" in California, and perhaps the perceived lack of eulachon in the Klamath River, currently and in the recent past, represent a low point in a natural cycle. In January 2007 six eulachon were reportedly caught by tribal fishermen on the Klamath River.[12]

The BRT was concerned that there are almost no scientifically obtained abundance data available for eulachon in the Klamath River or any other basin in northern California. Ethnographic studies, pioneer diaries, interviews with local fishers, personal communications from managers, and newspaper accounts are therefore the best information available that provide documentation of eulachon occurrence in the Klamath River and other rivers on the northern California coast.

The BRT discussed several possible interpretations of the available information. In particular, the BRT discussed the possibility that historically runs of eulachon in the Klamath River were episodic and perhaps only occasionally large enough to be noticed. The BRT also considered the possibility that eulachon still occur in low but viable numbers in northern California rivers but are not frequently observed because of the absence of a formal monitoring program. The BRT also discussed the possibility that some eulachon may spawn in estuarine environments and are not observed in the riverine environment.

The BRT concluded, however, that explanations that posit the absence of sustained Klamath River eulachon runs historically are less consistent with the available information than the hypothesis that Klamath River eulachon runs used to be regular and large enough to be readily noticeable and now are at most small and sporadic. In particular, various accounts written by CDFG personnel (Fry 1979, Sweetnam et al. 2001, CDFG 2008), Yurok Tribal Fisheries Department personnel (Larson and Belchik 1998), the National Resource Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin (NRC 2004), or available academic literature (Moyle et al. 1995, Moyle 2002, Hamilton et al. 2005) universally describe accounts of the past occurrence of eulachon in the Klamath River and their subsequent decline. Based on the available information, the BRT was therefore unable to estimate the historical abundance of eulachon in northern California, but the BRT found no reason to discount the veracity of these anecdotal sources, which span a period of approximately 100 years and are nearly universal in their description of noticeable runs of eulachon having once ascended the Klamath River.

Likewise, although the BRT was concerned about the absence of a contemporary monitoring program for eulachon, the information available strongly indicated that noticeable runs of eulachon are not currently spawning in Klamath River or other northern California rivers. In particular, the BRT thought it likely that if eulachon were returning in any substantial numbers, it would be reported by residents or those engaged in recreation, research, or management on rivers in northern California. The BRT noted that large eulachon runs tend to attract the attention of fishermen, and the previous runs on the Klamath River were readily noticeable (e.g., "the fish moved up in huge swarms, followed by large flocks of feeding seabirds" [Moyle 2002, p. 240]). The BRT therefore concluded that the available information was most readily interpreted as indicating that noticeable, regularly returning runs of eulachon used to be present in the Klamath River, but have been rare or sporadic for a period of several decades.

[12] D. Hillemeier, Yurok Tribal Fisheries Department, Klamath, CA. Pers. commun., 23 June 2008.

Although the BRT was reasonably confident that eulachon have declined substantially in northern California, it is also clear that they have not been totally absent from this area in recent years. In particular, recent reports from Yurok tribal fisheries biologists of a few eulachon being caught incidentally in other fisheries on the Klamath in 2007 indicates eulachon still on occasion enter the Klamath River in low numbers.

**Columbia River**

The Columbia River and its tributaries support the largest eulachon run in the world (Hay et al. 2002). Despite its size and the importance of the fishery (Appendix B and Appendix D), estimates of adult spawning stock abundance are unavailable and the primary information sources on trends in Columbia River eulachon abundance are catch records. In addition to regular returns to mainstem spawning locations in the Columbia River and on the Cowlitz River (most years), eulachon are known to spawn in the following lower Columbia River tributaries: Grays River (common use), Skamokawa Creek (infrequent use), Elochoman River (periodic use), Kalama River (common use), Lewis River (common use), and Sandy River (common use in large run years) (Table A-1, Figure 2) (WDFW and ODFW 2008).

Commercial fishery records begin in 1888 (Table 7 through Table 9, Figure 22) and local newspapers record catches in the Columbia River as early as 1867 (see Appendix B). A large recreational dip net fishery for which catch records are unavailable has existed in concert with commercial fisheries, and the importance of the eulachon run to local Indian tribes was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001). The Joint Columbia River Management Staff (JCRMS 2007) stated that "limited past creel census information suggest that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time."

The BRT did not have confidence in the fishery landings, particularly prior to 2001 in the Columbia River as an accurate index of the actual abundance of the species. Landings are influenced by market conditions, fishing effort, weather, and many other factors other than actual fish abundance (WDFW and ODFW 2008). After implementation in 2000 of the interim Joint State Eulachon Management Plan (WDFW and ODFW 2001), the commercial fishery landings have become a relatively accurate index of the trend in the run size of eulachon returning to the Columbia River. For instance, eulachon returns increased during 2001–2003, dropped slightly in 2004, then dropped dramatically in 2005, which is reflected in both the commercial landings and CPUE data collected during 2001–2007. This pattern was also essentially identical to that seen in offshore eulachon abundance indices (Figure 16 and Figure 17) and in abundance and catch records in several other rivers (e.g., Fraser and Klinaklini rivers) in the DPS. JCRMS (2007) has concluded that recent commercial landings "do provide a useful measure of the relative annual run strength." In particular, state fisheries managers of Columbia River eulachon use commercial landings to judge whether population trends are upward, neutral, or downward (JCRMS 2007).

Although not useful for estimating an accurate trend, the long-term landings data do indicate that commercial catch levels were consistently high (>500 mt and often >1,000 mt) for the three-quarters of a century period from about 1915 to 1992 (Table 9, Figure 22). Catches

Table 7. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1888 | | | | | | | 150,000 | | 150,000 | Collins 1892 (p. 231) |
| 1889 | | | | | | | 60,000 | | 60,000 | Reed et al. 1891 (p. 39) |
| 1890 | | | | | | | | 1,000 | 1,000 | Crawford 1890 (p. 8) |
| 1891 | | | | | | | 150,000 | | 150,000 | Reed et al. 1892 (p. 9) |
| 1892 | | | | | | | 125,000 | 500,000 | 625,000 | Reed et al. 1892 (p. 42), Crawford 1892 (p. 9–10) |
| 1893 | | | | | | | | | Unknown[b] | |
| 1894 | | | | | | | | 300,000[c] | 300,000 | Crawford 1894 (p.5) |
| 1895 | 31,125 | | 20,625 | | 230,500 | | | | 282,250 | Wilcox 1898 (p. 604, 607, 629) |
| 1896 | | | | | | | 338,675 | 338,675 | 677,350 | McGuire 1896 (p. 77), Crawford 1896 (p. 9) |
| 1897 | | | | | | | 677,480 | 344,000 | 1,021,480 | McGuire 1898 (p. 35), Little 1898 (p. 88) |
| 1898 | | | | | | | 450,000 | 287,000 | 737,000 | McGuire 1898 (p. 118), Little 1898 (p. 15) |
| 1899 | | | | | | | 280,500 | 280,420 | 560,920 | Reed 1900 (p. 19), Little 1901 (p. 72) |
| 1900 | | | | | | | 260,200 | 227,400 | 487,600 | Reed 1900 (p. 69), Little 1901 (p. 82) |
| 1901 | | | | | | | 265,380 | | 265,380 | Van Dusen 1903 (p. 52) |
| 1902 | | | | | | | 122,454 | 450,000 | 572,454 | Van Dusen 1903 (p. 135), Kershaw 1902 (p. 82) |
| 1903 | | | | | | | 102,000 | 300,000 | 402,000 | Van Dusen 1904 (p. 69), Kershaw 1904 (p. 81) |
| 1904 | | | | | | | 15,138 | 425,322 | 440,460 | Wilcox 1907 (p. 33–34, p. 45) |
| 1905 | | | | | | | 143,015 | 340,000 | 483,015 | Van Dusen 1907 (p. 111), Riseland 1907 (p. 81) |
| 1906 | | | | | | | 163,000 | 340,000 | 503,000 | Van Dusen 1907 (p. 190), Riseland 1907 (p. 56) |
| 1907 | | | | | | | 169,804 | | 169,804 | Van Dusen and McCallister 1908 (p. 110) |
| 1908 | | | | | | | 262,022 | 340,000 | 602,022 | Van Dusen and McCallister 1906 (p. 150), Riseland 1909 (p. 25) |
| 1909 | | | | | | | 209,608 | 340,000 | 549,608 | Van Dusen and McCallister 1911 (p. 36), Riseland 1909 (p. 37) |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1910 | | | | | | | 272,478 | 350,000 | 622,478 | McCallister and Clanton 1911 (p. 44), Riseland 1911 (p. 46) |
| 1911 | | | | | | | 174,639 | 175,000 | 349,639 | Clanton 1913 (p. 112), Riseland 1911 (p. 58) |
| 1912 | | | | | | | 320,336 | 175,000 | 495,336 | Clanton 1913 (p. 112), Riseland 1911 (p. 48) |
| 1913 | | | | | | | | 200,000 | 200,000 | Riseland 1913 (p. 63) |
| 1914 | | | | | | | | | Unknown[b] | |
| 1915 | | | 1,609,500 | | | | | | 1,609,500 | Radcliffe 1920 (p. 64–65) |
| 1916 | | | | | | | | 641,595 | 641,595 | Darwin 1917 (p. 103) |
| 1917 | | | | | | | | 2,806,129 | 2,806,129 | Darwin 1917 (p. 173) |
| 1918 | | | | | | | | 1,633,700 | 1,633,700 | Darwin 1920 (p. 64) |
| 1919 | | | | | | | | 2,405,360 | 2,405,360 | Darwin 1920 (p. 121) |
| 1920 | | | | | | | | 977,084 | 977,084 | Darwin 1920 (p. 162) |
| 1921 | | | | | | | | 1,051,283 | 1,051,283 | Darwin 1921 (p. 236) |
| 1922 | | | | | | | 215,000 | 1,156,180 | 1,371,180 | Sette 1926 (p. 306), Brennan 1936 (p. 100) |
| 1923 | | | | | | | 277,195 | 752,223 | 1,029,418 | Sette 1926 (p. 346–347), Brennan 1936 (p. 100) |
| 1924 | | | | | | | 226,800 | 779,422 | 1,006,222 | Sette 1928 (p. 409), Pollock 1925 (p. 44) |
| 1925 | | | | | | | 308,676 | 1,092,028 | 1,400,704 | Sette 1928 (p. 445), Pollock 1925 (p. 97) |
| 1926 | | | | | | | 72,900 | 1,194,314 | 1,267,214 | Sette and Fiedler 1929 (p. 514), Pollock 1928 (p. 104) |
| 1927 | | | | | | | 411,732 | 881,314 | 1,293,046 | Fiedler 1930 (p. 570), Pollock 1928 (p. 168) |
| 1928 | | | | | | | 19,148 | 1,149,670 | 1,168,818 | Maybury 1930 (p. 33), Cleaver 1951 (p. 80) |
| 1929 | | | | | | | 50,061 | 1,158,419 | 1,208,480 | Maybury 1930 (p. 84), Cleaver 1951 (p. 80) |
| 1930 | | | | | | | 194,172 | 1,260,314 | 1,454,486 | Pollock 1932 (p. 14, 49), Cleaver 1951 (p. 80) |
| 1931 | | | | | | | 435,306 | 1,521,966 | 1,957,272 | Pollock 1932 (p. 14, 103), Cleaver 1951 (p. 80) |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1932 | | | | | | | 233,993 | 1,349,955 | 1,583,948 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1933 | | | | | | | 520,418 | 872,172 | 1,392,590 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1934 | | | | | | | 536,036 | 957,120 | 1,520,156 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1935 | | | | | | | 132,773 | 2,199,185 | 2,331,958 | Brennan 1936 (p. 100), Cleaver 1951 (p. 80) |
| 1936 | 194,705 | 27,200 | 2,583,525 | 0 | 144,325 | 134,102 | | | 3,083,857 | Cleaver 1951 (p. 154) |
| 1937 | 432,063 | 7,350 | 1,999,030 | 0 | 0 | 0 | | | 2,438,443 | Cleaver 1951 (p. 154) |
| 1938 | 866,700 | 2,100 | 33,100 | 76,600 | 63,100 | 0 | | | 1,041,600 | WDFW and ODFW 2002 |
| 1939 | 721,600 | 35,700 | 996,400 | 0 | 1,342,700 | 0 | | | 3,096,400 | WDFW and ODFW 2002 |
| 1940 | 820,200 | 53,700 | 736,800 | 3,000 | 1,341,300 | 127,500 | | | 3,082,500 | WDFW and ODFW 2002 |
| 1941 | 193,200 | 0 | 1,793,000 | 0 | 377,000 | 168,600 | | | 2,531,800 | WDFW and ODFW 2002 |
| 1942 | 318,600 | 51,800 | 1,555,300 | 0 | 0 | 760,300 | | | 2,686,000 | WDFW and ODFW 2002 |
| 1943 | 643,000 | 3,700 | 2,972,500 | 0 | 273,200 | 84,900 | | | 3,977,300 | WDFW and ODFW 2002 |
| 1944 | 572,700 | 10,900 | 1,126,400 | 44,300 | 514,200 | 0 | | | 2,268,500 | WDFW and ODFW 2002 |
| 1945 | 633,300 | 59,200 | 2,048,400 | 32,500 | 1,552,800 | 1,393,100 | | | 5,719,300 | WDFW and ODFW 2002 |
| 1946 | 253,200 | 300 | 2,674,000 | 0 | 0 | 348,500 | | | 3,276,000 | WDFW and ODFW 2002 |
| 1947 | 352,300 | 0 | 1,192,600 | 0 | 0 | 0 | | | 1,544,900 | WDFW and ODFW 2002 |
| 1948 | 1,015,800 | 0 | 2,197,800 | 0 | 547,600 | 212,900 | | | 3,974,100 | WDFW and ODFW 2002 |
| 1949 | 919,100 | 300 | 800 | 0 | 1,940,900 | 472,500 | | | 3,333,600 | WDFW and ODFW 2002 |
| 1950 | 912,700 | 11,600 | 0 | 1,000 | 557,200 | 0 | | | 1,482,500 | WDFW and ODFW 2002 |
| 1951 | 1,337,600 | 0 | 0 | 0 | 0 | 179,300 | | | 1,516,900 | WDFW and ODFW 2002 |
| 1952 | 867,100 | 0 | 380,600 | 17,800 | 8,100 | 1,300 | | | 1,274,900 | WDFW and ODFW 2002 |
| 1953 | 439,300 | 15,600 | 795,400 | 2,800 | 0 | 457,900 | | | 1,711,000 | WDFW and ODFW 2002 |
| 1954 | 673,900 | 0 | 792,900 | 16,200 | 360,900 | 40,400 | | | 1,884,300 | WDFW and ODFW 2002 |
| 1955 | 887,500 | 0 | 1,349,600 | 0 | 0 | 0 | | | 2,237,100 | WDFW and ODFW 2002 |
| 1956 | 877,400 | 0 | 575,100 | 32,600 | 0 | 198,800 | | | 1,683,900 | WDFW and ODFW 2002 |
| 1957 | 377,500 | 2,200 | 987,800 | 0 | 0 | 211,500 | | | 1,579,000 | WDFW and ODFW 2002 |
| 1958 | 373,300 | 0 | 2,243,100 | 0 | 0 | 0 | | | 2,616,400 | WDFW and ODFW 2002 |
| 1959 | 760,000 | 0 | 62,300 | 44,100 | 889,700 | 0 | | | 1,756,100 | WDFW and ODFW 2002 |
| 1960 | 185,700 | 700 | 985,800 | 0 | 0 | 0 | | | 1,172,200 | WDFW and ODFW 2002 |
| 1961 | 466,400 | 0 | 585,900 | 0 | 0 | 0 | | | 1,052,300 | WDFW and ODFW 2002 |
| 1962 | 690,300 | 0 | 783,300 | 0 | 0 | 0 | | | 1,473,600 | WDFW and ODFW 2002 |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 222,300 | 21,300 | 833,500 | 0 | 0 | 0 | | | 1,077,100 | WDFW and ODFW 2002 |
| 1964 | 452,900 | 0 | 388,900 | 0 | 0 | 0 | | | 841,800 | WDFW and ODFW 2002 |
| 1965 | 828,700 | 0 | 0 | 0 | 82,000 | 0 | | | 910,700 | WDFW and ODFW 2002 |
| 1966 | 712,200 | 0 | 316,100 | 0 | 0 | 0 | | | 1,028,300 | WDFW and ODFW 2002 |
| 1967 | 357,100 | 23,200 | 620,500 | 0 | 0 | 0 | | | 1,000,800 | WDFW and ODFW 2002 |
| 1968 | 133,300 | 1,200 | 813,000 | 0 | 0 | 0 | | | 947,500 | WDFW and ODFW 2002 |
| 1969 | 113,700 | 52,800 | 917,200 | 0 | 0 | 0 | | | 1,083,700 | WDFW and ODFW 2002 |
| 1970 | 238,200 | 4,500 | 559,700 | 55,900 | 325,600 | 0 | | | 1,183,900 | WDFW and ODFW 2002 |
| 1971 | 364,500 | 0 | 509,400 | 0 | 902,800 | 0 | | | 1,776,700 | WDFW and ODFW 2002 |
| 1972 | 304,100 | 0 | 1,339,400 | 0 | 0 | 0 | | | 1,643,500 | WDFW and ODFW 2002 |
| 1973 | 132,000 | 0 | 2,302,400 | 0 | 0 | 0 | | | 2,434,400 | WDFW and ODFW 2002 |
| 1974 | 868,400 | 6,200 | 1,474,700 | 0 | 500 | 12,000 | | | 2,361,800 | WDFW and ODFW 2002 |
| 1975 | 28,300 | 0 | 2,049,300 | 0 | 0 | 0 | | | 2,077,600 | WDFW and ODFW 2002 |
| 1976 | 9,400 | 0 | 3,055,300 | 0 | 0 | 10,400 | | | 3,075,100 | WDFW and ODFW 2002 |
| 1977 | 662,700 | 0 | 0 | 326,200 | 0 | 764,100 | | | 1,753,000 | WDFW and ODFW 2002 |
| 1978 | 16,600 | 0 | 2,642,700 | 0 | 21,000 | 0 | | | 2,680,300 | WDFW and ODFW 2002 |
| 1979 | 313,600 | 0 | 18,200 | 0 | 233,300 | 591,600 | | | 1,156,700 | WDFW and ODFW 2002 |
| 1980 | 160,100 | 8,800 | 116,500 | 700 | 2,651,600 | 273,800 | | | 3,211,500 | WDFW and ODFW 2002 |
| 1981 | 158,200 | 0 | 932,500 | 0 | 567,100 | 14,500 | | | 1,672,300 | WDFW and ODFW 2002 |
| 1982 | 304,200 | 0 | 1,343,200 | 8,200 | 554,400 | 0 | | | 2,210,000 | WDFW and ODFW 2002 |
| 1983 | 58,700 | 0 | 1,307,300 | 0 | 1,364,400 | 0 | | | 2,730,400 | WDFW and ODFW 2002 |
| 1984 | 120,400 | 0 | 377,600 | 0 | 0 | 0 | | | 498,000 | WDFW and ODFW 2002 |
| 1985 | 537,800 | 34,900 | 1,160,800 | 0 | 0 | 304,500 | | | 2,038,000 | WDFW and ODFW 2002 |
| 1986 | 53,000 | 0 | 3,736,100 | 0 | 49,700 | 0 | | | 3,838,800 | WDFW and ODFW 2002 |
| 1987 | 73,600 | 0 | 1,321,000 | 700 | 500,400 | 0 | | | 1,895,700 | WDFW and ODFW 2002 |
| 1988 | 72,800 | 0 | 2,244,300 | 0 | 549,600 | 1,000 | | | 2,867,700 | WDFW and ODFW 2002 |
| 1989 | 65,200 | 0 | 3,001,600 | 0 | 0 | 0 | | | 3,066,800 | WDFW and ODFW 2002 |
| 1990 | 6,400 | 0 | 2,756,200 | 0 | 21,600 | 0 | | | 2,784,200 | JCRMS 2007 |
| 1991 | 5,800 | 0 | 2,944,600 | 0 | 0 | 0 | | | 2,950,400 | JCRMS 2007 |
| 1992 | 800 | 0 | 3,673,000 | 0 | 0 | 0 | | | 3,673,800 | JCRMS 2007 |
| 1993 | 33,200 | 0 | 413,900 | 66,800 | 0 | 0 | | | 513,900 | JCRMS 2007 |
| 1994 | 200 | 0 | 43,200 | 0 | 0 | 0 | | | 43,400 | JCRMS 2007 |
| 1995 | 7,700 | 0 | 431,400 | 900 | 0 | 0 | | | 440,000 | JCRMS 2007 |
| 1996 | 7,100 | 0 | 2,000 | 0 | 0 | 0 | | | 9,100 | JCRMS 2007 |
| 1997 | 37,100 | 0 | 21,500 | 0 | 0 | 0 | | | 58,600 | JCRMS 2007 |

Table 7 continued. Eulachon (aka Columbia River smelt) landings (pounds) from the Columbia River and tributary commercial fisheries. Prior to 1936, data were commonly reported by state; after that time data were reported by river basin, but not by individual state.

| Year | Columbia River | Grays River | Cowlitz River | Kalama River | Lewis River | Sandy River | Oregon only[a] | Washington only | Total | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 11,900 | 0 | 200 | 0 | 0 | 0 | | | 12,100 | JCRMS 2007 |
| 1999 | 20,900 | 0 | 0 | 0 | 0 | 0 | | | 20,900 | JCRMS 2007 |
| 2000 | 31,000 | 0 | 0 | 0 | 0 | 0 | | | 31,000 | JCRMS 2007 |
| 2001 | 158,800 | 0 | 154,300 | 0 | 0 | 0 | | | 313,100 | JCRMS 2007 |
| 2002 | 58,000 | 0 | 169,600 | 0 | 493,600 | 0 | | | 721,200 | JCRMS 2007 |
| 2003 | 66,900 | 0 | 464,400 | 0 | 529,100 | 23,000 | | | 1,083,400 | JCRMS 2007 |
| 2004 | 15,400 | 0 | 216,200 | 0 | 0 | 0 | | | 231,600 | JCRMS 2007 |
| 2005 | 100 | 0 | 100 | 0 | 0 | 0 | | | 200 | JCRMS 2007 |
| 2006 | 13,100 | 0 | 0 | 0 | 0 | 0 | | | 13,100 | JCRMS 2007 |
| 2007 | 7,100 | 0 | 1,200 | 0 | 0 | 0 | | | 8,300 | JCRMS 2007 |
| 2008 | 11,400 | 0 | 5,900 | 0 | 0 | 0 | | | 17,300 | JCRMS 2008 |
| 2009 | 5,551 | 0 | 12,093 | 0 | 0 | 0 | | | 17,644 | WDFW 2009 |

[a]Some Oregon commercial smelt catch values may be statewide smelt catch and may include an unknown number of noneulachon smelt caught in coastal streams.
[b]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[c]Crawford (1894, p. 5) reported landings that equated to a monetary value of $3,000. At an average of one cent per pound, this equates to approximately 300,000 pounds of eulachon.

Table 8. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1888 | 150,000 | 1,620,000 | 1,845,000 |
| 1889 | 60,000 | 648,000 | 738,000 |
| 1890 | 1,000 | 10,800 | 12,300 |
| 1891 | 150,000 | 1,620,000 | 1,845,000 |
| 1892 | 625,000 | 6,750,000 | 7,687,500 |
| 1893 | Unknown* | — | — |
| 1894 | 300,000 | 3,240,000 | 3,690,000 |
| 1895 | 313,375 | 3,384,450 | 3,854,513 |
| 1896 | 677,350 | 7,315,380 | 8,331,405 |
| 1897 | 1,021,480 | 11,031,984 | 12,564,204 |
| 1898 | 737,000 | 7,959,600 | 9,065,100 |
| 1899 | 560,920 | 6,057,936 | 6,899,316 |
| 1900 | 487,600 | 5,266,080 | 5,997,480 |
| 1901 | 265,380 | 2,866,104 | 3,264,174 |
| 1902 | 572,454 | 6,182,503 | 7,041,184 |
| 1903 | 402,000 | 4,341,600 | 4,944,600 |
| 1904 | 440,460 | 4,756,968 | 5,417,658 |
| 1905 | 483,015 | 5,216,562 | 5,941,085 |
| 1906 | 503,000 | 5,432,400 | 6,186,900 |
| 1907 | 169,804 | 1,833,883 | 2,088,589 |
| 1908 | 602,022 | 6,501,838 | 7,404,871 |
| 1909 | 549,608 | 5,935,766 | 6,760,178 |
| 1910 | 622,478 | 6,722,762 | 7,656,479 |
| 1911 | 349,639 | 3,776,101 | 4,300,560 |
| 1912 | 495,336 | 5,349,629 | 6,092,633 |
| 1913 | 200,000 | 2,160,000 | 2,460,000 |
| 1914 | Unknown* | — | — |
| 1915 | 1,609,500 | 17,382,600 | 19,796,850 |
| 1916 | 641,595 | 6,929,226 | 7,891,619 |
| 1917 | 2,806,129 | 30,306,193 | 34,515,387 |
| 1918 | 1,633,700 | 17,643,960 | 20,094,510 |
| 1919 | 2,405,360 | 25,977,888 | 29,585,928 |
| 1920 | 977,084 | 10,552,507 | 12,018,133 |
| 1921 | 1,051,283 | 11,353,856 | 12,930,781 |
| 1922 | 1,371,180 | 14,808,744 | 16,865,514 |
| 1923 | 1,029,418 | 11,117,714 | 12,661,841 |
| 1924 | 1,006,222 | 10,867,198 | 12,376,531 |
| 1925 | 1,400,704 | 15,127,603 | 17,228,659 |
| 1926 | 1,267,214 | 13,685,911 | 15,586,732 |
| 1927 | 1,293,046 | 13,964,897 | 15,904,466 |
| 1928 | 1,168,818 | 12,623,234 | 14,376,461 |
| 1929 | 1,208,480 | 13,051,584 | 14,864,304 |
| 1930 | 1,454,486 | 15,708,449 | 17,890,178 |

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1931 | 1,957,272 | 21,138,538 | 24,074,446 |
| 1932 | 1,583,948 | 17,106,638 | 19,482,560 |
| 1933 | 1,392,590 | 15,039,972 | 17,128,857 |
| 1934 | 1,520,156 | 16,417,685 | 18,697,919 |
| 1935 | 2,331,958 | 25,185,146 | 28,683,083 |
| 1936 | 3,083,857 | 33,305,656 | 37,931,441 |
| 1937 | 2,438,443 | 26,335,184 | 29,992,849 |
| 1938 | 1,041,600 | 11,249,280 | 12,811,680 |
| 1939 | 3,096,400 | 33,441,120 | 38,085,720 |
| 1940 | 3,082,500 | 33,291,000 | 37,914,750 |
| 1941 | 2,531,800 | 27,343,440 | 31,141,140 |
| 1942 | 2,686,000 | 29,008,800 | 33,037,800 |
| 1943 | 3,977,300 | 42,954,840 | 48,920,790 |
| 1944 | 2,268,500 | 24,499,800 | 27,902,550 |
| 1945 | 5,719,300 | 61,768,440 | 70,347,390 |
| 1946 | 3,276,000 | 35,380,800 | 40,294,800 |
| 1947 | 1,544,900 | 16,684,920 | 19,002,270 |
| 1948 | 3,974,100 | 42,920,280 | 48,881,430 |
| 1949 | 3,333,600 | 36,002,880 | 41,003,280 |
| 1950 | 1,482,500 | 16,011,000 | 18,234,750 |
| 1951 | 1,516,900 | 16,382,520 | 18,657,870 |
| 1952 | 1,274,900 | 13,768,920 | 15,681,270 |
| 1953 | 1,711,000 | 18,478,800 | 21,045,300 |
| 1954 | 1,884,300 | 20,350,440 | 23,176,890 |
| 1955 | 2,237,100 | 24,160,680 | 27,516,330 |
| 1956 | 1,683,900 | 18,186,120 | 20,711,970 |
| 1957 | 1,579,000 | 17,053,200 | 19,421,700 |
| 1958 | 2,616,400 | 28,257,120 | 32,181,720 |
| 1959 | 1,756,100 | 18,965,880 | 21,600,030 |
| 1960 | 1,172,200 | 12,659,760 | 14,418,060 |
| 1961 | 1,052,300 | 11,364,840 | 12,943,290 |
| 1962 | 1,473,600 | 15,914,880 | 18,125,280 |
| 1963 | 1,077,100 | 11,632,680 | 13,248,330 |
| 1964 | 841,800 | 9,091,440 | 10,354,140 |
| 1965 | 910,700 | 9,835,560 | 11,201,610 |
| 1966 | 1,028,300 | 11,105,640 | 12,648,090 |
| 1967 | 1,000,800 | 10,808,640 | 12,309,840 |
| 1968 | 947,500 | 10,233,000 | 11,654,250 |
| 1969 | 1,083,700 | 11,703,960 | 13,329,510 |
| 1970 | 1,183,900 | 12,786,120 | 14,561,970 |
| 1971 | 1,776,700 | 19,188,360 | 21,853,410 |
| 1972 | 1,643,500 | 17,749,800 | 20,215,050 |
| 1973 | 2,434,400 | 26,291,520 | 29,943,120 |

Table 8 continued. Eulachon landings from the Columbia River and tributary commercial fishery and total numbers of fish in the catch, assuming a range of 10.8 to 12.3 eulachon per pound, based on the mean reported weight of eulachon in the Columbia River of 37 to 42 g. Landings data from sources listed in Table 7.

| Year | Total landings (pounds) | Number of fish at 10.8 per pound | Number of fish at 12.3 per pound |
|---|---|---|---|
| 1974 | 2,361,800 | 25,507,440 | 29,050,140 |
| 1975 | 2,077,600 | 22,438,080 | 25,554,480 |
| 1976 | 3,075,100 | 33,211,080 | 37,823,730 |
| 1977 | 1,753,000 | 18,932,400 | 21,561,900 |
| 1978 | 2,680,300 | 28,947,240 | 32,967,690 |
| 1979 | 1,156,700 | 12,492,360 | 14,227,410 |
| 1980 | 3,211,500 | 34,684,200 | 39,501,450 |
| 1981 | 1,672,300 | 18,060,840 | 20,569,290 |
| 1982 | 2,210,000 | 23,868,000 | 27,183,000 |
| 1983 | 2,730,400 | 29,488,320 | 33,583,920 |
| 1984 | 498,000 | 5,378,400 | 6,125,400 |
| 1985 | 2,038,000 | 22,010,400 | 25,067,400 |
| 1986 | 3,838,800 | 41,459,040 | 47,217,240 |
| 1987 | 1,895,700 | 20,473,560 | 23,317,110 |
| 1988 | 2,867,700 | 30,971,160 | 35,272,710 |
| 1989 | 3,066,800 | 33,121,440 | 37,721,640 |
| 1990 | 2,784,200 | 30,069,360 | 34,245,660 |
| 1991 | 2,950,400 | 31,864,320 | 36,289,920 |
| 1992 | 3,673,800 | 39,677,040 | 45,187,740 |
| 1993 | 513,900 | 5,550,120 | 6,320,970 |
| 1994 | 43,400 | 468,720 | 533,820 |
| 1995 | 440,000 | 4,752,000 | 5,412,000 |
| 1996 | 9,100 | 98,280 | 111,930 |
| 1997 | 58,600 | 632,880 | 720,780 |
| 1998 | 12,100 | 130,680 | 148,830 |
| 1999 | 20,900 | 225,720 | 257,070 |
| 2000 | 31,000 | 334,800 | 381,300 |
| 2001 | 313,100 | 3,381,480 | 3,851,130 |
| 2002 | 721,200 | 7,788,960 | 8,870,760 |
| 2003 | 1,083,400 | 11,700,720 | 13,325,820 |
| 2004 | 231,600 | 2,501,280 | 2,848,680 |
| 2005 | 200 | 2,160 | 2,460 |
| 2006 | 13,100 | 141,480 | 161,130 |
| 2007 | 8,310 | 89,748 | 102,213 |
| 2008 | 17,300 | 186,840 | 212,790 |
| 2009 | 17,644 | 190,555 | 217,021 |

*Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.

Table 9. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 1888 | 68.04 | | | | | |
| 1889 | 27.22 | | | | | |
| 1890 | 0.45 | | | | | |
| 1891 | 68.04 | | | | | |
| 1892 | 283.50 | | | | | |
| 1893 | Unknown[a] | | | | | |
| 1894 | 136.08 | | | | | |
| 1895 | 142.14 | | | | | |
| 1896 | 307.24 | | | | | |
| 1897 | 463.34 | | | | | |
| 1898 | 334.30 | | | | | |
| 1899 | 254.43 | | | | | |
| 1900 | 221.17 | 113.40 | | | | 27.2 |
| 1901 | 120.37 | 108.86 | | | | 27.2 |
| 1902 | 259.66 | 90.72 | | | | 22.7 |
| 1903 | 182.34 | 128.97 | | | | 22.7 |
| 1904 | 199.79 | 129.27 | | | | 18.1 |
| 1905 | 219.09 | 22.68 | | | | 4.5 |
| 1906 | 228.16 | 13.61 | | | | 5.4 |
| 1907 | 77.02 | 6.80 | | | | 4.5 |
| 1908 | 273.07 | 10.21 | | | | 4.1 |
| 1909 | 249.30 | 31.75 | | | | 4.5 |
| 1910 | 282.35 | 42.50 | | | | 136.1 |
| 1911 | 158.59 | 32.66 | | | | 113.4 |
| 1912 | 224.68 | 36.29 | | | | 90.7 |
| 1913 | 90.72 | 10.52 | | | | 68.0 |
| 1914 | Unknown[a] | 6.44 | | | | 54.4 |
| 1915 | 730.06 | 12.34 | | | | 45.4 |
| 1916 | 291.02 | 12.52 | | | | 45.4 |
| 1917 | 1,272.84 | 17.28 | | | | |
| 1918 | 741.03 | 15.20 | | | | |
| 1919 | 1,091.05 | 5.94 | | | | 1.9 |
| 1920 | 443.20 | 5.22 | | | | |
| 1921 | 476.85 | 8.53 | | | | |
| 1922 | 621.96 | 7.98 | | | | |
| 1923 | 466.94 | 19.87 | | | | |
| 1924 | 456.41 | 36.51 | | | | 15.4 |
| 1925 | 635.35 | 16.19 | | | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 1926 | 574.80 | 17.24 | | | | 1.1 |
| 1927 | 586.52 | 12.97 | | | | 9.1 |
| 1928 | 530.17 | 18.73 | | | | |
| 1929 | 548.16 | 9.71 | | | | 6.6 |
| 1930 | 659.74 | 35.33 | | | | 5.4 |
| 1931 | 887.80 | 6.30 | | | | 2.7 |
| 1932 | 718.47 | 5.03 | | | | 3.3 |
| 1933 | 631.67 | 6.94 | | | | |
| 1934 | 689.53 | 10.25 | | | | |
| 1935 | 1,057.76 | 15.47 | | | | 0.9 |
| 1936 | 1,398.81 | 10.07 | | | | |
| 1937 | 1,106.06 | 4.08 | | | | |
| 1938 | 472.46 | 7.67 | | | | |
| 1939 | 1,404.50 | 20.59 | | | | |
| 1940 | 1,398.20 | 34.16 | | | | |
| 1941 | 1,148.41 | 50.1 | | | | 1.0 |
| 1942 | 1,218.35 | 152.7 | | | | |
| 1943 | 1,804.07 | 154.8 | | | | |
| 1944 | 1,028.97 | 65.7 | | Unknown[b] | | |
| 1945 | 2,594.23 | 73.87 | | 8.0 | | |
| 1946 | 1,485.97 | 115.7 | | 10.0 | | |
| 1947 | 700.75 | 231.1 | 135.0 | Unknown[b] | | |
| 1948 | 1,802.62 | 112.8 | | 20.0 | | |
| 1949 | 1,512.10 | 102.7 | 70.0 | 8.5 | | |
| 1950 | 672.45 | 36.2 | 100.0 | 44.0 | | |
| 1951 | 688.05 | 189.3 | 20.0 | 10.0 | | |
| 1952 | 578.28 | 421.0 | 27.5 | 12.3 | | |
| 1953 | 776.10 | 158.6 | | 41.7 | | |
| 1954 | 854.70 | 151.6 | | 69.4 | | |
| 1955 | 1,014.73 | 238.8 | | 7.6 | | |
| 1956 | 763.80 | 235.5 | | 6.2 | | |
| 1957 | 716.22 | 33.2 | | 5.6 | | |
| 1958 | 1,186.78 | 92.1 | | 8.4 | | |
| 1959 | 796.55 | 132.0 | 45.0 | 7.0 | | |
| 1960 | 531.70 | 84.0 | 60.0 | 0.3 | | |
| 1961 | 477.32 | 216.9 | | 2.0 | | |
| 1962 | 668.41 | 178.2 | 70.0 | 2.8 | | |
| 1963 | 488.56 | 159.3 | | 8.4 | | |
| 1964 | 381.83 | 105.5 | | 22.4 | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 1965 | 413.09 | 87.8 | 100.0 | 11.8 | | |
| 1966 | 466.43 | 101.9 | | 9.2 | | |
| 1967 | 453.96 | 86.8 | 100.0 | 11.5 | | |
| 1968 | 429.78 | 46.0 | 100.0 | 10.6 | | |
| 1969 | 491.56 | 29.8 | 80.0 | 7.8 | | |
| 1970 | 537.01 | 71.7 | 40.0 | 9.2 | | |
| 1971 | 805.90 | 34.5 | 20.0 | 16.8 | | |
| 1972 | 745.48 | 53.2 | 50.0 | 6.7 | | |
| 1973 | 1,104.23 | 53.1 | 40.0 | 12.3 | | |
| 1974 | 1,071.29 | 75.3 | | 10.6 | | |
| 1975 | 942.38 | 27.7 | | 12.0 | | |
| 1976 | 1,394.84 | 36.7 | | 50.0 | | |
| 1977 | 795.15 | 32.2 | 50.0 | 35.0 | | |
| 1978 | 1,215.76 | 38.6 | | 25.0 | | |
| 1979 | 524.67 | 22.3 | | 19.8 | | |
| 1980 | 1,456.71 | 24.4 | | 33.0 | | |
| 1981 | 758.54 | 21.2 | | 38.5 | | |
| 1982 | 1,002.44 | 13.7 | | 22.0 | | |
| 1983 | 1,238.49 | 10.8 | | 30.5 | | |
| 1984 | 225.89 | 11.8 | | 30.0 | | |
| 1985 | 924.42 | 29.2 | | Unknown[b] | | |
| 1986 | 1,741.25 | 49.6 | | Unknown[b] | | |
| 1987 | 859.88 | 19.3 | | Unknown[b] | | |
| 1988 | 1,300.77 | 39.5 | | Unknown[b] | 43.2 | |
| 1989 | 1,391.08 | 18.7 | | Unknown[b] | 50.2 | |
| 1990 | 1,262.89 | 19.9 | | Unknown[b] | 44.1 | |
| 1991 | 1,338.28 | 12.3 | | Unknown[b] | 57.2 | |
| 1992 | 1,666.41 | 19.6 | | Unknown[b] | 65.4 | |
| 1993 | 233.10 | 8.7 | | Unknown[b] | 93.0 | |
| 1994 | 19.69 | 6.1 | | 20.0 | 20.6 | |
| 1995 | 199.58 | 15.5 | | 22.0 | 69.2 | |
| 1996 | 4.13 | 63.2 | | Unknown[b] | 81.0 | |
| 1997 | 26.58 | Closed | | Unknown[b] | 41.9 | |
| 1998 | 5.49 | Closed | | Unknown[b] | 61.7 | |
| 1999 | 9.48 | Closed | | 0.0 | | |
| 2000 | 14.06 | Closed | | 0.0 | | |
| 2001 | 142.02 | Closed | | | | |
| 2002 | 327.13 | 5.8 | | | | |
| 2003 | 491.42 | Closed | | | | |

Table 9 continued. Estimated eulachon fishery landings (mt) for available subsets of the southern DPS. Data from sources listed in Table 7, Hay (2002), Lewis et al. (2002), Moody (2008), Parliament of Canada (1900–1916), and Canadian Bureau of Statistics (1917–1941). Fraser and Skeena river data reported in cwt (hundredweight) were assumed to be short hundredweight and were converted using 100 lb = 1 cwt, the conversion currently used by Statistics Canada.

| Year | Columbia River | Fraser River | Knight Inlet (Klinaklini River) | Bella Coola River | Kemano River | Skeena River |
|---|---|---|---|---|---|---|
| 2004 | 105.05 | 0.4 | | | | |
| 2005 | 0.09 | Closed | | | | |
| 2006 | 5.94 | Closed | | | | |
| 2007 | 3.77 | Closed | | | | |
| 2008 | 7.85 | Closed | | | | |
| 2009 | 8.00 | Closed | | | | |

[a]Official landings data were not located for 1893 and 1914; however, newspapers (Appendix B) and local periodicals (Appendix D) recorded that substantial eulachon landings did occur in the Columbia River basin in those years.
[b]Landings of unknown size occurred but data were not recorded (Hay 2002).

declined greatly to 233 mt in 1993 and to an average of less than 40 mt between 1994 and 2000. From 2001 to 2004, the catches increased to an average of 266 mt, before falling to less than 5 mt from 2005 to 2008. Fishing restrictions were instituted in 1995, so the low catches after that time are in part due to these restrictions (Figure 23 and Figure 24). Nonetheless, the steep decline in 1993 and subsequent low abundance as indexed by the fishery is generally accepted by fishery managers as indicating a marked decline in the abundance of the stock (Bargmann et al. 2005). The WDFW and ODFW Joint Columbia River Management Staff (JCRMS 2007) concluded that "run sizes [of Columbia River eulachon], as indexed by commercial landings, remained relatively stable for several decades until landings dropped suddenly in 1993 and remained low for several years thereafter." Following this period of time, "Due to reduced seasons during 1995–2000, landings are not completely comparable with previous years; however, it is apparent that the abundance of smelt in the Columbia River Basin was much reduced during 1993–2000" (JCRMS 2005) (Table 7, Figure 22 through Figure 25).

A previous petition (Wright 1999) and NMFS finding on this petition (NMFS 1999) mentioned years where zero catches were reported for eulachon in the Columbia River. The present status review uncovered additional published Columbia River commercial fishery landings data in annual reports of state and federal fisheries agencies that fill in most of these gaps in the catch record (Table 7, Figure 22), with the exception of 1893 and 1914. In both cases, a survey of periodicals (Appendix D) and available online digital newspaper resources (see Appendix B) found articles describing the presence of eulachon in the Columbia River in those years.

The Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001 (with an interim plan in effect in 2000), which provides for three levels of fishing based on parental run strength, juvenile production, and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005). Effort in this fishery

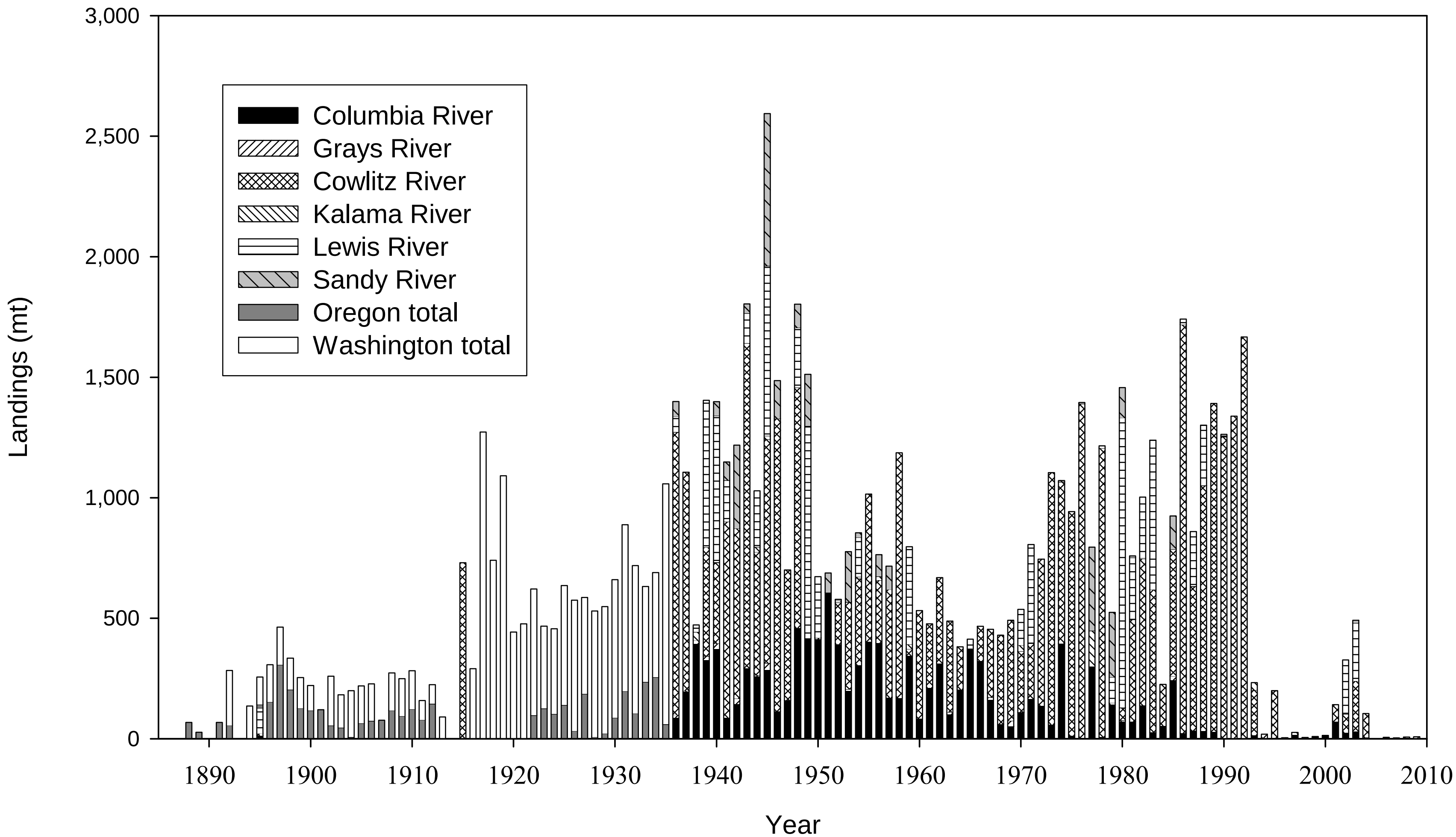



Figure 22. Commercial eulachon fishery landings in the Columbia River and tributaries from 1888 to 2009. Landings occurred in 1890 and in the Grays and Kalama rivers in many years; however, values are too small to be evident on the graph. Landings occurred in 1893 and 1914, based on newspaper and periodical sources (see Appendix B and Appendix D), but official records have not been located. Data sources listed in Table 7.

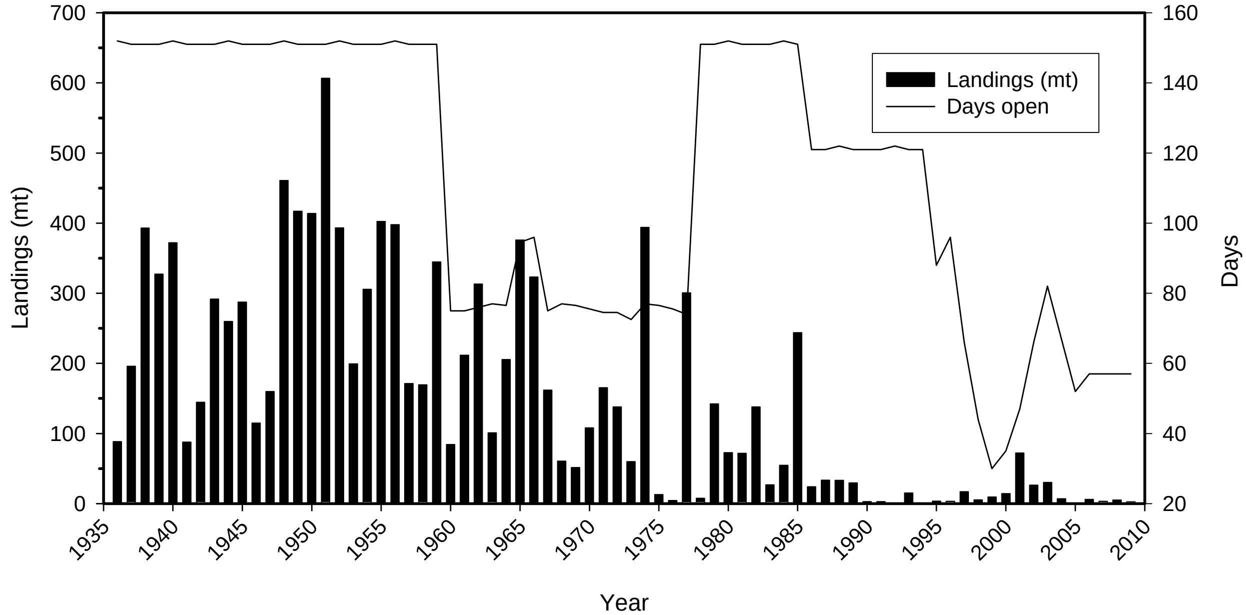



Figure 23. Commercial landings of eulachon and estimated total number of days the fishery was open in the Columbia River from 1935 to 2009.

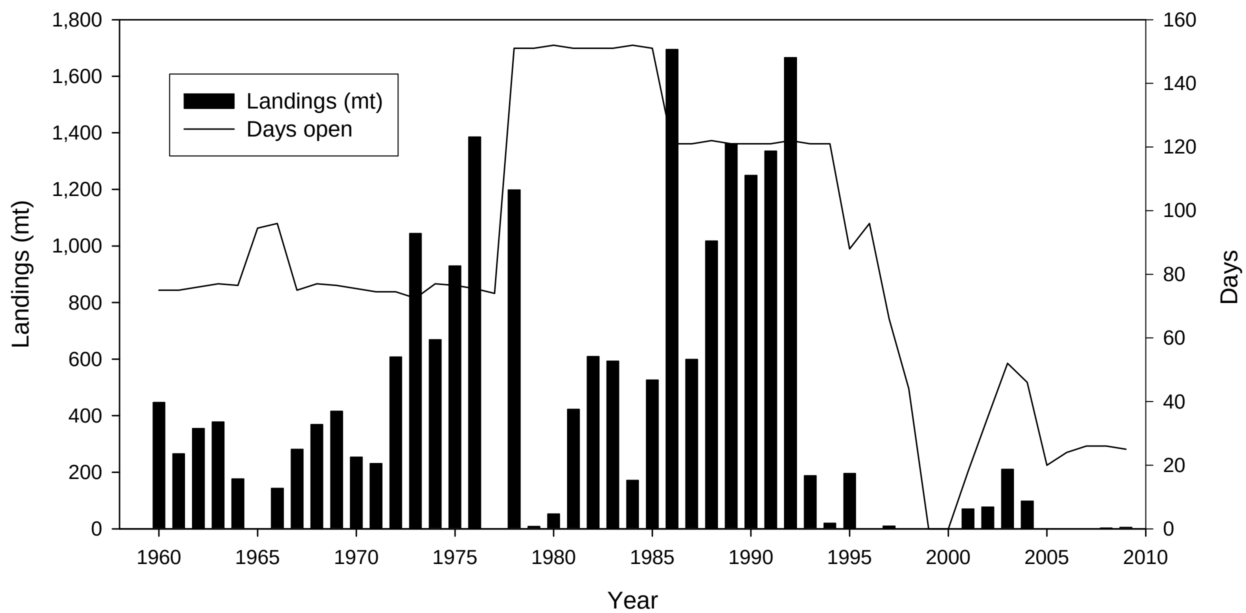



Figure 24. Commercial landings of eulachon and estimated total number of days the fishery was open in the Cowlitz River from 1960 to 2009.

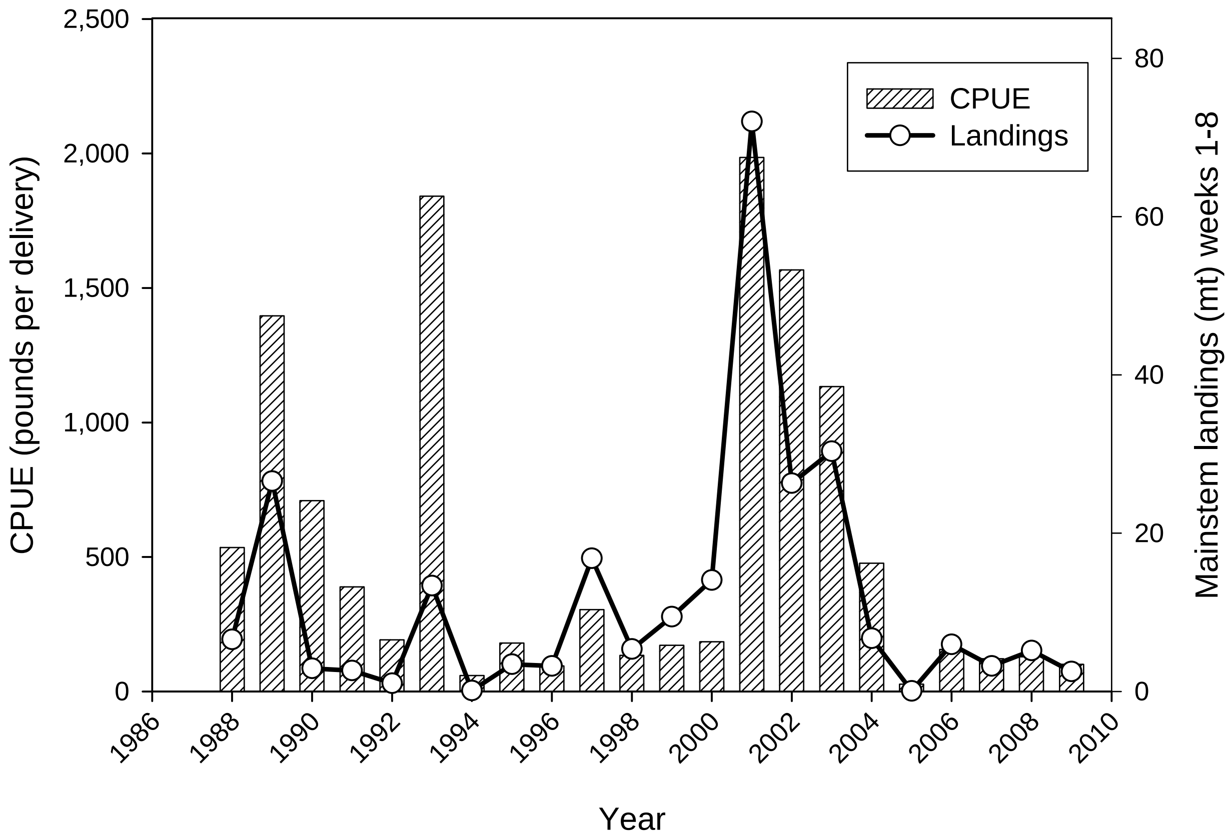


Figure 25. Columbia River commercial eulachon landings (season total may include landings during the previous December) and CPUE as pounds per delivery. Data from JCRMS (2009, their Table 17).

typically involves fewer than 10 vessels. WDFW and ODFW (2008) described these three levels of fishing: 1) Level One fisheries are the most conservative (commercial and recreational openings of 12–24 hours per week for Columbia and Cowlitz rivers) and are designed to act as a test fishery when there are indications of a poor return or great uncertainty in potential run strength, 2) Level Two fisheries (commercial and recreational openings of 2–3 days per week and potential of expansion to other tributaries) are indicated when fishery data suggest a moderate or strong run size, and 3) Level Three fisheries (commercial openings up to 4 days per week in all areas and all tributaries open to recreational fishing 4–7 days per week) may occur when abundance and productivity indicators are very strong.

The Columbia River eulachon fishery operated as a Level One test fishery in 2001; began as a Level Two fishery in 2002, switching to Level Three on February 1; operated at Level Three in 2003; started off as Level Three in 2004, with some later tributary commercial fishery restrictions; operated at Level Two in 2005 until February 23 when it was reduced to a Level One fishery; and has operated as a Level One test fishery in 2006 through 2009 (JCRMS 2005, 2006, 2007, 2008, 2009). The ability to adjust in-season fishery levels based on observed returns to the fishery, and its accurate tracking of past fluctuations in run strength, illustrates the utility of the Columbia River eulachon fishery statistics as an index of relative annual abundance (JCRMS 2007) (Figure 23 and Figure 24).

There is some information indicating that there have been periods of relatively low eulachon abundance in the past in the Columbia River. In particular, several anecdotal sources reported on a decline in the 1830s to 1860s (Suckley 1860, Lord 1866, Anderson 1872, 1877, Crawford 1878, Huntington 1963, Hinrichsen 1998, Martin 2008). Eulachon were once again seen in large numbers in the early to mid 1860s (Anderson 1872, 1877, Huntington 1963, Summers 1982, Urrutia 1998, Hinrichsen 1998, Martin 2008). Based on the available information, the BRT concluded that this information was probably accurate and likely indicated that a true and severe decline in eulachon returns and subsequent recovery occurred during that time period.

Subsequent to the decline in 1993, state and tribal fishery agencies have instituted additional monitoring efforts for Columbia River eulachon. For example, Figure 26 presents data from a larval sampling program that measures larval densities (averaged across stations and depths at selected index sites) that was initiated in 1994 for the Cowlitz River and expanded to include the Kalama River in 1995, the mainstem Columbia River in 1996, Elochoman and Lewis rivers in 1997, and Grays and Sandy rivers in 1998 (JCRMS 2005). Interannual comparison of larval densities prior to about 2003 is unreliable because "larval sampling techniques … did not include repeat sampling of the same area over the duration of the out migration period" (JCRMS 2007, p. 23), but since that time multiple surveys have been conducted each season at mainstem Columbia River sites that sample downstream of all the potential spawning locations, with the exception of Grays River. Notably, the larval densities show a peak in 2001–2002 that corresponds to a similar peak in catches (Figure 22) and offshore juvenile abundance (Figure 16 and Figure 17). Although spawning stock abundance has not been estimated using these larval surveys, the combination of data from the larval density survey and commercial and recreational landings "provides an indication of the relative run strength of eulachon in the Columbia River" (JCRMS 2007, p. 23).

The BRT had concerns about the absence of fishery-independent abundance data for Columbia River eulachon prior to the mid-1990s. The BRT agreed with state fishery managers, however, that the available catch and effort information indicate an abrupt decline in abundance in the early 1990s, and there is no evidence that the population has returned to its former level. The decline in the early 1990s appeared to coincide with a decline of eulachon in British Columbia, suggesting that a common cause, such as changing ocean conditions, was responsible for declines in both areas.

### Fraser River

Eulachon return on a regular basis to the Fraser River and on an irregular basis to the Squamish River in Howe Sound to the north (Table A-1, Figure 3) (Hay and McCarter 2000, Moody 2008). Eulachon usually begin to ascend the Fraser River at the end of March and spawning occurs in April until the middle of May. Eulachon are no longer seen spawning in some areas of the Fraser River where they used to occur. Historically, spawning occurred "primarily between Chilliwack and Mission in areas of coarse sand but also in localized areas of the North and South Arms as well as in the vicinity of the Pitt and Alouette rivers" (Higgins et al. 1987). Currently spawning is confined to areas downstream of Mission.

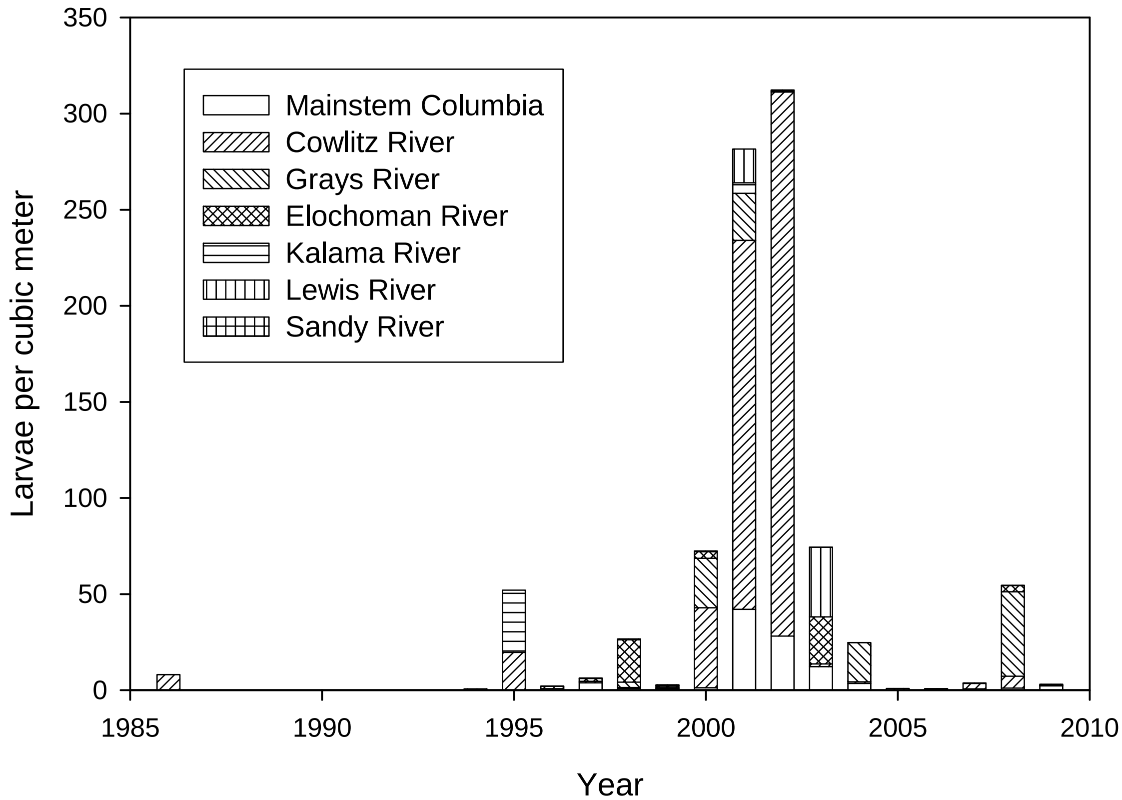



Figure 26. Columbia River larval eulachon sampling. Interannual comparisons are problematic due to inconsistent effort and methods from year to year. Larvae were encountered in the Sandy River in 1998–2000 and 2003; however, values are too small (0.1 per cubic meter) to be evident on the graph. Data from JCRMS (2008, 2009, its Table 18).

In the past, Fraser River eulachon runs supported First Nations subsistence fisheries and large commercial and recreational fisheries. Between 1941 and 1996, commercial landings averaged about 83 mt (Table 9, Table 10, and Figure 27). For much of this period, the commercial fishery landings are not a good indicator of relative abundance, since landings were largely driven by market demand (Moody 2008). In 1997 the commercial eulachon fishery was closed and commercial landings have occurred in only 2 of the last 10 years; 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a). Hay et al. (2003) estimated that First Nations and recreational fisheries historically landed about 10 mt annually. Estimates of recreational fishery landings were presented in graphical form in Moody (2008, her Figure 2.22) for a portion of the Fraser River (1956, 1963–1967, 1970–1980, closed since 2005).

Moody (2008) stated that the First Nation catch amounted to 2.57 mt in 2003. However, by 2005 all First Nation, commercial, and recreational fisheries were closed due to conservation concerns (DFO 2006a). A eulachon test fishery operated on the Fraser River near New Westminster from 1995 to 2005 (with the exception of 1999) (Figure 27); however, this fishery has not operated since 2005 (DFO 2008a). This test fishery was meant to be an in-season

Table 10. Estimated eulachon spawner biomass (mt) in the north arm and south arm of the Fraser River and total number of eulachon, assuming a range of 9.9 to 13.3 eulachon per pound, based on the mean reported weight of eulachon in the Fraser River of 34 to 46 g. Biomass data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

| Year | South arm | North arm | Total biomass (mt) | Total biomass (pounds) | Number of fish at 9.9 per pound | Number of fish at 13.3 per pound |
|---|---|---|---|---|---|---|
| 1995 | 258 | 44 | 302 | 665,796 | 6,591,381 | 8,855,087 |
| 1996 | 1,582 | 329 | 1,911 | 4,213,034 | 41,709,035 | 56,033,350 |
| 1997 | 57 | 17 | 74 | 163,142 | 1,615,107 | 2,169,790 |
| 1998 | 107 | 29 | 136 | 299,829 | 2,968,304 | 3,987,721 |
| 1999 | 392 | 26 | 418 | 921,532 | 9,123,169 | 12,256,379 |
| 2000 | 76 | 54 | 130 | 286,601 | 2,837,349 | 3,811,793 |
| 2001 | 422 | 187 | 609 | 1,342,615 | 13,291,890 | 17,856,782 |
| 2002 | 354 | 140 | 494 | 1,089,084 | 10,781,927 | 14,484,812 |
| 2003 | 200 | 66 | 266 | 586,430 | 5,805,653 | 7,799,514 |
| 2004 | 24 | 9 | 33 | 72,753 | 720,250 | 967,609 |
| 2005 | 14 | 2 | 16 | 35,274 | 349,212 | 469,144 |
| 2006 | 24 | 5 | 29 | 63,934 | 632,947 | 850,323 |
| 2007 | 34 | 7 | 41 | 90,390 | 894,856 | 1,202,181 |
| 2008 | 8 | 2 | 10 | 22,046 | 218,258 | 293,215 |
| 2009 | 12 | 2 | 14 | 30,865 | 305,561 | 410,501 |

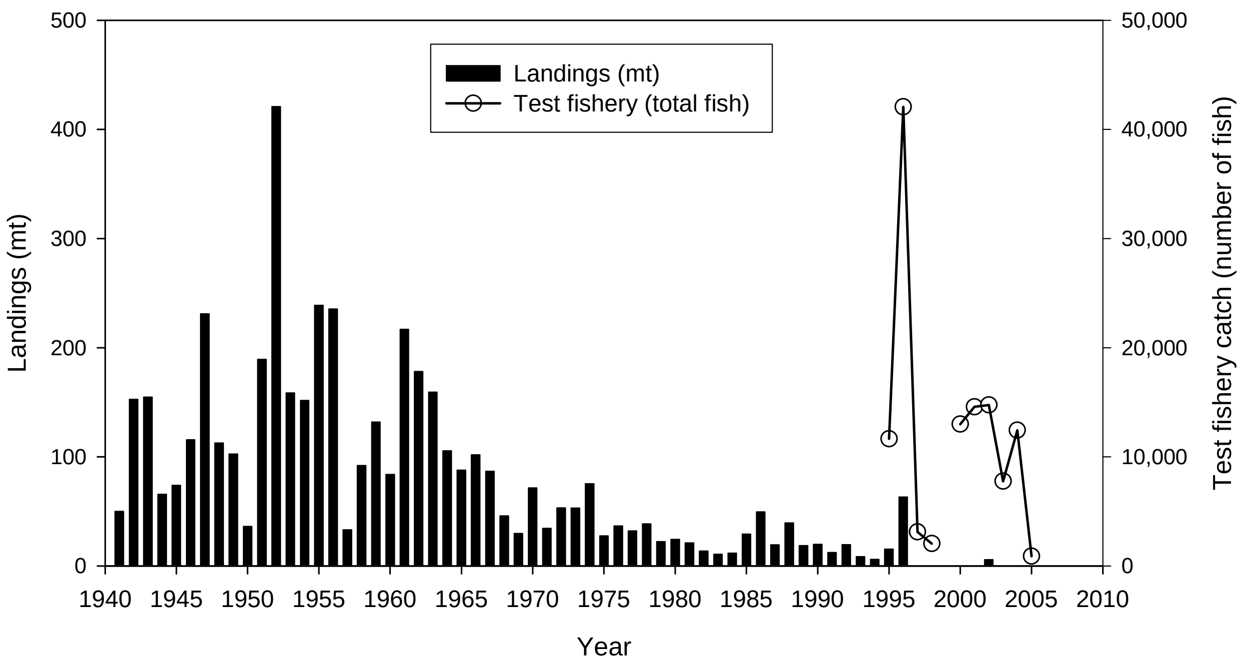



Figure 27. Eulachon landings in Fraser River commercial fishery (1940–2009) and total fish caught in Fraser River test fishery (1995–2005). Commercial fishery was closed in 1997–2001, 2003, and 2005–2009. Data from Hay (2002) and DFO (2008a).

measure of eulachon run strength and resulting data consisted of the total number of eulachon caught daily at the same site, with the same gear, over the same time period, and at similar tidal conditions (Therriault and McCarter 2005, DFO 2008a). When in operation, a catch of less than 5,000 in this test fishery was considered a conservation concern (DFO 2006a).

Table 10, Table 11, and Figure 28 present spawning stock biomass data (DFO 2008a, p. 11) that is derived from:

> an intensive sampling process [that] takes place in the Fraser River during the seven to eight weeks following spawning (April/May). This survey uses towed, small mesh nets to gather samples of eulachon eggs and larvae. The number of eggs and larvae gathered in each tow are hand counted at the Pacific Biological Station. The egg and larval count is then combined with data on the daily Fraser River discharge and historical data on eulachon fecundity (eggs produced per female) to generate an estimate of spawning stock biomass.

DFO (2008a, p. 11) stated that:

> A low spawning stock biomass for one year is cause for caution and a low spawning stock biomass for two consecutive years indicates a conservation concern. A low spawning stock biomass has been defined as less than 150 mt.

A recent population assessment of Fraser River eulachon by DFO (2007a, p. 3) stated that:

> Despite limited directed fisheries in recent years, the Fraser River eulachon stock remains at a precariously low level. This stock has failed to recover from its collapse. SSB [spawning stock biomass] estimated from the egg and larval survey conducted in 2006 was 29 tonnes. The framework documents suggest that a low SSB (<150 tonnes) for one year is cause for concern and a restriction on removals should be activated, while a low SSB for two (or more) consecutive years is more cause for alarm and should signal a halt to all removals (Hay et al. 2003, 2005). Since 2007 is the fourth consecutive year where Fraser River eulachon SSB has been below 150 tonnes, unprecedented in this short time series, no removals should be allowed in 2008.

Subsequent to this statement, spawner biomass for the 2008 and 2009 eulachon run in the Fraser River has been estimated at 10 and 14 mt, respectively (data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm). Figure 29 presents the Fraser River eulachon spawner abundance trend over the time period of the available data (1995–2009). A trend of 0.76 (95% CI, 0.67–0.88) for Fraser River eulachon was calculated from these data. Over the three-generation time of approximately 10 years, the overall biomass of the Fraser River eulachon population has undergone a 96.6% decline (1999, 418 mt; 2009, 14 mt). Under the International Union for the Conservation of Nature (IUCN) decline criteria (A1), a reduction in population size of this magnitude, "where the reduction or its causes may not have ceased or may not be understood or may not be reversible" (IUCN 2006), would place Fraser River eulachon in the IUCN critically endangered category (IUCN 2001, 2006).

The methodology on the Fraser River of utilizing mean egg and larval plankton density and river discharge rates (gathered throughout a seven-week outmigrant period at five locations) in combination with known relative fecundity (egg production per gram of female) and sex ratio

Table 11. Available estimated eulachon spawner biomass (mt) or estimated total number of spawners in British Columbia rivers in the DPS.

| Year | Fraser River (mt)[a] | Klinaklini River (mt)[b] | Kingcome River (mt)[b] | Wannock/Kilbella rivers (no. of fish)[c] | Bella Coola River (mt)[c] | Kitimat River (no. of fish)[d] | Skeena River (mt)[e] |
|---|---|---|---|---|---|---|---|
| 1993 | — | | | | | 514,000 | |
| 1994 | — | | | | | 527,000 | |
| 1995 | 302 | 40 | | | | | |
| 1996 | 1,911 | | | | | 440,000 | |
| 1997 | 74 | | 14.4 | | | | 3.0 |
| 1998 | 136 | | | | | | |
| 1999 | 418 | | | | | | |
| 2000 | 130 | | | | | | |
| 2001 | 609 | | | | 0.039 | | |
| 2002 | 494 | | | | ≈0.050 | | |
| 2003 | 266 | | | | 0.016 | | |
| 2004 | 33 | | | | 0.007 | | |
| 2005 | 16 | | | 2,700 | | | |
| 2006 | 29 | | | 23,000 | | <1,000 | |
| 2007 | 41 | | | | | | |
| 2008 | 10 | | | | | | |
| 2009 | 14 | | | | | | |

[a]Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.
[b]Berry and Jacob 1998 (as cited in Moody 2008).
[c]Moody 2008.
[d]Pederson et al. 1995 and Ecometrix 2006 (as cited in Moody 2008).
[e]Lewis 1997.

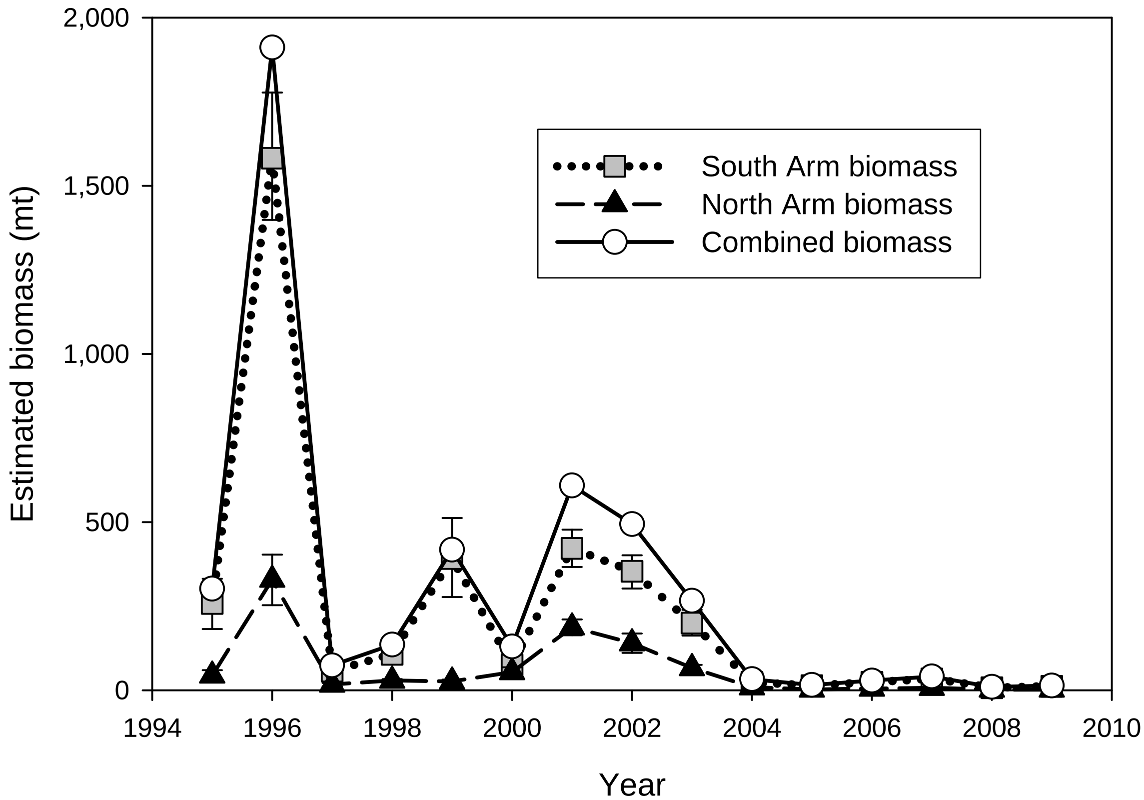


Figure 28. Fraser River eulachon spawning stock biomass from 1995 to 2009 (estimated from egg and larval surveys). Data online at http://www.pac.dfo-mpo.gc.ca/sci/herring/herspawn/pages/river1_e.htm.

to estimate spawning stock biomass has passed rigorous scientific review in Canada (Hay et al. 2002, 2003, 2005, McCarter and Hay 2003, Therriault and McCarter 2005). This methodology is similar to methods used since the early 1970s by many fisheries agencies (WDFW, DFO, CDFG, and Alaska Department of Fish and Game) to calculate Pacific herring spawning stock abundance based on estimates of intertidal and subtidal egg deposition and relative fecundity. The BRT therefore was confident that observed trends in the Fraser River spawning stock abundance data represented a true picture of the status of Fraser River eulachon.

According to Therriault and McCarter (2005), the Fraser River test fishery data did not correspond well with the spawning stock estimates that were based on the egg and larval survey and this may have resulted from variation in the catchability of adults. Eulachon abundance can be inflated when they form dense schools, which can lead to an overestimate of abundance. On the other hand, eulachon may avoid the test fishery gear, leading to an underestimate of the run size. Due to these and other problems with the test fishery methodology (Therriault and McCarter 2005), the BRT did not put a lot of confidence in these data.

The BRT did not formally analyze commercial, recreational, or subsistence fishery landings between 1881 and the present in the Fraser River, as it is believed that for much of this period the commercial fishery landings were largely driven by market demand (Hay et al. 2002,

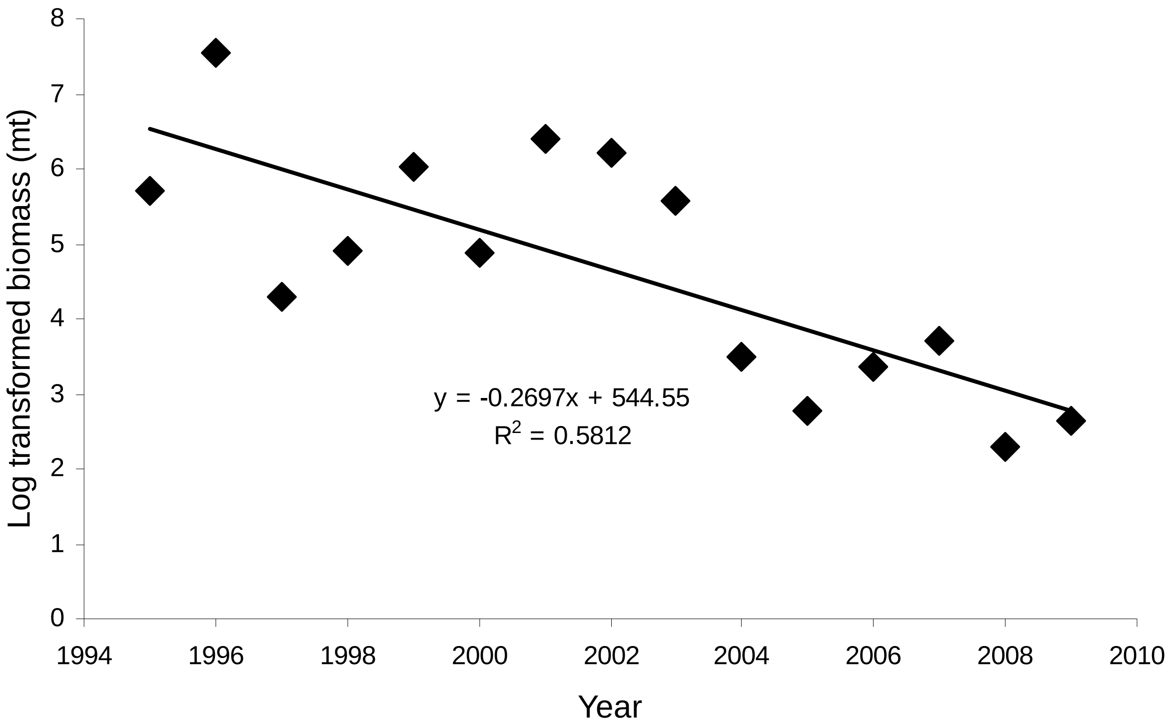



Figure 29. Trend of Fraser River eulachon spawner abundance (mt) from 1995 to 2009. Trend calculated from data in Figure 28.

Moody 2008). However, these data do indicate that eulachon were generally present at harvestable abundance levels in the Fraser River during this time period.

**Knight Inlet**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Klinaklini River at the head of Knight Inlet on the British Columbia coast (Table A-1, Figure 3). Irregular eulachon runs in the Johnstone Strait Region include the Kakweiken River, Homathko River (Bute Inlet), and Stafford and Apple rivers (Loughborough Inlet). Peak spawn timing in the area occurs about the middle of April (Hay and McCarter 2000, Hay 2002, Moody 2008).

There is only a single year's estimate of spawning stock biomass for the Klinaklini River (1995) (Table 11). Records of a commercial fishery are available for 1943–1945 and 1947. First Nations fisheries landings on the Klinaklini River are available for 1947, 1949–1950, 1952, 1959–1973, and 1977 (Table 9); however, after 1977 there is very limited documentation of run sizes of eulachon on the Klinaklini River and these are all anecdotal in nature. These anecdotal qualitative run size comments are listed in Table 12 and indicate an improvement in recent run size estimates.

Prior to 1943 when fisheries-dependent catch records begin, our information for run size of the Klinaklini River is either anecdotal or comes from ethnographic studies. Numerous ethnographic studies describe a large First Nations eulachon fishery on the Klinaklini River that

Table 12. Qualitative assessments of eulachon run strength for rivers north of the Fraser River, 1991–2007.

| Year | Klinaklini River | Kingcome River | Bella Coola River | Rivers Inlet | Kemano River | Kitimat River | Skeena River |
|---|---|---|---|---|---|---|---|
| 1991 | | | | | | Last strong run[a] | |
| 1992 | | | | | | | |
| 1993 | | | | | | | |
| 1994 | | | | | | | |
| 1995 | ≈15% of the historic run size[a] | | | | | | |
| 1996 | | | Last large run[a] | | | | |
| 1997 | | | | | | | |
| 1998 | | | Average run[a] | | | Nonexistent[b] | Very few[a] |
| 1999 | | | No run[a]<br>Small run[b] | No run[b]<br>Run failed[a] | Negligible[b] | Nonexistent[b] | Very few[a] |
| 2000 | None or poor[b]<br>Very low[c] | No run[b] | No run[c] | No run[b] | Kowesas–low[b]<br>Kemano–low[b]<br>Kitlope–low[b] | Very low in 2000[c] | Little activity observed[c] |
| 2001 | | Improved run[a] | | No catch[a] | Low catch[a] | | |
| 2002 | | Good run[a] | | No catch[a] | Low catch[a] | | |
| 2003 | | Poor run[a] | | No catch[a] | | Good[c] | |
| 2004 | Low returns[a] | Poor run[a] | Run virtually gone[c] | No catch[a] | Good spawning success[d] | | |
| 2005 | Low returns[a] | Average run[a] | | Run size of 2,700[a] | Almost no eulachon returned[e] | | Good run[a] |
| 2006 | | Run absent[a] | Run virtually gone[c] | Run size of 23,000[a] | No significant eulachon returns[f] | Lowest on record, <1,000 spawners[a] | Virtually no run[a] |
| 2007 | Very good run[a] | Small returns[a] | | | In estuary but did not ascend the river[a] | Small run of short duration[g] | |

[a]Moody 2008
[b]Hay and McCarter 2000
[c]Appendix C in Pickard and Marmorek 2007
[d]Alcan 2005
[e]Alcan 2006
[f]Alcan 2007
[g]Kitamaat Village Council 2007

attracted up to 2,000 Kwakiutl First Nation members in the late nineteenth century (Macnair 1971), some from as far as 250 miles away by canoe (Codere 1990).

There were commercial eulachon fisheries in Knight Inlet in the 1940s that primarily supplied food for the fur farm industry. Combined commercial and First Nations subsistence fisheries landed between 18 and 90 mt annually from 1943 and 1977 in Knight Inlet (Moody 2008), although landings reported by Hay and McCarter (2000) and reported in Table 9 were somewhat higher. At times, eulachon landings from Kingcome and Knight Inlet may have been reported as Knight Inlet landings, which may explain some of this discrepancy (Moody 2008). Berry and Jacob (1998, as cited in Moody 2008) "estimated spawning biomass at approximately 40 mt in the Klinaklini River in 1995" with a larval-based assessment (Hay and McCarter 2000). This value was "thought to be approximately 15% of the historic run size" (Berry and Jacob 1998, as cited in Moody 2008). Based on anecdotal information, Moody (2008) stated that eulachon returns to the Klinaklini River were said to be low "during the 2004 and 2005 seasons … but in 2007, the Klinaklini returns improved and, overall, it appeared to be a very good run" (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Knight Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the available information. However, the BRT concluded that available catch records, the extensive ethnographic literature, and anecdotal information indicates that Klinaklini River eulachon were probably present in larger annual runs in the past and that current run sizes of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (summaries in Macnair 1971, Codere 1990). However, anecdotal information indicates that recent returns of eulachon to the Klinaklini River have improved from a low point in 2004–2005, so the status of this population is not entirely clear.

### Kingcome Inlet

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kingcome River at the head of Kingcome Inlet on the British Columbia central coast (Table A-1, Figure 3). Peak spawn timing in the area occurs about the middle of April (Moody 2008). Berry and Jacob (1998, p. 4) reported that "there were at least four waves of spawning with peaks on April 2, April 15, April 21, and May 2, 1997, with the largest occurring around April 15" in the Kingcome River. Berry and Jacob (1998) also reported that there was a spawn in the Kingcome River prior to March 16 and again in early June as indicated by the presence of eggs in the water column.

There is only a single year's estimate of spawning stock biomass for the Kingcome River (1997) (Table 11). First Nations fisheries landings on the Kingcome River are available for 1950, 1957, 1960, 1961, 1963, and 1966 (Moody 2008, her Figure 2.20); however, after 1977 there is very limited documentation of run sizes of eulachon on the Kingcome River and these are all anecdotal in nature. These qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

When Kingcome Inlet First Nation fisheries landings have been reported separately from Knight Inlet, the estimates have averaged around an annual catch of 9 mt (Moody 2008). Moody (2008) reported that the eulachon run in the Kingcome River in 1971 was very small and light catches were reported in 1972. Berry and Jacob (1998) stated that a minimum estimated 14.35 mt of eulachon spawned in the Kingcome River from March 16 to June 3, 1997. Based on anecdotal information, Moody (2008) reported that "In 2001 the Kingcome run improved and was considered good in 2002, with approximately 330 gallons of grease produced." The eulachon run to the Kingcome River was considered to be poor in 2003 and 2004 and of average size in 2005 (Moody 2008). However, eulachon were reportedly absent from the Kingcome River in 2006 "and only small returns were seen in 2007" (Table 12) (Moody 2008).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Kingcome Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicates that Kingcome River eulachon were probably present in larger annual runs in the past.

**Rivers Inlet**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Wannock, Chuckwalla, and Kilbella rivers in Rivers Inlet on the central coast of British Columbia (Table A-1, Figure 3). The spawning stock biomass of eulachon in Rivers Inlet was estimated using scientific survey methods in 2005 and 2006. First Nations fisheries landings on the Wannock River are available for 1967, 1968, and 1971; however, after 1971 there is very limited documentation of run sizes of eulachon in Rivers Inlet and (with the exception of the information available for 2005 and 2006) these are anecdotal in nature. These anecdotal qualitative run-size comments are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fishery landings data for the Wannock River were limited to the years 1967, 1968, and 1971 when catches were 1.81, 2.27, and 4.54 mt, respectively (Moody 2008). Moody (2008) stated that eulachon in "the Wannock River had been gradually declining since the 1970s" and that no eulachon have been caught in First Nations fisheries in the Rivers Inlet area since 1997, when about 150 kg of eulachon were landed from the Kilbella and Chuckwalla rivers (Berry and Jacob 1998). Berry and Jacob (1998, p. 3–4) further reported that "Virtually no eulachon eggs or larvae were found in any of the 376 samples from the Wannock River in 1997" and "this observation is consistent with in-field observations of eulachon entering the river mouth only to exit and possibly go to the nearby Chukwalla or Kilbella rivers to spawn." In 2005 an estimated 2,700 adults returned to the Wannock River, based on the capture of only 11 adults during spawner abundance surveys (Moody 2008) (Table 11). An additional three adult eulachon were taken on the Kilbella River in 2005 (Moody 2008). Moody (2008) stated that this adult spawner survey was repeated in 2006 and although "no adults [were] captured … an estimate of 23,000 adult spawners was calculated" (Table 11 and Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in Rivers Inlet, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. The BRT was also concerned that the incomplete record of eulachon catch and spawn biomass in Rivers Inlet does not establish whether eulachon returned on an annual basis to this system in the past. However, the BRT believed that available recent estimates of spawning stock abundance, catch records, ethnographic literature (Hilton 1990), and anecdotal information indicates that Rivers Inlet eulachon were present in larger annual runs in the past. The BRT also believed that the recent spawning stock estimates of 2,700 to 23,000 individual spawners is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

**Dean Channel**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Bella Coola, Dean, and Kimsquit rivers in Dean Channel (Table A-1, Figure 3). Kennedy and Bouchard (1990, p. 325) summarized ethnographic studies on the Nuxalk (Bella Coola) First Nation and stated that "because of their abundance and their value as a trade item, eulachons (particularly when rendered into highly valued grease) were second only to salmon in importance to the Bella Coola." Moody (2008) indicated that historically, peak run timing of eulachon in the Bella Coola River occurred in late March or early April (Table A-9). Moody (2007) also reported that recent run timing of eulachon to the Bella Coola River occurs earlier in the season than it did historically.

Spawning stock biomass data for the Bella Coola River were available for 2001–2004 (Table 11). Records of the Nuxalk First Nation eulachon fishery on the Bella Coola River are available for 1945 and 1946, 1948–1989, 1995, and 1998 (Moody 2008, her Figure 3.13). Moody (2008) also provided estimated First Nations eulachon catch based on a model of eulachon grease production from 1980 to 1998. Anecdotal qualitative run-size comments are listed in Table 12.

Moody (2007) reports relative abundance estimates, based on egg and larval surveys similar to those used on the Fraser River, for the Bella Coola River in 2001 (0.039 mt), 2002 (0.045–0.050 mt), 2003 (0.016 mt), and 2004 (0.0072 mt) (Table 11). Nuxalk First Nation subsistence fishery landings of eulachon from the Bella Coola River show an average catch of 18 mt between 1948 and 1984 (Table 9, Figure 30), with a low of 0.3 mt in 1960 and a high of nearly 70 mt in 1954, based on data available in Hay (2002). These data suggest that recent (2001–2004) spawner biomass in the Bella Coola River is approximately two orders of magnitude less than the average First Nations eulachon landings were between 1948 and 1984. According to Moody (2007), it has been 9 years since the last First Nations fishery occurred on the Bella Coola River.

Anecdotal information indicated that only a very few eulachon are currently found in other rivers in Dean Channel such as the Kimsquit River and the Taleomy, Assek, and Noeick rivers in South Bentnick Arm off Dean Channel (Moody 2008). Moody (2007, 2008) also stated that "it appears that 1996 was the last large run of eulachon to the Bella Coola River" and noticeable runs have not returned to the Dean Channel/Bella Coola area since 1999 (Table 12).

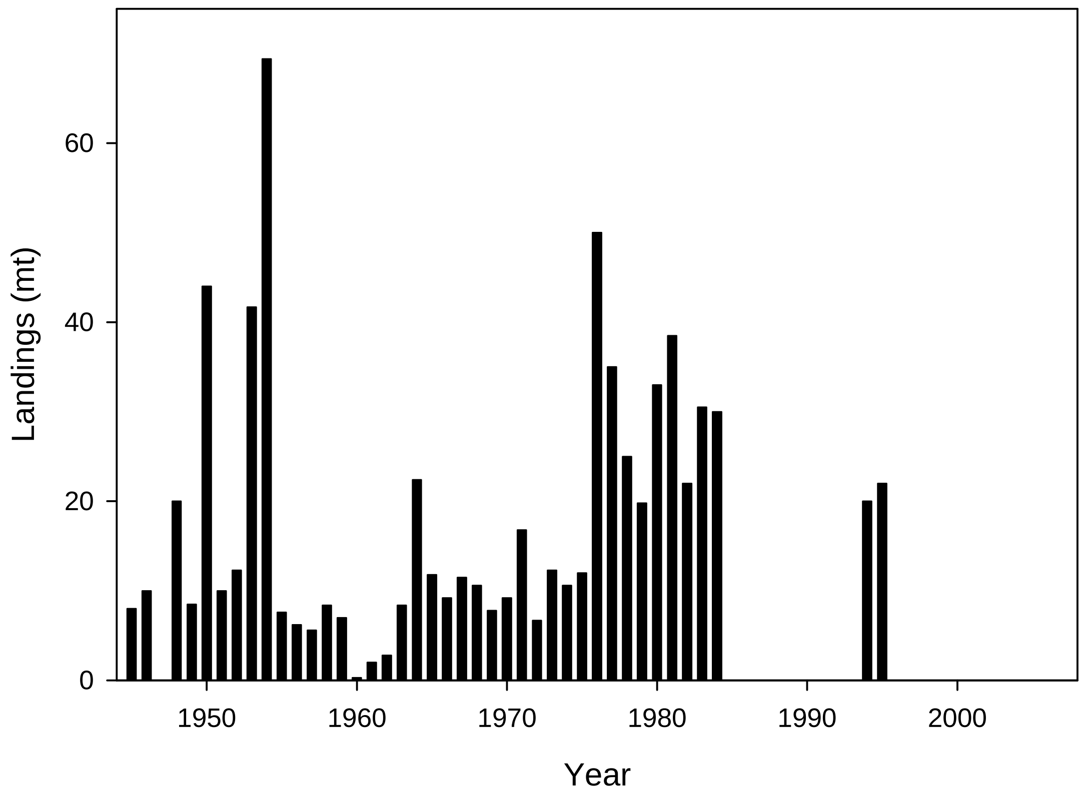


Figure 30. Estimated eulachon First Nations fishery landings on the Bella Coola River (data from Hay 2002). Landings of unknown size occurred from 1985 to 1993 and from 1996 to 1998 (Hay 2002). No fishery has occurred on the Bella Coola River since 1999.

The BRT believed that available spawning stock biomass data collected since 2001, catch records, extensive ethnographic literature, and anecdotal information indicate that Bella Coola River and Dean Channel eulachon in general were present in much larger annual runs in the past. The present run sizes of eulachon appear inconsistent with the historic level of grease production that is extensively documented in the ethnographic literature on the Nuxalk First Nations Peoples (Kennedy and Bouchard 1990, Moody 2008). The BRT was concerned that this information and available data indicate that eulachon in Dean Channel may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

**Gardner Canal**

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kemano, Kowesas, and Kitlope rivers in Gardner Canal (Table A-1, Figure 3). Eulachon spawn in late March and early April on the Kemano River, which is unusual in that it is a clear, nonturbid system in a region that is dominated by glacially turbid rivers (Moody 2008).

First Nations fisheries landings on the Kemano River are available for 1969–1973 and 1988–2007. CPUE data in this fishery from 1988–2007 (reported as metric tons caught per set) were presented in graphical form in Moody (2008, her Figure 2.16). A summary of ethnographic studies of the Haisla First Nation indicates that "eulachon were especially important with runs in the … Kemano and Kitlope rivers … in such numbers that they were an important export" (Hamori-Torok 1990, p. 306). Anecdotal qualitative run-size comments on Kemano River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

First Nation fisheries landings on the Kemano River ranged from 18.1 to 81.7 mt from 1969 to 1973 (average of 44.3 mt) (Moody 2008, her Figure 2.16). Rio Tinto Alcan Inc. operates a hydroelectric generation facility on the Kemano River and, as part of an environmental management plan, has funded monitoring of eulachon since 1988 (Lewis et al. 2002). From 1988 to 1998, landings ranged from 20.6 to 93.0 mt (average of 57 mt) (Lewis et al. 2002, Moody 2008) (Table 9). However, according to Moody (2008), no run occurred in 1999.

First Nations landings in the Kemano River were low from 2000 to 2002, but improved to between 60 and 80 mt in 2003 and 2004 (Alcan 2005, Moody 2008, her Figure 2.16); however, anecdotal information indicated that eulachon returns were not detected in the Kemano River in 2005 and 2006 (Table 12) (Alcan 2006, 2007, EcoMetrix 2006, as cited in Moody 2008). Based on anecdotal information, Moody (2008) reported that "eulachon were seen in the Kemano estuary in 2007. However, they did not ascend the river." CPUE data showed similar trends to First Nation fishery landings, with a sharp drop from about 2.5 mt per set in 1998 to less than 0.5 mt per set from 1999 to 2002, a rebound to between 0.5 and 1 mt per set in 2003–2004, and no fish caught in 2005–2007 (Lewis et al. 2002, Moody 2008, her Figure 2.16).

It was the BRT's best professional judgment that available CPUE data collected since 1988, First Nations catch records, extensive ethnographic literature, and anecdotal information indicate that Kemano River, and Gardner Canal eulachon in general, were present in larger annual runs in the past and that present run sizes of eulachon appear inconsistent with the historic level of grease production that is well documented for this region in the ethnographic literature (Hamori-Torok 1990).

In addition, the BRT believed that the inability to detect eulachon in the Kemano River since 2004 using the same monitoring methods that have been in place since 1988 (Lewis et al. 2002, Moody 2008, her Figure 2.16) and anecdotal information from Rio Tinto Alcan biological surveys that eulachon have failed to return to the Kemano River in 2005–2007 (Alcan 2005, 2006, 2007) is cause for concern, as this information indicates that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

### Douglas Channel

Hay and McCarter (2000) reported that an annual run of eulachon return on a regular basis to the Kitimat and Kildala rivers in Douglas Channel (Table A-1, Figure 3). Spawning in the Kitimat River reportedly peaks in mid to late March (Moody 2008).

The spawning stock biomass of eulachon in the Kitimat River was estimated using scientific survey methods in 1993 (Table 11). First Nations fisheries landings on the Kitimat

River are available for 1969 to 1972. CPUE in this fishery, reported as number of fish caught in a 24-hour period, and estimated spawner abundance are available for 1994–1996 and 1998–2007. A summary of ethnographic studies of the Haisla First Nation indicates that "eulachon were especially important with runs in the Kitimat [and] Kildala … rivers in such numbers that they were an important export" (Hamori-Torok 1990, p. 308). Anecdotal qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Between 1969 and 1972, Kitimat River First Nations fisheries landings of eulachon ranged from 27.2 to 81.6 mt (Moody 2008, her Figure 2.14). The Kitimat River First Nations eulachon fishery reportedly came to an end in 1972 as pollution by industrial (pulp mill) and municipal effluent discharges made the eulachon unpalatable (Pederson et al. 1995, Moody 2008). Pederson et al. (1995) estimated a total spawning biomass in the Kitimat River of 22.6 mt or about 514,000 individual eulachon in 1993. According to Moody (2008, p. 34), CPUE of eulachon on the Kitimat River, as presented in EcoMetrix (2006), declined from 50–60 fish per 24-hour gill net set in 1994–1996 to less than 2 eulachon per gill net set since 1998. According to EcoMetrix (2006, as cited in Moody 2008), abundance of eulachon from 1994 to 1996 ranged between 527,000 and 440,000 individual spawners and from 1998 to 2005 ranged between 13,600 and less than 1,000 (Table 11). Based on anecdotal information, Moody (2008, p. 34) stated that "the last strong run returned to the Kitimat River in 1991 and runs from 1992 to 1996 were estimated at half the size of 1991" (Table 12).

The BRT believed that the available spawning stock biomass data available for 1993, CPUE data since 1994, First Nations landing records, extensive ethnographic literature, and anecdotal information indicate that Kitimat River and Douglas Channel eulachon in general were present in larger annual runs in the past and that present run-size estimates of eulachon appear inconsistent with the historic level of grease production extensively documented in the ethnographic literature (Hamori-Torok 1990). The BRT believed that the decline in estimated spawning stock on the Kitimat River from an annual run size of more than 500,000 eulachon in the mid-1990s to levels of less than 1,000 individual eulachon in 2005 (EcoMetrix 2006, Moody 2008) is cause for concern, as these numbers indicate that this subpopulation may be at risk from small population concerns, such as Allee effects and random genetic and demographic effects.

### Skeena River

Hay and McCarter (2000) and Moody (2008) reported that an annual run of eulachon return on a regular basis to the Skeena River and its tributaries (particularly the Ecstall and Khyex rivers) (Table A-1, Figure 3). The Skeena River run was reportedly small, of short duration, and difficult to harvest because of the large size of the mainstem Skeena River (Stoffels 2001, Moody 2008). Based on anecdotal information, eulachon historically returned to the Skeena River around the first week of March, but in the past decade returns have occasionally returned as early as mid-February (Moody 2008).

The spawning stock biomass of eulachon in the Skeena River was estimated using scientific survey methods in 1997 (Table 11). Combined commercial and First Nations fisheries landings on the Skeena River are available for 1900–1916, 1919, 1924, 1926, 1927, 1929–1932, 1935, and 1941 (Table 9). Qualitative run-size comments on Kitimat River eulachon are listed in Table 12 and indicate a decline in recent run-size estimates.

Lewis (1997) estimated the total spawning stock abundance of the Skeena River eulachon at only 3.0 mt in 1997. A small commercial eulachon fishery operated between 1924 and 1946 (landings ranged from 15.4 mt in 1924 to 0.9 mt in 1935) (Moody 2008). However, total landings records were as high as 100 mt at one time and averaged 27.5 mt from 1900 to 1941 (Table 9). It is likely that local market demands have driven subsistence and past commercial fisheries statistics on the Skeena River and the BRT did not believe that these data were a good index of abundance. Moody (2008) reported anecdotal information indicating that very few Skeena River eulachon were observed between 1997 and 1999, a good run occurred in 2005, and virtually no eulachon were observed in 2006 (Table 12).

The BRT was concerned that there are few scientifically obtained abundance data available for eulachon in the Skeena River, about the absence of a contemporary monitoring program for eulachon, and about the anecdotal nature of the evidence. However, the BRT believed that available catch records and anecdotal information indicate that Skeena River eulachon were present in larger annual runs in the past that at one time supported a large fishery. Although the current status of this subpopulation is unknown, the BRT believed that anecdotal information indicates declines in abundance have occurred.

## Assessment of Demographic Risk and the Risk Matrix Approach

In previous NMFS status reviews, BRTs have used a risk matrix as a method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used for more than 10 years in Pacific salmonid status reviews (e.g., Good et al. 2005, Hard et al. 2007), as well as in reviews of Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), and black abalone (*Haliotis cracherodi*) (VanBlaricom et al. 2009). In this risk matrix approach, the collective condition of individual populations is summarized at the DPS level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity (Table 13). These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk. The summary of demographic risks and other pertinent information obtained by this approach is then considered by the BRT in determining the species' overall level of extinction risk.

After reviewing all relevant biological information for the species, each BRT member assigns a risk score (see below) to each of the four demographic criteria. The scores are tallied (means, modes, and range of scores), reviewed, and the range of perspectives discussed by the BRT before making its overall risk determination (see Table 13 for a summary of demographic risk scores). Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. For example, a DPS with a single extant subpopulation

Table 13. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four viable salmonid population parameters (McElhany et al. 2000) plus a recent events category.

| **Risk category** | **Mean (± SD) and modal score** |
|---|---|
| Abundance[a]<br>Comments: | 4.3 (±0.48)<br>4 |
| Growth rate/productivity[a]<br>Comments: | 3.0 (±1.05)<br>2 |
| Spatial structure and connectivity[a]<br>Comments: | 3.7 (±0.67)<br>4 |
| Diversity[a]<br>Comments: | 2.6 (±0.52)<br>3 |
| Recent events[b] | |

[a]Rate overall risk to the DPS on 5-point scale (1–very low risk, 2–low risk, 3–moderate risk, 4–high risk, 5–very high risk).
[b]Rate recent events from double plus (++) strong benefit to double minus (– –) strong detriment.

might be at a high level of extinction risk because of high risk to spatial structure/connectivity, even if it exhibited low risk for the other demographic criteria. Another species might be at risk of extinction because of moderate risks to several demographic criteria.

For scoring population viability criteria, risks for each demographic criterion are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. *Very low risk*. Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.

2. *Low risk*. Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3. *Moderate risk*. This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

4. *High risk*. This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.

5. *Very high risk*. This factor by itself indicates danger of extinction in the near future.

Recent events: The recent events category considers events that have predictable consequences for DPS status in the foreseeable future but have occurred too recently to be reflected in the demographic data. Examples include a climatic regime shift or El Niño that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

| | |
|---|---|
| ++ | expect a strong improvement in status of the DPS, |
| + | expect some improvement in status, |
| 0 | neutral effect on status, |
| – | expect some decline in status, and |
| – – | expect strong decline in status. |

# Threats Analysis

According to Section 4 of the ESA, the Secretary of Commerce or the Interior shall determine whether a species is threatened or endangered as a result of any (or a combination) of the following factors: 1) destruction or modification of habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors. Collectively, these are often referred to as factors for decline. Herein we examine four of these five factors for their historical, current, or potential impact on eulachon. The consideration of the inadequacy of existing regulatory mechanisms (section 4(a)(1)(D)) will be conducted by the regional office or offices in concert with the evaluation of efforts being made to protect the species. Current and potential threats, along with current species distribution and abundance, help determine the species' present vulnerability to extinction. We include information regarding historic threats to assist in interpretation of population trends. The relationship between historic threats and population trends also provides insights that may help project future population changes in response to current and potential threats.

## Destruction or Modification of Habitat

### Dams and water diversions

Dams and water diversions can change downstream flow intensity and flow timing, reduce transport of fine sediments, and cut off the source of larger sediments like sand and gravel for downstream habitats. Reduced peak flows as a result of upstream dams can also lead to less scouring of the streambed, less erosion, and less deposition of sediments. The streambed downstream of dams may become progressively coarser and become dominated by cobbles and large gravels as smaller gravels and sand are transported downstream without being replaced by transport from upstream sources.

**Klamath River**—There are six hydroelectric dams on the Klamath River (Link River, Keno, J.C. Boyle, Copco 1, Copco 2, and Iron Gate) (NRC 2008). The impact of these dams, and others on the tributary Trinity River (Lewiston and Trinity dams), as well as associated irrigation withdrawals in the upper Klamath River basin, have shifted the spring peak flow of the lower Klamath River from its historical peak in April to its current peak in March, one full month earlier (NRC 2004).

**Columbia River**—Operation of 28 mainstem and about 300 tributary dams and water withdrawals for irrigation have significantly altered the natural hydrologic pattern of the Columbia River (Sherwood et al. 1990, Bottom et al. 2005). According to Bottom et al. (2005, p. xxix):

> the magnitude of maximum spring freshet flow [in the Columbia River] has decreased more than 40% from the predevelopment period (1859–1899) to the present. Flow regulation is responsible for approximately 75% of this loss, irrigation withdrawal for approximately 20%, and climate change for approximately 5% … The timing of maximum spring freshet flow also has changed, primarily because of hydropower and irrigation development upriver, resulting in an approximate two-week shift earlier in the year (mean predevelopment date of 12 June compared to modern mean date of 29 May).

Bottom et al. (2005, p. xx) also stated that:

> Riverine sediment transport to the estuary, an important process affecting the quantity and quality of estuarine habitat for salmon [and other fishes], is correlated with peak river flows … [It] is estimated that the … change in annual average sediment transport (at Vancouver, Washington) for 1945–1999 flows has been about 50–60% of the nineteenth century (1858–1899) virgin sediment transport. The reduction in sands and gravels is higher (>70% of predevelopment) than for silts and clays.

Bonneville Dam on the mainstem Columbia at RKM 235 also impedes migration of eulachon to historical spawning habitat above the dam in the Hood River and possibly the Klickitat River (Smith and Saalfeld 1955, WDFW and ODFW 2008). Eulachon reportedly are unable to ascend fish ladders designed for Pacific salmon (LCFRB 2004a).

**Columbia River tributaries**—In the mid 2000s, Sandy River Basin Partners (2005, p. 2-30) stated that:

> Natural discharge patterns in the Sandy River Basin are primarily altered by 1) storage and diversion of water on the Sandy River (Marmot Dam at RM 30 [RKM 48.3]) and Little Sandy River (Little Sandy Diversion Dam at RM 1.7 [RKM 2.7]), 2) storage and diversion of water from the Bull Run River since 1891 to supply the City of Portland's municipal water needs (the Headworks Dam at RM

> 6 [RKM 9.6]), and 3) diversion of water from the Sandy Hatchery weir on Cedar Creek at RM 0.05 (RKM 0.8), as well as withdrawal of water from Alder Creek to partially supply the City of Sandy's municipal requirements.

Subsequently, Marmot Dam was removed in 2007 and the Little Sandy Dam was taken down in 2008, which should restore much of the river's natural hydrology and result in significant sediment transport into the lower Sandy River where eulachon have spawned in the past.

There are two major dams on the mainstem Cowlitz River: Mayfield Dam at RKM 83.7 forms Mayfield Lake and Mossyrock Dam at RKM 104.6 forms Riffe Lake (Wade 2000b). These dams and other run-of-river dams in the hydropower system largely control flow in the mainstem Cowlitz River. Following the eruption of Mount St. Helens in 1980, the USACE constructed an SRS on the North Fork Toutle "to prevent the continuation of severe downstream sedimentation of stream channels, which created flood conveyance, transportation, and habitat degradation concerns" (LCFRB 2004a, p. E-374). The SRS was constructed in 1989 about 49 km above the confluence of the Toutle and Cowlitz rivers, is approximately 50 m in height, and extends 600 m across the valley of the North Fork Toutle River. The SRS continues to be a source of fine sediment to the lower Cowlitz River (LCFRB 2004a). Anderson (2009, p. 5) stated that:

> The SRS [on the Toutle River], constructed by the USACE, has become ineffective at trapping sediments. Lower Cowlitz River eulachon spawning habitat is considered degraded while the Toutle River is assumed absent of spawning habitat due to this fine sediment inundation. … WDFW considers past and continued fine sediment deposition in the Toutle and Cowlitz rivers as a moderate to high risk for eulachon.

There are three major dams on the mainstem Lewis River, also known as the North Fork Lewis River: Merwin Dam (aka Ariel Dam) at RKM 31.4, built in 1931, forms Lake Merwin; Yale Dam at RKM 55, built in 1953, forms Yale Lake; and Swift Dam at RKM 77.1, built in 1958, forms Swift Creek Reservoir (Wade 2000a). The Lower Columbia Fish Recovery Board (LCFRB 2004a, p. G-35) stated that:

> Hydropower regulation has altered the hydrograph of the lower mainstem [of the Lewis River].… Predam data reveals peaks due to fall/winter rains, winter rain-on-snow, and spring snowmelt. Postdam data shows less overall flow variation, with a general increase in winter flows due to power needs. Postdam data shows a decrease in spring snowmelt flows due to reservoir filling in preparation for dry summer conditions.… The risk of extreme winter peaks has also been reduced, with the trade-off being the reduction of potentially beneficial large magnitude channel-forming flows. … The long-term effects on channel morphology and sediment supply have not been thoroughly investigated.

**British Columbia**—In the mid-1980s there were an estimated 802 licensed dams in the Fraser River basin, mostly for irrigation purposes in the dryer areas above Hope (Birtwell et al. 1988). The impact on eulachon of water withdrawals associated with reservoirs in the Fraser

River has not been studied. The other eulachon river in British Columbia where hydrology has been significantly altered by water diversions is the Kemano River. A hydroelectric plant began operating on the Kemano River in 1954 (Lewis et al. 2002, p. 1), that is powered by:

> water from the Nechako Reservoir [in the Fraser River basin] [that] passes through a 16-km-long diversion tunnel, past the turbines at the Kemano Powerhouse, and into the Kemano River, dropping a total of 850 m. ... The powerhouse outflow combines with the natural flow of the Kemano River and tributaries and flows 16 km to saltwater at Kemano Bay on Gardner Canal.

Lewis et al. (2002, p. 22) further stated that:

> Flow at the Kemano/Wahoo confluence is composed of Kemano Powerhouse discharge and the natural flow from the Kemano River and tributaries. On average, the Kemano powerhouse contributes 57% of the flow at the Kemano/Wahoo confluence. Within the period of eulachon spawning, when natural flows are near the seasonal minimum, discharge from the powerhouse accounts for 80% of the flow at the Kemano/Wahoo confluence. The relative contribution of powerhouse discharge declines to 64% during eulachon incubation and later, during larval migration, to 38% as natural discharges increase.

According to DFO and Transport Canada (2008):

> Kleana Power Corporation proposes to develop a run-of-river hydroelectric power project on the Klinaklini River. … The project consists of: head pond, diversion weir and intake, 18 km penstock/tunnel, powerhouse, tailrace, waste rock disposal, upgrading of the existing logging roads and new road extension where necessary, upgrade to the existing barge landing facility, construction camp, concrete batch plant, and a 180 km twinned aerial transmission line from the powerhouse to Campbell River.

**Sediment dredging**

Potential dredging impacts on eulachon consist of direct effects of entrainment of adults and eggs and potential for smothering of eggs with sediment (Howell and Uusitalo 2000, Howell et al. 2001). Indirect effects may consist of altering the freshwater spawning habitat and estuarine nursery habitat. Larson and Moehl (1990) documented direct entrainment of small amounts of eulachon by hopper dredge at the mouth of the Columbia River during May-October 1985–1988. Johnston (1981, p. 427) reviewed dredging activities in estuarine environments and listed “increased turbidity; altered tidal exchange, mixing, and circulation; reduced nutrient outflow from marshes and swamps; increased saltwater intrusion; and creation of an environment highly susceptible to recurrent low dissolved oxygen levels” as negative impacts. In addition, dredging can resuspend harmful contaminants contained in sediments where they may be more available to estuarine biota in the water column. Lasalle (1990, p. 1) also reviewed the potential physical effects of dredging and listed mobilization of sediment-associated chemical compounds and increased turbidity, as well as the potential “reduction in dissolved oxygen (resulting from the oxidation of anoxic sediment compounds)” as generally expected alterations.

Hay and McCarter (2000) indicated that dredging during the eulachon spawning season in the Fraser River continued until the late 1990s. Tutty and Morrison (1976) estimated about 0.9 mt of adult eulachon were directly entrained during hopper dredging activities between March 15 and June 4, 1976, on the lower Fraser River. Hay and McCarter (2000, p. 38) stated that "the direct loss of about 1 tonne of eulachons may have been small relative to potential deleterious impacts on survival of eulachons eggs—either from the direct effect of entrainment of spawned eggs, or the silt-induced smothering of eggs deposition [sic] in waters downstream of the dredging operations." Hay and McCarter (2000) suggested dredging should be confined to periods outside of the spawning season to minimize impacts on eulachon and that the effects of sediment removal on eulachon spawning habitats should be a topic of research.

FREMP (2007) estimated that from 0.76 to 3.22 million cubic meters of sediment were dredged annually from the lower Fraser River during the years 1997–2007 to prevent grounding of commercial shipping. Increases in vessel size have required deepening of the shipping channel in recent years (FREMP 2007). As mentioned in Pickard and Marmorek (2007), suction dredging is currently restricted to months when eulachon are not spawning in the Fraser and Kitimat rivers. According to FREMP (2006, p. 40), "hydraulic suction dredging and large-scale clamshell dredging undertaken in the Fraser River estuary is restricted so that there is no dredging conducted from March 1 to June 15 of any given year."

It has been suggested that eulachon spawning distribution in the Fraser River has changed in response to dredging and channelization and that dredging, even outside of the spawning period, affects eulachon by destabilization of substrates (Pickard and Marmorek 2007). Pickard and Marmorek (2007, p. 8) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "there is consensus that dredging is not the cause of the coastwide decline in eulachon, but there is disagreement about the importance of dredging impacts on eulachon resilience in rivers where it occurs."

The Cowlitz Indian Tribe (2007, p. 15–16) observed that:

> the Cowlitz River and in particular the Toutle River has been greatly impacted by the eruption of Mount St. Helens in 1980 and the resulting SRS built by the U.S. Army Corps of Engineers. Releases of fine sediment from behind the SRS during the spring, when normally the river is clear, have been negatively correlated with Cowlitz River eulachon returns 3 to 4 years later (Lou Reebs, personal communication).

USACE (2007) stated that:

> as much as 414 million cubic yards (mcy) of material will erode from the Mount St. Helens sediment avalanche through year 2035. In addition, it was estimated that over the period from 2000 to 2035 as much as 27 mcy of this material would be deposited in the lower Cowlitz River and will need to be removed in order to maintain flood protection levels in Kelso, Longview, Castle Rock, and Lexington. … This trend is a result of increased sedimentation from the Toutle River watershed from sediments being passed through the SRS in greater amounts. The ability of the SRS to trap sand has decreased since 1998 when the sediment reservoir behind the dam filled in. All flow now passes through the spillway as

designed, carrying sediment downstream. … Significant sand deposition … continues to occur at the mouth of the Cowlitz River, which has severely reduced the capacity of the river channel to transport sand. … Channel capacity and the authorized levels of flood protection for Kelso, Longview, Lexington, and Castle Rock have been reduced below authorized levels due to sediment deposition in the lower Cowlitz River. … In addition to the initial dredging effort, annual follow-on dredging from the transition area to Cowlitz RM 2.5 [RKM 4.0] to maintain the dredged channel depths and bottom widths will be needed to maintain flood protection levels for the next 5 years. The Corps is also investigating long-term dredging and nondredging alternatives that would maintain the authorized levels of flood protection for the communities on the lower Cowlitz River through the year 2035.

Furthermore, USACE's environmental assessment of interim dredging activities on the Cowlitz River (USACE 2007, p. 33) indicated that:

> The proposed … dredging action may affect spawning adults, outmigrating juveniles, and larvae [of eulachon] in the water column by entrainment. Eggs may be affected by removing substrate needed to allow egg adhesion for incubation and by covering of incubating eggs by increasing suspended sediment.

Sherwood et al. (1990) provided a detailed analysis of historical dredging activities in the Columbia River estuary through the 1980s. They estimated that about 300 million cubic meters of largely sand-sized material were removed from the estuary and river channels between 1909, when substantial dredging started, and 1982. Currently, USACE routinely dredges the mainstem Columbia River shipping channel. The Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001, p. 25) stated that this "Dredging should not be conducted in winter and early spring to avoid entrainment of eulachon adults or larvae." Romano et al. (2002) suggested that the dynamic nature of sand sediments in areas proposed for channel deepening in the Columbia River were unlikely to support eulachon egg incubation and that direct effects of dredging in these areas on eulachon would be minimal. However, "[eulachon] eggs incubating in near-shore areas in the proximity of dredging activities might be affected if these activities alter flow patterns or increase sedimentation" (Romano et al. 2002, p. 8).

In response to an earlier draft of the present status review document, Anderson (2009, p. 4–5) stated that:

> Risks dependent on timing, location, and life history stage in relation to dredging and in-water dredge material disposal pose a low to moderate threat for adult eulachon and a high risk for incubating eggs. … WDFW considers dredging effects on adult eulachon as a low risk in the mainstem Columbia River and a low to moderate risk in the tributaries. … The risk to larval eulachon from mainstem Columbia River dredging activities is low and in the tributaries is moderate. … Dredging activities can affect egg survival through direct entrainment and from suffocation through burial. The risk to eulachon eggs from dredging and in-water dredge material disposal in eulachon spawning habitat is high.

## Shoreline construction

**Columbia River**—Estuarine habitat in the Columbia River has been modified through "shoreline armoring and construction of structures over water, channel dredging and removal of large woody debris, channelization by pile dikes, and other structures" (Bottom et al. 2005, p. 18). Thomas (1983) estimated that estuarine acreage at the time of his study was only about 76% of the acreage of the estuary in 1870. This reduction was largely the result of dike and levee construction. Approximately 43% of tidal marshes and 77% of tidal swamps in the Columbia River estuary were estimated to have been lost since 1870 (Thomas 1983). Sherwood et al. (1990, p. 299) also reviewed historical changes in the Columbia River estuary and found that "large changes in the morphology of the estuary have been caused by navigational improvements (jetties, dredged channels, and pile dikes) and by the diking and filling of much of the wetland area." Sherwood et al. (1990) suggested that the greatest cause of change in the morphology of the Columbia River estuary was due to construction of permeable pile dikes and jetties, particularly jetties at the mouth of the river. LCFRB (2004a, p. A-157) reported that:

> Artificial channel confinement has altered river discharge and hydrology, as well as disconnected the [Columbia] river from much of its floodplain. … Additionally, channel manipulations for transportation or development have also had substantial influence on river discharge and hydrologic processes in the river.

Bottom et al. (2005, p. xxii) provided a chronology of changes in the Columbia River estuary and stated that:

> The productive capacity of the estuary has likely declined over the past century through the combined effects of diking and filling of shallow-water habitats…. Loss of approximately 65% of the tidal marshes and swamps that existed in the estuary prior to 1870, combined with the loss of 12% of deepwater area, has contributed to a 12–20% reduction in the estuary's tidal prism.

**Columbia River tributaries**—The LCFRB (2004a, p. E-89) observed that "the mainstem Cowlitz below Mayfield Dam has been heavily altered due to adjacent land uses including agriculture, rural residential development, transportation corridors, urbanization, and industry." The LCFRB (2004a, p. E-30) also reported that "the lower 20 miles of the Cowlitz has experienced severe loss of floodplain connectivity due to dikes, riprap, or deposited dredge spoils originating from the Mount St. Helens eruption" (see also Wade 2000b). Major population centers in the lower Cowlitz River basin with their associated industrial and residential development include the towns of Castle Rock, Longview, and Kelso (LCFRB 2004a).

The only urban area in the Kalama River basin is the City of Kalama, located near the river's mouth where dikes have been constructed in the historical floodplain to protect nearby roads and industrial developments (Wade 2000a, LCFRB 2004a). Future development is likely to be concentrated along the lower mainstem Kalama River, where increasing residential development has also occurred in recent years (LCFRB 2004a).

Much of the lower mainstem Lewis River is also "disconnected from its floodplain by dikes and levees" (LCFRB 2004a, p. G-55) and "the largest urban population center, the City of Woodland, lies near the mouth of the river" (Wade 2000a, p. 23). According to (LCFRB 2004a, p. G-87), "the mainstem Lewis below Merwin Dam has been heavily altered due to adjacent land uses including agriculture, residential development, transportation corridors, and industry."

**British Columbia**—Pickard and Marmorek (2007) reported that results of a DFO workshop to determine research priorities for eulachon indicated that shoreline construction in the form of roads, bridges, dikes, piers, wharfs, and so forth may have an impact on eulachon in the Skeena, Kitimat, Kemano, Fraser, and Columbia rivers. According to Pickard and Marmorek (2007, p. 14):

> There is evidence of change in the habitat in developed rivers such as the Fraser and Kitimat. These changes include the loss of side channels, loss of habitat complexity/diversity, and increase in velocity. These habitat changes are thought to affect eulachon, however the magnitude of the effect is not clear.

Pickard and Marmorek (2007) also suggested that an increase in river velocities likely would result in eggs and larvae being rapidly washed downstream, where they may encounter high salinities at an early age. The fate of eggs and larvae that may be prematurely washed out to sea is unknown.

The largest city in British Columbia, Vancouver, together with all of its associated industrial and urban development, abuts the Fraser River estuary (Birtwell et al. 1988). Moody (2008) indicated that an extensive system of dikes was constructed in the lower Fraser River following the 1948 flood. According to Plate (2009, p. 3 and p. iii), recent plans to construct "a new 10-lane Port Mann Bridge [over the Fraser River] represents a major addition to shoreline and in-river construction on the lower Fraser River" and is of concern because "eulachon spawn directly beneath the [current] Port Mann Bridge pillars and in the close upstream vicinity of the bridge, and as expected eulachon use all channels under the bridge for migration to upstream areas."

### Climate change impacts on freshwater habitat

Analyses of temperature trends for the U.S. Pacific Northwest (Mote et al. 1999); the maritime portions of Oregon, Washington, and British Columbia (Mote 2003a); and the Puget Sound–Georgia Basin region (Mote 2003b) have shown that air temperature increased 0.8°C, 0.9°C, and 1.5°C in these respective regions during the twentieth century. Warming in each of these areas was substantially greater than the global average of 0.76 ± 0.19°C (IPCC 2007). During the next century, warming in the Pacific Northwest is predicted to range from 0.1°C to 0.6°C per decade with a mean estimate of 0.3°C per decade, compared to an approximate 0.1°C per decade warming that occurred during the twentieth century (Mote et al. 2005b). Although fluctuations in climate related indices like the PDO and El Niño Southern Oscillation (ENSO) may explain about a third of this temperature rise, "the widespread and fairly monotonic increases in temperature exceed what can be explained by Pacific climate variability and are consistent with the global pattern of anthropogenic temperature increases" (Mote et al. 2005a, p. 47). Results from 10 different climate model simulations that assume two different greenhouse gas emission scenarios predict a 1ºC to 6ºC increase in air temperature for the Pacific Northwest by 2100 (ISAB 2007).

These higher temperatures have led to declines in snowpack, measured as springtime snow water equivalent, in much of the North American west, with the Oregon (Mote et al. 2005a) and Washington (Mote 2006) Cascade Mountains having the largest losses in snow water equivalent. Projected milder wintertime temperatures in much of the North American west suggest that "losses in snowpack observed to date will continue and even accelerate" (Mote et al. 2005a, p. 48). Additional hydrological changes that have occurred in the North American west over the past 50–70 years include more precipitation falling as rain rather than snow (Knowles et al. 2006) and an earlier onset of snowmelt (Groisman et al. 2004, Knowles et al. 2006), resulting in "increased fractions of annual flow occurring earlier in the water year by 1–4 weeks" relative to conditions during the 1950s to 1970s (Stewart et al. 2005, p. 1,136). Trends toward earlier flows "are strongest for midelevation gauges in the interior Northwest, western Canada, and coastal Alaska" (Stewart et al. 2005, p. 1,152).

It is expected that snowmelt dominated systems at low to moderate elevations (Regonda et al. 2005, Knowles et al. 2006) and near-coastal mountains in the Pacific Northwest and California (Hamlet et al. 2005, p. 4,560) will be particularly impacted by declines in the fraction of precipitation falling as snow and thus may experience the greatest changes in river hydrology. Some systems are expected to change from a pattern of steady snow accumulation to a pattern of repeated snow accumulation and loss during the winter season. The Independent Scientific Advisory Board (ISAB 2007, p. iii) summarized projected changes associated with climate change in the Columbia Basin and stated that "Warmer temperatures will result in more precipitation falling as rain rather than snow; snow pack will diminish, and stream flow timing will be altered; and peak river flows will likely increase."

Pickard and Marmorek (2007) summarized similar findings, reported by participants at a DFO workshop to determine research priorities for eulachon, relative to climate-driven changes in freshwater hydrology that are occurring in coastal British Columbia. This report presented evidence that "snowpack accumulations have been declining in many watersheds (e.g., Kitimat, Fraser)" (Pickard and Marmorek 2007, p. 20). Spring freshets throughout British Columbia are also reported to be occurring earlier in the year and more precipitation at lower elevations is reported to be coming as rain than in snow (Pickard and Marmorek 2007, p. 20). Glaciers in British Columbia are also reported to be melting at a faster rate, although "overall runoff from B.C. glaciers is declining due to their reduced size" (Pickard and Marmorek 2007, p. 20).

Foreman et al. (2001) and Morrison et al. (2002) examined historical temperatures and flows in the Fraser River over the past 100 years. Foreman et al. (2001) found that the date at which one-half of the Fraser River yearly discharge is reached occurred at a rate of 0.09 days earlier each year between 1913 and 2000, and that average summer temperatures at Hell's Gate on the Fraser River increased at a rate of 0.022°C per year (0.2°C per decade) from 1953 to 1998. Morrison et al. (2002) developed a flow model based on these trends and predicted that by 2070–2090 spring freshets in the Fraser River would occur on average 24 days earlier in the year and mean summer water temperatures would likely increase by 1.9°C. DFO (2008d) also predicted that peak flows will come earlier in the year and peak flows will be lower over the coming century in the Fraser River.

Meier et al. (2003) and Barry (2006) summarized data on the worldwide status of glaciers, which shows that pervasive glacial retreat has occurred over the past 100 years and suggests that glacial wastage has accelerated in the last several decades. Meier et al. (2003, p. 133) stated that "the retreats of the last century exceed any seen in the last several millennia and are out of the range of normal climate variability for this time period." ISAB (2007, p. 12), in reference to the Pacific Northwest stated that:

> Most glaciers in the region reached their recent maximum extent in the mid-1800s and since that time have been in rapid retreat. Recent studies indicate that the retreat of the past approximately 150 years has now brought many Northwest glaciers back to levels last seen approximately 6,000 years ago.

Since the majority of eulachon rivers are fed by extensive snowmelt or glacial runoff, elevated temperatures, changes in snow pack, and changes in the timing and intensity of stream flows will likely have impacts on eulachon. In most rivers, eulachon typically spawn well before the spring freshet, near the seasonal flow minimum, and this strategy typically results in egg hatch coinciding with peak spring river discharge. The expected alteration in stream flow timing may cause eulachon to spawn earlier or be flushed out of spawning rivers at an earlier date. Early emigration, together with the anticipated delay in the onset of coastal upwelling (see Climate Change Impacts on Ocean Conditions subsection below), may result in a mismatch between entry of larval eulachon into the ocean and coastal upwelling, which could have a negative impact on marine survival of eulachon during this critical transition period.

There are already indications, perhaps in response to warming conditions or altered stream flow timing, that adult eulachon are returning earlier in the season to several rivers within the southern DPS (Moody 2008). Based on accounts in Portland, Oregon, newspapers between 1867 and 1923, the mean date of initial appearance of eulachon in the Columbia River during that time was February 12 (Figure 6, Appendix B). Documented initial landings in the Columbia River commercial eulachon fishery for the years 1949 to 2008 were more than a month earlier, averaging around January 8, based on data supplied by WDFW.[13] Similarly, Lewis et al. (2002, p. 68) noticed a trend for the eulachon run in the Kemano River, British Columbia, to begin and end earlier over the 11-year period from 1988 to 1998. Pickard and Marmorek (2007, p. 20) also reported that "run timing has been getting earlier since 1988–2003 in [the] Kemano [River]."

### Climate change impacts on ocean conditions

Evidence has accumulated over the last decade to demonstrate that there are natural decadal-scale oscillations in North Pacific climatic and oceanic conditions (Mantua et al. 1997, Zhang et al. 1997). One indicator of the ocean-atmosphere variation for the North Pacific is the PDO index whose opposite regimes, characterized by a positive and negative PDO, typically last for 20–30 years (Mantua and Hare 2002) (Figure 15). Negative PDO values are associated with relatively cool ocean temperatures off the Pacific Northwest, and positive values are associated

[13] B. James, Statewide Eulachon Landings database, WDFW, Vancouver, WA. Pers. commun., 20 June 2008.

with warmer, less productive conditions. Warmer, less productive conditions off the Pacific Northwest are also associated with the ENSO, which is unrelated to the PDO and occurs on average every 2 to 7 years and may last from 6 to 18 months.

Changes in regional patterns of the PDO and ENSO have been associated with variation in the abundance of Pacific salmon, forage fish, and species such as Pacific hake in the ocean off the Pacific Northwest (McFarlane et al. 2000, ISAB 2007). ISAB (2007, p. 57–58) suggested that conditions that occur during a positive PDO or an El Niño period may represent possible analogs for future impacts of global warming in the North Pacific and Pacific Northwest. However, as the Intergovernmental Panel on Climate Change (IPCC) stated in its fourth assessment report (IPCC 2007, p. 399), "Long-term trends [in temperature] are rather difficult to discern in the upper Pacific Ocean because of the strong interannual and decadal variability (ENSO and the PDO) and the relatively short length of the observational records."

According to ISAB (2007, p. v):

> Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity … [and] the structure of marine communities.

**Warmer ocean temperatures**—Levitus et al. (2000, 2005) documented warming of the world's oceans that corresponds to a mean temperature increase of 0.037°C from 1955 to 1998 (Levitus et al. 2005, p. 1). Most of this warming has occurred in the upper 700 m of the ocean over the past 50 years (Levitus et al. 2005). Relatively smaller temperature increases in the world ocean over the past 50 years, compared to the mean worldwide terrestrial air temperature increase of 0.76 ± 0.19°C (IPCC 2007) over the past 100 years, illustrates the ocean's enormous heat capacity compared to the atmosphere (Levitus et al. 2005). According to the IPCC (2007, p. 387):

> The oceans are warming. Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m. … Relative to 1961 to 2003, the period 1993 to 2003 has high rates of warming but since 2003 there has been some cooling.

The ISAB (2007, p. 65) reported that "In the subarctic Northeast Pacific, sea surface temperatures show a warming trend and salinities a decreasing trend, over the last half century." Sea surface temperatures compiled from lighthouse records in the Canadian portion of the Strait of Georgia show an increase from 1915 to 2004 of 1.0°C (Beamish et al. 2008). However, long-term temperature increase in the ocean off the Pacific Northwest is not occurring in a linear fashion. Crawford et al. (2007, p. 176) reported that the long-term temperature records along Line P, which extends out more than 1,400 km from the North American west coast into the mid Gulf of Alaska, show an increase in temperature by 0.9°C from 1958 to 2005 between depths of 10 and 50 m. But Line P temperature records showed no significant increase prior to 1972 or after 1981 and most of the long-term temperature trend was likely driven by the PDO increase associated with the 1977 regime shift (Crawford et al. 2007, IPCC 2007). Water temperatures off British Columbia were reportedly warmer in 2004 and 2005 than the previous 50 years (DFO 2006b); however, in 2008 water temperatures "off the Pacific coast of Canada were the coldest in 50 years of observations, and the cooling extended far into the Pacific Ocean and south along the American coast" (DFO 2009e, p. 4).

**Changes in intensity and timing of upwelling**—Primary productivity in the northern California Current ecosystem is fueled by wind-driven upwelling of cold, nutrient-rich, deep waters to the surface. Along the coasts of British Columbia, Washington, and Oregon, ocean upwelling is dependent on strong coastal northerly or equator-ward winds which drive warm surface waters offshore and induce upwelling of the deep waters (Bakun 1990, Ware and Thomson 1991, ISAB 2007). Upwelling-favorable winds are more frequent in the spring and summer, but do not occur uniformly even at those times. Ocean upwelling off California is much more consistent, less seasonal, and stronger on average than in areas farther north.

Coastal, upwelling-favorable winds are generated by the "pressure gradient between a thermal low-pressure cell that develops over the heated land mass and the higher barometric pressure over the cooler ocean" (Bakun 1990, p. 198). Bakun (1990) hypothesized that climate warming will intensify these thermal land-sea differences, since land areas are predicted to warm twice as fast as the oceans, and should lead to more intense coastal upwelling in the California Current Province. These land-sea pressure gradients may be further enhanced, leading to even more intense upwelling, if warming leads to less terrestrial vegetation and thus even higher land-sea thermal differences (Diffenbaugh et al. 2004). More intense upwelling should lead to increased primary productivity in the California Current, but the peak upwelling season might occur up to one month later, and primarily from June to September in the northern portion of the California Current (Snyder et al. 2003, Barth et al. 2007, ISAB 2007). Barth et al. (2007, p. 3719) stated that "Delayed early season upwelling and stronger late season upwelling are consistent with predictions of the influence of global warming on coastal upwelling regions." In addition, warming conditions are likely to increase the density of surface waters, resulting in strong water column stratification, which may impede wind-driven upwelling and reduce the availability of nutrients at the ocean surface (ISAB 2007).

**Ocean acidification**—Global increases in atmospheric $CO_2$ have caused an increase in the amount of $CO_2$ absorbed by the oceans. According to the IPCC (2007, p. 387):

> Ocean biogeochemistry is changing. The total inorganic carbon content of the oceans has increased by 118 ± 19 GtC [gigatons carbon] between the end of the preindustrial period (about 1750) and 1994 and continues to increase. … The increase in total inorganic carbon caused a decrease in the depth at which calcium carbonate dissolves, and also caused a decrease in surface ocean pH by an average of 0.1 units since 1750. Direct observations of pH at available time series stations for the last 20 years also show trends of decreasing pH at a rate of 0.02 pH units per decade.

Decreased pH of ocean waters "decreases the availability of carbonate ions and lowers the saturation state of major shell-forming carbonates in marine animals" and is expected to severely impact the abundance and distribution of calcareous organisms such as corals, shelled mollusks, foraminifera, coccolithophores, and pelagic pteropods (ISAB 2007, p. 71). These changes will have unknown consequences for pelagic communities.

**Expected impact on eulachon**—The ISAB functions to provide independent scientific advice to NMFS, the Columbia River Indian Tribes, and the Northwest Power and Conservation Council. In its document Climate Change Impacts on Columbia River Basin Fish and Wildlife, the ISAB (2007, p. 72) stated that:

> Global climate change in the Pacific Northwest is predicted to result in changes in coastal ecosystems … that may be similar or potentially even more severe than those experienced during past periods of strong El Niño events and warm phases of the PDO, with warmer upper ocean temperatures, increased stratification and decreased productivity along the coast. However, a lack of certainty in future wind and weather patterns yields large uncertainties for future changes. …if upwelling winds remain unchanged from those of the past century, coastal upwelling may become less effective at pumping cold, nutrient-rich [water] to the upper ocean because of increased stability in the upper ocean caused by surface warming. Or, as some modeling studies and hypotheses suggest, upwelling winds may become more intense, and perhaps the timing for the upwelling season will change because of timing shifts in upwelling wind patterns. With warmer ocean temperatures we can expect shifts in the size and species composition of zooplankton to smaller lipid-replete zooplankton instead of large, lipid-rich, cool-water species. Because of food chain effects and warm ocean waters, forage fishes will decline and warm-water predators will increase.

All the above predicted changes will likely influence the growth, productivity, survival, and migration of eulachon. Pacific hake undergo seasonal migrations from their winter spawning grounds off southern California to their northern feeding grounds off the west coast of Vancouver Island in summer (Ware and McFarlane 1995, Benson et al. 2002). Large adult Pacific hake are known to prey on eulachon, and the dominant prey of both small Pacific hake and eulachon are euphuasiids (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Beamish et al. (2008, p. 34) stated that "The projected long-term increase in temperatures may result in more offshore hake moving into the Canadian zone, and in the spawning and rearing area off California moving north." Thus projected ocean warming is likely to result in an altered distribution of both predators on eulachon and competitors for food resources.

Initial eulachon survival during the critical transition period between larval and juvenile stages is likely linked to the intensity and timing of upwelling in the northern California Current Province. However, the potential shift of peak upwelling to one month later than normal may result in a temporal trophic match-mismatch between eulachon larval entry into the ocean and presence of preferred prey organisms whose productivity is dependent on the early initiation of upwelling conditions. These conditions would likely have significant negative impacts on marine survival rates of eulachon and recent recruitment failure of eulachon may be traced to mortality during this critical period. Larval and juvenile eulachon are planktivorous and are adapted to feed on a northern or boreal suite of copepods during the critical larval/juvenile transition.

There are two main suites or assemblages of copepod species over the continental shelf off the west coast of North America: a boreal shelf assemblage (e.g., *Calanus marshallae*, *Pseudocalanus mimus*, and *Acartia longiremis*) that normally occurs from central Oregon to the Bering Sea and a southern assemblage (e.g., *Paracalanus parvus*, *Mesocalanus tenuicornis*, *Clausocalanus* spp., and *Ctenocalanus vanus*) that is most abundant along the California coast (Mackas et al. 2001, 2007). Changes in the relative abundance and distribution of these copepod assemblages covary with oceanographic conditions (Roemmich and McGowan 1995, Mackas et al. 2001, 2007, Peterson and Keister 2003, Zamon and Welch 2005, Hooff and Peterson 2006). When warm conditions prevail, as during an El Niño year or when the PDO is positive, the distribution of zooplankton communities can shift to the north and the southern assemblage of copepods can become dominant off southern Vancouver Island (Mackas et al. 2007). For example, abundance of boreal shelf copepods was much lower than normal and southern species dominated off southern Vancouver Island during the warm years between 1992 and 1998 (Mackas et al. 2007). Thus warmer ocean conditions may be expected to contribute to a mismatch between eulachon life history and preferred prey species.

Ocean conditions off the Pacific Northwest in 2005 were similar to what may be expected if climate change predictions for the next 100 years are accurate. According to Barth et al. (2007, p. 3,719), there was a "1-month delay in the 2005 spring transition to upwelling-favorable wind stress in the northern California Current," and during May to July, upwelling-favorable winds were at their lowest levels in 20 years and "nearshore surface waters averaged 2°C warmer than normal." Eulachon returns to spawning rivers in the southern DPS were poor during this period of unfavorable ocean conditions from 2004 to 2008 (JCRMS 2008) and may portend how eulachon will respond to warming ocean conditions.

### Water quality

**General contaminants**—The high lipid content of eulachon suggests they are susceptible to absorption of lipophilic organic contaminants (Higgins et al. 1987, Pickard and Marmorek 2007). Contaminants considered of most concern include: 1) synthetic chlorinated organic chemicals, such as hexachlorobenzene, DDTs, and the polychlorinated biphenyls (PCBs); 2) polycyclic aromatic hydrocarbons (PAHs) from petroleum and creosoted pilings; 3) dioxins and a host of other organic compounds; 4) metals such as mercury, arsenic, and lead; and 5) endocrine-disrupting compounds and new toxics like PBDE (polybrominated diphenyl ether, flame retardants).

No rigorous toxicological studies of the effects of environmental contaminants on eulachon were found. In the Washington Department of Fisheries Annual Report for 1953, Schoettler (1953, p. 54) stated that:

> The effects of the industrial waste products discharged directly into the Columbia River near the mouth of the Cowlitz are under study by the Fisheries Department in cooperation with the State Pollution Commission. In 1951 shipments of artificially fertilized smelt eggs were taken to the Deception Pass Marine laboratory. After hatching, the fry were subjected to various intensities of waste sulfite liquor. Results indicate that the liquors were harmful to young smelt. … Of equal importance were preliminary pollution studies on adult smelt. Effluents

> from three industrial plants at Longview were used. The smelt were placed in a partitioned trough which held pure river water on one side and river water mixed with certain dilutions of effluent on the other. The number of fish emerging from either side of the trough were carefully enumerated. Under these circumstances smelt showed an aversion to the effluents in dilutions approximating 1 part to 800.

The Environmental Protection Agency (EPA 2002) examined contaminants in fish, including whole eulachon, from the Columbia River in 1996–1998. In general EPA (2002, p. 9-204) stated that whole body analysis revealed that:

> While eulachon … had a high lipid content, they had some of the lowest levels of organic chemicals of all the species tested. Aroclors [a mixture of PCBs] and chlordane were not detected in the eulachon. Eulachon had the highest average concentration of arsenic and lead.

Contamination levels in three combined whole body samples of eulachon in the Columbia River collected at RKM 63–66 ranged 860–930 µg/kg arsenic, 9–10 µg/kg cadmium, 920–990 µg/kg copper, 370–680 µg/kg lead, less than 35 µg/kg mercury, 270–300 µg/kg selenium, 10–11 µg/kg p,p'-DDE, less than 4 µg/kg p,p'-DDT, less than 37 µg/kg Aroclor 1254, less than 37 µg/kg Aroclor 1260, less than 0.00005–0.0001 µg/kg 2,3,7,8-TCDD [a chlorinated dioxin], and 0.00058–0.00078 µg/kg 2,3,7,8-TCDF [a chlorinated furan] (EPA 2002). In addition, EPA (2002, p. E-4) stated that:

> DDE [a metabolite of DDT], the most commonly found pesticide in fish tissue from our study … [was found at] 11 ppb [parts per billion] in whole body eulachon. … Aroclors [a PCB mixture] [were] … nondetectable in eulachon … [and] concentrations of arsenic … [were] 890 ppb in whole body eulachon. Mercury … [was at] nondetectable levels in … whole body eulachon.

Rogers et al. (1990, p. 713) examined tissues and whole eulachon from the Fraser River for organochlorine contaminants and found that:

> [eulachon] tissue samples contained chlorophenols from wood preservation operations and chloroguaiacols from pulp bleaching. Whole fish also contained DDE and DDD [metabolites of DDT], while PCBs were present in some fish gonads in 1986, but not in 1988. With the exception of whole body concentrations of 2,3,4,6-tetrachlorophenol (TeCP), concentrations of pentachlorophenol (PCP), 3,4,5- trichloroguaiacol (3,4,5-TCG), tetrachloroguaiacol (TtiCG), DDE, and DDD in whole bodies, livers and gonads revealed an increasing trend with distance of the eulachon capture site upstream from the Fraser River mouth.

Chan et al. (1996, p. 32) examined eulachon collected from the Nass, Kitimat, and Bella Coola rivers and from Kingcome and Knight inlets for levels of persistent organic pollutants including dichlorodiphenyltrichloroethane, hexachlorobenzene, hexachlorohexanes, dieldrin, chlordane, mirex, and PCBs and found that "levels of chlorinated pesticides and PCB increased from the north to the south, with the lowest from Nass River and highest from Knight Inlet." However, contaminant levels in eulachon "were at least an order of magnitude lower than the maximum residual limit established by Health Canada or the action level established by the U.S. Food and Drug Administration" (Chan et al. 1996, p. 40). Since eulachon do not feed during their freshwater spawning run, "the uptake of toxic chemicals must occur directly from the environment" (Rogers et al. 1990, p. 725).

There are innumerable publications analyzing chemical contaminants and their sources in the lower Columbia River basin and only a select number of large-scale reviews are mentioned herein. Rosetta and Borys (1996) estimated that approximately 48% of the volume of contaminant discharges to the lower Columbia River came from industrial sources (5% from chemical and allied products, 3% from primary metal, and 39% from paper and other product manufacturers) and 52% from sewage treatment plants. Fifty-seven facilities in the lower Columbia River were identified as having the potential to release chlorinated dioxins and furans and "55 environmental cleanup sites in the State of Oregon, and 13 sites in the State of Washington [were found to] contain PCB contamination in either groundwater, sediment, or soil which may have the potential to impact the lower Columbia River" (Rosetta and Borys 1996, p. E-7).

Further breakdown of contaminant sources for the lower Columbia River are presented in Tetra Tech (1996). Hinck et al. (2004, 2006) examined contaminant levels throughout the Columbia River Basin, primarily in three resident nonanadromous target species: common carp (*Cyprinus carpio*), bass (*Micropterus* sp.), and largescale sucker (*Catostomus macrocheilus*). Fish were exposed to a variety of chemical and elemental contaminants throughout the Columbia River (Hinck et al. 2004). Temporal trend analyses indicated that PCBs were decreasing in concentration in sites with historical data; however, concentrations of the organochlorine contaminants PCBs and total p,p′-DDE were higher in the lower and middle Columbia River than in the upper Columbia River (Hinck et al. 2004, 2006).

Hall (1976, p. 45) reviewed water quality and sources of pollution in the lower Fraser River and stated that:

> There appear to be two main water quality problems in the lower Fraser, both apparently attributable to the urban-industrial complex of metropolitan Vancouver, namely pathogens and trace metals. … Potential problems are apparent regarding toxic substances such as trace metals. Concentrations are not high enough to be acutely toxic to fish but the sporadic occurrence of higher concentrations of trace metals such as lead, mercury, and zinc in the lower reaches of the river and accumulations in sediments give some cause for concern, especially since these substances are not biodegradable and bioamplification through food chain concentration or direct absorption by the organism cannot be ignored in the sensitive estuarine areas of the lower Fraser.

Types and sources of contaminants in the lower Fraser River consist of insecticides and herbicides used in agricultural production; wood preservatives associated with the lumber industry (e.g., chromium, copper, arsenic, chlorinated phenols, dioxins, polynuclear aromatic hydrocarbons, phenolics, and creosote); leachates from landfills; a wide range of contaminants in stormwater discharge; industrial effluents associated with metal, cement, forest products, and food industries; and municipal effluents (Birtwell et al. 1988).

Although the central and north coast regions of British Columbia possess relatively pristine environments compared to areas to the south, even this area has marine environmental quality concerns. Haggerty et al. (2003) identified a number of contaminant sources in British Columbia's central coast, which extends from northern Vancouver Island to just south of the Queen Charlotte Islands, including: salmon aquaculture, oil pollution, wastewater, pollution from cruise ships, shipping and boating, forestry and forest products, mining, and atmospheric and oceanic transport of chemical contaminants.

Similarly, Johannessen et al. (2007a) identified the 10 main contaminant sources in the north coast regions of British Columbia, which includes eulachon spawning rivers from the Klinaklini to the Nass rivers, to be: vessel traffic, ports, forestry, pulp and paper mills, mining and smelting, aquaculture, Coast Guard and military sites, global pollutants, offshore oil and gas, and ocean dumping. In a larger context, incorporating both the central and north coasts of British Columbia (aka Pacific North Coast Integrated Management Area [PNCIMA]), Johannessen et al. (2007b) listed the main sources of chemical contaminants as: aquaculture, vessel traffic, ports/harbors/marinas, forestry, pulp and paper, mining and smelting, ocean dumping, Coast Guard and military sites, oil and gas, and global pollutants. Detailed analyses of these contaminant sources are found in the relevant publications (Haggerty et al. 2003, Johannessen et al. 2007a, 2007b) and only a selected few major contaminant sources are mentioned below.

Johannessen et al. (2007b) indicates that 78 finfish and 24 shellfish farms operate in the PNCIMA. Many of these are located in the Queen Charlotte Strait near Knight and Kingcome inlets and pose a source of organic waste materials and of "pesticides and other persistent pollutants in fish used in the production of feed" (Johannessen et al. 2007b, p. ix). An average of more than 400,000 vessels of all types transit the PNCIMA annually. About 56% of these vessels are passenger ferries and cruise ships that transport about 1.5 million passengers yearly through the PNCIMA (Johannessen et al. 2007b). According to Johannessen et al. (2007b, p. 12), "Contaminant issues associated with marine traffic include the discharge of sewage, grey water, oily bilge water, shipboard solid wastes, and release of antifouling compounds from ablative coatings."

Prince Rupert and Kitimat, the two main industrial ports in the PNCIMA, are expanding and increasing their capacity for large industrial shipping. The industrial port of Kitimat currently serves the Alcan aluminum smelter, the Eurocan paper mill, and the Methanex methanol plant (Johannessen et al. 2007b). A new Kitimat liquefied natural gas terminal is to begin construction in 2010, and there are plans for a new Kitimat Marine Terminal and pipeline to transport petroleum from near Edmonton, Alberta, to Kitimat and condensate from Kitimat to near Edmonton, together with numerous other industrial terminal projects (Port of Kitimat 2009). Johannessen et al. (2007b, p. ix) stated that:

> Four [pulp] mills exist in the area [PNCIMA], though two of them have operated intermittently. All Canadian pulp mills underwent significant effluent treatment upgrades in the 1990s such that discharge of solids, discharge of oxygen demand, and chlorinated compounds such as dioxins and furans are now significantly reduced.

Johannessen et al. (2007b, p. 25–26) indicated that within the PNCIMA, “12 [mine] sites are a risk to produce acid rock drainage and heavy metal leachate” and that the only active smelter in the PNCIMA is the aluminum smelter at Kitimat, where “several studies have detected elevated PAH concentrations in both marine biota and sediments in the Kitimat Arm area.” Johnson et al. (2009) detected elevated concentrations of PAHs in sediments of Kitimat Arm, that are similar to PAHs originating from the Alcan smelter, and in salmon and flatfish collected in Kitimat arm. However, Johnson et al. (2009, p. xv) concluded that:

> The process changes introduced by Alcan appear to be effective at reducing inputs of PAHs into the environment and biota of Kitimat Arm, as PAH concentrations in sediments and fish and fish disease prevalences have remained stable or declined over the past 5 years of sampling.

Kime (1995, p. 67–68) reviewed the literature on the effects of contaminants on fish reproduction prior to fertilization, showed that these effects can occur throughout the reproductive system, and stated that:

> They may cause lesions, haemorrhage, or malformations in the gonads, pituitary, liver, and the brain. Production and secretion of hormones of the hypothalamus, pituitary, and gonads is usually inhibited and their metabolism by the liver can be altered. … Gametes have been shown to be particularly sensitive to pollutants, both in their development, particularly the production and growth of oocytes involving vitellogenin synthesis, and in their fertility. Sperm motility, in particular, has special potential as a rapid and sensitive indicator of pollutant activity.

Analyses of these reproductive biomarkers (quantifiable parameters of an organism’s biological state) go beyond the traditional toxicological test of establishing the dose of a contaminant causing death in 50% of the test organisms ($LD_{50}$) and are an example of the problems researchers have in assessing the effects of chronic low-level exposure of contaminants or mixtures of contaminants on fish and fish populations (Eggen et al. 2004, Carvan et al. 2008). As pointed out by Carvan et al. (2008, p. 1,023), most of the problems facing modern ecotoxicology are much more subtle and require development of a suite of biomarkers and the use of controlled laboratory experiments on sentinel fish species, such as zebrafish (*Danio rerio*) (much as laboratory rats are used to assess risk of toxicant exposure to higher mammals), to assess risk to closely related fish species.

**Temperature**—Smith and Saalfeld (1955) reported that eulachon are present in the Columbia River when water temperatures are between 2°C and 10°C and delay migration into spawning tributaries until temperatures are above about 4.4°C (WDFW and ODFW 2001). When river temperatures vary above or below normal, eulachon may fail to spawn in normal areas, delay spawning, or migrate into other tributaries (Smith and Saalfeld 1955, WDFW and ODFW 2001).

Snyder (1970) reported on studies in 1968 and 1969 that examined the temperature tolerance of adult eulachon and eggs taken from the Columbia and Cowlitz rivers and found that eggs were more tolerant to temperature increases than were adults. Increases of 2.8°C and 5.6°C killed 50% and 100% of adult smelt, respectively, within 8 days. Even when exposed to temperatures elevated by 9°C for a single hour, 50% of adult eulachon were dead after 32 hours. When placed in water 3.9°C above river temperatures, females failed to deposit eggs (Snyder 1970). Slightly different results were reported by Blahm and McConnell (1971) on effects of increased temperature on eulachon collected from the Cowlitz River in 1968 and 1969. They reported that the incipient lethal temperature for eulachon acclimated to 5°C was 11°C. All eulachon exposed to 11°C were dead after 8 days exposure. When eulachon had been acclimated to 10°C, a sudden exposure to 18°C for one hour followed by return to 10°C resulted in at least 50% mortality within 50 hours (Blahm and McConnell 1971). All female fish exposed to elevated temperatures failed to deposit eggs within 50 hours, in contrast to female eulachon in control conditions that successfully deposited eggs (Snyder and Blahm 1971).

When evaluating temperature criteria for Washington's water quality standards, Hicks (2000, p. 99) stated that:

> The studies on smelt indicate they have a lower lethal temperature limit than do the salmonids and a lower optimum temperature preferendum. … Given that adult spawners and outgoing juveniles may be in fresh waters as late as March to mid-April, and their temperature requirements may be more strict than most salmonids, the protection of smelt is an important consideration in setting water quality standards. In waters supporting smelt, it is recommended that the 7-day average of the daily maximum temperatures not exceed 12–14°C prior to May 1, with no single daily maximum temperature greater than 16°C.

### Catastrophic events

Larson and Belchik (1998, p. 7) reported that "The eruption of Mount St. Helens severely impacted Cowlitz River spawning success in 1980 and the consequent return of adults in 1984."

Emmett et al. (1990) documented the effects of the dramatic increase in turbidity in the Columbia River on fishes in the estuary following the 18 May 1980 eruption of Mount St. Helens, which resulted in introduction of large quantities of volcanic ash and sediment into the Columbia River estuary. Although hampered by the absence of long-term pre-eruption data, Emmett et al. (1990) showed that densities of benthic invertebrates, particularly amphipods, were significantly reduced and feeding habits and distribution of estuarine fishes were altered following the eruption.

## Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

### Commercial harvest

Landing records of eulachon in commercial fisheries in the Fraser and Columbia rivers were discussed in the above Summary of Regional Demographic Data subsection. Eulachon have been commercially harvested in the Columbia River since the late 1860s and commercial landing records begin in 1888 (Table 7, Figure 22). Smith and Saalfeld (1955), the Washington and Oregon Eulachon Management Plan (WDFW and ODFW 2001), and Bargmann et al. (2005) describe gear types and fishery regulations pertaining to the modern era of the Columbia River commercial eulachon fishery. As described in the Summary of Regional Demographic Data subsection, the Columbia River eulachon commercial fishery has been managed according to the Joint State Eulachon Management Plan since 2001, which provides for three levels of fishing intensity based on an in-season estimate of parental run strength and preseason estimates of juvenile production and ocean productivity (WDFW and ODFW 2001, Bargmann et al. 2005).

More recently, JCRMS (2009, p. 26–27) stated that:

> For January 1–March 31, 2009, the mainstem Columbia River commercial fishery was open from 7 a.m. to 2 p.m. on Mondays and Thursdays. … The Cowlitz River was open from 6 a.m. to 10 p.m. on Saturdays. The Sandy River was open year-round, 7 days a week, 24 hours a day, per permanent regulations. ... Pounds landed in the mainstem Columbia River commercial fisheries [amounted to] 5,600 pounds. No commercial landings were made in Oregon tributaries (i.e., Sandy River) during 2009. Pounds landed in the Cowlitz River commercial fishery [amounted to] 12,100 pounds. … All other Washington tributaries were closed to commercial fishing during 2009.

DFO (2008c) provides a brief history of the Fraser River commercial eulachon fishery, which began in the 1870s and, besides the Nass River fishery which ended in the 1940s, has been the only commercial eulachon fishery operating in British Columbia. DFO (2008c) reported that:

> From 1903 to 1912, the Fraser River eulachon fishery was the fifth largest commercial fishery in BC. … Historically, anyone with a Category C licence or a limited entry vessel-based category of licence was eligible to fish eulachon. … Up to 1995, the fishery was passively managed with an open time from March 15 to May 31 for commercial drift gill nets with a one day per week closure. In 1995 … the fishery was restricted to three days per week in an attempt to provide a "spawning window" which would allow some fish to swim unimpeded by nets to their spawning areas. … The commercial eulachon fishery was closed in 1997 due to the inability to control effort and participation and to ensure conservation objectives were met. … The commercial eulachon fishery sells to the fresh fish market for food. Some of the catch is sold as bait for recreational sturgeon fishing. Based on fish slip records for the period 1980 to 1995, the number of active vessels ranged between 8 and 45.

The Fraser River commercial fishery for eulachon has essentially been closed since 1997, only opening briefly in 2002 and 2004, when 5.76 and 0.44 mt were landed, respectively (Table 9, Figure 27) (DFO 2006a).

**Recreational harvest**

Fry (1979, p. 90) reported that in California, in the past, there were "relatively minor [eulachon] sport fisheries near river mouths, the Klamath fishery being the largest. Dip nets are used." Numerous anecdotal digital newspaper sources were found that indicate substantial recreational fisheries existed in the Klamath River and in other northern California rivers, as well as in the Umpqua River during the 1960s to the 1980s (see Appendix B).

A large recreational dipnet fishery that occurs almost exclusively in Columbia River tributaries, and for which catch records are unavailable, has existed in concert with commercial fisheries (Bargmann et al. 2005). JCRMS (2008) stated that:

> Prior to 1997, the recreational fishery in Washington tributaries was open 7 days per week the entire year. ... Smelt dippers in Washington were allowed 20 pounds [9.1 kg] per person each day, but beginning in late 1998 the limit has sometimes been 10 pounds [4.5 kg] per person. In Oregon the daily limit remains 25 pounds [11.4 kg] per person with the season open throughout the year. The recreational dip net fishery is very popular, drawing thousands of participants. Smelt are used for human consumption and are also in great demand for sturgeon bait. Annual recreational catch estimates are not available; however, limited past creel census information suggests that the recreational catch may equal the commercial landings in some years when smelt are abundant for a long period of time.

USACE (1952, p. 2,873) reported that:

> During the smelt run literally thousands of people line the banks of the streams, utilizing all sorts of gear to make a catch of this delectable fish. Data are lacking to show the magnitude of this catch, but during the 1948 smelt run to the Sandy River, 32,422 noncommercial licenses were issued to persons engaged in dipping this fish.

In reference to the 2009 recreational fishery season, JCRMS (2009, p. 27) stated that:

> The mainstem Columbia River was open to both Washington and Oregon recreational fishers 7 days per week on a 24-hour basis, with a bag limit of 25 pounds per person under Level One restrictions. The Washington tributary season was restricted to the Cowlitz River from 6 a.m. to 10 p.m. on Saturdays with a bag limit of 10 pounds per person. All Oregon tributaries were open to recreational dipping 7 days per week the entire year as per permanent regulations. Recreational fishing was poor due to low abundance.

Currently, recreational fishing for eulachon with dip nets, gill nets, minnow nets, or cast nets is prohibited in all freshwater systems of British Columbia (DFO Web site at http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/opportunities-possibilites/fin-nageoire-eng.htm. In saltwater, recreational fishing for eulachon is prohibited due to conservation concerns in Areas 6 to 10 (central coast of British Columbia) and 28 and 29 (near the mouth of the Fraser River). In Areas 1 to 5 (north coast of British Columbia) and 11 to 27 (Queen Charlotte Strait, Strait of Georgia, and west coast Vancouver Island), a year round daily limit of 20 kg of eulachon can be recreationally harvested with dip net or gill net, although this harvest is likely minor since eulachon are only accessible to the recreational fishery when they return to spawn in the spring and are close enough to the surface and shore to be caught (DFO 2009f).

### Tribal and First Nations fisheries

The importance of the eulachon run to local Indian tribes in the lower Columbia River was documented as early as the Lewis and Clark Expedition (Burroughs 1961, WDFW and ODFW 2001). JCRMS (2009, p. 26) stated that currently:

> Tribal harvest is essentially nonexistent. … However, the Yakama Nation has taken a few pounds of smelt from the Cowlitz River annually, for ceremonial and subsistence purposes.

Available landing records of eulachon in First Nations subsistence fisheries in British Columbia south of the Nass River were discussed in the above Summary of Regional Demographic Data subsection. Rivers where some data were available included the Fraser, Klinaklini, Kingcome, Wannock, Bella Coola, Kemano, and Kitimat. DFO (2008c) stated that:

> Aboriginal communal licences specify the locations and method permitted for use by First Nations for food, social, and ceremonial harvests. Eulachons are harvested when they return to freshwater to spawn. … Fishing methods will vary by First Nations and river system, but may include beach seine, gill net, conical nets, and dip nets. … Limited information is available on the extent of First Nations' harvest of eulachons for food, social, and ceremonial purposes.

Pickard and Marmorek (2007, p. 40) reported in their summary of findings of a DFO workshop to determine research priorities for eulachon that "it seems unlikely that overfishing is the cause of the recent sharp declines in eulachon abundance; however, it is important to understand how harvesting severely depressed populations may affect the recovery of populations."

## Predation and Disease

### Predation

WDFW and ODFW (2001, p. 5) stated that "impressive numbers of predators and scavengers accompany large runs of smelt from the time they first enter the Columbia through completion of spawning." Beach et al. (1981, 1985) and Jeffries (1984) observed that harbor seals, California sea lions, and Steller sea lions (*Eumetopias jubatus*) move into the Columbia River to feed on eulachon runs in the winter. Jeffries (1984, p. 20) observed that "harbor seals were frequently reported in the area where the Cowlitz River enters the Columbia" and "these population increases … were apparently due to the migration of eulachon into spawning tributaries." Many harbor seals migrate from Grays Harbor and Willapa Bay to the Columbia River in the winter (Beach et al. 1985). Between 1,000 and 1,500 harbor seals have been observed using haul out sites as far as 45 miles upriver on the Columbia River at this time of year and "are frequently seen as far upriver as Longview, Washington (RM 55 [RKM 88.5]), apparently following eulachon runs into this area" (Beach et al. 1981, p. 73). NMFS (1997, p. 29) stated that the highest counts of seals in the river coincide with the winter spawning of eulachon.

Based on the presence of otoliths in harbor seal scat collected from the Columbia River during 1981–1982, Jeffries (1984) reported that eulachon were eaten by 50%, 87%, 44%, and 12% of the harbor seals present in January, February, March, and April, respectively. Brown et al. (1989) determined that 98% of the prey eaten by harbor seals in the Columbia River during the winters of 1986 to 1988 were eulachon, and that 100% of harbor seal stomachs examined contained eulachon (Brown et al. 1989, NMFS 1997). Brown et al. (1989) also estimated that the more than 2,000 harbor seals present during mid winter 1987 in the Columbia River consumed from 2.5 to 10.2 million eulachon or from 105 to 428 mt (assuming an average weight of 42 g per eulachon), which is equal to 12% to 50% of the Columbia River commercial fishery landings of eulachon for that year.

Although accounting for only 0.4% of the diet, Olesiuk (1993) estimated that the 12,000–15,000 harbor seals present in the Strait of Georgia during 1988 consumed an average of approximately 40 mt of eulachon. Harbor seals were known to concentrate and feed on eulachon in the Klinaklini River estuary at the head of Knight Inlet during the eulachon spawning migration in March (Spalding 1964). Eulachon also congregate in the Skeena River off Point Lambert during the eulachon spawning migration in that river (Fisher 1947) and likely follow the eulachon up the tributary Ecstall River (Fisher 1952). Both Imler and Sarber (1947) and Pitcher (1980) indicate that eulachon were the dominant prey of harbor seals from late May to mid-July during eulachon spawning migrations on the Copper River Delta in Alaska. Based on stomach content analyses, harbor seals also prey on eulachon in Prince William Sound (Pitcher 1980, Lowry et al. 2001), lower Cook Inlet, and off Kodiak Island (Pitcher 1980). Nearly 5% of 269 harbor seal stomachs examined in all areas of the Gulf of Alaska by Pitcher (1980) contained eulachon remains.

Eulachon are also a primary prey species of California sea lions in the Columbia River in January to June (Beach et al. 1985, Brown et al. 1995, NMFS 1997), and California sea lions have been observed near Longview at the time of the eulachon run (Beach et al. 1981). Jeffries (1984, p. 17) observed that peak numbers of California sea lions (200–250) in the Columbia River occurred during the months of February and March and they were believed to "move upriver following and feeding on the annual eulachon smelt runs." Maximum numbers of Steller sea lions (80–100) in the Columbia River also occurred during this time of year when they "have been observed feeding upriver on eulachon" (Jeffries 1984, p. 19). Seals and sea lions have also been observed above New Westminster in the Fraser River during the eulachon spawning migration (Hay and McCarter 2000).

Bigg (1988) noted that about 60 individual Steller sea lions congregated each year between 1978 and 1982 near the mouth of the Fraser River at Sand Heads in mid-March to early May to feed on eulachon that spawn in the Fraser at that time. Steller sea lions were similarly reported by fishery officers to enter numerous inlets on the mainland coast of British Columbia to feed on returning eulachon during February to April (Bigg 1988). Although Pitcher (1981) reported that eulachon were not a part of the diet of Steller sea lions in the Gulf of Alaska, numerous other studies (Womble 2003, Sigler et al. 2004, Womble and Sigler 2006, Womble et al. 2005, 2009) have emphasized the seasonal importance of eulachon to Steller sea lions in Southeast Alaska. Steller sea lions are attracted in large numbers to spawning eulachon runs in April and May in various locations in northern Southeast Alaska, especially the Yakutat forelands and Lynn Canal (Sigler et al. 2004, Womble et al. 2005, 2009). Eulachon provide a predictable energy-rich prey item for Steller sea lions during the spring gestation and pupping season (Womble 2003, Sigler et al. 2004). Sigler et al. (2004) estimated that about 10% of the population of Southeast Alaska Steller sea lions were in Berners Bay on Lynn Canal during the 2002 eulachon run and that many other Steller sea lions were likely aggregated in the vicinity of one of the 32 other documented eulachon spawning runs in Southeast Alaska. Large aggregations of Steller sea lions have also been found in the vicinity of the mouth of the Alsek River and Taku, Lutak, and Taiya inlets during eulachon runs (Womble 2003).

Northern fur seals consume eulachon in the California Current (Antonelis and Fiscus 1980) and particularly offshore of Oregon and Washington (Antonelis and Perez 1984). Peak numbers of northern fur seals appear off Oregon and Washington in April (Antonelis and Perez 1984). Based on fur seal diet analyses, Antonelis and Perez (1984) calculated that fur seals consumed a yearly average of 600 mt of eulachon in this offshore region between 1958 and 1974. By comparison, the Columbia River commercial fishery landed an average yearly catch of 650 mt of eulachon over this same time period (Table 9). Spalding (1964) reported that about 100 yearling fur seals congregated at the head of Knight Inlet in March 1961 and that four of these fur seals had been feeding exclusively on eulachon in the Klinaklini River estuary, while another 60 fur seals in the middle of the inlet were feeding on squid. Clemens et al. (1936, p. 6) reported on an analysis of stomach contents of 593 northern fur seals sampled from late March to late June off the west coast of Vancouver Island and stated that:

> Eulachon proved to be the third most important organism in the food of the fur seals [after herring and salmon]. It was found to occur in some 20% of the full stomachs but as a rule in rather small quantities. It comprised about 3% of the total food.

Moore et al. (2000) reported that feeding behavior of beluga whales appears to coincide with the timing and pattern of eulachon runs in Cook Inlet, Alaska. Belugas congregate near the Susitna River Delta at the time of early summer eulachon runs and eulachon have been identified in beluga stomachs (Moore et al. 2000).

Marston et al. (2002) documented 34 separate bird species feeding on eulachon returning to spawn in rivers draining into Berners Bay, Alaska, amounting to more than 46,000 avian predators in 1996 and more than 36,500 in 1997. Thousands of gulls and some of the hundreds of eagles were observed feeding heavily on eulachon during the upriver migration, while shorebirds, waterfowl, corvids, and many eagles fed on spawned-out, dying fish (Marston et al. 2002). WDFW and ODFW (2001, p. 5) stated that "gull counts in the mid-1980s along the lower Cowlitz River during the peak of eulachon abundance exceeded 10,000 birds of 8 species" and that during the 1980s "peak counts of bald eagles in conjunction with eulachon upstream migration and spawning were as high as 50 in areas of the lower mainstem Columbia, along the Cowlitz, and along the Lewis" (Table A-10).

According to Fry (1979, p. 15) "Green sturgeon take advantage of spawning eulachon in the Klamath River, but (like eagles and gulls) probably do more scavenging than actual preying." Analysis of stomach contents revealed that eulachon eggs were a seasonally important prey item for juvenile white sturgeon in May and June 1988 in the Columbia River below Bonneville Dam at RKM 153 (2–12 % of the diet) and RKM 211 (25–50% of the diet) (McCabe et al. 1993).

Eulachon occurred in 100% of 229 spiny dogfish stomachs containing food taken in the Fraser River in May 1953, and in 23% and 92% of stomachs analyzed outside the river's mouth in May 1950 and 1953, respectively (Chatwin and Forrester 1953). According to Chatwin and Forrester (1953, p. 38), "The dogfish which support the fishery in the Fraser River in mid-May are clearly dependent upon the appearance of the eulachon." Analyses of more than 14,000 spiny dogfish stomachs in British Columbia waters over a 30-year period ending in 1977 revealed that eulachon represented approximately 5.5% of the annual dogfish diet, and represented a greater percentage of food types consumed for young (13.4%) and immature (10.2%) dogfish than for adults (1.6%) (Jones and Geen 1977).

Eulachon occurred at low frequency (<1%) in 416 Pacific cod stomachs examined in British Columbia (Hart 1949). Eulachon are also eaten by large Pacific hake, which become increasingly piscivirous as they age, with euphausiids being the dominant prey of small Pacific hake (Rexstad and Pikitch 1986, Buckley and Livingston 1997). Livingston (1983, p. 630) determined that eulachon off Oregon in the spring of 1980 "comprised 22% by weight of the diet of 450–549 mm Pacific whiting [hake] and 79.6% by weight of the diet of 550+ mm fish." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents 61% of the offshore pelagic biomass in the California Current system (Ware and McFarlane 1995), and recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that the feeding migration of Pacific hake may be extending further north within the northern California Current system. Although only about 5% of Pacific hake stomachs examined by Outram and Haegele (1972) off the west coast of Vancouver Island in 1970 contained eulachon, the large biomass of Pacific hake in this region in summer may have a significant impact on eulachon biomass in the area (Hay and McCarter 2000).

Yang and Nelson (2000, p. 159–160) stated that "eulachon [in the Gulf of Alaska in 1990, 1993, and 1996] were consumed by the main piscivorous species (arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and pollock) but … comprised no more than 5% of the stomach content weight of each of the predator species in every year." These predator species consumed eulachon whose mean standard length ranged from 100 to 150 mm (Yang and Nelson 2000). In 1990 and 2001, eulachon comprised about 5.5% and 2.5% by weight, respectively, of the total sablefish stomach contents examined in the Gulf of Alaska (Yang 1993, Yang et al. 2006). In the Gulf of Alaska, "sablefish less than 55 cm FL only consumed smaller eulachon (<100 mm SL), whereas larger sablefish (>55 cm FL) also consumed some larger eulachon (about 150 mm SL)" (Yang 1993, p. 97). Eulachon were prey items in about 4% of 753 arrowtooth flounder stomachs examined (70% of stomachs contained no food) off the west coast of Vancouver Island in 1968 and 1969 (Kabata and Forrester 1974). Similarly, eulachon were found in about 5% of 341 arrowtooth flounder stomachs examined (about 49% of stomachs were empty) in the summer of 1989 off the coast north of Cape Blanco, Oregon (Buckley et al. 1999).

Barraclough (1967) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 6–8 June 1966, when eulachon larvae

(4.5–16 mm FL) and postlarvae/juveniles (24–49 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (33–182 mm FL), surf smelt (70–133 mm FL), Pacific sand lance (35–73 mm FL), and Chinook (67–148 mm FL), sockeye (88–140 mm FL), and chum (37.5 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged from 3–14 for Pacific herring, 1–4 for surf smelt, 1–8 for Pacific sand lance, 9–137 for Chinook, 4–12 for sockeye, and 100 for chum salmon (Barraclough 1967). Similarly, Robinson et al. (1968b) reported on the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 5–9 June 1967, when large numbers of eulachon larvae (5–12 mm FL) were in the water column. Species and the range of fork lengths of fish consuming eulachon larvae included Pacific herring (37–258 mm FL), surf smelt (75 mm FL), Pacific sand lance (44–106 mm FL), kelp greenling (63–67 mm FL), threespine stickleback (68 mm FL), steelhead (150 mm FL), and Chinook (100 mm FL), sockeye (98 mm FL), and chum (63–86 mm FL) salmon. Numbers of eulachon larvae consumed by individual fish ranged 1–300 for Pacific herring, 1 for surf smelt, 3–16 for Pacific sand lance, 1–19 for kelp greenling, 12 for threespine stickleback, 1 for steelhead, and 4 for Chinook, 3 for sockeye, and 2–60 for chum salmon (Robinson et al. 1968b).

Barraclough and Fulton (1967) reported on larval/postlarval eulachon (16–26 mm FL) in the stomach contents of surface trawl–caught fish in the Strait of Georgia near the mouth of the Fraser River during 4–8 July 1966. Species and the range of fork lengths of fish consuming eulachon larvae and postlarvae included coho (160 mm FL), sockeye (117 mm FL), chum (95–112 mm FL), and pink (88–135 mm FL) salmon. Numbers of eulachon larvae and postlarvae consumed by individual fish ranged 7 for coho, 13 for sockeye, 2–20 for chum, and 2–118 for pink salmon (Barraclough and Fulton 1967). Moffitt et al. (2002, p. 4) indicated that coho salmon parr and adult Dolly Varden feed on eulachon eggs and larvae in rivers in Southeast Alaska and "returning adult sockeye salmon in the Copper River delta have been found with adult eulachon in their stomachs." Similarly, adult spring-run Chinook salmon have been found with upwards of a dozen eulachon in their stomachs on the Cowlitz River during the spring spawning migration of the two species (Rich 1921). These instances of returning adult salmon feeding on eulachon are highly unusual as "it is well known that the habit of adult salmon, entering streams for the purpose of spawning, is to cease feeding at least as soon as the freshwater is entered" (Rich 1921, p. 7).

Ecosystem impacts of the recent and ongoing expansion of large numbers of jumbo (aka Humboldt) squid (*Dosidicus gigas*) into waters off Oregon, Washington, and British Columbia are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). An analysis of the contents of 503 jumbo squid stomachs collected in the northern California Current, including 40 collected off Oregon and Washington, failed to record the presence of eulachon or other osmerid smelts in the jumbo squid diet (Field et al. 2007). Jumbo squid, however, were shown to prey heavily on Pacific hake in the size range of 15–45 cm and adult Pacific hake are known predators on eulachon. The absence of eulachon in the diet of jumbo squid analyzed by Field et al. (2007) may be due to a combination of low eulachon abundance in the study area and a lack of significant overlap in the two species' depth range; eulachon are commonly found between 20 and 150 m deep (Hay and McCarter 2000) and are seldom encountered below 200 m and jumbo squid in the Field et al. (2007) study were mostly collected below this depth. Further diet studies of jumbo squid collected off Oregon in 2009 are ongoing; however, a further 400 squid stomachs examined since the publication of Field et al. (2007) has yet to yield eulachon or any osmerids in the diet of jumbo squid.[14] Rapid digestion of small pelagic fish may also limit the ability to detect eulachon in jumbo squid stomachs.

### Disease

Very little information was found relative to impacts of diseases on eulachon. Hedrick et al. (2003) isolated viral hemorrhagic septicemia virus (VHSV) for the first time from adult eulachon collected in March 2001 in Oregon's Sandy River. Six of 15 pooled samples, each consisting of 5 fish, tested positive for VHSV. The overall impact of this virus on eulachon is difficult to assess. This virus has been isolated from a wide range of marine fish hosts and given the right conditions may "cause significant disease associated with morbidity and mortality in populations of marine fish" (Hedrick et al. 2003, p. 212).

## Other Natural or Man-made Factors

### Competition

Euphausiids (principally *Thysanoessa spiniferia* and *Euphausia pacifica*) are a primary prey item of eulachon in the open ocean and are also eaten by many other competing species. Tanasichuk et al. (1991) showed that euphausiids were the most important prey for both spiny dogfish and Pacific hake off the lower west coast of Vancouver Island. Livingston (1983) determined that euphausiids constituted 72% and 90% of the diet by weight of Pacific hake examined off Oregon and Washington, respectively, in 1967, and 97% of the diet by weight of Pacific hake 350–449 mm long off Oregon in 1980. Similarly, Outram and Haegele (1972) indicated that euphausiids were the most numerous prey item of Pacific hake off the British Columbia coast in 1970, occurring in 94% of Pacific hake stomachs analyzed. Rexstad and Pikitch (1986, p. 955) stated that "euphausiids constitute the primary source of food for Pacific hake in the North Pacific." The offshore Pacific hake stock migrates northward from winter spawning grounds to feed off the coast of the Pacific Northwest in the summer. This stock represents the largest component of the offshore pelagic fish biomass in the California Current system (Ware and McFarlane 1995). Recent evidence (Benson et al. 2002, Cooke et al. 2006, Phillips et al. 2007) indicates that Pacific hake spawning may be shifting further north within the northern California Current system. This places more young of the year Pacific hake in that ecosystem (Phillips et al. 2007) in direct competition with eulachon for their preferred prey, euphausiids.

Several studies (Suchman and Brodeur 2005, Ruzicka et al. 2007, Brodeur et al. 2008, Suchman et al. 2008) have suggested that seasonal predation by large jellyfish can have a substantial impact on zooplankton populations in the California Current and these jellyfish may represent significant competitors with pelagic fishes for zooplankton resources. Brodeur et al. (2008, p. 649) examined spatial and dietary overlap of large jellyfish with a number of pelagic fishes in the California Current and stated that:

---

[14] J. Field, Southwest Fisheries Science Center, Santa Cruz, CA. Pers. commun., 15 October 2009.

> isotope and diet analyses suggest that jellyfish occupy a trophic level similar to that of small pelagic fishes such as herring, sardines, and northern anchovy. Thus jellyfish have the potential, given their substantial biomass, of competing with these species.

Although eulachon were not specifically examined in this study, a large percentage of the diets of the two large jellyfish examined (*Chrysaora fuscescens* and *Aurelia labiata*) consisted of copepods and various euphausiid life history forms from eggs to adults (Brodeur et al. 2008) that are also significant components of the eulachon diet.

### Euphausiid fisheries

A commercial fishery for euphausiids (also known as krill) occurs in the British Columbia portion of the Strait of Georgia (DFO 2007b). According to DFO (2007b, p. 6), euphausiid biomass in British Columbia waters "is dominated by five [species]: *Euphausia pacifica*, *Thysanoessa spinifera*, *T. inspinata*, *T. longipes* and *T. raschii*," and *E. pacifica* accounts for 70–100% of the biomass in the Strait of Georgia. The Integrated Fisheries Management Plan for euphausiids limits annual total allowable catch (TAC) of euphausiids in the Strait of Georgia to 500 mt (DFO 2007b). DFO (2007b, p. 3 of its Appendix A) stated that this level of harvest is considered to "be conservative and sustainable" within the Strait of Georgia. Eulachon originating from rivers draining into the Strait of Georgia likely leave the strait for waters over the continental shelf prior to reaching a size where they would begin consuming euphausiids, and thus the impact of this euphausiid fishery on eulachon is expected to be minor.

Although no directed commercial fishery for euphausiids has occurred in U.S. waters off the West Coast, recognition of the importance of krill in the diet of many species influenced the Pacific Fisheries Management Council to propose a ban on commercial harvest of all species of krill (euphausiids) in the Exclusive Economic Zone off the U.S. West Coast, which includes California, Oregon, and Washington (PFMC and NMFS 2008). This krill harvest ban was formally implemented as Amendment 12 to the Coastal Pelagic Species Fishery Management Plan in July 2009 (NMFS 2009).

### Eulachon bycatch

Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Hay et al. 1999a, 1999b, Olsen et al. 2000, NWFSC 2008, Hannah and Jones 2009). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur from the west coast of Vancouver Island to the U.S. West Coast off Cape Mendocino, California (Hannah and Jones 2003) (Figure 31). *Pandalus jordani* is known as the ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific ocean shrimp in California. Herein we use the common name ocean shrimp in reference to *P. jordani* as suggested by the American Fisheries Society (McLaughlin et al. 2005). Similar trawl fisheries operate in British Columbia, which mainly target ocean shrimp (aka smooth pink shrimp in Canada), northern pink shrimp (*P. borealis eous*), and sidestripe shrimp (*Pandalopsis dispar*) (Hay et al. 1999a, 1999b, Olsen et al. 2000, Hannah and Jones 2007, NWFSC 2008, DFO 2009c). Information on ocean shrimp fisheries can be found for Washington online at

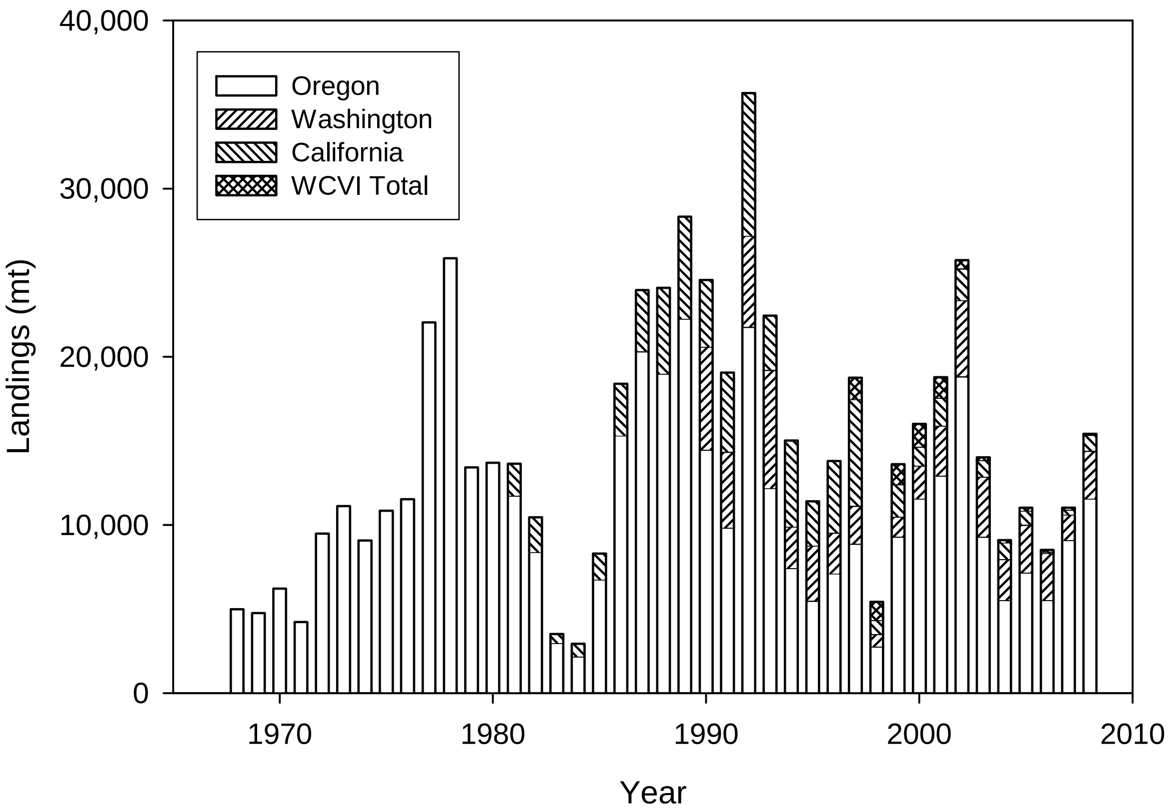


Figure 31. Commercial landings in ocean shrimp trawl fisheries off the U.S. West Coast and in British Columbia, Canada, off the west coast of Vancouver Island. Data for Washington from tables online at http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon from Rien[15] and Hannah and Jones (2009), for California from tables online at http://swr.nmfs.noaa.gov/fmd/bill/landings.htm, and for the west coast of Vancouver Island from DFO (2009a).

http://wdfw.wa.gov/fish/shelfish/shrimp/comm/index.html, for Oregon online at http://www.dfw.state.or.us/MRP/shellfish/commercial/shrimp_landings.asp#about, for California in Frimodig et al. (2007), and for British Columbia online at http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/shrimp/Default_e.htm.

Prior to the mandated use of bycatch reduction devices (BRDs) in the ocean shrimp fishery, 32–61% of the total catch in the ocean shrimp fishery consisted of nonshrimp biomass, made up mostly of Pacific hake, various species of smelt, yellowtail rockfish, sablefish, and lingcod (*Ophiodon elongatus*) (Hannah and Jones 2007). Reducing bycatch in this fishery has long been an active field of research (Hannah et al. 1996, 2003, Hannah and Jones 2007, 2009, Frimodig 2008) and great progress has been made in reducing bycatch, particularly of larger-bodied fishes. As of 2005, following required implementation of BRDs, the total bycatch by weight had been reduced to about 7.5% of the total catch and osmerid smelt bycatch was reduced to an estimated average of 0.73% of the total catch across all BRD types (Hannah and Jones 2007).

---

[15] T. Rein, ODFW, Clackamas, OR. Pers. commun., 24 June 2008.

Beginning in 2000 in British Columbia and 2003 in Washington, Oregon, and California, mandated use of of BRDs in offshore shrimp trawl fisheries has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007, Frimodig 2008). The nearly 97% use of rigid-grate BRDs and increasing use of grates with bar spacing of one inch or less in the Oregon shrimp trawl fishery (Hannah and Jones 2009), and the required use of rigid-grate BRDs with a grid space no greater than 44.5 mm (1.75 inches) and the recommendation to use a 25 mm (1 inch) space between the grid bars when targeting pink shrimp in the British Columbia shrimp trawl fisheries (DFO 2009c) are likely to reduce bycatch rates of small-bodied fishes even further.

Following recognition that large numbers of eulachon were occurring as bycatch in Queen Charlotte Sound shrimp fisheries (Hay and McCarter 2000, Olsen et al. 2000) and of a concurrent decline in central coast British Columbia eulachon stocks, DFO closed the Queen Charlotte Sound shrimp trawl fishery in 1999, which has remained closed "because of concerns for central coast eulachon stocks" (DFO 2009c, p. 11). Concerns over eulachon bycatch in offshore west coast Vancouver Island shrimp trawl fisheries also led DFO to set eulachon bycatch action levels for west coast Vancouver Island (DFO 2009c, 2009d). This action level is set at 1% of the west coast Vancouver Island eulachon abundance index, which is based on biomass estimates of eulachon derived from the annual shrimp abundance survey (DFO 2009c, p. 11). If estimated eulachon bycatch exceeds this 1% level, additional "management actions could include: closure of the shrimp trawl fishery, closure of certain areas to shrimp trawling, or restricting trawling to beam trawlers which have been found to have a lower impact on eulachon than otter trawlers" (DFO 2009d, p. 15). Similar action levels are not in place off the U.S. West Coast.

Although ocean shrimp fisheries operate in Washington, Oregon, and northern California, NMFS's West Coast Groundfish Observer Program (WCGOP) only observes vessels in Oregon and California, since Washington State has not yet issued a ruling allowing federal observer coverage of its state-managed fisheries (NWFSC 2008, p. 1). The BRT has recently received revised data collected by NMFS's WCGOP that update previous estimates of bycatch ratios of eulachon in the Oregon ocean shrimp fishery. Eulachon bycatch in the Oregon ocean shrimp trawl fishery in the years 2004, 2005, and 2007 was estimated at 0.0005, 0.0007, and 0.0008, respectively (WCGOP[16]). Based on these bycatch ratios, the estimated biomass of eulachon taken as bycatch in the Oregon ocean shrimp fishery was calculated at about 2.9 mt in 2004, 5.0 mt in 2005, and 7.7 mt in 2007—assuming total ocean shrimp catches of 5,534 mt (12.2 million lb), 7,167 mt (15.8 million lb), and 9,117 mt (20.1 million lb) in 2004, 2005, and 2007, respectively (Figure 31). Similar eulachon bycatch ratio and total biomass data for California ocean shrimp fisheries were only available for 2004; the eulachon bycatch ratio for that year was 0.0002 (WCGOP[17]) and the biomass of eulachon bycatch was estimated at 0.20 mt—based on a total ocean shrimp catch of 992 mt (2.2 million lb). These data were calculated by applying the yearly observed bycatch ratio of eulachon (observed biomass of eulachon/observed ocean shrimp biomass) to the total yearly Oregon or California ocean shrimp fishery landings (Figure 31).

[16] J. Majewski, unpublished data, NWFSC West Coast Groundfish Observer Program. Pers. commun., 14 October 2009.
[17] See footnote 16.

Unfortunately, no data are available on the level of eulachon bycatch that may be occurring in the Washington State ocean shrimp trawl fishery. In addition, due to sampling conditions and time constraints, not all smelt were identified to the species level in the Oregon and California ocean shrimp trawl fishery observer database and thus a portion of the bycatch in these fisheries was recorded as unidentified smelt. Estimated average biomass of unidentified smelt occurring as bycatch in the Oregon ocean shrimp trawl fishery was reported as 5.6 mt across the 3 years with observer data: 2004, 2005, and 2007 (NWFSC 2008, its Table 3).

Based on the portion of the smelt bycatch biomass identified to species in the Oregon ocean shrimp fishery by the WCGOP (NWFSC 2008), the unidentified smelt biomass was likely about 60% eulachon. NWFSC (2008, p. 24) calculated a eulachon bycatch rate of 0.0004 (±0.0030 SE) in the 2007 ocean shrimp trawl fishery north of 40°10′N latitude. Bellman et al. (2008, p. 38) used the ratio from NWFSC (2008) and total fleet landings of pink shrimp (mt, based on fish tickets) to calculate a bycatch of 4.7 mt of eulachon in the pink shrimp fishery north of 40°10′N latitude in 2007 including northern California, Oregon, and Washington. The depressed abundance of the southern DPS of eulachon may also be contributing to the above estimated levels of eulachon bycatch.

Presumably, most eulachon caught as bycatch in offshore ocean shrimp trawl fisheries off Oregon and California originate in the Columbia River, as apparent abundance of populations spawning to the south of the Columbia River have suffered severe declines. However, eulachon off California, Oregon, and Washington represent only a portion of the Columbia River eulachon subpopulation. Triennial groundfish trawl surveys conducted off the U.S. West Coast in 1995 (Wilkins 1998), 1998 (Wilkins and Shaw 2000), and 2001 (Wilkins and Weinberg 2002) indicate that 80 to 90% of all the eulachon biomass in these surveys occurred in the Canadian portion of the Vancouver INPFC area (Table 4, Figure 4, and Figure 19), where eulachon are believed to be largely a mixture of Columbia River and Fraser River subpopulations (Beacham et al. 2005, DFO 2009d).

Genetic analyses of this stock mixture “indicated that there are continued stock proportions of approximately 60:40 Columbia:Fraser in these areas” (DFO 2009d, p. 14). The genetic composition of eulachon off northern California, Oregon, and Washington has not been studied, and it is not known whether eulachon ocean migratory patterns may be specific to certain genetically differentiated stocks, as has been shown for certain Chinook (Myers et al. 1998, Weitkamp 2010) and coho (Weitkamp and Neely 2002) salmon ESUs. Why some eulachon juveniles turn north and some turn south as they exit the Columbia River mouth is unknown, but if there is a genetic or stock specific component to this behavior, then threats to the smaller segment of the subpopulation that occurs south of the Columbia River would be of even greater concern.

As shown above, it is likely that the majority of eulachon originating in the Columbia River are subject to bycatch in the West Coast Vancouver Island shrimp trawl fishery. Offshore of west coast Vancouver Island, most eulachon occur in SMAs 23OFF, 21OFF, 124OFF, and 125OFF (Figure 21). According to DFO (2009c, p. 8) recent effort and shrimp catch are down, due to low demand for pink shrimp since “no machine peelers were operating in BC.” Thus in SMAs 124OFF and 125OFF offshore of west coast Vancouver Island, where encounters with eulachon are high, "no shrimp trawl fishing occurred in … 2004 and very little effort has occurred in 2005, 2006, 2007, and 2008" (DFO 2009c, p. 11). The combination of reduced effort and required BRD use may be partly why the 1% eulachon action level has not been reached since the year 2000. The current 1% eulachon action level is 20 mt for SMAs 124OFF and 125OFF and 7.5 mt for the combination of SMAs 23OFF, 21OFF, and 23IN (DFO 2009a, p. 10) (Figure 21).

A recent workshop to determine research priorities for eulachon in Canada examined many hypotheses concerning threats to eulachon in British Columbia and concluded that eulachon bycatch in shrimp trawl fisheries was "potentially an important contributing factor in reducing recovery, along with temperature/food/hake, other harvest, but of uncertain or unknown magnitude" (Pickard and Marmorek 2007, p. 36). Hay and McCarter (2000) stated that "Although the shrimp trawl industry probably has not caused the recent decline in eulachons, we cannot rule out the possibility that it could be a factor in limiting the recovery of certain stocks."

### Collateral BRD mortality

Although data on survivability of BRDs by small pelagic fishes such as eulachon are scarce, many studies on other fishes indicate that "among some species groups, such as small-sized pelagic fish, mortality may be high" and "the smallest escapees often appear the most vulnerable" (Suuronen 2005, p. 13–14). Results of several studies have shown a direct relationship between length and survival of fish escaping trawl nets, either with or without deflecting grids (Sangster et al. 1996, Suuronen et al. 1996, Ingólfsson et al. 2007), indicating that smaller fish with their poorer swimming ability and endurance may be more likely to suffer greater injury and stress during their escape from trawl gear than larger fish (Broadhurst et al. 2006, Ingólfsson et al. 2007). A recent workshop (Pickard and Marmorek 2007, p. 31–33) to determine research priorities for eulachon in Canada recommended the need to research the effectiveness of BRDs and the need to estimate mortality, not just bycatch. It is difficult to evaluate the true effectiveness of BRDs in a fishery without knowing the survival rate of fish that are deflected by the BRD and escape the trawl net (Broadhurst 2000, Suuronen 2005, Broadhurst et al. 2006).

### Nonindigenous species

Potential impacts and risks of nonindigenous aquatic species to native fish species include increased predation, increased competition for habitats and food, alteration of food webs, and transmission of new diseases and parasites (ISAB 2008). The negative impact of nonindigenous species is recognized as one of the leading factors causing imperilment of native North American freshwater aquatic species (Lassuy 1995, ISAB 2008) and was listed as a factor leading to the extinction of 40 North America fish species and subspecies, representing a full 68% of those lost over the past 100 years (Miller et al. 1989). NRC (2004) reported that 17 nonindigenous fish species inhabit the lower Klamath River basin, but their impact on eulachon has not been studied. Schade and Bonar (2005) estimated that the percent of total fish species that are nonnative in streams in California, Oregon and Washington, were 39.6%, 24.5%, and 18.4%, respectively.

Systma et al. (2004, p. 50) surveyed the lower Columbia River for nonindigenous species at 134 stations between 2001 and 2004 and found that:

> Of the 269 species identified, 54 (21%) were introduced, 92 (34%) were native, and 123 (45%) were cryptogenic [origin unknown]. … Over the past 10 years, a new [nonindigenous] invertebrate species was discovered about every 5 months [in the lower Columbia River].

By contrast, the rate of discovery of nonindigenous fish species in the lower Columbia River peaked in the 1950s (Systma et al. 2004). The Systma et al. (2004) survey identified 33 nonindigenous fish species in the lower Columbia River. Similarly, Pickard and Marmorek (2007, p. 41) stated that "Invasive, nonnative fish (carp, largemouth bass, crappie, catfish) have been increasing in the lower Fraser River." ISAB (2008) and Sanderson et al. (2009) recently documented the risks posed by nonindigenous species to native salmonids in the Columbia River basin and the Pacific Northwest, respectively. There is evidence that nonnative striped bass (*Morone saxatilis*) ate substantial numbers of adult eulachon in the Umpqua River when eulachon were abundant in that river in the late 1960s to early 1980s (see Umpqua River newspaper articles in Appendix B).

Bottom et al. (2005, p. xxii) examined the potential impacts of three prominent nonindigenous species on the lower Columbia River and stated that:

> Significant changes in the modern estuarine community through species introductions have not been assessed. However, the Asian clam, *Corbicula fluminea*, has expanded far into the lower mainstem reservoirs and tributary basins since its introduction into the estuary in 1938. *Pseudodiaptomus inopinus,* a calanoid copepod also introduced from Asia, has appeared prominently in the estuary since 1980, and American shad (*Alosa sapidissima*) has grown to a substantial population in the Columbia River since its introduction in 1885–1886. Fifteen other nonindigenous fishes are now common in the estuary. The specific impacts on the estuarine ecosystem … from any of these populations are speculative. However, given the tremendous abundance of *C. fluminea* and American shad (peak Bonneville Dam passage counts of $3 \times 10^6$), it is not unreasonable to expect that their consumption rates may have significantly modified the estuarine food web.

Cordell et al. (2008) documented the presence of several additional Asian copepods in the lower Columbia River and found that the calanoid copepod *P. inopinus* has largely been replaced by other Asian species, particularly *P. forbesi*. How these ongoing invasions of nonindigenous zooplanketers, mediated by ballast water exchange of large ships, will affect the estuarine food web is unknown, although the lower Columbia River may eventually come to resemble the San Francisco estuary, which "now has an East Asian copepod fauna" (Cordell et al. 2008).

## Qualitative Threats Assessment

Although the question of how a DPS came to be at risk is important, a population or DPS that has been reduced to low abundance will continue to be at risk for demographic and genetic reasons until it reaches a larger size, regardless of the reasons for its initial decline. Furthermore, in some cases, a factor that was important in causing the original declines may no longer be an impediment to recovery. Unlike some ESA-listed species that face a single primary threat, eulachon face numerous potential threats throughout every stage of their life cycle. It is therefore relatively easy to simply list current and past potential threats to eulachon populations, but it is much more difficult to evaluate the relative importance of a wide range of interacting factors. The BRT also recognized that evaluating the degree to which factors for decline will continue to pose a threat generally requires consideration of issues that are more in the realm of social science than biological science—such as whether proposed changes will be funded, and, if funded, will be implemented effectively.

Nevertheless, the potential role that various threats have played in the decline of the southern DPS of eulachon was examined by the BRT in light of the question posed by the Northwest Region's Draft BRT Eulachon Instructions, articulated as follows:

> In [your] evaluation of extinction risk, please include a consideration of the threats facing the species/DPS that may or may not be manifested in the current demographic status of populations. Please document your consideration of these threats according to the statutory listing factors (ESA section 4(a)(1)(A)–(C), and (E)): the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; and other natural or man-made factors affecting its continued existence. In describing the threats facing the species/DPS, please distinguish between threats (e.g., human actions or natural events) and limiting factors (e.g., the physical, biological, or chemical processes that result in demographic risks to the species/DPS), and qualitatively rank, if possible, the severity of identified threats to the species' persistence.

The potential roles that 16 current threats may play in the decline of the southern DPS of eulachon were ranked according to severity in the Klamath, Columbia, and Fraser rivers and in that portion of the DPS along the mainland coast of British Columbia (Table 14 through Table 18). Also noted is the ESA factor for decline within which each threat falls (Table 14). The results of the BRT's analysis of the severity of threats to eulachon are presented in Table 15 through Table 18 in rank order from most severe to least severe for each geographical subset as determined by the mean BRT threat scores. Also presented in these tables are the standard deviation about the mean threat scores, the modal score, the range of scores, and the number of BRT members scoring the threat.

The BRT ranked climate change impacts on ocean conditions as the most serious threat to persistence of eulachon in all four subareas of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subareas of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats. In most categories, some portion of the BRT felt that insufficient data were available to score the threat severity (thereby marking the threat severity as unknown) as indicated by the number of BRT members voting (column N) in Table 15 through Table 18.

Table 14. Example worksheet for analysis of the severity of current threats to the southern DPS of eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. Insufficient data to score the threat severity is indicated by “u” for unknown. Threats that are not applicable to the area are indicated by NA. Threats are grouped within the four statutory listing factors: 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; and 4) other natural or man-made factors affecting its continued existence.

| **River basin** | **Dams/water diversions** | **Dredging** | **Shoreline construction** | **Climate change impacts on ocean conditions** | **Climate change impacts on freshwater habitat** | **Water quality** | **Catastrophic events** | **Commercial harvest** | **Recreational harvest** | **Tribal/First Nations fisheries** | **Scientific monitoring** | **Disease** | **Predation** | **Competition** | **Eulachon bycatch** | **Nonindegenous species** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Klamath River | | NA | | | | | | NA | | | NA | | | | | |
| Columbia River | | | | | | | | | | | | | | | | |
| Fraser River | | | | | | | | | | | | | | | | |
| British Columbia coast | | | | | | | | NA | | | | | | | | |
| | Listing factor 1) The present or threatened destruction, modification, or curtailment of habitat or range | | | | | | | Listing factor 2) Over-utilization for commercial, recreational, scientific, or educational purposes | | | | Listing factor 3) Disease or predation | | Listing factor 4) Other natural or man-made factors | | |

Table 15. Results of qualitative ranking by the eulachon BRT of severity of threats for Klamath River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.2 | 0.6 | 4 | 3–5 | 10 |
| Dams/water diversions | 3.4 | 0.9 | 3 | 2–5 | 8 |
| Eulachon bycatch | 3.3 | 0.7 | 3 | 2–4 | 9 |
| Climate change impacts on freshwater habitat | 3.3 | 0.7 | 3 | 2–4 | 10 |
| Predation | 2.7 | 0.9 | 3 | 1–4 | 9 |
| Water quality | 2.5 | 1.1 | 3 | 1–4 | 10 |
| Catastrophic events | 2.3 | 1.8 | 1 | 1–5 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Shoreline construction | 1.9 | 1.1 | 1 | 1–4 | 9 |
| Tribal/First Nations fisheries | 1.7 | 0.8 | 1 | 1–3 | 10 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Recreational harvest | 1.4 | 0.9 | 1 | 1–3 | 9 |

Table 16. Results of qualitative ranking by the eulachon BRT of severity of threats for Columbia River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.3 | 0.7 | 4 | 3–5 | 10 |
| Eulachon bycatch | 3.8 | 0.7 | 4 | 3–5 | 9 |
| Climate change impacts on freshwater habitat | 3.4 | 0.5 | 3 | 3–4 | 10 |
| Dams/water diversions | 3.3 | 1.1 | 3 | 2–5 | 9 |
| Water quality | 3.0 | 0.7 | 3 | 2–4 | 10 |
| Dredging | 2.9 | 0.6 | 3 | 2–4 | 9 |
| Predation | 2.9 | 0.8 | 3 | 1–4 | 9 |
| Catastrophic events | 2.8 | 1.5 | 2 | 1–5 | 8 |
| Commercial harvest | 2.5 | 1.0 | 2 | 1–4 | 10 |
| Shoreline construction | 2.4 | 1.0 | 3 | 1–4 | 9 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Recreational harvest | 1.8 | 0.8 | 2 | 1–3 | 10 |
| Tribal/First Nations fisheries | 1.7 | 0.8 | 1 | 1–3 | 10 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 10 |

Table 17. Results of qualitative ranking by the eulachon BRT of severity of threats for Fraser River eulachon. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.1 | 0.6 | 4 | 3–5 | 9 |
| Eulachon bycatch | 3.7 | 0.7 | 3 | 3–5 | 9 |
| Predation | 3.1 | 0.4 | 3 | 3–4 | 8 |
| Climate change impacts on freshwater habitat | 3.1 | 0.6 | 3 | 2–4 | 9 |
| Water quality | 2.7 | 0.7 | 3 | 2–4 | 9 |
| Commercial harvest | 2.7 | 0.9 | 2 | 2–4 | 9 |
| Dredging | 2.6 | 0.7 | 2 | 2–4 | 8 |
| Dams/water diversions | 2.5 | 1.6 | 1 | 1–5 | 6 |
| Shoreline construction | 2.3 | 1.0 | 3 | 1–4 | 9 |
| Catastrophic events | 2.3 | 1.8 | 1 | 1–5 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Tribal/First Nations fisheries | 1.8 | 0.8 | 1 | 1–3 | 9 |
| Recreational harvest | 1.7 | 0.9 | 1 | 1–3 | 9 |
| Nonindigenous species | 1.7 | 0.8 | 1 | 1–3 | 6 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 9 |

Table 18. Results of qualitative ranking by the eulachon BRT of severity of threats for eulachon in mainland British Columbia Rivers south of the Nass River. Threats were scored as: 1–very low, 2–low, 3–moderate, 4–high, and 5–very high. N = number of BRT members voting; members not voting marked severity of threat as either unknown or not applicable.

| Threat | Mean | SD | Mode | Range | N |
|---|---|---|---|---|---|
| Climate change impacts on ocean conditions | 4.1 | 0.6 | 4 | 3–5 | 9 |
| Eulachon bycatch | 3.6 | 0.9 | 4 | 2–5 | 9 |
| Predation | 3.1 | 0.4 | 3 | 3–4 | 8 |
| Climate change impacts on freshwater habitat | 2.9 | 1.2 | 3 | 1–4 | 9 |
| Catastrophic events | 2.4 | 1.7 | 2 | 1–5 | 8 |
| Shoreline construction | 2.3 | 0.9 | 2 | 1–4 | 8 |
| Disease | 2.3 | 1.9 | 1 | 1–5 | 4 |
| Water quality | 2.1 | 1.0 | 2 | 1–4 | 8 |
| Competition | 2.0 | 0.8 | 2 | 1–3 | 7 |
| Tribal First Nations fisheries | 1.9 | 0.8 | 2 | 1–3 | 9 |
| Dam/water diversions | 1.8 | 1.2 | 1 | 1–4 | 6 |
| Dredging | 1.7 | 1.0 | 1 | 1–4 | 9 |
| Nonindigenous species | 1.5 | 0.8 | 1 | 1–3 | 6 |
| Recreational harvest | 1.4 | 0.9 | 1 | 1–3 | 9 |
| Scientific monitoring | 1.2 | 0.4 | 1 | 1–2 | 9 |

# Overall Risk Determination

The BRT's determination of overall risk to the species used these categories: at high risk of extinction, at moderate risk of extinction, or not at risk of extinction. Table 19 describes these qualitative reference levels of extinction risk. Quantitative and qualitative conservation assessments for other species have often used a 100-year time frame in their extinction risk evaluations (Morris et al. 1999, McElhany et al. 2000), and the BRT adopted this time scale as the period over which it had confidence in evaluating risk. The overall extinction risk determination reflected informed professional judgment by each BRT member. This assessment was guided by the results of the risk matrix analysis, integrating information about demographic risks with expectations about likely interactions with threats and other factors.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the BRT adopted the likelihood point method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under the Northwest Forest Plan (FEMAT 1993). Table 20 is an example worksheet and results. In this approach, each BRT member distributes 10 likelihood points among the 3 species extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status. Thus if a member were certain that the species was in the not at risk category, he or she could assign all 10 points to that category. A reviewer with less certainty about the species' status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999, as well as in reviews of Puget Sound rockfishes (Stout et al. 2001b), Pacific herring (Stout et al. 2001a, Gustafson et al. 2006), Pacific hake, walleye pollock, Pacific cod (Gustafson et al. 2000), and black abalone (VanBlaricom et al. 2009).

# Summary of Risk Conclusions for the Southern DPS of Eulachon

The BRT's scores for overall risk to the southern DPS of eulachon, throughout all of its range, were heavily weighted to moderate risk with this category receiving 60% of the likelihood points. High risk received 32% of the likelihood points and not at risk received 8% of the points. The BRT was concerned that, although eulachon are a relatively poorly monitored species, most of the available information indicates that the southern DPS of eulachon has experienced an abrupt decline in abundance throughout its range. The BRT was particularly concerned that two large spawning populations—in the Columbia and Fraser rivers—have declined to what appear to be historically low levels in the Fraser River and nearly so in the Columbia River. Overall risk scores for abundance ranged from 4 to 5 (see Table 13).

The BRT was concerned that there is very little monitoring data available for northern California eulachon, but determined that the available information suggests that eulachon in northern California experienced an abrupt decline several decades ago. The BRT was also concerned that recent attempts to estimate actual spawner abundance in some rivers in British Columbia that are known to have supported significant First Nations fisheries in the past have resulted in very low estimates of spawning stock. The BRT was also concerned that the current sizes of central and north coast British Columbia eulachon populations appear inconsistent with

Table 19. Description of reference levels for the BRT's assessment of the species' or DPS extinction risk.

| | **Qualitative reference levels of relative extinction risk** |
|---|---|
| Continuum of decreasing relative risk of extinction | 1). Moderate risk: A species or DPS is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to be at a high level of extinction risk (see description of high risk below). A species/DPS may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or DPS is more likely than not to be at high risk depends on various case-specific and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or DPS (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. Please explain the time scale over which the BRT has confidence in evaluating moderate risk. |
| | 2. High risk: A species or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, or diversity that place its persistence in question. The demographics of a species/DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species/DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create such imminent demographic risks. |
| Extinct | A species or DPS is extinct when there is no longer a living representative. |

the ethnographic literature that describes an extensive grease trading network based on eulachon catch (discussed by Hay, 2002, p. 103).

In addition, the BRT was concerned that the current abundance of the many individual populations within the DPS may be sufficiently low to be an additional risk factor, even for populations (such as the Columbia and Fraser) where the absolute population size seems large compared to many other at-risk fish populations. Indeed, the BRT considered a central question in this status review to be whether a DPS or subpopulation may be at risk of extinction when there may be hundreds of thousands or perhaps millions of individuals remaining in the population. In evaluating this issue, the BRT concluded that eulachon (and other similar forage fishes) (see Dulvy et al. 2004) may be at significant risk at population sizes that are a fraction of their historical levels but are still large compared to what would be considered normal for other ESA listed species (see above discussion in the Absolute Numbers subsection).

Of relevance to this issue are recent reviews of extinction risk in marine fishes illustrating that forage fish are not immune to risk of extirpation at the population scale (Dulvy et al. 2003, Reynolds et al. 2005). Hutchings (2000, 2001a, 2001b) and others (Dulvy et al. 2003, Mace and

Table 20. Example worksheet and results of the evaluation of the overall level of extinction risk for the southern DPS of eulachon using the likelihood point method (FEMAT 1993).

| | Overall extinction risk category[a] | | |
|---|---|---|---|
| | **Not at risk** | **Moderate risk** | **High risk** |
| Number of likelihood points[b] | 8 | 60 | 32 |

*Comments*:

[a]These evaluations do not consider protective efforts, and therefore are not recommendations regarding ESA listing status.
[b]Each BRT member distributes 10 likelihood points among the 3 overall extinction risk categories. Placement of all 10 points in a given risk category reflect 100% certainty that level of risk reflects the true level of extinction risk for the species. Distributing points between risk categories reflects uncertainty in whether a given category reflects the true species status.

Hudson 1999, Hutchings and Reynolds 2004) cite empirical analyses indicating that marine fishes likely have similar extinction probabilities to those of nonmarine taxa. A number of inshore populations of Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*) have either been extirpated or have not shown signs of recovery from depletions that are unprecedented in the historic record (Smedbol and Stevenson 2001). An example involves the disappearance of the Icelandic spring-spawning population of Atlantic herring (Beverton 1990), whose last known census population size in 1972 was 700,000 (Dulvy et al. 2004).

The BRT believes that high eulachon MVP sizes are necessary 1) to ensure that a critical threshold density of adult eulachon are available during breeding events for maintenance of normal reproductive processes, 2) to produce enough offspring to counteract high in-river egg and larval mortality and planktonic larval mortality in the ocean, and 3) to produce enough offspring to buffer against the action of local environmental conditions which may lead to random sweepstake recruitment events, where only a small minority of spawning individuals contribute to subsequent generations. In species with this life history pattern, the genetically effective population size can be several orders of magnitude lower than the census size (Hedgecock 1994, ICES 2004), and minimum viable census sizes may therefore be on the order of 50,000 to 500,000 (Dulvy et al. 2004). The BRT was concerned that in a number of subareas of the DPS (Klamath, Fraser, and Bella Coola rivers, Rivers Inlet, etc.), population sizes of eulachon are below what would be considered MVP sizes for highly fecund species.

The BRT noted that variable year-class strength in marine fishes with pelagic larvae is dependent on survival of larvae prior to recruitment and is driven by match-mismatch of larvae and their planktonic food supply (Hjort 1914, Lasker 1975, Sinclair and Tremblay 1984), oceanographic transport mechanisms (Parrish et al. 1981), variable environmental ocean conditions (Shepherd et al. 1984, McFarlane et al. 2000), and predation (Bailey and Houde 1989). The operation of these dynamic ocean conditions and their impacts on eulachon recruitment were amply illustrated in the Columbia River population where high larval densities were observed in 2000–2003, followed by lower than average adult returns in 2004, 2005, and 2006 (JCRMS 2007).

Failure to time spawning activity with river conditions conducive to successful fertilization and egg survival, and to the appearance of larval prey species in the oceanic environment, also contribute to high rates of environmentally driven egg and larval mortality. The BRT was concerned that there is evidence that climate change is leading to relatively rapid changes in both oceanic and freshwater environmental conditions that eulachon are unable to tolerate. Eulachon are basically a cold-water species adapted to feed on a northern suite of copepods in the ocean during the critical transition period from larvae to juvenile and much of their recent recruitment failure may be traced to mortality during this critical period. However, there have been recent shifts in the suite of copepod species available to eulachon that favor a more southerly species assemblage (Mackas et al. 2001, 2007, Hooff and Peterson 2006) and the BRT was concerned that climate change may be contributing to a mismatch between eulachon life history and prey species. It is also likely that pelagic fish with their shorter life cycles may be less resilient to long-term climatic changes than longer-lived demersal species.

However, the ability of the Columbia River eulachon stock to respond rapidly to the good ocean conditions of the late 1999–early 2002 period illustrates the species' resiliency, and the BRT viewed this resiliency as providing the species with a buffer against future environmental perturbations. The productivity potential or intrinsic rate of increase of eulachon (Musick et al. 2000) as indicated by life history characteristics such as low age-at-maturity, small body size, and planktonic larvae was recognized by the BRT as likely conferring eulachon with some resilience to extinction as they retain the ability to rapidly respond to favorable ocean conditions. However, the BRT was concerned that there is no empirical or theoretical grounds to conclude that high fecundity as a life history character confers resilience on a fish species in comparison to a species with lower fecundity (Sadovy 2001, Reynolds et al. 2005).

Overall, the BRT's risk scores for growth rate and productivity of the DPS ranged from 2 to 5 with a mean score of 3 (Table 13). Recent ocean conditions in the California Current Province in the fall of 2007 and spring-summer of 2008 were considered favorable for eulachon (PDO data online at http://jisao.washington.edu/pdo/ and http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/b-latest-updates.cfm), and the BRT postulated that this may indicate elevated eulachon returns may be expected starting with the 2011 run year. However, the BRT was concerned that these changes in the ocean, favorable to eulachon larval survival, may be of short-term duration, similar to the late 1998-early 2002 period.

In terms of threats related to diversity, the BRT was concerned that not only are eulachon semelparous (spawn once and die) but if recent estimates of age structure in eulachon are correct (Clarke et al. 2007), then spawning adults—particularly in southern areas such as the Columbia and Fraser rivers—may be limited to a single age class, which likely increases their vulnerability to perturbations and provides less of a buffer against year-class failure than species such as herring that spawn repeatedly and have variable ages at maturity.

The BRT was also concerned about the apparently very low abundance of the Klamath River subpopulation, which might be expected to have unique adaptations to conditions at the southernmost extent of the range, and about the potential loss of biocomplexity in Fraser River eulachon due to contraction of spawning locations, as documented by Higgins et al. (1987). The BRT noted some positive signs including observations that eulachon continue to display variation in spawn timing, age-at-maturity, and spawning locations and a high degree of biocomplexity (i.e., many spawning locations and spawn-timing variation) in Columbia River eulachon, which may buffer this stock from freshwater environmental perturbations. Overall, the BRT risk scores for diversity of the DPS ranged from 2 to 3 with a mean score of 2.6 (Table 13).

The BRT also had concerns about risks related to spatial structure and distribution. In particular, because the major spawning populations within the DPS appear to have declined substantially, the BRT was concerned that if some formerly significant populations, such as in the Klamath River, become extirpated, there will be less opportunity for successful recolonization. In addition, the apparent decline of populations in northern California may result in contraction of the southern portion of the DPS's range. The BRT also noted that several populations that used to support significant First Nations fisheries on the British Columbia coast have declined to very low levels (e.g., Bella Coola and Wannock rivers). Positive signs for spatial structure and connectivity noted by the BRT include considerations that eulachon appear to have the potential to recolonize given their apparent ability to stray from the natal spawning area, at least within rivers sharing the same estuary. In addition, the perceived historical spatial structure of the DPS, with the possible exception of the Klamath River, remains intact. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 (Table 13).

The BRT noted several recent events that appear likely to impact eulachon. Global patterns suggest the long-term trend is for a warmer, less-productive ocean regime in the California Current and the Transitional Pacific. The recent decline in abundance or relative abundance of eulachon in many systems coupled with the probable disruption of metapopulation structure may make it more difficult for eulachon to adapt to warming ocean conditions. In addition, warming conditions have allowed both Pacific hake (Phillips et al. 2007) and Pacific sardine (Emmett et al. 2005) to expand their distributions to the north, increasing predation on eulachon by Pacific hake and competition for food resources by both species. The recent and ongoing expansion of large numbers of jumbo squid into waters off Oregon, Washington, and British Columbia are also likely to have a significant impact on eulachon; however, ecosystem impacts of jumbo squid are uncertain (Zeidberg and Robison 2007, Holmes et al. 2008). Recent invasions of Asian copepods into the Columbia River estuary (Cordell et al. 2008) may have a negative influence on the Columbia River population. However, cold ocean conditions in spring 2008 suggest that this may have been a good year for eulachon recruitment. The effects of these recent positive and negative events are difficult to estimate; most members indicated that the net effect is likely to be negative.

## Significant Portion of Its Range Question

The BRT concluded that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range and in effect answered the question in the affirmative as to whether the southern DPS of eulachon is at risk throughout a significant portion of its range.

# Glossary

**adipose fin.** A fin without a bone or cartilage, located behind the dorsal fin.

**ADFG.** For *Alaska Department of Fish and Game*. Department that manages certain fisheries in the State of Alaska.

**AFSC.** For *Alaska Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**Allee effect.** The circumstance of reduced population growth occurring at low population size. This can result from the impact of low spawner density on fertilization success or some other vital reproductive function.

**allele.** An alternative form of a gene that can occur at the same location (locus) on homologous (paired) chromosomes. A population can have many alleles for a particular locus, but an individual can carry no more than two alleles at a diploid locus.

**anadromous.** Species that spend their adult lives in the ocean but move into freshwater streams to reproduce or spawn (e.g., salmon).

**anthropogenic.** Caused or produced by human action.

**ATU.** For *accumulated thermal unit*. An ATU is a measurement that describes the accumulation of heat over time. One ATU is equal to one degree Celsius for one day. In water of 10°C, an organism would accumulate 10 ATUs per day.

**BRD**. For *bycatch reduction device*.

**BRT.** For *Biological Review Team*. The team of scientists who evaluates scientific information considered in a National Marine Fisheries Service status review.

**bycatch.** Animals caught by fishing that were not the intended target of the fishing activity. Such unwanted catch is often wasted. Both discarded and retained species can be considered bycatch.

**CDFG.** For *California Department of Fish and Game*. Department that comanages certain fisheries in the State of California.

**comanagers.** Federal, state, and tribal agencies that cooperatively manage fish in the Pacific Northwest.

**CPUE.** For *catch per unit effort*. A measure of the density or population size of an animal that is targeted by fishing. Large CPUEs indicate large populations, since many individuals are caught for every unit of fishing effort.

**DFO.** For *Department of Fisheries and Oceans Canada*. Department that manages fisheries in Canada.

**DDT.** For *dichlorodiphenyltrichloroethane* and its metabolites, including *p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD, *o,p'*-DDE, and *o,p'*-DDT. These are banned organochlorine pesticides that were used to control insects that harm crops, as well as malaria-carrying mosquitoes. DDTs are still used in some parts of the world to control mosquitoes.

**DPS.** For *distinct population segment*. A DPS is a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. The Endangered Species Act provides for listing species, subspecies, or distinct population segments of vertebrate species.

**DNA.** For *deoxyribonucleic acid***.** DNA is a complex molecule that carries an organism's heritable information. DNA consists of a polysugar-phosphate backbone from which the bases (nucleotides) project. DNA forms a double helix that is held together by hydrogen bonds between specific base pairs (thymine to adenine, guanine to cytosine). Each strand in the double helix is complementary to its partner strand in terms of its base sequence. The two types of DNA commonly used to examine genetic variation are *mitochondrial DNA* (mtDNA), a circular molecule that is maternally inherited, and microsatellite (nuclear) DNA, which is organized into a set of chromosomes. See also **allele, microsatellite DNA, mitochondrial DNA**.

**endangered species.** A species in danger of extinction throughout all or a significant portion of its range, with respect to the Endangered Species Act. See also **ESA, threatened species**.

**effective population size (Ne).** The number of reproducing individuals in an ideal population that would lose genetic variation due to genetic drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration. Typically, Ne is less than either a population's total number of sexually mature adults present or the total number of adults that reproduced. Effective population can be defined in terms of the amount of increase in homozygosity (inbreeding effective number) or the amount of allele frequency drift (variance effective number).

**ENSO.** For *El Niño-Southern Oscillation*. Pattern of climate variability most clearly defined by year-to-year variations in sea surface temperature in the tropical equatorial Pacific Ocean in the zone extending from the South American coast to slightly west of the international date line.

**ESA.** For U.S. *Endangered Species Act* of 1973. Passed by Congress, it provides a means whereby the ecosystem on which threatened and endangered species depend may be conserved.

**estuary.** A semienclosed body of water having connections to the ocean at the downstream end and freshwater streams at the upstream end. Water in estuaries thus tends to be at an intermediate and variable salinity and temperature.

**ESU.** For *evolutionarily significant unit*. An ESU represents a distinct population segment of Pacific salmon under the Endangered Species Act that 1) is substantially reproductively isolated from nonspecific populations, and 2) represents an important component of the evolutionary legacy of the species.

**fecundity.** The potential reproductive capacity of an organism or population, measured by the number of gametes (eggs).

**FEMAT**. For *Forest Ecosystem Management Assessment Team*.

**FL.** For *fork length*. Length in millimeters from the tip of the snout to the center of the fork in the tail or caudal fin. Compare **SL** and **TL.**

**genetic distance.** A quantitative measure of genetic difference between a pair of samples.

**haplotype.** The collective genotype of a number of closely linked loci; the constellation of alleles present at a particular region of genomic or mitochondrial DNA.

**INPFC.** For *International North Pacific Fisheries Commission*.

**ISAB**. For *Independent Scientific Advisory Board*.

**IUCN.** For *International Union for the Conservation of Nature*. The full, legal name of the organization is the International Union for Conservation of Nature and Natural Resources. Online at http://www.iucn.org.

**iteroparous.** Said of an organism that reproduces several or many times during a lifetime. Compare **semelparous**.

**JCRMS**. For *Joint Columbia River Management Staff*. A joint undertaking of the Washington Department of Fish and Wildlife and the Oregon Department of Fish and Wildlife.

**$LC_{50}$.** The lethal concentration of a chemical or substance that kills 50% of the test organisms in a given time period, normally 96 hours for aquatic organisms.

**LCFRB.** For *Lower Columbia Fish Recovery Board*.

**meristic trait.** A discretely varying and countable trait (e.g., number of fin rays or basibranchial teeth).

**metapopulation.** An assembly of closely related subpopulations (usually spatially fragmented) that were established by colonists, survive for a while, send out migrants, and eventually disappear. The persistence of a subpopulation depends on the rate of colonization successfully balancing the local extinction rate.

**microsatellite DNA.** A class of repetitive DNA. Microsatellites are simple sequence repeats one to eight nucleotides in length. For example, the repeat unit can be simply "CA" and might exist in a tandem array (CACACACACA) 50 or more repeat units in length. The number of repeats in an array can be highly polymorphic. See also **DNA**.

**mitochondrial DNA.** The DNA genome contained within mitochondria and encoding a small subset of mitochondrial functions; mtDNA is typically circular and 15–20 kilobases in size, containing little noncoding information between genes. See also **DNA**.

**morphometric trait.** A discretely varying trait related to the size and shape of landmarks from whole organs or organisms analyzed by appropriately invariant biometric methods in order to answer biological questions.

**MVP.** For *minimum viable population*.

**NMFS**. For *National Marine Fisheries Service*. Also known as NOAA Fisheries Service

**NWFSC.** For *Northwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**ODFW.** For *Oregon Department of Fish and Wildlife*. Department that comanages certain fisheries in the State of Oregon.

**otolith.** Crystalline calcium carbonate structure within the inner ear of fish. These structures have distinctive shapes, sizes, and internal and surface features that can be used for age determination and species identification.

**ppb.** For *parts per billion*. A unit of chemical concentration.

**ppm.** For *parts per million*. A unit of chemical concentration.

**ppt.** For *parts per thousand*. A unit of chemical concentration.

**PDO.** For *Pacific Interdecadal Oscillation*. A long-term pattern of North Pacific climate variability. PDO events persist for 20–30 years, while typical El Niño events persist for 6 to 18 months. The climatic indicators of the PDO are most visible in the North Pacific region.

**phenotypic.** Pertaining to the appearance (or other measurable characteristic) of an organism that results from interaction of the genotype and environment.

**PCB.** For *polychlorinated biphenyl***.** Persistent contaminants of aquatic sediments and biota that are very widespread. Commercial formulations of PCBs are mixtures of individual chlorinated biphenyls (congeners) varying according to the numbers of chlorines and their ring positions on the biphenyl. Prior to the 1975 congressional ban on PCB manufacture, various mixtures of some 209 individual PCBs were used extensively in electrical transformers, capacitors, paints, waxes, inks, dust control agents, paper, and pesticides.

**PAH.** For *polycyclic aromatic hydrocarbon***.** PAHs are widely distributed throughout the marine environment and commonly occur in sediments in urban coastal and estuarine areas. Sources include crude oil, petroleum products, and residues from combustion of fossil fuels. They are composed of fused benzene rings, with or without alkyl substituents (e.g., methyl groups).

**population.** A group of individuals of a species living in a certain area that maintain some degree of reproductive isolation.

**Puget Sound.** A coastal fjord-like estuarine inlet of the Pacific Ocean located in northwest Washington State between the Cascade and Olympic mountains and covering an area of more than 9,000 $km^2$ including 3,700 km of coastline.

**semelparous.** Said of an organism that reproduces but once during its lifetime. Compare **iteroparous**.

**SL.** For *standard length***.** Length in millimeters from the tip of the snout to the base of the caudal peduncle. Compare **FL** and **TL**.

**SMA**. For *shrimp management area*.

**SWFSC.** For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**species.** Biological: A small group of organisms formally recognized by the scientific community as distinct from other groups. Legal: Refers to joint policy of the USFWS and NMFS that considers a species as defined by the ESA to include biological species, subspecies, and DPSs.

**SRS**. For *sediment retention structure*.

**Strait of Georgia.** A strait between Vancouver Island and the mainland Pacific coast of British Columbia. It is approximately 220 km long, averages 35 km wide, and has a surface area of approximately 6,900 $km^2$. Archipelagos and narrow channels mark each end of the Strait of Georgia, including the Gulf Islands and San Juan Islands in the south and the Discovery Islands in the north. The main channels to the south are Haro Strait and Rosario Strait, which connect the Strait of Georgia to the Strait of Juan de Fuca. In the north, Discovery Passage is the main channel connecting the Strait of Georgia to Johnstone Strait.

**SWFSC.** For *Southwest Fisheries Science Center*. One of six regional research centers of the National Marine Fisheries Service.

**threatened species.** A species not presently in danger of extinction but likely to become so in the foreseeable future, with respect to the Endangered Species Act. See also **endangered species, ESA**.

**TL.** For *total length*. Length in millimeters from the tip of the snout to the tip of the farthest lobe of the tail or caudal fin. Compare **FL** and **SL**.

**trophic.** Pertaining to nutrition. A trophic migration would be a movement of fish to a feeding area.

**USACE**. For *U.S. Army Corps of Engineers*.

**USFWS.** For *U.S. Fish and Wildlife Service*.

**viable salmonid population.** An independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a long time frame (McElhany et al. 2000).

**WDFW.** For *Washington Department of Fish and Wildlife***.** Department that comanages certain fisheries in Washington State. The agency was formed in the early 1990s by combining the Washington Department of Fisheries and Washington Department of Wildlife.

# References


Acuna, E., P. Goddard, and S. Kotwicki (compilers). 2003. 2002 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2003-01. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202003-01.pdf [accessed 23 February 2010].

Acuna, E., and S. Kotwicki (compilers). 2004. 2003 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2004-02. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202004-02.pdf [accessed 23 February 2010].

Acuna, E., and S. Kotwicki (compilers). 2006. 2004 bottom trawl survey of the Eastern Bering Sea continental shelf. AFSC Processed Rep. 2006-09. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202006-09.pdf [accessed 23 February 2010].

Acuna, E., and R. R. Lauth. 2008. Results of the 2007 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-181. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-181.pdf [accessed 23 February 2010].

ADFG (Alaska Dept. Fish and Game). 1972. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 13:53–54, 66–71 [as cited in Spangler et al. 2003].

ADFG (Alaska Dept. Fish and Game). 1973. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 14:53–54, 66–71 [as cited in Spangler et al. 2003].

ADFG (Alaska Dept. Fish and Game). 1974. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and central Cook Inlet drainages. Alaska Dept. Fish Game 15:161–162, 170–172 [as cited in Spangler et al. 2003].

Alcan. 2005. Alcan Primary Metal–British Columbia Environmental Annual Report 2004. Online at http://www.riotintoalcaninbc.com/environmental-reports/2004/index.html [accessed 23 February 2010].

Alcan. 2006. Alcan Primary Metal–British Columbia Environmental Annual Report 2005. Online at http://www.riotintoalcaninbc.com/media/reports/2005%20Alcan%20EAR.pdf [accessed 23 February 2010].

Alcan. 2007. Alcan Primary Metal–British Columbia Annual Environmental Report 2006. Online at http://www.riotintoalcaninbc.com/media/reports/2006%20AER%205.1.pdf [accessed 23 February 2010].

Alheit, J., and E. Hagen. 1997. Long-term climate forcing of European herring and sardine populations. Fish. Oceanogr. 6:130–139.

Allen, L. G., M. M. Yoklavich, G. M. Cailliet, and M. H. Horn. 2006. Bays and estuaries. *In* L. G. Allen, D. J. Pondella, and M. H. Horn (eds.), The ecology of marine fishes: California and adjacent waters, p. 119–148. University of California Press, Berkeley.

Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. U.S. Dept. Commer., NOAA Tech. Rep. NMFS 66.

Alton, M. S., and M. O. Nelson. 1970. Food of Pacific hake, *Merluccius productus*, in Washington and northern Oregon coastal waters. *In* Pacific hake, p. 35–42. U.S. Fish and Wildlife Service Circ. 332.

Anchor Environmental. 2003. Fish periodicity in WRIA 1. Anchor Environmental LLC, Seattle, WA. Online at http://whatcomsalmon.whatcomcounty.org/pdf/fishperiodicity_january2003.pdf [accessed 23 February 2010].

Anderson, A. C. 1872. The dominion at the west: A brief description of the province of British Columbia, its climate, and resources. The government prize essay, 1872. Richard Wolfenden, Government Printer, Victoria, BC.

Anderson, A. C. 1877. Report of the Inspector of Fisheries for British Columbia for the year of 1876. Appendix No. 21. *In* Report of the Commissioner of Fisheries for the year ending 31st December 1876, p. 339–347. MacLean, Roger & Co., Ottawa, ON.

Anderson, P. 2009. Letter from P. Anderson (Interim Director, Washington Dept. Fish and Wildlife) to G. Griffin (Protected Resources Division, NMFS Northwest Region) dated 12 May 2009. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Anthony, J. A., D. D. Roby, and K. R. Turco. 2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. J. Exp. Mar. Biol. Ecol. 248:53–78.

Antonelis Jr., G. A., and C. H. Fiscus. 1980. The pinnipeds of the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 21:68–78.

Antonelis Jr., G. A., and M. A. Perez. 1984. Estimated annual food consumption by northern fur seals in the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 25:135–145.

Arai, H. P. 1967. A preliminary report on a study of the parasites of marine fishes of Burke Channel, British Columbia. Fish. Res. Board Can. Manuscr. Rep. Ser. 925.

Arai, H. P. 1969. Preliminary report on the parasites of certain marine fishes of British Columbia. Bull. Fish. Res. Board Can. 26:2319–2337.

Armstrong, R. H., and M. Hermans. 2007. Eulachon (*Thaleichthys pacificus*). Coastal forests and mountains ecoregions of Southeastern Alaska and the Tongass National Forest: A conservation assessment and resource synthesis–Chapter 8.9. Online at conserveonline.org/workspaces/akcfm/pdfs/8.9_Eulachon.pdf [accessed 23 February 2010].

Atkinson, D. 1994. Temperature and organism size—A biological law for ectotherms? Adv. Ecol. Res. 25:1–58.

Auth, T. B., and R. D. Brodeur. 2006. Distribution and community structure of ichthyoplankton off the coast of Oregon, USA, in 2000 and 2002. Mar. Ecol. Prog. Ser. 319:199–213.

Avise, J. C., J. Arnold, R. M. Ball, E. Bermingham, T. Lamb, J. E. Neigel, C. A. Reeb, and N. C. Saunders. 1987. Intraspecific phylogeography: The mitochondrial DNA bridge between population genetics and systematics. Annu. Rev. Ecol. Syst. 18:489–522.

Babcock, J. P. 1927. The food value of some British Columbia fish. *In* Report of the Commissioner of Fisheries for the year ended December 31st, 1926, with appendices, p. E72–E75. Charles F, Banfield, Printer to the King's Most Excellent Majesty, Victoria, BC.

Bailey, B. E. 1952. Marine oils, with special reference to those of Canada. Bull. Fish. Res. Board Can. 89.

Bailey, K. M., and E. D. Houde. 1989. Predation on eggs and larvae of marine fishes and the recruitment problem. Adv. Mar. Bio. 25:1–83.

Bakun, A. 1990. Global climate change and intensification of coastal upwelling. Science 247:198–201.

Bargmann, G., J. DeVore, and B. Tweit. 2005. Risk-averse management of eulachon in the Columbia River system. Fisheries assessment and management in data-limited situations, p. 21–29. Rep. AK-SG-05-02. Alaska Sea Grant College Program, Fairbanks.

Barnhart, R. A., M. J. Boyd, and J. E. Pequegnat. 1992. The ecology of Humboldt Bay, California: An estuarine profile. U.S. Fish and Wildlife Service Biol. Rep. No. 1.

Barraclough, W. E. 1964. Contribution to the marine life history of the eulachon *Thaleichthys pacificus*. Bull. Fish. Res. Board Can. 21:1333–1337.

Barraclough, W. E. 1967. Data record. Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 6–8, 1966. Bull. Fish. Res. Board Can. Manuscr. Rep. Ser. 928.

Barraclough, W. E., and J. D. Fulton. 1967. Data record. Number, size composition, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, July 4–8, 1966. Bull. Fish. Res. Board Can. Manuscr. Rep. Ser. 940.

Barrett, B. M., F. M. Thompson, and S. N. Wick. 1984. Adult anadromous investigations: May-October 1983. Alaska Dept. Fish and Game, Susitna Hydro Aquatic Studies., Rep. No. 1, Alaska Power Authority document 1450 [excerpts published in Willson et al. 2006, p. 63–66].

Barry, R. G. 2006. The status of research on glaciers and global glacier recession: A review. Prog. Phys. Geog. 30:285–306.

Barth, J. A., B. A. Menge, J. Lubchenco, F. Chan, J. M. Bane, A. R. Kirincich, M. A. McManus, K. J. Nielsen, S. D. Pierce, and L. Washburn. 2007. Delayed upwelling alters nearshore coastal ocean ecosystems in the northern California Current. Proc. Natl. Acad. Sci. USA 194:3719–3724.

Bath, G. E., S. R. Thorrold, C. M. Jones, S. E. Campana, J. W. McLaren, and J. H. W. Lam. 2000. Strontium and barium uptake in aragonitic otoliths of marine fish. Geochim. Cosmochim. Acta 64:1705–1714.

Baumgartner, T. R., A. Soutar, and V. Ferreira-Bartrina. 1992. Reconstruction of the history of Pacific sardine and northern anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California. Calif. Coop. Ocean. Fish. Investig. Rep. 33:24-40.

BC Ministry of Sustainable Resource Management. 2002. British Columbia marine ecological classification: Marine ecosections and ecounits, Version 2.0. Province of British Columbia, Resources Information Standards Committee. Online at http://ilmbwww.gov.bc.ca/risc/pubs/coastal/marine/version%202/bcmec_version_2.pdf [accessed 23 February 2010].

Beach, R. J., A. C. Geiger, S. J. Jeffries, and S. D. Treacy. 1981. Marine mammal-fishery interactions on the Columbia River and adjacent waters, 1981. NWAFC Processed Rep. 82-04. NWAFC, Seattle, WA.

Beach, R. J., A. C. Geiger, S. J. Jeffries, S. D. Treacy, and B. L. Troutman. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980–82. NWAFC Processed Rep. 85-04. Seattle, WA

Beacham, T. D., D. E. Hay, and K. D. Le. 2005. Population structure and stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt, in the Pacific Northwest. Mar. Biotechnol. 7:363–372.

Beacham, T. D., J. F. Schweigert, C. MacConnachie, K. D. Le, K. Labaree, and K. M. Miller. 2002. Population structure of herring (*Clupea pallassi*) in British Columbia determined by microsatellites, with comparisons to Southeast Alaska and California. Dept. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat. Research Document 2002/109. Online at http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/2002/2002_109_e.htm [accessed 23 February 2010].

Beamish, R. J., J. R. King, and G. A. McFarlane. 2008. Country reports, Canada. *In* R. J. Beamish, (ed.), Impacts of climate and climate change on the key species in the fisheries in the North Pacific, p. 15–51. PICES Working Group on Climate Change Shifts in Fish Production and Fisheries Management. PICES Scientific Report No. 35. Online at http://www.pices.int/publications/scientific_reports/Report35/Rep_35_default.aspx [accessed 23 February 2010].

Beamish, R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112:735–743.

Begg, G. A., J. A. Hare, and D. D. Sheehan. 1999. The role of life history parameters as indicators of stock structure. Fish. Res. 43:141–163.

Bellman, M., E. Heery, and J. Hastie. 2008. Estimated discard and total catch of selected groundfish species in the 2007 U. S. West Coast fisheries. Pacific States Marine Fisheries Commission and Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division, Seattle, WA. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/totalmortality2007.pdf [accessed 23 February 2010].

Benson, A. J., G. A. McFarlane, S. E. Allen, and J. F. Dower. 2002. Changes in Pacific hake (*Merluccius productus*) migration patterns and juvenile growth related to the 1989 regime shift. Can. J. Fish. Aquat. Sci. 59:1969–1979.

Berry, M. D., and W. Jacob. 1998. 1997 eulachon research on the Kingcome and Wannock rivers–Final rep. Final rep. to Science Council of British Columbia (SCBC #96/97-715). Online at http://www.for.gov.bc.ca/hfd/library/FRBC1997/FRBC1997MR206.PDF [accessed 23 February 2010].

Betts, M. F. 1994. The subsistence hooligan fishery of the Chilkat and Chilkoot rivers. Tech. Paper No. 213. Alaska Dept. Fish and Game, Division of Subsistence, Juneau.

Beverton, R. J. H. 1990. Small pelagic fish and the threat of fishing; are they endangered? J. Fish Biol. 37(Suppl. A):5–16.

Bigg, M. A. 1988. Status of the Steller sea lion, *Eumetopias jubatus*, in Canada. Can. Field Nat. 102:315–336.

Birtwell, I. K., C. D. Levings, J. S. Macdonald, and I. H. Rogers. 1988. A review of fish habitat issues in the Fraser River system. Water Pollut. Res. J. Can. 23:1–30.

Blahm, T. H., and McConnell, R. J. 1971. Mortality of adult eulachon (*Thaleichthys pacificus*) subjected to sudden increases in water temperature. Northwest Sci. 45:178–82.

Blaylock, R. B., L. Margolis, and J. C. Holmes. 1998. Zoogeography of the parasites of Pacific halibut (*Hippoglossus stenolepis*) in the northeast Pacific. Can. J. Zool. 76:2262–2273.

Bond, G., W. Broecker, S. Johnson, J. McManus, L. Labeyrie, J. Jouzel, and G. Bonani. 1993. Correlation between climate records from North Atlantic sediments and Greenland ice. Nature 365: 143-147.

Borgerson, L. A., N. E. Stewart, K. K. Jones, and S. R. Mamoyac. 1991. Yaquina River Basin Management Plan. Oregon Dept. Fish and Wildlife, Salem.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-68.

Bowlby, C. E. 1981. Feeding behavior of pinnipeds in the Klamath River, northern California. Master's thesis. Humboldt State Univ., Arcata, CA.

Boyd, R. T., and Y. P. Hajda. 1987. Seasonal population movement along the lower Columbia River: The social and ecological context. Am. Ethnol. 14:309–326.

Brennan, B. M. 1936. Forty-second to forty-fifth annual reports of the State Department of Fisheries for the period from April 1, 1931 to March 31, 1935, fiscal years of 1931 to 1934, inclusive. Washington Dept. Fisheries, Olympia.

Briggs, J. C. 1974. Marine zoogeography. McGraw-Hill, New York.

British Columbia Conservation Data Centre. 2008. BC species and ecosystems explorer. BC Ministry of Environment, Victoria. Online at http://a100.gov.bc.ca/pub/eswp/ [accessed 23 February 2010].

Broadhurst, M. K. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. Revs. Fish Biol. Fish. 10:27–60.

Broadhurst, M. K., P. Suuronen, and A. Hulme. 2006. Estimating collateral mortality from towed fishing gear. Fish Fish. 7:180–218.

Brocklesby, H. N. 1941. The chemistry and technology of marine animal oils with particular reference to those of Canada. Bull. Fish. Res. Board Can. 59.

Brocklesby, H. N., and O. F. Denstedt. 1933. The industrial chemistry of fish oils with special reference to those of British Columbia. Bull. Fish. Res. Board Can. 37.

Brodeur, R. D., C. L. Suchman, D. C. Reese, T. W. Miller, and E. A. Daly. 2008. Spatial overlap and trophic interactions between pelagic fish and large jellyfish in the northern California Current. Mar. Biol. 154:649–659.

Brown, R. F., S. J. Jeffries, and J. T. Harvey. 1989. Seasonal abundance and winter feeding ecology of harbor seals in the Columbia River. *In* Abstracts 8th biennial conference on the biology of marine mammals, Pacific Grove, CA, 7–11 December 1989, p. 9, Society for Marine Mammalogy. The society's Web site is http://marinemammalscience.org/ [accessed 10 May 2010].

Brown, R. F., S. D. Riemer, and S. J. Jeffries. 1995. Food of pinnipeds collected during the Columbia River area salmon gillnet observation program, 1991–1994. Wildlife Diversity Program Tech. Rep. 95-6-01. Oregon Dept. Fish and Wildlife, Salem.

BRT (Biological Review Team). 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. December 15 draft. NMFS Northwest Fisheries Science Center, Seattle, WA. Online at http://www.nwr.noaa.gov/Other-Marine-Species/upload/Eulachon-Review.pdf [accessed 18 March 2009].

Buchheister, A., and M. T. Wilson. 2005. Shrinkage correction and length conversion equations for *Theragra chalcogramma*, *Mallotus villosus,* and *Thaleichthys pacificus*. J. Fish Biol. 67:541–548.

Buckley, T. W., and P. A. Livingston. 1997. Geographic variation in the diet of Pacific hake, with a note on cannibalism. Calif. Coop. Ocean. Fish. Investig. Rep. 38:53–62.

Buckley, T. W., G. E. Tyler, D. M. Smith, and P. A. Livingston. 1999. Food habits of some commercially important groundfish off the coasts of California, Oregon, Washington, and British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-102. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-102.pdf [accessed 23 February 2010].

Builder Ramsey, T., T. A. Turk, E. L. Fruh, J. R. Wallace, B. H. Horness, A. J. Cook, K. L. Bosley, D. J. Kamikawa, L. C. Hufnagle Jr., and K. Piner. 2002. The 1999 Northwest Fisheries Science Center Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-55. Online at http://www.nwfsc.noaa.gov/assets/25/4277_06162004_130254_tm55.pdf [accessed 23 February 2010].

Burroughs, R. D. 1961. The natural history of the Lewis and Clark expedition. Michigan State University Press, Lansing.

Byram, S., and D. G. Lewis. 2001. Ourigan: Wealth of the Northwest Coast. Ore. Hist. Quart. 102:127–157.

Cambria Gordon Ltd. 2006. Eulachon of the Pacific Northwest: A life history. Living Landscapes Program, Royal BC Museum. Online at http://www.livinglandscapes.bc.ca/northwest/eulachon/resources/lifehisreport.pdf [accessed 23 February 2010].

Canadian Bureau of Statistics. 1941. Fisheries Statistics of Canada, 1917–1941. Canada Dept. Trade and Commerce, Dominion Bureau of Statistics, Fisheries Statistics Branch. Printer to the King's Most Excellent Majesty, Ottawa, ON.

Carls, M. G., S. W. Johnson, M. R. Lindeberg, A. D. Neff, P. M. Harris, and R. Waples. 2008. Status review of Lynn Canal herring (*Clupea pallasii*). Online at http://www.fakr.noaa.gov/protectedresources/herring/statusrev0308.pdf [accessed 22 February 2010].

Carvan III, M. J., J. P. Incardona, and M. L. Rise. 2008. Meeting the challenges of aquatic vertebrate ecotoxicology. Bioscience 58:1015–1025.

Caughley, G. 1994. Directions in conservation biology. J. Anim. Ecol. 63:215–244.

Caughley, G., and A. Gunn. 1996. Conservation biology in theory and practice. Blackwell Science, Cambridge, MA.

CDFG (California Dept. Fish and Game). 2008. Letter dated 13 June 2008 to Peter B. Adams, Southwest Fisheries Science Center, from Steve Cannata, California Dept. Fish and Game. Subject: Eulachon data search. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Chan, H. M., M. El Khoury, M. Sedgemore, S. Sedgemore, and H. V. Kuhnlein. 1996. Organochlorine pesticides and polychlorinated biphenyl congeners in ooligan grease: A traditional food fat of British Columbia First Nations. J. Food Compos. Anal. 9:32–42.

Chatwin, B. M., and C. R. Forrester. 1953. Feeding habits of dogfish (*Squalus suckleyi* (Girard)). Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 95:35–38.

Chen, L. 1971. Systematics, variation, distribution, and biology of rockfishes of the subgenus *Sebastomus* (Pisces, Scorpaenidae, Sebastes). Bull. Scripps Inst. Oceanogr. Univ. Calif. 18:1–107.

Clanton, R. E. 1913. Biennial report of the Department of Fisheries of the State of Oregon to the Twenty-seventh Legislative Assembly, regular session, 1913. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Clark, E. D., and R. W. Clough. 1926. Chemical composition of fish and shellfish. Bureau of Fisheries document No. 1000. *In* H. R. Beard (ed.), Nutritive value of fish and shellfish, p. 502–526. Report of the U. S. Commissioner of Fisheries for the fiscal year 1925, Appendix X.

Clarke, A. D., A. Lewis, and K. H. Telmer. 2007. Life history and age at maturity of an anadromous smelt, the eulachon *Thaleichthys pacificus* (Richardson). J. Fish Biol. 71:1479–1493.

Cleaver, F. C. 1951. Fisheries statistics of Oregon. Oregon Fish Commission contribution No. 16. Oregon Fish Commission, Portland.

Clemens, W. A., J. L. Hart, and G. V. Wilby. 1936. Analysis of stomach contents of fur seals taken off the west coast of Vancouver Island in April and May, 1935. Stud. Sta. Biol. Bd. Can. 160. DFO, Ottawa, ON.

Clemens, W. A., and G. V. Wilby. 1946. Fishes of the Pacific Coast of Canada. Bull. Fish. Res. Board Can. 68.

Clemens, W. A., and G. V. Wilby. 1967. Fishes of the Pacific coast of Canada. Bull. Fish. Res. Board Can. 68 (2nd printing of 2nd edition).

Codere, H. 1990. Kwakiutl: Traditional culture. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 359–377. Smithsonian Institution, Washington, DC.

Coleman, B. A. 1986. The 1980 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length, and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-100. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc100.pdf [accessed 23 February 2010].

Coleman, B. A. 1988. The 1986 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-152. Online at: http://www.st.nmfs.noaa.gov/tm/nwc/nwc152.pdf [accessed 23 February 2010].

Collins, J. W. 1892. Report on the fisheries of the Pacific coast of the United States. Rep. U.S. Comm. Fish and Fisheries XVI, Appendix 1:3–269. U.S. Government Printing Office, Washington, DC.

Collison, H. A. 1941. The oolichan fishery. B.C. Hist. Q. 5(1):25–31.

Cooke, K. D., J. Holmes, G. W. Fleischer, R. E. Thomas, and P. H. Ressler. 2006. Distributional changes observed in the geographic range of Pacific hake (*Merluccius productus*) in association with ocean conditions off the Pacific coast of Canada and the United States. ICES 2005 Annual Science Conference Products. Online at http://www.ices.dk/asc2006/Abstracts/Blist.pdf [accessed 23 February 2010].

Cooper, A. B., and M. S. Mangel. 1999. The dangers of undetected metapopulation structure for the conservation of salmonids. Fish. Bull. 97:213–226.

Cordell, J. R., S. M. Bollens, R. Draheim, and M. Sytsma. 2008. Asian copepods on the move: Recent invasions in the Columbia-Snake River system, USA. ICES J. Mar. Sci. 65:753–758.

Cowlitz Indian Tribe. 2007. Petition to list the southern eulachon (*Thaleichthys pacificus*) distinct population segment as threatened or endangered under the federal Endangered Species Act, 9 November 2007. Cowlitz Indian Tribe, Longview, WA. Online at http://www.nwr.noaa .gov/Other-Marine-Species/upload/Smelt_Petition_11_07.pdf [accessed 23 February 2010].

Craig, J. A. 1947. Letter dated 11 August 1947 from Joe A. Craig, acting director, Washington Dept. Fisheries, to Gordon M. Quarnstrom, editor, Longview Daily News, Longview, WA. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Craig, J. A., and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bull. U.S. Bur. Fish. 49:132–216.

Craig, J. A., and A. J. Suomela. 1940. A survey of the Sandy River and its tributaries, 1940, with reference to fish management. Special Scientific Rep. No. 14. U.S. Fish and Wildlife Service, Washington, DC.

Crawford, J. 1890. First report of the State Fish Commissioner, State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1892. Third annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1894. Fifth annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, J. 1896. Seventh annual report of the State Fish Commissioner of the State of Washington. O. C. White, State Printer, Olympia.

Crawford, P. W. 1878 (unpubl. manuscr.). Narrative of the overland journey to Oregon. Microfilm A92, Univ. Washington, Suzzalo Library, Seattle (original in Bancroft Library, Univ. California Berkeley).

Crawford, W., J. Galbraith, and J. N. Bolingbroke. 2007. Line P ocean temperature and salinity, 1956–2005. Progr. Oceanogr.75:161–178.

Cummings, E., and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Coastal Rivers Investigation Information Rep. 70-11. Fish Commission of Oregon, Research Division, Corvallis.

Curtis, E. S. 1915. The North American Indian, Vol. 10. Johnson Reprint Corp., New York. Online at http://curtis.library.northwestern.edu/ [accessed 24 February 2010].

Dammers, W. 1988. Columbia River smelt commercial harvest, age, and larval sampling. Memo from Wolf Dammers to Don McIsaac ,Washington Dept. Fisheries, 28 January 1988. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd, Suite 1100, Portland, OR 97232.)

Darwin, L. H. 1917. Twenty-sixth and twenty-seventh annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1915, to 31 March 1917. Washington Dept. Fish and Game, Olympia.

Darwin, L. H. 1920. Twenty-eighth and twenty-ninth annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1917, to 31 March 1919. Washington Dept. Fish and Game, Olympia.

Darwin, L. H. 1921. Thirtieth and thirty-first annual reports of State Fish Commissioner to the Governor of the State of Washington, 1 April 1919, to 31 March 1921. Washington Dept. Fish and Game, Olympia.

DeLacy, A. C., and B. S. Batts. 1963. Possible population heterogeneity in the Columbia River smelt. Fisheries Research Institute Circular No. 198. Univ. Washington, College of Fisheries, Seattle.

DeLacy, A. C., B. S. Miller, and S. F. Borton. 1972. Checklist of Puget Sound Fishes. WSG 72-3. Univ. Washington, Washington Sea Grant, Division of Marine Resources, Seattle.

Deschamps, G., S. G. Wright, and R. E. Watson. 1970. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964–1966, p. 1–55. Tech. Rep. No.7. Washington Dept. Fisheries, Olympia.

DFO (Dept. Fisheries and Oceans Canada). 2006a. Fraser River eulachon (*Thaleichthys pacificus*): 2006 population assessment and harvest recommendations for 2007. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/039. Online at http://www.dfo-mpo.gc.ca/csas/Csas/status/2006/SAR-AS2006_039_E.pdf [accessed 10 May 2010].

DFO (Dept. Fisheries and Oceans Canada). 2006b. State of the Pacific Ocean 2005. Ocean Status Rep. 2006/001. DFO Canada, Pacific Region. Online at http://www.pac.dfo-mpo.gc.ca/science/psarc-ceesp/osrs/StateofOceans2005fnl.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2007a. Fraser River eulachon (*Thaleichthys pacificus*): 2007 population assessment and harvest recommendations for 2008. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/048. Online at http://www.dfo-mpo.gc.ca/csas/Csas/status/2007/SAR-AS2007_048_e.pdf [accessed 10 May 2010].

DFO (Dept. Fisheries and Oceans Canada). 2007b. Integrated fisheries management plan euphausiids, 1 January 2007 to 31 December 2012. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans07/Krill07-12.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008a. Eulachon integrated fisheries management plan, 1 April 2008 to 31 March 2009. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans08/2008_IFMP-Eulachon.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008b. Shrimp survey bulletin 08-02, July 2008. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008c. Overview of the eulachon fishery. Pelagics & Minor Finfish-Pacific Region. Online at http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/pelagic-pelagique/eulachon-eulakane/overview-apercu-eng.htm [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2008d. Predicting the temperature of the Fraser River, climate change conditions. Online at http://www-sci.pac.dfo-mpo.gc.ca/osap/projects/fraser/climate_e.htm [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009a. Shrimp survey bulletin 09-01, July 2009. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009b. Shrimp survey bulletin 09-02, July 2009. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0802.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009c. Integrated fisheries management plan shrimp trawl, 1 April 2009 to 31 March 2010. DFO Canada, Pacific Region. Online at http://www.dfo-mpo.gc .ca/Library/336240.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009d. Eulachon integrated fisheries management plan, 1 April 2009 to 31 March 2010. DFO Canada, Pacific Region. Online at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/mplans/plans09/IFMP_Eulachon_2009.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009e. State of the Pacific Ocean 2008. Canadian Science Advisory Secretariat Science Advisory Rep. 2009/030. DFO Canada, Pacific Region. Online at http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2009/2009_030_e.pdf [accessed 23 February 2010].

DFO (Dept. Fisheries and Oceans Canada). 2009f. 2009-2011 British Columbia tidal waters sport fishing guide. Online at http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/SFG-GPS/SFGtidal-GPSmaree-eng.pdf [accessed 23 February 2010].

DFO and Transport Canada. 2008. Comprehensive study scoping document pursuant to Section 21(1) of the Canadian Environmental Assessment Act for the Klinaklini River Hydroelectric Project proposed by Kleana Power Corporation in south-central coast of British Columbia. CEA Registry Reference No.: 07-03-36321. Online at http://a100.gov.bc.ca/appsdata/epic/documents/p289/1210953739414_8e248a8d30d90ddfeb0b46a94c6ea47bd9c755f2db90.pdf [accessed 23 February 2010].

Diffenbaugh, N. S., M. A. Snyder, and L. C. Sloan. 2004. Could $CO_2$-induced land-cover feedbacks alter near-shore upwelling regimes? Proc. Natl. Acad. Sc. USA 101:27–32.

Dodimead, A. J., F. Favorite, and T. Hirano. 1963. Salmon of the North Pacific Ocean–Part II. Review of oceanography of the subarctic Pacific region. Int. North Pac. Fish. Comm. Bull. 13.

Doyle, M. J., K. L. Mier, M. S. Busby, and R. D. Brodeur. 2002. Regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean. Prog. Oceanogr. 53:247–281.

Duff, W. 1952. The upper Stalo Indians: An introductory ethnography. Master's thesis. Univ. Washington, Seattle.

Dulvy, N. K., J. R. Ellis, N. B. Goodwin, A. Grant, J. D. Reynolds, and S. Jennings. 2004. Methods of assessing extinction risk in marine fishes. Fish Fish. 5:255–276.

Dulvy, N. K., Y. Sadovy, and J. D. Reynolds. 2003. Extinction vulnerability in marine populations. Fish Fish. 4:25–64.

EcoMetrix (EcoMetrix Inc.). 2006. Summary of 2006 eulachon study results and 2007 study design. Report prepared for Eurocan Pulp and Paper Co., Kitimat, BC. EcoMetrix Inc., Brampton, ON.

Eggen, R. I., R. Behra, P. Burkhardt-Holm, B. I. Escher, and N. Schweigert. 2004. Challenges in ecotoxicology. Environ. Sci. Technol. 38:58A–64A.

Ekman, S. 1953. Zoogeography of the sea. Sidgwick and Jackson Ltd., London.

Eldridge, M. B., and C. F. Bryan. 1972. Larval fish survey of Humboldt Bay, California. U.S. Dept. Commer., NOAA Tech. Rep. NMFS-SSRF-665.

Eller, A., and N. Hillgruber. 2005. Eulachon larvae *(Thaleichthys pacificus)* retention in the surface waters of Berners Bay, Alaska [abstract]. American Fisheries Society, 135th Annual Meeting, Anchorage, AK, Sept. 2005. American Fisheries Society, Bethesda, MD.

Emmett, R. L., P. J. Bentley, and G. K. Krutzikowsky. 2001. Ecology of marine predatory and prey fishes off the Columbia River, 1998 and 1999. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-51. Online at http://www.nwfsc.noaa.gov/assets/25/4015_06162004_141153_tm51.pdf [accessed 23 February 2010].

Emmett R. L., R. D. Brodeur, T. W. Miller, S. S. Pool, G. K. Krutzikowsky, P. J. Bentley, and J. McCrae. 2005. Pacific sardine (*Sardinops sagax*) abundance, distribution, and ecological relationships in the Pacific Northwest. Calif. Coop. Ocean. Fish. Investig. Rep. 46:122–143.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, Vol. II: Species life history summaries. ELMR Rep. 8. U.S. Dept. of Commer., NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Emmett, R. L., G. T. McCabe Jr., and W. D. Muir. 1990. Effects of the 1980 Mount St. Helens eruption on Columbia River estuarine fishes: Implications for dredging in Northwest estuaries. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes, p. 74–91. Workshop proceedings, Sept. 8–9, 1988. Univ. Washington, Sea Grant Program, Seattle.

Environment Canada. 2008. A national ecological framework for Canada. Online at http://sis.agr.gc.ca/cansis/nsdb/ecostrat/intro.html [accessed 23 February 2010].

EPA (U.S. Environmental Protection Agency). 2002. Columbia River basin fish contaminant survey 1996–1998. EPA 910-R-02-006. EPA, Region 10, Seattle, WA. Online at http://yosemite.epa.gov/r10/oea.nsf/0703bc6b0c5525b088256bdc0076fc44/c3a9164ed269353788256c09005d36b7/$FILE/Fish%20Study.PDF [accessed 23 February 2010].

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Forest Service, BLM, USFWS, NOAA, EPA, and National Park Service, Portland, OR.

Fiedler, R. H. 1930. Fishery industries of the United States, 1928. Bureau of Fisheries document No. 1067. Appendix IX (p. 401–625) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1929 with appendixes. U.S. Government Printing Office, Washington, DC.

Fiedler, R. H. 1939. Fishery industries of the United States, 1936. Administrative Rep. No. 27. Appendix I (p. 1–276) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1937 with appendixes. U.S. Government Printing Office, Washington, DC.

Fiedler, R. H. 1941. Fishery industries of the United States, 1938. Administrative Rep. No. 37. Appendix III (p. 169–554) in Rep. U. S. Commissioner of Fisheries for the fiscal year 1939 with appendixes. U.S. Government Printing Office, Washington, DC.

Field, J. C., K. Baltz, A. J. Phillips, and W. A. Walker. 2007. Range expansion and trophic interactions of the jumbo squid, *Dosidicus gigas*, in the California Current. Calif. Coop. Ocean. Fish. Investig. Rep. 48:131–146.

Fisher, H. D. 1947. The harbour seals (*Phoca vitulina richardii*) on the Skeena River, B.C. Fish. Res. Board Can. Progress Reports of the Pacific Coast Stations 72:36–40.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bull. Fish. Res. Board Can. 93.

Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, L. C. Hufnagle, A. R. Kronlund, J. A. Holmes, and C. D. Wilson. 2005. The 2003 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-65. Online at http://www.nwfsc.noaa .gov/assets/25/6233_06272005_114457_haketm65final.pdf [accessed 23 February 2010].

Fleischer, G. W., K. D. Cooke, P. H. Ressler, R. E. Thomas, S. K. de Blois, and L. C. Hufnagle. 2008. The 2005 integrated acoustic and trawl survey of Pacific hake, *Merluccius productus*, in U.S. and Canadian waters off the Pacific coast. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-94. Online at http://www.nwfsc.noaa.gov/assets/25/6835_11062008_165201 _Hake2005SurveyTM94Final.pdf [accessed 23 February 2010].

Flory, E. 2008a. Biological assessment/biological evaluation threatened, endangered, and Forest Service sensitive listed wildlife species. Cascade Point, Berners Bay Barge Ramp Permit Application, Supplemental Information, Attachment 8. Aquatic Science Inc., Juneau, AK. Online at http:// www.juneau.org/plancomm/documents/Attachment8.PDF [accessed 22 February 2010].

Flory, E. 2008b. Eulachon distribution in the Taku River, Juneau, Alaska, 2008. Aquatic Science Inc., Juneau. Online at http://dnr.alaska.gov/mlw/mining/largemine/tulsequah/pdf2/eulachon2tuls.pdf [accessed 22 February 2010].

Foley, P. 1997. Extinction models for local populations. *In*: I. Hanski and M. E. Gilpin (eds.), Metapopulation biology, p. 215–246. Academic Press, New York.

Foreman, M. G. G., D. K. Lee, J. Morrison, S. Macdonald, D. Barnes, and I. V. Williams. 2001. Simulations and retrospective analyses of Fraser watershed flows and temperatures. Atmos. Ocean 39:89–105.

Franchère, G. 1967. Adventure at Astoria, 1810–1814 [edited and translated by H. C. Franchère]. University of Oklahoma Press, Norman.

Franchère, G. 1968. A voyage to the northwest coast of America, M. M. Quaife (ed.). The Citadel Press, New York.

Franchère, G. 1969. The Journal of Gabriel Franchère, 1811–1814. The Champlain Society, Toronto, ON.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fish. Oceanogr. 7:1–21.

Franzel, J., and K. A. Nelson. 1981. Stikine River eulachon (*Thaleichthys pacificus*). U.S. Forest Service, Petersburg Ranger District, Petersburg, AK. Abstract reprinted in Willson et al. 2006, AFSC Processed Report 2006-12, p. 100–101.

FREMP (Fraser River Estuary Management Program). 2006. Environmental management strategy for dredging in the Fraser River estuary. Burrard Inlet Environmental Action Program and Fraser River Estuary Management Program. Online at http://bieapfremp.org/fremp/pdf_files/Environmental%20Management%20Strategy%20for%20Dredging%20FINAL%20FINAL.pdf [accessed 22 February 2010].

FREMP (Fraser River Estuary Management Program). 2007. Sediment budget and dredging activities annual report for the fiscal year 1 April 2006 to 31 March 2007. Fraser River Estuary Management Program. Online at http://bieapfremp.org/fremp/pdf_files/Dredging%20AR%202006-2007%20FINAL%20Jan%2008.pdf [accessed 19 February 2010].

Frimodig, A. 2008. Informational report: Bycatch reduction devices used in the pink shrimp trawl fishery. Rep. to California Fish and Game Commission. California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project. Online at http://www.dfg.ca.gov/marine/pdfs/brd_report.pdf [accessed 23 February 2010].

Frimodig, A., M. Horeczko, T. Mason, B. Owens, M. Prall, and S. Wertz. 2007. Information concerning the pink shrimp trawl fishery off northern California. Rep. to California Fish and Game Commission, California Dept. Fish and Game, Marine Region, State Fisheries Evaluation Project. Online at http://www.dfg.ca.gov/marine/pdfs/pinkshrimp.pdf [accessed 23 February 2010].

Fry Jr., D. H. 1979. Anadromous fishes of California, California Dept. Fish and Game, Sacramento. Online at http://cdm15024.contentdm.oclc.org/cdm4/item_viewer.php?CISOROOT=/p178601ccp2&CISOPTR=103 [accessed 19 February 2010].

Gabriel, W. L., and A. V. Tyler. 1980. Preliminary analysis of Pacific coast demersal fish assemblages. Mar. Fish. Rev. 42(3–4):83–88.

Gallant, A. L., E. F. Binnian, J. W. Omernik, and M. B. Shasby. 1995. Ecoregions of Alaska. U.S. Geological Survey Prof. Pap. 1567. U.S. Government Printing Office, Washington, DC

Garrison, K. J., and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. FRI-UW-8216. Univ. Washington, Fisheries Research Institute, Seattle.

Gass, P. 1807. A journal of the voyages and travels of a Corps of Discovery, under the command of Capt. Lewis and Capt. Clark of the Army of the United States, from the mouth of the River Missouri through the interior parts of North America to the Pacific Ocean, during the years 1804, 1805, and 1806. D. McKeehan, Pittsburgh. Reprinted in 1996 as The definitive journals of Lewis and Clark, Patrick Gass. G. E. Moulton (ed.), Vol. 9 of the Nebraska edition. University of Nebraska Press, Lincoln, and in 1997 as The journals of Patrick Gass: Member of the Lewis and Clark Expedition, edited and annotated by Carol Lynn MacGregor. Mountain Press, Missoula, MT.]

Gaumer, T., D. Demory, and L. Osis. 1973. 1971 Coquille River estuary resource use study. Fish Commission of Oregon, Division of Management and Research. (Available from Oregon Dept. Fish and Wildlife, Fish Division, 3406 Cherry Ave. NE, Salem 97303.)

Gestring, K. B. 1991. Stomach contents of striped bass × white bass hybrids in the Tenmile Lake system. Oregon Dept. Fish and Wildlife Fish Division information report No. 91-1.

Gibson, D. I. 1996. Guide to the parasites of fishes of Canada, Part IV, Trematoda. Can. Spec. Publ. Fish. Aquat. Sci. No. 124.

Gilpin, M. E., and M. E. Soule. 1986. Minimum viable populations: Process of species extinctions. *In* M. E. Soule (ed.), Conservation biology: The science of scarcity and diversity, p. 19–34. Sinauer, Sunderland, MA.

Girard, G. 1858. General report upon the zoology of the several Pacific Railroad routes. Fishes. *In* Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, Pacific Railroad Rep. 10 (Pt. IV), p. 1–400.

Good, T. P., R. S. Waples, and P. Adams (eds.). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66. Online at http://www.nwfsc.noaa.gov/assets/25/6226_08302005_132955 _brttechmemo66final2.pdf [accessed 23 February 2010].

Gotshall, D. W., G. H. Allen, and R. A. Barnhart. 1980. An annotated checklist of fishes from Humboldt Bay, California. Calif. Fish Game 66:220–232.

Gough, B. M. (ed.). 1992. The journal of Alexander Henry the Younger 1799–1814. Vol. II, The Saskatchewan and Columbia rivers. The Champlain Society, Toronto, ON.

Green, A. 1891. The economic fishes of British Columbia. Papers and communications read before the Natural History Society of British Columbia 1(1):20–33.

Groisman, P. Y., R. W. Knight, T. R. Karl, D. R. Easterling, B. Sun, and J. H. Lawrimore. 2004. Contemporary changes of the hydrological cycle over the contiguous United States: Trends derived from in situ observations. J. Hydrometerol. 5:64–85.

Gustafson, R. G., J. Drake, M. J. Ford, J. M. Myers, E. E. Holmes, and R. S. Waples. 2006. Status review of Cherry Point Pacific herring *(Clupea pallasii)* and updated status review of the Georgia Basin Pacific herring distinct population segment under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-76. Online at http://www.nwfsc.noaa.gov/ assets/25/6539_08072006_141228_HerringTM76Final.pdf [accessed 23 February 2010].

Gustafson R. G., W. H. Lenarz, B. B. McCain, C. C. Schmitt, W. S. Grant, T. L. Builder, and R. D. Methot. 2000. Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-44. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm44/tm44.htm [accessed 23 February 2010].

Guttormsen, M. A., and P. T. Yasenak. 2007. Results of the 2003 and 2005 echo integration-trawl surveys in the Gulf of Alaska during summer, cruises MF2003-09 and OD2005-01. AFSC

Processed Rep. 2007-04. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR2007-04.pdf [accessed 23 February 2010].

Haggerty, D. R., B. McCorquodale, D. I. Johannessen, C. D. Levings, and P. S. Ross. 2003. Marine environmental quality in the central coast of British Columbia, Canada: A review of contaminant sources, types and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2507. DFO, Sidney, BC.

Hall, K. J. 1976. The quality of water in the lower Fraser River and sources of pollution. *In* A. H. J. Dorcey (ed.), The uncertain future of the lower Fraser, p. 21–46. Westwater Research Centre, University of British Columbia Press, Vancouver.

Halpin, M. M., and M. Seguin. 1990. Tsimshian, peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitskan. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 267–284. Smithsonian Institution, Washington, DC.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams—A synthesis of the historical evidence. Fisheries 30(4):10–20.

Hamlet, A. F., P. W. Mote, M. P. Clark, and D. P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. J. Climate 18:4545–4561.

Hamori-Torok, C. 1990. Haisla. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 306–311. Smithsonian Institution, Washington, DC.

Hannah, R. W., and S. A. Jones. 2003. Measuring the height of the fishing line and its effect on shrimp catch and bycatch in an ocean shrimp (*Pandalus jordani*) trawl. Fish. Res. 60:427–438.

Hannah, R. W., and S. A. Jones. 2007. Effectiveness of bycatch reduction devices (BRDs) in the ocean shrimp (*Pandalus jordani*) trawl fishery. Fish. Res. 85:217–225.

Hannah, R., and S. Jones. 2009. 20th annual pink shrimp review. Oregon Dept. Fish Wildlife, Marine Resources Program, Newport. Online at http://www.dfw.state.or.us/MRP/publications/shrimp_newsletter2009.pdf [accessed 22 February 2010].

Hannah, R. W., S. A. Jones, and V. Hoover. 1996. Evaluation of fish excluder technology to reduce finfish bycatch in the ocean shrimp trawl fishery. ODFW Information Rep. 96-4. Oregon Dept. Fish and Wildlife, Marine Region, Newport.

Hannah, R. W., S. A. Jones, and K. M. Matteson. 2003. Observations of fish and shrimp behavior in ocean shrimp (*Pandalus jordani*) trawls. ODFW Information Rep. 2003-03. Oregon Dept. fish and Wildlife, Marine Resources Program, Newport.

Hanski, I. A., and M. E. Gilpin (eds.). 1997. Metapopulation biology. Academic Press, San Diego, CA.

Hard, J. J., J. M. Myers, M. J. Ford, R. G. Cope, G. R. Pess, R. S. Waples, G. A. Winans, B. A. Berejikian, F. W. Waknitz, P. B. Adams. P. A. Bisson, D. E. Campton, and R. R. Reisenbichler. 2007. Status review of Puget Sound steelhead *(Oncorhynchus mykiss)*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81. Online at http://www.nwfsc.noaa.gov/assets/25/6649_07312007_160715_SRSteelheadTM81Final.pdf [accessed 23 February 2010].

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaskan and west coast salmon. Fisheries 24:6–14.

Hart, J. L. 1943. Comparison of eulachon catch statistics for three years. J. Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 56:6.

Hart, J. L. 1949. Food of fish of the cod family. J. Fish. Res. Board Can., Progress Reports of the Pacific Coast Stations 79: 35–36.

Hart, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. 180.

Hart, J. L., and J. L. McHugh. 1944. The smelts (Osmeridae) of British Columbia. J. Fish. Res. Board Can. 64.

Hauser, L., and G. R. Carvalho. 2008. Paradigm shifts in marine fisheries genetics: Ugly hypotheses slain by beautiful facts. Fish Fish. 9:333–362.

Hawthorn, H. B., Belshaw, C. S., and S. M. Jamieson. 1960. The Indians of British Columbia. A study of contemporary social adjustment. University of Toronto Press, ON.

Hay, D. E. 1996. Coastal pelagics—Herring and eulachon. *In* Can. Tech. Rep. Fish. Aquat. Sci. 2108, Proceedings, Marine Ecosystem Monitoring Network—1995 March, p. 33–36. DFO, Nanaimo, BC.

Hay, D. 2002. The eulachon in Northern British Columbia. *In* T. Pitcher, M. Vasconcellos, S. Heymans, C. Brignall, and N. Haggan (eds.), Information supporting past and present ecosystem models of Northern British Columbia and the Newfoundland Shelf, p. 98–107. Fisheries Centre Research Reports, Vol. 10 No. 1. Univ. British Columbia, Fisheries Centre, Vancouver.

Hay, D. 2007. Eulachons-biological review. Presentation at the Feb. 2007 Workshop to Determine Research Priorities for Eulachon. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/ 2007eulawkshp_ch.pdf [accessed 23 February 2010].

Hay, D. E., and T. D. Beacham. 2005. Stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt in the eastern Pacific. Paper presented at ICES 2005 Annual Science Conference, Aberdeen, Scotland, UK. Online at http://www.ices.dk/products/CMdocs/2005/ K/K1405.pdf [accessed 23 February 2010].

Hay, D. E., R. Harbo, J. Boutillier, E. Wylie, L. Convey, and P. B. McCarter. 1999a. Assessment of bycatch in the 1997 and 1998 shrimp trawl fisheries in British Columbia, with emphasis on eulachons. Canadian Stock Assessment Secretariat research document 1999/179. DFO, Ottawa, ON.

Hay, D. E., R. Harbo, K. Southey, J. E. Clarke, G. Parker, and P. B. McCarter. 1999b. Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch, with emphasis on eulachons. Canadian Stock Assessment Secretariat research document 99/26. DFO, Ottawa, ON.

Hay, D. E., and McCarter, P. B. 1997. Larval distribution, abundance, and stock structure of British Columbia herring. J. Fish Biol. 51(suppl. A):155–175.

Hay, D. E., and McCarter, P. B. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Canadian Stock Assessment Secretariat research document 2000-145. DFO, Ottawa, ON. Online at http://www.dfo-mpo.gc.ca/csas/csas/DocREC/2000/PDF/2000_145e.pdf [accessed 23 February 2010].

Hay, D. E., P. B. McCarter, R. Joy, M. Thompson, and K. West. 2002. Fraser River eulachon biomass assessments and spawning distribution: 1995–2002. Canadian Science Advisory Secretariat research document 2002/117. DFO, Nanaimo, BC.

Hay, D. E., K. C. West, and A. D. Anderson. 2003. Indicators and "response" points for management of Fraser River eulachon: A comparison and discussion with recommendations. Canadian Science Advisory Secretariat research document 2003/051. DFO, Nanaimo, BC. Online at http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2003/RES2003_051_E.pdf [accessed 23 February 2010].

Hay, D. E., K. West, A. D. Anderson, and D. Rutherford. 2005. Indicators and "response" points for management of Fraser River eulachon: Protocols for managing a data-limited fishery. Fisheries Assessment and Management in Data-Limited Situations. Rep. AK-SG-05-02. Alaska Sea Grant College Program, Fairbanks.

Hedgecock, D. 1994. Does variance in reproductive success limit effective population sizes of marine organisms? *In* A. R. Beaumont (ed.), Genetics and evolution of aquatic organisms, p. 122–134. Chapman & Hall, London.

Hedgpeth, J. W. 1957. Marine biogeography. *In* J. W. Hedgpeth (ed.), Treatise on marine ecology and paleoecology, p. 359–382. Geological Society of America, Boulder, CO.

Hedrick, R. P., W. N. Batts, S. Yun, G. S. Traxler, J. Kaufman, and J. R. Winton. 2003. Host and geographic range extensions of the North American strain of viral hemorrhagic septicemia virus. Dis. Aquat. Organ. 55:211–220.

Hicks, M. 2000. Evaluating standards for protecting aquatic life in Washington's surface water quality standards: Temperature criteria (preliminary review draft discussion paper). Washington Dept. Ecology, Water Quality Program, Watershed Management Section, Olympia.

Higgins, P. S., I. K. Birtwell, B. T. Atagi, D. Chilton, M. Gang, G. M. Kruzynski, H. Mahood, G. E. Piercey, B. A. Raymond, I. H. Rogers, and S. Spohn. 1987. Some characteristics of the eulachon (*Thaleichthys pacificus*) captured in the Fraser River estuary, B.C., April 1986. Can. Manuscr. Rep. Fish. Aquat. Sci. 1913.

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proc. Natl. Acad. Sci. USA 100:6564–6568.

Hilton, S. F. 1990. Haihais, Bella Bella, and Oowekeeno. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 312–322. Smithsonian Institution, Washington, DC.

Hinck, J. E., C. J. Schmitt, T. M. Bartish, N. D. Denslow, V. S. Blazer, P. A. Anderson, J. J. Coyle, G. M. Dethloff, and D. E. Tillitt. 2004. Biomonitoring of environmental status and trends (BEST) program: Environmental contaminants and their effects on fish in the Columbia River basin. U.S. Geological Survey scientific investigations Rep. 2004-5154. USGS, Columbia, MO. Online at http://www.cerc.usgs.gov/pubs/center/pdfDocs/BEST-Columbia_River.pdf [accessed 23 February 2010].

Hinck, J. E., C. J. Schmitt, V. S. Blazer, N. D. Denslow, T. M. Bartish, P. J. Anderson, J. J. Coyle, G. M. Dethloff, and D. E. Tillitt. 2006. Environmental contaminants and biomarker responses in fish from the Columbia River and its tributaries: Spatial and temporal trends. Sci. Total Environ. 366:549–578.

Hinrichsen, R. A. 1998. The ghost run of the Cowlitz. Cowlitz Hist. Q. 40(2):5–21.

Hirch, M. 2003. Trading across time and space: Culture along the North American “grease trails” from a European perspective. Canadian Studies International Interdisciplinary Conference: Across time & space visions of Canada from abroad, Univ. College of the Cariboo, Kamloops, BC, 12–14 September 2003. Online at http://www.cwis.org/fwdp/pdf/Oolichan%20Paper%20(Mirjam).pdf [accessed 23 February 2010].

Hjort, J. 1914. Fluctuations in the great fisheries of Northern Europe. Cons. Perm. Int. Explor. Mer Rapp. P.-V. Reun. 20:1–228.

Hochachka, P. W., and G. N. Somero. 2002. Biochemical adaptation: Mechanism and process in physiological evolution. Oxford University Press, New York.

Holmes, J., K. Cooke, and G. Kronkite. 2008. Interactions between jumbo squid (*Dosidicus gigas*) and Pacific hake (*Merluccius productus*) in the northern California Current in 2007. Calif. Coop. Ocean. Fish. Investig. Rep. 49:129–141.

Hooff, R. C., and W. T. Peterson. 2006. Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California Current ecosystem. Limnol. Oceanogr. 51:2607–2620.

Hoskins, G. E., G. R. Bell, and T. P. T. Evelyn. 1976. The occurrence, distribution, and significance of infectious diseases and of neoplasms observed in fish in the Pacific Region up to the end of 1974. Fisheries and Marine Service, Tech. Rep. 609. Environment Canada, Ottawa, ON.

Hostick, G. A. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Coastal Rivers Investigation Information Rep. 74-11. Fish Commission of Oregon, Division of Management and Research, Salem.

Howell, M. D. 2001. Characterization of development in Columbia River prolarval eulachon, *Thaleichthys pacificus*, using selected morphometric characters. Washington Dept. Fish and Wildlife, Vancouver. Online at http://wdfw.wa.gov/fish/creel/smelt/USACE-20larval-20development.pdf [accessed 23 February 2010].

Howell, M. D., M. D. Romano, and T. A. Rien. 2001. Outmigration timing and distribution of larval eulachon, *Thaleichthys pacificus*, in the lower Columbia River, spring 2001. Washington Dept. Fish and Wildlife, Vancouver, and Oregon Dept. Fish and Wildlife, Clackamas.

Howell, M. D., and N. Uusitalo. 2000. Eulachon (*Thaleichthys pacificus*) studies related to lower Columbia River channel deepening operations. Washington Dept. Fish and Wildlife, Vancouver, and Oregon Dept. Fish and Wildlife, Clackamas.

Hubbs, C. L. 1925. A revision of the osmerid fishes of the North Pacific. Proc. Biol. Soc. Wash. 38:49–56.

Huntington, E. 1963. Reminiscences of Cowlitz County. Cowlitz County Hist. Q. 5(3):1–9.

Hutchings, J. A. 2000. Collapse and recovery of marine fishes. Nature 406:882–885.

Hutchings, J. A. 2001a. Conservation biology of marine fishes: Perceptions and caveats regarding assignment of extinction risk. Can. J. Fish. Aquat. Sci. 58:108–121.

Hutchings, J. A. 2001b. Influence of population decline, fishing, and spawner variability on the recovery of marine fishes. J. Fish Biol. 59(Suppl. A):306–322.

Hutchings, J. A., and J. D. Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. Bioscience 54:297–309.

Hutchinson, J. M. 1979. Seasonal distribution of fishes in Siuslaw Bay. Oregon Dept. Fish and Wildlife, Corvallis (as cited in Monaco et al. 1990).

ICES (International Council for the Exploration of the Seas). 2004. Report of the working group on the application of genetics in fisheries and mariculture. ICES CM No. 2004/F:04. ICES, Copenhagen, Denmark.

Imbrie, J., J. D. Hays, D. G. Martinson, A. McIntyre, A. C. Mix, J. J. Morley, N. G. Pisias, W. L. Prell, and N. J. Shackleton. 1984. The orbital theory of Pleistocene climate: Support from a revised chronology of the marine $\delta^{18}O$ record. *In* A. L. Berger, (ed.), Milankovitch and climate, Part 1, p. 269–305. D. Reidel, Norwell, MA.

Imler, R. H., and H. R. Sarber. 1947. Harbor seals and sea lions in Alaska. Spe. Sci. Rep. No. 28. U.S. Fish and Wildlife Service, Washington, DC.

Ingólfsson, O. A., A. V. Soldal, I. Huse, and M. Breen. 2007. Escape mortality of cod, saithe, and haddock in a Barents Sea trawl fishery. ICES J. Mar. Sci. 64:1836–1844.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment rep. of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York. Online at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm [accessed 23 February 2010].

Irving, W. 1868. Astoria, or, anecdotes of an enterprise beyond the Rocky Mountains. G. P. Putnam and Sons, New York.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, National Marine Fisheries Service, Portland, OR. Online at http://www.nwcouncil.org/library/isab/ISAB%202007-2%20Climate%20Change.pdf [accessed 23 February 2010].

ISAB (Independent Scientific Advisory Board). 2008. Nonnative species impacts on native salmonids in the Columbia River Basin, including recommendations for evaluating the use of non-native fish species in resident fish substitution projects. ISAB nonnative species rep., ISAB 2008-4. Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, NMFS, Portland, OR. Online at http://www.nwcouncil.org/library/isab/isab2008-4.htm [accessed 23 February 2010].

IUCN (International Union for the Conservation of Nature). 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland, and Cambridge, UK. Online at http://www.iucnredlist.org/technical-documents/categories-and-criteria [accessed 23 February 2010].

IUCN (International Union for the Conservation of Nature). 2006. Guidelines for using the IUCN Red List categories and criteria. Version 6.2. Prepared by Standards and Petitions Working Group of the IUCN SSC Biodiversity Assessments Subcommittee in December 2006. Online at http://intranet.iucn.org/webfiles/doc/SSC/RedList/RedListGuidelines.pdf [accessed 23 February 2010].

Iverson, S. J., K. J. Frost, and S. L. C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: Factors contributing to, among, and within species variability. Mar. Ecol. Prog. Ser. 241:161–181.

JCRMS (Joint Columbia River Management Staff). 2005. Joint staff report concerning commercial seasons for sturgeon and smelt in 2006. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/dec0605jointstaff.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2006. 2007 joint staff report: Stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/sturgeon_smelt07.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2007. 2008 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/crc2008_sturgeon_smelt_js_rpt.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2008. 2009 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/crc2009_sturgeon_smelt_js_rpt.pdf [accessed 23 February 2010].

JCRMS (Joint Columbia River Management Staff). 2009. 2010 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Dept. Fish and Wildlife and Washington Dept. Fish and Wildlife. Online at http://wdfw.wa.gov/fish/crc/2010_sturgeon_smelt.pdf [accessed 23 February 2010].

Jeffries, S. J. 1984. Marine mammals of the Columbia River Estuary. Final rep. on the Marine Mammals Work Unit of the Columbia River Estuary Data Development Program, Washington Department of Game, Olympia. Online at http://www.lcrep.org/pdfs/17%20MARINE %20MAMMALS%20OF%20THE%20COLUMBIA%20RIVER%20ESTUARY.pdf [accessed 23 February 2010].

Jennings, M. R. 1996. Past occurrence of eulachon, *Thaleichthys pacificus*, in streams tributary to Humboldt Bay, California. Calif. Fish Game 82(6):147–148.

Johannessen, D. I., J. S. Macdonald, K. A. Harris, and P. S. Ross. 2007a. Marine environmental quality in the Pacific North Coast Integrated Management Area (PNCIMA), British Columbia: A summary of contaminant sources, types and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2716.

Johannessen, D. I., K. A. Harris, J. S. Macdonald, and P. S. Ross. 2007b. Marine environmental quality in the north coast and Queen Charlotte Islands, British Columbia, Canada: A review of contaminant sources, types, and risks. Can. Tech. Rep. Fish. Aquat. Sci. 2717.

Johnson, J. A., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua estuary, April 1977 through January 1986. Information Rep. 86-6. Oregon Dept. Fish and Wildlife, Corvallis.

Johnson, L. L., G. M. Ylitalo, M. S. Myers, B. F. Anulacion, J. Buzitis, W. L. Reichert, and T. K. Collier. 2009. Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98.

Online at http://www.nwfsc.noaa.gov/assets/25/6917_05122009_141859_PAHsKitimat TM98WebFinal.pdf [accessed 23 February 2010].

Johnston Jr., S. A. 1981. Estuarine dredge and fill activities: A review of impacts. Environ. Manag. 5:427–440.

Jones, B. C., and G. H. Geen. 1977. Food and feeding of spiny dogfish (*Squalus acanthias*) in British Columbia waters. J. Fish. Res. Board Can. 34:2067–2078.

Jordan, D. S., and C. H. Gilbert. 1899. The fishes of Bering Sea. *In* D. S. Jordan (ed.), The fur seals and fur-seal islands of the North Pacific Ocean, Part 3, p. 433–492. U.S. Government Printing Office, Washington, DC.

Jordan, D. S., and E. C. Starks. 1895. The fishes of Puget Sound. Contributions to biology from the Hopkins Laboratory of Biology No. 3. Proc. Calif. Acad. Sci. Ser. 2 5:785–855.

Joyce, T. L., M. B. Lambert, and S. Moffitt. 2004. Eulachon subsistence harvest opportunities. Final Rep. No. FIS02-075-1. USFWS Office of Subsistence Management, Fisheries Resource Monitoring Program, Anchorage, AK.

Kabata, Z. 1988. Copepoda and Branchiura. *In* L. Margolis and Z. Kabata (eds.). Guide to the parasites of fishes of Canada, Part II–Crustacea, p. 3–127. Can. Spec. Publ. Fish. Aquat. Sci. 101.

Kabata, Z., and C. R. Forrester. 1974. *Atheresthes stomias* (Jordan and Gilbert 1880) (Pisces: Pleuronectiformes) and its eye parasite *Phrixocephalus cincinnatus* Wilson 1908 (Copepoda: Lernaeoceridae) in Canadian Pacific waters. J. Fish. Res. Board Can. 31:1589–1595.

Kajimura, H., C. H. Fiscus, and R. K. Stroud. 1980. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington: With appendices on size and food of Dall's porpoise from Alaskan waters. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/NWC 2.

Kaukinen, K. H., K. J. Supernault, and K. M. Miller. 2004. Development of microsatellite loci in eulachon fish (*Thaleichthys pacificus*). Mol. Ecol. Notes 4:632–634.

Keller, A. A., T. L. Wick, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, and B. H. Horness. 2005. The 2000 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-70. Online at http://www.nwfsc.noaa.gov/assets/25/6459_03102006_131701_Slope2000FinalV2SA.pdf [accessed 23 February 2010].

Keller, A. A., E. L. Fruh, K. L. Bosley, D. J. Kamikawa, J. R. Wallace, B. H. Horness, V. H. Simon, and V. J. Tuttle. 2006a. The 2001 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-72. Online at http://www.nwfsc.noaa.gov/assets/25/6460_03202007_121309_ Slope2001TechMemo.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, V. J. Tuttle, J. R. Wallace, V. H. Simon, E. L. Fruh, K. L. Bosley, and D. J. Kamikawa. 2006b. The 2002 U.S. West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-

75. Online at http://www.nwfsc.noaa.gov/assets/25/6493_04062006_150352_ Slope2002TM75Final.pdf [accessed 23 February 2010].

Keller, A. A., V. H. Simon, B. H. Horness, J. R. Wallace, V. J. Tuttle, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007a. The 2003 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-86. Online at http://www.nwfsc.noaa.gov/assets/25/6719_01082008_151554_ GroundfishSurvey2003TM86FinalSA.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, V. H. Simon, V. J. Tuttle, J. R. Wallace, E. L. Fruh, K. L. Bosley, D. J. Kamikawa, and J. C. Buchanan. 2007b. The 2004 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-87. Online at http://www.nwfsc.noaa.gov/assets/25/6656_01152008_153323_ GroundfishSurvey2004TM87FinalSA.pdf [accessed 23 February 2010].

Keller, A. A., B. H. Horness, E. L. Fruh, V. H. Simon, V. J. Tuttle, K. L. Bosley, J. C. Buchanan, D. J. Kamikawa, and J. R. Wallace. 2008. The 2005 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-93. Online at http://www.nwfsc.noaa.gov/assets/25/6802_08122008_165005_ GroundfishSurveyTM93Final.pdf [accessed 23 February 2010].

Kelson, J. 1996. Kitamaat River 1995 oolichan (*Thaleicthys pacificus*) study. Report prepared by Kitamaat Village Council for British Columbia Ministry of Forests (as cited in Moody 2008).

Kelson, J. 1997. Kitamaat River 1997 oolichan (*Thaleicthys paclficus*) study progress report (May-July, 1997). Final report to Science Council of British Columbia (SCBC No. 96/97-025). Online at http://www.for.gov.bc.ca/hfd/library/frbc1997/frbc1997mr215.pdf [accessed 23 February 2010].

Kennedy, D. I. D., and R. T. Bouchard. 1990. Bella Coola. *In* W. Suttles (ed.), Handbook of North American Indians, Vol. 7, Northwest Coast, p. 323–339. Smithsonian Institution, Washington, DC.

Kershaw, T. R. 1902. Thirteenth annual report of the State Fish Commissioner to the Governor of the State of Washington. Metropolitan Press, Seattle.

Kershaw, T. R. 1904. 14th and 15th annual reports of the State Fish Commissioner to the Governor of the State of Washington. Metropolitan Press, Seattle.

Kime, D. E. 1995. The effects of pollution on reproduction in fish. Rev. Fish Biol. Fish. 5:52–96.

Kitamaat Village Council. 2007. Haisla Dootilh. Haisla Community Newsletter, Vol. 1, Issue 1. Kitamaat Village Council, Kitamaat Village, BC. Online at http://www.haisla.ca/files/ May%202007.pdf [accessed 23 February 2010].

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. J. Climate 19:4545–4559.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, B. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein, R. S. Waples. 2004. 2004 Status Review of Southern Resident Killer Whales (Orcinus orca) under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-62.

Krause, A. 1885. Die Tlinkit-Indianer. Ergebnisse einer Reise nach der Nordwestküste von Amerika und der Beringstrasse. H. Costenoble, Jena. Published in 1956 [Translated by E. Gunther] as The Tlingit Indians: Results of a trip to the northwest coast of America and the Bering Straits. University of Washington Press, Seattle.

Kreag, R. A. 1979. Natural resources of Coquille Estuary. Estuary Inventory Rep. Vol. 2, No. 7. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Kubik, S. W., and R. Wadman. 1977. Inventory and cataloging of sport fish and sport fish waters of the lower Susitna River and Cook Inlet drainages. Federal Aid in Sport Fish Restoration, Annual Performance Rep. 1976–1977, Project F-9-9(18)G-I-H. Alaska Dept. Fish and Game, Sport Fish Division, Juneau.

Kubik, S. W., and R. Wadman. 1978. Inventory and cataloging of sport fish and sport fish waters of western Prince William Sound, lower Susitna and central Cook Inlet drainages. Federal Aid in Fish Restoration, Annual Performance Rept. 1977–1978, Project F-9-10(19)G-I-H. Alaska Dept. Fish and Game, Sport Fish Division, Juneau.

Kuhnlein, H. V., A. C. Chan, J. N. Thompson, and S. Nakai. 1982. Ooligan grease: A nutritious fat used by native people of coastal British Columbia. J. Ethnobiol. 2:154–161.

Kuhnlein, H. V., F. Yeboah, M. Sedgemore, S. Sedgemore, and H. M. Chan. 1996. Nutritional qualities of ooligan grease: A traditional food fat of British Columbia First Nations. J. Food Compos. Anal. 9:18–31.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochasticity and random catastrophes. Am. Nat. 142:911–927.

Langer, O. E., B. G. Shepherd, and P. R. Vroom. 1977. Biology of the Nass River eulachon (*Thaleichthys pacificus*). Canadian Fisheries and Marine Service Tech. Rep. 77-10.

Larson, K. W., and C. E. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes, workshop proceedings, 8–9 September 1988, p. 102–112. Univ. Washington, Sea Grant Program, Seattle.

Larson, Z. S., and M. R. Belchik. 1998. A preliminary status review of eulachon and Pacific lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program, Klamath, CA.

Lasalle, M. W. 1990. Physical and chemical alterations associated with dredging: An overview. *In* C. A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast fishes. Workshop proceedings, 8–9 September 1988, p. 1–12. Univ. Washington, Sea Grant Program, Seattle.

Lasker, R. 1975. Field criteria for survival of anchovy larvae: The relation between inshore chlorophyll maximum layers and successful first feeding. Fish. Bull. 73:453–462.

Lassuy, D. 1995. Introduced species as a factor in extinction and endangerment of native fish species. Am. Fish. Soc. Symp. 15:391–396.

Lauth, R. R. 1997a. The 1995 Pacific West Coast upper continental slope trawl survey of groundfish resources off southern Oregon and northern California: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-80. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-80.pdf [accessed 23 February 2010].

Lauth, R. R. 1997b. The 1996 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington and Oregon: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-81. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-81.pdf [accessed 23 February 2010].

Lauth, R. R. 1999. The 1997 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington, Oregon and California: Estimates of distribution, abundance, and composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-98. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-98/Text%20from %20NOAA-TM-AFSC-98.pdf [accessed 23 February 2010].

Lauth , R. R. 2000. The 1999 Pacific West Coast upper continental slope trawl survey of groundfish resources off Washington , Oregon and California: Estimates of distribution , abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-115. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-115/Text%20from %20NOAA-TM-AFSC-115%20.pdf [accessed 23 February 2010].

Lauth, R, and E. Acuna (compilers). 2007a. 2005 bottom trawl survey of the eastern Bering Sea continental shelf. AFSC Processed Rep. 2007-1. Online at http://www.afsc.noaa.gov/ Publications/ProcRpt/PR2007-01.pdf [accessed 23 February 2010].

Lauth, R. R., and E. Acuna. 2007b. Results of the 2006 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-176. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-176.pdf [accessed 23 February 2010].

Lauth, R. R., M. E. Wilkins, and P. A. Raymore Jr. 1997. Results of trawl surveys of groundfish resources of the West Coast upper continental slope from 1989 to 1993. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-79.

Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6–10.

LCFRB (Lower Columbia Fish Recovery Board). 2004a. Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. Online at http://www.nwcouncil.org/fw/subbasinplanning/ lowerColumbia/plan/ [accessed 23 February 2010].

LCFRB (Lower Columbia Fish Recovery Board). 2004b. Eulachon. Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan, Appendix B, Ch. 15. Online at http://www.nwcouncil.org/ fw/subbasinplanning/lowerColumbia/plan/AppendixB_OtherSpecies.pdf [accessed 10 May 2010].

Levitus, S., J. I. Antonov, and T. P. Boyer. 2005. Warming of the world ocean, 1955–2003. Geophys. Res. Lett. 32: L02604. Online at http://dx.doi.org/ [DOI name 10.1029/2004GL021592, accessed 23 February 2010].

Levitus, S., J. Antonov, T. P. Boyer, and C. Stephens. 2000. Warming of the world ocean. Science 287:2225–2229.

Lewis, A. F. J. 1997. Skeena eulachon study 1997. Report prepared by Triton Environmental Consultants Ltd., Terrace, BC, and the Tsimshian Tribal Council, Prince Rupert, BC, for Forest Renewal BC. Final rep. to Science Council of British Columbia (SCBC #96/97-123). Online at http://www.for.gov.bc.ca/hfd/library/FRBC1997/FRBC1997MR216.PDF [accessed 23 February 2010].

Lewis, A. F. J., M. D. McGurk, and M. G. Galesloot. 2002. Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988–1998. Consultant's report prepared by Ecofish Research Ltd. for Alcan Primary Metal Ltd., Kitimat, BC.

Lindsey, C. C. 1966. Body sizes of poikilotherm vertebrates at different latitudes. Evolution 20:456–465.

Little, A. C. 1898. Ninth annual report of the state fish commissioner to the governor of the State of Washington. Gwin Hicks, state printer, Olympia.

Little, A. C. 1901. Tenth and eleventh annual reports of the state fish commissioner to the governor of the State of Washington, 1899–1900. Gwin Hicks, state printer, Olympia.

Livingston, P. 1983. Food habits of Pacific whiting, *Merluccius productus*, off the west coast of North America, 1967 and 1980. Fish. Bull. 81:629–636.

Longhurst, A. R. 2006. Ecological geography of the sea, 2nd edition. Elsevier Academic Press, Amsterdam.

Lord, J. K. 1866. The naturalist in Vancouver Island and British Columbia, Vol. 1. Richard Bentley, London. Republished by Elibron Classics, New York.

Lowry, L. F., K. J. Frost, J. M. Ver Hoef, and R. A. DeLong. 2001. Movements of satellite tagged subadult and adult harbor seals in Prince William Sound, Alaska. Mar. Mam. Sci. 17:835–861.

Mace, G. M., and E. J. Hudson. 1999. Attitudes toward sustainability and extinction. Conserv. Biol. 13:242–246.

MacFie, M. 1865. Vancouver Island and British Columbia: Their history, resources, and prospects. Longman, Green, Longman, Roberts & Green, London.

Mackas, D. L., S. Batten, and M. Trudel. 2007. Effects on zooplankton of a warmer ocean: Recent evidence from the Northeast Pacific. Prog. Oceanogr. 75:223–252.

Mackas, D. L., R. E. Thomson, and M. Galbraith. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985–1999, and their covariation with oceanographic conditions. Can. J. Fish. Aquat. Sci. 58:685–702.

Mackie, R. S. 1997. Trading beyond the mountains: The British fur trade on the Pacific, 1793–1843. University of British Columbia Press, Vancouver.

MacLachlan, M. (ed.). 1998. The Fort Langley Journals, 1827–1830. University of British Columbia Press, Vancouver.

Macnair, P. L. 1971. Descriptive notes on the Kwakiutl manufacture of eulachon oil. Syesis 4:169–177.

Maggiulli, N., Reeves, G. H., and R. A. Schmitz. 2006 eulachon spawning migration dynamics and associated avian feeding aggregation characteristics on the Copper River delta, Alaska [abstract]. *In* 2006 Annual Meeting of the Oregon Chapter of The Wildlife Society, p. 26. 14–17 February 2006, Agate Beach, OR. Oregon Chapter of the Wildlife Society, Corvallis, OR.

Mantua, N. J., and S. R. Hare. 2002. The Pacific decadal oscillation. J. Oceanogr. 58:35–44.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteorol. Soc. 78:1069–1079.

Margolis, L., and J. R. Arthur. 1979. Synopsis of the parasites of fishes of Canada. Bull. Fish. Res. Board Can. 199.

Marston, B. H., M. F. Willson, and S. M. Gende. 2002. Predator aggregations during eulachon *Thaleichthys pacificus* spawning runs. Mar. Ecol. Prog. Ser. 231:229–236.

Martin, I. 2008. Notes on historical smelt migrations in the Columbia and Cowlitz rivers, Exhibit AA. Attachment to letter to Chief NMFS, Protected Resources Division, from T. V. Dulcich; Schwabe, Williamson & Wyatt, Attorneys at Law, re. Code No. RIN0648-XF87-Comment on request for information regarding proposed listing of Pacific eulachon as an endangered or threatened species under the Endangered Species Act, 12 May 2008. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.) Online at http://www.regulations.gov/search/Regs/contentStreamer?objectId=090000648098f309 &disposition=attachment&contentType=pdf [accessed 24 February 2010].

Martin, I. 2009. Letter from Irene Martin (Skamokawa, WA) to Chief, NMFS, Protected Resources Division, dated 11 May 2009. Eulachon Status Review Response, May 2009, by Irene Martin, 11 p. + 5 attachments. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Martin, M. H., and D. M. Clausen. 1995. Data Report: 1993 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-59. Online at http://www.afsc.noaa.gov/ Publications/AFSC-TM/NOAA-TM-AFSC-59.pdf [accessed 23 February 2010].

Martindale, A. R. C. 2003. A hunter-gatherer paramount chiefdom: Tsimshian developments through the contact period. *In* R. G. Matson, G. Coupland, and Q. Mackie (eds.), Emerging from the mist: Studies in Northwest Coast culture history, p. 12–49. University of British Columbia Press, Vancouver.

Maybury, C. R. 1930. Thirty-eighth and thirty-ninth annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1927, to March 31, 1929, fiscal years of 1927 and 1928. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

McAllister, D. E. 1963. A revision of the smelt family, Osmeridae. Nat. Mus. Can., Biol. Ser. 71, Bull. 191:1–53.

McCabe Jr., G. T., R. L. Emmett, and S. A. Hinton. 1993. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Sci. 67:170–180.

McCallister, H. C., and R. E. Clanton. 1911. Biennial report of the Department of Fisheries of the State of Oregon to the twenty-sixth legislative assembly 1911. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

McCarter, P. B., and D. E. Hay. 1999. Distribution of spawning eulachon stocks in the central coast of British Columbia as indicated by larval surveys. Canadian Stock Assessment Secretariat research document 99/177. DFO, Ottawa, ON.

McCarter, P. B., and D. Hay. 2003. Eulachon embryonic egg and larval outdrift sampling manual for ocean and river surveys. Can. Tech. Rep. Fish. Aquat. Sci. 2451.

McDonald, T. E., and L. Margolis. 1995. Synopsis of the parasites of fishes of Canada: Supplement (1978–1993). Can. Spec. Publ. Fish. Aquat. Sci. No. 122.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42. Online at http://www.nwfsc.noaa.gov/assets/25/5561_06162004_143739_tm42.pdf [accessed 23 February 2010].

McFarlane, G. A., and R. J. Beamish. 1985. Biology and fishery of Pacific whiting, *Merluccius productus*, in the Strait of Georgia. Mar. Fish. Rev. 47:23–34.

McFarlane, G. A., J. R. King, and R. J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progr. Oceanogr. 47:147–169.

McGuire, H. D. 1896. Third and fourth annual reports of the Fish and Game Protector of the State of Oregon, 1895–1896. W. H. Leeds, state printer, Salem.

McGuire, H. D. 1898. Fifth and sixth annual reports of the Fish and Game Protector of the State of Oregon, 1897–1898. W. H. Leeds, state printer, Salem.

McHugh, J. L. 1939. The eulachon. Progress report of the Pacific Biological Station, Nanaimo, B.C., and Pacific Fisheries Experimental Station, Prince Rupert, BC 40:17–22.

McHugh, J. L. 1940. Where does the eulachon spawn? Progress Rep. of the Pacific Biological Station, Nanaimo, BC, and Pacific Fisheries Experimental Station, Prince Rupert, BC 44:18–19.

McHugh, J. L. 1954. Geographic variation in the Pacific herring. Copeia 1954:139–154.

McLaughlin, P. A., D. K. Camp, M. V. Angel, E. L. Bousfield, P. Brunel, R. C. Brusca, D. Cadien, A. C. Cohen, K. Conlan, L. G. Eldredge, D. L. Felder, J. W. Goy, T. Haney, B. Hann, R. W. Heard, E. A. Hendrycks, H. H. Hobbs III, J. R. Holsinger, B. Kensley, D. R. Laubitz, S. E. LeCroy, R. Lemaitre, R. F. Maddocks, J. W. Martin, P. Mikkelsen, E. Nelson, W. A. Newman, R. M. Overstreet, W. J. Poly, W. W. Price, J. W. Reid, A. Robertson, D. C. Rogers, A. Ross, M. Schotte, F. R. Schram, C. T. Shih, L. Watling, G. D. F. Wilson, and D. D. Turgeon. 2005. Common and scientific names of aquatic invertebrates from the United States and Canada: Crustaceans. American Fisheries Society, Bethesda, MD.

McLean, J. E. 1999. Marine population structure in an anadromous fish: Life history influences patterns of neutral molecular variation in the eulachon, *Thaleichthys pacificus*. Master's thesis. Univ. British Columbia, Vancouver.

McLean, J. E., D. E. Hay, and E. B. Taylor. 1999. Marine population structure in an anadromous fish: Life history influences patterns of mitochondrial DNA variation in the eulachon, *Thaleichthys pacificus*. Mol. Ecol. 8:S143–S158.

McLean, J. E., and Taylor, E. B. 2001. Resolution of population structure in a species with high gene flow: Microsatellite variation in the eulachon (Osmeridae: *Thaleichthys pacificus*). Mar. Biol. 139:411–420.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Bull. Fish. Res. Board Can. 173.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, MD.

Meffe, G., and R. Carroll. 1994. Principles of conservation biology. Sinauer Associates Inc., Sunderland, MA.

Meier, M. F., M. B. Dyurgerov, and G. J. McCabe. 2003. The health of glaciers: Recent changes in glacier regime. Clim. Change 59:123–135.

Middleton, D. A. J., and R. M. Nisbet. 1997. Population persistence time: Estimates, models, mechanisms. Ecol. Appl. 7:107–117.

Miller, B. S., and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. Vol. 1. Family Petromysontidae (lampreys) through family Syngnathidae (Pipefishes). Univ. Washington, Fisheries Research Institute, Seattle.

Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game Fish Bull. 157.

Miller, D. J., and R. N. Lea. 1976. Guide to the coastal marine fishes of California, addendum added 1976. Calif. Dept. Fish Game Fish Bull. 157. 2nd edition.

Miller, J. A., and A. L. Shanks. 2005. Abundance and distribution of larval and juvenile fish in Coos Bay, Oregon: Time-series analysis based on light-trap collections. Mar. Ecol. Prog. Ser. 305:177–191.

Miller R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22–38.

Mills, D. D. 1982. Historical and contemporary fishing for salmon and eulachon at Klukwan: An interim report. ADFG Tech. Paper 69. Alaska Dept. Fish and Game, Division of Subsistence, Juneau.

Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationship to intracontinental tectonism. *In* C. H. Hocutt and E. O. Wiley (eds.), The zoogeography of North American freshwater fishes, p. 519–613. John Wiley and Sons, New York.

Mitchell, D. H. 1983. Seasonal settlements, village aggregations, and political autonomy on the central Northwest Coast. *In* E. Tooker (ed.), The development of political organization in native North America, p. 97–107. American Ethnological Society, Washington, DC.

Moffitt, S., B. Marston, and M. Miller. 2002. Summary of eulachon research in the Copper River Delta, 1998–2002. Regional information rep. 2A02-34. Alaska Dept. Fish and Game, Anchorage.

Monaco, M. E., R. L. Emmett, S. A. Hinton, and D. M. Nelson. 1990. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Vol. I: Data summaries. ELMR Rep. 4. U.S. Dept. Commerce, NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Moody, M. 2007. The Bella Coola eulachon fishery, its importance and its past and current status. Presentation at the February 2007 workshop to determine research priorities for eulachon. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/2007eulawkshp_ch.pdf [accessed 23 February 2010].

Moody, M. F. 2008. Eulachon past and present. Master's thesis. Univ. British Columbia, Vancouver. Online at https://circle.ubc.ca/bitstream/2429/676/1/ubc_2008_spring_moody_megan.pdf [accessed 23 February 2010].

Moore, S. E., K. E. W. Shelden, L. K. Litzky, B. A. Mahoney, and D. J. Rugh. 2000. Beluga, *Delphinapterus leucas*, habitat associations in Cook Inlet, Alaska. Mar. Fish. Rev. 62(3):60–80.

Moring, J. R. 1996. Fish discoveries by the Lewis and Clark and Red River expeditions. Fisheries 21(7):6–12.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy, Washington, DC.

Morrison, J., M. Quick, and M. G. G. Foreman. 2002. Climate change in the Fraser River watershed: Flow and temperature predictions. J. Hydrol. 263:230–244.

Morstad, S. 1998. Eulachon—1998 season summary. Alaska Dept. Fish and Game, Anchorage (as cited in Spangler et al. 2003).

Morton, A. 2000. Occurrence, photo-identification and prey of white-sided dolphins *(Lagenorhyncus obliquidens)* in the Broughton Archipelago, Canada, 1984–1998. Mar. Mam. Sci. 16: 80–93.

Mote, P. W. 2003a. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. Northwest Sci. 77:271–282.

Mote, P. W. 2003b. Twentieth-century fluctuations and trends in temperature, precipitation, and mountain snowpack in the Georgia Basin-Puget Sound region. Can. Water Res. J. 28:567–586.

Mote, P. W. 2006. Climate-driven variability and trends in mountain snowpack in western North America. J. Climate 19:6209–6220.

Mote, P. W., D. J. Canning, D. L. Fluharty, R. C. Francis, J. F. Franklin, A. F. Hamlet, M. Hershman, M. Holmberg, K. N. Ideker, W. S. Keeton, D. P. Lettenmaier, L. R. Leung, N. J. Mantua, E. L. Miles, B. Noble, H. Parandvash, D. W. Peterson, A. K. Snover, and S. R. Willard. 1999. Impacts of climate variability and change in the Pacific Northwest. NOAA, Office of Global Programs, and JISAO/SMA Climate Impacts Group, Seattle, WA. Online at http://cses.washington.edu/db/pdf/moteetalgreenbook96.pdf [accessed 23 February 2010].

Mote, P. W., A. F. Hamlet, M. Clark, and D. P. Lettenmaier. 2005a. Declining mountain snowpack in western North America. Bull. Am. Meteorol. Soc. 86:39–49.

Mote, P.M., E. Salathé, and C. Peacock. 2005b. Scenarios of future climate for the Pacific Northwest. Univ. Washington Climate Impacts Group, Tech. Rep., October 2005. Online at http://cses.washington.edu/db/pdf/kc05scenarios462.pdf [accessed 23 February 2010].

Moulton, G. E. (ed.). 1990. The definitive journals of Lewis and Clark, Down the Columbia to Fort Clatsop. Vol. 6 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1991. The definitive journals of Lewis and Clark, From the Pacific to the Rockies. Vol. 7 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1995. The definitive journals of Lewis and Clark, John Ordway and Charles Floyd. Vol. 9 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moulton, G. E. (ed.). 1997. The definitive journals of Lewis and Clark, Joseph Whitehouse. Vol. 11 of the Nebraska edition. University of Nebraska Press, Lincoln.

Moyle, P. B. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley and Los Angeles.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Eulachon. *In* Fish species of special concern in California, 2nd edition, p. 123–127. California Dept. Fish and Game, Inland Fisheries Division, Rancho Cordova.

Mueter, F. J., and B. L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fish. Bull. 100:559–581.

Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Information Rep. 77-3. Oregon Dept. Fish and Wildlife, Research Section, Salem.

Musick, J. A. 1999. Criteria to define extinction risk in marine fishes. Fisheries 24:6–14.

Musick, J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, G. R. Sedberry, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, H. Weeks, and S. G. Wright. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25(11): 6–30.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35. Online at http://www.nwfsc.noaa.gov/assets/25/4234_06172004_115524_chinook.pdf [accessed 23 February 2010].

Nebenzahl, D. (compiler). 2001. 2001 bottom trawl survey of the eastern Bering Sea continental shelf. AFSC Processed Rep. 2001-08. Online at http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202001-08.pdf [accessed 23 February 2010].

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, sixth edition. American Fisheries Society, Bethesda, MD.

Niblack, A. P. 1890. The coast Indians of southern Alaska and northern British Columbia. Based on the collections in the U.S. National Museum, and on the personal observation of the writer [a U.S. Navy Ensign] in connection with the survey of Alaska in the seasons of 1885, 1886, and 1887. *In* Report of the U.S. National Museum, 1888, p. 225–386. Smithsonian Institution, Washington, DC.

NMFS (National Marine Fisheries Service). 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-28.

NMFS (National Marine Fisheries Service). 1999. Endangered and threatened wildlife and plants; 90-day finding for a petition to list Columbia River eulachon (*Thaleichthys pacificus*) as endangered or threatened. Federal Register (Docket No. 991116306-9306-01; 29 November 1999) 64(228):66601–66603.

NMFS (National Marine Fisheries Service). 2000. Endangered and threatened species: Puget Sound populations of Pacific hake, Pacific cod, and walleye pollock. Federal Register (Docket No. 001103310-0310-01; 24 November 2000) 65(227):70514–70521.

NMFS (National Marine Fisheries Service). 2001. Endangered and threatened species: Puget Sound populations of copper rockfish, quillback rockfish, brown rockfish, and Pacific herring. Federal Register (Docket No. 010312061-1061-01; 3 April 2001) 66(64):17659–17668.

NMFS (National Marine Fisheries Service). 2002. Endangered and threatened wildlife and plants; 12-month finding on a petition to list bocaccio as threatened. Federal Register (50 CFR Parts 223 and 224; 19 November 2002) 67(223):69704–69708.

NMFS (National Marine Fisheries Service). 2003. Endangered and threatened species; Final endangered status for a distinct population segment of smalltooth sawfish (*Pristis pectinata*) in the United States. Federal Register (Docket No. 000303059-3034-03; 1 April 2003) 68(62):15674–15680.

NMFS (National Marine Fisheries Service). 2005. Listing endangered and threatened species and designating critical habitat: 12-month finding on petition to list the Cherry Point stock of Pacific herring as an endangered or threatened species. Federal Register (Docket No. 040511147-5142-02; I.D. 042804B; 7 June 2005) 70(108):33116–33122.

NMFS (National Marine Fisheries Service). 2008a. Listing endangered and threatened species: Notification of finding on a petition to list Pacific eulachon as an endangered or threatened species under the Endangered Species Act. Federal Register (Docket No. 080229343-8368-01; 21 March 2008) 73(49):13185–13189.

NMFS (National Marine Fisheries Service). 2008b. Endangered and threatened species; Notice of finding on a petition to list the Lynn Canal population of Pacific herring as a threatened or endangered species. Federal Register (Docket No. 070727423-8495-02; 11 April 2008) 73(71):19824–19825.

NMFS (National Marine Fisheries Service). 2009. Fisheries off West Coast states; Coastal pelagic species fishery; Amendment 12 to the Coastal Pelagic Species Fishery Management Plan, final rule. Federal Register (Docket No. 071106669-81372-03; 31 July 2009) 74(132):33372–33373.

NRC (National Research Council). 2004. Endangered and threatened fishes in the Klamath River basin: Causes of decline and strategies for recovery. Committee on Endangered and Threatened Fishes in the Klamath River Basin, National Research Council. The National Academies Press, Washington, DC.

NRC (National Research Council). 2008. Hydrology, ecology, and fishes of the Klamath River basin. Committee on Hydrology, Ecology, and Fishes of the Klamath River, National Research Council. The National Academies Press, Washington, DC.

NWFSC (Northwest Fisheries Science Center). 2008. Data report and summary analyses of the California and Oregon pink shrimp fisheries, December 2008. NWFSC, Fishery Resource Analysis and Monitoring Division, West Coast Groundfish Observer Program, Seattle, WA. Online at http://www.nwfsc.noaa.gov/research/divisions/fram/observer/datareport/docs/pink_shrimp_report_final.pdf [accessed 23 February 2010].

NWIFC (Northwest Indian Fisheries Commission). 1998. Quinaults welcome rare visit by candlefish. Northwest Indian Fish. Comm. News 18(1):11.

Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50:305–307.

ODFW (Oregon Dept. Fish and Wildlife). 1991. Tenmile Basin Fish Management Plan. Oregon Dept. Fish and Wildlife, Citizen Advisory Committee, and Public Agency Cooperators. (Available from National Marine Fisheries Service, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

ODFW (Oregon Dept. Fish and Wildlife). 2006. The Oregon nearshore strategy. Online at http://www.dfw.state.or.us/MRP/nearshore/strategy/Strategy.pdf [accessed 23 February 2010].

ODFW and WDF (Oregon Dept. Fish and Wildlife and Washington Dept. Fisheries). 1987. Status report: Columbia River fish runs and fisheries 1960–1986. Oregon Dept. Fish and Wildlife, Portland, and Washington Dept. Fisheries, Olympia.

OFC (Oregon Fish Commission). 1953. Columbia River Progress Report 1953. Fish Commission of Oregon, Portland.

OFC (Oregon Fish Commission). 1970. Pelagic fisheries and coastal rivers investigation. Progress Report-Coastal Rivers Section, July 1, 1966–June 30, 1967. Fish Commission of Oregon, Research Division, Portland.

Olesiuk, P. F. 1993. Annual prey consumption by harbor seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia. Fish. Bull. 91:491–515.

Olsen, N., J. A. Boutillier, and L. Convey. 2000. Estimated bycatch in the British Columbia shrimp trawl fishery. Canadian Stock Assessment Secretariat research document 2000/168. Online at http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2000/PDF/2000_168e.pdf [accessed 23 February 2010].

Olson, R. L. 1936. The Quinault Indians. Univ. Wash. Publ. Anthropol. 6(1).

Olson, W. M., and L. T. Hubbard Jr. 1984. Fishing: The key to Tlingit culture. *In* B. Gunda (ed.), The fishing culture of the world: Studies in ethnology, cultural ecology, and folklore, Vol. 2, p. 917–938. Akademiai Kiado, Hungary.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geogr. 77:118–125.

Omernik, J. M., and A. L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency Rep. EA/600/3-86/033.

Ormseth, O. A., L. Conners, M. Guttormsen, and J. Vollenweider. 2008. Appendix 2: Forage fishes in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 657–702. North Pacific Fishery Management Council, Anchorage. Online at http://www.afsc.noaa.gov/refm/docs/2008/GOAforage.pdf [accessed 23 February 2010].

Ormseth, O. A., and J. Vollenweider. 2007. Appendix 2: Forage fishes in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 1021–1023. North Pacific Fishery Management Council, Anchorage. Online at http://www.afsc.noaa.gov/REFM/docs/2007/GOAforage.pdf [accessed 23 February 2010].

Outram, D. N., and C. Haegele. 1972. Food of Pacific hake (*Merluccius productus*) on an offshore bank southwest of Vancouver Island, British Columbia. J. Fish. Res. Board Can. 29:1792–1795.

Parente, W. D., and G. R. Snyder. 1970. A pictorial record of the hatching and early development of the eulachon (*Thaleichthys pacificus*). Northwest Sci. 44:50–57.

Parks, N. B., F. R. Shaw, and R. L Henry. 1993. Results of a 1988 trawl survey of groundfish resources of the upper continental slope off Oregon. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-23. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-23.pdf [accessed 23 February 2010].

Parliament of Canada. 1900–1916. Annual report on the fisheries of British Columbia (1900–1916). *In* Sessional papers of the Dominion of Canada, Canadian Department of Marine Fisheries, Annual reports of the Inspector of Fisheries for British Columbia, 1900–1916.

Parnell, M. M., R. L. Emmett, and R. D. Brodeur. 2008. Ichthyoplankton community in the Columbia River plume off Oregon: Effects of fluctuating oceanographic conditions. Fish Bull. 106:161–173.

Parrish, R. H., C. S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceanogr. 1(2):175–203.

Payne, S. A., B. A. Johnson, and R. S. Otto. 1997. Proximate composition of some northeastern Pacific forage species. *In* Forage fishes in marine ecosystems, p. 721–724. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Rep. 97-01. Univ. Alaska Fairbanks.

Payne, S. A., B. A. Johnson, and R. S. Otto. 1999. Proximate composition of some northeastern Pacific forage fish species. Fish. Oceanogr. 8:159–177.

Pearsall, C. E. 1928. Autobiography of Clarence E. Pearsall. *In* C. E. Pearsall (ed.), History and genealogy of the Pearsall family in England and America, p. 1483–1757. H. S. Crocker Co., San Francisco.

Peden, A. E., and D. E. Wilson. 1976. Distribution of intertidal and subtidal fishes of northern British Columbia and southeastern Alaska. Syesis 9:221–248.

Pederson, R. V. K., U. N. Orr, and D. E. Hay. 1995. Distribution and preliminary stock assessment (1993) of the eulachon *Thaleichthys pacificus* in the lower Kitimat River, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2330. Online at http://dsp-psd.pwgsc.gc.ca/collection_2007/dfo-mpo/Fs97-4-2330E.pdf [accessed 23 February 2010].

Penttila, D. 2007. Marine forage fishes in Puget Sound. Puget Sound Nearshore Partnership Rep. 2007-03. Published by Army Corps of Engineers, Seattle District, Seattle, WA. Online at http://www.pugetsoundnearshore.org/technical_papers/marine_fish.pdf [accessed 23 February 2010].

Perez, M. A. 1994. Calorimetry measurements of energy value of some Alaskan fishes and squid. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-32.

Petersen, R. S. 2006. The role of traditional ecological knowledge in understanding a species and river system at risk: Pacific lamprey in the lower Klamath Basin. Master's thesis. Oregon State Univ., Corvallis.

Peterson, W. T., and J. E. Keister. 2003. Interannual variability in copepod community composition at a coastal station in the northern California Current: A multivariate approach. Deep-Sea Res. Pt. II Top. Stud. Oceanogr. 50:2499–2517.

PFMC (Pacific Fishery Management Council). 2008. Status of the Pacific Coast coastal pelagic species fishery and recommended acceptable biological catches. Stock assessment and fishery evaluation—2008. Online at http://www.pcouncil.org/bb/2008/0608/G1a_ATT1_0608.pdf [accessed 23 February 2010].

PFMC (Pacific Fishery Management Council) and NMFS (National Marine Fisheries Service). 2008. Management of krill as an essential component of the California Current ecosystem, Amendment 12 to the Coastal Pelagic Species Fishery Management Plan. Prepared by NMFS Southwest Region and Pacific Fishery Management Council. Online at http://www.pcouncil.org/wp-content/uploads/CPS_Am12_Krill_DraftEA.pdf [accessed 23 February 2010].

Phillips, A. J., S. Ralston, R. D. Brodeur, T. D. Auth, R. L. Emmett, C. Johnson, and V. G. Wespestad. 2007. Recent pre-recruit Pacific hake (M*erluccius productus*) occurrences in the northern California Current suggest a northward expansion of their spawning area. Calif. Coop. Ocean. Fish. Investig. Rep. 48:215–229.

Pickard, D., and D. R. Marmorek. 2007. A workshop to determine research priorities for eulachon, workshop report. Prepared by ESSA Technologies Ltd., Vancouver, BC, for Dept. Fisheries and Oceans Canada. Online at http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/2007eulawkshp.pdf [accessed 23 February 2010].

Pilling, A. R. 1978. Yurok. *In* R. F. Heizer (ed.), Handbook of North American Indians, Vol. 8, California, p. 137–154. Smithsonian Institution, Washington, DC.

Pitcher, K. W. 1980. Food of the harbor seal, *Phoca vitulina* Richards, in the Gulf of Alaska. Fish. Bull. 78: 544–549.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fish. Bull.. 79: 467–472.

Plate, E. M. 2009. Fraser River, Port Mann Bridge-Douglas Island eulachon study, 2009. LGL Limited, Environmental Research Associates, Sidney, BC, and Terra Remote Sensing Inc., Sidney, BC. Online at http://www.watershed-watch.org/publications/files/FraserEulachonReport-July15_2009.pdf [accessed 23 February 2010].

Pollock, C. R. 1925. Thirty-fourth and thirty-fifth annual reports of the state supervisor of fisheries for the period from April 1, 1923, to March 31, 1925. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Pollock, C. R. 1928. Thirty-sixth and thirty-seventh annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1925, to March 31, 1927. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Pollock, C. R. 1932. Fortieth and forty-first annual reports of the State Department of Fisheries and Game, Division of Fisheries, for the period from April 1, 1929, to March 31, 1931. Washington Dept. Fisheries and Game, Jay Thomas, public printer, Olympia.

Port of Kitimat. 2009. Investment summary, 2005–2015, from the Office of the Mayor: Joanne Monaghan. Online at http://www.kitimat.ca/assets/Business/PDFs/port-of-kitimat-investment-summary.pdf [accessed 23 February 2010].

Radcliffe, L. 1920. Fishery industries of the United States. Report of the Division of Statistics and Methods of the fisheries for 1918. Appendix X in Report of the U.S. Commissioner of Fisheries for the fiscal year 1918, with appendixes.

Ratti, F. 1979a. Natural resources of Umpqua estuary. Estuary inventory report, Vol. 2, No. 5. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Ratti, F. 1979b. Natural resources of Rogue estuary. Estuary inventory report, Vol. 2, No. 8. Oregon Dept. Fish and Wildlife, Research and Development Section, Portland.

Ray, C. 1960. The application of Bergmann's and Allen's rules to the poikilotherms. J. Morphol. 106:85–108.

Raymore Jr., P. A., and K. L. Weinberg. 1990. 1984 spring and autumn surveys of Pacific West Coast upper continental slope groundfish resources. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-179.

Reed, F. C. 1900. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-first regular session, 1901. Oregon Dept. Fisheries, W. H. Leeds, state printer, Salem.

Reed, F. C., E. P. Thompson, and R. C. Campbell. 1891. Third and fourth annual reports of the State Board of Fish Commissioners to the Governor of Oregon, sixteenth regular session legislative assembly, 1889–1890. F. C. Baker, state printer, Salem.

Reed, F. C., E. P. Thompson, and G. T. Myers. 1892. Fifth and sixth annual reports of the State Board of Fish Commissioners to the Governor of Oregon, 1891–1892. F. C. Baker, state printer, Salem.

Regonda, S. K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal cycle shifts in hydroclimatology over the western United States. J. Clim. 18:373–384.

Reimers, P. E., and K. J. Baxter. 1976. Fishes of Sixes River, Oregon. Information Rep. 76-4. Oregon Dept. Fish and Wildlife, Research Section, Salem.

Rexstad, E. A., and E. K. Pikitch. 1986. Stomach contents and food consumption estimates of Pacific hake, *Merluccius productus*. Fish. Bull. 84:947–956.

Reynolds, J. D., N. K. Dulvy, N. B. Goodwin, and J. A. Hutchings. 2005. Biology of extinction risk in marine fishes. Proc. R. Soc. Lond. Ser. B Biol. Sci. 272:2337–2344.

Rich, W. H. 1921. An instance of adult, sea-run Chinook salmon found feeding in freshwater. Calif. Fish Game 7:7–8.

Richardson, J. 1836. *Salmo* (*Mallotus*?) *pacificus* (Richardson) North-west Capelin. *In* Fauna Boreali-Americana; or the zoology of the northern parts of British America. Part third, the fish, p. 226–228. R. Bentley, London. (Reprint published 1974–1978 by Arno Press, New York).

Richardson, S. L., and W. G. Pearcy 1977. Coastal and oceanic fish larvae in an area of upwelling off Yaquina Bay, Oregon. Fish. Bull. 75:125–145.

Ricker, W. E., D. F. Manzer, and E. A. Neave. 1954. The Fraser River eulachon fishery, 1941–1953. Fish. Res. Board Can. Manuscr. Rep. 583.

Ridenhour, R. L., and T. D. Hofstra. 1994. Fishery resources of the Redwood Creek basin (California). Online at http://coastalwatersheds.ca.gov/Watersheds/NorthCoast/RedwoodCreek/RedwoodCreekBasin/RedwoodCreekAssessmentComponents/AnadromousSalmonidFisheryResources/tabid/193/Default.aspx [accessed 9 February 2010].

Riseland, J. L. 1907. Sixteenth and seventeenth annual reports of the state fish commissioner and game warden to the governor of the State of Washington. C. W. Corham, public printer, Olympia.

Riseland, J. L. 1909. Eighteenth and nineteenth annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington, 1907–1908. E. L. Boardman, public printer, Olympia.

Riseland, J. L. 1911. Twentieth and twenty-first annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington 1909–1910. E. L. Boardman, public printer, Olympia.

Riseland, J. L. 1913. Twenty-second and twenty-third annual reports of the state fish commissioner and ex-officio game warden to the governor of the State of Washington. Dept. Fisheries and Game, Frank Lamborn, public printer, Olympia.

Robinson, D. G., W. E. Barraclough, and J. D. Fulton. 1968a. Data record. Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, May 1–4, 1967. Fish. Res. Board Can. Manuscr. Rep. Ser. 964.

Robinson, D. G., W. E. Barraclough, and J. D. Fulton. 1968b. Data record. Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, June 5–9, 1967. Fish. Res. Board Can. Manuscr. Rep. Ser. 972.

Roemmich, D., and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324–1326.

Roffe, T., and B. Mate. 1984. Abundance and feeding habits of pinnipeds in the Rogue River, OR. J. Wildl. Manag. 48:1262–1274.

Rogers, B. J., M. E. Wangerin, K. J. Garrison, and D. E. Rogers. 1980. Epipelagic meroplankton, juvenile fish, and forage fish: Distribution and relative abundance in coastal waters near Yakutat. Interim report to Outer Continental Shelf Environmental Assessment Program. Univ. Washington, College of Fisheries, Fisheries Research Institute, Seattle.

Rogers, I. H., I. K. Birtwell, and G. M. Kruzynski. 1990. The Pacific eulachon (*Thaleichthys pacificus*) as a pollution indicator organism in the Fraser River estuary, Vancouver, British Columbia. Sci. Total Environ. 97(98):713–727.

Rohner, R. P. 1967. The people of the Gilford: A contemporary Kwakiutl village. Natl. Mus. Canada Bull. 225, Anthropol. Ser. 83.

Rollins, P. A. (ed.). 1995. The discovery of the Oregon Trail: Robert Stuart's narratives of his overland trip eastward from Astoria in 1812–13. University of Nebraska Press, Lincoln. (Originally published in 1935 by Edward Eberstadt & Sons, New York).

Romano, M. D., M. D. Howell, and T. A. Rien. 2002. Use of an artificial substrate to capture eulachon eggs in the lower Columbia River. *In* Report C: Eulachon studies related to lower Columbia River channel deepening operations. Contract no. W66QKZ13237198. Final rep. by Oregon Dept. Fish and Wildlife to the U. S. Army Corps of Engineers, Portland.

Rosetta, T., and D. Borys. 1996. Identification of sources of pollutants to the lower Columbia River basin. Oregon Dept. Environmental Quality, prepared for the Lower Columbia River Bi-state Program. Online at http://www.lcrep.org/pdfs/58.%2002750.pdf [accessed 23 February 2010].

Ross, A. 1849. Adventures of the first settlers on the Oregon or Columbia River &c. Alexander Ross, London. Reprinted in 1986 as Adventures of the first settlers on the Oregon or Columbia River, 1810–1813. University of Nebraska Press, Lincoln.

Roye, C. 1979. Natural resources of Coos Bay estuary. Estuary inventory rep., Vol. 2, No. 6. Oregon Dept. Fish and Wildlife, Corvallis.

Rugh, D. J., K. E. W. Shelden, and B. A. Mahoney. 2000. Distribution of belugas in Cook Inlet during June, July 1993–2000. Mar. Fish. Rev. 62(3):6.

Ruzicka, J. J., R. D. Brodeur, and T. J. Wainwright. 2007. Seasonal food web models for the Oregon inner-shelf ecosystem: Investigating the role of large jellyfish. Calif. Coop. Ocean. Fish. Investig. Rep. 48:106–128.

Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. J. Fish Biol. 59(Suppl. A):90–108.

Samis, S. C. 1977. Sampling eulachon eggs in the Fraser River using a submersible pump. Tech. Rep. PAC/T-77-18. Department of Fisheries and the Environment, Pacific Region, Water Quality Division Habitat Protection Directorate, Vancouver, BC.

Sanderson, B. L., K. A. Barnas, and A. M. W. Rub. 2009. Nonindigenous species of the Pacific Northwest: An overlooked risk to endangered salmon? Bioscience 59:245–256.

Sandy River Basin Partners. 2005. Sandy River basin characterization report. Online at http://www.sandyriverpartners.org/pdfs/SRBCR7-20-05.pdf (accessed 23 February 2010].

Sangster, G. I., K. M. Lehmann, and M. Breen. 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh codends. Fish. Res. 25:323–345.

Schade, C. B., and S. A. Bonar. 2005. Distribution and abundance of nonnative fishes in streams of the western United States. N. Am. J. Fish. Manag. 25:1386–1394.

Schlosser, I. J., and P. L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: Conceptual models, empirical evidence, and implications for conservation. *In* J. L. Nielsen (ed.), Evolution and the aquatic ecosystem: Defining unique units in population conservation, p. 392–401. Am. Fish. Soc. Symp. 17, Bethesda, MD.

Schoettler, R. J. 1953. Washington Department of Fisheries 62nd annual report. Washington Dept. Fisheries, Olympia.

Schultz, L. P., and A. C. DeLacy. 1935. Fishes of the American Northwest. J. Pan-Pacific Res. Inst. 10:365–380.

Schweigert, J., B. McCarter, T. Therriault, L. Flostrand, C. Hrabok, P. Winchell, and D. Johannessen. 2007. Ecosystem overview: Pacific North Coast Integrated Management Area (PNCIMA), Appendix H: Pelagic fishes. Can. Tech. Rep. Fish. Aquat. Sci. 2667. Online at http://www.dfo-mpo.gc.ca/library/328842%20Appendix%20H.pdf [accessed 24 February 2010].

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184.

Sette, O. E. 1926. Fishery industries of the United States. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1925, and appendixes, p. 209–408. Bureau of Fisheries document 997. Appendix VII.

Sette, O. E. 1928. Fishery industries of the United States, 1926. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1927, with appendixes, p. 337–483. Bureau of Fisheries document 1025.

Sette, O. E., and R. H. Fiedler. 1929. Fishery industries of the United States, 1927. *In* Report of the U.S. Commissioner of Fisheries for the fiscal year 1928, with appendixes, p. 401–547. Bureau of Fisheries document 1050.

Shaffer, J. A., D. Penttila, M. McHenry, and D. Vilella. 2007. Observations of eulachon, *Thaleichthys pacificus*, in the Elwha River, Olympic Peninsula, Washington. Northwest Sci. 81:76–81.

Shaw, F. R., M. E. Wilkins, K. L. Weinberg, M. Zimmermann, and R. R. Lauth. 2000. The 1998 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/NOAA-TM-AFSC-114.pdf [accessed 24 February 2010].

Shepherd, J. G., J. G. Pope, and R. D. Cousens. 1984. Variations in fish stocks and hypotheses concerning their links with climate. Cons. Perm. Int. Explor. Mer Rapp. P.-V. Reun. 185:255–267.

Sherwood, C. R., D. A. Jay, R. B. Harvey, P. Hamilton, and C. A. Simenstad. 1990. Historical changes in the Columbia River estuary. Prog. Oceanogr. 25:299–352.

Sidwell, V. D. 1981. Chemical and nutritional composition of finfishes, whales, crustaceans, mollusks, and their products. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/SEC-11.

Sigler, M. F., J. N. Womble, and J. J. Vollenweider. 2004. Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: A prespawning aggregation of eulachon (*Thaleichthys pacificus*). Can. J. Fish. Aquat. Sci. 61:1475–1484.

Simenstad, C. A., A. J. Wick, J. R. Cordell, R. M. Thom, and G. D. Williams. 2001. Decadal development of a created slough in the Chehalis River estuary: Year 2000 results. Report to U.S. Army Corps of Engineers, Seattle District, SAFS-UW-0110. Univ. Washington, School of Aquatic and Fishery Sciences, Seattle.

Sinclair, M., and M. J. Tremblay. 1984. Timing of spawning of Atlantic herring (*Clupea harengus harengus*) populations and the match-mismatch theory. Can. J. Fish. Aquat. Sci. 41:1055–1065.

Small, M., J. Loxterman, A. Frye, J. Von Bargen, C. Bowman, and S. Young. 2005. Temporal and spatial genetic structure among some Pacific herring population in Puget Sound and the southern Strait of Georgia. Trans. Am. Fish. Soc. 134:1329–1341.

Smedbol, R., and R. Stephenson. 2001. The importance of managing within-species diversity in cod and herring fisheries of the northwestern Atlantic. J. Fish Biol. 59(Suppl. A):109–128.

Smith, R. T. 1941 (unpubl. manuscr.). Notes on 1941 Nemah River (Washington) smelt run. Typewritten manuscript. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.

Smith, W. E., and R. W. Saalfeld. 1955. Studies on Columbia River smelt *Thaleichthys pacificus* (Richardson). Washington Dept. Fisheries, Olympia. Fish. Res. Pap. 1(3):3–26.

Smith, W. E., R. W. Saalfeld, E. H. LeMier, J. M. Smith, E. L. Preston, and C. O. Junge. 1953. 1953 smelt investigations, January through April. *In* Columbia River progress report, January through April 1953, p. 3–15. Washington Dept. Fisheries, Olympia.

Snyder, G. R. 1970. Thermal pollution of Columbia River might threaten smelt. Commer. Fish. Rev. 32(12):58–64.

Snyder, G. R., and T. H. Blahm. 1971. Effects of increased temperature on cold-water organisms. J. Water Poll. Control Fed. 43:890–899.

Snyder, M. A., L. C. Sloan, N. S. Diffenbaugh, and J. L. Bell. 2003. Future climate change and upwelling in the California Current. Geophys. Res. Lett. 30 (15):1823. Online at http://dx.doi.org/ [DOI name 10.1029/2003GL017647, accessed 24 February 2010].

Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Bull. Fish. Res. Board Can. 146.

Spangler, E. A. K. 2002. The ecology of eulachon (*Thaleichthys pacificus*) in Twentymile River, Alaska. Master's thesis. Univ. Alaska Fairbanks.

Spangler, E., R. Spangler, and B. Norcross. 2003. Eulachon subsistence use and ecology investigations of Cook Inlet, 2000–2002. Fisheries Resource Monitoring Program, Final Rep. 00-041. U.S. Fish and Wildlife Service, Office of Subsistence Management, Anchorage, AK.

Speckman, S. G., and J. F. Piatt. 2000. Historic and current use of Lower Cook Inlet, Alaska, by belugas, *Delphinapterus leucas*. Mar. Fish. Rev. 62(3):22–26.

Stables, T. B., C. J. Perrin, and M. L. Rosenau. 2005. Acoustic and trawl surveys to locate eulachon aggregations in the lower Fraser River, British Columbia. N. Am. J. Fish. Manag. 25:675–688.

Stacey, D. A. 1995. Eulachon: An historical overview. Common resources fishery research, report prepared for Department of Fisheries and Oceans Canada.

Stansby, M. E. 1976. Chemical characteristics of fish caught in the northeast Pacific Ocean. Mar. Fish. Rev. 38(9):1–11.

Stark, J. W., and D. M. Clausen. 1995. Data report: 1990 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-49. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-49.pdf [accessed 24 February 2010].

Starlund. G. C. 1960. 1960 annual report. Washington Dept. Fisheries, Olympia.

Stewart, F. L. 1975. The seasonal availability of fish species used by the coast Tsimshians of northern British Columbia. Syesis 8:375–388.

Stewart, H. 1977. Indian fishing: Early methods on the Northwest Coast. University of Washington Press, Seattle.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes towards earlier streamflow timing across western North America. J. Clim. 18:1136–1155.

Stockley. C. 1981. Smelt deadline in Cowlitz River. Memorandum. Washington Dept. Fisheries, Vancouver.

Stockley, C. E., and I. E. Ellis. 1970. Otter trawl trials for Columbia River smelt with associated notes and recommendations. Columbia River investigations supplemental progress report. Washington Dept. Fisheries, Management and Research Division, Olympia.

Stoffels, D. 2001. Background report: Eulachon in the north coast. Royal British Columbia Museum, Living Landscapes Outreach Program, Victoria, BC. Online at http://www.livinglandscapes.bc.ca/northwest/eulachon/resources/NCeulachon.pdf [accessed 24 February 2010].

Stout, H. A., R. G. Gustafson, W. H. Lenarz, B. B. McCain, D. M. Van Doornik, T. L. Builder, and R. D. Methot. 2001a. Status review of Pacific herring in Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-45. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm45/tm45.htm [accessed 24 February 2010].

Stout, H. A., B. B. McCain, R. D. Vetter, T. L. Builder, W. H. Lenarz, L. L. Johnson, and R. D. Methot. 2001b. Status review of copper rockfish, quillback rockfish, and brown rockfish in Puget Sound, Washington. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-46. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm46/tm46.htm [accessed 24 February 2010].

Stroud, R. K., C. H. Fiscus, and H. Kajimura. 1981. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington. Fish. Bull. 78:951–959.

Suchman, C. L., and R. D. Brodeur. 2005. Abundance and distribution of large medusae in surface waters of the northern California Current. Deep-Sea Res. Pt. II Top. Stud. Oceanogr. 52:51–72.

Suchman, C. L., E. A. Daly, J. E. Keister, W. T. Peterson, and R. D. Brodeur. 2008. Feeding patterns and predation potential of scyphomedusae in a highly productive upwelling region. Mar. Ecol. Progr. Ser. 358:161–172.

Suckley, G. 1860. Report on the fishes collected on the survey. Chapter I. Report upon the Salmonidae. *In* Reports of explorations and surveys: To ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, p. 307–368. Pacific Railroad Rep. 12 (Pt. III), No. 5.

Suckley, G., and J. G. Cooper. 1860. The natural history of Washington Territory and Oregon with much relating to Minnesota, Nebraska, Kansas, Utah, and California, between the thirty-sixth and forty-ninth parallels of latitude, being those parts of the final reports on the survey of the Northern Pacific Railroad route, relating to the natural history of the regions explored, with full catalogues and descriptions of the plants and animals collected from 1853 to 1860. Baillière Brothers, New York.

Summers, C. G. 1982. About Kelso, an historical gem, Cowlitz County, Washington. Speedy Litho Press, Longview.

Sutherland, R. 2001. Oolichan fishery of northern British Columbia. B. C. Hist. News 34:8–13.

Suuronen, P. 2005. Mortality of fish escaping trawl gears. FAO Fish. Tech. Pap. 478. FAO Rome.

Suuronen, P., J. A. Perez-Comas, E. Lehtonen,, and V. Tschernij. 1996. Size-related mortality of herring (*Clupea harengus* L.) escaping through a rigid sorting grid and trawl codend meshes. ICES J. Mar. Sci. 53:691–700.

Swain, D. P. 1999. Changes in the distribution of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence–Effects of environmental change or change in environmental preferences? Fish. Oceanogr. 8:1–17.

Swan, J. G. 1881. The eulachon or candle-fish of the Northwest Coast. Proc. U.S. Nat. Mus. (1880) 3:257–264.

Sweetnam, D. A., R. D. Baxter, and P. B. Moyle. 2001. True smelts. *In* W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson (eds.), California's living marine resources: A status report, p. 472–479. California. Dept. Fish and Game, Sacramento.

Sytsma, M. D., J. R. Cordell, J. W. Chapman, and R. C. Draheim. 2004. Lower Columbia River aquatic nonindigenous species survey 2001–2004. Final Tech. Rep. October + appendices. Prepared for the U.S. Coast Guard and the U.S. Fish and Wildlife Service. Online at http://www.clr.pdx.edu/docs/LCRANSFinalReport.pdf [accessed 24 February 2010].

Tanasichuk, R. W., D. M. Ware, W. Shaw, and G. A. McFarlane. 1991. Variations in diet, daily ration, and feeding periodicity of Pacific hake (*Merluccius productus*) and spiny dogfish (*Squalus acanthias*) off the lower west coast of Vancouver Island. Can. J. Fish. Aquat. Sci. 48:2118–2128.

Tetra Tech. 1996. Lower Columbia River bi-state program: The health of the river 1990–1996. Tetra Tech integrated Tech. Rep. 0253-01. Redmond, WA. Online at http://www.lcrep.org/pdfs/59.%2002939.pdf [accessed 24 February 2010].

Therriault, T. W., and P. B. McCarter. 2005. Using an eulachon indicator framework to provide advice on Fraser River harvest opportunities for 2006. Canadian Science Advisory Secretariat research document 2005/077.

Thomas, D. W. 1983. Changes in Columbia River estuary habitat types over the past century. Columbia River Estuary Data Development Program (CREDDP), Columbia River Estuary Study Taskforce, Astoria, OR.

Thompson, G. G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-198. Online at http://www.nwfsc.noaa.gov/publications/techmemos/tm198/index.html [accessed 24 February 2010].

Thomson, R. E. 1981. Oceanography of the British Columbia coast. Can. Spec. Publ. Fish Aquat. Sci. 56.

Tilman, D., and C. L. Lehman. 1997. Habitat destruction and species extinctions. *In* D. Tilman and P. Kareiva (eds.), Spatial ecology: The role of space in population dynamics and interspecific interactions, p. 233–249. Princeton University Press, NJ.

Trihey and Associates. 1996. Instream flow requirements for tribal trust species in the Klamath River. Prepared for the Yurok Tribe, Eureka, CA, by Trihey and Associates Inc., Concord, CA.

Tutty, B. D., and J. A. Morrison. 1976. Dredge monitoring capture data and entrainment estimates during the 1976 juvenile salmonid migration in the lower Fraser River. Tech. Rep. Ser. No. PAC/T-76-21. Environment Canada, Fisheries and Marine Service, Pacific Region, Habitat Protection Directorate.

Urrutia, V. 1998. They came to six rivers: The story of Cowlitz County. Cowlitz County Historical Society, Kelso, WA.

USACE (U.S. Army Corps of Engineers). 1952. Columbia River and tributaries, northwestern United States: Letter from the secretary of the army transmitting a letter from the chief of engineers, United States Army, dated June 28, 1949, submitting a report, together with accompanying papers and illustrations, on a review of reports on, and preliminary examinations and surveys of, the Columbia River and tributaries, northwestern United States, made pursuant to several congressional authorizations listed in the report. In eight volumes, Volume VII. House Document No. 531, 81st Congress, 2nd session. U.S. Govt. Printing Office, Wash., DC.

USACE (U.S. Army Corps of Engineers). 2007. Mount St. Helens project lower Cowlitz River interim dredging environmental assessment. Draft 13 June 2007. U.S. Army Corps of Engineers, Portland District, OR.

USFWS-NMFS (U.S. Fish and Wildlife Service and National Marine Fisheries Service). 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register, 7 February 1996, 61(26):4722–4725.

Valentine, J. W. 1966. Numerical analysis of marine molluscan ranges on the extratropical northeastern Pacific shelf. Limnol. Oceanogr. 11:198–211.

VanBlaricom, G., M. Neuman, J. Butler, A. DeVogelaere, R. Gustafson, C. Mobley, D. Richards, S. Rumsey, and B. Taylor. 2009. Status review report for black abalone (*Haliotis cracherodii* Leach, 1814). Online at http://swr.nmfs.noaa.gov/bfrp/BASR_Report_Final_8_Jan_2009-ver4.pdf [accessed February 2009].

Van Dusen, H. G. 1903. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-second regular session, 1903. Oregon Dept. Fisheries, W. H. Leeds, state printer, Salem.

Van Dusen, H. G. 1904. Annual reports of the Department of Fisheries of the State of Oregon for the years 1903 and 1904 to the twenty-third Legislative Assembly (regular session), 1905. Oregon Dept. Fisheries, J. R. Whitney, state printer, Salem.

Van Dusen, H. G. 1907. Annual reports of the Department of Fisheries of the State of Oregon to the Legislative Assembly, twenty-fourth regular session, 1909. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Van Dusen, H. G., and H. C. McCallister. 1908. Annual reports of the Department of Fisheries of the State of Oregon for the years 1907–1908 to the twenty-fifth Legislative Assembly, regular session, 1909. Oregon Dept. Fisheries, Willis S. Duniway, state printer, Salem.

Vincent-Lang, D. S., and I. Queral. 1984. *In* C. C. Estes and D. Vincent-Lang (eds.), Eulachon spawning habitat in the lower Susitna River. Susitna Hydro Aquatic Studies Report No. 3, Chapter 5, Aquatic habitat and instream flow investigations, May-October 1983. Alaska Power Authority Doc. No. 1934.

Vincik, R. F., and R. G. Titus. 2007. Occurrence of a eulachon, *Thaleichthys pacificus*, in the Lower Sacramento River, California. Calif. Fish Game 93:161–165.

von Szalay, P. G., M. E. Wilkins, and M. M. Martin. 2008. Data report: 2007 Gulf of Alaska bottom trawl survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-189. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-189.pdf [accessed 24 February 2010].

Wade, G. 2000a. Salmon and steelhead habitat limiting factors: Water Resource Inventory Area 27. WRIA 27 final report. Washington State Conservation Commission, Olympia.

Wade, G. 2000b. Salmon and steelhead habitat limiting factors: Water Resource Inventory Area 26. WRIA 26 final report. Washington State Conservation Commission, Olympia.

Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, J. A. Hurtado, W. G. Mullarkey, P. E. Reimers, N. T. Richmond, and T. J. Rumreich. 1990. Coos River basin fish management plan. Online at https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/6771/coos+river+basin.pdf;jsessionid=72F413C7D0DCF1D47062D792892BF9C8?sequence=1 [accessed 18 March 2010].

Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, W. G. Mullarkey, N. T. Richmond, and T. J. Rumreich. 1988. Coos Bay Fish Management Plan. Draft No.3. Oregon Dept. Fish and Wildlife, Corvallis (as cited in Monaco et al. 1990).

Wainwright, T. C., and R. G. Kope. 1999. Short communication: Methods of extinction risk assessment developed for U.S. West Coast salmon. ICES J. Mar. Sci. 56:444–448.

Waldman, J. R. 2005. Meristics. *In* S. X. Cadrin, K. D. Friedland, and J. R. Waldman (eds.), Stock identification methods applications in fishery science, p. 197–207. Elsevier Academic Press, Amsterdam.

Waldron, K. D. 1972. Fish larvae collected from the northeastern Pacific Ocean and Puget Sound during April and May 1967. U.S. Dept. Commer., NOAA Tech. Rep. NMFS-SSRF-663.

Ward, D., R. Robison, G. Nye, and D. Reed. 1971. 1970 fisheries statistical report. Washington Dept. Fisheries, Olympia.

Ware, D. M., and G. A. McFarlane. 1989. Fisheries production domains in the northeast Pacific Ocean. *In* R. J. Beamish, and G. A. McFarlane (eds.), Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108:359–379.

Ware, D. M., and G. A. McFarlane. 1995. Climate-induced changes in Pacific hake (*Merluccius productus*) abundance and pelagic community interactions in the Vancouver Island upwelling system. Can. Spec. Publ. Fish. Aquat. Sci. 121:509–521.

Ware, D. M., and R. E. Thomson. 1991. Link between long-term variability in upwelling and fish production in the northeast Pacific Ocean. Can. J. Fish. Aquat. Sci. 48:2296–2306.

WDFHMD (Washington Dept. Fisheries Habitat Management Division). 1992. Salmon, marine fish and shellfish resources, and associated fisheries in Washington's coastal and inland marine waters. Tech. Rep. 79. Washington Dept. Fisheries, Olympia.

WDFW (Washington Dept. Fish and Wildlife). 2009. Final season smelt update, Tuesday–March 31, 2009. Online at http://wdfw.wa.gov/fish/creel/smelt/2009/mar3109.pdf [accessed 24 February 2010].

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2001. Washington and Oregon Eulachon Management Plan. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem. Online at http://wdfw.wa.gov/fish/creel/smelt/wa-ore_eulachonmgmt.pdf [accessed 24 February 2010].

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2002. Status report Columbia River fish runs and fisheries 1938–2000. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem.

WDFW (Washington Dept. Fish and Wildlife) and ODFW (Oregon Dept. Fish and Wildlife). 2008. Summary of questions and requested information. Washington Dept. Fish and Wildlife, Olympia, and Oregon Dept. Fish and Wildlife, Salem.

Weinberg, K. L., M. E. Wilkins, and T. A. Dark. 1984. The 1983 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-70.

Weinberg, K. L., M. E. Wilkins, R. R. Lauth, and P. A. Raymore Jr. 1994a. The 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-33.pdf [accessed 24 February 2010].

Weinberg, K. L., M. Zimmermann and R. R. Lauth. 1994b. Appendices to the 1989 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-33.

Weinberg, K. L., M. E. Wilkins, F. R. Shaw, and M. Zimmermann. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-128.pdf [accessed 24 February 2010].

Weitkamp, L. 2010. Marine distributions of Chinook salmon from the West Coast of North America determined by coded wire tag recoveries. Trans. Am. Fish. Soc. 139:147–170.

Weitkamp, L., and K. Neely. 2002. Coho salmon (*Oncorhynchus kisutch*) ocean migration patterns: Insight from marine coded-wire tag recoveries. Can. J. Fish. Aquat. Sci. 59:1100–1115.

Wendler, H. O., and G. Nye. 1962. Columbia River investigations progress report, January through December, 1959. Washington Dept. Fisheries, Research Division, Olympia.

Wilcox, W. A. 1898. Notes on the fisheries of the Pacific coast in 1895. Report of the U.S. Commissioner of Fish and Fisheries for the year ending June 30, 1896, XXII:575–659. U.S. Government Printing Office, Washington, DC.

Wilcox, W. A. 1907. The commercial fisheries of the Pacific coast states in 1904. Bureau of Fisheries document 612. *In* Report of the Commissioner of Fisheries for the fiscal year 1905 and special papers. U.S. Government Printing Office, Washington, DC.

Wilkins, M. E. 1998. Appendices to the 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/ Publications/AFSC-TM/NOAA-TM-AFSC-89a.pdf [accessed 24 February 2010].

Wilkins, M. E., and F. R. Shaw. 2000. Appendices to the 1998 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-114. Online at http://www.afsc.noaa

.gov/Publications/AFSC-TM/NOAA-TM-AFSC-114/Appendices%20to%20NOAA-TM-AFSC-114.pdf [accessed 24 February 2010].

Wilkins, M. E., and K. L. Weinberg. 2002. Appendices to the 2001 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-128. Online at http://www.afsc.noaa.gov/race/media/publications/archives/pubs2002/techmemo128_append.pdf [accessed 24 February 2010].

Wilkins, M. E., M. Zimmermann, and K. L. Weinberg. 1998. The 1995 Pacific West Coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length and age composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-89. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-89.pdf [accessed 24 February 2010].

Williams, S. 2009. Letter from S. Williams (Assistant Fish Division Administrator, Oregon Dept. Fish and Wildlife) to G. Griffin (Protected Resources Division, NMFS Northwest Region) 12 May 2009, re: Comments on federal proposed rule to list Pacific eulachon as threatened. (Available from NMFS, Protected Resources Division, 1201 NE Lloyd Blvd., Suite 1100, Portland, OR 97232.)

Willoughby, C. 1889. Indians of the Quinaielt [sic] Agency, Washington Territory. *In* Annual report of the Smithsonian Institution, year ending June 30, 1886, Part 1, p. 267–282. Smithsonian Institution, Washington, DC.

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K Koski. 2006. Eulachon: A review of biology and an annotated bibliography. Alaska Fisheries Science Center Processed Rep. 2006-12. U.S. Dept. Commer., AFSC, Auke Bay Laboratory, Juneau. Online at http://www.afsc.noaa.gov/publications/ProcRpt/PR%202006-12.pdf [accessed 24 February 2010].

Willson, M. F., and B. F. Marston. 2002. Fishing success of gulls at a Southeast Alaskan smelt run. J. Field Ornithol. 73:91–96.

Witteveen, B. H., R. J. Foy, and K. M. Wynne. 2004. The effect of predation (current and historical) by humpback whales (*Megaptera novaeangliae*) on fish abundance near Kodiak Island, Alaska. Fish. Bull. 104:10–20.

Womble, J. N. 2003. Seasonal distribution of Steller sea lions (*Eumetopias jubatus*) in relation to high-quality ephemeral prey species in southeastern Alaska. Master's thesis. Univ. Alaska Fairbanks.

Womble, J. N., and M. F. Sigler. 2006. Seasonal availability of abundant, energy-rich prey influences the abundance and diet of a marine predator, the Steller sea lion *Eumetopias juhatus*. Mar. Ecol. Progr. Ser. 325:281–293.

Womble, J. N., M. F. Sigler, and M. F. Willson. 2009. Linking seasonal distribution patterns with prey availability in a central-place forager, the Steller sea lion. J. Biogeogr. 36:439–451.

Womble, J. N., M. F. Willson, M. F. Sigler, B. P. Kelly, and G. R. VanBlaricom. 2005. Distribution of Steller sea lions *Eumetopias jubatus* in relation to spring-spawning fish in Southeast Alaska. Mar. Ecol. Progr. Ser. 294:271–282.

Wood, C. C., J. W. Bickham, J. Nelson, C. J. Foote, and J. C. Patton. 2008. Recurrent evolution of life history ecotypes in sockeye salmon: Implications for conservation and future evolution. Evol. Appl. 1:207–221.

Workman, L. J. 1997. Land of trees: Scannings from Quinault Country, the Grays Harbor Region, and beyond 1774–1997. Quinault Indian Nation, Taholah, WA.

Wright, S. 1999. Petition to list eulachon *Thaleichthys pacificus* as threatened or endangered under the Endangered Species Act. Online at http://www.nwr.noaa.gov/Other-Marine-Species/upload/ Smelt_Petition_7_99.pdf [accessed 24 February 2010].

Wydoski, R. S., and R. R. Whitney. 2003. Inland fishes of Washington, second edition, revised and expanded. University of Washington Press, Seattle.

Yang, M. S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-22. Online at http://www.afsc .noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-22.pdf [accessed 24 February 2010].

Yang, M. S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-164. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-164.pdf [accessed 24 February 2010.

Yang, M. S., and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-112. Online at http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-112.pdf [accessed 24 February 2010].

Young, J. S. 1984. Identification of larval smelt (Osteichthyes: Salmoniformes: Osmeridae) from northern California. Master's thesis. Humboldt State Univ., Arcata, CA.

Zamon, J. E., and D. W. Welch. 2005. Rapid shift in zooplankton community composition on the northeast Pacific shelf during the 1998–1999 El Niño-La Niña event. Can. J. Fish. Aquat. Sci. 62:133–144.

Zeidberg, L. D., and B. H. Robison. 2007. Invasive range expansion by the Humboldt squid, *Dosidicus gigas,* in the eastern North Pacific. Proc. Natl. Acad. Sci. USA 104:12948–12950.

Zhang, Y., J. M. Wallace, and D. S. Battisti. 1997. ENSO-like interdecadal variability. J. Clim. 10:1004–1020.

Zimmermann, M. 1994. Appendices to the 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

Zimmermann, M., M. E. Wilkins, R. R. Lauth, and K. L. Weinberg. 1994. The 1992 Pacific west coast bottom trawl survey of groundfish resources: Estimates of distribution, abundance, and length composition. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-42.

# Appendix A: Life History Tables

This appendix contains the following tables:

Table A-1. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **California** | | | |
| Sacramento River | Single fish | | Vincik and Titus 2007 |
| Gualala River | Anecdotal | | Fry 1979 |
| Jacoby and Jolly Giant creeks | Rare | Humboldt Bay | Jennings 1996 |
| Mad River | Irregular | | Moyle et al. 1995, Moyle 2002 |
| Redwood Creek | Irregular | | Moyle et al. 1995, Moyle 2002 |
| Klamath River | Regular | | Moyle et al. 1995, Moyle 2002 |
| Smith River | Rare | | Moyle et al. 1995, Moyle 2002 |
| **Oregon** | | | |
| Winchuk River | Unknown | | Willson et al. 2006 |
| Chetco River | | Chetco Estuary | WDFW and ODFW 2008 |
| Pistol River | Unknown | | Willson et al. 2006 |
| Hunter Creek | Unknown | | Willson et al. 2006 |
| Rogue River | Unknown | | Roffe and Mate 1984 |
| Euchre Creek | Unknown | | Willson et al. 2006 |
| Elk River | Unknown | | Willson et al. 2006 |
| Sixes River | Unknown | Sixes Estuary | Reimers and Baxter 1976 |
| Coquille River | Unknown | | Gaumer et al. 1973, Kreag 1979 |
| Coos Bay/ River | Unknown | Coos Bay | Cummings and Schwartz 1971 |
| Umpqua River | Unknown | Umpqua Estuary | OFC 1970, Johnson et al. 1986 |
| Tenmile Creek (drains lake system) | Unknown | | Willson et al. 2006 |
| Siuslaw River | Unknown | | Willson et al. 2006 |
| Tenmile Creek | Irregular | | WDFW and ODFW 2008 |
| Yaquina River | Unknown | | Borgerson et al. 1991, Willson et al. 2006 |
| Clatskanie River | One-time | Columbia River | Williams 2009 |
| Sandy River | Irregular | Columbia River | WDFW and ODFW 2008 |
| Tanner Creek | One-time | Columbia River | WDFW and ODFW 2008 |
| Hood River | Anecdotal | Columbia River | Smith and Saalfeld 1955 |
| **Washington** | | | |
| Columbia River mainstem | Regular | Columbia River | Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008 |
| Grays River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Skamokawa Creek | Irregular | Columbia River | WDFW and ODFW 2001, 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **Washington, continued** | | | |
| Elochoman River | Irregular | Columbia River | WDFW and ODFW 2001, 2008 |
| Cowlitz River | Regular | Columbia River | Smith and Saalfeld 1955, WDFW and ODFW 2001, 2008 |
| Toutle River | Occasional | Columbia River | WDFW and ODFW 2008 |
| Kalama River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Lewis River | Regular | Columbia River | WDFW and ODFW 2001, 2008 |
| Washougal River | Unknown | Columbia River | WDFW and ODFW 2008 |
| Klickitat River | Anecdotal | Columbia River | Smith and Saalfeld 1955 |
| Bear River | Occasional | Willapa Bay | WDFW and ODFW 2001, 2008 |
| Naselle River | Occasional | Willapa Bay | WDFW and ODFW 2001, 2008 |
| Nemah River | Unknown | Willapa Bay | Smith 1941, WDFW and ODFW 2001, 2008 |
| Wynoochie River | Unknown | | WDFW and ODFW 2001, 2008 |
| Quinault River | Occasional | | WDFW and ODFW 2001, 2008 |
| Queets River | Occasional | | WDFW and ODFW 2001, 2008 |
| Quillayute River | Unknown | | WDFW and ODFW 2008 |
| Elwha River | Occasional | | Shaffer et al. 2007 |
| Puyallup River | Unknown | | Miller and Borton 1980 |
| **British Columbia** | | | |
| Fraser River | Regular | Fraser Estuary | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Squamish River | Irregular | Howe Sound | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Homathko River | Irregular | Bute Inlet-Johnstone Strait | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Stafford/Apple rivers | Unknown | Loughborough Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Port Neville | Unknown | Johnstone Strait | Hay and McCarter 2000, Hay 2002 |
| Franklin River | Unknown | Knight Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Klinaklini River | Regular | Knight Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kakweiken River | Unknown | Thompson Sound-Johnstone Strait | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kingcome River | Regular | Kingcome Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Nekite River | Unknown | Smith Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Hardy Inlet | Unknown | Rivers Inlet | Hay and McCarter 2000, Hay 2002 |
| Clyak River | Unknown | Moses Inlet-Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Wannock River | Regular | Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **British Columbia, continued** | | | |
| Chuckwalla/Kilbella rivers | Regular | Rivers Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kwatna River | Unknown | Burke Channel-Kwatna Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Quatlena River | Unknown | Burke Channel-Kwatna Inlet | Moody 2008 |
| Cascade Inlet | Unknown | Dean Channel | Hay and McCarter 2000, Hay 2002 |
| Skowquiltz River | Unknown | Dean Channel | Hay and McCarter 2000, Hay 2002 |
| Taleomy River | Unknown | Dean Channel-South Bentinck Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Noeick River | Unknown | Dean Channel-South Bentinck Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Aseek River | Unknown | Dean Channel-South Bentinck Arm | Moody 2008 |
| Kimsquit River | Regular | Dean Channel | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Dean River | Regular | Dean Channel | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Necleetsconay River/Paisla Creek | Regular | Dean Channel-North Bentick Arm | Moody 2008 |
| Bella Coola River | Regular | Dean Channel-North Bentick Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kainet or Lard Creek | Unknown | Kynoch Inlet-Mathieson Channel | Hay and McCarter 2000, Hay 2002 |
| Aaltanhash River | Unknown | Princess Royal Channel-Aaltanhash Inlet | Hay and McCarter 2000, Hay 2002 |
| Khutze River | Unknown | Princess Royal Channel-Khutze Inlet | Hay and McCarter 2000, Hay 2002 |
| Kemano/Wahoo rivers | Regular | Gardner Canal-Kemano Bay | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kowesas River | Regular | Gardner Canal-Chief Matthew's Bay | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Kitlope River | Regular | Gardner Canal | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Foch Lagoon | Irregular | Douglas Channel | Hay and McCarter 2000, Hay 2002 |
| Giltoyees Inlet | Irregular | Douglas Channel | Hay and McCarter 2000, Hay 2002 |
| Kildala River | Regular | Douglas Channel-Kitimat Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **British Columbia, continued** | | | |
| Kitimat River | Regular | Douglas Channel-Kitimat Arm | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| Skeena River | Regular | Chatham Sound | Hay and McCarter 2000, Stoffels 2001,Hay 2002 |
| Ecstall River | Unknown | | Stoffels 2001, Moody 2008 |
| Khyex River | Unknown | | Stoffels 2001, Moody 2008 |
| Scotia Creek | Unknown | | Stoffels 2001 |
| Khtada Creek | Unknown | | Stoffels 2001 |
| Kasiks River | Unknown | | Stoffels 2001 |
| Gitnadoix River | Unknown | | Stoffels 2001 |
| Nass River | Regular | Portland Inlet | Hay and McCarter 2000, Hay 2002, Moody 2008 |
| **Southeast Alaska** | | | |
| Wilson / Blossom rivers | | Smeaton Bay | Willson et al. 2006 |
| Chickamin River | | | Willson et al. 2006 |
| Unuk/Klahini/Eulachon rivers | Regular | Burroughs Bay | Willson et al. 2006 |
| Stikine River | | | Womble 2003,Willson et al. 2006 |
| Hulakon River, Grant Creek | | Bradfield Canal | Willson et al. 2006 |
| Bradfield River | | | Willson et al. 2006 |
| Speel/Whiting rivers | | Port Snettisham | Womble 2003,Willson et al. 2006 |
| Taku River | | | Womble 2003,Willson et al. 2006,Flory 2008b |
| Mendenhall River | | | Willson et al. 2006 |
| Eagle River | | | Willson et al. 2006 |
| Berners/Lace/Antler rivers | Regular | Berners Bay | Womble 2003, Willson et al. 2006 |
| Katzehin River | | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Skagway River | | Chilkoot Inlet | Willson et al. 2006 |
| Taiya River | | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Chilkoot/Ferebee rivers | Regular | Chilkoot Inlet | Womble 2003, Willson et al. 2006 |
| Chilkat River | Regular | Chilkat Inlet | Womble 2003, Willson et al. 2006 |
| Endicott River | | | Womble 2003, Willson et al. 2006 |
| Excursion River | | | Womble 2003, Willson et al. 2006 |
| Adams Inlet | | Glacier Bay | Womble 2003, Willson et al. 2006 |
| **Yakutat area, Alaska** | | | |
| Dixon River | | | Womble 2003, Willson et al. 2006 |

Table A-1 continued. List and classification of known and possible eulachon (*Thaleichthys pacificus*) spawning areas and estuarine areas as given in Hay and McCarter (2000), Hay (2002), Willson et al. (2006), and Moody (2008). Spawning regularity categories are derived from comments within the cited references and should not be considered as endorsed by NMFS or the biological review team (BRT).

| Eulachon spawning areas | Spawning regularity | Estuary | Reference |
|---|---|---|---|
| **Yakutat area, Alaska, continued** | | | |
| Fairweather Slough | | | Willson et al. 2006 |
| Sea Otter Cr. | | | Willson et al. 2006 |
| Doame R. | | | Willson et al. 2006 |
| Alsek R., Clear Cr. | | Dry Bay | Womble 2003, Willson et al. 2006 |
| Dangerous/Italio/Akwe rivers | | | Willson et al. 2006 |
| Situk/Ahrnklin rivers/Tawah Cr. | | | Willson et al. 2006 |
| Lost R. | | | Willson et al. 2006 |
| **Southcentral Alaska** | | | |
| Pillar Cr., Kalsin R. (Kodiak Island) | | | Willson et al. 2006 |
| Martin R., Alaganik Slough, Ibeck Slough, Eyak R., Scott R., Copper R. (Copper River Delta) | | | Willson et al. 2006 |
| Resurrection R. | | Resurrection Bay | Willson et al. 2006 |
| Twentymile R., Portage Cr., Placer R., Chickaloon R., Virgin Cr. | | Turnagain Arm | Willson et al. 2006 |
| Susitna R., Yentna R., Beluga R., Kenai R. | | Cook Inlet | Willson et al. 2006 |
| **Western Alaska** | | | |
| Kametolook R. | Unknown | Gulf of Alaska | Willson et al. 2006 |
| Three Star R. | Unknown | Gulf of Alaska | Willson et al. 2006 |
| King Salmon R. | Unknown | Bristol Bay | Willson et al. 2006 |
| Meshik R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Sandy R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Bear R./Milky R. | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| Unnamed river on Unimak Island | Unknown | Bristol Bay | Moffitt et al. 2002, Willson et al. 2006 |
| King Salmon R. | Unknown | Bristol Bay | Willson et al. 2006 |
| Nushagak R. | Unknown | Bristol Bay | Willson et al. 2006 |

Table A-2. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Skagit Bay | 260 rare | D. Penttila, Washington Dept. Fisheries, Seattle | 260. Miller, B. S., and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. 3 Volumes. Washington Sea Grant Program and Washington State Dept. Ecology, Seattle. |
| Hood Canal | 260 not found | D. Penttila, Washington Dept. Fisheries, Seattle | 260. Miller and Borton 1980 (Complete listing above.) |
| Puget Sound | 260, 452 rare | | 260. Miller and Borton 1980 (Complete listing above)<br>452. Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington, University of Washington Press, Seattle. |
| Grays Harbor | 96 | R. Brix, Washington Dept. Fisheries, Montesano | 96. Deschamps, G., S. G. Wright, and R. E. Watson. 1971. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. *In* Grays Harbor cooperative water quality study 1964-1966, p. 1–55. Tech. Rep. No. 7. Washington Dept. Fisheries, Olympia. |
| Willapa Bay | | R. Brix, Washington Dept. Fisheries, Montesano | |
| Columbia River | 118, 269 | R. McConnell, NMFS, Hammond, OR | 118. EPA (U.S. Environmental Protection Agency). 1971. Columbia River thermal effects study. Vol. 1: Biological effects studies. EPA, U.S. Atomic Energy Commission, and National Marine Fisheries Service.<br>269. Misitano, D. A. 1977. Species composition and relative abundance of larval and post-larval fishes in the Columbia River estuary, 1973. Fish. Bull. 75(1):218–222. |
| Nehalem Bay | Not found | G. Cailliet, Moss Landing Marine Laboratories, Moss Landing, CA | |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Tillamook Bay | 39, 131 not found | | 39. Bottom, D. L., and B. Forsberg. 1978. The fishes of Tillamook Bay. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis.<br>131. Forsberg, B. O., J. A. Johnson, and S. M. Klug. 1977. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Federal Aid Progress Rep., Fish. Oregon Dept. Fish and Wildlife, Corvallis. |
| Netarts Bay | 399 not found | A. Chung, Oregon State Univ., Corvallis | 399. Stout, H. (ed.). 1976. The natural resources and human utilization of Netarts Bay, Oregon. Oregon State Univ., Corvallis. |
| Siletz River | 384 not found | G. Stewart, Oregon Dept. Fish and Wildlife, Newport | 384. Starr, R. 1979. Natural resources of Siletz estuary. Oregon Dept. Fish and Wildlife, Corvallis. |
| Yaquina Bay | Not found | J. Butler, Oregon Dept. Fish and Wildlife, Newport<br>W. DeBen, U.S. EPA, Newport, OR<br>G, Stewart, Oregon Dept. Fish and Wildlife, Newport | |
| Alsea River | Not found | J. Butler, Oregon Dept. Fish and Wildlife, Newport<br>G. Stewart, Oregon Dept. Fish and Wildlife, Newport | |
| Siuslaw River | 197 rare | J. McCleod, Oregon Dept. Fish and Wildlife, Florence | 197. Hutchinson, J. M. 1979. Seasonal distribution of fishes in Siuslaw Bay. Oregon Dept. Fish and Wildlife, Corvallis. |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Umpqua River | 200, 277, 323 | J. Johnson, Oregon Dept. Fish and Wildlife, Reedsport | 200. Johnson, J., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua estuary April 1977 through January 1986. Information Rep. 86-6. Oregon Dept. Fish and Wildlife, Corvallis.<br>277. Mullen, R. 1977. The occurrence and distribution of fish in the Umpqua River estuary, June through October 1972. Information Rep. 77-3. Oregon Dept. Fish and Wildlife, Corvallis.<br>323. Ratti, F. 1979b. Natural resources of Umpqua estuary. Estuary Inventory Rep. 2(5). Oregon Dept. Fish and Wildlife, Corvallis. |
| Coos Bay | 91, 193, 337, 429 rare | W. Mullarkey, Oregon Dept. Fish and Wildlife, Charleston | 91. Cummings, E, and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Information Rep. 70-11. Fish Commission of Oregon, Portland.<br>193. Hostick, G. A. 1975. Numbers of fish captured in beach seine hauls in Coos River estuary, Oregon, June through September 1970. Information Rep. 74-11, Fish Commission of Oregon, Portland.<br>337. Roye, C. 1979. Natural resources of Coos Bay estuary. Oregon Dept. Fish and Wildlife, Corvallis.<br>429. Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, W. G. Mullarkey, N. T. Richmond, and T. J. Rumreich. 1988. Coos Bay fish management plan. Draft No. 3, Oregon Dept. Fish and Wildlife, Corvallis. |
| Rogue River | 322 rare | A. Riikula, Oregon Dept. Fish and Wildlife, Gold Beach | 322. Ratti, F. 1979a. Natural resources of Rogue Estuary. Estuary Inventory Rep. 2(8). Oregon Dept. Fish and Wildlife, Corvallis. |

Table A-2 Continued.  Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Klamath River | 138 | T. Kisanuki, U.S. Fish and Wildlife Service, Arcata, CA<br>M. Orcutt, Hoopa Valley Tribe, Hoopa, CA.<br>M. Pisano, California Dept. Fish and Game, Arcata<br>R. Warner, California Dept. Fish and Game, Eureka | 138.  Fry Jr., D. H.  1979.  Anadromous fishes of California.  Calif. Dept. Fish and Game, Sacramento. |
| Humboldt Bay | 165, 454 rare | R. Barnhart, U. S. Fish and Wildlife Service, Coop. Fish. Research Unit, Arcata, CA<br>C. Toole, Univ. California Cooperative Extension, Eureka<br>R. Warner, California Dept. Fish and Game, Eureka | 165.  Gotshall, D. W., G. H. Allen, and R. A. Barnhart.  1980.  An annotated checklist of fishes from Humboldt Bay, California.  Calif. Fish Game 66(4):220–232.<br>454.  Young, J. S.  1984.  Identification of larval smelt (Osteichthes: Salmoniformes: Osmeridae) from northern California.  Master's thesis. Humboldt State Univ., Arcata, CA. |
| Eel River | 270, 313 not found | | 270.  Monroe, G. W., F. Reynolds, B. M. Browning, and J. W. Speth.  1974.  Natural resources of the Eel River delta.  Coastal Wetland Series No. 9, California Dept. Fish and Game, Sacramento.<br>313.  Puckett, L. K.  1977.  The Eel River estuary observations on morphometry, fishes, water quality, and invertebrates.  Memo. Rep.  California Dept. Fish and Game, Sacramento. |

Table A-2 Continued. Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| Tomales Bay | 22, 264, 292 not found | | 22. Bane, G. W., and A. W. Bane. 1971. Bay fishes of northern California with emphasis on the Bodega Tomales Bay area. Mariscos Publications, Hampton Bays, NY.<br>264. Miller, D. J.,and R. N. Lea. 1972. Guide to the coastal marine fishes of California. California Dept. Fish Game. Fish Bull. 157.<br>292. Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. Calif. Fish Game 50(4):305–307. |
| Central San Francisco/ Suisun/San Pablo bays | 264, 292 not found | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| South San Francisco Bay | Not found, 292, 294 | | 292. Odemar 1964<br>(Complete listing above.)<br>294. Oregon Dept. Fish and Wildlife and Washington Dept. Fisheries. 1987. Status report: Columbia River fish runs and fisheries 1960–1986. ODFW, Portland, and WDF, Olympia. |
| Elkhorn Slough | Not found, 264, 292 | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| Morro Bay | Not found, 264, 292 | | 264. Miller and Lea 1972<br>(Complete listing above.)<br>292. Odemar 1964<br>(Complete listing above.) |
| Santa Monica Bay | Not found, 264 | | 264. Miller and Lea 1972<br>(Complete listing above.) |

Table A-2 Continued.  Eulachon distribution information in U.S. West Coast estuaries as compiled in Monaco et al. (1990).

| Estuary | Reference no. and occurrence | Personal communication | Reference source |
|---|---|---|---|
| San Pedro Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Alamitos Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Anaheim Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Newport Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Mission Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| San Diego Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |
| Tijuana Bay | Not found, 264 | | 264. Miller and Lea 1972 (Complete listing above.) |

Table A-3. Documented occurrence of eulachon in northern California rivers (see Appendix B for transcription of cited newspaper articles).

| Run year | Month | Klamath River | Redwood Creek | Mad River | Humboldt Bay tributaries | Source |
|---|---|---|---|---|---|---|
| 1908 | April-May | | X | | | San Francisco Call, San Francisco, CA |
| 1916 | February | X | | | | Calif. Academy of Sciences ichthyology collection |
| 1919 | February | X | | | | San Jose Mercury Herald, San Jose, CA |
| 1947 | March | X | | | | Calif. Academy of Sciences ichthyology collection |
| 1952 | February | X | | | | Humboldt Standard, Eureka, CA |
| 1955 | February | | X | | | Calif. Academy of Sciences ichthyology collection |
| 1963 | March | X | | | | Calif. Academy of Sciences ichthyology collection |
| | April | X | X | X | | Humboldt Standard, Eureka, CA; Odemar 1964 |
| 1965 | April | X | | | | Humboldt Standard, Eureka, CA |
| 1967 | April | | X | | | The Times-Standard, 14 March 1968, Eureka, CA |
| 1968 | March | X | | | | The Times-Standard, Eureka, CA |
| 1969 | April | X | | | | The Times-Standard, Eureka, CA |
| 1971 | March | X | | | | Humboldt Standard, Eureka, CA |
| 1972 | — | X | | | | Humboldt Standard, Eureka, CA |
| 1976 | April | X | X | X | | Humboldt Standard, Eureka, CA |
| 1977 | May | | | | X | Jennings 1996 |
| 1978 | April | X | X | | | Young 1984 |
| 1979 | March | X | | | | Young 1984 |
| | April | X | | | | |
| 1980 | March | X | | | | Young 1984 |
| | April | X | | | | |
| 1988 | December | X | | | | Larson and Belchik 1998 |
| 1989 | May | X | | | | Larson and Belchik 1998 |

Table A-4. Latitudinal and depth distribution of eulachon in fishery-independent upper continental slope and continental shelf bottom trawl surveys of groundfish on the U.S. West Coast.

| Year | Total no. of hauls | No. hauls with eulachon | Eulachon frequency in hauls | Survey depth range (m) | Survey latitudinal range (dd.mm) | Depth (m) | | | Latitudinal range (dd) | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Min | Max | South | North | |
| **Upper continental slope** | | | | | | | | | | | |
| 1989–1993 | 401 | 25 | 0.06 | 183–1,280 | 38.20–48.10 | 330 | 194 | 589 | 40.40 | 47.51 | Lauth et al. 1997 |
| 1995 | 106 | None | — | 183–1,280 | 40.30–43.00 | — | — | — | — | — | Lauth 1997a |
| 1996 | 203 | 2 | 0.01 | 183–1,280 | 43.00–48.10 | 377 | 366 | 387 | 44.56 | 46.17 | Lauth 1997b |
| 1997 | 182 | 2 | 0.01 | 183–1,280 | 34.30–48.10 | 319 | 259 | 379 | 46.17 | 47.11 | Lauth 1999 |
| 1999 | 199 | 2 | 0.01 | 183–1,280 | 34.30–48.10 | 291 | 242 | 339 | 42.07 | 46.17 | Lauth 2000 |
| 2000 | 330 | 10 | 0.03 | 183–1,280 | 35.00–48.10 | 291 | 186 | 608 | 41.82 | 45.81 | Keller et al. 2005 |
| 2001 | 334 | 1 | <0.01 | 183–1,280 | 34.15–48.10 | 214 | 214 | 214 | 45.03 | 45.03 | Keller et al. 2006a |
| 2002 | 427 | 9 | 0.02 | 183–1,280 | 32.30–48.10 | 250 | 189 | 390 | 44.69 | 46.28 | Keller et al. 2006b |
| **Continental shelf triennial survey** | | | | | | | | | | | |
| 1989 | 539 | 222 | 0.41 | 55–366 | 34.30–49.40 | 141 | 60 | 333 | 34.36 | 49.35 | Weinberg et al. 1994a |
| 1992 | 501 | 196 | 0.39 | 55–366 | 34.30–49.40 | 139 | 59 | 348 | 40.44 | 49.25 | Zimmerman et al. 1994 |
| 1995 | 522 | 88 | 0.17 | 55–500 | 34.30–49.40 | 137 | 66 | 328 | 41.24 | 49.34 | Wilkins et al. 1998 |
| 1998 | 527 | 45 | 0.08 | 55–500 | 34.30–49.40 | 147 | 79 | 322 | 42.24 | 49.14 | Shaw et al. 2000 |
| 2001 | 506 | 130 | 0.26 | 55–500 | 34.30–49.40 | 147 | 62 | 466 | 42.25 | 49.05 | Weinberg et al. 2002 |
| **Continental slope and shelf** | | | | | | | | | | | |
| 2003 | 574 | 29 | 0.05 | 55–1,280 | 32.30–48.10 | 126 | 51 | 237 | 33.97 | 48.40 | Keller et al. 2007a |
| 2004 | 508 | 40 | 0.08 | 55–1,280 | 32.30–48.10 | 119 | 55 | 220 | 34.51 | 48.23 | Keller et al. 2007b |
| 2005 | 675 | 19 | 0.03 | 55–1,280 | 32.30–48.10 | 130 | 96 | 169 | 42.00 | 47.90 | Keller et al. 2008 |

Table A-5. Latitudinal, longitudinal, and depth distribution of eulachon in AFSC fishery-independent bottom trawl surveys of groundfish in the Gulf of Alaska, eastern Bering Sea, and Aleutian Islands. Data available online at http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm.

| Year | No. hauls with eulachon | Depth (m) | | | Latitudinal range (dd.mm) | | Longitudinal range (dd.mm) | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | Min. | Max. | South | North | East | West |
| **Gulf of Alaska** | | | | | | | | |
| 1984 | 178 | 188 | 27 | 393 | 54.40 | 60.28 | 134.23 | 162.40 |
| 1987 | 226 | 170 | 26 | 402 | 54.42 | 60.25 | 132.94 | 162.65 |
| 1990 | 284 | 184 | 20 | 432 | 54.49 | 60.27 | 133.07 | 162.96 |
| 1993 | 294 | 181 | 20 | 351 | 54.35 | 60.32 | 133.33 | 162.60 |
| 1996 | 272 | 165 | 28 | 474 | 53.80 | 60.19 | 132.90 | 166.39 |
| 1999 | 277 | 172 | 16 | 409 | 53.54 | 60.20 | 132.82 | 166.63 |
| 2001 | 117 | 174 | 62 | 297 | 52.64 | 59.87 | 146.97 | 165.43 |
| 2003 | 230 | 173 | 31 | 566 | 52.77 | 60.30 | 132.89 | 169.00 |
| 2005 | 259 | 169 | 23 | 548 | 53.66 | 60.21 | 132.88 | 164.78 |
| 2007 | 237 | 165 | 32 | 516 | 54.24 | 60.30 | 132.83 | 162.10 |
| **Eastern Bering Sea** | | | | | | | | |
| 1982 | 29 | 103 | 40 | 159 | 55.00 | 56.68 | 159.76 | 168.20 |
| 1983 | 43 | 91 | 29 | 159 | 55.00 | 59.65 | 158.42 | 176.56 |
| 1984 | 30 | 108 | 49 | 163 | 54.98 | 57.34 | 159.67 | 170.07 |
| 1985 | 19 | 126 | 101 | 157 | 55.00 | 56.83 | 166.31 | 170.49 |
| 1986 | 38 | 106 | 49 | 155 | 54.99 | 57.01 | 160.37 | 170.07 |
| 1987 | 27 | 114 | 33 | 155 | 55.00 | 57.98 | 159.76 | 168.20 |
| 1988 | 17 | 95 | 31 | 155 | 55.01 | 58.09 | 158.42 | 167.04 |
| 1989 | 21 | 114 | 49 | 159 | 54.82 | 58.00 | 162.79 | 172.20 |
| 1990 | 25 | 102 | 18 | 159 | 55.01 | 60.32 | 158.32 | 170.07 |
| 1991 | 23 | 119 | 49 | 155 | 55.00 | 57.69 | 162.82 | 167.64 |
| 1992 | 27 | 109 | 27 | 155 | 55.00 | 60.36 | 161.00 | 170.07 |
| 1993 | 20 | 95 | 22 | 148 | 55.32 | 59.68 | 159.06 | 171.52 |
| 1994 | 40 | 92 | 16 | 154 | 54.99 | 60.00 | 159.09 | 171.53 |
| 1995 | 38 | 97 | 29 | 143 | 54.99 | 57.01 | 159.08 | 172.66 |
| 1996 | 38 | 104 | 35 | 155 | 54.99 | 57.98 | 158.32 | 172.63 |
| 1997 | 38 | 100 | 39 | 157 | 55.01 | 57.68 | 159.76 | 168.87 |
| 1998 | 56 | 94 | 34 | 154 | 54.99 | 57.99 | 158.97 | 170.49 |
| 1999 | 39 | 106 | 53 | 155 | 55.01 | 57.01 | 162.80 | 168.26 |
| 2000 | 46 | 98 | 37 | 153 | 55.00 | 60.34 | 159.07 | 171.41 |
| 2001 | 62 | 90 | 46 | 153 | 54.99 | 58.00 | 159.02 | 168.90 |
| 2002 | 44 | 91 | 32 | 153 | 55.00 | 58.67 | 158.40 | 168.30 |
| 2003 | 36 | 103 | 32 | 156 | 55.00 | 60.00 | 158.42 | 175.27 |
| 2004 | 39 | 102 | 25 | 156 | 54.99 | 59.32 | 158.35 | 174.46 |
| 2005 | 36 | 101 | 24 | 154 | 55.00 | 61.00 | 159.12 | 176.24 |
| 2006 | 37 | 98 | 36 | 146 | 55.33 | 58.02 | 158.97 | 170.70 |
| 2007 | 48 | 96 | 21 | 155 | 55.00 | 59.00 | 160.36 | 172.86 |
| 2008 | 37 | 100 | 44 | 156 | 54.99 | 61.32 | 160.37 | 174.89 |
| **Aleutian Islands** | | | | | | | | |
| 1986-1997 | 13 | 170 | 62 | 404 | 51.90 | 53.76 | 166.96 | 176.46 |
| 2000-2006 | 12 | 164 | 89 | 197 | 53.58 | 53.78 | 166.77 | 167.37 |

Table A-6. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

| | | | Proportion of fish in each age class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Sex** | **N** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Reference** |
| **Columbia River** | | | | | | | | | | | |
| 1984 | NR | 104 | | | <0.11 | **0.50** | 0.27 | 0.08 | <0.05 | | Dammers 1988 |
| 1985 | NR | 100 | | | 0.02 | 0.25 | **0.48** | 0.20 | 0.03 | 0.02 | Dammers 1988 |
| 1986 | NR | 144 | | 0.04 | **0.35** | **0.35** | 0.15 | 0.10 | 0.01 | <0.01 | Dammers 1988 |
| 1992 | NR | NR | | | 0.26 | **0.49** | 0.25 | | | | WDFW and ODFW 2001 |
| 1993 | NR | NR | | | **0.39** | **0.39** | 0.22 | | | | WDFW and ODFW 2001 |
| 1994 | NR | NR | | | **0.66** | 0.28 | 0.006 | | | | WDFW and ODFW 2001 |
| 1995 | NR | NR | | | 0.41 | **0.46** | 0.13 | | | | WDFW and ODFW 2001 |
| 1996 | NR | NR | | | **0.56** | 0.39 | 0.05 | | | | WDFW and ODFW 2001 |
| 1997 | NR | NR | | | **0.60** | 0.33 | 0.07 | | | | WDFW and ODFW 2001 |
| 1998 | NR | NR | | | **0.56** | 0.37 | 0.07 | | | | |
| **Frazier River** | | | | | | | | | | | |
| 1986 | NR | 20 | | | | 0.40 | **0.45** | 0.10 | 0.05 | | Higgins et al. 1987 |
| **Kemano River** | | | | | | | | | | | |
| 1988 | M | 76 | | | 0.24 | **0.45** | 0.29 | 0.03 | | | Lewis et al. 2002 |
| 1989 | M | 101 | | 0.01 | 0.15 | 0.29 | **0.43** | 0.13 | | | Lewis et al. 2002 |
| 1990 | M | 143 | | | 0.15 | **0.48** | 0.33 | 0.03 | | | Lewis et al. 2002 |
| 1992 | M | 158 | | | 0.28 | **0.37** | 0.33 | 0.02 | | | Lewis et al. 2002 |
| 1993 | M | 213 | | | 0.31 | **0.37** | 0.31 | 0.01 | | | Lewis et al. 2002 |
| 1994 | M | 152 | | | **0.41** | 0.40 | 0.19 | | | | Lewis et al. 2002 |
| 1995 | M | 124 | | | 0.13 | **0.39** | 0.32 | 0.15 | 0.01 | | Lewis et al. 2002 |
| 1996 | M | 135 | | | 0.21 | **0.45** | 0.23 | 0.10 | | | Lewis et al. 2002 |
| 1997 | M | 171 | | 0.05 | **0.55** | 0.28 | 0.11 | 0.01 | | | Lewis et al. 2002 |
| 1998 | M | 86 | | | 0.26 | 0.31 | **0.43** | | | | Lewis et al. 2002 |
| 1988 | F | 120 | | | 0.16 | **0.42** | 0.39 | 0.03 | | | Lewis et al. 2002 |
| 1989 | F | 111 | | 0.09 | 0.26 | **0.32** | 0.28 | 0.05 | | | Lewis et al. 2002 |
| 1990 | F | 144 | | | 0.17 | **0.41** | 0.34 | 0.08 | | | Lewis et al. 2002 |
| 1992 | F | 96 | | | **0.47** | 0.39 | 0.14 | 0.01 | | | Lewis et al. 2002 |
| 1993 | F | 192 | | | **0.45** | 0.38 | 0.18 | | | | Lewis et al. 2002 |
| 1994 | F | 175 | | | **0.51** | 0.36 | 0.13 | | | | Lewis et al. 2002 |

Table A-6 continued. Age distribution of selected adult eulachon populations as determined by reading otolith increments. NR = data not recorded, N = number aged, proportions in bold indicate the mode for that year.

| | | | Proportion of fish in each age class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Sex** | **N** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Reference** |
| 1995 | F | 118 | | | 0.14 | **0.37** | 0.36 | 0.12 | | | Lewis et al. 2002 |
| 1996 | F | 140 | | | 0.17 | **0.52** | 0.24 | 0.06 | | | Lewis et al. 2002 |
| 1998 | F | 91 | | 0.01 | 0.19 | **0.54** | 0.26 | | | | Lewis et al. 2002 |
| **Kitimat River** | | | | | | | | | | | |
| 1993 | F | 59 | | | **0.75** | 0.20 | 0.02 | 0.03 | | | Pederson et al. 1995 |
| **Nass River** | | | | | | | | | | | |
| 1969 | NR | 53 | | | 0.15 | **0.83** | 0.02 | | | | Langer et al. 1997 |
| 1970 | NR | 256 | | | 0.38 | **0.56** | 0.06 | | | | Langer et al. 1997 |
| 1971 | NR | 378 | | 0.04 | **0.68** | 0.24 | 0.04 | | | | Langer et al. 1997 |
| **Copper River delta** | | | | | | | | | | | |
| Eyak River | | | | | | | | | | | |
| 2002 | NR | 445 | | | 0.01 | **0.97** | 0.02 | | | | Moffit et al. 2002 |
| Alaganik Slough | | | | | | | | | | | |
| 1998 | NR | 460 | | | 0.01 | 0.08 | **0.91** | | | | Moffit et al. 2002 |
| 2000 | NR | 99 | | | **0.73** | 0.27 | | | | | Moffit et al. 2002 |
| Ibeck Creek | | | | | | | | | | | |
| 2001 | NR | 1,215 | | | 0.04 | **0.96** | <0.01 | <0.01 | | | Moffit et al. 2002 |
| **Copper River** | | | | | | | | | | | |
| Flag Point Channel | | | | | | | | | | | |
| 1998 | NR | 2,591 | | | <0.01 | 0.09 | **0.90** | <0.01 | | | Moffit et al. 2002 |
| 2000 | NR | 1,338 | | <0.01 | **0.48** | **0.48** | 0.40 | <0.01 | | | Moffit et al. 2002 |
| 2001 | NR | 1,699 | | <0.01 | **0.56** | 0.43 | 0.01 | | | | Moffit et al. 2002 |
| 2002 | NR | 1,290 | | | 0.01 | **0.98** | 0.01 | | | | Moffit et al. 2002 |
| 60-km Bridge | | | | | | | | | | | |
| 2002 | NR | 812 | | | 0.01 | **0.98** | 0.01 | | | | Moffit et al. 2002 |
| **Twentymile River** | | | | | | | | | | | |
| 2000 | M | 235 | | 0.09 | **0.51** | 0.36 | 0.04 | | | | Spangler et al. 2003 |
| 2001 | M | 585 | | 0.06 | **0.83** | 0.01 | | | | | Spangler et al. 2003 |
| 2000 | F | 49 | 0.02 | 0.23 | **0.57** | 0.14 | 0.04 | | | | Spangler et al. 2003 |
| 2001 | F | 425 | | 0.08 | **0.88** | 0.04 | | | | | Spangler et al. 2003 |

Table A-7. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NR = not recorded, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| **Alaska** | | | | | | | | | | | | | |
| Susitna River | 1982[a] | — | NR, NS | 213.0 | — | — | — | — | — | — | — | — | — |
| | 1983[a] | — | NR, NS | 206.0 | — | — | — | — | — | — | — | — | — |
| Twentymile River | 1976[b] | — | NR | 228.0 | — | — | 209–249 | 22 | 224 | — | — | 210–246 | 40 |
| | 1977[c] | — | NR | 228.0 | — | — | 162–270 | — | 223 | — | — | 202–255 | 408 |
| | | | | | | | | | | | | | Total |
| | 2000[d] | — | FL | 215.0 | — | 0.9 | 166–242 | 222 | 202 | — | 3.0 | 143–234 | 49 |
| | 2001[d] | — | FL | 209.0 | — | 0.5 | 100–241 | 585 | 203 | — | 0.6 | 99–253 | 425 |
| Copper River delta | | | | | | | | | | | | | |
| Eyak River | 2002[e] | 3 | SL | 180.0 | — | 4 | — | 4 | — | — | — | — | — |
| | | 4 | SL | 187.0 | — | 0 | — | 430 | 187 | — | 12 | — | 2 |
| | | 5 | SL | 192.0 | — | 3 | — | 9 | — | — | — | — | — |
| Ibeck Creek | 2001[e] | 3 | SL | 180.0 | — | 2 | — | 40 | 164 | — | 4 | — | 2 |
| | | 4 | SL | 177.0 | — | 0 | — | 1,089 | 171 | — | 1 | — | 75 |
| | | 5 | SL | 186.0 | — | 3 | — | 5 | — | — | — | — | — |
| | | 6 | SL | 182.0 | — | 3 | — | 4 | — | — | — | — | — |
| | 2003[f] | — | SL | 179.0 | — | 10 | 138–207 | 1,249 | 173 | — | 9 | 154–206 | 101 |
| Alaganik Slough | 1998[e] | 3 | SL | 179.0 | — | 3 | — | 6 | — | — | — | — | — |
| | | 4 | SL | 175.0 | — | 2 | — | 35 | 172 | — | 2 | — | 2 |
| | | 5 | SL | 179.0 | — | 0 | — | 377 | 175 | — | 2 | — | 40 |
| | 2000[e] | 3 | SL | 160.0 | — | 1 | — | 47 | 160 | — | 2 | — | 25 |
| | | 4 | SL | 174.0 | — | 3 | — | 21 | 173 | — | 9 | — | 6 |
| Copper River | | | | | | | | | | | | | |
| Flag Point Channel | 1998[e] | 3 | SL | 179.0 | — | 3 | — | 7 | 181 | — | 1 | — | 2 |
| | | 4 | SL | 182.0 | — | 1 | — | 151 | 175 | — | 1 | — | 96 |
| | | 5 | SL | 183.0 | — | 0 | — | 1,848 | 177 | — | 0 | — | 478 |
| | | 6 | SL | 176.0 | — | 2 | — | 7 | 186 | — | 10 | — | 2 |
| | 2000[e] | 2 | SL | 182.0 | — | NA | — | 1 | — | — | — | — | — |
| | | 3 | SL | 174.0 | — | 0 | — | 534 | 168 | — | 1 | — | 109 |
| | | 4 | SL | 176.0 | — | 0 | — | 547 | 172 | — | 1 | — | 99 |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Flag Point Channel | | 5 | SL | 183.0 | — | 2 | — | 43 | 164 | — | 5 | — | 5 |
| (continued) | | 6 | SL | 192.0 | — | NA | — | 1 | — | — | — | — | — |
| | 2001[e] | 2 | SL | — | — | — | — | — | 154 | — | NA | — | 1 |
| | | 3 | SL | 174.0 | — | 0 | — | 643 | 167 | — | 1 | — | 306 |
| | | 4 | SL | 180.0 | — | 0 | — | 571 | 172 | — | 1 | — | 155 |
| | | 5 | SL | 179.0 | — | 2 | — | 21 | 166 | — | 3 | — | 2 |
| | 2002[e] | 3 | SL | 178.0 | — | 3 | — | 16 | 185 | — | 6 | — | 2 |
| | | 4 | SL | 183.0 | — | 0 | — | 1,081 | 178 | — | 1 | — | 175 |
| | | 5 | SL | 188.0 | — | 3 | — | 15 | 190 | — | NA | — | 1 |
| 60-km Bridge | 2002[e] | 3 | SL | 181.0 | — | 8 | — | 3 | 176 | — | 4 | — | 7 |
| | | 4 | SL | 186.0 | — | 0 | — | 575 | 181 | — | 1 | — | 218 |
| | | 5 | SL | 191.0 | — | 3 | — | 9 | — | — | — | — | — |
| Southeast Alaska | | | | | | | | | | | | | |
| Stikine River[g] | 1979 | 2 | FL | 180.0 | — | — | 141–197 | — | — | — | — | — | — |
| | | 3 | FL | 190.0 | — | — | 165–210 | — | — | — | — | — | — |
| | | 4 | FL | 194.0 | — | — | 173–211 | — | — | — | — | — | — |
| | 1980 | 2 | FL | 172.0 | — | — | 155–179 | — | — | — | — | — | — |
| | | 3 | FL | 186.0 | — | — | 162–208 | — | — | — | — | — | — |
| | | 4 | FL | 201.0 | — | — | 195–208 | — | — | — | — | — | — |
| **British Columbia** | | | | | | | | | | | | | |
| Nass River[h] | 1970 | 3 | SL | 173.0 | 11.3 | — | — | 87 | 171 | 16.2 | — | — | 11 |
| | | 4 | SL | 179.0 | 11.2 | — | — | 123 | 181 | 11.8 | — | — | 19 |
| | | 5 | SL | 188.0 | 6.1 | — | — | 12 | 192 | 3.5 | — | — | 4 |
| | 1971 | 2 | SL | 155.0 | 10.9 | — | — | 5 | 144 | 6.9 | — | — | 9 |
| | | 3 | SL | 167.0 | 52.3 | — | — | 74 | 157 | 16.2 | — | — | 183 |
| | | 4 | SL | 174.0 | 10.2 | — | — | 33 | 171 | 10.3 | — | — | 60 |
| | | 5 | SL | 188.0 | 19.8 | — | — | 7 | 183 | 11.3 | — | — | 7 |
| Skeena River | 2003[i] | — | FL, NS | 189.0 | — | 2 | — | 52 | | | | | |
| Kitimat River | 1993[j] | 3 | SL | — | — | — | — | — | 169 | — | 1.5 | 149–187 | 44 |
| | | 4 | SL | — | — | — | — | — | 175 | — | 1.5 | 165–181 | 12 |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, SL = standard length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kitimat River (cont.) | | 5 | SL | — | — | — | — | — | 184 | — | NA | NA | 1 |
| | | 6 | SL | — | — | — | — | — | 170 | — | 9.5 | 160–189 | 2 |
| | 1997[k] | 2 | SL | 173.0 | 9.9 | — | — | 2 | 162 | 0.0 | — | — | 1 |
| | | 3 | SL | 176.0 | 14.4 | — | — | 28 | 180 | 9.9 | — | — | 25 |
| | | 4 | SL | 175.0 | 12.9 | — | — | 16 | 174 | 11.6 | — | — | 37 |
| | | 5 | SL | 184.0 | 15.6 | — | — | 13 | 183 | 12.7 | — | — | 10 |
| | | 6 | SL | 182.0 | 0.0 | — | — | 1 | 178 | 17.7 | — | — | 2 |
| Kemano River | 1988[l] | 3 | FL | 168.0 | — | — | — | — | 165 | — | — | — | — |
| | | 4 | FL | 175.0 | — | — | — | — | 174 | — | — | — | — |
| | | 5 | FL | 187.0 | — | — | — | — | 186 | — | — | — | — |
| | | 6 | FL | 195.0 | — | — | — | — | 196 | — | — | — | — |
| | 1989[l] | 2 | FL | 190.0 | — | — | — | — | 181 | — | — | — | — |
| | | 3 | FL | 188.0 | — | — | — | — | 181 | — | — | — | — |
| | | 4 | FL | 189.0 | — | — | — | — | 184 | — | — | — | — |
| | | 5 | FL | 189.0 | — | — | — | — | 181 | — | — | — | — |
| | | 6 | FL | 183.0 | — | — | — | — | 176 | — | — | — | — |
| | 1990[l] | 3 | FL | 177.0 | — | — | — | — | 182 | — | — | — | — |
| | | 4 | FL | 188.0 | — | — | — | — | 187 | — | — | — | — |
| | | 5 | FL | 196.0 | — | — | — | — | 194 | — | — | — | — |
| | | 6 | FL | 206.0 | — | — | — | — | 194 | — | — | — | — |
| | 1992[l] | 3 | FL | 177.0 | — | — | — | — | 173 | — | — | — | — |
| | | 4 | FL | 187.0 | — | — | — | — | 182 | — | — | — | — |
| | | 5 | FL | 196.0 | — | — | — | — | 198 | — | — | — | — |
| | | 6 | FL | 207.0 | — | — | — | — | 214 | — | — | — | — |
| | 1993[l] | 3 | FL | 176.0 | — | — | — | — | 170 | — | — | — | — |
| | | 4 | FL | 187.0 | — | — | — | — | 186 | — | — | — | — |
| | | 5 | FL | 198.0 | — | — | — | — | 195 | — | — | — | — |
| | | 6 | FL | 207.0 | — | — | — | — | — | — | — | — | — |
| | 1994[l] | 3 | FL | 169.0 | — | — | — | — | 166 | — | — | — | — |
| | | 4 | FL | 182.0 | — | — | — | — | 181 | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, NS = not sexed, FL = fork length, SL = standard length.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kemano River (cont.) | | 5 | FL | 186.0 | — | — | — | — | 186 | — | — | — | — |
| | 1995[l] | 3 | FL | 171.0 | — | — | — | — | 174 | — | — | — | — |
| | | 4 | FL | 181.0 | — | — | — | — | 182 | — | — | — | — |
| | | 5 | FL | 183.0 | — | — | — | — | 181 | — | — | — | — |
| | | 6 | FL | 190.0 | — | — | — | — | 195 | — | — | — | — |
| | | 7 | FL | 201.0 | — | — | — | — | — | — | — | — | — |
| | 1996[l] | 3 | FL | 188.0 | — | — | — | — | 185 | — | — | — | — |
| | | 4 | FL | 192.0 | — | — | — | — | 185 | — | — | — | — |
| | | 5 | FL | 195.0 | — | — | — | — | 186 | — | — | — | — |
| | | 6 | FL | 193.0 | — | — | — | — | 195 | — | — | — | — |
| | 1998[l] | 2 | FL | — | — | — | — | — | 175 | — | — | — | — |
| | | 3 | FL | 177.0 | — | — | — | — | 172 | — | — | — | — |
| | | 4 | FL | 174.0 | — | — | — | — | 172 | — | — | — | — |
| | | 5 | FL | 181.0 | — | — | — | — | 174 | — | — | — | — |
| | 2003[i] | — | FL, NS | 196.0 | — | 3 | — | 36 | — | — | — | — | — |
| Fraser River | 1986[m] | — | FL | 182.0 | 13.3 | — | 129–212 | 325 | 164 | 21.6 | — | 124–200 | 95 |
| | 1995[n] | — | SL | 158.0 | 11.0 | — | — | 311 | 158 | 10.4 | — | — | 352 |
| | 1996[n] | — | SL | 156.0 | 10.4 | — | — | 241 | 155 | 10.7 | — | — | 218 |
| | 1997[n] | — | SL | 161.0 | 12.0 | — | — | 254 | 158 | 10.4 | — | — | 259 |
| | 1998[n] | — | SL | 158.0 | 12.6 | — | — | 260 | 158 | 15.6 | — | — | 156 |
| | 2000[n] | — | SL | 162.0 | 10.4 | — | — | 108 | 163 | 9.3 | — | — | 93 |
| | 2001[n] | — | SL | 160.0 | 6.4 | — | — | 50 | 156 | 5.3 | — | — | 50 |
| | 4/25/2001[o] | — | FL, NS | 171.0 | 7.2 | — | 117–186 | 138 | — | — | — | — | — |
| | 5/2/2001[o] | — | FL, NS | 171.0 | 7.4 | — | 154–195 | 47 | — | — | — | — | — |
| | 5/3/2002[o] | — | FL, NS | 181.0 | 22.0 | — | 116–206 | 20 | — | — | — | — | — |
| | 2003[i] | — | FL, NS | 183.0 | — | 3 | — | 45 | — | — | — | — | — |
| | 2009[p] | — | — | 192.0 | — | — | — | 77 | 180 | — | — | — | 171 |
| **Washington** | | | | | | | | | | | | | |
| Columbia River | 3/2/1962[q] | — | FL | 155.0 | — | — | 132–180 | 99 | | | | | |
| | 1968 | — | FL | 153.0 | — | — | — | — | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Columbia River (cont.) | 1969 | — | FL, NS | 161.0 | — | — | — | — | — | — | — | — | — |
| | 1978[r] | — | FL | 183.0 | 13.1 | — | 142–250 | 674 | 178 | 12.9 | — | 153–205 | 59 |
| | 1984[s] | 3 | FL, NS | | | | 134–158 | 11 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 125–167 | 52 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 115–185 | 28 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 156–189 | 8 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 148–191 | 5 | — | — | — | — | — |
| | 1985[s] | 3 | FL, NS | — | — | — | 148–150 | 2 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 153–183 | 25 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 156–196 | 48 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 170–204 | 20 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 178–188 | 3 | — | — | — | — | — |
| | | 8 | FL, NS | — | — | — | 192–203 | 2 | — | — | — | — | — |
| | 1986[s] | 2 | FL, NS | — | — | — | 134–145 | 5 | — | — | — | — | — |
| | | 3 | FL, NS | — | — | — | 133–198 | 50 | — | — | — | — | — |
| | | 4 | FL, NS | — | — | — | 125–201 | 50 | — | — | — | — | — |
| | | 5 | FL, NS | — | — | — | 165–211 | 22 | — | — | — | — | — |
| | | 6 | FL, NS | — | — | — | 182–220 | 14 | — | — | — | — | — |
| | | 7 | FL, NS | — | — | — | 201–209 | 2 | — | — | — | — | — |
| | | 8 | FL, NS | 217.0 | — | — | NA | 1 | — | — | — | — | — |
| | 1992[t] | 3 | FL, NS | 169.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 189.3 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 190.8 | — | — | — | — | — | — | — | — | — |
| | 1993[t] | 3 | FL, NS | 164.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 159.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 149.0 | — | — | — | — | — | — | — | — | — |
| | 1994[t] | 3 | FL, NS | 178.7 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 177.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 164.8 | — | — | — | — | — | — | — | — | — |
| | 1994[r] | 2 | FL | 181.0 | 16.8 | — | 151–201 | 12 | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed, TL = total length, NA = not applicable.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Columbia River (cont.) | | 3 | FL | 181.0 | 11.6 | — | 163–205 | 25 | 179 | 13.2 | — | 163–193 | 7 |
| | | 4 | FL | 179.0 | 15.8 | — | 156–209 | 16 | 168 | 10.6 | — | 160–175 | 2 |
| | | 5 | FL | 168.0 | 7.5 | — | 160–178 | 5 | 150 | NA | — | NA | 1 |
| | 1995[t] | 3 | FL, NS | 171.3 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 181.0 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 197.5 | — | — | — | — | — | — | — | — | — |
| | 1996[t] | 3 | FL, NS | 168.5 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 179.4 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 170.2 | — | — | — | — | — | — | — | — | — |
| | 1997[t] | 3 | FL, NS | 165.4 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 170.5 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 162.8 | — | — | — | — | — | — | — | — | — |
| | 1998[t] | 3 | FL, NS | 173.5 | — | — | — | — | — | — | — | — | — |
| | | 4 | FL, NS | 181.5 | — | — | — | — | — | — | — | — | — |
| | | 5 | FL, NS | 175.9 | — | — | — | — | — | — | — | — | — |
| | 2003[i] | — | FL, NS | 175.0 | — | 3 | — | 25 | — | — | — | — | — |
| Cowlitz River | 2/21/1962[q] | — | FL | 162.0 | — | — | 138–195 | 100 | — | — | — | — | — |
| | 3/17/1962[q] | — | FL | 157.0 | — | — | 133–191 | 100 | — | — | — | — | — |
| | 3/19/1962[q] | — | FL | 159.0 | — | — | 143–185 | 50 | 163 | — | — | 121–198 | 98 |
| | 3/31/1962[q] | — | FL | 164.0 | — | — | 134–196 | 99 | 160 | — | — | 121–197 | 98 |
| | 4/5/1962[q] | — | FL | 153.0 | — | — | 128–180 | 100 | 150 | — | — | 118–185 | 95 |
| | 4/7/1962[q] | — | FL | 161.0 | — | — | 134–193 | 97 | — | — | — | — | — |
| Elochoman River | 3/28/1962[q] | — | FL | 153.0 | — | — | 126–190 | 96 | 159 | — | — | 136–194 | 95 |
| Elwha River[u] | 2005 | — | TL | 180.0 | 10.1 | — | 171–195 | 7 | 166 | 28.5 | — | 125–250 | 18 |
| **Oregon** | | | | | | | | | | | | | |
| Tenmile Creek[v] | 1992 | — | FL, NS | 189.0 | — | — | — | 24 | — | — | — | — | — |
| | 1993 | — | FL, NS | 170.0 | — | — | — | 6 | — | — | — | — | — |
| | 1994 | — | FL, NS | 155.0 | — | — | — | 1 | — | — | — | — | — |
| | 2001 | — | FL, NS | 177.0 | — | — | — | 23 | — | — | — | — | — |
| | 2003 | — | FL, NS | 208.0 | — | — | — | 3 | — | — | — | — | — |

Table A-7 continued. Mean length of adult eulachon for selected river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, FL = fork length, NS = not sexed.

| Location | | | | Male length (mm) | | | | | Female length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Date | Age | Method | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Tenmile Creek (cont.) | 2005 | — | FL, NS | 165.0 | — | — | — | 7 | — | — | — | — | — |
| | 2007 | — | FL, NS | 170.0 | — | — | — | 1 | — | — | — | — | — |
| | 2008 | — | FL, NS | 182.0 | — | — | — | 1 | — | — | — | — | — |

[a]Barrett et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubik and Wadman 1977
[c]Kubik and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Langer et al. 1977
[i]Clarke et al. 2007
[j]Pedersen et al. 1995
[k]Kelson 1997
[l]Lewis et al. 2002
[m]Higgins et al. 1987
[n]Hay et al. 2002 (their Table 3)
[o]Stables et al. 2005
[p]Plate 2009
[q]DeLacy and Batts 1963
[r]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[s]Dammers 1988
[t]WDFW and ODFW 2001
[u]Shaffer et al. 2007
[v]WDFW and ODFW 2008

Table A-8. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

| Location | | | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Year | Age | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| **Alaska** | | | | | | | | | | | | |
| Susitna River | 1982[a] Not sexed | — | 72.0 | — | — | — | — | — | — | — | — | — |
| | 1983[a] Not sexed | — | 64.0 | — | — | — | — | — | — | — | — | — |
| Twentymile River | 1976[b] | — | 66.0 | — | — | 41–91 | 200 | 68.0 | — | — | 45–95 | 40 |
| | 1977[c] | — | 90.7 | — | — | 45.4–127 | — | 86.2 | — | — | 54.4–127 | 408 |
| | 2000[d] | — | 69.9 | — | 1.0 | 26.5–104 | 222 | 60.0 | — | 2.8 | 29–101 | 49 |
| | 2001[d] | — | 65.8 | — | 0.5 | 6-106 | 585 | 60.1 | — | 0.5 | 28–122 | 425 |
| Copper River delta | | | | | | | | | | | | |
| Eyak River | 2002[e] | 3 | 43.0 | — | 2.0 | — | 4 | — | — | — | — | — |
| | | 4 | 55.0 | — | 0.0 | — | 430 | 50.0 | — | 10.0 | — | 2 |
| | | 5 | 58.0 | — | 2.0 | — | 9 | — | — | — | — | — |
| Ibeck Creek | 2001[e] | 3 | 53.0 | — | 2.0 | — | 40 | 38.0 | — | 2.0 | — | 3 |
| | | 4 | 50.0 | — | 0.0 | — | 1,089 | 46.0 | — | 1.0 | — | 75 |
| | | 5 | 60.0 | — | 5.0 | — | 5 | — | — | — | — | — |
| | | 6 | 52.0 | — | 4.0 | — | 4 | — | — | — | — | — |
| | 2003[f] | — | 56.0 | | 10.0 | 23–89 | 1,249 | 47.0 | — | 9.0 | 31–82 | 101 |
| Alaganik Slough | 1998[e] | 3 | 53.0 | — | 4.0 | — | 6 | — | — | — | — | — |
| | | 4 | 44.0 | — | 1.0 | — | 35 | 34.5 | — | 1.0 | — | 2 |
| | | 5 | 48.0 | — | 0.0 | — | 377 | 39.9 | — | 1.0 | — | 40 |
| | 2000[e] | 3 | 37.0 | — | 1.0 | — | 47 | 35.0 | — | 2.0 | — | 25 |
| | | 4 | 48.0 | — | 3.0 | — | 21 | 43.0 | — | 6.0 | — | 6 |
| Copper River | | | | | | | | | | | | |
| Flag Point channel | 1998[e] | 3 | 52.0 | — | 2.0 | — | 7 | 56.0 | — | 8.0 | — | 2 |
| | | 4 | 57.0 | — | 1.0 | — | 151 | 49.6 | — | 1.0 | — | 96 |
| | | 5 | 55.0 | — | 0.0 | — | 1,848 | 51.1 | — | 0.0 | — | 478 |
| | | 6 | 52.0 | — | 3.0 | — | 7 | 67.0 | — | 14.0 | — | 2 |
| | 2000[f] | 2 | 55.0 | — | NA | — | 1 | — | — | — | — | — |
| | | 3 | 47.0 | — | 0.0 | — | 534 | 43.0 | — | 1.0 | — | 109 |
| | | 4 | 47.0 | — | 0.0 | — | 547 | 47.0 | — | 1.0 | — | 99 |

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured, NA = not applicable.

| Location | | | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Year | Age | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Flag Point Channel | | 5 | 53 | — | 2.0 | — | 43 | 39.0 | — | 3.0 | — | 5 |
| (cont.) | | 6 | 60 | — | NA | — | 1 | — | — | — | — | — |
| | 2001[f] | 2 | — | — | — | — | — | 37.0 | — | NA | — | 1 |
| | | 3 | 48 | — | 0.0 | — | 643 | 45.0 | — | 1.0 | — | 306 |
| | | 4 | 52 | — | 0.0 | — | 571 | 48.0 | — | 1.0 | — | 155 |
| | | 5 | 52 | — | 2.0 | — | 21 | 47.0 | — | 3.0 | — | 2 |
| | 2002[f] | 3 | 53 | — | 3.0 | — | 16 | 47.0 | — | 2.0 | — | 2 |
| | | 4 | 57 | — | 0.0 | — | 1,081 | 52.0 | — | 1.0 | — | 175 |
| | | 5 | 62 | — | 3.0 | — | 15 | 66.0 | — | NA | — | 1 |
| 60-km Bridge | 2002[f] | 3 | 57 | — | 7.0 | — | 3 | 51.0 | — | 3.0 | — | 7 |
| | | 4 | 62 | — | 0.0 | — | 575 | 58.0 | — | 1.0 | — | 218 |
| | | 5 | 68 | — | 3.0 | — | 9 | — | — | — | — | — |
| Southeast Alaska | | | | | | | | | | | | |
| Stikine River[g] | 1979 | 2 | 38 | — | — | 18–50 | — | — | — | — | — | — |
| | | 3 | 46 | — | — | 28–60 | — | — | — | — | — | — |
| | | 4 | 52 | — | — | 34–58 | — | — | — | — | — | — |
| | 1980 | 2 | 35 | — | — | 30–42 | — | — | — | — | — | — |
| | | 3 | 46 | — | — | 32–60 | — | — | — | — | — | — |
| | | 4 | 58 | — | — | 52–64 | — | — | — | — | — | — |
| **British Columbia** | | | | | | | | | | — | — | — |
| Skeena River | 2003[h] | — | 48.7 | — | 1.7 | — | 52 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| Kitimat River | 1993[i] | 3 | — | — | — | — | — | 43.0 | — | 1.5 | 27–71 | 44 |
| | | 4 | — | — | — | — | — | 50.5 | — | 2.0 | 40–60 | 12 |
| | | 5 | — | — | — | — | — | 52.0 | — | NA | NA | 1 |
| | | 6 | — | — | — | — | — | 40.2 | — | 7.8 | 48–80 | 2 |
| | 1997[j] | 2 | 42.4 | 5.9 | — | — | 2 | 33.8 | NA | — | — | 1 |
| | | 3 | 46.2 | 11.3 | — | — | 28 | 44.9 | 10.5 | — | — | 25 |
| | | 4 | 45.6 | 11.0 | — | — | 16 | 41.9 | 9.1 | — | — | 37 |
| | | 5 | 55.0 | 16.6 | — | — | 13 | 48.6 | 12.6 | — | — | 10 |
| | | 6 | 50.4 | N/A | — | — | 1 | 47.2 | 19.7 | — | — | 2 |

Table A-8 continued. Mean weight of adult eulachon for all available river basins for individual years, sex, and age. Dashes indicate data were unavailable. SD = standard deviation, SE = standard error, No. = number measured.

| Location | | | Male weight (g) | | | | | Female weight (g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (river basin) | Year | Age | Mean | SD | SE | Range | No. | Mean | SD | SE | Range | No. |
| Kemano River | 1988–1998[k] | — | 47.5 | 10.9 | — | — | 1,110 | 44.2 | 10.7 | — | — | 1,433 |
| | 2003[h] | — | 57.5 | — | 2.3 | — | 36 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| Fraser River | 1986[l] | — | 46.3 | 10.7 | — | 13.8–81 | 325 | 34.7 | 14.5 | — | 12.9–63.7 | 95 |
| | 1995[m] | — | 42.8 | 10.9 | — | — | 311 | 44.3 | 9.6 | — | — | 352 |
| | 1996[m] | — | 40.8 | 9.5 | — | — | 241 | 42.8 | 9.9 | — | — | 218 |
| | 1997[m] | — | 38.1 | 9.1 | — | — | 254 | 38.0 | 7.1 | — | — | 259 |
| | 1998[m] | — | 36.7 | 8.6 | — | — | 260 | 37.0 | 9.9 | — | — | 156 |
| | 2000[m] | — | 43.2 | 9.0 | — | — | 108 | 46.2 | 8.4 | — | — | 93 |
| | 2001[m] | — | 36.7 | 5.0 | — | — | 50 | 37.4 | 3.5 | — | — | 50 |
| | 2003[h] | — | 47.2 | — | 1.6 | — | 45 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| | 2009[n] | — | 59.0 | — | — | — | 77 | 51.0 | — | — | — | 171 |
| **Washington** | | | | | | | | | | | | |
| Columbia River | 1978[o] | — | 42.0 | 9.9 | — | 20–76.1 | 674 | 39.6 | 10.6 | — | 20.5–64.3 | 59 |
| | 2003[h] | — | 37.3 | — | 1.8 | — | 25 | — | — | — | — | — |
| | Not sexed | | | | | | | | | | | |
| Elwha River[p] | 2005 | — | 40.3 | 5.8 | — | 36–49 | 7 | 28.9 | 12.2 | — | 11–58 | 18 |

[a]Barret et al. 1984 (as reprinted in Willson et al. 2006)
[b]Kubic and Wadman 1977
[c]Kubic and Wadman 1978
[d]Spangler 2002
[e]Moffit et al. 2002
[f]Joyce et al. 2004
[g]Franzel and Nelson 1981 (in Willson et al. 2006, their Table 2b)
[h]Clarke et al. 2007
[i]Pederson et al. 1995
[j]Kelson 1997
[k]Lewis et al. 2002
[l]Higgins et al. 1987
[m]Hay et al. 2002, their Table 3
[n]Plate 2009
[o]Data provided by Brad James, WDFW, Vancouver, WA, 2008
[p]Shaffer et al. 2007

Table A-9. Range (gray) and peak (black) timing of documented river entry or spawn timing for eulachon.

[a]References in Table A-3.
[b]WDFW and ODFW 2008
[c]WDFW and ODFW 2001
[d]Shaffer et al. 2007
[e]Ricker et al. 1954, Hart 1943, Hart and McHugh 1944
[f]Mills 1982
[g]Lewis et al. 2002
[h]Moody 2008
[i]Pedersen et al. 1995, Kelson 1996 (cited in Moody 2008).
[j]Lewis 1997
[k]Langer et al. 1977
[l]Franzel and Nelson 1981
[m]Flory 2008b, Berry and Jacob 1998
[n]Marston et al. 2002, Eller and Hillgruber 2005
[o]Betts 1994
[p]Joyce et al. 2004
[q]Moffitt et al. 2002
[r]Kubik and Wadman 1977, 1978, Spangler et al. 2003
[s]Barrett et al. 1984 (cited in Spangler et al. 2003).

Table A-10. Documented avian predators on spawning runs of eulachon.

| Avian predator | River system: Twentymile River[a] | Copper River delta[b] | Berner's Bay[c, d] | Columbia River[e] |
|---|---|---|---|---|
| Gulls (*Larus* spp.) | X | | | |
| Herring gull (*Larus argentatus*) | | X | X | X |
| Thayer's gull (*L. thayeri*) | | | X | X |
| Glaucous-winged gull (*L. glaucescens*) | | X | X | X |
| Glaucus gull (*L. hyperboreus* ) | | | | X |
| Mew gull (*L. canus*) | | X | X | |
| Western gull (*L. occidentalis*) | | | | X |
| California gull (*L. californicus*) | | | | X |
| Bonaparte's gull (*L. philadelphia*) | | X | X | X |
| Ring-billed gull (*L. delawarensis*) | | | | X |
| Terns (*Sterna* spp.) | | | X | |
| Bald eagle (*Haliaeetus leucocephalus*) | X | X | X | X |
| Marbled murrelet (*Branchyrhamphus marmoratus*) | | | X | |
| Cormorants (*Phalacrocorax* spp.) | | | | X |
| Mergansers (*Mergus* spp.) | | | X | X |
| Grebes (*Podiceps* spp.) | | | X | |
| Scoters (*Melanitta* spp.) | | | X | |
| Loons (*Gavia* spp.) | | | X | |
| Corvids | | | X | |
| Common raven (*Corvus corax*) | | X | | |
| Northwestern crow (*C. caurinus*) | | X | | |
| Black-billed magpie (*Pica hudsonia*) | | X | | |

[a]Spangler 2002
[b]Maggiulli et al. 2006
[c]Willson and Marston 2002
[d]Marston et al. 2002
[e]WDFW and ODFW 2001

Table A-11. Temperatures at the time of river entry and spawning for eulachon in different river systems.

| Location | Temperature | Incubation time | Reference |
|---|---|---|---|
| Columbia River | 6.5°–9.0°C | ≈ 21 days | Parente and Snyder 1970 |
| Cowlitz River | 4.5°–7.0°C | 30–49 days | Smith and Saalfeld 1955 |
| Fraser River | 4.0°–5.0°C | ≈ 28 days | Hay and McCarter 2000 |
| Fraser River | 4.4°–7.2°C | 30–40 days | Hart 1973 |
| Kemano River | 1.1°–6.5°C | 50 days | Lewis et al. 2002 |
| Kitimat River | 4.0°–7.0°C | ≈ 42 days | Willson et al. 2006, their Table 4 |
| Nass River | 0.0°–2.0°C | Unknown | Langer et al. 1977 |

# Appendix B: Selected Accounts of Eulachon in Local Newspapers

[*Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting obvious typographical errors without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncracies of spelling and phrasing in the older works are generally preserved. Some of the excerpts are market ads.*]

Table B-1. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| Oregon Spectator | Oregon City, Oregon Territory | Smelt, eulachon | 2-5-1846 | 3-1855 | Oregon Spectator Index, 1846–1855, Vol. 1 and 2 |
| Oregonian | Portland, Oregon Territory | Smelt, eulachon | 12-4-1850 | 1-28-1850 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Morning Oregonian | Portland, OR | Smelt, eulachon | 8-19-1861 | 4-23-1890 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Weekly Oregonian | Portland, OR | Smelt, eulachon | 2-4-1854 | 11-15-1862 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Daily Oregonian | Portland, OR | Smelt, eulachon | 7-19-1869<br>8-11-1869<br>8-19-1869<br>8-23-1869<br>10-2-1875 | | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Oregonian | Portland, OR | Smelt, eulachon | 2-4-1861 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Democratic Standard | Portland, Oregon Territory | Smelt, eulachon | 8-30-1854 | 2-16-1859 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Eugene Register-Guard | Eugene, OR | Umpqua smelt | 1912 | 2007 | Online at news.google.com |
| Vancouver Register | Vancouver, Wash. Territory | Visual search for smelt | 10-7-1865<br>2-15-1868<br>6-6-1868 | 9-14-1867<br>3-7-1868<br>0-9-1869 | Historic Newspapers in Washington. http://www.secstate.wa.gov/ history/newspapers.aspx |
| Olympia Record | Olympia, WA | Smelt, eulachon | 5-13-1902 | 1-3-1923 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Morning Olympian | Olympia, WA | Smelt, eulachon | 3-15-1891 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Tacoma Daily News | Tacoma, WA | Smelt, eulachon | 8-25-1890 | 12-31-1898 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Bellingham Herald | Bellingham, WA | Smelt, eulachon, hooligan, candlefish | 10-2-1903 | 12-30-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| Centralia Chronicle | Centralia, WA | Smelt, eulachon | 8-1-1889<br>2-7-1902 | 6-26-1890<br>6-13-1902 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| Centralia Daily Chronicle | Centralia, WA | Smelt, eulachon | 5-1-1908 | 1-11-1913 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 9-2-1918 | 2-28-1920 | |
| | | | 7-14-1928 | 12-31-1937 | |
| Centralia Daily Chronicle-Examiner | Centralia, WA | Smelt, eulachon | 1-13-1913 | 12-31-1913 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 7-1-1914 | 12-31-1915 | |
| Centralia News-Examiner | Centralia, WA | Smelt, eulachon | 9-23-1904 | 2-23-1910 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 12-28-1911 | | |
| | | | 10-3-1912 | | |
| | | | 10-21-1912 | | |
| | | | 12-29-1912 | | |
| | | | 12-11-1913 | | |
| | | | 4-11-1916 | 05-18-1916 | |
| Centralia Weekly Chronicle | Centralia, WA | Smelt, eulachon | 11-9-1910 | 10-2-1912 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Chehalis Bee-Nugget | Chehalis, WA | Smelt, eulachon | 10-28-1921 | 5-24-1938 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Chehalis Bee | Chehalis, WA | Smelt, eulachon | 5-21-1897 | | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| | | | 7-16-1897 | | |
| | | | 7-23-1897 | | |
| Kalama Beacon | Kalama, Wash. Territory | Visual search | 5-19-1871 | 2-10-1874 | Univ. Washington Library, Microfilm A-48 |
| Eureka Humboldt Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 1-1-1958 | 05-31-1967 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Humboldt Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 1-1-1952 | 12-31-1957 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |
| Times-Standard | Eureka, CA | Smelt, candlefish, candle fish, eulachon | 6-1-1967 | 12-31-1977 | Newspaper ARCHIVE.com. http://www.kcls.org/databases/ |

Table B-1 continued. Available newspaper indices and records in online digital and microfilm format searched for reference to the presence of information on eulachon (*Thaleichthys pacificus*) spawning runs in Washington, Oregon, and California.

| Newspaper | City, state | Keywords searched | Start date | End date | Database and online URL |
|---|---|---|---|---|---|
| San Francisco Call | San Francisco, CA | Smelt, candlefish, candle fish, eulachon | 1895 | 1910 | California Digital Newspaper Collection. http://cbsr.tabbec.com/ |
| San Francisco Bulletin | San Francisco, CA | Smelt, candlefish, candle fish, eulachon | 10-8-1855 | 12-31-1891 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |
| San Jose Mercury News | San Jose, CA | Smelt, candlefish, candle fish, eulachon | 11-5-1861 | 12-31-1922 | America's Genealogy Bank, Historical Newspapers. http://www.spl.org/default.asp?pageID=collection_db |

# Oregon (Columbia River)

**Morning Oregonian (Portland), Saturday, 6 April 1867, p. 4, col. 2**

> Smelt—Holman & Co. of the Union Fish Market have just received a fine lot of smelt, halibut, etc. They keep on hand the best and freshest fish of the season. Call on them on Washington Street near Second.

**Morning Oregonian (Portland), Thursday, 9 April 1868, p. 4, col. 6**

Fish! Fish!
At the Franklin Fish Market!
134 First St., Portland
Just Received Fresh from the Fisheries, Smelt by the Million

**Morning Oregonian (Portland), Friday, 15 January 1869, p. 2, col. 4**

New To-Day, Oak Point Smelt!
At the Franklin Fish Market, 134 First Street.
Just Received by the Str. Ranger—large supply.

**Morning Oregonian (Portland), Thursday, 21 January 1869, p. 2, col. 4**

Fresh Oak Point Smelt at the Franklin Fish Market by the Steamer "Okanagan"

**Morning Oregonian (Portland), Tuesday, 25 January 1870, p. 2, col. 4**

New Today, Fresh Smelt, Three Pounds for 25 Cents
Arrived last night at the "Union Fish Market," Washington Street between First and Second
Hotels and Restaurants Supplied Cheap—J. Quinn.

**Daily Oregonian (Portland), Saturday, 28 January 1871, p. 2, col. 3**

New To-Day, Fresh Smelt
A Fresh Lot Arrived Last Night for Sale at Quinn's Union Fish Market on Waddington Street.
Hotels and Restaurants Supplied at Low Rates.

**Daily Oregonian (Portland), Wednesday, 1 February 1871, p. 4, col. 1**

Local Brevities

> Six tons of smelt arrived from down the river on Monday night, and the market may be said to be full and terms in favor of the buyer.

**Daily Oregonian (Portland), Saturday, 20 January 1872, p. 3, col. 2**

Local Brevities

> The first smelt of the season appeared in the market last evening.
>
> The First Smelt at Quinn's—Quinn, of the Union Market, Washington Street, is, as usual, the first on hand with the delicacies of the season. This time he has the first catch of smelt. Call early, if you would make sure of a mess.

**Daily Oregonian (Portland), Friday, 16 February 1872, p. 3, col. 3**

> Smelt—Quinn, of the Union Fish Market, has sufficient quantity of smelt now to supply all demands. The prices are so low that everybody can eat 'em. … Don't go home without a mess of smelt.

**Daily Oregonian (Portland), Tuesday, 8 December 1874, p. 2, col. 2**

First Smelt!
The First Lot of Smelt of the Season!
At Quinn's, 3 lbs for 25 Cents

**Daily Oregonian (Portland), Wednesday, 17 March 1875, p. 3, col. 3**

> Smelt—the first of the season—from the Columbia River in large quantities at Malarkey's, Second Street, between Stark and Washington. Get a mess.

**Daily Oregonian (Portland), Tuesday, 22 February 1876, p. 2, col. 5**

Columbia River Smelt!
First of the Season of 1876
At C. A. Malarkey's New York Market, S.E. Cor. Stark and Second streets

**Daily Oregonian (Portland), Friday, 25 February 1876, p. 3, col. 3**

1,000 Pounds Fresh Columbia River Smelt, for Sale Wholesale and Retail by C. A. Malarkey, S.E. Corner Stark and Second streets.

**Daily Oregonian (Portland), Wednesday, 1 March 1876, p. 2, col. 4**

Fresh Columbia River Smelt. I received last night the largest lot that has come to market this season. 3 lbs for 25 cts. C. A. Malarkey New York Market, S. E. Cor. Stark and Second streets.

**Daily Oregonian (Portland), Saturday, 4 March 1876, p. 2, col. 3**

Caution.

> Fresh Columbia River Smelt. The public are cautioned against buying Puget Sound Smelt for Columbia River Smelt. Come to headquarters for the latter.

Large lot received again last night. C. A. Malarkey, New York Market, S. E. Cor. Stark and Second.

**Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3**

Columbia River Smelt!
First of the Season of 1878!
Wholesale and Retail at Chas. A. Malarkey's New York Market
S.E. Cor. Stark and Second sts., Portland

**Daily Oregonian (Portland), Saturday, 2 February 1878, p. 2, col. 3**

Hurra! Hurra!
First Columbia River Smelt of the Season
Smelt! Smelt! Smelt!
At 5 Cents per Pound
Wholesale and Retail at Dougherty & Browne's Washington Market
Corner Fourth and Washington streets

**Daily Oregonian (Portland), Thursday, 22 January 1880, p. 2, col. 3**

Smelt, Smelt, Columbia River Smelt
First of the season 1880
At C. A. Malarkey's New York Market, Stark Street between First and Second

**Morning Oregonian (Portland), Thursday, 5 February 1880, p. 1, col. 4**

Smelt fishermen are making good wages on the river now. Some make $40 a night with dip nets. Hapgood Cannery at Waterford has put up 8,000 pounds. There is a big run.

**Daily Oregonian (Portland), Thursday, 12 February 1880, p. 3, col. 1**

Dead Smelt—A gentlemen who came up the river from Astoria yesterday, informs us that millions of smelt are dying from some unknown cause in the Columbia and floating ashore. In the vicinity of Pillar Rock the bank is lined with these little fish for some distance, and hundreds of voracious sea gulls are constantly devouring them.

**Morning Oregonian (Portland), Saturday, 8 January 1881, p. 2, col. 3**

Smelt, Columbia River Smelt, Season 1881
A Fine Lot just Received by C. A. Malarkey, New York Market
N.E. Corner Oak and Second Street
Country Orders Promptly Filled

**Morning Oregonian (Portland), Wednesday, 27 February 1882, p. 3, col. 1**

C. A. Malarkey, Second and Oak, Will Receive this Morning a Choice Lot of Columbia River Smelt.

**Morning Oregonian (Portland), Tuesday, 6 March 1883, p. 2, col. 4**

New To-Day, Smelt, First of the Season
At Williams & Sons General Market

**Morning Oregonian (Portland), Tuesday, 13 March 1883, p. 3, col. 7**

Smelt! Smelt! Columbia River Smelt!
These Most Delicious Fish Are Now Being Received by C. A. Malarkey Daily
Orders from the Country Will Be Filled Promptly.
C. A. Malarkey, New York Market, N.E. Corner Oak and Second St.

**Morning Oregonian (Portland), Monday, 25 February 1884, p. 1, col. 8**

Smelt, Smelt, Columbia River Smelt!
First of the season of 1884 have now arrived
Send your orders to Chas. A. Malarkey, N.W. Corner Fourth and Morrison streets

**Morning Oregonian (Portland), Tuesday, 4 March 1884, p. 2, col. 4**

Smelt, Smelt, Columbia River Smelt!
The Most Delicious of All Fish are Now Coming to Market
Country Customers Will Find It to their Advantage to Order from C. A. Malarkey, Fourth and Morrison sts

**Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 1**

Columbia River Smelt

> These delicious little fish have made their appearance at Astoria, and C. A. Malarkey corner of Fourth and Morrison has made arrangements to receive a full supply during the season. He expects the first lot to-day. Call early and leave your order.

**Morning Oregonian (Portland), Friday, 13 February 1885, p. 3, col. 3**

Local and General

> The Little Fish Coming—Polish up your frying pan, for Malarkey says he is going to have Columbia River smelt to-day. These little fish have become of considerable importance to fishermen and several boats have been kept on the lookout for their advent for the past two weeks. The advance guard of the immigration came up the river a little way some days since, but smelling the snow

in eastern Oregon, took a wheel back. The ones behind are shoving on the ones before, and countless millions of smelt are crossing in over the bar, anxious to reach the Cowlitz or the Sandy.

**Oregonian (Portland), Wednesday, 25 February 1885, p. 3, col. 1**

Brief Mention

Considerable anxiety has been expressed about the Columbia River smelt fleet now overdue here and anxiously awaited by all good citizens. It is now stated that the smelt are hovering off the bar waiting for a pilot.

**Oregonian (Portland), Friday, 27 February 1885, p. 3, col. 2**

Fish In Supply. … The first box of Columbia River smelt, so long looked for, was received by J. W. and V. Cook last evening. It contained about 20 pounds—the result of a night's fishing by five men. There will be plenty in a few days, sure.

**Daily Oregonian (Portland), Friday, 13 March 1885, p. 3, col. 2**

Local and General

No Hope For Smelts—Fishermen generally have about given up hope of a smelt harvest this year. In speaking of the matter yesterday, a pioneer, who resided for many years on the lower Columbia, says that there were no smelt or oolachan, as they were called by Indians, in the Columbia from the time he came here till in 1863, when they appeared in vast numbers about the middle of February, and have been plentiful every season since. In Irving's "Astoria" mention is made of the great quantities of smelt in the Columbia in 1826. Shortly after they forsook the river entirely and did not return till 1863, having been absent nearly 40 years. It would be interesting to know why the smelt deserted the river and in what ocean wilderness they wandered all these 40 years. If they have gone again to stay 40 years, most of us may as well say good-bye to them for we'll eat no more Columbia River smelt unless the doctrine of transmogrification is true, in which case if a fellow is changed into a seal or a sturgeon he may have a chance at them once more.

**Morning Oregonian (Portland), Sunday, 31 January 1886, p. 5, col. 1**

There is a great rivalry just now among the fish dealers. The first smelt are now in the market. Malarkey went down the river yesterday, met the steamer as she was coming up and secured all the smelt, which were piled up last night triumphantly on his tables.

**Morning Oregonian (Portland), Tuesday, 2 February 1886, p. 3, col. 1**

Wm. McGuire & Co., corner Third and Morrison streets, corralled all of the smelt that came to town yesterday, consequently they have the only fresh smelt in the city. They received 25 large boxes—over 4,000 pounds—and are prepared to furnish everybody at reasonable prices. They are prepared to fill all orders from the country at lowest rates and guarantee perfect satisfaction. Send in your orders. Telephone 371.

**Morning Oregonian (Portland), Sunday, 7 February 1886, p. 5, col. 6**

Columbia River Smelt

Wm. McGuire & Co., Third and Morrison, have made arrangements to receive large supplies of fresh smelt daily and are prepared to fill all orders from the country at lowest rates. Send in your orders early.

**Morning Oregonian (Portland), Tuesday, 10 February 1886, p. 2, col. 4**

Smelt And Salmon

Columbia River smelt and genuine Chinook salmon received daily and for sale in any quantity from one pound to one ton by C. A. Malarkey, corner of Fourth and Morrison streets.

**Morning Oregonian (Portland), Saturday, 11 December 1886, p. 5, col. 1**

The first Columbia River smelt of the season came up yesterday to George Ginstin, of the Baltimore Market, No. 290 First.

**Morning Oregonian (Portland), Wednesday, 19 January 1887, p. 3, col. 2**

Local and General

A Few Good Fish— … Vin Cook says they had a mess of Columbia River smelt down at Clifton the other day, but have not been able to catch any since. It will not be long till these delicious little fish are here.

**Oregonian (Portland), Friday, 28 January 1887, p. 3, col. 2**

Local and General

Fish In Demand— … while [another fisherman] proudly exhibited a sample of genuine Columbia River smelt. Vin Cook has a party on the lookout for the arrival of these anxiously awaited little fish, and they yesterday sent him up several pounds. The advance of the main school of smelt may be expected any day now. It was about this time last year that the first shipment came up.

**Oregonian (Portland), Thursday, 24 February 1887, p. 5, col. 2**

Local and General

Fishing For Smelt—No doubt many people once in a while give a thought to the Columbia River smelt, which would have been in market before now but for the cool spell, but probably very few have any idea of the number who are keeping a sharp lookout along the Columbia for the advent of these little fish. Although the Columbia from the mouth of the Willamette for a long way up has been frozen for some time and there has been snow all along down the river, not a day has passed for the last three weeks but what seines have been put out and dip nets plied at various points in vain search for the smelt. At Oak Point two men in the employ of a fish dealer here have been going out twice every day for the past three weeks and probing the Columbia with dip nets, but nary a smelt have they caught. As the ice is now going out the fish may be expected any day.

**Morning Oregonian (Portland), Monday, 1 March 1887, p. 3, col. 4**

Fish dealers were all on hand when the [steamer ship] Telephone arrived yesterday, expecting to see a shipment of Columbia River smelt. They were disappointed, but the little fish will be here soon or not at all.

**Morning Oregonian (Portland), Saturday, 5 March 1887, p. 3, col. 3**

Brief Mention

The prospect is that we are to have no Columbia River smelt this season.

**Oregonian (Portland), Wednesday, 9 March 1887, p. 3, col. 3**

Local and General

Coming Up on the Rise—People had about given up all idea of seeing any Columbia River smelt this season, but it appears that they have not deserted us but were only lying off the mouth of the river waiting for the water to become decently warm in order to swarm to their spawning place in the Cowlitz and Sandy. Deep sea fishermen at Astoria report that the cod and groupers caught by them of late have been literally filled with smelt and they predict a large run. The late heavy warm rains have put the schools a motion and in a few days it will perhaps be possible to walk across the Sandy on the backs of the smelt. …

Smelt at Last—Late last night McGuire & Co., fish dealers, corner o' Third and Morrison streets, received a telegram from down the river stating that several boxes of Columbia River smelt would arrive on the [steamer ship] Telephone today for them. These will be the first smelt of the season and as the steamer will arrive about 2:30 everybody can have smelt for dinner by leaving orders early today.

**Morning Oregonian (Portland), Thursday, 10 March 1887, p. 5, col. 3**

Local and General

> The Smelt Here—The first lot of smelt of the season arrived on the [steamer ship] Telephone yesterday, and very fine they were, being much larger and plumper than the first to arrive usually are. A number of them were evidently caught by Indians in the old-fashioned way by sweeping a stick armed with sharp pointed nails through the water and impaling the smelts thereon.

**Morning Oregonian (Portland), Friday, 11 March 1887, p. 3, col. 3**

> And now the smelt come in earnest. C. A. Malarkey came up the river last evening having secured the entire catch of these delicious fish along the Columbia for the day some two tons in all. He is prepared to furnish all both great and small, and as he has the only smelt in the city orders should be left early this forenoon.

**Sunday Oregonian (Portland), 26 February 1888, p. 5, col. 3**

Fish and Fishing

> … The smelt season is about over apparently. They have not come above the Cowlitz as yet, and are not likely to visit the Sandy this season. They have gone so far up the Cowlitz now that there is trouble to get them and boxes of them which a few days ago could be bought for 50 cents have jumped to $3.

**Sunday Oregonian (Portland), 11 March 1888, p. 5, col. 2**

In and About Portland

> Large quantities of smelt still continue to be sent up from the Cowlitz. Nothing has been heard of them reaching the Sandy yet.

**Morning Oregonian (Portland), Thursday, 13 December 1888, p. 8, col. 1**

Picked Up About the Town

> The First, Lone Smelt—Mr. Calper, who has a salmon fishery on Lewis River, a day or two since caught a fine large Columbia River smelt, which in some manner became entangled in his net. This is the first smelt of the season, and it comes to hand unusually early, as they generally put in an appearance some time in February. It is also a little strange that the first smelt heard from should be taken in Lewis River, as for the three past seasons the shoals of these fish have not come any farther up than the Cowlitz. It will hardly be worth while for our epicures to make up their mouths for smelt yet awhile. One swallow does not make it summer, nor does one smelt make it spring, and in all probability we shall have a cold snap before we shall see smelt in the market.

**Morning Oregonian (Portland), Thursday, 27 December 1888, p. 5, col. 2**

Portland and Vicinity

Smelt for Christmas Dinner—Last evening a gentleman marched into the reporter's room of The Oregonian office and left a parcel with the compliments of Vin Cook. On opening the package it was found to be a cigar box filled with genuine Columbia River smelt, which glistened in the lamplight like silver. A short time since a notice was published in The Oregonian of a single smelt having been caught by Mr. Calper in his salmon seine in Lewis River. Mr. Cook, who is at Clifton, seeing this, sent out a boat to drift for smelt and enough was caught to make a course for the Christmas dinner for all hands at Clifton and some left to send to The Oregonian. It is hardly probable that any one in this region ever had Columbia River smelt for dinner on Christmas before. The smelt usually arrive in February and what they mean by coming so much earlier than usual this year it is impossible to say. They have some queer ways, as only a few years since they forgot to come up entirely. It may be that they have had some premonition that there would be no winter this time and if so the chances are ten to one that they will find themselves fooled. If the weather should "come off" warm with rain it is not unlikely that there will be smelt in the market very soon.

**Morning Oregonian (Portland), Saturday, 12 January 1889; p. 8, col. 1**

Gathered by Reporters
First Shipment for the Season of Columbia River
Smelt Quickly Disposed Of

Nothing Too Rich For Us—The first shipment of Columbia River smelt of this season arrived here yesterday. There were only 35 pounds of them, and they were all disposed of by McGuire & Co. before they arrived for 50 cents per pound, that being the price fixed by the fishermen, who have been out drifting for several nights in hopes of making a haul. The price made no difference, and many more could have been sold. Wealthy people at the East think nothing of paying a dollar a pound or more for the first salmon or trout of the season, and our wealthy people are not going to be left on the first Columbia River smelt, no matter what the price is.

**Morning Oregonian (Portland), Thursday, 21 February 1889, p. 5, col. 1**

Columbia River Smelt—Columbia River smelt are coming in plentiful and Malarkey & Co., corner of Fourth and Morrison streets, have enough to supply everybody at cheaper prices than ever before. The run will not last long and if you want a mess of these delicious little fish now is the time to get them. This firm makes a specialty of shipping these fish and orders from the country for any quantity will be promptly filled.

**Morning Oregonian (Portland), Friday, 22 February 1889, p. 4, col. 3**

Smelt, Smelt

> Columbia River Smelt are now growing plentiful and cheap. Parties wishing to procure smelt for salting down can buy them by the box at a low price. Remember that the run lasts but a short time. Malarkey & Co., Fourth and Morrison streets.

**Morning Oregonian (Portland), Wednesday, 18 December 1889, p. 6, col. 7**

The Very First of the Season
A Small Lot of Smelt Have Put in an Appearance in the City

> A small lot of genuine Columbia River smelt were displayed at C. A. Malarkey & Co.'s market yesterday. They were, it is needless to say, the first of the season, and as the fisherman who sent them up wrote, "they are the earliest smelt that ever went into Portland market." J. B. Johnson captured them near Quinn's Landing, and the 25 pounds represent three night's work out in the cold. He has got ahead of Vin Cook this year, and broken the record, for no living man has ever seen Columbia River smelt here so early before. They generally arrive about the 1st of January, and when they come it is considered that winter is over. Many who saw the smelt yesterday, said "well winter is over," but it is more probable that the smelt have made a mistake. Many things have been mentioned as tending to indicate that we are to have a hard winter, but the arrival of these smelt is the first thing which seems to indicate that winter is over, and we might as well cling to the hope till it is dispelled.

**Morning Oregonian (Portland), Monday, 23 December 1889, p. 5, col. 1**

> Something about Early Smelt—Mr. James Quinn, formerly a well-known resident of this city, but for years a resident at Quinn's Landing on the lower Columbia, demurs to the statement published in these columns a few days since, to the effect that some Columbia River smelt received here on that day were, as the man who caught them claimed, the earliest smelt ever seen in the Portland market. Mr. Quinn says he had fresh Columbia River smelt in his market on Washington Street, on the 8th of December, 1869. From this it appears that Mr. Johnson in 1889 was 10 days behind Mr. Quinn in 1869 in getting smelt to this market. It is the belief of many fishermen that smelt and Chinook salmon both are in the river all winter, and could be taken if fished for, but the game would hardly be worth the candle.

**Morning Oregonian (Portland), Friday, 22 January 1892, p. 5, col. 2**

> The Smelt as a Weather Prophet—The shoals of smelt which have been in the Columbia River for the past month or six weeks have struck into the Cowlitz. Over a ton of these fish were sent up from the Cowlitz Wednesday evening, and it was supposed that they would continue to be plentiful, but the next day only a

small lot arrived, and it is feared that the shoals will soon go up the river out of reach, and the smelt season will be over. The fact that the smelt have started up for their spawning grounds is considered by many to indicate that winter is over. It is scarcely probable that there will be any ice or snow this winter.

**Morning Oregonian (Portland), Monday, 28 November 1892, p. 6, col. 2**

Columbia Smelt. An Unusually Early Catch of the Dainty Little Fish

A lot of Columbia River smelt were received in this city Saturday, and very fine ones they were. This is the earliest time of year that smelt have ever been caught. They were taken by J. B. Johnson, near Eagle Cliff, and the first sales were made at 75 cents per pound, which is the highest price ever paid for the delicious little pan fish.

The Columbia River smelt did not put in an appearance formerly, as a general thing, till about the 1st of February, and if there happened to be a cold winter and ice in the Columbia, they did not materialize until after the ice had gone out, when they arrived in the Cowlitz in immense shoals, and shortly after in the Sandy in like numbers. For several years past fishermen have been using dip nets in the Columbia, searching for smelt, and last year and the year before at Christmastime they caught small lots right along. The first man who got a shipment into market received a high price, as every market man was anxious to have the first lot, which he had no trouble in disposing of at 50 cents per pound. The price would soon drop to 25 cents, then to a bit, and when the shoals of fish got into the Cowlitz they would sell for 5 cents. Soon they would be shipped all over the country, and then there would be many more smelt than could be got rid of at any price.

The fact that the smelt were to be found in the river in December led some to imagine that they were there all winter, staying in deep water. If such is the case, Mr. Johnson, who made this early catch and broke the record, has probably found one of their haunts. Some people think that the freshet in the Columbia—if a rise of five feet at Vancouver can be called a freshet—has brought the fish up the river. There is no probability, however, of their going up the Cowlitz to their spawning grounds till the snow is gone out of the mountains at the headwaters of that stream.

The Columbia River smelt is what is called farther north the oolihan, or candlefish, and is esteemed as one of the most delicious little fish caught. Salmon and trout have no superiors in their season, but the smelt comes at a season when other fish are scarce, and so is most esteemed. If it is going to come at this season and mix itself up with Sound smelt and all the other fish in the market, its good qualities will have to submit to the test of comparison.

**Morning Oregonian (Portland), Monday, 1 January 1893, p. 5, col. 1**

Smelt Have Returned—The Columbia River smelt, which arrived earlier this season than ever before so far as known, and were well along on their way up the

Cowlitz River to their spawning grounds when the snow storm came on and drove them back, have re-entered the Cowlitz and will for a time be plentiful in the local market. They re-entered the Cowlitz last Friday, and a man who happened to be loafing along the bank of the river saw them pouring up the stream in a solid column about two feet in width. He hastily secured a dip net, worked with a will for two hours, caught the boat coming to this city and sold his catch for $25. He was much elated with his success, and expressed his intention of devoting the remainder of his life to fishing.

**Morning Oregonian (Portland), Wednesday, 2 January 1895, p. 9, col. 1–2**

Great Quantities of Smelt

The Columbia River smelt, the most delicious of panfish, during the past year commenced coming to market in October, more than a month earlier than ever known before. Small quantities have been received almost daily ever since, but within the past week the shoals have entered the Cowlitz River, on their way to their spawning grounds, and they have been taken in large quantities. The change in the weather has been so slight as hardly to check them, although ice or snow might send them back into the deep waters of the Columbia. With the first rains, the immense shoals of these fish will swarm the Cowlitz and tons of them will be coming to market, and they will be shipped to all parts of the country. No method has yet been discovered of preserving the delicate flavor of these fish, which are so fat as to be known to the Indians as the candle fish. Large quantities might be put up yearly if any process could be discovered which would preserve their good qualities.

**Morning Oregonian (Portland), Thursday, 28 March 1895, p. 8, col. 3–4**

The Big Run of Smelt

The enormous run of smelt in the Sandy River is attracting wide attention. If all the statements of those who have been out there are true, and they seem to be verified by the wagonloads of smelt taken, the run is the biggest that has been seen in the Sandy for the past 15 years. When the O. R. & N. railroad was in course of construction, and there was a large encampment on the river, the water suddenly came alive with the fish, and the railroad employees feasted on smelt for several days. Great wagonloads were taken. The next run occurred six years ago, it is claimed by those who know, but the run was comparatively small, and was soon over. There are now hundreds of people catching smelt by the tons. A wagon may be filled in half an hour. The wagon is driven into the shallow water, and the fish are scooped into the wagon by means of a small scoop net. It is stated some of the farmers are catching the fish in wagonloads and distributing them over their farms for fertilizing purposes, where some are smoking them, and many are being packed in salt. The fish move along close to the shore. The females come with the first run, and the males afterward. One can put his hands in the water and feel the fish bumping against them. Mr. Joseph Paquet was down the river several days ago and saw indications that the fish were going up the river. They were followed by droves of seagulls, watching, apparently, to catch the fish which happen to come near the surface. They were on the way to spawning-ground. The habits of the smelt are rather peculiar. They have usually appeared in the Cowlitz River, and not in the Lewis River, but this year they have entered the Lewis and very few in the Cowlitz. The run went on past the Willamette and entered the turbid and always discolored waters of the Sandy River. W. F. Allen, who was on the Sandy in all the smelt runs for the past 30 years, will go out today and see how the present run sizes up with what he saw in the long ago.

**Morning Oregonian (Portland), Monday, 1 April 1895, p. 5, col. 4–5**

All Fished for Smelt
Large Number of Portlanders Visit the Sandy to Enjoy the Sport

The banks of the Sandy River for many miles were the scene of great activity all day yesterday, made so by the presence of hundreds of pleasure seekers, bent upon catching smelt or watching others catch them. A gentleman who has made a careful estimate, from personal observation, states that the catch during the week has fully averaged 100 tons per day. It is thought that this run is the greatest that has occurred for over 30 years, and of the longest duration. The runs do not usually last over five or six days, but the fish were still running very thick yesterday, the eighth day. It is thought the run will now dwindle down, as all fish now going up are males. The females go up to the spawning grounds first and they are followed by the males. It is inferred that the run is almost over, as the males have already been running since the middle of the week. As far as could be ascertained yesterday no females were caught, all being males, very firm and plump. A few of the fish gave evidence of some hard knocks during their trip up the river. If the gentleman who estimated the catch at 100 tons a day is right the entire catch during the run will foot up a 1,000 tons.

All yesterday vehicles of every sort, loaded with families, well supplied with boxes and sacks and dip nets, prepared to catch smelt, poured to the banks of the Sandy. The favorite place was at the county bridge. The river has here cut a deep channel through the slightly wooded uplands, and winds its sinuous ways like a thread of silver to blend with the majestic Columbia, a few miles below. Where the bridge spans the river there is a sort of open space, and to the southeast the river makes a gentle curve, sweeping around a gravel and sandbar of about five acres in extent. A full view of the bridge and surroundings may be had from the county road to the westward, just before it plunges down a winding grade to the bridge. The gravel was covered with fishermen and women, both great and small. With long poles, on which were suspended dip nets made of most anything that will allow the water to run off, they were constantly dipping out the sluggish smelt. Toward the point of the gravel bank, which the water sweeps around swiftly, a dozen or more of wagons had been backed into the stream up to the hub, and these were being filled by means of nets of larger size. It was an interesting sight to see these wagons fill up and others take the place. The men swung the nets with monotonous regularity, and rarely ever failed to bring up from a dozen to half a dozen wriggling fish. The smelt seemed to run around this point in more condensed bunches than below, along the margin of the gravel bank. The experienced fisherman was provided with a sort of metal funnel, well perforated with holes, on the end of a light pole, about eight feet long. But it was comparatively an easy matter to catch in a few minutes all anyone would care to take of them.

From a sportsman's point of view the taking of fish in this manner cannot be regarded as very exhilarating exercise, still it is a sort of change. One good thing about it is that no one went home without a fine string, or rather sack of fish. The smelt caught in the Sandy were very plump and firm. At this time of year the river is very clear and cold. Evidence of prodigality and waste was apparent from the piles of half-dried fish near the bridge. And yet, with all the millions which were taken from the river, millions went on to the spawning ground. On their return trip they keep well in the center of the river and move faster than when on the way up.

A large number of people went out from the city in carriages and on bicycles merely to see the fishing. It was a day that will not soon be forgotten in the interior of the county, and if there is a family within 10 miles of the Sandy that has not had a feast of fish last week, it has not been because they could not be had in unlimited quantities.

**Morning Oregonian (Portland), Wednesday, 4 December 1895, p. 12, col. 3**

First Smelt Arrive
But They're Mighty Dear—Wait, and They'll Soon Be Cheaper.

Among the various species of fish which form the great harvest of the mighty Columbia, none is more eagerly looked for or more highly appreciated than the smelt, the Columbia River smelt, or "candle-fish," being considered by many people of this section the prince of all pan fish. Ten or a dozen years ago, they did not appear in this market as a general thing till after the cold weather was past, in February or March, or as soon as the main school began crowding up the Cowlitz and other tributaries of the Columbia to their breeding grounds. Of late years fishermen have taken to fishing for them with seines in the Columbia, and it has been found that they are in the river nearly all winter, and year after year they have been coming earlier and earlier to market, the fishermen who gets in the first lot reaping a rich reward for his trouble. The first lots have sold for 50 cents per pound, and, as they become more plentiful, the price goes down to 25 cents, then to 15 cents, and finally to 5 cents, when they come in by scores of bushels at a time, till finally they are so plentiful that there is no sale for them.

Last year the smelt arrived just before Christmas, and the run lasted a long time, the quantity of little fish disposed of here being probably much greater than in any previous year and yielding a handsome return to the fishermen. This was the earliest the smelt ever came to market; but the record has been beaten this season, as a small lot, just a few pounds, were received here yesterday. This is positively the earliest arrival of smelt known, and unless freezing weather comes on and drives them back, or to the bottom, it may be expected that the fish will soon arrive in quantities. They were held at 75 cents per pound, as they were looked upon more as a curiosity than as an article of merchandise.

The sturgeon, which, until within the past year or two, thronged the Columbia and devoured enormous quantities of smelt, are now very scarce, and this will probably result in an increase in the shoals of smelt, which, however, have always been immense.

**Morning Oregonian (Portland), Tuesday, 29 December 1896, p. 9, col. 4**

The Story of Smelt
How It Is Mentioned by an Early Visitor to Oregon

A gentleman of this city, who has a copy of "Francheve's Narrative," which is the diary of Gilbert Francheve [Franchère], of Montreal, who was a clerk in the trading company of John Jacob Astor, and who visited the Columbia in 1811, is of the opinion that Francheve makes the first mention of the Columbia River smelt. He says:

"February brings a small fish about the size of a sardine. It has an exquisite flavor, and is taken in immense quantities by means of a scoop net, which the Indians, seated in canoes, plunge into the schools, but the season is short, not even lasting two weeks."

The season for smelt has grown much longer within the past few years, since fishermen have made it a business of going out hunting for the advance guards of the schools. Some years since, they were seldom seen in market until February, when the great schools began pushing their way up the Cowlitz and Sandy to their spawning grounds, and in a short time the run was over, or the fish had become soft and not fit for food. Last year the first smelt caught in the Columbia in drift nets came to market in December, and the season lasted nearly three months, the fish being good all the time till after they were well on their way to the spawning grounds.

It is probable that mention has been made of the vast schools of smelt entering the Columbia before Francheve [Franchère] wrote his diary, as the smelt were always here, and the earliest residents along the river have described how the Indians caught them by means of a long rod, through which nails had been driven, forming a sort of comb, or rake, which they moved swiftly through the schools of smelt, bringing up many impaled upon these nails. Smelt fishing now brings in considerable money to the fishermen, owing to the greater length of the season. Late in the season the price gets very low, but then the only limit to the catch is the amount that can be disposed of. Many are salted by farmers along the river, and some are smoked, but the fish is best in a fresh state, and for the pan has no superior on the coast.

**Morning Oregonian (Portland), Saturday, 7 December 1907, p. 12, col. 1–2**

Good Things in Portland Markets, by Lilian Tingle

> Columbia River smelt cost 50 cents [per pound].

**Morning Oregonian (Portland), Saturday, 14 December 1907, p. 12, col. 1–2**

Good Things in Portland Markets, by Lilian Tingle

> Columbia River smelt … are 20 to 25 cents per pound.

**Morning Oregonian (Portland), Saturday, 29 February 1908, p. 5, col. 1–2**

Good Things in Markets, by Lilian Tingle

> I saw even more varieties of fish in the market than there were last week. Columbia River smelt were 12½ cents a pound, and scarce at that, when I inquired about it, but more may be in today.

**Morning Oregonian (Portland), Saturday, 7 March 1908, p. 12, col. 1–2**

Good Things in Markets, by Lilian Tingle

> Columbia River smelt was selling at two pounds for 25 cents ….

**Morning Oregonian (Portland), Saturday, 19 December 1908, p. 10, col. 2**

What the Markets Offer, by Lilian Tingle

> Columbia River smelt are more plentiful and are to be had at a reasonable price.

**Morning Oregonian (Portland), Saturday, 24 December 1908, p. 15, col. 2**

What the Markets Offer, by Lilian Tingle

> The cold weather has kept the price of Columbia River smelt up to 30 and 35 cents a pound.

**Morning Oregonian (Portland), Saturday, 9 January 1909, p. 8, col. 2**

Good Things in Markets

> Columbia River smelt was about 10 cents a pound yesterday, but the supply is of course affected by the weather.

**Morning Oregonian (Portland), Tuesday, 2 February 1909, p. 9, col. 2**

The Run Is On—Fresh Columbia River smelt, 5 cents a pound. Maces Market, 151 Fourth Street.

**Morning Oregonian (Portland), Saturday, 13 February 1909, p. 12, col. 4**

Good Things in Markets

Columbia River smelt was selling at 4 and 5 cents a pound earlier in the week, but cost 7 to 10 cents when I inquired; and no man would risk a statement as to whether it was likely to be down again today or up higher.

**Morning Oregonian (Portland), Friday, 24 December 1909, p. 10, col. 2**

Good Things in Markets

The fish market is exceedingly well supplied with the sea dainties for which Portland is famous … Columbia River smelt, 40 to 50 cents [per pound].

**Morning Oregonian (Portland), Saturday, 12 February 1910, p. 12, col. 2**

Good Things in Portland Markets, by Lilian Tingle

Columbia River smelt may be considered the most interesting feature of the market this week, of interest alike to epicure and economist. At 5 cents a pound, or six pounds for a quarter, this dainty fish is within the reach of everyone. Many thrifty housekeepers take advantage of the season of plenty, and buying smelt by the box at about 3 cents a pound. Proceed to secure inexpensive future breakfast or luncheon dishes by salting, smoking, pickling or canning this "violet of the waters."

**Sunday Oregonian (Portland), 13 February 1910, p. 9, col. 4–5**

Smelt Cannery Offered
Kelso Owners Seek Someone to Operate Plant
Heavy Catches Are Accompanied by No Diminution of Supply—Cowlitz Yields Well

Owners of an idle canning plant in Kelso are seeking someone who will engage in the packing of Columbia River smelt in that city.

F. L. Stewart, a banker of Kelso, who is in Portland, expresses the conviction that the opportunities are good for using the plant for smelt canning in winter and fruit and vegetable canning in the spring and summer. The cannery was started as a cooperative venture, but has been idle about two years.

Although the smelt, now so generously in the Portland markets, bear the name "Columbia River," the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately

15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

In spite of the heavy catches there is apparently no diminution in the yearly runs of fish and at the height of the season they get down to a low figure.

At the beginning of the present season fishermen got $3 a box for the first run, but the price, as the run increased, dropped rapidly until now the fishermen realize about 25 cents a box. Last year the price went as low as 15 cents. The largest catch reported this season was 45 boxes, taken between 7 and 11 a.m., by two men in one boat.

Some of the residents of Kelso smoke the fish as they would herring and find that smoked smelt are a delicacy. The cannery plan, however, would be to put them up in form similar to sardines.

**Morning Oregonian (Portland), Thursday, 17 February 1910, p. 8, col. 4**

Cowlitz Full of Smelt
Big Run May Presage Prosperous Salmon Season Later On

Astoria, Ore., Feb. 16—The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fisherman.

This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon.

**Sunday Oregonian (Portland), 27 February 1910, Section 5, p. 8**

Smelt Fishing on the Cowlitz
How an Army of Men Catch the Biggest Run Known in the Last 20 Years
By R. G. Callvert

A hobo the other day wandered along the fringe of the riverbank that lies between the floating docks and the railroad track at Kelso, picking up discarded smelt for an easy meal.

"Here, drop those rotten fish and come down and get some fresh ones," shouted a fisherman from a float where smelt were being packed into boxes for shipment.

Discarded fish may look good to a tramp in most countries, but in Kelso during the smelt run only a stranger with a most aggravated antipathy to exertion need go without the freshest product of the Cowlitz River.

Had the tramp known it and been inclined toward the effort, an old can tied at the end of a stick plunged into the water from a nearby log boom would have brought him up in one sweep all the smelt he could eat in a day. Or by lying on the log boom he could have pulled out enough fish with his bare hands for a square meal.

There is not much romance connected with the taking of the smelt that are so plentiful in the markets of Portland and the Northwest during four or five months of each winter. There is no battling with waves and storms such as are encountered by the hardy herring fishermen of the Atlantic. For the sportsman, smelt fishing would be just about as exciting as clam digging and the amount of skill required about the same. Smelt fishing furnishes tales, however, that are novelties among fish stories in that while almost unbelievable they are nevertheless true.

During the smelt runs fish are so plentiful that even the voracious seagull becomes almost sated. When the gulls are at all hungry the fishermen sometimes find amusement tossing smelt into the air, which the birds catch before they reach the water. A seagull on the wing will seize a fish perhaps by the tail and reverse it with a toss in the air and gulp it head first in the twinkling of an eye.

So plentifully do the smelt run that frequently children bail them out of the water with tin cans securing half fish and half water. When the water is shallow enough the smelt can be taken with the bare hands, for the skin of the fish is not slimy when in the water.

While the Cowlitz River is the only known spawning ground for smelt where the fish may be taken year by year, they have been known to run up the Lewis River and also up the Sandy. At the time the smelt ran up the Lewis River, 14 years ago, there was only a small run of male smelt in the Cowlitz and the fishermen transferred their operations to the Lewis. When smelt run in numbers up the river it is apparently independently of the Cowlitz run and it is said to occur in the Sandy about once in eight years. It is truthfully related that at the time of the last run up the Sandy a party of Portland young men went out with dip nets on a fishing expedition. One man lost his dip net, but luckily found an old, rusty, discarded birdcage. This he attached to the end of a pole and successfully kept pace with his more fortunate companions. This is the only record in fishing annals of successful fishing with a birdcage, although if the novelty of the experiment invites one it can undoubtedly be successfully duplicated in the Cowlitz River any day between now and April 1.

During the last big smelt run in the Sandy farmers drove their wagons to stream, filled them with dip nets and used the fish for fertilizing fruit trees. An unusually large quantity of pork with a fishy taste sold in the markets some months afterwards revealed the fact that some of the farmers had utilized the fish surplus in feeding their hogs.

This season the Cowlitz River is the spawning ground of the greatest run of smelt ever known by fishermen who have been engaged in the business for 20 years. It is now estimated that by the close of the season the river will have yielded 300,000 boxes of smelt, each box weighing 50 pounds. This will represent an output of 10,000,000 pounds or 5,000 tons and a smelt average about eight fish to the pound means the marketing of 80,000,000 fish.

The smelt has peculiarities of his own, as pronounced as those of the salmon. What is known commercially as the “Columbia River smelt” is caught in paying quantities regularly year by year only in Cowlitz River, which is a tributary of the Columbia River rising in the State of Washington.

The main fishing grounds of the river extend over an area during the season of not more than eight or 10 miles as a rule. Like those of the salmon the smelt runs come in from the sea through the mouth of the Columbia River. In the earliest catches, when smelt bring from $3.50 to $3 per box, the fish are taken in limited numbers in the Columbia.

In the Columbia some fish are caught in the early season by gillnetters, but when the season is well along the gillnetter cannot compete with the regular smelt fisherman, for the former has to pick the fish out one by one from the meshes of his net. The latter uses a dip net attached to a long pole, and after locating a school of fish simply bails them out of the river and into his boat, sometimes getting as many fish as he can lift out of the water.

The smelt lie in schools close to the bottom of the river and are therefore found at varying depths. The fisherman prospects for the schools with the reverse end of his pole, and if the end of the pole is plunged into an accumulated number of fish, the wriggles of the small bodies that results is communicated to the hands of the fisherman.

Most of the fishing is done at night, for the light of day seems to scatter the fish, yet even in daylight hours the fishermen are able to pursue their occupation with good results.

Before Kelso accumulated a variety of industries along its waterfront, one of the best fishing points was opposite the Northern Pacific depot, from where one can toss a stone into the water. The driving of piles, however, seems to have driven the fish farther up the stream, and this season they have been found most plentifully about one and one-half miles above the town. Between the small floating docks and the fishing grounds boats are continually plying, going upstream empty and returning ladened with fish. Fully 500 boats are utilized in the industry and of these about 75 are powerboats.

As a rule there are two men to each boat and the crafts are filled in almost an incredibly short space of time. Last Tuesday night J. A. Sprague, one of the principal shippers of Kelso, and one companion loaded his launch to its capacity in 45 minutes. This represents a catch of 45 boxes, or one 50-pound box a minute. Last year a catch of 125 boxes for two men held the record for a night's fishing. This year there have been frequent occasions when two men brought in 200 boxes to represent a day's work.

To the ordinary fisherman who has no regular market to supply, a catch of 200 boxes of smelt in the height of the season is worth about $50. On the Cowlitz River; however, there are a number of men who ship direct to retail markets, maintain boats of their own and buy from other fishermen. Portland wholesalers have buyers at Kelso and probably the greater portion of the retail trade is supplied through Portland. At Kelso, however, smelt have been shipped direct as far East as Wisconsin.

The output of the river, say the fishermen, could be greatly increased if the market demands were sufficient to justify more men engaging in the industry. Kelso has no facilities for shipping fish in cold storage. A cold storage plant is one of the enterprises the town wants, for it is believed that the market can be broadened and a demand created in the Far Eastern states. Canning in the form of sardines is also suggested, and in Kelso there is a cannery that was utilized as a cooperative plant by fruit and vegetable growers until last year, that will be turned over to any experienced man who will engage in the business.

Kelso has a group of enterprising citizens who have done much to build up the town to its present population of 2,800. Practically the same group of businessmen established the electric light plant and city waterworks, built a $15,000 opera house, erected a drawbridge across the Cowlitz River, which they afterwards sold to the county, established a newspaper office, invested in the cooperative cannery mentioned and have aided and encouraged several other enterprises.

They are now seeking to put the smelt fishing on a basis where it will pay better returns to the fishermen and increase the number of men engaged in the industry. This effort is apparently justified, for though the output of smelt is slowly growing year by year, the increasing inroads upon the schools of fish do not seem to diminish their number.

Cowlitz River fishermen are now advocating the licensing of persons engaged in commercial smelt fishing. Frequently, during the season, schoolboys will go out, load up a few boats with fish and become easy marks for the buyers. The result is a demoralizing market, the boys being content with enough money to buy candy or a few toys. Often too, groups of Greeks or Italians will come up the Cowlitz in boats, remain at the fishing grounds for a few days and sell their catches for whatever they can get, again upsetting the prices paid the regular fishermen. The men who are regularly engaged in the industry want the protection of a reasonable license, which, they believe, will cut out the itinerant fisherman.

It is a saying among fishermen that a big run of smelt presages a big run of salmon. If this is true, the salmon fisheries of the Columbia should have a prosperous season this year, for the smelt run is unprecedented in volume.

**Morning Oregonian (Portland), Thursday, 8 December 1910, p. 21, col. 6**

Smelt in the River
Good Hauls Looked For in about 10 Days

Astoria, Ore., Dec. 7— … Two days ago a few smelt were seen at the mouth of Grays River, showing that they are beginning to come in, and good hauls of this class of fish may be looked for in about 10 days or two weeks.

**Morning Oregonian (Portland), Thursday, 5 January 1911, p. 21, col. 1**

Run of Smelt is Small

> Astoria, Ore., Jan 4.—(Special)—Quite a few smelt have been caught during the last few days in the vicinity of Clifton, but none has been taken as yet in the Grays River. It is said the water in that stream is too low and a freshet must come before the smelt will be attracted that way.

**Morning Oregonian (Portland), Saturday, 7 January 1911, p. 12, col. 4**

Good Things in Markets

> Columbia River smelt, though less costly than on its first appearance, sold yesterday at 25 cents a pound, but will probably soon reach the lower prices we are accustomed to.

**Morning Oregonian (Portland), Saturday, 11 February 1911, p. 8, col. 4**

Good Things in Markets

> The day of very cheap Columbia River smelt is not yet, though any market man will tell you it may be expected at any time now. Smelt were selling yesterday at 10 to 12½ cents a pound, and were quite scarce at that, though earlier in the week they were to be had at three pounds for 25 cents.

**Morning Oregonian (Portland), Friday, 18 February 1911, p. 10, col. 3**

Good Things in the Market

> The smelt are here! The run is sufficiently strong to reduce the price to 5 cents a pound, and at every dealer's the fish are on hand in boxfuls.

**Morning Oregonian (Portland), Wednesday, 22 February 1911, p. 18, col. 2**

Marine Notes

> First of the season's catch of smelt in the Cowlitz River, amounting to 35 tons was brought to Portland on the steamer Lurline. Another consignment was transported by the steamer Joseph Kellogg.

**Morning Oregonian (Portland), Saturday, 25 February 1911, p. 12, col. 2**

Good Things in Markets, by Lilian Tingle

> The heavy run of Columbia River smelt has come in earnest this week. The delicious little fish are selling at three pounds for a dime, 10 pounds for a quarter, or one dollar a box, and there is enough for every one.

**Morning Oregonian (Portland), Saturday, 2 December 1911, p. 11, col. 2**

First Columbia River Smelt of the Season at Mace's Market

**Morning Oregonian (Portland), Saturday, 27 January 1912, p. 4, col. 3**

Good Things in Markets

> Columbia River smelt is not really plentiful, but is to be had at 6 to 8 cents a pound.

**Morning Oregonian (Portland), Saturday, 10 February 1912, p. 12, col. 4**

Good Things in Markets, by Lilian Tingle

> Columbia River smelt are still the leading feature in the fish markets, and are selling at about 8 cents a pound.

**Morning Oregonian (Portland), Tuesday, 2 April 1912, p. 7, col. 3**

Smelt Run Now On
Millions of Small Fish Enter the Sandy River
Sunday Crowds Active

> Troutdale, Ore., April 1—(Special)—This thriving little city should have been named Smeltdale, as there isn't a trout anywhere near it. But the dainty little smelt is just now the attraction that has made the town the Mecca of thousands who are all returning home laden down with all the fish they care to take away with them.
>
> The great run of smelt from the Columbia River began on Thursday last and was at its greatest yesterday. An ideal day and the prospect of unlimited catches, together with the exciting sport of taking them, brought people from every direction. The banks were lined with teams from all over the county and automobiles from the city, and the entire day was spent in a vain effort to deplete the Sandy River of its finny denizens.
>
> Millions Will Die [subhead]
>
> Thousands were caught but millions got away, only to swim against the strong current for a few days longer and then float back dead, dying or exhausted, when the greatest run known will all be over.
>
> Nine years ago there was a similar run of smelt in the Sandy. This is the only river, excepting the Cowlitz that is ever entered by them from the Columbia. No one can ever predict when they are coming. It is only when the water is seen to be fairly alive with them that the word goes out and for a few days all other business is suspended while the people from far and near lay in a big supply.
>
> Birdcages Used as Nets [subhead]

Yesterday's sport was exciting enough. It was attended with many involuntary baths and much mirth. The fishing appliances consisted of nets tied to long poles and every scoop into the water brought up fish.

In place of the regulation net there were to be seen improvised scoops made of wire gauze, coal oil cans and even birdcages. A motion picture outfit made films and every sort of a water craft did a rushing business all day long.

The great run will cease as suddenly as it began.

**Morning Oregonian (Portland), Saturday, 23 November 1912, p. 16, col. 4**

Smelt Are Running Early
Fish Caught Close to Ocean Bring Fancy Prices

ASTORIA, Ore., Nov. 22—(Special)—Smelt are entering the river earlier this year than ever before. Last night one man who was fishing for herring in the lower river not far from Sand Island caught a pound and a half of smelt in his net, and as a result he is going out with a regular smelt net.

Columbia River smelt are considered the most toothsome fish found on the coast, and when caught close to the ocean are exceptionally fine, those taken early in the season often selling as high as a dollar a pound.

**Sunday Oregonian (Portland), 15 December 1912, p. 14, col. 4**

Good Things in Markets

Columbia River smelt is the "newest thing" in the fish market and is available, in small quantities only, at 25 cents a pound.

**Sunday Oregonian (Portland), 2 February 1913, p. 16, col. 5**

Good Things in Markets

Columbia River smelt again is in the market, in generous supply, and can now be had at six pounds for 25 cents.

**San Jose Evening News (San Jose, CA), Monday, 14 April 1913, p. 5, col. 4–5**

Unusual Run of Smelt near Portland—Farmers Carry Fish by Wagonloads for Fertilizer

Portland, Ore., April 14—A run of smelt which promises to break all records has come into the Sandy River, a tributary of the Columbia, 12 miles from Portland.

An army of farmers and people from the city are busy scooping out the little fish in water buckets, dip nets, inverted birdcages and with pitchforks. The supply is so far beyond the demands of the markets that farmers are hauling them off by the wagonload and distributing them over their plowed lands as fertilizer.

One cent a pound is the market price for smelt along the Sandy, with but scant demand, since people there and in Portland have become surfeited with them.

Heavy runs of smelt in the Sandy appear at intervals of several years, but this one is denominated a freak.  The run is both ahead of time and unusually heavy.

**Morning Oregonian (Portland), Saturday, 29 November 1913, p. 12, col. 1**

Good Things in Portland Markets

The first Columbia River smelt of the season is on the market this week at $1 a pound.

**Morning Oregonian (Portland), Friday, 5 December 1913, p. 14, col. 4**

Columbia Smelt on Sale
Weather Makes Fish Scarce and Retail Price is 25 Cents a Pound

Columbia River smelt have appeared in the market.  The run, so far, has been a small one, and as long as the present kind of weather continues, the fish will not be plentiful, but warm rains and higher water in the river will bring them in abundance.

The big run, which is due later, will be in the Cowlitz River.  Smelt are retailing in the markets at 25 cents a pound.

**Morning Oregonian (Portland), Wednesday, 14 January 1914, p. 14, col. 2**

Marine Notes

First of the smelt caught this season in the Cowlitz River arrived yesterday on the steamer Joseph Kellogg, the shipment consisting of 60 boxes.  Owing to high water in that stream the catch is regarded as light.

**Sunday Oregonian (Portland), 18 January 1914, p. 6, col. 6**

Columbia River smelt are so plentiful as to confound the price jugglers.

**Morning Oregonian (Portland), Thursday, 5 February 1914, p. 16, col. 6**

Marine Notes

It was estimated that the deliveries of smelt from the Cowlitz River and lower Columbia district yesterday were between 1,200 and 1,500 boxes.  The launch Frolic brought 425 cases from the Cowlitz.

**Morning Oregonian (Portland), Friday, 27 February 1914, p. 14, col. 3–4**

Good Things in Markets

> Columbia River smelt is still at flood tide and is expected to be abundant [in the fish market] until possibly the middle of March.

**Morning Oregonian (Portland), Tuesday, 31 March 1914, p. 10, col. 6**

Smelt Are Destroyed
Prosecutions May Follow Use of Fish as Fertilizer
Mr. Finley Says Law against Wanton Waste of Food Will Be Enforced against Sandy River People

> The smelt running in the Sandy River are attracting many people to that locality. Inasmuch as the fish are extremely plentiful, it is no trouble at all to catch them in nets or makeshift scoops. The fact that the fish are so abundant has led many persons to catch them without limit.
>
> "The State Board of Fish and Game Commissioners desire to give public notice that the law passed as the last session of the Legislature concerning the wanton waste of fish will be strictly enforced," said William L. Finley. "The Columbia River smelt is one of our most valuable commercial fish. The fact that it comes in great numbers into Cowlitz, the Sandy and certain other streams at about this time of the year, leads some people to believe that the supply is inexhaustible.
>
> "These fish come in from the sea and go into the rivers to spawn. We have to depend upon our future supply from the natural spawning of these fish. At the present time many people living in the vicinity of Troutdale are catching far greater numbers of these fish than they have any use for; in fact, they are loaded into gunny sacks and into wagons and not used in any way except as a fertilizer.
>
> "It is an economic waste and an outrage that such a fine pan fish as the smelt should be wantonly destroyed and wasted. There is nothing governing the amount of these fish that can be caught or the method of catching them, yet there is a strict law against the wanton waste of food of this kind. If it is not observed, complaints will be sworn out and arrests will follow."

**Morning Oregonian (Portland), Saturday, 2 January 1915, p. 5, col. 4**

Kelso Prepares for Smelt Run

> Kelso, Wash., Jan. 1—(Special)—The Columbia River Smelt Company is erecting a new dock near the depot at Kelso to facilitate the work of handling and shipping the smelt catch during the approaching season. It is now almost time for the arrival of the fish and old fishermen expect the run to start as soon as the river rises. The fish never start their run until the river is muddied by rains. Plans are

being made to open an Eastern market on a more extensive scale than last year when shipments in refrigerator cars were made for the first time.

**Morning Oregonian (Portland), Saturday, 9 January 1915, p. 8, col. 6–7**

Good Things in Markets

In the fish market: Variety is considerable this week still and the ripple on the surface is caused by a run of smelt up the Columbia River. They are in the Cowlitz strong and here in Portland are selling at two pounds for 25 cents, with every prospect of rapid descent in price.

**Morning Oregonian (Portland), Monday, 15 February 1915, p. 9, col. 6–7**

Cowlitz Has No Smelt

Vancouver, Wash., Feb. 14—(Special)—That some person desiring to keep the smelt from running up the Cowlitz River at Kelso dumped several barrels of lime in the mouth of the river, just as the smelt were beginning to run, is a story told at Kelso.

It is known that for two or three days the smelt passed the Cowlitz River and went into the Kalama River, the first time since 1847. There is not a great deal of current at the mouth of the river where it is said the lime was dumped into the river. Many persons say, however, that it was just a whim of the smelt themselves to select the Kalama River. It is reported that another big run of smelt has started in at the mouth of the Columbia River.

**Morning Oregonian (Portland), Wednesday, 8 March 1915, p. 11, col. 1**

New Run Fresh Columbia River Smelt, 75c for 50-lb Box, Order Shipped Promptly
Sanitary Fish Co., First and Washington

**Morning Oregonian (Portland), Tuesday, 9 March 1915, p. 5, col. 4–5**

Smelt in Lewis on Wane
Gulls Prey on Third Run that is Wakened by Swift Current

Vancouver, Wash., March 8—(Special)—The third run of smelt in the Lewis River at Woodland is beginning to wane and the price has dropped. The smelt, which are said not to eat after they leave salt water, are dying by thousands, and may be seen floating downstream. Many are weak and cannot swim against the current.

Seagulls by the thousands hover over the Columbia River and follow the smelt from the time the smelt enter the mouth of the Columbia River. They refuse to eat the dead smelt. So thick are the smelt in the Lewis River that they are dipped out in bunches from 50 to 75 pounds. One man made a dip yesterday that weighed 68 pounds.

**Morning Oregonian (Portland), Friday, 31 December 1915, p. 9, col. 4**

Smelt Are Becoming Plentiful

Kelso, Wash., Dec. 20—(Special)—Columbia River smelt are being taken in increasing numbers in the mouth of the Cowlitz and along the Columbia by the gillnetters, and fishermen are expecting a large enough supply of the fish so as to permit of dip net fishing at almost any time. Many boxes of smelt are leaving the Kelso depot daily, and the fishermen are securing good prices for their catches.

**Morning Oregonian (Portland), Friday, 31 December 1915, p. 12, col. 3–4**

Good Things in the Market

The fish market is enlivened by the intelligence that a considerable run of Columbia River smelt appeared in the Cowlitz on Wednesday, and consequently the price has dropped to 15 cents a pound.

**Morning Oregonian (Portland), Friday, 28 January 1916, p. 11, col. 1–2**

Good Things in the Market

The influx of Columbia River smelt has been completely checked by the cold, but frozen stock sells at 12½ cents a pound.

**Morning Oregonian (Portland), Tuesday, 7 March 1916, p. 16, col. 6**

Marine Notes.

Smelt shipments delivered here yesterday aboard the launch Beaver, which came from the Cowlitz River, numbered 212 boxes.

**Morning Oregonian (Portland), Saturday, 21 December 1918, p. 18, col. 7**

Columbia River Smelt 15c per lb. Single frozen, properly packed to arrive in good condition in 5-pound to 15-pound lots, within 150 miles of Portland. Write for quotations on larger quantities. Northwest Fish Products Co., 205 Yamhill St., Portland, Ore. Phone Main 4760.

**Morning Oregonian (Portland), Wednesday, 5 February 1919, p. 13, col. 6**

Run of Smelt Begins
Farmers Join Fishermen in Cowlitz River Catches

The annual run of smelt in the Cowlitz River has started, according to reports received in Portland yesterday. Farmers and people living in the vicinity of the river have joined with the smelt fishermen in catching the fish, which are said to be running in large schools.

As a result of the commencement of the run, prices of Columbia River smelt dropped to 4 and 5 cents per pound in Portland. It will be several months before the smelt can be expected in the Sandy River, although the fish do not ply through this stream every year. However, for the past two years Portland people have made large smelt catches in the Sandy.

**Morning Oregonian (Portland), Monday, 17 February 1919, p. 8, col. 6**

Disappearance of Smelt Feared
Pioneer Cowlitz Fishermen Deplores Lack of Protective Laws

KALAMA, Wash., Feb. 13—(To the Editor.)—I have been fishing smelt since 1879 and for over 25 years after that date never saw the Cowlitz River without a big run of smelt. Some winters they would come as early as January and sometimes as late as March. Then they would come so thick that a fish boat could be loaded with a small dip net in a few hours.

For the last eight years I have noticed the large runs have disappeared; for three years, or three winters, the most smelt have been caught in the Kalama, Lewis and Sandy rivers, and it looks like the smelt were done for in the Cowlitz forever.

This winter we got a surprise. A big run of smelt entered the Cowlitz after the markets had been well supplied from the smelt caught by gill nets in the lower Columbia. As soon as the smelt entered the Cowlitz several hundred launches loaded up. My boy caught a ton and one-half in five or six hours and expected to make a stake out of it. He went over to Rainier, but the smelt buyers were blocked, and also in Kelso. At least 150 fish boatloads at two tons each have been dumped overboard inside of three days and a big troller loaded and bound for a lower river port with seven tons of smelt got foul of a bootlegger just after being loaded and bound out of the Cowlitz, and struck the sandbar in the mouth of the Cowlitz. He kept driving ahead and drove her high and dry. The river falling about his launch, he was compelled to jettison his cargo overboard, as nobody wanted his smelt for nothing.

The whole thing is a disgrace. Every fisherman and cannery man knows that the smelt is the natural food for the Chinook salmon. The young salmon, after leaving the spawning ground and hatcheries, feed on the young smelt, and the large salmon fatten on the grown smelt. This run of smelt, most likely the last big run ever to come into the Cowlitz, will be followed up by launches to the very spawning grounds. My boy was offered a contract by one of our big smelt merchants at $8 per boatload of 2⅓ tons, a trifle over ⅛ of a cent per pound.

There is no law against dumping a few hundred tons of these fine fish overboard, but we should have a law to protect the smelt, as well as the salmon. Our lawmakers in Salem and Olympia are not all to blame, but the fish law agitators in both houses, who fight all kinds of battles between themselves on how to protect the salmon, let the salmon starve and don't think of feeding this royal fish. I am sure that in less than 15 years from now smelt will be as scarce as the elk in the mountains. These plentiful launches with the big scoop nets will soon finish the smelt business. I am able to see it. It is my trade and business. The smelt-buying merchants about Kelso and Kalama consist of about a dozen, and get discharged sailors and soldiers to dip the smelt at from $3 to $5 a ton. They get fat on the destruction of the smelt. Whatever can be dumped fresh on the market at 75 cents to $1 a box goes. Several hundred tons may go into cold storage and be retailed later from 10 to 12½ cents per pound. It would be wise and easy to draft a law that would be of benefit to the salmon, the fishermen and the children. —Charles Wood

**Morning Oregonian (Portland), Tuesday, 1 April 1919, p. 10, col. 5**

Those Who Come and Go

Run of smelt in the Sandy River attracted scores of guests from the hotels yesterday. To the easterners and people from California the sight was wonderful. "About everyone in the hotels has gone out to the Sandy River," said Clerk J. J. O'Brien, at the Hotel Portland. "Those who went yesterday came back so excited and talked so much about the fish that they caused others to go out today. One easterner declared there was more fish than water in the river."

**Morning Oregonian (Portland), Saturday, 1 January 1920, p. 1, col. 2**

Smelt on Market Here
First Shipments of Cowlitz River Run Are Received

Portland markets yesterday were selling the first of the new run of Columbia River smelt, the fish having been shipped from Cowlitz River, where the run is said to be quite heavy. The fish are what is known as the "widow" run, being the forerunners of the main run, which starts generally in February. About 20 boxes of the fish were received yesterday from the Cowlitz by the Portland Fish Company, which reports that they will continue to receive consignments daily until the run ceases. Heavy catches generally reduce the "widow" run within a short time, it is stated, and smelt are off the market until the main run starts.

The wholesale price for the smelt yesterday was 13 cents a pound, and the retail price at most of the markets was 20 cents. When the main run begins the fish are caught in such quantities that the price generally drops much lower.

**Morning Oregonian (Portland), Tuesday, 27 April 1920, p. 10, col. 6**

Those Who Come and Go

When A. N. Ward gets back to the Hot Stove Club at Malden, Mass., [he] will have a fish story to tell that his fellow townsmen will probably not believe and will stamp it as a traveler's tale. When Mr. Ward recounts that he saw a river so filled with fish that the stream was virtually one solid mass of fish for miles, and contained millions of smelt, the Maldenites will sniff with suspicion. When he says that in five minutes he, or anyone, could gather enough fish from the Sandy River with his coat, or auto robe, or any old thing, to fill a car to overflowing, they'll be certain that he is drawing the long bow. And yet, those were the things which Mr. Ward saw when he toured the Columbia River highway yesterday. He saw the great smelt run and saw miles upon miles of parked cars, while their drivers were filling gunny sacks, cans, buckets, tubs, boxes and any container they could secure, with smelt. At home Mr. Ward is an undertaker, and with his wife he is at the Multnomah, returning from the profiteer belt of California.

**Morning Oregonian (Portland), Wednesday, 28 April 1920, p. 15, col. 4–5**

Smelt Run Biggest Ever
Prow of Boat Turns Up Hundreds All Night Long

"My observation is that this is the biggest smelt run that has ever come up the Columbia River," was the statement made yesterday by State Game Warden Carl D. Shoemaker after he spent Monday night on the river in a motorboat. "We found early this morning that the seagulls are following the smelt all the way from Vancouver Bridge to the mouth of Sandy and that a solid wave of smelt is coming upstream between these points, or a distance of about 10 miles. The prow of our boat turned up hundreds of them all night long."

Mr. Shoemaker says there are no indications of the run slacking and that tons of fish are being shipped to Oregon and Washington points and many are going into local cold-storage plants. It is found that female smelt predominate over males in the present run, indicative of another heavy one next year.

**Morning Oregonian (Portland), Monday, 3 May 1920, p. 4, col. 2**

Smelt Run Nears End
School in Sandy Keeps over Spawning Beds
Within Next Few Days Dipnetters Will Be Hard Put to Get a Meal from Waters

The record run of smelt, so far as the Sandy River is concerned, is all but over. Within the next few days the gulls and the dipnetters will be hard put to find a meal in the deeps and shallows that aforetime held smelt by the billion. But few fish were obtained yesterday and the disappointments were in keeping—for not more than 50 fishermen were congregated at the Troutdale Bridge at any one time during the day.

Most of the dipnetters, however, managed to get a sack or so, by watching for the stray fringes of the now depleted and rapidly vanishing school. The main body of the run held well to the center of the stream, over the spawning beds, and only the commercial fishermen, with improvised piers and rowboats, were able to reach the profitable coigns of vantage.

The Sandy River smelt run, more than a month overdue by comparison with previous seasons, began 10 days ago and within half a week had attained unheard of proportions. Launches in the Columbia River outside, near the mouth of the

Sandy, ploughed through pools of smelt so dense that the curving wave at the bow was a cascade of shining fish. The smelt even drove far past the Sandy and as far up the river as Bonneville.

**Morning Oregonian (Portland), Wednesday, 5 May 1920, p. 10, col. 2**

Like the Sands of the Sea

Take all the hyperbolic similes expressive of vastitude of numbers, stir them well together, segregate the triple-extracted essence and confine it in a humdinger of extravagant comparison, and one will but have paid tribute to the fringes of the Columbia River smelt run. Naught save deity could give it census, for the count would worst mortal mathematics as that science is ordinarily employed. These observations are by way of preface to the statement that a Portland resident has been arrested on the count of wasting food fish, because he sought to fertilize his fruit trees with passé smelt.

There are those who will charge the game department with mulish conformance to law, asserting that the statute invoked was never intended to deal with billions upon billions of silver “hooligans,” swimming up the Columbia just as they did on the morning Captain Gray’s visit, ever and ever so long ago. To chirk up a cherry tree or two with half a peck from that seemingly inexhaustible measure, the sea, would to many commend itself not only as a trifling tithe on nature’s largess but as a most sensible procedure.

When the grandfathers of the present were the boys of yesterday, back in Ohio, Michigan, Minnesota, Wisconsin, and New York, along the entire Atlantic coast and well into the middle-west, the flight of passenger pigeons was an annual event comparable to the smelt run of the Columbia. On sunny days, with the spring mornings all golden and green, when those epochal pilgrimages were on the wing, it is recorded that the face of the sky was darkened as by a heavy cloud—a living veil of plumage that swept on and on, and endured till dusk. And thus for many days. They narrate, those same grandsires, that one might feed a bullet to the muzzle-loading squirrel rifle and fire at random upward, through the hurtling avalanche of pigeons. Not one but several birds would fall to that hazard, it is recounted. Yet the passenger pigeon is gone, and wealth would reward the man who could prove the existence of a single flock, a single bird. The species is with the great auk and the dodo, and while it may have perished in some stormy passage between the northern and southern continents, there is abundant evidence against the market hunter and the game assassin.

Natural history is replete with tragedies in which man plays the role of villain. Ethically and economically—and merely, for an additional reason, because all waste is wicked—the game department is fortified in its enforcement of the law with respect to the smelt run.

**Morning Oregonian (Portland), Friday, 7 May 1920, p. 10, col. 7**

Habits of Smelt Little Known
Study Made of Fish which Authorities Know under Several Names

Portland, May 6—(To the Editor)—Please publish the following information, and any other interesting facts, about the smelt. How long until they hatch, and how long do they stay in fresh water after hatching? How long before they come back to spawn? Do all that come up the river die, and what becomes of them when dead? What is their correct name? Are there such fish other places than the Columbia River? —A Subscriber

The scientific name of the Columbia River smelt is Thaleichthys pacificus. It is described in encyclopedias and dictionaries under "candlefish." The Indians called it "oolachan," sometimes spelled "eulachon," which has been corrupted by whites into "hooligan." It is common in Alaska and British Columbia streams, as well as in the Columbia.

R. E. Clanton, master fish warden, is authority for the statement that the longevity and habits of the Columbia River smelt have never been made the subject of exhaustive study, and that this season is the first in which trained observation has been directed.

The present attempt includes a study of the reproductive organs of the female smelt, to discover whether nature has provided for a second spawning. It is not known at present whether smelt return to the ocean or perish in the rivers—as does the salmon after visiting the spawning beds.

If the billions of smelt in an ordinary run were to die in freshwater, it is contended, the evidence of such demise would be prevalent, even to the point of pollution, of so mighty a stream as the Columbia. On the other hand, the return of the smelt run to salt water, if it does return, never has been observed. Fish commission officials, including Master Warden Clanton and Secretary Carl Shoemaker, of the fish commission, expect to make tests this week toward solving the riddle.

The journey of the smelt fry to the ocean is another phase of the life cycle that is darkness. None has seen, so far as the records show, the migration of the infant fish from the birthplace river to salt water. Their numbers must be uncounted myriads, and even if the fry were even an inch in length the passage of the infant smelt would be plainly discernible. It is conjectured that the fry run to sea when extremely small.

But all this is guesswork. An attempt is now launched to learn more of the actual life history of the Columbia River smelt. Specimens now held at Bonneville hatchery will be kept under observation to determine whether they are subject to demise after spawning, while an attempt will also be made, with nets, to discover whether any portion of the recent heavy run has retraced its course to the Pacific.

**Morning Oregonian (Portland), Thursday, 20 January 1921, p. 4, col. 2**

Smelt Enter Cowlitz River

Kelso, Wash., Jan. 19—(Special)—For the first time this season smelt were dipped in the Cowlitz River today. A few smelt had been gillnetted in the Cowlitz earlier this winter before the freshet, and for the last two weeks the Columbia River gillnetters have been getting smelt on the lower Columbia. It is thought that the present run is what is known as the early winter run and that the main run of the little fish will not be here for several weeks more.

**Morning Oregonian (Portland), Friday, 18 February 1921, p. 11, col. 1**

Lewis River Rises

Woodland, Wash., Feb. 17—(Special)—Warm winds and melting snow in the mountains have caused a decided rise in the Lewis River. The water has already reached within a foot of the high-water record. Muddy water is driving the run of smelt out of the river into the Columbia.

**Morning Oregonian (Portland), Saturday, 19 February 1921, p. 13, col. 1–2**

Many Fruits in Season

Columbia River smelt retailed at two pounds for 15 cents yesterday.

**Morning Oregonian (Portland), Saturday, 19 March 1921, p. 13, col. 2**

Fish for Lent Plenty

Prices will cover all the stages between 5 cents a pound for Columbia River smelt to 50 cents a pound for lobster shipped from the Atlantic seaboard.

**Morning Oregonian (Portland), Saturday, 24 December 1921, p. 12, col. 1**

Smelt Put in Appearance

Columbia River smelt have appeared for the holiday season in large quantities. They are being dipped up with nets and selling retail here at 15 cents a pound, in comparison with 25 cents a pound, which was the price until yesterday.

**Morning Oregonian (Portland), Saturday, 14 January 1922, p. 10, col. 2–3**

Did the Smelt Neglect their Tryst?

If nature forgot us for a single season, in all her bounties, we should be like so many children squalling in the dark. Quite helpless, very hungry and probably petulant. Occasionally the good dame does forget, neglecting some customary gift, and men puzzle themselves to discover the reason. They do not always find an answer. Why was it, as was recorded 25 years ago, that there had been noted long periods during which the smelt run deserted the Columbia River? For 20 years, so these observers asserted, the pleasing little eulachon was—to put it tritely—conspicuous by his absence.

The drying racks of the Indians were not laden, and the residents along the great river and its tributaries scanned the streams vainly for the return of their favorite fish, who was wont to be as punctual as April. There is no record of the year in which the run reappeared, nor is there more than the testimony of a few individuals, as preserved in news reports, to substantiate the disappearance. Undoubtedly it was the ancient and continuous custom of the smelt to frequent the Columbia as spawning time. Captain Robert Gray, whose good ship lent its name to the river, found them plentiful in 1792, and did not neglect to pay his compliments. It is to be regretted that the record of their truancy is not more specific, better verified, for instances in which anadromous fish fail to keep their natural appointments are more than rare.

Regarded across a third of a century, the claim is doubtful, and one cannot but incline to an opinion that the smelt were punctual, but unobserved. It might have been that the run, lengthy as it is, passed the specific points of observation at periods of high and murky water, to spawn far upstream. The weakness of this theory, which is otherwise entirely tenable, is that such conditions would scarcely be repeated annually over a long period of years. An instance that proves how easy it is to overlook the presence of the run is that of the appearance of the smelt in the Sandy River last spring. Unusually high water prevailed at the time the run was expected, and all observers were confident that the hordes of smelt had not entered the stream. Later they revised their opinion, for schools of infant smelt were noticed in early summer, and it became apparent that the fish had arrived and fulfilled their destiny without a single person glimpsing the millions of adult fish in the muddy current. Yet, as has been said, it is a bit far-fetched to fancy that such conditions could be indefinitely repeated.

The habits of anadromous fish are definite and precise. They return from the sea at well established seasons to the waters of their own birth to deposit their eggs. In this impulse the smelt are one with the salmon, whose cousins they are, and the confirmed belief is that such runs do not fail until the run itself is obliterated. With salmon this has repeatedly been proved. It is logical to assume that the multitudinous smelt conform to the same law, and that those early observers confused loose report and limited observation with fact until they had for themselves established a tradition. This may not be true, but if it is not true one of ocean's mysteries remains unsolved, and it is to be regretted that the record is so imperfectly preserved.

**Morning Oregonian (Portland), Monday, 6 February 1922, p. 6, col. 2**

Smelt Run in Cowlitz Small

Kelso, Wash., Feb. 5—(Special)—A small run of Columbia River smelt is in the Cowlitz River and the fishermen are making small catches of the little fish, which are a great table delicacy throughout the northwest. Boats can get but three or four boxes a night. It may be several weeks before a heavier run arrives, say those familiar with smelt fishing operations, as few fish have been caught by the Columbia River gillnetters.

**Morning Oregonian (Portland), Saturday, 11 February 1922, p. 12, col. 1**

A large supply of Columbia River smelt is available at 15 cents a pound, and in some places at two pounds for 25 cents.

**Morning Oregonian (Portland), Tuesday, 21 February 1922, p. 7, col. 6**

Smelt Run Again Enters Cowlitz

Kelso, Wash., Feb. 20—(Special)—What is thought to be the main run of Columbia River smelt entered the Cowlitz River last night and large catches of smelt were made by the fishermen. Later, however, the run decreased, and there is some doubt whether or not this is the main run. The fish have been late in coming up the river this year, although there have been small runs in the Cowlitz several times during the winter.

**Morning Oregonian (Portland), Saturday, 25 February 1922, p. 12, col. 1**

Columbia Smelt Price Is Reduced, Fresh Seafood Sells Three Pounds for 25 Cents
Large Supply on Hand, Smelt Prices Cut

The price of a popular seafood that is recognized in Portland as a real delicacy was cut almost in two when dealers reduced prices of Columbia River smelt. These tasty, silvery fish are now available at three pounds for 25 cents. The price a week ago was 15 cents a pound. Dealers report a good supply on hand to supply a brisk popular demand. The smelt are fresh from the Columbia River.

**Morning Oregonian (Portland), Saturday, 4 March 1922, p. 15, col. 1**

Smelt Also Take Fall

Another popular product that has dropped in price is Columbia River smelt. These tasty little fish may be had at two pounds for 15 cents or four pounds for a quarter. In some stores the price is three pounds for 15 cents. These prices are the lowest of the season so far and caused a heavy demand.

**Morning Oregonian (Portland), Wednesday, 12 April 1922, p. 13, col. 3**

Smelt Reported Running in Sandy
Fish Keeping to Middle of Stream, It Is Said
Licenses Not Needed

Nets, sieves, baskets and dippers of various kinds will be at a premium for a few days, and many thousand gallons will be consumed along the Columbia River highway route between Portland and the Sandy River, for the smelt are running again.

A silvery phalanx 15 feet wide and six inches deep is flowing upstream in the Sandy for the first time in two years, the dainty little fish completely ignoring the stream last year. By the millions, the tiny smelt are seeking the headwaters, a phenomenon which will attract thousands to the river banks and flood Portland homes with the toothsome little delicacy for many days.

For the true fisherman there is no sport in catching smelt during a run, for it requires no more effort than the dipping of a net into the water and removing it filled to the brim with flopping, silver fish, but the run has a great attraction for the fireside fisherman who desires great results from a minimum of effort.

Length of Run Uncertain [subhead]

How long will the run last? This is a question which cannot be answered with any degree of certainty. Runs have been known to last from two days to 24 days. A good deal depends on the weather. Should conditions moderate and a heavy, warm rain develop, high water in the Sandy will prove too great an obstacle for the small fish to negotiate. They have traveled a long distance by the time they arrive in the Sandy and are tired.

On the other hand, should the weather continue cool, with little rain, a long run can be anticipated. Indications are that there still will be a considerable run next Sunday to accommodate the holiday flow of autoists.

Though the smelt have been known to ignore the Sandy for as high as eight consecutive years, of late the runs have been quite constant, the failure of the fish to appear last year being quite out of the ordinary. A late spring usually presages a heavy smelt run, according to Lou Karlow, deputy county clerk, whose home is on the banks of the river and whose wife telephoned to Portland the first news of the run yesterday morning.

Run Appears Big [subhead]

The run looks like a big one, similar to that of two years ago, according to Carl Shoemaker, master fish warden, although he said yesterday the fish were keeping to the middle of the stream. However, he expected the run would reach such proportions, probably by today, that the merest tyro fisherman can stand on the bank of the stream and dip up all he wants.

No fishing license will be required, said Mr. Shoemaker, for persons who desire only to take smelt for their own use. Those who operate commercially, however, and sell their catch, must provide themselves with a dip net or dragnet license. No waste will be tolerated, said Mr. Shoemaker.

**Morning Oregonian (Portland), Thursday, 13 April 1922, p. 8, col. 2**

Smelt Thick in Sandy
Autoists Congest Highway in Rush for Fish
Calls for Assistance Cause Sheriff to Dispatch Entire Motorcycle Squad to District

Smelt scouts up the Sandy River evidently reported favorably concerning that stream as a spawning ground, for millions of the silvery little fish reached from bank to bank yesterday by the time autoists in any number began to gather in the vicinity of Troutdale.

More than 2,000 automobiles congested the Columbia River highway near the Sandy before noon and calls for assistance caused Sheriff Hurlburt to dispatch his entire motorcycle squad of six men and machines to the district to direct traffic and break the jam which had ensued.

Birdcages, lace curtains and many other substitutes for fish nets made their appearance and only a few minutes in the stream sufficed to supply any family with enough smelt for a reunion. All indications are that the run will last for a week or more and it is expected that the traffic will attain proportions by next Sunday which may make it necessary to employ traffic officers in addition to the sheriff's complement.

It is not necessary to have a fishing license if the smelt are dipped out of the river for the use of oneself and family.

**Morning Oregonian (Portland), Thursday, 13 April 1922, p. 10, col. 7**

Those Who Come and Go
Tales of Folks at the Hotels

Smelt in the Sandy River, out near Troutdale, are as interesting to tourists at the hotels as they are to the householders of Portland. News of the annual run of smelt in the Sandy was received at the hotels yesterday and many persons chartered automobiles to go out and see this famous run. To the easterner who is not familiar with a run of fish and particularly to people who live in the interior, the smelt are a wonderful attraction. The march of millions of these silver fish swarming up the confines of the glacial waters of the Sandy River toward their spawning grounds never fails to evoke exclamations of astonishment. Hotel clerks have learned that they can recommend a real attraction to visitors by sending them out the highway to see the run of smelt. Tourists yesterday were so notified and they were also advised to equip themselves with nets or buckets or something with which to scoop up the fish, for no one can stand on the bank of the stream and see the myriad of fish passing them without a wild desire to go fishing on the spot. The trouble with catching smelt is that the fisher gets more than he needs or can use, so he brings back a gunnysack or two with the fish and inflicts them on everyone who can be induced to accept them. Smelt are as fine eating fish as can be found when scooped from the Sandy waters, but a person cannot eat more than several dozen.

**Sunday Oregonian (Portland), 16 April 1922, p. 3, col. 2**

Smelt Season Ends at Kelso

Kelso, Wash., April 15—(Special)—Final shipment of smelt was made by Kelso fishermen this week, and they will be busy the rest of this month getting their salmon fishing equipment ready for the spring season and moving their outfits to drifts along the Columbia River. This has been a very good smelt season, the prolonged cold weather being a benefit to the industry.

**Morning Oregonian (Portland), Tuesday, 18 April 1922, p. 1, col. 2**

Locks Block Smelt Run
Millions of Tiny Fish Caught at Cascades of Columbia

Hood River, Ore., April 17—(Special)—The run of smelt has reached the Cascades of the Columbia, where they are blocked. Millions of the fish are trying to get to the headwaters by way of the government locks. Deputy Sheriff Meyers today telephoned to Sheriff Johnson that residents of Cascade Locks, utilizing as various an assortment of improvised nets as one sees at the Sandy, are taking fish by the boxfuls at the lower end of the locks.

Schools of smelt appeared at Eagle Creek Saturday.

**Morning Oregonian (Portland), Monday, 1 May 1922, p. 4, col. 2**

Pantries Stocked with Smelt

Hood River, Ore., April 30—(Special)—Residents of Cascade Locks and Stevenson, Wash., made the most of the recent smelt run up the Columbia to the foot of the rapids below the Cascades, and many pantries have been stocked with dried and salted fish. A. J. Pratt, a Stevenson, Wash. man, who captured 1,600 pounds of smelt, salted and smoked them. His shrinkage, he reports was 66 percent, as he now has left 575 pounds of kippered smelt.

**Morning Oregonian (Portland), Monday, 1 May 1922, p. 8, col. 3**

Marvel of the Smelt

The Eugene Register has printed what we think is a timely warning concerning smelt. It predicts that unless there is some curb on the taking of this variety of fish, smelt will go the way of the passenger pigeon and the buffalo.

Probably the fact made impressive by these early tragedies that wild life cannot long maintain itself against man’s unrestrained rapacity, will cause us to take heed before the smelt have disappeared. But why not for once depart from the usual custom of delaying regulation until scarcity is upon us?

Smelt fishing in the Sandy River is an asset to Portland whose importance is hardly realized. The incidents of the spring run have no counterpart anywhere. The Sandy is not the only stream in which smelt appear in vast numbers, but it is the one stream in which they swarm that is readily accessible from a populous community.

Sandy River is a stream worth visiting for its scenic beauty alone. The point where the Columbia highway crosses it is within less than an hour's automobile ride from Portland over a paved road. It happens that the reaches of the stream directly above and below the highway bridge are the smelt fishing grounds.

There, in beautiful surroundings and without license, hindrance, or limit, the Portland citizen, one hour's journey from home, may with the crudest of home-made appliance dip out and take away as many delectable food fishes as the novelty of the occasion impels him to take. It is as the Eugene paper remarks—the rule is to take more than one can possibly use or give away. Smelt taking in the Sandy, in which thousands of persons—rich and poor—participate annually, is one of the spectacles, one of the marvels, of the northwest and of the Columbia highway.

The habits of the smelt, or candlefish as it is properly called, are little understood. Presumably they return to the stream in which they were spawned. If that be true, whatever protection given them elsewhere will not restock Sandy River if it is once fished out. As an important contribution to the food supply and as an advertisement for this community, smelt runs are worthy of scientific study and of protection, if need be, from greed and waste.

**Morning Oregonian (Portland), Tuesday, 9 May 1922, p. 10, col. 8**

How Indians Once Took Smelt
Nails in Canoe Paddles Impaled Fish, Recalls Captain Gray

Pasco, Wash., May 7—(To the Editor)—The Oregonian's editorial "Marvel of the Smelt" reminds me of the first runs of smelt in the Cowlitz River. The Indians drove sharp pointed nails through thin paddles, and as they forced their canoes upstream through the school, or rather stream of smelt, would soon fill their canoes by shaking the smelt from the nails in their paddles.

I have not been on the Cowlitz for many years, but understand that the smelt runs on that river do not compare with the runs of the '60s, when steamboats did not run above Monticello or Freeport—they now run to Kelso. Did steamboats on the Columbia or log booms at its mouth check its smelt run? If so your Sandy River runs are safe, as steamboats cannot disturb them.

We used to know when the smelt were in the Columbia by the number of seagulls that followed the schools.

Another thought: Is there not a danger of “overpopulation” of smelt if their taking is restricted? Hundreds of millions of eggs are deposited every year. Will the few thousands of fish captured relieve a congestion that would drive the smelt to some other stream? You are in error in saying the smelt is properly called a candle fish. The candle fish is only taken in salt waters like Puget Sound, and takes its name from the fact that when it is dried its mouth opens wide and makes a base to support the greasy bones that stand upright. A lighted match touched to the tail of the dried fish makes a perfect candle. The flesh of the candle fish is far inferior to the smelt.

The Columbia seems to be the only river that has the two distinct varieties of the best of fish, salmon and smelt.

The Yukon River salmon is larger and compares in flavor with our Columbia River variety, but there are no smelt to compare with the genuine Columbia River variety, which seek the Cowlitz, Kalama, Sandy and other small streams every spring to spawn. —W. P. Gray

**Morning Oregonian (Portland), Friday, 29 December 1922, p. 12, col. 5**

New Today in the Markets

A few smelt made their appearance on the Portland market yesterday, bringing the price, which was formerly about 35 cents, down to 30 cents. Marketmen state that fishermen have discovered a school of the fish making their way up the Columbia River.

# Oregon (Umpqua River)

**Eugene Register-Guard, Friday, 21 February 1969, p. C1**

Streams Back in Shape, Fishing Slow, by Pete Cornacchia

Smelt dippers at Scottsburg Park, downstream from the highway bridge across the Umpqua, hadn’t netted much since early in the week, reported Hugh Smith at the Tackle Box in Reedsport. But, judging from past years, the migration up to spawning grounds somewhere above Elkton is expected to continue at least another two weeks and a new batch of smelt could show at any time.

Lots of 25-pound limits were collected among the mob of dippers at the park last weekend, he said. Nearly all of the silvery fish were males, which usually are the first to show. Dipping was best along the bank and at night on the ebb tide. [Online at http://news.google.com/newspapers?id=SGkRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=3321,4455711&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 28 February 1969, p. 5B**

Long-handle Nets Ambush Smelt Migrating Close to Banks of Umpqua River [lead-in head], Action Slow on Steelhead, Smelt Run, by Pete Cornacchia

> The lower Umpqua has produced a few sturgeon recently in the Gardiner area but has been offering only a trickle of smelt to dippers up at Scottsburg Park. Regardless of reports in the Portland papers, Umpqua smelt dippers aren't getting their 25-pound limits.
>
> Smelt traffic has been light ever since the opening surge two weeks ago and hopes of another buildup in the run are dwindling. Oldtimers point out that swarms of gulls always follow the smelt up the river but there is no great number of birds on the river now. [Online at http://news.google.com/newspapers?id=T2kRAAAAIBAJ&sjid=B-gDAAAAIBAJ&pg=5316,6039358&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 22 March 1970, p. 2C**

It's Striper Time, by Pete Cornacchia

> … About a month ago several Mapleton fishermen started catching big stripers which apparently had followed a previously unheard-of smelt run into upper tidewater on the Siuslaw. [Online at http://news.google.com/newspapers?id=IcIUAAAAIBAJ&sjid=8eADAAAAIBAJ&pg=5240,5619960&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 5 February 1971, p. 3C**

Umpqua Yielding Variety: Steelhead, Smelt, Sturgeon, by Pete Cornacchia

> And if you've had enough steelhead and/or hang-ups for one winter, Umpqua tidewater offers a good but sporadic run of smelt for dippers in the Scottsburg vicinity and increasing white sturgeon activity down in the bay. …
>
> The Umpqua appears to have a good smelt run, though they're coming through in spurts. Success for dippers on the banks at the state park below Scottsburg has varied from day to day. [Online at http://news.google.com/newspapers?id=9gwRAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=3712,778489&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 26 February 1971, p. 2B**

Outlook Poor for Anglers, Good for Dippers, Diggers, by Pete Cornacchia

> Get that dip net out again, for those sneaky smelt are back again. Bigger than ever.
>
> But if you're less than thrilled with the chase and taste of the eulachon … tides are good … for dredging bay clams. …

After most of the smelting fraternity on the lower Umpqua had put their nets away for the year, these unpredictable fish suddenly showed again last weekend. Dippers at Scottsburg State Park have done quite well every night this week, reported Jim DiBala at Echo Resort. More smelt than before and they're larger than usual. [Online at http://news.google.com/newspapers?id=Cw0RAAAAIBAJ&sjid=EeEDAAAAIBAJ&pg=4477,5470935&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 8 February 1972, p. 3B**

On the Outside [column head], Passing the Word, by Pete Cornacchia

When the smelt come up the Umpqua to spawn, usually about this time of year, I forget the steelhead and head for tidewater. Not to dip for smelt with all the others at Scottsburg State Park below the Highway 38 bridge, but to prey on the great white sturgeon and the striped bass which prey on the smelt as they move up the river.

Sure enough, smelt are beginning to show in the lower Umpqua. Just a trickle as yet, however. Several persons have told recently of seeing stripers feeding on smelt at the surface, but dippers at the park haven't been collecting much in their long-handled nets.

"Commercial netters have been getting a few from time to time," said Jim DiBala at Echo Resort. "But dipping has hardly been worth the effort. I fished about an hour yesterday and got three smelt, which is about how it's been.

"They should be here any time now, though. Could be on the next tide."

As in other streams, the smelt run in the Umpqua is a very unpredictable thing which has been quite strong in some years and very weak in others. Sometimes the fish go through when the river is too high and muddy to get at them.

Water conditions have been good for the past week, but the Umpqua was rising again Monday and probably will continue to climb if the thaw continues in the upper reaches. [Online at http://news.google.com/newspapers?id=Q8kTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=3531,1895262&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 25 February 1972, p. 1B**

Smelt Run Picking Up in Umpqua, by Pete Cornacchia

The smelt run in the Umpqua, which for several weeks had been a slow walk rather than a run, came on strong Wednesday afternoon to spur hopes of both dippers and striped bass fishermen.

"Dipnetters took several limits last night and were still taking smelt this morning," Mrs. Jim DiBala reported Thursday from Echo Resort. She was referring to the dippers at the state park below the Highway 38 bridge at Scottsburg. For personal use, daily limit on smelt is 25 pounds.

How long the run would remain strong was anybody's guess. [Online at http://news.google.com/newspapers?id=UskTAAAAIBAJ&sjid =JuEDAAAAIBAJ&pg=3871,6403187&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Sunday, 27 February 1972, p. 3D**

Smelt Run Draws Many to Umpqua, by Pete Cornacchia

It had started raining again and the cold wind which had been whipping up whitecaps on the flats along the lower Umpqua had an awfully mean bite for a southwester.

But the men, women, kids and dogs strung along the silty beach above and below the boat ramp at Scottsburg State Park didn't seem to mind. In shiny wet rain gear or soggy wool jackets, some huddled by the spitting and sputtering fires while others knee-deep at the edge of the high and muddy river swung long-handle nets out into the chocolate flow.

When they lifted the nets from the water after a long sweep downstream, usually a handful of silvery fish flashed in the bottom of the cords. The fish were dumped into a bucket or plastic container, then the dipper waded back into the water to make another sweep.

The smelt were running strong at last and some of the dippers were getting their 25-pound limits, as had others the previous afternoon and night. The run had been light up to this last week of February, as it had been on other streams in Oregon and Washington.

But now lots of the little fish were moving upstream to spawn and the dippers were there to get their share, no matter how raw the weather or how muddy the river. The strong run might continue for several more days, or it could be back to a sporadic trickle by tomorrow.

Like the swarms of gulls which follow the smelt up the river and tell of their presence, the dippers can't count on tomorrows.

For a host of anglers, the arrival of smelt raises hope not so much for a tasty meal as for the oncoming of voracious striped bass which also prey on the little fish as they travel upstream. [Online at http://news.google.com/newspapers?id= VMkTAAAAIBAJ&sjid=JuEDAAAAIBAJ&pg=4273,6843290&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 3 March 1972, p. 5B**

High, Muddy Streams Ruin Angling Hopes.

Lower Umpqua: … Smelt still in river; few limits. [Online at http://news .google.com/newspapers?id=4mkRAAAAIBAJ&sjid=DuEDAAAAIBAJ&pg =6514,720966&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 21 April 1972, p. 3B**

Fish Prospects Better as Streams Improve, by Pete Cornacchia

> … Discovery of the very late smelt run brought the dipnetters back to Scottsburg Park, where several quick 25-pound limits were collected early in the week. [Online at http://news.google.com/newspapers?id=6cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6493,5070734&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 25 April 1972, p. 3B**

On the Outside [column head], High Lakes, by Pete Cornacchia

> … weather was great but catches fell off sharply.
>
> So did smelt dipping on the Umpqua. …
>
> The Chinook in the Umpqua apparently haven't done much reading and aren't aware that salmon don't eat much after moving into freshwater on their spawning runs, [the Game Commission's Dave Anderson] noted. Many of the fish which he has checked recently were packed with smelt, just like the stripers.
>
> Dipnetters weren't doing quite that well on smelt, though Dave did check a 25-pound limit for one patient and persistent soul near Scottsburg Park. The man got his quota with about one smelt on each dip. At a few ounces per fish, that took a few dips. [Online at http://news.google.com/newspapers?id=7cQUAAAAIBAJ&sjid=SOEDAAAAIBAJ&pg=6535,6170162&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 4 February 1973, p. B1**

Arrival of Smelt Draws Gulls, Stripers, Sturgeon, Anglers to Lower Umpqua [lead-in head], Smelt: Tiny, Tasty, Unpredictable, by Pete Cornacchia

> "They were getting quite a few smelt here last weekend," remarked a man standing beside a fire. "Some came close to getting their 25 pounds, too.
>
> "Not much since then, though. We had a big crowd here last night, but nobody did much."
>
> But the unpredictable smelt might suddenly start showing again any time, he said.
>
> "Last year, the run faded out for several weeks and we figured that was it," he went on. "Then a lot of smelt came through in the middle of April. Wife and I caught two Chinook and a 30-pound striper that were stuffed with them. …"
>
> For many anglers, the arrival of smelt in the Umpqua raises hope not so much for a tasty meal of them as for the oncoming of sturgeon and striped bass. Like the gulls and the dippers, sturgeon and stripers also come running when the smelt

are running. [Online at http://news.google.com/newspapers?id=o2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4621,691873&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 9 February 1973, p. 3D**

Lower Umpqua Promising; Angling Slow on Steelhead, by Pete Cornacchia

Smelt keep coming up Umpqua tidewater in spurts ….

The Umpqua has lost its winter tan and in turning green has cleared enough that most of the smelt are traveling well out in the middle of the river. At Scottsburg State Park, dippers in boats have been doing better than those on the banks. [Online at http://news.google.com/newspapers?id=qGoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4830,2011247&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Friday, 16 February 1973, p. 3D**

From Smelt to Sturgeon, Prospects Best on Umpqua, by Pete Cornacchia

Smelt are still running in the lower Umpqua but they're staying well out in the middle of the relatively clear flow and dipnetters on the bank at Scottsburg State Park haven't been doing much. [Online at http://news.google.com/newspapers?id=r2oRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=4286,3686790&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 20 February 1973, p. 3B**

On the Outside [column head], Wary Bass, by Pete Cornacchia

In checking angling pressure and catch on the lower Umpqua from February into fall last year, Game Commission biologist Dave Anderson also did a lot of stomach content analysis on stripers.

… In the spring, from the middle of March through the middle of May, 46.7 percent of the stomachs examined in the river above Reedsport had nothing in them.

In that stretch and during that period, smelt were found in 50.7 percent of the stomachs and made up 91 percent of the springtime diet. …

In mid-April, when anglers in the Scottsburg area were catching both spring Chinook and stripers, a late and large run of smelt suddenly showed up. Salmon or striper, most of the fish caught in the next couple weeks were stuffed with smelt. [Online at http://news.google.com/newspapers?id=smoRAAAAIBAJ&sjid=JOEDAAAAIBAJ&pg=5421,4513119&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 31 January 1974, p. 3B**

Outlook for Outside [lead-in head], Rivers Rising; Smelt Arrive, by Pete Cornacchia

> Arrival of smelt in the lower Umpqua has made dippers happy, but there's little good news to precede the bad for steelhead anglers.
>
> Swarming gulls pointed to the first waves of the Umpqua's smelt run the latter part of last week and dipnetters have been taking fish each day since then, according to Dave Anderson, State Wildlife Commission fisheries biologist at Reedsport.
>
> He said dippers along the banks at Scottsburg State Park below the highway 38 bridge have had varying success from day to day, with some 25-pound limits for the harder workers. The Umpqua like most coast streams remains muddy and rather high. [Online at http://news.google.com/newspapers?id =jLoUAAAAIBAJ&sjid=P-ADAAAAIBAJ&pg=6688,6779760&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 February 1974, p. 3B**

Outlook for Outside [lead-in head], Hopes Better for Anglers, by Pete Cornacchia

> Dipnetters are still taking smelt from the Umpqua below Scottsburg, with success varying from day to day. Best hauls have come at low tide. [Online at http://news.google.com/newspapers?id=tQUTAAAAIBAJ&sjid =A9gDAAAAIBAJ&pg=6348,1409295&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Sunday, 17 February 1974, p. 5B**

Monsters lurk in Umpqua, by Pete Cornacchia

> … we had seen no sign of the big white sturgeon which usually follow close behind the smelt at this time of year. The smelt had been running for nearly three weeks and the dippers were still taking a few up at Scottsburg. [Online at http:// news.google.com/newspapers?id=vgUTAAAAIBAJ&sjid=A9gDAAAAIBAJ &pg=4770,3459056&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 26 March 1974, p. B1**

On the Outside [column head], Sun Out, Fish In, by Pete Cornacchia

> The poor water conditions and long spell of foul weather didn't keep dipnetters from converging on a strong smelt run at Scottsburg. [Online at http://news.google.com/newspapers?id=ABMRAAAAIBAJ&sjid =NOADAAAAIBAJ&pg=6255,5535261&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Thursday, 29 January 1976, p. 2D**

On the Outside [column head], Sturgeon Following Smelt into Umpqua Fishing Holes, by Pete Cornacchia

> [White sturgeon are] gathering in the murky depths near Gardiner and above Reedsport to feed on spawned-out smelt. …
>
> As for the smelt, the run has shriveled to a trickle and dipnetters at Scottsburg have had to work hard for the few fish they've panned this week. [Online at http://news.google.com/newspapers?id=knkRAAAAIBAJ&sjid=PeADAAAAIBAJ&pg=6627,7406766&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Sunday, 8 February 1976, p. 3B**

Like the Gulls, the Great White Sturgeon Comes Running when Smelt Are Running [lead-in head], Waiting for the Big Ones, by Pete Cornacchia

> Like the gulls that were cruising back and forth, the several people who were standing knee-deep near the bank weren't finding much in the green waters of the lower Umpqua.
>
> Like the white and grey birds winging along or resting in the eddies, they had gathered where the river rolls past Scottsburg State Park in hopes of scooping up smelt. But not since the arrival of a good run three weeks ago had there been much sign of the silvery little fish.
>
> Time after time, the men dipped their long-handled nets into the water, lifted, and dipped again. Neither was there much reward for the efforts of the two men who were dipping from a boat anchored in the middle of the river.
>
> Still, the dippers knew, the smelt could suddenly show again at any time.
>
> For many anglers, however, the arrival of smelt in the Umpqua raises hope not so much for a tasty fried meal as the oncoming of the great white sturgeon. Like the gulls and the people, these huge fish come running when the smelt are running. [Online at http://news.google.com/newspapers?id=CxMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=2919,1791554&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 26 February 1976, p. 2B**

On the Outside [column head], Conditions Remain Lousy for Anglers, by Pete Cornacchia

> Smelt are running again in the lower Umpqua. …
>
> Smelt were back in the Umpqua at Scottsburg early in the week but they were running deep and in the middle of the river. Dippers in boats took some 25-pound limits on the evening low tides. [Online at http://news.google.com/newspapers

?id=HRMRAAAAIBAJ&sjid=K-ADAAAAIBAJ&pg=6253,6671366&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 25 January 1977, p. B1**

Steelies in Mind, Smelt in Net, by Pete Cornacchia

> And that's where we finally came upon a gathering of fish [on the Siuslaw River].
>
> Scattered over the sand and gravel along the shallow edges, like purplish noodles, were rafts of smelt.
>
> O'Neal grabbed the big landing net and went splashing and slashing through the shallows like an Alaskan brown bear ankle-deep in sockeyes. But the mesh, of course, was too wide for dipping fish six to seven inches long. So he folded the cords over in a wad and tied them so that the net looked more like King Kong's fly swatter.
>
> Then he stood in one spot while I circled around and drove the scurrying groups of smelt past him, where he flipped them onto the bank in quick scoops. Before the little devils finally tired of all this nonsense and departed, we managed to gather enough for a meal or two. …
>
> For either steelhead or smelt, however, the much larger Umpqua should offer better prospects than the Siuslaw in the next month. While the unpredictable smelt usually are beginning to arrive in both streams about this time, the Umpqua normally draws a much greater run over a longer period. [Online at http://news.google.com/newspapers?id=KYoQAAAAIBAJ&sjid=KuADAAAAIBAJ&pg=3816,6033795&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 3 February 1977, p. 2B**

Outlook for Outside [lead-in head], Prospects Remain Poor for Anglers, by Pete Cornacchia

> No smelt are evident yet in the Scottsburg vicinity on the Umpqua, reports Ben Carlson at Greenacres. [Online at http://news.google.com/newspapers?id=UXwRAAAAIBAJ&sjid=mtkDAAAAIBAJ&pg=4244,542469&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 24 March 1977, p. 3B**

Outlook for Outside [lead-in head], Chinook Caught in Lower Rivers, by Pete Cornacchia

> Still no sign of smelt in the Scottsburg area. …
>
> At midweek, state police reported that the heavy smelt run in the Sandy [River] was on the decline but dippers were still doing fairly well at Troutdale. The fish have been staying in the deepest water during the day and running close to the banks only at night. [Online at http://news.google.com/newspapers?id

=2XkRAAAAIBAJ&sjid=JOADAAAAIBAJ&pg=4351,5873279&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 2 February 1978, p. 2B**

Outlook for Outside [lead-in head], Lower Umpqua Good for Smelt, Sturgeon, by Pete Cornacchia

> Smelt dippers are still doing well around Scottsburg State Park, according to Ben Carlson in Ben's Bait and Tackle Shop at Green Acres. He reported that 25-pound limits have been rare but dippers have been taking fish consistently at night and at low tide. Daytime dipping has been better from boats in midstream than from the bank. [Online at http://news.google.com/newspapers?id =cHARAAAAIBAJ&sjid=7uEDAAAAIBAJ&pg=6680,369906&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 February 1978, p. 6B**

Outlook for Outside [lead-in head], Bay Catches Better, But Streams Stingy, by Pete Cornacchia

> … The Umpqua … has been slow … for smelt at Scottsburg. [Online at http://news.google.com/newspapers?id=hXARAAAAIBAJ&sjid =7uEDAAAAIBAJ&pg=6645,6113567&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Thursday, Feb 15, 1979, p. 2C**

Outlook for Outside [lead-in head], Smelt Make their Move, But Not the Steelhead, by Pete Cornacchia

> The slowly receding waters have brought a new batch of smelt to the lower Umpqua but no great upswing in catches for steelhead anglers on most other streams.
>
> The Umpqua was high and muddy Wednesday after rising five feet from the previous day, but smelt dippers on the bank and in boats were doing well at Scottsburg Park, reported John Johnson, state fisheries biologist at Reedsport. [Online at http://news.google.com/newspapers?id=724RAAAAIBAJ&sjid =_uEDAAAAIBAJ&pg=6561,4446377&dq=site:news.google.com+Umpqua +smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 February 1980, p. 2D**

On the Outside [lead-in head], Siuslaw Good Steelhead Bet, by Pete Cornacchia

> … Increasing sturgeon activity at Gardiner on the lower Umpqua points to the arrival of smelt, though dippers have not found much sign of the latter up at Scottsburg. …

Lower Umpqua and Smith rivers: … Some smelt are showing. The run is not large enough to dip. [Online at http://news.google.com/newspapers?id =uBoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=6685,1874436&dq=site:news .google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 28 February 1980, p. 4B**

On the Outside [lead-in head], Streams Are High, Fish Are Dark, by Pete Cornacchia

The lower Umpqua remains slow … and smelt dippers at Scottsburg no longer have much hope of getting a run this winter. [Online at http://news.google.com/ newspapers?id=xRoRAAAAIBAJ&sjid=1OEDAAAAIBAJ&pg=4258,7969800 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 19 February 1981, p. 2B**

Brood Rainbows Planted in Ponds, by Pete Cornacchia

… smelt could be pleasing dippers near the head of tidewater at Scottsburg before long. A big rise often will bring a rush of these unpredictable fish, which may arrive any time from January into spring and sometimes never show. Dippers on the bank usually will do better when the river is up and colored, rather than low and clear, for the smelt frequently will be running along the edge of the water instead of deep in midstream. [Online at http://news.google.com/ newspapers?id=EHERAAAAIBAJ&sjid=S-IDAAAAIBAJ&pg=6662,5105936 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 5 March 1981, p. 7B**

Cold Water Hasn’t Helped Fishing Prospects, by Pete Cornacchia

Lower Umpqua: … No smelt showing. [Online at http://news.google.com/ newspapers?id=_EkVAAAAIBAJ&sjid=SuIDAAAAIBAJ&pg=6624,1285997 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 11 February 1982, p. 2C**

Outlook for Outside [lead-in head], It Depends on the Weather, by Pete Cornacchia

… Smelt dippers are still waiting for another batch to show near the head of tidewater at Scottsburg [on the Umpqua River], where a small run faded soon after appearing about two weeks ago. [Online at http://news.google.com/ newspapers?id=wnERAAAAIBAJ&sjid=XOIDAAAAIBAJ&pg=3596,2269070 &dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 17 February 1983, p. 2C**

Outlook for Outside [lead-in head], Steelhead There, But Fishing Isn't, by Pete Cornacchia

> … Little sign of smelt has been reported in the Scottsburg area. [Online at http://news.google.com/newspapers?id=k3ERAAAAIBAJ&sjid=WeIDAAAAIBAJ&pg=6567,3925333&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Tuesday, 15 March 1983, p. D1**

Spring Fever, by Pete Cornacchia

> The only smelt seen in the Umpqua this winter have come from the market, which may be the chief reason for the generally poor response from sturgeon. [Online at http://news.google.com/newspapers?id=0soTAAAAIBAJ&sjid=QOIDAAAAIBAJ&pg=6221,3529041&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 February 1984, p. 6C**

Outlook for Outside [lead-in head], Lake Creek Fishing Good, by Pete Cornacchia

> The high water has brought no sign of smelt in the lower Umpqua or in the Sandy on the Columbia. [Online at http://news.google.com/newspapers?id=uGoVAAAAIBAJ&sjid=juEDAAAAIBAJ&pg=6505,5503108&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 14 February 1985, p. 2C**

The Coastal Streams Too Full to Fish, by Pete Cornacchia

> Very little sign of smelt in the Columbia, Sandy and Umpqua. [Online at http://news.google.com/newspapers?id=McUUAAAAIBAJ&sjid=i-EDAAAAIBAJ&pg=6681,3015823&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 7 March 1985, p. 2B**

Outlook for Outside [lead-in head], State's Angling Action is Better on the Coast, by Pete Cornacchia

> Despite a lack of smelt as attractive forage, the lower Umpqua has been yielding a fair number of sturgeon … . [Online at http://news.google.com/newspapers?id=j2oVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6658,1567378&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 14 March 1985, p. 2B**

Outlook for Outside [lead-in head], Trout Plants Spice Action, by Pete Cornacchia

> Apparently this will be another year in which smelt dippers will not be taking very many fish from the Sandy or Umpqua. Smelt entered the Sandy last week but have remained below the Interstate 84 bridge, where state police report dipping has not been worth the effort. [Online at http://news.google.com/newspapers?id=lWoVAAAAIBAJ&sjid=iOEDAAAAIBAJ&pg=6742,3370082&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 30 January 1986, p. 3C**

Outlook for Outside [lead-in head], Steelheading Good on Upper Siuslaw, by Pete Cornacchia

> … No smelt have been reported [on the Umpqua River]. [Online at http://news.google.com/newspapers?id=12AVAAAAIBAJ&sjid=BeEDAAAAIBAJ&pg=4531,6382367&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 27 February 1986, p. 2B**

Outlook for Outside, Fishing

> Lower Umpqua: … No smelt reported. [Online at http://news.google.com/newspapers?id=JsUUAAAAIBAJ&sjid=kOEDAAAAIBAJ&pg=3330,6304140&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 19 February 1987, p. 2B**

Outlook for Outside [lead-in head], Coast Rivers Improve But Not Fishing, by Pete Cornacchia

> Lower Umpqua: … No smelt have shown so far. [Online at http://news.google.com/newspapers?id=Z2kVAAAAIBAJ&sjid=fOEDAAAAIBAJ&pg=5540,4244267&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 21 January 1988, p. 2D**

Outlook for Outside [lead-in head], Conditions Improve for Steelhead Anglers, by Pete Cornacchia

> Lower Umpqua [under subhead Angling]: … No smelt have shown. [Online at http://news.google.com/newspapers?id=5msVAAAAIBAJ&sjid=n-EDAAAAIBAJ&pg=2617,4250273&dq=site:news.google.com+Umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday 11 February 1988, p. 1D-2D**

Cowlitz Smelt a Quick Catch for Dipnetters, by Pete Cornacchia

> Smelt also used to make frequent January-April appearances in Oregon's Umpqua but have forsaken this river in recent years. [Online at http://news.google.com/newspapers?id=FmwVAAAAIBAJ&sjid=p-EDAAAAIBAJ&pg=5029,2166079&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 2 March 1989, p. 2D**

Outlook for Outside, Angling

> Lower Umpqua: … No smelt have shown yet. [Online at http://news.google.com/newspapers?id=0W0VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=4949,391197&dq=site:news.google.com+umpqua+smelt&hl=en]

**Eugene Register-Guard, Thursday, 23 March 1989, p. 2D**

Outlook for Outside, Angling

> Lower Umpqua: … no harvestable numbers of smelt. [Online at http://news.google.com/newspapers?id=420VAAAAIBAJ&sjid=seEDAAAAIBAJ&pg=2299,6102792&dq=site:news.google.com+umpqua+smelt&hl=en]

# Washington

**Vancouver Register (Washington Territory), Wednesday, 6 April 1867, p. 3, col. 1**

> Smelt—This delicate fish, which has never before been known to come up higher than Lewis River, has made its appearance off this city in large numbers. They can be caught by hand—evening, just after dark is the best time.

**Kalama Beacon (Washington Territory), Friday, 1 March 1872, p. 1, col. 1**

> A Piscatorial Exploit—A few days ago, at Camp Enterprise on the Cowlitz, Johnny McGrath, who "runs" things there, performed a feat at smelt catching that places him in the van of fishers. With a little dip net of only 16 inches diameter across the open end, he stood on the river bank and caught by scooping two barrels of fish within half an hour! In the lower Columbia River tributaries this species of herring are now running in schools of myriads, and literally fill the Cowlitz in shoals that occupy the entire space of the stream; and what is singular, although apparently moving forward up the river, there is at present no diminution of their volume.

**Kalama Beacon, (Washington Territory), Friday, 22 March 1872, p. 1, col. 1**

The Smelts—These piscatory phenomenon seemed to pass the rear of their column up the Cowlitz and tributaries last week. There seems to be no return of any portion of them downstream; and whither they are tending, and where can such myriads find room at the head of the Cowlitz, is something that would not be an inappropriate study for an Agassiz, or some other piscatorial student.

**Kalama Beacon, (Washington Territory), Saturday, 8 February 1873, p. 1, col. 2**

A Piscatory Advent—The annual return to the Cowlitz River of that delicious little fish called the smelt commenced a couple of weeks ago, and the river is literally alive with them. With a scoop net of about 15 to 20 inches in diameter, it is practicable to stand anywhere on the bank and scoop a barrel full in 10 or 15 minutes. The run will last about a month longer, but toward the latter end of the season they are pronounced inferior and the catch is abandoned. A few days ago, the steamer Rescue transported seven tons of these fish at once to fill orders from Portland.

**Kalama Beacon, (Washington Territory), Tuesday, 10 February 1874, p. 1, col. 1**

The Smelt Run—That delicious little fish is playing truant this season, so far. According to the period of their annual visits heretofore, they have been due in the Cowlitz for two or three weeks past; but they have not yet put in an appearance, and may fail altogether, as they do sometimes in streams frequented by them.

**Daily Olympian, Monday, 16 March 1896, p. 3, col. 4**

Fresh Supply of Fish

The Columbia Market today received a fresh supply of … Columbia River smelt … All fresh and nice. Columbia foot of Sixth.

**Daily Olympian, Wednesday, 2 February 1898, p. 3, col. 1**

Brevities of the Day

M. Giles of the Main Street Market has just received an invoice of fine Columbia River smelt.

**Centralia Daily Chronicle, Wednesday, 3 February 1909, p. 3, col. 1**

Fresh Columbia River Smelts, 5 c per Pound at Kent’s Fish Market, Tower Avenue Phone 613 and Your Order Will Be Promptly Delivered

**Centralia Daily Chronicle, Tuesday, 16 March 1909, p. 3, col. 2**

The Last Run of Fresh Smelts Is On and Will Last Only a Few Days Longer
A Good Supply at Kent's Fish Market on Tower Avenue, 5 Cents per Pound, Phone 613

**Centralia Daily Chronicle, Tuesday, 8 February 1910, p. 3, col. 2**

The Columbia River Smelt Are Now In. Get Them at the Main Street Fish Market

**Centralia Daily Chronicle, Thursday, 23 February 1911, p. 3, col. 1**

Columbia River Smelt Can Be Had at the Main St. Fish Market and the Centralia Fish Market on North Tower Ave, 5 Cents per Pound

**Centralia Daily Chronicle, Thursday, 1 February 1912, p. 3, col. 5**

Centralia Fish Market
Columbia River Smelts, Per lb 5c

**Centralia Daily Chronicle-Examiner, Thursday, 16 January 1913, p. 6, col. 6**

Columbia River Smelts, 5c per Pound, City Fish Market, Carsten Building

**Centralia Daily Chronicle-Examiner, Friday, 17 January 1913, p. 6, col. 2**

Smelt Run Is On in Earnest

> Kelso, Jan. 17—Columbia River smelt, or Cowlitz River smelt, as they should be called, have come into the Cowlitz in ever increasing numbers since the fag end of last week, and fishermen now report that the run is a satisfactory one, although not extremely large. Monday saw the first large catch, more than one thousand boxes of 50 pounds each, or 50,000 pounds, being caught and shipped from Kelso. The gill nets have been discarded for the nets of the dip variety, and a force of a score or more of boats has been busy in midstream.

**Centralia Daily Chronicle, Friday, 31 January 1913, p. 3, col. 6**

We are Now Well Supplied with Choice Columbia River Smelt, Shipments Daily, 5 Cents a Pound, City Fish Market, Carstens Building

**Centralia Daily Chronicle-Examiner, Monday, 10 February 1913, p. 6, col. 6**

> 1,200,000 smelt were caught in the Cowlitz River last Sunday.

**Olympia Daily Recorder, Wednesday, 14 January 1914, p. 2, col. 7**

Run of Smelt Largest Ever in the Columbia

> Portland, Ore., Jan. 14—The greatest run of smelt ever in the Columbia River is now being harvested. Fresh offerings of Columbia River smelt were quoted at 5 cents a pound today by the wholesale fish trade and there were indications that even this low price would be cut. The market is glutted.
>
> Such heavy catches by gillnetters of the lower Columbia River were never before seen in this market. As a rule the gillnetters catch only limited supplies before the fish enter the Cowlitz, when they are caught in abundance with dip nets.

**Centralia Daily Chronicle-Examiner, Tuesday, 23 February 1915, p. 3, col. 3**

Heavy Smelt Run in Lewis

> Kelso, Feb. 23—That the heavy run of smelt have passed up the Cowlitz River for this season seems certain from the enormous numbers of the tiny fish which have poured up the Lewis River during the past few days. Not satisfied with the Kalama River, which they first entered, the main run of the fish went into the Lewis River, and at the present time that stream looks like the Cowlitz at this season of other years. Smelt everywhere in the waters, filling it from bank to bank and all the way from the mouth far above Woodland.

**Centralia Daily Chronicle, Wednesday, 17 March 1915, p. 3, col. 4**

Big Smelt Run

> Woodland, Wash., March 17—The great run of smelt in the Lewis River during the past month and which seemed to be decreasing last week has been increased by another run which started yesterday, and the fish coming now are of as good quality as have ever been caught here, but the price has ruled so low that there are not many fishermen taking them. Seagulls and other fish-eating birds are doing their best to clean them up. The gulls are on the river by the hundreds of thousands, their flight being almost solid at times, and the sand bars when covered by them look like a snow bank. Immense numbers of the little fish are lying dead in the river and a good rain, with a rise in the river, would be a great help, as it would wash the dead fish out. This is the first season in seven years the fish have come in here.

**Centralia Daily Chronicle-Examiner, Wednesday, 31 March 1915, p. 1, col. 3**

Smelt Come Too Late

> Kelso, March 31—Too late to do the fishermen of the Cowlitz River any good, because the market is already loaded up and the price down, large numbers

of smelt came into the river some time last week. For some unknown reason the smelt this year wandered everywhere except into the Cowlitz, which in seasons past has been their regular abode. This is the first run of smelt of any size in the Cowlitz this year.

**Centralia Daily Chronicle-Examiner, Friday, 17 December 1915, p. 2, col. 2**

Smelt Coming In

Kelso, Dec. 17—Smelt are coming into the Cowlitz River in increasing numbers, as shown by growing catches of the gillnetters. Gillnetting for smelt at this season of the year is profitable, as the fish bring 20 cents a pound. Later on the fishermen will be lucky to get that much a box.

**Centralia Daily Chronicle-Examiner, Friday, 31 December 1915, p. 7, col. 5**

Many Smelt Caught

Kelso, Dec. 31—Since the drop in the Cowlitz River smelt have been plentiful in the stream and gillnetting for them has been going on merrily. Many boxes of fish are being caught daily in this manner and the fishermen are getting good prices for them.

**Centralia Daily Chronicle, Wednesday, 12 February 1920, p. 8, col. 4**

Wait for Smelt

Kelso, Feb. 12—A few smelt have been caught in the Cowlitz River the past two years and fishermen are hopeful that a heavy run of the fish will soon appear in the stream. Smelt in large numbers were reported to be nearing the mouth of the Cowlitz just before the recent cold weather and fishermen think that they may soon be in the stream now that the ice is gone. Last year was the only one in the last three years that the smelt came into the Cowlitz, the main run going up the Lewis River in 1927 and 1928.

**Centralia Daily Chronicle, Friday, 25 January 1929, p. 2, col. 5-6**

Smelt Running

Longview, Jan. 25—The annual horde of smelt is coming up the Columbia River. The run is at present in the vicinity of Cathlamet, about 40 miles west of here, according to local fishermen. There is considerable conjecture here as to whether the shining silvery millions of little fish will journey up the Cowlitz or the Lewis rivers. The Cowlitz was the usual habitat until two years ago when they selected the Lewis, 30 miles further up stream. It was thought to be an "off year," which occurred once in about seven years previous. But last season the smelt passed by the Cowlitz and went up the Lewis again. Fishermen are scratching their heads and wondering which stream will be selected this year.

**Centralia Daily Chronicle, Saturday, 23 February 1929, p. 4, col. 4**

Smelt Overdue

Kelso, Feb. 23—The main run of Columbia River smelt into the Cowlitz or Lewis rivers is considerably past due and fishermen are waiting for the run to enter one of the streams. The run has gone up the Lewis River for the past two years. The fish have been caught by gillnetters in large quantities in the Columbia River near Rainier, Ore., recently. It is believed the cold spell and the low stage of water in the streams has held up the migration.

**Centralia Daily Chronicle, Tuesday, 5 March 1929, p. 8, col. 5**

Smelt Shipped

Kelso, March 5—Shipments of Columbia River smelt from Kelso have averaged 150 boxes a day during the past week, according to express company representatives. The fish are taken by gillnetters operating in the Columbia River, the run not having entered either the Cowlitz or Lewis rivers to date this year. Ordinarily the run enters one of the streams late in January or early in February and it has never been known to be as late as it has been this year.

**Centralia Daily Chronicle, Saturday, 8 March 1930, p. 4, col. 1**

Smelt Are Running—Stories of "smelt catches" are running rampant about town this week. The silvery fish entered the Cowlitz several days ago and are now reported to be working their way upstream between Ostrander and Castle Rock. A net on the end of a long pole, a little deftness in its use and one's smelt order is soon filled.

**Chehalis Bee Nugget, Friday, 21 March 1930, p. 5, col. 2**

Smelt at Toledo

For the past week the Cowlitz River bank has been crowded with people who are busy dipping smelt from the river.

**Centralia Daily Chronicle, Wednesday, 31 December 1930, p. 8, col. 3**

Smelt Are Running

Kelso, Dec. 31—A few Columbia River smelt, are being dipped from the Cowlitz River each night, but the run of fish this winter is lighter than the usual small midwinter run and the fish will be gone within a few days. The main run of smelt does not come into the Cowlitz until late in February ordinarily. Smelt are now selling at about 15 cents a pound.

**Centralia Daily Chronicle, Thursday, 29 January 1931, p. 4, col. 4**

Smelt Run Begins

Longview, Jan. 29—(AP)—The smelt run is on! Innumerable thousands of the little fish are wriggling their way up the Cowlitz River today after meandering for several weeks in the Columbia below here. Several score boxes were packed from last night's dipping by eager commercial fishermen and heavy shipments to outside points have begun. The fish sell locally at four pounds for 25 cents.

**Centralia Daily Chronicle, Saturday, 21 February 1931, p. 5, col. 3**

Smelt Still Run

Kelso, Feb. 21—Heavy rains the past few days, which brought the Cowlitz River up several feet, have not interfered with the run of smelt that came into the river early this month, and heavy catches of fish were made the past two days. A new run of fish came into the Cowlitz this week. The demand for the fish is holding firm and heavy shipments are going out by rail, truck and boat daily.

**Centralia Daily Chronicle, Thursday, 12 March 1931, p. 2, col. 2**

Smelt Still Run

Kelso, Mar. 12—Another heavy run of smelt came in the Cowlitz River Sunday. They are of fine quality and fishermen are catching great quantities of them. The markets are holding up well this year and heavy shipments continue by rail, mail and truck. Distribution of smelt by truck has been developing on a large scale, and trucks now carry the smelt to points as far distant as Idaho and northern California.

**Centralia Daily Chronicle, Tuesday, 22 December 1931, p. 3, col. 5**

First Smelt of Season Show Up

Kelso, Dec. 22—(AP)—Mother Nature presented Cowlitz County a Christmas present today when the first smelt of the season appeared in the Cowlitz River. Johnny Wannassay, veteran Indian smelt fisherman, dipped the first catch. It ran about 200 pounds. For several years Wannassay has beaten other fishermen to this honor.

This first run [of] smelt is small. In fishing parlance it is called the scout run and precedes a major or larger run. The smelt come into the Cowlitz in large schools between December and May. When smelt fishing is at its height approximately 200 men find employment in dipping, packing and processing the fish, which are shipped to all parts of the world in one form or another.

**Centralia Daily Chronicle, Wednesday, 6 January 1932, p. 8, col. 6**

Quality of Smelt Unusually Good

> Portland, Jan. 6—(AP)—"The smelt are running." This was the call today from many Columbia River and Cowlitz River points as hordes of the small fish piled up stream in silvery waves. Reports from the two streams said the run is one of the earliest large invasions on record, and it was taken by many to presage an early spring.
>
> Dealers here report the quality of the fish this year is unusually good. The present showing is regarded as rather spectacular and wholly unexpected. Many unemployed persons are working with dip nets on the two rivers. Fancy smelt are selling in Portland markets as low as three pounds for 25 cents.

**Centralia Daily Chronicle, Monday, 1 February 1932, p. 2, col. 8**

May Plant Smelt

> Kelso, Feb. 1—Another attempt will probably be made this year by the state fisheries department to transplant Columbia River smelt to streams flowing into Puget Sound. Attempts have been made in the past and a large number of smelt were planted in the Nisqually River several years ago. Floyd [Lloyd] Royal of the state biological department is making a study of the matter here, and it is probable that smelt spawn will be hatched in the state hatchery on the Kalama River and the young smelt planted in both the Snohomish and Skagit rivers if the attempt to hatch them proves successful. The smelt are believed to have a four-year cycle, returning to their native stream after four years, to spawn.

**Centralia Daily Chronicle, Monday, 4 April 1932, p. 4, col. 7**

Smelt Run Ends

> Kelso, April 4—(AP)—The annual smelt run in the Cowlitz River appears to be over and from other points comes word that catches in the Lewis River and in the Sandy River near Portland are also practically nil. Shipments from Kelso last Friday, when catches made before the closed period beginning Friday morning were sent to market, were very light and yesterday several fishing boats that went as far upstream as the regulations permit, found no smelt worth dipping in the Cowlitz River.

**Centralia Daily Chronicle, Wednesday, 4 January 1933, p. 6, col. 5**

Smelt Running

> Longview, Jan. 4—(AP)—The annual winter run of smelt, forerunner of a spring run to come a month or two later, is hovering in the mouth of the Cowlitz River this week. The run has been proceeding slowly up the Columbia River for

the past several weeks. Gillnetters in the Columbia are making most of the catches while a few commercial fishermen with dip nets are operating in the Cowlitz.

**Centralia Daily Chronicle, Monday, 7 April 1933, p. 3, col. 2**

Fish Notes—Smelt fishing in the Cowlitz River ended several days ago, but the seagulls remained to do their own fishing. Now, according to fishermen returning from the river, each day sees fewer gulls hovering over the water. This is taken as a sure indication that the smelt run is just about over.

**Centralia Daily Chronicle, Wednesday, 28 February 1934, p. 6, col. 2**

Smelt Season—Smelt are in the Cowlitz River but in "straggly" quantities, according to fishermen who have been after them with nets. Welfare people here received smelt yesterday that were collected at Castle Rock by fish inspectors, who took them from persons having in their possession more than the legal limit of 20 pounds. The Cowlitz is closed from 8 a. m. Friday to 8 p. m. Saturday to both individual and commercial fishermen.

**Centralia Daily Chronicle, Friday, 1 February 1935, p. 8, col. 2**

Shipping Smelt

Kelso, Feb. 1—The largest shipments of Columbia River smelt of the year have been made from here the past few days. Approximately 400 boxes, or more than 10 tons of the fish have been shipped daily by express to the more distant points and by truck to Portland and Puget Sound.

The heaviest shippers are the Columbia River Smelt Company and the Central Smelt Company. The latter is an organization of gill-net operators.

**Centralia Daily Chronicle, Thursday, 5 December 1935, p. 14, col. 3**

Smelt Running

Longview, Dec. 5—(AP)—The first smelt run of the 1935–36 season was reported off Clatskanie, in the lower Columbia River, today. A small shipment was made from that point to Portland markets yesterday, and two boxes were shipped from Kelso.

Smelt takes so far are males, indicating them to be the advance, or scout run. The female schools are due later.

# California

**Daily Evening Bulletin (San Francisco), Friday, 5 December 1879, p. 1, col. 1**

> Candle Fish of the Klamath—A very odd fish is found in large numbers in the Klamath, near its mouth. They are called candle fish. When grown, they are only six or eight inches long. They are very full of oil, which seems to be distributed all through their bodies. Dry them thoroughly and light either end and they will burn with as bright a light as a candle, and for about as long a time. Hence their name. They can be caught abundantly with seines. In their dry state they are quite pleasant to eat, the oil in them not having an odor or disagreeable flavor.

**San Francisco Call, Saturday, 2 May 1908, p. 12, col. 5**

> Redwood City, May 1—The local Izaak Waltons, who have been pressed for time, have been enjoying good fishing within the city limits. Redwood Creek, especially, near the works of the Alaska Codfish Company, is teeming with smelt, some of those recently caught running over a foot in length.

**San Jose Mercury Herald, Saturday, 15 February 1919, p. 5, col. 4**

Candle Fish Run Opens in the North

> Eureka, Cal., Feb. 14—The yearly run of candle fish has begun in the Klamath River and fishermen state that it exceeds in volume anything heretofore recorded. It is said that if any means could be found of canning this fish a new product of high food value could find its way to the market. The candle fish is particularly rich in valuable oils.

**Humboldt Standard (Eureka), Thursday, 21 February 1952, p. 9, col. 7–8**

Around Our Town, by Scoop Bean

> Scattered Notes—Candle fish are running in the Klamath River—they are caught at night with dip nets—the fish are said to have received their present name from early white settlers who sometimes inserted a wick in the smoked fish for a source of candlelight.

**Humboldt Standard (Eureka), Friday, 1 April 1955, p. 10, col. 3–5**

How're They Biting? by Chet Schwarzkopf

> … Jack Morris, maestro at Blue Creek Lodge on the Klamath, … says … "I guess you know we also have a big run of candlefish each spring that affords the people here lots of fun as well as good eating."

**Humboldt Standard (Eureka), Wednesday, 10 April 1963, p. 10, col. 3**

Heavy Candlefish Run in Klamath

> Klamath—Meat market sales showed a sharp decline around Klamath over the weekend and Monday. Almost everyone was eating crisp-fried candlefish. Awaited by the old-timers, as a heavy run of candlefish seems to herald a good salmon and steelhead fishing season to come, word spread fast, when the "run" started, a little late this year. Most popular "dipping" area was near the public boat ramp in the Klamath Glen area, perhaps due to easy accessibility.
>
> Owners of the large nets needed to dip for these small fish reported a "turn-over" practically every hour, as each one borrowing it returned the net within a very short time. A few dips netted each one their limit in pounds, and more than enough to feed their families.

**Humboldt Standard (Eureka), Monday, 15 April 1963, p. 13**

Thousands of Candlefish in Heavy Redwood Creek Run

> [Photo caption 1:] Joe January of Sacramento dips up a net load of candlefish at the mouth of Redwood Creek near Orick. Thousands of the silvery fish, called Columbia River smelt in most waters, are running in the creek and the Klamath River, heading upstream to spawn. According to local Fish and Game authorities, this is the first time candlefish have run up Redwood Creek in large numbers. Normally the fish are found only in the Klamath River and a few other northern rivers.
>
> [Photo caption 2:] Commercial fishermen net candlefish in the ocean at the mouth of Redwood Creek. Left to right are Fred Shipman, Stanley Dombek and Lawrence Lazio. Commercial catches must be made in salt water.
>
> [Photo caption 3:] A herd of sea lions enjoys a feast of candlefish as the silvery smelt run by the thousands at Redwood Creek. Fish derive their local name from the fact Indians dried them and used them for candles.
>
> [Photo caption 4:] Silvery candlefish measure five to six inches in length, with a few up to nine inches. Thousands of the small smelt are running up Redwood Creek and the Klamath River to spawn.
>
> [Photo caption 5:] Lawrence Lazio of Eureka demonstrates the density of the current candlefish runs by catching them with his hands. Many people lacking nets did just that and caught enough fish for a large fish fry.
>
> [Photo caption 6:] Fred Shipman, left, and Stanley Dombeck deliver a large commercial catch of candlefish to a local fish company. The smelt will be sent to the Bay Area and Los Angeles.

**Humboldt Standard (Eureka), Tuesday, 16 April 1963, p. 7**

Candlefish Running in Mad River

> [Photo captions:] Local fishermen use nets for an unusual run of silvery candlefish in the Mad River. In top photo, two unidentified men watch as Bill Damgaard, left, and Bob Hoffman, both of McKinleyville, wade into the water to net the fish. Mrs. Sarah Gillman, below, of McKinleyville, empties her net laden with candlefish into a bucket. Heavy runs of the fish, also known as Columbia River smelt, also are reported in Redwood Creek and the Klamath River.

**Humboldt Standard (Eureka), Tuesday, 23 April 1963, p. 20**

Surf Netters Catch Candlefish near Redwood Creek

> [Photo caption:] Countless candlefish are still running at Redwood Creek, this time in the Pacific surf. Scores of fishermen took advantage of Sunday's spring weather to enjoy the sport and prepare for a fish fry. The silvery fish, commonly called Columbia River smelt, derived their local name from the fact Indians used them as candles. The fish normally run only in the Klamath River and other northern streams but recently heavy runs have been reported in Redwood Creek and Mad River and now in the surf.

**Humboldt Standard (Eureka), Friday, 9April 1965, p. 13, col. 1**

Sideline Slants[column head], Candlefish Run Top Weekend Prospect, by Don Terbush

> The annual spawning run of candlefish is on in the Klamath River and the oily rascals are said to be numerous. Big runs are usually followed by large runs of salmon, according to veteran anglers along the river.
>
> Don't forget—a valid fishing license is required.

**Times-Standard (Eureka), Thursday, 14 March 1968, p. 19, col. 1**

Anglin' Around, by Ray Peart

> Candlefish at Klamath—It has started. The small fish called candlefish or eulachon are making their spawning run up the Klamath and should be found in Redwood Creek and Mad River soon.
>
> Eulachon normally die after spawning, but Marine Resources biologists tell me they have recovered a few spawned-out fish in the ocean while conducting shrimp sampling cruises.
>
> The eulachon (Thaleichthys pacificus) was first recorded from British Columbia waters in 1866 by A. Gunther on the basis of four specimens eight to nine inches in length, collected near Vancouver Island by C. B. Wood, surgeon on HMS Plumper, and presented to the British Museum. The fish is common along the whole coast of British Columbia, and enters large rivers during March, April

and May to spawn. It matures at two to three years of age and usually dies after spawning. The average female spawns 25,000 eggs which hatch in two to three weeks. The young are then carried by the current to the sea where they mature.

In the old days, eulachon were used extensively by Indians for food and production of oil for cooking. Previous to the advent of manufactured candles and other lighting devices, these fish were dried, fitted with wicks and used as candles, hence the frequently used name, candlefish.

Most people now smoke the fish, and some of the oil is worked out this way. They are very rich. Others pickle them. A gourmet treat is the roe from females mixed with salami and eggs, made into patties and fried.

Last year there was a huge run of candlefish in Redwood Creek. For eight days, these small dry-feeling fish swam up past Orick in a continuous school from bank to bank. That was around the first week in April.

It's fun to net these fish. Take the family for a day at the beach. The limit is 25 pounds and you do need a license. Check the 1968 Sport Fishing Regulations for new rules concerning netting candlefish in Redwood Creek and Mad River.

**Times-Standard (Eureka), Wednesday, 16 April 1969, p. 21, col. 5**

Candlefish Run Again in Klamath

Klamath—Large catches of candlefish have been taken from the Klamath River this past week, and were still running heavily Sunday evening.

Quite a number of fish are brought up each dip of the large nets used. The heavy run is late this year, as usually the month of March is the time of most of the run. A number of the local people smoke large quantities of the fish, as well as those who enjoy them just fried very crisp.

Candlefish are similar to the Columbia River smelt. A heavy concentration of seagulls and large groups of sea lions accompany the run. Several days last week, the sand spit at the mouth of the river was covered with the sea lions, as they sunned themselves, after dining on the fish, no doubt.

**Times-Standard (Eureka), Friday, 19 March 1971, p. 11, col. 1**

Sideline Slants [column head], Candlefish Running, by Steve Terbush

"Candlefish are running at the mouth of the Klamath River," was Bill Dimmick's comment from Orick. "I've seen a lot of nets heading that way."

**Times-Standard (Eureka), Friday, 5 May 1972, p. 19, col. 1**

Sideline Slants, by Steve Terbush

Mrs. Paul observes from Klamath that "this has been a wonderful candlefish year and that usually means a good salmon year on the Klamath River."

**Times-Standard (Eureka), Friday, 16 April 1976, p. 13, col. 1**

Sideline Slants, by Steve Terbush

> Humboldt County Fish hatchery chief Steve Sanders … noted that "they are still picking up candlefish at Redwood Creek. The catches are light although some limits are being taken."

**Times-Standard (Eureka), Friday, 23 April 1976, p. 9, col. 1**

Sideline Slants, by Steve Terbush

> Candlefish in the Klamath, Redwood Creek and Mad River … are the major items of interest to North coast sports anglers this weekend.
>
> "There are lots of candlefish in the Mad River," reports hatchery superintendent Bob Will. "Last weekend it was hot. They are higher up than I've ever seen them—clear up to Blue Lake which is unusual. Of course, the fishing area is only open to the railroad bridge at Essex.
>
> "About every third year there are always a few," Bob added. "This year it seems there is an extraordinary amount."
>
> "They are still picking up candlefish in Redwood Creek, said Humboldt County Fish Hatchery chief Steve Sanders. "And I would recommend Stone Lagoon for fishing. There's not much pressure and I'm sure there are fish in there. If they (anglers) have a boat all the better."

# Appendix C: Selected Accounts of Eulachon in Early Historical References

*[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling and phrasing in these older works are generally preserved.]*

# Klamath River

**Autobiography of Clarence E. Pearsall (Pearsall 1928, p. 1614)**

Early 1890s

> At other times, with a single haul of their dip nets they [the Yurok fishers] caught fifteen or twenty pounds of quah-rah [candlefish], a small fish that when thoroughly dried burns like a candle.

# Columbia River

**Journal of Patrick Gass [Sergeant on the Lewis and Clark Expedition] (Gass 1807, p. 194–197 in Moulton's 1996 reprint edition)**

25 February 1806 (Fort Clatsop)

> Tuesday 25. The rain continued and the weather was stormy. About 10 o'clock the Natives went away, though it continued to rain very fast. They brought us yesterday a number of small fish [eulachon], of a very excellent kind, resembling a herring, and about half the size.

26 February 1806 (Fort Clatsop)

> Wednesday 26. We had a fair morning; some of the hunters went out, as our store of provisions was getting small, and three men went in search of these small fish, which we had found very good eating.

2 March 1806 (Fort Clatsop)

> Sunday 2. This day was also wet. The fishing party returned at night, and brought with them some thousands of the same kind of small fish, we got from the Natives a few days ago, and also some sturgeons.

6 March 1806 (Fort Clatsop)

> Thursday 6. Our stock of provisions being nearly exhausted, six men were sent out in different directions to hunt, and three more were sent to endeavor to procure some fish, as the Natives take a great number of the small fish about 20 miles distant from the fort by water.

9 March 1806 (Fort Clatsop)

> In the afternoon some of the Natives came to visit us, and brought some of the small fish, which they call ulken.

11 March 1806 (Fort Clatsop)

At noon our fishermen returned with some ulken and sturgeon.

**The Definitive Journals of Lewis and Clark, Down the Columbia to Fort Clatsop (Moulton 1990)**

24 February 1806 (p. 342–344)

> This evening we were visited by Comowooll the Clatsop Chief and 12 men women & children of his nation. … The chief and his party had brought for sail … a species of small fish which now begin to run, and are taken in great quantities in the Columbia R. about 40 miles above us by means of skiming or scooping nets. On this page I have drawn the likeness of them as large as life; it is as perfect as I can make it with my pen and will serve to give a general idea of the fish. The rays of the fins are boney but not sharp tho' somewhat pointed. The small fin on the back next to the tail has no rays of bone being a thin membranous pellicle. The fins next to the gills have eleven rays each. Those of the abdomen have eight each, those of the pinna-ani [anal fin] are 20 and 2 half formed in front. That of the back has eleven rays. All the fins are of a white colour. The back is of a bluish duskey colour and that of the lower part of the sides and belley is of a silvery white. No spots on any part. The first bone of the gills next behind the eye is of a bluis cast, and the second of a light goald colour nearly white. The puple of the eye is black and the iris of a silver white. The underjaw exceeds the upper; and the mouth opens to great extent, folding like that of the herring. It has no teeth. The abdomen is obtuse and smooth; in this differing from the herring, shad anchovey &c of the Malacopterygious Order & Class Clupea, to which however I think it more nearly allyed than to any other, altho' it has not their accute and serrate abdomen and the underjaw exceeding the upper. The scales of this little fish are so small and thin that without minute inspection you would suppose they had none. They are filled with roes of a pure white colour and have scarcely any perceptable alimentary duct. I find them best when cooked in Indian stile, which is by roasting a number of them together on a wooden spit without any previous preparation whatever. They are so fat they require no additional sauce, and I think them superior to any fish I ever tasted, even more delicate and lussious than the white fish of the lakes which have heretofore formed my standart of excellence among the fishes. I have heard the fresh anchovey much extolled but I hope I shall be pardoned for believing this quite as good. The bones are so soft and fine that they form no obstruction in eating this fish. We purchased all the articles which these people brought us …. The sturgeon which they brought us was also good of it's kind. We determine to send a party up the river to procure some of those fish.

2 March 1806 (p. 368)

> … late this evening Drewyer arrived with a most acceptable supply of fat sturgeon, fresh anchovies [eulachon] and a bag containing about a bushel of wappetoe. We feasted on anchovies and wappetoe.

4 March 1806 (p. 378)

> The anchovey [eulachon] is so delicate that they soon become tainted unless pickled or smoked. The Natives run a small stick through their gills and hang them in the smoke of their lodges, or kindle a small fire under them for the purpose of drying them. They need no previous preparation of guting &c and will cure in 24 hours.

**The Definitive Journals of Lewis and Clark, From the Pacific to the Rockies (Moulton 1991)**

16 [March 1806] (p. 44)

> The anchovey [eulachon] had ceased to run; the white salmon trout [steelhead] have succeeded them.

25 March 1806 (p. 12)

> ... at noon we halted and dined. Here some Clatsops came to us in a canoe loaded with dryed anchovies [eulachon], which they call olthen [Chinookan ú-lxan, meaning dried eulachon], wappetoe and sturgeon.

29 March 1806 (Sauvies Island) (p. 27)

> They had large quantities of dryed anchovies [eulachon] strung on small sticks by the gills and others which had been first dryed in this manner were now arranged in large sheets with strings of bark and hung suspended by poles in the roofs of their houses.

**The Journals of John Ordway [Member of the Lewis and Clark Expedition] May 14, 1804–September 23, 1906, (Moulton 1995, p. 275–278)**

2 March 1806 (Fort Clatsop)

> … in the evening the three men returned from the village with a considerable quantity of the little fish [eulachon] resembling herren [sic] only a size smaller—and some sturgeon and a few wapatoes, which they purchased from them. The Natives catch a vast quantity of fish.

9 March 1806 (Fort Clatsop)

> Several of the Clatsop Indians came to the fort with some small fish [eulachon] … to trade to us.

11 March 1806 (Fort Clatsop)

> Sergt. Pryor returned with a considerable quantity of small fish and sturgeon.

21 March 1806 (Fort Clatsop)

> … a number of Natives visited us with some dryed small fish to trade which they call in their language oll-can [dried eulachon].

**The Journals of Joseph Whitehouse [Sergeant on the Lewis and Clark Expedition], May 14, 1804–April 2, 1806 (Moulton 1997, p. 423–430)**

26 February 1806 (Fort Clatsop)

> … 2 of our men went in a canoe in order to go to the Clatsop & Cathlameht Village in order to purchase some fish from the Natives. We found the fish that we had purchased from them 2 days past, to be well tasted & fat, especially the small fish [eulachon], which had the resemblance of a herring but much better tasted.

2 March 1806 (Fort Clatsop)

> In the evening, three of our men returned who had been trading at the Clatsop Village. They brought with them a considerable quantity of those small kind of fish, which we purchased from the Natives some days past; these fish were a size smaller than the herring. … The Natives gave them some fish without any recompence being made to them. These Indians catch great quantities of different kinds of fish in a creek lying a small distance above their village.

5 March 1806 (Fort Clatsop)

> … a number of the Natives came in canoes to the fort. They brought with them some sturgeon & some small fish [eulachon] to trade with us. Our officers purchased the whole of them.

17 March 1806 (Fort Clatsop)

> … purchased from the Natives … a few small fish [eulachon], the small fish not unlike a herring getting scarce among the Natives.

21 March 1806 (Fort Clatsop)

> The Natives came to the fort & brought some dried fish, which the Indians called all-can [dried eulachon], we purchased some of these fish from them.

**The Discovery of the Oregon Trail: Robert Stuart's Narratives of his Overland Trip Eastward from Astoria in 1812–13 (Rollins 1995)**

1812 (p. 8)

> … the dreary months of January and February, after which sturgeon and uth-le-chan [eulachon] may be taken in great numbers, the former sometimes by the spear, but more generally by the hook and line; and the latter by the scoop net. The uthlechan is about six inches long and somewhat similar to our smelt, is a very delicious little fish, and so fat as to burn like a candle, and are often used for that purpose by the Natives.

1 July 1812 (p. 30)

> Here are the best and almost only fisheries of uthulhuns [eulachon] and sturgeon—the former they take in immense numbers by the operation of the scoop net from the middle of March till the middle of April, and the latter [principally] by the hook and line during the spring and fall seasons—the uthulhuns are a kind of smelt, and when dried for preservation, are much similar to smoked herrings.

**Wilson Price Hunt's Diary of his Overland Trip Westward to Astoria in 1811–12 (Rollins 1995, p. 308)**

15 February 1812

> On the 15th, we passed several large islands. The land on the left bank was covered with oaks and ash trees, but all was inundated. I stopped at some Indian huts where I found four of our fellow countrymen who were bartering for sturgeon and were fishing for excellent small fish, which were about six inches long. The Indians call them othlecan [eulachon], and catch many of them in the springtime.

**A Voyage to the Northwest Coast of America (Franchère 1968, p. 180)**

> February brings a small fish about the size of a sardine. It has an exquisite flavor and is taken in immense quantities by means of a scoop net which the Indians, seated in canoes, plunge into the schools: but the season is short, not even lasting two weeks.

**Adventure at Astoria, 1810–1814 (Franchère 1967, p. 108)**

> February brings a little fish, somewhat longer and broader than the sardine, that we took at first to be a smelt [eulachon]. It has a delicate flavor and is abundant, but the season for catching it lasts only a short time.

**The Journal of Gabriel Franchère, 1811–1814 (Franchère 1969, p. 110–111)**

> At the beginning of February [1812] the Indians brought us large quantities of a small fish [eulachon] six or seven inches long, which we found excellent. …
>
> The Natives continued to supply us with small fish until the 20th, when the season was over. This fish, which is very abundant, is caught by means of a scoop or rake, which is simply a long pole to one end of which they have fastened sharply pointed pegs; by pulling it back and forth through the water they catch the fish on the pegs and soon have a canoe full. The women dry these fish, which furnish their principal food supply during the months of April, May, and June, threading them when dry in a double row on cords which are six feet long. They even trade in them with the Natives of the upper river, for these fish are not caught further up than the territory of the Chreluits [Chinook Indians], about 15 leagues from the mouth of the Columbia.

**The Journal of Alexander Henry the Younger 1799–1814 (Gough 1992)**

6 January 1814 (p. 635)

> This evening a canoe arrived from above which brought us four large sturgeon and a few smelt [eulachon]. These are the first of these small fish we have seen here this season. They generally make their appearance here in February, but the gentlemen who arrived today from above tell us the Indians take them at present in great abundance about the entrance of the Willamette River.

7 January 1814 (p. 637)

> The great smoke which now rises from the three Chinook villages denotes the return of these people to their winter quarters, which is usually at this period. They will contrive to augment in numbers daily, as the smelt [eulachon] fishing is approaching fast and then the sturgeon fishing follows, and, as the spring draws near, the salmon fishing approaches, the Natives from the northward will also bend their course here also.

11 January 1814 (p. 642)

> Passed Mount Coffin on the north side. … We saw … many of the Natives fishing smelt [eulachon] with a scoop net along the shores.

27 January 1814 (p. 665)

> The insides of these Indians houses are crowded with smelt [eulachon] drying, suspended by the heads to poles, the roofs are lined everywhere excepting the fire place is full, all hanging tail downwards. Several canoes were also full laying off at anchor. ... We passed several fishing parties, tented on the beach, who had … canoes loaded with smelt. …. At 9 o'clock we passed Mount Coffin, and at 11 o'clock we passed Oak Point. We saw several sea lions. … The number of gulls

and other birds that feed on fish are surprisingly numerous here at present, much more so than last fall. The cause I presume is they are attracted by the numerous shoals of smelt which are going up the river at this season of the year. Seals are very numerous also.

8 February 1814 (between Mount Coffin and Oak Point on the Columbia River, p. 676)

We observed on the beach and floating on the surface of the water great numbers of smelt [eulachon] dead and dying, the same fate which attends the salmon, and seems to attack the small fish in the river. They all die apparently for want of food, there being not the least particle of any substance in their gut, which consists of only one very small green filament. Gulls, shell drakes, and other waterfowl that feed on fish are uncommonly numerous, also eagles both baldhead and grey. Herons are very common along the shore and perched on the trees.

26 February 1814 (Fort George, aka FortAstoria, p. 683)

Two Indian canoes came over, on their way up to catch sturgeon and smelt [eulachon]. I saw a kind of pole about 10 feet long and 2 inches broad, one side was fixed a range of small bones, about a ¼ of an inch asunder, and about one inch in length, and very sharp; the range of teeth extending about six feet up the blade, this I understand is used in the smelt fisheries.

6 March 1814 (Fort George, aka Fort Astoria, p. 695)

Several canoes deeply loaded with smelt [eulachon] and sturgeon arrived from above and proceeded to the Calpoh's Village, having sold some of the smelt to us and passed on.

19 March 1814 (Fort George, aka Fort Astoria, p. 701)

The sturgeon continue to be plenty, and the smelt [eulachon] few; they do not all die as soon as I had imagined when I was last above in the beginning of February, as Mr McKay tells me they are now in the same state as they were then, a few found dead along the beach, and others dead and dying in the water.

3 April 1814 (p. 708)

We now have sufficient of their dried smelt [eulachon] which has been purchased mostly from the Chinooks and Clatsop, who buy the fish above themselves, and before it is brought down and strung up to dry it is spoiled. The dried smelt from above is much better by being dried on the spot. I now desired them to be traded at 1 fathom of small blue Canton beads for 5 fathoms of smelt. Yesterday we had traded at 4 fathoms.

**Adventures of the First Settlers on the Oregon or Columbia River &c (Ross 1849, p. 94–95)**

> There is a small fish resembling the smelt or herring, known by the name of ulichan, which enters the [Columbia] river in immense shoals, in the spring of the year. The ulichans are generally an article of trade with the distant tribes, as they are caught only at the entrance of large rivers. To prepare them for a distant market, they are laid side to side, head and tail alternately, and then a thread run through both extremities links them together, in which state they are dried, smoked, and sold by the fathom, hence they have obtained the name of fathom-fish.

**Trading Beyond the Mountains: The British Fur Trade on the Pacific, 1793–1843 (Mackie 1997, p. 30)**

> In April 1821, James Keith of Fort George [at Astoria, Oregon] wrote to his supplier, Perkins and Company, about the difficulties of obtaining a provision supply in this extremely remote region. Keith was dependent on the Chinook people of the lower Columbia for salmon, sturgeon, and wildfowl. "The winter has been unusually severe both as to the degree of cold & quality & duration of the snow," he wrote. "The fishery of the smelt [eulachon] being lately over, the Natives begin to bring us a chance sturgeon & wild fowl, which when more abundant will be gratifying to people from a long sea voyage…."

***Salmo* (*Mallotus*?) *pacificus* (Richardson) North-west Capelin (Richardson 1836, p. 226–227)**

> The Indian name of this fish is oulachan. It comes annually in immense shoals into the Columbia about the 23rd of February, but ascends no higher than the Katpootl [Lewis River], a tributary which joins it about 60 miles from its mouth. It keeps close to the bottom of the stream in the day, and is caught only in the night. The instrument used in its capture by the Natives is a long stick armed with sharp points, which is plunged into the midst of the shoal, and several are generally transfixed by each stroke. It is the favourite food of the sturgeon, which enters the river at the same time, and never has a better flavour than when it preys on this fish. The oulachan spawns in the different small streams which fall into the lower part of the Columbia. It is much prized as an article of food by the Natives and arrives opportunely in the interval between the expenditure of their winter stock of dry salmon and the first appearance of the quinnat [Chinook salmon] in May.

**Report on the Fishes Collected on the Survey (Suckley 1860, p. 348–349)**

> They [eulachon] formerly entered the Columbia River in great numbers, and were equally abundant in Puget Sound. At present, although sparingly found in the waters named, they cannot be considered as occurring in large numbers south or east of the southern end of Vancouver's Island. In the latter locality they are very abundant in certain seasons, but nearly always a season of abundance is followed

by three or four years of scarcity. Further northward they are constantly abundant. The Haida, Stickene, and Chumtseyan Indians, living along the coasts of British and Russian America, bring vast quantities of these fish with them when visiting the white settlements on Puget Sound. The fish thus brought are for the consumption of the strangers during their stay, and have been simply dried, without salt, and for convenience in drying or transportation have been strung on sharp, pliable sticks which are passed through the heads.

In July 1856, Dr. William Fraser Tolmie, chief factor of the Hon. Hudson Bay Company, a gentleman well known to naturalists for his interest in science, presented me with a bunch of dried eulachon, which he had obtained from some of the "Northern" Indians. Dr. Tolmie also gave me the following memoranda: "These fish were caught at the mouth of Nass River, which empties into salt water near latitude 54°40′ north. The Indian name of the species is almost unspellable. Formerly they were quite abundant between the 46th and 49th parallels of north latitude. They are now but seldom caught south of latitude 50° north in any great number. North of that point they are still taken by the savages in vast quantities, and are smoked and dried for trade and home consumption. When eaten after being thus prepared they should be either steamed or broiled."

**The Naturalist in Vancouver Island and British Columbia, Vol. 1 (Lord 1866, p. 96)**

Some 50 years ago, vast shoals of eulachon used regularly to enter the Columbia; but the silent stroke of the Indian paddle has now given place to the splashing wheels of great steamers, and the Indian and the candle-fish have vanished together. From the same causes the eulachon has also disappeared from Puget's Sound, and is now seldom caught south of latitude 50°N.

**The Dominion at the West: A Brief Description of the Province of British Columbia, its Climate and Resources (Anderson 1872, p. 30–32)**

A very valuable fish entering Fraser River to spawn in early spring, is the *Thaleichthys* (or preferably *Osmerus*) *Richardsonii*—locally known as the oolâhan.* It appears in immense shoals, and is caught either with the scoop net, or, like the herring on the seaboard, with the rake. This simple device is merely a long light pole, flattened in one direction so as to pass readily through the water, and with the edge set towards the lower extremity with a row of sharply pointed teeth. The fisherman, entering the shoal, passes the implement repeatedly through the water, with a rapid stroke, each time transfixing several fish. Thus a copious supply is soon secured. The oolâhan is, in the estimation of most people, one of the most delicious products of the sea. Smaller than the herring, it is of a far more delicate flavor; and so rich that, when dried, it is inflammable.† This fish is not confined to Fraser River, but frequents likewise the Nass, a large stream issuing on the frontier between British Columbia and Alaska; another stream debouching into Gardner's Canal; and probably other rivers along the coast. Those caught at the mouth of the Nass are of a qua1ity even richer than those of Fraser River. The Natives, who assemble there in great numbers in spring to prosecute the fishery, besides drying them in large quantities, extract from the surplus a fine oil, which is highly prized by them as a luxury, and forms a staple article of barter with the interior tribes.

* I was long under the impression that this fish was a variety of Pilchard (*Clupanodon thrissa*) peculiar to the Pacific; and am indebted to Dr. Robert Brown, of Edinburgh, formerly in command of the Vancouver Island Exploring Expedition, for the correction adopted above.

† So much so, indeed, that, in Alaska, where it is likewise found, it is I believe called the "candle-fish." It is mentioned by Franchère, in his account of the Columbia River, under the name of outhelekane, from which its present designation is modified; and, from the circumstance of its being strung on cords by the Natives to dry, was called by the voyageurs poisson à la brasse, or fathom-fish. They were formerly very abundant in spring on the lower Columbia; but suddenly, about the year 1835, they ceased to appear, and thence forward up at least to 1858, none frequented the river. I have been informed, however, that they have since reappeared, and that there is now a regular supply as formerly.

**Reminiscences of Cowlitz County (Huntington 1963, p. 5)**

Not within the memory of the oldest white inhabitant had there been any smelt in the Cowlitz River until some time in the early sixties. I am not certain what year I first saw them, but there was a heavy run and nobody paid much attention to them—not even the Indians. The Indians and white people at times caught a few with a stick with a sharp nail in it. After the second or third year of their return, people began to sit up and take notice. In 1865, a young lady school teacher, Miss Baker (afterward my wife), having learned how to make hair nets, conceived the idea of making dip nets in which to catch them and soon everybody had nets and were catching them by the ton and shipping them to Portland. The Indians had a tradition that there had been smelt here many many years before, but to punish them for some offense the Sahely Tyee had taken them away and it must have been a good many years as the oldest of them did not seem to know much about tradition.

**Narrative of the Overland Journey to Oregon (Crawford 1878, unpublished manuscript, p. 369)**

Events of 1865
Appearance of Smelts on Cowlitz

In Feby and March 1865, there appeared a strange little fish unknown to the early settlers of Cowlitz or lower Columbia River. Although the Indians declared that those little finny swarming beings of the deep had frequented the waters of the Cowlitz River before but had absented themselves for 17 years, during which period no Indian had seen a school. They always go along in close trains from one foot wide to two or three feet wide, falling in close concert. The early settlers on the lower Cowlitz remember having a few such little fellows in small numbers.

**Report of the Inspector of Fisheries for British Columbia for the Year of 1876 (Anderson 1877, p. 345)**

> The oolá-han, called also in Alaska, the candle-fish, (*Thale-chthys* or *Osmerus Richardson*) although it may occur low down in the list of marine and anadromous fishes which I undertake at present only partially to furnish, is not therefore to be regarded as in my estimation the least important. I again venture to refer to certain notes which I have already made public; and I now repeat my increased conviction that the value of this fish for diverse economical purposes has not yet been fully understood. Formerly resorting in enormous shoals to the estuary of the Columbia River, it disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently, when it suddenly reappeared in shoals as numerous as of yore. In Fraser River these fish are found, and resort thither regularly in heavy shoals; but little advantage is taken of their advent, beyond what are caught and consumed as a luxurious adjunct to the table while fresh, and a few casks hastily salted for sale and consumption at home, chiefly in fulfilment of private orders. At the Squawmish River, discharging at the head of Howe Sound, I found, on enquiry, that these fish enter the river, as elsewhere, early in the spring, and ascend as high as the head or the Island of Stââ-mis, forming the delta; thence, after spawning, returning to the sea. Several other rivers along the coast are known to be frequented by these fish; and there are doubtless others of which we are not, so far, cognizant. The Nass River, however, discharging into Observatory Inlet, close to the Alaskan boundary, stands preeminent as an oolá-han fishery, as well for the enormous supply it yields, as for the superior quality of its fish.

**Astoria, or, Anecdotes of an Enterprise beyond the Rocky Mountains (Irving 1868, p. 404)**

> About the beginning of February, a small kind of fish, about six inches long, called by the Natives the uthlecan, and resembling the smelt, made its appearance at the mouth of the river. It is said to be of delicious flavor, and so fat as to burn like a candle, for which it is often used by the Natives. It enters the river in immense shoals, like solid columns, often extending to the depth of five or more feet, and is scooped up by the Natives with small nets at the end of poles. In this way they will soon fill a canoe, or form a great heap upon the riverbanks. These fish constitute a principal article of their food; the women drying them and stringing them on cords. As the uthlecan is only found in the lower part of the river, the arrival of it soon brought back the Natives to the coast; who again resorted to the factory to trade, and from that time furnished plentiful supplies of fish.

**The Eulachon or Candle-fish of the Northwest Coast (Swan 1881, p. 258)**

> The eulachon are found in limited numbers at certain seasons in the Columbia River, Shoalwater Bay [Willapa Bay], Gray's Harbor, and at the mouth of the various small streams of the coast, and also in the waters of Puget Sound, where they are taken in seines and nets with smelt and other varieties of small fish, but

they are thin and poor, and not to be compared to the same varieties further north. Even those taken in Fraser's River near the boundary line between Washington Territory and British Columbia are superior to those taken further south, and are sold in the Victoria market, where their excellence is highly prized. The few secured on Puget Sound are sold by the fishermen as smelts. The best kinds are caught further north, and great quantities are salted by the Hudson's Bay Company, at their trading post at Fort Simpson, British Columbia, and either sold in the Victoria market or shipped direct to London in tierces, barrels, and kits.

As an article of food and for the grease or fat contained in them, the eulachon are highly prized by the Indians of northern British Columbia and southern Alaska, where they abound; particularly at the Nass River, British Columbia, where they are annually taken in enormous quantities, and where they seem to attain their very finest condition.

# Fraser River, British Columbia

### The Fort Langley [a Hudson's Bay Company post on the lower Fraser] Journals, 1827–1830 (MacLachlan 1998)

28 April 1828 (p. 60)

> The little fishes which the Chinooks call ullachun [eulachon] begin to make their appearance here, and are joyfully hailed by the Indians of the river.

29 April 1828 (p. 60)

> We made a trial to take some of the little fish Chinook fashion [with the rake], and proved very successful as enough were taken to give a prog [?] to all hands.

14 April 1829 (p. 109)

> The small fish in the Columbia called ulluchans [eulachons] is also within the river, but not yet this high.

4 May 1830 (p. 147)

> The small fish called ulachans [eulachons] are arrived.

# Other British Columbia Waters

### The Economic Fishes of British Columbia (Green 1891, p. 30)

> The oolachan (*Thaleichthys pacificus*), an anadromous fish of about 9 inches in length, makes its appearance in the tidal waters of the Fraser about the middle of April, and in the Nass about the 23rd of March. When fresh is a delicious little fish, but it deteriorates with carriage, and is never seen to perfection in the

Victoria market. Numbers of oolachans are put up in pickle in small kits, and some are cured and smoked like bloaters.

Oolachan grease is an article much used and appreciated by the Indians. A large trade is done in this commodity between the Indians of the Nass River and those of the interior, in exchange for furs. In appearance and consistency it resembles lard, and is used on dried salmon or halibut, much in the same manner as we use butter on bread. A short account of its manufacture on the northern rivers may be of interest to you. As I before stated the oolachans arrive in March when the ice is still on the river. All the Indians who have any right to fish in the river, and this priviledge is jealously guarded, come from far and near to the fishery, and erect temporary dwellings along the banks or on the ice. The firewood for drying out the oil has to be brought from a distance, all that in the immediate vicinity of the fishery having been used long ago. The fish are taken under the ice with purse nets, and are left in heaps until they are, to say the least of it, high; partial decomposition assisting the extraction of the oil. They are then boiled in troughs which are about 5 feet long by 2 feet wide, and the fat is skimmed off, and put into square cedar boxes about the size and shape of a coal oil tin. Originally the grease was extracted by filling a wooden trough with water, and heating it with red-hot stones; this mode is now obsolete, the troughs having a sheet iron bottom built over a long and narrow furnace.

The oolachan has more than its fair share of enemies; sturgeon, salmon and porpoises follow it into the rivers, while bears and the settler's pigs gorge themselves with the exhausted shotten [sic] fish. At Port Hammond I once saw two pigs standing up to their backs in the water, and diving for oolachans; they seldom failed to bring one up.

### Vancouver Island and British Columbia: Their History, Resources, and Prospects (MacFie 1865, p. 163–165)

Hoolakans ascend the streams in April in dense shoals. Their approach is indicated by the presence of seagulls swooping down to devour them, and causing the banks of the river to echo with their screeching. This species are about the size of a small herring, and are so fat as to baffle ordinary methods of cooking to prepare them for the table. Oil is pressed from them by the Indians on the coast, and disposed of to tribes in the interior. …

When dried, the hoolakan is often used by the Natives as a torch, and, when lighted, it emits a brilliant light. The Indians catch this species of fish by impaling them on rows of nails at the end of a stick, about four feet long, and so thickly do they swarm, that every time this rude implement is waved in the water, two or three of them adhere to it.

### The Coast Indians of Southern Alaska and Northern British Columbia (Niblack 1890, p. 276 and p. 299)

Eulachon (*Thaleichthys pacificus*), the so-called "candle-fish," a kind of smelt, run in March and April at the mouth of the Skeena, Nass, and Stikeen rivers.

These have the greatest proportion of fatty matter known in any fish. In frying they melt almost completely into oil, and need only the insertion of some kind of a wick to serve as a candle. …

Eulachon or “candle-fish” run only in the mouths of rivers, particularly the Skeena, Nass, and Stikine in this region. They are considered great delicacies, and are dried and traded up and down the coast by the Indians who are fortunate enough to control the season’s catch.

# Appendix D: Selected Accounts of Eulachon in an Early Periodical

*[Editor's note: Minimal silent correction has been applied to these excerpts, such as changing the initial letter of a word to a capital or lowercase letter, correcting minor misspellings without inserting a comment or the word sic in brackets, or minor modification of punctuation. Idiosyncrasies of spelling are generally preserved.]*

**Pacific Fisherman, March 1905, vol. 3(3), p. 19**

Big Catch of Smelt

C. R. Gatchet, a Portland fish dealer, reports that 150 tons of smelt were taken from the Cowlitz River between February 1 and 7. All were caught between Kelso and the mouth of the river. Mr. Gatchet kept a close account of the output. Allowing five smelt to the pound, the catch represents 1,500,000 fish. At the market price of five cents a pound they are worth $15,000.

**Pacific Fisherman, April 1905, vol. 3(4), p. 11**

Kelso Smelt Industry

Kelso, in Cowlitz County, Washington, with 1,200 population, is the center of the smelt industry. No other point visited by the myriad schools of fish can rival it. The season lasts several months, that just closed having commenced November 19, and ended March 15. During this period Kelso records show that 400 tons of smelt were sent from there to the world. This tonnage represents 16,000 boxes of smelt, each box weighing 50 pounds.

The fact that you can dip smelt from the Cowlitz River with a pitch fork, drive a wagon into the stream and load the bed in a short time, or annually ship to the hungry world 400 tons of this diminutive fish is a matter of pride at Kelso, for this community takes first honors in the smelt industry.

Catching smelt on the Cowlitz is an interesting process. The fleet of small boats stand out in the stream, one man to each craft, armed with dip net having a 15-foot handle. The ring at the end of the pole has a spread of 18 inches, while the net behind it is of sufficient capacity to carry many pounds of fish. The schools of fish, which surge up the river, are soon located, when the fishermen commence dipping down stream. Each stroke is richly rewarded, for, after a school is located, there are few water hauls. Lee Galloway, one of the best fishermen of the stream, has last season's record, catching 96 boxes in one night, each box weighing 50 pounds. This record means that with one of these poles he lifted from the stream 4,800 pounds of fish, or about two and a half tons.
—Charles R. Gatchet

**Pacific Fisherman, April 1906, vol. 4(4), p. 16**

Smelt Cease Running—The run of smelt on the Cowlitz River has ceased after a very successful season. The season's catch was the largest ever taken from the Cowlitz River. Over 700 tons were shipped, the amount being double that handled last year.

**Pacific Fisherman, April 1907, vol. 5(4), p. 8**

Kelso's Important Smelt Fishing Industry, by G. E. Kellogg

There are places, hundreds of them, which are noted for the production of some staple or marketable article, and of all the thus noted towns in Western Washington, Kelso has the distinction of being the best known on account of the smelt industry.

The little fish which tickles the palates of thousands of people each winter are the mainstay of the fishing people of this vicinity and not only put thousands of dollars in their pockets each year, but they add a great deal to the prosperity of Kelso and vicinity.

The smelt are a peculiar fish. Hatched in the headwaters of the Cowlitz or Sandy they return to the open sea in the spring. Returning in the fall and winter they unfailingly enter the Cowlitz, seeking the old spawning grounds beyond the reach of fishermen's nets. They travel in schools, or rather strings, the first run arriving at or near Kelso about the Holidays. The run of fish is most uncertain. Sometimes they last until the middle of March and sometimes they stop short in January.

So far this season there have been upwards of 3,000 boxes shipped from Kelso, a total of 37,350 pounds, going by express in the month of January alone. Carload shipments have been made in years when smelt were plentiful and cheap, but lately the demand has kept up so steadily that the fish are shipped almost as fast as they can be taken from the water.

Smelt have always been so plentiful that they never needed protection by law other than licensing fishermen, and there has never been any thought or fear of their extinction entertained by anyone who knew their habits.

Thus we have an industry which might be called perpetual, as there is no doubt of its continuance for many years to come.

We are enabled to produce the accompanying engravings showing smelt fishing scenes in the vicinity of Kelso by the courtesy of the Kelso Journal.

**Pacific Fisherman, April 1907, vol. 5(4)**

Smelt in the upper Columbia River—For the first time in many years smelt are running up the Columbia River above Kalama. Large schools have been passing Vancouver, Wash., and fishermen have reaped a rich harvest. The few smelt which have hitherto gone further up the river have been of poor quality, but these have been of the best. Just what turned the smelt aside from their favorite haunts up past Kelso has not yet been determined.

**Pacific Fisherman, January 1910, vol. 8(1), p. 19**

Columbia River

> … Smelt have arrived in the river for the first time this winter and are being caught in the vicinity of Kathlamet. They are a luxury on the breakfast table as the fishermen are wholesaling them at 25 cents per pound, but at the same time their flesh is so firm and high flavored that they are well worth the price for an epicure.

**Pacific Fisherman, March 1910, vol. 8(3), p. 14**

Columbia River

> The largest run of smelt for years in the Cowlitz River is now in progress. The river has never been known to contain so many smelt in the memory of the oldest fishermen. This may bode good for the coming fishing season in the Columbia, as it is said that a good run of smelt has always been followed by a good run of salmon. The increased run found the trade unprepared to handle it successfully and this accounts for the breaking of values to 10c and even lower. … Although the smelt, now so generously in the Portland markets, bear the name "Columbia River," the great preponderance of them is taken in the vicinity of Kelso from the Cowlitz River. Kelso this season has shipped out approximately 15,000 boxes. Each box contains 50 pounds and the fish average eight to the pound. The catch, so far, therefore represents approximately 6,000,000 fish.

**Pacific Fisherman, April 1913, vol. 11(4)**

Donate Carload of Smelt to Sufferers

> The citizens of Kelso, Wash., donated a carload of Columbia River or Cowlitz River smelt, 20,000 pounds in all, to the Ohio flood sufferers. The Kelso fishermen donated 400 boxes of fish, the businessmen paid for the boxes and labor and an express company and the railroad furnished the transportation free.

**Pacific Fisherman, February 1914, vol. 12(2), p. 20**

Heavy Run of Smelts in Columbia River Valley

> An unusually heavy run of smelts appeared in the Columbia River in January and large catches are now being made in that river and its numerous tributaries, more particularly in the Cowlitz River, where the annual run of this delicious species forms the basis of a considerable commercial industry. This year, in addition to being shipped fresh on ice, large numbers are being dried at the Kelso plant of the Northwestern DeAquating Company, thus making it possible to almost indefinitely extend the market for Cowlitz smelts.

**Pacific Fisherman, February 1915, vol. 13(2), p. 29**

Smelt in the Kalama River

> Early in February smelt entered the Kalama River in large numbers and the fishermen reaped a harvest for a time. It is a rare thing for the smelt to enter this river in any numbers. In the Cowlitz River, where the smelt usually run in immense numbers, few have been seen this season. Considerable catches have been made in the Columbia River proper.

**Pacific Fisherman, March 1918, vol. 16(3), p. 51**

Eulachon Run Late

> Great preparations were made this year for handling large shipments of eulachon from the Columbia River, as the fish has become well established in several Eastern markets and interest has been greatly stimulated by the Bureau of Fisheries exploitation work. The run, however, has so far been very disappointing. Up to the first of March the usual run in the Cowlitz River has not appeared, and a fair run that started in the Kalama River was of short duration.
>
> During the second week of March the eulachon appeared in large numbers in the Lewis River, and large catches have been made, with the fish in unusually good condition. The handling of the catch is somewhat more difficult than if the fish had run in the usual direction, but a heavy shipping movement to the East has been started, and it is expected that the shipments in that direction will reach important figures before the run is over. There was a fairly large movement last year, and the fish were well liked wherever they appeared, a large quantity having been placed on the New York market at a time of acute food shortage.

**Pacific Fisherman, May 1920, vol. 18(5), p. 48**

Oregon Smelt Running

> The annual run of smelt in the Sandy River, an Oregon tributary of the Columbia, started April 24.

**Pacific Fisherman, March 1924, vol. 23(3), p. 35**

Shipping Smelt

> For several weeks during February, shipments of smelt from Kelso, Wash., amounted to about 2,000 fifty-pound boxes daily, according to W. A. Mabie, manager of the Columbia River Smelt Company. Most of the shipments went to Portland, Ore., for distribution to consuming markets.

**Pacific Fisherman, February 1926, vol. 24(3), p. 30**

Columbia River Activities

Up to the last of January, the run of smelt in the Columbia River, which usually starts about January 15, had not appeared. About the middle of the month there was a small run, but few went up as high as the Cowlitz River or any of the other small streams which empty into the Columbia, except for about one day Grays River on the Washington side opposite Astoria fishermen secured considerable poundage. The run is still looked for by experienced men.

**Pacific Fisherman, March 1926, vol. 24(4), p. 44**

Good Oulachan Pack

The Candle Fish Company, Kelso, Wash., engaged in dry salting oulachans, or Cowlitz River smelts, for the Chinese market, reports that owing to the unusually good run this year little difficulty is anticipated in filling their contracts. More than 80 tons of salted oulachans were in the company's vats on the Kelso dock Feb. 15. Profiting by this year's experience the company is planning on improvements that will more than double their production next year.

Most of the catches during February were made at Sandy Bend between Kelso and Castle Rock. Fishermen and individual shippers of fresh smelts have been reaping a harvest from their catches, the Columbia River Smelt Company shipping on an average of 500 boxes daily.

**Pacific Fisherman, Annual Statistical Volume, January 1930, vol. 28(2), p. 189**

The run of Columbia River smelt appeared in the Cowlitz River again in 1929 in volume reported to exceed that of any previous season. The two preceding years had been complete failures and had given rise to the fear that pollution had destroyed the Cowlitz smelt, a supposition adequately disproved by the experience in 1929.

**Pacific Fisherman, Annual Statistical Volume, January 1933, vol. 31(2), p. 167**

Cowlitz Smelt

At the opening of the year production of fresh fish in the Pacific Northwest centered to a large degree on the Columbia River, where the winter salmon season yielded in a normal way, while the smelt run supplied another item of fresh fish. Before the smelt entered the Cowlitz the fishermen were able to hold the price to them at 2c per lb or above by the simple expedient of suspending their operations whenever the price went below that figure.

When the smelt run struck the Cowlitz the price dropped off sharply, as has been mentioned. The Washington smelt catch was one of the largest on record, being 1,476,939 lbs, surpassed in the previous seven years only by 1931.

# Appendix E: Substantive Scientific Comments from Peer Review

We received comments from five peer reviewers of the summary of the eulachon (*Thaleichthys pacificus*) status review completed in December 2008 (BRT 2008) and respond to them here. Reviewers were asked to assess the scientific validity of the status review, including any assumptions, methods, results, and conclusions. Reviewers were asked to focus on the quality of the data collected or used for the assessment, appropriateness of the analyses, validity of the results and conclusions, and appropriateness of the scope of the assessment (e.g., whether all relevant data and information were considered). We have summarized and organized the reviewers' comments into categories relevant to issues raised by the Eulachon Biological Review Team (BRT), composed of 10 federal scientists from 3 agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, and U.S. Forest Service. The peer reviewers are identified by number in order to preserve their anonymity.

In general, four of the five reviewers supported the conclusions of the Eulachon BRT. One reviewer did not agree with the delineation of the southern DPS of eulachon and argued that genetic and demographic evidence supports a much finer distinct population segment (DPS) structure for eulachon in this region. This same reviewer also pointed out a lack of information on eulachon marine distributions off the U.S. West Coast.

## Delineation of a Distinct Population Segment

### Review

Reviewer 1 stated that the discreteness and significance decisions were "well considered and defensible" and agreed that "the proposed DPS is discrete and significant and that its northern boundary is most defensibly delineated by Nass River, British Columbia." Reviewer 2 commented extensively on the proposed DPS scenario, and a summary of this reviewer's comments and our responses are presented below. Reviewer 3 stated that "the possibility exists that the Klamath River population (and associated populations to the south) is or was distinct." Reviewer 4 stated that the "conclusion that multiple discrete populations of eulachon exist appears well supported by the available evidence" and that "designation of a DPS encompassing all areas south of the Nass River/Dixon Entrance … appears to be the most strongly supported by the weight of available evidence, although other configurations of DPS(s) cannot be ruled out." Reviewer 5 did not address the appropriateness of the proposed southern DPS of eulachon, but requested clarification on one item, which we respond to below.

## Response

No response is required to comments by reviewers 1 and 4. With regard to the comment of Reviewer 3, the BRT was also cognizant of the possibility that the eulachon population in the Klamath River and in other steams of California may represent fish that have unique characteristics; however, the best available information is insufficient at present to identify what these characteristics are or were and whether they may have risen to the level of identifying eulachon in California as being “markedly separated” from populations to the north.

## Reviewer 2, Item 1

Reviewer 2 felt that it was not clear “why there were only six [DPS] scenarios when many more might have been proposed” and found “it puzzling that the BRT did not consider the option that the Columbia River was a DPS.” Furthermore, Reviewer 2 suggested that “the scenario that each river system represents a DPS … would have an approximate conceptual model of a river-based or stream-based salmon (*Oncorhynchus* spp.) stock structure as a precedent.”

## Response

As described in the “Evaluation of Discreteness and Significance for Eulachon” subsection of the BRT report, “other possible geographic configurations [of a DPS] that incorporated the petitioned unit were contemplated, but were not seriously considered by the BRT” (BRT 2008, p. 26) The BRT did discuss during its deliberations whether the Columbia River was a DPS, and after examining the available data and applying the discreteness and significance criteria for delineation of a DPS, no member of the BRT advocated for including this scenario in the final list that was voted on. The inclusion of scenario 6 (Multiple DPSs of eulachon in Washington, Oregon, and California) in the final voting process allowed BRT members to place some “likelihood points” in this scenario, which was representative of a scenario where every river is a DPS (including the Columbia River). Only 4% of all members’ likelihood points were cast for scenario 6.

We agree that, conceptually, it is reasonable to view stock structure of eulachon in a similar manner to Pacific salmon, and believe we have applied the DPS policies with regard to eulachon in a manner consistent with how previous BRTs have applied this policy to Pacific salmon. With regard to most Pacific salmon that have been examined under the U.S. Endangered Species Act, DPSs (which in the case of Chinook [*O. tshawytscha*], coho [*O. kisutch*], sockeye [*O. nerka*], chum [*O. keta*], and pink salmon [*O. gorbuscha*] are statutorily defined as Evolutionarily Significant Units [ESUs]) of these species consist of numerous demographically independent populations occupying a large number of individual drainages spread over large geographic areas. In only a few instances (e.g., some sockeye salmon ESUs) have Pacific salmon ESUs been designated on the basis of a single river basin. Pacific salmon DPS structure is thus conceptually consistent with the structure of the proposed southern DPS of eulachon, which may be composed of multiple subpopulations or stocks.

## Reviewer 2, Item 2

Reviewer 2 stated that "it is difficult to reconcile the conclusion of the BRT that there is one major DPS with the assertion that the BRT also acknowledges that finer population structure may exist." Reviewer 2 felt that spawn timing and genetic differences represent compelling evidence "that finer structure does exist between the Fraser and Columbia rivers."

## Response

The ESA requires the best available scientific and commercial information be used in determining the listing status of a species. However, the best available scientific information for eulachon is at present inadequate to define a particular DPS with 100% certainty, as reflected in the percentage distribution of likelihood points among four of six proposed DPS scenarios (see Table 1). Thus the BRT acknowledges that additional scientific research might result in evidence supporting either subdivision or expansion of the current DPS boundaries.

It is also important to acknowledge that the discreteness and significance criteria (USFWS-NMFS 1996) define a DPS, which is likely to be composed of many stocks or subpopulations. Previously designated DPSs of several marine fish include a number of identifiable subpopulations with numerous isolated spawning locations and a substantial level of life history, genetic, and ecological diversity (Gustafson et al. 2000, 2006, Stout et al. 2001a, Carls et al. 2008). Similarly, application of NMFS's ESU policy to Pacific salmon in the contiguous United States has resulted in designation of 52 ESUs, each of which is commonly composed of numerous populations that are often genetically and demographically differentiated one from another. In practical terms, if all genetically differentiated populations were to receive ESU status, there could conceivably be thousands of Pacific salmon ESUs.

The BRT did not believe that the available genetic or demographic data provide evidence that eulachon in the Fraser and Columbia rivers were "markedly separated" populations, as required by the DPS policy. With regard to the genetic microsatellite DNA study of Beacham et al. (2005), the BRT was concerned that this study compared samples between the Fraser and Columbia rivers taken in a single year, and thus the temporal stability of the genetic variation observed between these two rivers could not be adequately assessed. The BRT concerns with regard to temporal stability derive from the realization that reported year-to-year genetic variation within three British Columbia coastal river systems (Nass, Kemano, and Bella Coola rivers) in that study was as great as the variation among the rivers (Beacham et al. 2005). This temporal genetic variation indicates that additional research is needed to identify appropriate sampling and data collection strategies to fully characterize genetic relationships among eulachon populations.

## Reviewer 2, Item 3

Reviewer 2 invoked "significant genetic differences" between the Columbia and Fraser rivers described in Beacham et al. (2005) as evidence supporting a finer DPS structure, but at the same time described the statistically "significant differences in genetic composition between a sample taken in the Cowlitz River and one taken in the main stem of the Columbia" as "puzzling" in light of the assumption that the "basis for a [eulachon] population would be an estuary, perhaps formed by the confluence of a number of rivers." Reviewer 2 felt that "clearly some additional genetic analyses focusing on examination of potential differences within the Columbia River system would be very revealing."

### Response

Genetic samples described in Beacham et al. (2005) were taken in the Cowlitz and Columbia rivers in different years, which may partly explain the statistical differences in genetic composition between these two samples from the Columbia River drainage. Comparison of multiple year samples in the Kemano, Bella Coola (2 years of sampling each), and Nass (3 years of samples) rivers also showed statistically significant differences among samples from the same river across years. Beacham et al. (2005, p. 367) stated that "differentiation among sampling years within populations was similar to the level of differentiation among populations for these three putative populations." Thus it is uncertain whether some of the observed genetic differences described in Beacham et al. (2005) are temporally stable. We agree with the reviewer that further genetic studies of eulachon within the Columbia River and elsewhere are necessary to resolve these questions.

### Reviewer 5, Item 1

In reference to the third item in our list of evidence supportive of DPS scenario 4 (one DPS from Fraser River to California), Reviewer 5 stated that:

> … you argue that the pattern [of increasing length and weight with an increase in latitude] is found in many other vertebrate poikilotherms, so you tended to discount this evidence. However, in other places in the document, you seem to use parallels found in other fishes to support your findings. I found this somewhat contradictory, so perhaps a little more explanation would be useful.

### Response

Many quantifiable marine fish life history characters—such as body size-at-age, maximum age, and fecundity—increase with increasing latitude and the associated decline in rearing temperatures. Although some of these traits may have a broad genetic basis and may reflect local adaptations of evolutionary importance, they are usually strongly influenced by environmental factors over the lifetime of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and they can sometimes be used to infer the degree of independence among populations. However, differences in phenotypic and life history traits among populations do not provide definitive information on reproductive isolation between populations, because the genetic basis of many phenotypic and life history traits is weak or unknown.

At decreasing rearing temperatures, which can be expected in the northern portion of a species range in the northern hemisphere, a near universal relationship ensues among poikilotherms (i.e., cold-blooded organisms) where rates of growth are slower and size at a given age is larger (Ray 1960, Atkinson 1994). As most vertebrate poikilotherms exhibit similar latitudinal clines in these life history characters, their presence in eulachon offers at best weak evidence that eulachon in the southern and northern portion of their range are "markedly separated" from one another.

In both DPS scenario 4 (one DPS from Fraser River and south) and DPS scenario 1 (no DPS structure), where latitudinal differences in quantifiable life history characters or lack of differences other than those associated with latitude were mentioned as a supportive factor, parallel patterns with other fish species were pointed out to illustrate the apparent weakness of this evidence. We considered these geographic patterns in life history characters similarly in considering both DPS scenarios. Latitudinal variation in life history characters offered little support for either scenario (although other evidence may be more supportive), a fact which is reflected in the BRT's assignment of likelihood points to these two DPS scenarios (about 27% to scenario 4 and about 12% to scenario 1).

# Appropriateness of the Scope of the Assessment

### Review

Reviewer 1 stated that "it is my opinion that the best available data on eulachon spawning from California north to Alaska have been detailed and analyzed as part of the review" and the BRT "has made appropriate and exhaustive use of the best available scientific data that bear upon the questions at hand." Reviewer 2 commented that "the thoroughness of the literature review is impressive and … all facets of life history, historical use, habitat, commercial fisheries and traditional uses are described." However, Reviewer 2 questioned whether the BRT examined all available databases relevant to marine distribution of eulachon in offshore waters of Washington, Oregon, and California. Reviewer 3 commented that the "Summary of the Scientific Conclusions" was an "excellent review of the literature." Reviewer 4 stated that the "status review is very thorough" and "it appears that the BRT has based its conclusions on the best available information." Reviewer 4 also stated that inclusion "of historical anecdotal records (e.g., old newspaper reports) and aboriginal traditional knowledge … were important in filling out the gaps in scientific data, and were influential in developing a qualitative 'weight of evidence' of eulachon status." Reviewer 5 stated that "it seems to me you have been very thorough."

### Response

No response is required to comments by reviewers 1, 3, 4, and 5. Although known marine distribution and abundance of eulachon was thoroughly discussed during the BRT's deliberations, we agree that the summary of the status review (BRT 2008) failed to present or summarize all available information on marine distribution of eulachon off the U.S. West Coast and we attempt to rectify that oversight in this technical memorandum (see the Marine Distribution subsection in the Historical and Current Distribution subsection).

# Status of the Southern DPS of Eulachon

### Reviewers 2 and 4

Reviewer 2 did not address the appropriateness of the status assessment of the southern DPS of eulachon. Reviewer 4 stated that the BRT's conclusion that the southern DPS of eulachon is at moderate risk of extinction throughout all of its range "appears to be strongly supported by the available information, which indicates severe declines in abundance and historically low population levels throughout most of the species range." Comments of the other reviewers are addressed below.

### Reviewer 1

Reviewer 1 stated that the "BRT has appropriately weighed the various degrees to which age and size at maturity and fecundity can influence rate of population recovery." Furthermore Reviewer 1 felt that the BRT "note[d] correctly (in my opinion) the high probability that eulachon require comparatively high minimum viable population sizes to persist throughout the DPS." Reviewer 1 also believed that the BRT's application of the risk matrix approach "is not unreasonable when assessing extinction risk." However, in light of the demographic risks outlined by the BRT, Reviewer 1 "was somewhat surprised by the conclusion that the DPS is at moderate, rather than high, risk of extinction" and "might have expected a greater percentage of the available points to have been in the high risk category." In addition, although Reviewer 1 acknowledged that "the BRT has concluded that the DPS is at moderate risk of extinction throughout all of its range," the reviewer felt that "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range would be useful."

### Response

The BRT also noted and discussed the apparent discrepancy between its high concern for individual demographic risks (abundance, productivity, spatial connectivity, and diversity) and the placement of the majority of likelihood points in the "moderate" rather than "high risk" category. It was apparent that some BRT members placed substantial emphasis on the innate productivity and demonstrated resilience of eulachon to ameliorate concerns they may have had in the categories of abundance, spatial connectivity, and diversity, and that factor weighed heavily on their overall consideration of the DPS's relative risk of extinction. This divergence of opinion on the productivity category is also reflected in the risk matrix scores for that demographic criterion compared to abundance, spatial connectivity, and diversity. For instance, BRT scores for abundance of the DPS ranged from 4 ("high risk") to 5 ("very high risk") with a modal score of 4, whereas BRT scores for growth rate and productivity of the DPS ranged from 2 ("low risk") to 5 ("very high risk") with a modal score of 2. This divergence of opinion on the ability of the species' innate productivity potential to buffer its extinction risk is also likely reflected in the final risk vote; although all BRT members put the preponderance of their points in the moderate or high risk category, only 3 of 10 members put the majority of their points in the high risk category.

In the memo from the NMFS Northwest Region Office to the Northwest Fisheries Science Center requesting the formation of a BRT to review the status of eulachon, the BRT was instructed as follows:

> If the BRT determines that the species or delineated DPS is at neither moderate nor high risk throughout all of its range, please consider whether it is at moderate or high risk throughout a significant portion of its range. In determining whether a portion of the species' or DPS' range is "significant," please follow the guidance articulated in Waples et al. 2007 (Waples, R. S., P. B. Adams, J. Bohnsack, and B. Taylor. 2007. A biological framework for evaluating whether a species is threatened or endangered in a significant portion of its range. Conserv. Biol. 21(4):964–974).

Once the BRT had concluded that the southern DPS of eulachon was at "moderate risk" of extinction throughout all of its range, the BRT did begin to discuss the implications of whether the DPS may be at "high risk" of extinction in a significant portion of its range, but determined that its instructions from the region did not require a formal analysis of this question. Thus the BRT believes that providing "an explicit statement as to whether the BRT considers the southern eulachon DPS to be at high risk of extinction in a significant part of its range" involves legal and policy issues that are currently beyond the scope of its mandate. The BRT was also cognizant of the fact that previous BRTs involved in ESA status reviews, which had resulted in equivalent conclusions of moderate risk ("likely to become at risk of extinction") throughout a species' range, had not felt compelled to formally pursue the question of whether the species was then at high risk ("at risk of extinction") in a significant portion of its range (Good et al. 2005, Hard et al. 2007).

**Reviewer 3**

Reviewer 3 agreed with the BRT's "conclusion that the southern DPS of eulachon, as defined in the report, is at moderate risk of extinction throughout its range." However, Reviewer 3 stated the evidence also "suggests that eulachon … are on the verge of extinction" in California.

**Response**

The BRT had similar concerns about eulachon in northern California. As presented in the summary of the status review (BRT 2008, p. 63), with the exception of abundance, the BRT had most concerns about demographic risks related to spatial structure and connectivity of the southern DPS of eulachon (see Table 13); and the BRT was particularly concerned about the potential for extirpation of the northern California subpopulation. Overall, the BRT scores for spatial structure and connectivity of the DPS ranged from 3 to 5 with a mean score of 3.7 and a modal score of 4, indicating that risks to the spatial structure of the southern DPS of eulachon were rated as high risk by the BRT (see Table 13).

**Reviewer 5**

In reference to Table 9 through Table 13 in the summary of the status review (BRT 2008, Table 15 through Table 19 in the present document), which summarized the results of the BRT's attempt to qualitatively rank the severity of threats to eulachon, Reviewer 5 was “troubled by the statement that an opinion of not applicable for a particular threat criterion was rated the same as unknown (i.e., equivalent to not voting on that criterion)” and the reviewer stated that, “If a factor is not applicable to a given river system, then it seems to me that this would mean a rating of 1; (low threat)—or even better a zero (if that were possible). I have to wonder if this would change the rankings of factors in these lists.”

### Response

In practical terms, 2 members of the BRT voted a total of 5 times that a threat was “not applicable” out a total of 600 individual votes on the various threat categories and subareas of the DPS. Nearly all members voted “unknown” at least once, for a total of 100 times. If these 5 “not applicable” votes are scored as 1 or very low threat, the rankings of threats in the Klamath and Columbia River subpopulations are unaffected. “Dams/water diversions” in the Fraser River subpopulation drops from 8th place to 11th place and “dams/water diversions” in the mainland British Columbia subpopulation drops from 11th place to 12th place, based on rankings of the mean scores. Modal scores are unaffected. These readjustments would have no impact on the BRT’s identification of the severity of the top four identified threats in each subarea of the DPS.

## Use of Political Boundaries for Defining a DPS

### Review

Reviewer 2 commented extensively on the petitioner’s argument (see Cowlitz Indian Tribe 2007) that, under the DPS policy, eulachon populations in Washington, Oregon, and California are collectively “discrete” from more northerly populations because they are delimited by an international governmental boundary (i.e., the U.S.-Canada border between Washington and British Columbia) across which there is a significant difference in exploitation control, habitat management, or conservation status. After providing comments on differences in management of eulachon between the U.S. and Canada, Reviewer 2 stated that “the delineation of DPSs on the basis of political boundaries is probably mistaken, both on biological and operational grounds.”

### Response

We agree. Although the joint USFWS-NMFS policy (USFWS-NMFS 1996) states that international boundaries within the geographical range of the species may be used to delimit a DPS in the United States, in past assessments of DPSs of marine fish and ESUs of Pacific salmon, NMFS has placed the emphasis on biological information in defining DPSs and ESUs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused only on biological and ecological information in identifying whether DPSs of eulachon could be delineated.

# Recent NOAA Technical Memorandums

**published by the**

## Northwest Fisheries Science Center

**NOAA Technical Memorandum NMFS-NWFSC-**

104 **Horne, P.J., I.C. Kaplan, K.N. Marshall, P.S. Levin, C.J. Harvey, A.J. Hermann, and E.A. Fulton. 2010.** Design and parameterization of a spatially explicit ecosystem model of the central California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-104, 140 p. NTIS number pending.

103 **Dufault, A.M., K. Marshall, and I.C. Kaplan. 2009.** A synthesis of diets and trophic overlap of marine species in the California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-103, 81 p. NTIS number pending.

102 **Reppond, K.D. 2009.** Biochemistry of red king crab (*Paralithodes camtschaticus*) from different locations in Alaskan waters. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-102, 16 p. NTIS number pending.

101 **Sands, N.J., K. Rawson, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Determination of independent populations and viability criteria for the Hood Canal summer chum salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-101, 58 p. NTIS number pending.

100 **Linbo, T.L. 2009.** Zebrafish *(Danio rerio)* husbandry and colony maintenance at the Northwest Fisheries Science Center. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-100, 62 p. NTIS number PB2009-113299.

99 **Rawson, K., N.J. Sands, K.P. Currens, W.H. Graeber, M.H. Ruckelshaus, R.R. Fuerstenberg, and J.B. Scott. 2009.** Viability criteria for the Lake Ozette sockeye salmon evolutionarily significant unit. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-99, 38 p. NTIS number PB2009-113298.

98 **Johnson, L.L., G.M. Ylitalo, M.S. Myers, B.F. Anulacion, J. Buzitis, W.L. Reichert, and T.K. Collier. 2009.** Polycyclic aromatic hydrocarbons and fish health indicators in the marine ecosystem in Kitimat, British Columbia. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-98, 123 p. NTIS number PB2009-110295.

97 **Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2009.** Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-97, 63 p. NTIS number PB2009-113671.

**Most NOAA Technical Memorandums NMFS-NWFSC are available online at the Northwest Fisheries Science Center web site (http://www.nwfsc.noaa.gov).**

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to NMFS No:
2011/03866

December 30, 2011

Kevin Moynahan
Chief, Regulatory Branch
Portland District, Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Endangered Species Act Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Ocean Terminals Dock Construction, Sheet Pile, and Placement of Fill, Coos Bay (Coos Bay 6th field HUC 171003040303), Coos County, Oregon (Corps No.: NWP-1995-501/3)

Dear Mr. Moynahan:

The enclosed document contains a biological opinion (opinion) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects of a proposal by the Portland District of the U.S. Army Corps of Engineers (Corps) to authorize construction of the above-mentioned dock, sheet pile, and placement of fill under the authorities of section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act.

In this opinion, NMFS concludes that the proposed action is not likely to adversely affect Steller sea lions (*Eumotopias jubatus*), blue whales (*Balaenoptere musculus*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), Southern Resident killer whales (*Orcinus orca*), Sei whales (*Balaenoptera borealis*), sperm whales (*Physeter macrocephalus*), green sea turtles (*Chelonia mydas*), leatherback sea turtles (*Dermochelys coriacea*), loggerhead sea turtles (*Caretta caretta*), and olive ridley sea turtles (*Lepidochelys olivacea*).

The NMFS also concluded that the proposed action is not likely to jeopardize the continued existence of Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), southern distinct population segment (southern)of Pacific eulachon (*Thaleichthys pacificus*), southern distinct population segment (southern) North American green sturgeon (*Acipenser medirostris*) or result in the destruction or adverse modification of their designated critical habitats.

As required by section 7 of the ESA, NMFS is providing an incidental take statement with the opinion. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The take statement sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal action agency must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of listed species.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and includes five conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. Two of these conservation recommendations are a subset of the ESA take statement's terms and conditions. Section 305(b) (4) (B) of the MSA requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations.

If the response is inconsistent with the EFH conservation recommendations, the Federal action agency must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the action and the recommendations. In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Please direct questions regarding this opinion to Jim Muck, fisheries biologist in the Oregon Coast Habitat Branch of the Oregon State Habitat Office, at 541.957.3394.

Sincerely,

William W. Stelle, Jr.
Regional Administrator

cc: John Craig, Consultant
Garret Dorsey, Corps
Jim Lyons, OTC

# Endangered Species Act Biological Opinion
# and
# Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response
# for the

Ocean Terminals Dock Construction, Sheet Pile, and Placement of Fill
Coos Bay (Coos Bay 6th field HUC 171003040303)
Coos County, Oregon
(Corps No.: NWP-1995-501/3)

NMFS Consultation Number: 2011/03866

Federal Action Agency: U.S. Army Corps of Engineers

Affected Species and Determinations:

| ESA-Listed Species | ESA Status | Is the action likely to adversely affect this species or its critical habitat? | Is the Action likely to jeopardize this species? | Is the action likely to destroy or adversely modify critical habitat for this species? |
|---|---|---|---|---|
| Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) | Threatened | Yes | No | No |
| Southern distinct population segment green sturgeon (*Acipenser medirostris*) | Threatened | Yes | No | No |
| Southern distinct population segment Pacific eulachon (*Thaleichthys pacificus*) | Threatened | Yes | No | No |
| Eastern distinct population segment Steller sea lion (*Eumetopias jubatus*) | Threatened | No | No | No |
| Blue whale (*Balaenoptera musculus*) | Endangered | No | No | No |
| Fin whale (*Balaenoptera physalus*) | Endangered | No | No | No |
| Humpback whale (*Megaptera novaeangliae*) | Endangered | No | No | No |
| Southern resident killer whale (*Orcinus orca*) | Endangered | No | No | No |
| Sei whale (*Balaenoptera borealis*) | Endangered | No | No | No |
| Sperm whale (*Physeter macrocephalus*) | Endangered | No | No | No |
| Green turtle (*Chelonia mydas*) | Endangered | No | No | No |
| Leatherback turtle (*Dermochelys coriacea*) | Endangered | No | No | No |
| Loggerhead turtle (*Caretta caretta*) | Threatened | No | No | No |
| Olive ridley turtle (*Lepidochelys olivacea*) | Endangered | No | No | No |

| Fishery Management Plan that Describes EFH in the Action Area | Would the action adversely affect EFH? | Are EFH conservation recommendations provided? |
|---|---|---|
| Pacific Coast Salmon | Yes | Yes, five recommendations |
| Coastal Pelagic Species | Yes | Yes, five recommendations |
| Pacific Coast Groundfish | Yes | Yes, five recommendations |

| | |
|---|---|
| Consultation Conducted By: | National Marine Fisheries Service<br>Northwest Region |
| Issued by: | William W. Stelle, Jr.<br>Regional Administrator |
| Date: | December 30, 2011 |

**TABLE OF CONTENTS**

## GLOSSARY

For purposes of this consultation –

Action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by a Federal action agency.

Action area means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action.

Applicant means any person who requires formal approval, authorization, or funding from a Federal action agency as a prerequisite to conducting the action.

Conserve, conserving, and conservation mean to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to the Federal Endangered Species Act are no longer necessary.

Conservation recommendation means a suggestion by NMFS regarding a discretionary measure to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information.

Critical habitat means any geographical area designated as critical habitat in CFR part 226.

Cumulative effects are those effects of future state or private activities, not involving Federal action, that are reasonably certain to occur within the action area of the Federal action subject to consultation.

Effects of the action are the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action that will be added to the environmental baseline.

Endangered species are in danger of extinction throughout all or a significant portion of its range.

Environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process.

Fishery biologist means a person that has an ecological education, thorough knowledge of aquatic biology and fish management, and is professionally engaged in fish research or management activities; a supervisory fishery biologist is professionally responsible for the supervision of biologists and technical staff engaged in fish research or management.

Harm means significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

Hazardous material means any chemical or substance which, if released into an aquatic habitat, could harm fish, including, but not limited to, petroleum products, radioactive material, chemical agents, and pesticides.

Incidental take means takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal action agency or applicant.

Indirect effects are caused by the proposed action and are later in time, but still are reasonably certain to occur.

Interdependent actions have no independent utility apart from the action under consideration.

Interrelated actions are part of a larger action and depend on the larger action for their justification.

In-water work includes any part of an action that occurs below ordinary high or within the wetted channel, *e.g.*, excavation of streambed materials, fish capture and removal, flow diversion, streambank protection, and work area isolation.

Jeopardize the continued existence of means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Listed species are any species of fish, wildlife, or plant which has been determined to be endangered or threatened under section 4 of the Federal Endangered Species Act.

Ordinary high water (OHW) elevation means the elevation to which the high water ordinarily rises annually in season, excluding exceptionally high water levels caused by large flood events. The ordinary high water elevation is typically below the bankfull elevation. The ordinary high water elevation is considered equivalent to the bankfull elevation if the ordinary high water lines are indeterminate.

Primary constituent elements (PCE) are the biological and physical features of critical habitat that are essential to the conservation of listed species.

Reasonable and prudent measures (RPM) are actions the NMFS believes necessary or appropriate to minimize the amount or extent of incidental take.

Recovery means an improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Federal Endangered Species Act.

Scope of the action means the range of actions and impacts to be considered in the analysis of effects.

Sound exposure level (SEL) means a measure of sound energy dose that is defined as the constant sound level acting for one second that has the same acoustic energy as the original sound (Hastings and Popper 2005). SEL is calculated by summing the cumulative pressure squared over time as decibels re 1 micropascal$^2$-second.
Stream-floodplain corridor means the main stream channel and its functional floodplain.

Take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

Threatened species are likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Working adequately means erosion controls that do not allow ambient stream turbidity to increase by more than 10% above background 100 feet below the discharge, when measured relative to a control point immediately upstream of the turbidity-causing activity.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| CFR | Code of Federal Regulations |
| CHART | Critical Habitat Analytical Review Team |
| dB | decibel (dB) |
| EFH | Essential Fish Habitat |
| ESA | Endangered Species Act |
| FR | Federal Register |
| HUC | Hydraulic Unit Code |
| LAA | Like to adversely affect |
| MSA | Magnuson Stevens Act |
| NLAA | Not likely to adversely affect |
| NMFS | National Marine Fisheries Service |
| NDPS | Northern distinct population segment |
| OC | Oregon Coast |
| ODFW | Oregon Department of Fish and Wildlife |
| OHW | Ordinary High Water |
| OTC | Ocean Terminals Company |
| PCE | Primary constituent element |
| RPM | Reasonable and prudent measure |
| SEL | Sound exposure level |
| TRT | Technical Review Team |
| VSP | Viable Salmonid Population |

# 1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into sections 2 and 3 below.

## 1.1 Background

The biological opinion (opinion) and incidental take statement portions of this document were prepared by the National Marine Fisheries Service (NMFS) in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531, *et seq*.), and implementing regulations at 50 CFR 402.

The NMFS also completed an essential fish habitat (EFH) consultation. It was prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600.

The opinion and EFH conservation recommendations are both in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-5444) ("Data Quality Act") and underwent pre-dissemination review. The administrative record for this consultation is on file at the Oregon Coast Habitat Branch in Roseburg, Oregon.

## 1.2 Consultation History

The NMFS based this opinion on information provided in the consultation request letter dated August 23, 2011, from the Portland District of the U.S. Army Corps of Engineers (Corps) and the enclosed project description. The Corps determined that the proposed action is likely to adversely affect (LAA) Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*), southern distinct population segment (southern) of North American green sturgeon (*Acipenser medirostris*), southern distinct population segment (southern)of Pacific eulachon (*Thaleichthys pacificus*), the eastern distinct population segment of Steller sea lions (*Eumetopias jubatus)*(referred to as Steller sea lion) , and designated critical habitat for OC coho salmon and southern green sturgeon. Although the Corps determined that the proposed action is LAA the Steller sea lion as in their request for formal consultation, NMFS concluded in this opinion that the proposed action is NLAA Steller sea lions.

The NMFS sent an additional information request letter to the Corps on September 23, 2011. The Corps and the consultant for Ocean Terminals Company (OTC) worked with NMFS to provide the necessary information. The information requested was received on October 21, 2011, and formal consultation was initiated by NMFS.

Previously, the Corps issued Clean Water Act section 404 and Rivers and Harbors Act section 10 permits to OTC on July 16, 1997, but these permits expired on April 30, 2000. The Corps and NMFS consulted on a proposed  dock expansion and improvements for the OTC project in 2001, which resulted in a biological opinion written by NMFS (NWP 1995-00501; refer to NMFS No.: 2001/00519). This action was never completed and now is modified from the original proposed action.

In the original permit application, OTC proposed as mitigation for adverse effects of the proposed activities to restore a 24.7-acre site to a functional intertidal wetland. This site is located 9 miles from the project area and 6 miles upstream in Isthmus Slough. Although the dock expansion was never completed, OTC did complete the associated mitigation. The physical actions necessary for this restoration were completed by OTC in October 1997.

The dredging necessary to maintain the OTC docks is covered in a previous biological opinion 'Unified Maintenance Dredging Program for Oregon Coastal Projects' (refer to NMFS No: 2009/01756). Since the effects of dredging were addressed by this consultation, no further discussion of the effects of the maintenance dredging is warranted in this opinion.

Jim Muck (NMFS staff biologist) toured the project site with John Craig (consultant) on September 16, 2011. Mr. Muck also toured the OTC dock site again and the mitigation site with Ken Phippen (NMFS), John Craig (consultant), and Jim Lyons (OTC) on October 20, 2011.

### 1.3 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

The Corps, with regulatory authority found in section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act, proposes to issue a permit to OTC for dock improvements, construction of sheet pile, placement of fill, and placement of riprap along the Coos Bay estuary located in Section 10, Township 25 South, Range 13 West, North Bend, Oregon (Coos Bay 6$^{th}$ field HUC 171003040303).

The proposed project is the construction of a new dock measuring 400 feet long by 50 feet wide. The new dock will be located to the north of the existing dock (see Figure 1). The new dock and improvement to the existing dock will require installation of 194 concrete piles and concrete decking. The pilings measure 24 inches in diameter and OTC will install the pilings using a vibratory hammer. The OTC will not proof the piles with strikes from an impact hammer. Additionally, OTC is planning to remove 256 treated pilings unneeded treated wood piles during the existing dock improvements. Only piles that are used for structural integrity of the existing dock will remain. The OTC estimates that over 90% of the existing piles are to be removed.

OTC is proposing to construct a sheet pile bulkhead located inside the new and existing 800-foot docks (Figure 2). At the north end, the sheet pile bulkhead will incorporate a 45 degree wing directly to the shore. At the southern end, OTC is planning a smaller length of wing-wall angled toward the shore. Backfill will consist of clean sand from the North Spit of Coos Bay. The additional fill will allow for employee parking, log storage, and direct access for the front loaders to load ships at the dock.


**Figure 1.** Ocean Terminals Company site view showing log yard and existing dock.

To the south of the existing dock, the applicant is proposing a 400 linear-foot section of shoreline to be filled with clean, compacted sand and a rock face consisting of 12- inch minus riprap and 36-inch riprap used for the toe (Figure 2). The total amount of rock proposed is 3,000 yards. The toe of the riprap is figured near the 12-foot depth contour.

Placement of fill will impact 3.9 acres behind the sheet pile and riprap. The applicant will build the project in three phases. Phase 1 will consist of the construction of the 800 feet of sheet pile and associated backfill. Erosion control measures will be implemented during construction as appropriate. Phase 2 will consist of fill placement and riprap to the south of the existing dock. During Phase 3, 400 linear feet of new dock will be constructed to the north of the existing dock.

No dredging is proposed with this action. The facility is one of the sites included in the unified dredging permit held and managed by the Port of Coos Bay. The ODFW-preferred in-water work period for Coos Bay estuary including the project site is October 1 through February 15.

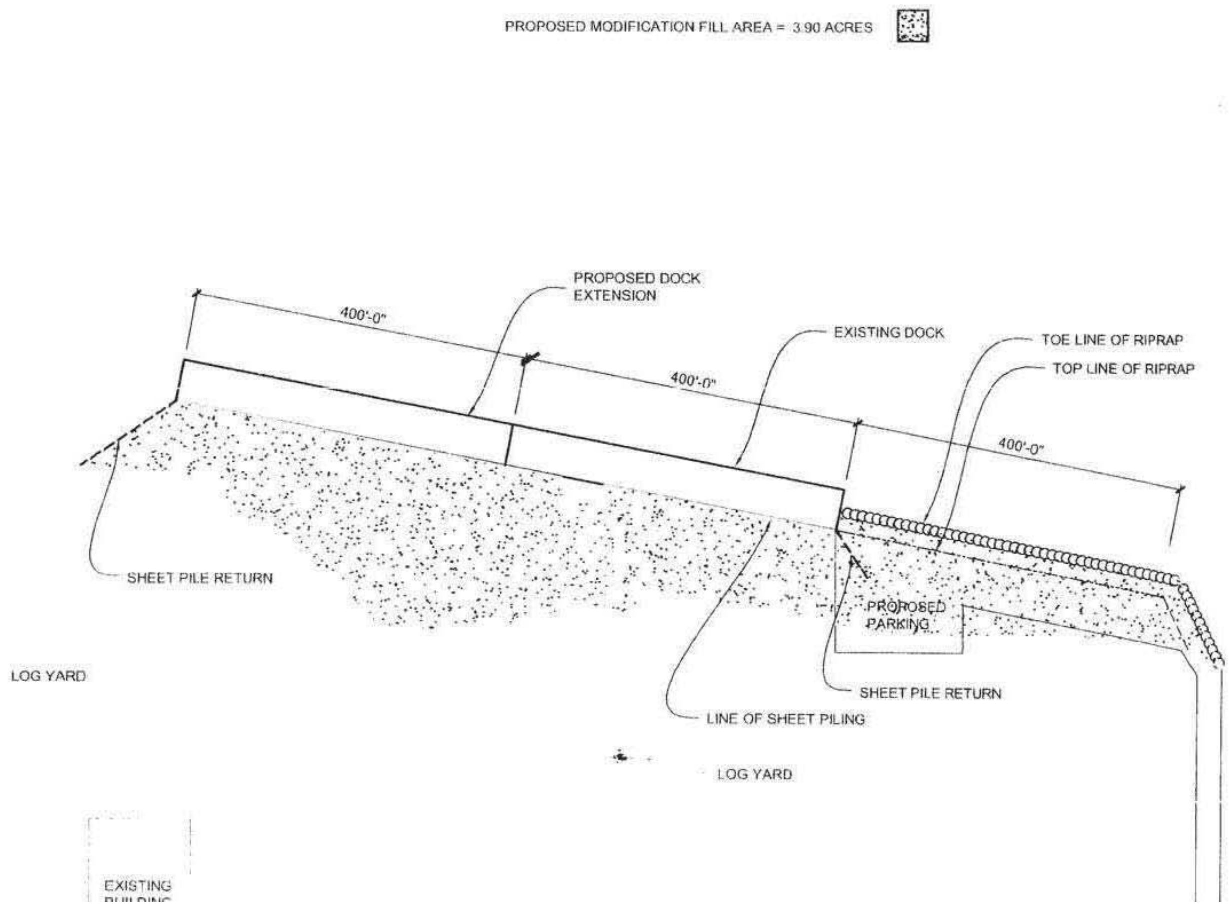



**Figure 2**. Ocean Terminals Company proposed action including 400- by 50-foot northern dock, 3.9 acres of fill, sheet pile location, and riprap located to the south.

The construction fill will create 3.9 additional impervious acres. The southern area of the construction fill will be used for employee parking; the rest of the OTC site is used for log storage and dock loading. The OTC will route all water from the dock back into the stromwater facilities (Figure 3). The OTC will treat stormwater by constructing oil/water separators in the ten catch basins and by the filtration that occurs through two ditch lines located on the western property lines. The OTC will inspect catch basins monthly, clean catch basins at a minimum twice yearly, and clean drains as needed. Stormwater will enter the estuary through three culvert outflows and one drainage ditch.

In OTC's original consultation with NMFS in 1997, OTC proposed to restore a 24.7-acre site, 9 miles from the project area and 6 miles upstream, on Isthmus Slough to a functional intertidal wetland as mitigation for adverse effects of the proposed activities. The physical actions necessary for this restoration were completed by OTC in October of 1997.

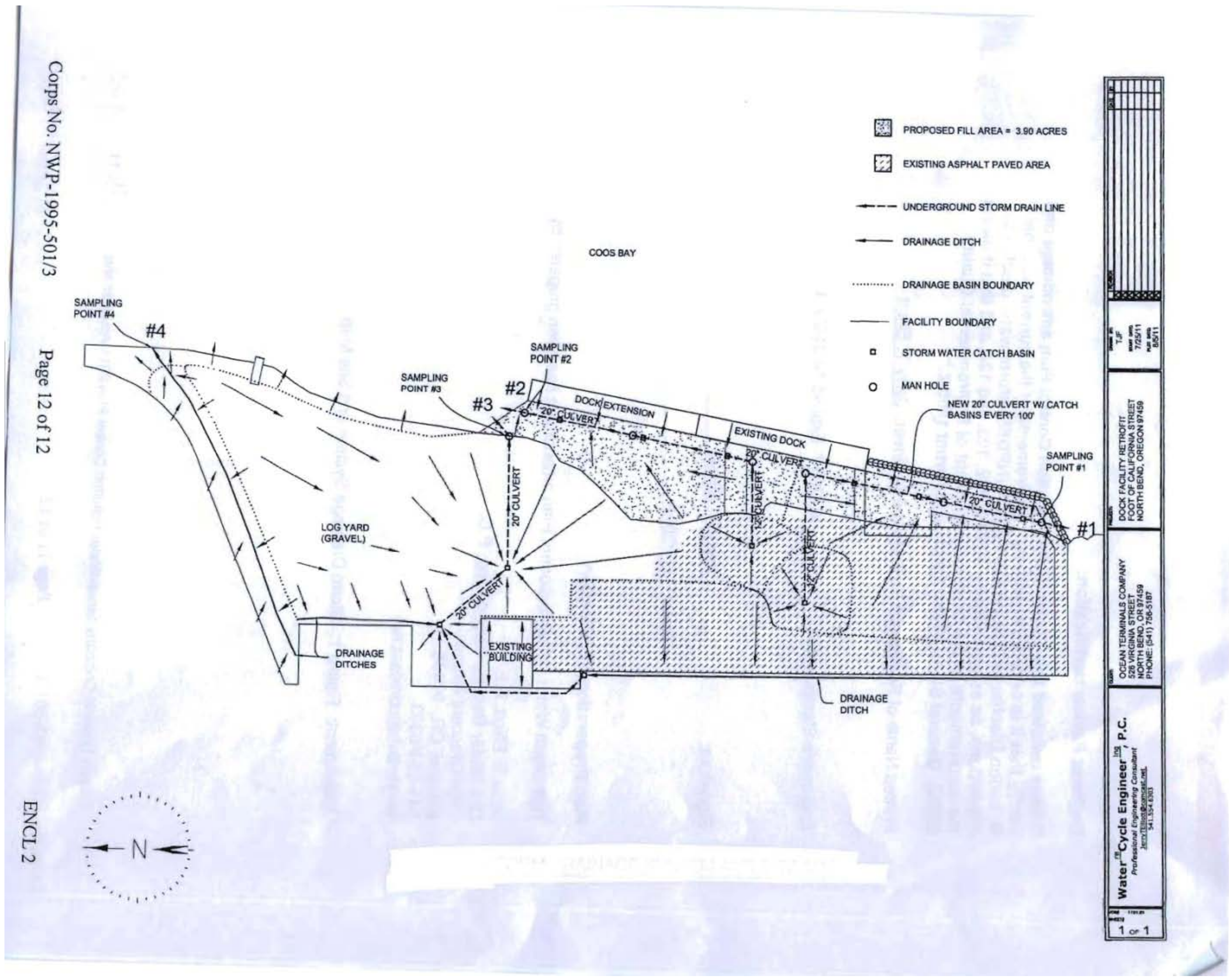



**Figure 3.** Location and flow diagram for stormwater at Ocean Terminals Company facility at North Bend, Oregon.

The Corps determined that the OTC mitigation requirements for the new dock, improvements to the existing dock, and fill did not require all of the 24.7 credit acres accrued at the Lyons mitigation site on Isthmus Slough and therefore OTC has sold the additional credits to other interests. After the site was restored to natural tidal function, the site now contains 32 credit acres. All credits from the site have been sold.

The OTC completed the mitigation for the proposed action in 1997. The OTC mitigation requirements from the Corps included 1.4 acres in restoration credits (1 to 1 ratio) and 10.65 acres enhancement credits (3 to 1 ratio). The initial fill impact from the 1997 OTC application was 4.95 acres. The Corps mitigation requirements for the 4.95 acre fill in 1997 required a 1 to 1 ratio of 1.4 acres dike removal, and required 3 to 1 enhancement ratio mitigation totaled 10.65 acres. The total acre of mitigation equates to 12.05 acres. The proposed action in 2011 calls for 3.9 acres fill, however, OTC is not modifying the original mitigation such that enhancement credits now exceed a ratio over 4 to 1.

In 1997, the OTC removed the 1.4 acres of dike, filled in the agriculture ditches, removed the existing tidegate, and allowed the 24.7 acres of pastureland to flood with water. No vegetation planting was required in the original mitigation plan. Wetland mitigation monitoring reports have been submitted to the Corps. Later, mapping showed that actually 32.0 acres were flooded.

### 1.4 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). For this consultation, the action area is within the Coos Bay Frontal 5$^{th}$ field HUC 1710030403 (Coos Bay 6$^{th}$ field HUC 171003040303). The action area for this consultation includes all riverine and estuarine habitats accessible to OC coho salmon, southern green sturgeon, and eulachon (Table 1) in Coos Bay estuary within the project area located at approximately river mile 10. The action area includes areas where stormwater effects extends downstream, approximately 10 miles to the confluence with the Pacific ocean, and extends approximately 40 miles upstream to the head of tide. Effects due to stormwater include contribution of dissolved copper, which has a fate and transport showing it stays in the system until it finally dilutes in the ocean. The head of tide is Coos River and is located at the confluence of East and West forks of the Millicoma Rivers, and at the Dellwood area for the South Coos River. The piling installation impact and fill zone extends 100 feet upstream and downstream from the project fill activities.

The action area also includes the shipping lanes from the OTC terminal including outside the breakwaters of Coos Bay Jetty until the ships reach their port in China, specifically for ESA marine mammals and turtles (Table 1). These species are discussed in the not likely to adversely affect (NLAA) Section 2.11 of this opinion.

Adult OC coho salmon use the action area as a migratory corridor and staging area as they move upstream to spawning habitat in Coos River tributaries. Adult OC coho salmon begin to arrive in Coos Bay in the fall and peak in abundance in November through early December. Juvenile OC coho salmon begin their outmigration from their natal streams to the ocean in late February and use the Coos Bay estuary for rearing, refuge and the physiological transition to saltwater. They are likely present in the action area from March through June, with a peak from mid-April to mid-May. Juvenile OC coho salmon are not expected in the action area during construction.

The NMFS defined two distinct population segments of green sturgeon: a northern distinct population segment with spawning populations in the Klamath and Rogue rivers and a southern that spawns in the Sacramento River. The southern green sturgeon was listed as threatened in 2006 (71 FR 17757), and includes all spawning populations south of the Eel River in California. Critical habitat for southern green sturgeon within the Coos Bay terminates at head of tide (74 FR 52300). Subadult and adult southern green sturgeon use the action area as habitat for growth and development to adulthood and for adult and subadult feeding. Southern green sturgeon are known to congregate in coastal waters and estuaries, including non-natal estuaries such as Coos Bay. Beamis and Kynard (1997) suggest that southern green sturgeon move into estuaries of non-natal rivers to feed. Data from Washington studies indicate that southern green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007). The NMFS does not expect adult or juvenile southern green sturgeon to be present in the action area during the construction period of October 1 to February 15.

Eulachon range from the Mad River in northern California to the Skeena River in British Columbia, Canada. They inhabit several riverine and estuarine systems along the west coast and population sizes vary between these systems. Eulachon are rarely observed in Coos Bay.. The NMFS listed Pacific eulachon as threatened under the ESA, protective regulations were issued on March 18, 2010 (75 FR 13012). The NMFS did not designate critical habitat for Pacific eulachon in the Coos Bay watershed. Eulachon adults return to freshwater from January to March and evidence suggests that adult eulachon may return as early as December to spawn (WDFW and ODFW 2001). Adult eulachon are unlikely to be present in the estuary during October through December, but may become present in January through February. Although eulachon are not known to spawn in Coos Bay tributaries, typical spawning for eulachon occurs from January through July, with the peak in mid-April to mid-June, though there is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuarine and near-shore marine areas. When eggs hatch in 20 to 40 days, eulachon larvae immediately wash downstream to estuarine and ocean areas where they feed on phytoplankton and zooplankton.

Steller sea lions in Oregon are from the eastern distinct population segment, listed by NMFS as threatened on November 26, 1990 (55 FR 49204) (Table 1). Steller sea lions can occur in Oregon waters throughout the year. Breeding rookeries for eastern Steller sea lions are located at Long Brown and Seal Rocks at Orford Reef, and Pyramid Rock at Rogue Reef. These locations are designated critical habitat for Steller sea lions. However, the area of critical habitat closest to the action area is more than 50 miles away and therefore the proposed action will have no effect on critical habitat for Steller sea lions.

The NMFS listed the following marine mammals and turtle under the ESA: (1) Southern Resident (SR) killer whales as endangered under the ESA on November 18, 2005 (70 FR 69903) and designated critical habitat on November 29, 2006 (71 FR 69054); (2) blue, humpback, fin, and sei whales as endangered on December 2, 1970 (35 FR 18319); and (3) leatherback sea turtles as endangered on June 2, 1970 (Table 1).

Individuals of these species are migratory along the Oregon Coast and their presence in the ocean portion of the action area is likely only transitory, with the exception of leatherback sea turtles. Leatherback sea turtles likely use the action area for feeding, too. The action area is not designated critical habitat for SR killer whales and the closest area of critical habitat is 480 miles away in the Puget Sound of Washington State. Additionally, Chinook salmon affected by the proposed action do not occur in SR killer whale critical habitat (based on knowledge of their marine distribution from coded-wire tag recoveries (Weitkamp 2010). Therefore, no effects to SR killer whale critical habitat are anticipated, and no further mention of it will occur in this document. The action area is proposed critical habitat for leatherback sea turtles, but there is no mechanism for the proposed action to affect either of the two identified physical or biological features essential to their conservation (vessel traffic is not considered a threat to turtle passage; 75 FR 319). Therefore, no effects to proposed leatherback turtle critical habitat are anticipated, and no further mention of it will occur in this document.

**Table 1.** Federal Register notices for final rules that list threatened and endangered species, designate critical habitats, or apply protective regulations to listed species considered in this consultation. Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered; "P" means proposed.

| Species | | Listing Status | Critical Habitat | Protective Regulations |
|---|---|---|---|---|
| **Anadromous Fish** | | | | |
| **Coho salmon (*O. kisutch*)** | | | | |
| | Oregon Coast | T 6/20/11; 76 FR 35755 | 2/11/08; 73 FR 7816 | 2/11/08; 73 FR 7816 |
| **Green sturgeon** *(Acipenser medirostris)* | | | | |
| | Southern | T 4/07/06; 71 FR 17757 | 10/09/09; 74 FR 52300 | 6/02/10; 75 FR 30714 |
| **Eulachon** (*Thaleichthys pacificus*) | | | | |
| | Eulachon | T 3/18/10; 75 FR 13012 | 10/20/2011, 76 FR 65324 | |
| **Marine Mammals** | | | | |
| **Steller sea lion (***Eumetopias jubatus***)** | | | | |
| | Eastern | T 5/5/1997; 63 FR 24345 | 8/ 27/93; 58 FR 45269 | 11/26/90; 55 FR 49204 |
| **Blue whale** (*Balaenoptera musculus*) | | | | |
| | | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Fin whale** (*Balaenoptera physalus*) | | | | |
| | | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Humpback whale** (*Megaptera novaeangliae*) | | | | |
| | | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Killer whale** (*Orcinus orca*) | | | | |
| | Southern Resident | E 11/18/05; 70 FR 69903 | 11/26/06; 71 FR 69054 | ESA section 9 applies |
| **Sei whale** (*Balaenoptera borealis*) | | | | |
| | | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Sperm whale** (*Physeter macrocephalus*) | | | | |
| | | E 12/02/70; 35 FR 18319 | Not applicable | ESA section 9 applies |
| **Marine Turtles** | | | | |
| **Green sea turtle** (*Chelonia mydas*) | | | | |
| | Excludes Pacific Coast of Mexico and Florida | ET 7/28/78; 43 FR 32800 | 9/02/98; 63 FR 46693 | ESA section 9 applies |
| **Leatherback sea turtle** (*Dermochelys coriacea*) | | | | |
| | | E 6/02/70 ; 39 FR 19320 | 3/23/79; 44 FR 17710<br>P 1/5/2010; 75 FR 319 | ESA section 9 applies |
| **Loggerhead sea turtle** (*Caretta caretta*) | | | | |
| | | T 7/28/78; 43 FR 32800 | Not applicable | 7/28/78; 43 FR 32800 |
| **Olive ridley sea turtle** (*Lepidochelys olivacea*) | | | | |
| | | ET 7/28/78; 43 FR 32800 | Not applicable | ESA section 9 applies |

## 2. ENDANGERED SPECIES ACT BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA established a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat on which they depend. Section 7(a)(2) of the ESA requires Federal agencies to consult with the U.S. Fish and Wildlife Service, NMFS, or both, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Section 7(b)(3) requires that at the conclusion of consultation, the Service provide an opinion stating how the agencies' actions will affect listed species or their critical habitat. If incidental take is expected, Section 7(b)(4) requires the provision of an incidental take statement (ITS) specifying the impact of any incidental taking, and including reasonable and prudent measures to minimize such impacts.

### 2.1 Introduction to the Biological Opinion

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The jeopardy analysis considers both survival and recovery of the species. The adverse modification analysis considers the impacts to the conservation value of the designated critical habitat.

"To jeopardize the continued existence of a listed species" means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02).

This opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat.[1]

We will use the following approach to determine whether the proposed action described in section 1.3 is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- *Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action*. This section describes the current status of each listed species and its critical habitat relative to the conditions needed for recovery. For listed salmon and steelhead, NMFS has developed specific guidance for analyzing the status of the listed species' component populations in a "viable salmonid populations" paper (VSP; McElhany *et al.* 2000). The VSP approach considers the abundance, productivity, spatial structure, and diversity of each population as part of the overall review of a species' status. For listed salmon and steelhead, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, we rely on viability assessments and criteria in

[1] Memorandum from William T. Hogarth to Regional Administrators, Office of Protected Resources, NMFS (Application of the "Destruction or Adverse Modification" Standard Under Section 7(a)(2) of the Endangered Species Act) (November 7, 2005).

technical recovery team documents and recovery plans, where available, that describe how VSP criteria are applied to specific populations, major population groups, and species. We determine the rangewide status of critical habitat by examining the condition of its physical or biological features (also called "primary constituent elements" or PCEs in some designations) – which were identified when the critical habitat was designated. Species and critical habitat status are discussed in section 2.2.

- *Describe the environmental baseline for the proposed action*. The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities in the action area. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in section 2.3 of this opinion.
- *Analyze the effects of the proposed actions*. In this step, NMFS considers how the proposed action would affect the species' reproduction, numbers, and distribution or, in the case of salmon and steelhead, their VSP characteristics. The NMFS also evaluates the proposed action's effects on critical habitat features. The effects of the action are described in section 2.4 of this opinion.
- *Describe any cumulative effects.* Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in section 2.5 of this opinion.
- *Integrate and synthesize the above factors to assess the risk that the proposed action poses to species and critical habitat.* In this step, NMFS adds the effects of the action (section 2.4) to the environmental baseline (section 2.3) and the cumulative effects (section 2.5) to assess whether the action could reasonably be expected to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (section 2.2). Integration and synthesis occurs in section 2.6 of this opinion.
- *Reach jeopardy and adverse modification conclusions*. Conclusions regarding jeopardy and the destruction or adverse modification of critical habitat are presented in section 2.7. These conclusions flow from the logic and rationale presented in the Integration and Synthesis section (2.6).
- *If necessary, define a reasonable and prudent alternative to the proposed action.* If, in completing the last step in the analysis, NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify a reasonable and prudent alternative (RPA) to the action. The RPA must not be likely to jeopardize the continued existence of ESA-listed species nor adversely modify their designated critical habitat and it must meet other regulatory requirements.

In this opinion, NMFS concludes that the proposed action is NLAA Steller sea lions, blue whales, fin whales, humpback whales, Southern Resident killer whales, Sei whales, sperm whales, green sea turtles, leatherback sea turtles, loggerhead sea turtles, olive ridley sea turtles. The applicable standard to find that a proposed action is NLAA ESA-listed species is that all of the effects of the action are expected to be discountable, insignificant or completely beneficial. Discountable effects cannot be reasonably expected to occur. Insignificant effects are so mild that the effect cannot be meaningfully measured, detected or evaluated. Beneficial effects are contemporaneous positive effects without any adverse effect on the listed species or critical habitat, even if the long-term effects are beneficial. These species are discussed in Section 2.11 of the opinion under NLAA species.

**2.2 Rangewide Status of the Species and Critical Habitat**

The summaries that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, can be found in the listing regulations and critical habitat designations published in the Federal Register (Table 1).

Climate change is likely to play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. Areas with elevations high enough to maintain temperatures well below freezing for most of the winter and early spring will be less affected. Low-elevation areas are likely to be more affected.

During the last century, average regional air temperatures increased by 1.5°F, and increased up to 4°F in some areas (USGCRP 2009). Warming is likely to continue during the next century as average temperatures increase another 3°F to 10°F (USGCRP 2009). Overall, about one-third of the current cold-water fish habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (USGCRP 2009).

Precipitation trends during the next century are less certain than for temperature but more precipitation is likely to occur during October through March and less during summer months, and more of the winter precipitation is likely to fall as rain rather than snow (ISAB 2007, USGCRP 2009). Where snow occurs, a warmer climate will cause earlier runoff so stream flows in late spring, summer, and fall will be lower and water temperatures will be warmer (ISAB 2007, USGCRP 2009).

Higher winter stream flows increase the risk that winter floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (USGCRP 2009). Earlier peak stream flows will also flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and the risk of predation (USGCRP 2009). Lower stream flows and warmer water temperatures during summer will degrade summer rearing conditions, in part by increasing the prevalence and virulence of fish diseases and parasites (USGCRP 2009). Other adverse effects are likely to include altered migration patterns, accelerated embryo development, premature emergence of fry, variation in quality and quantity of tributary rearing habitat, and increased competition and predation risk from warm-water, non-native species (ISAB 2007).

The earth's oceans are also warming, with considerable interannual and inter-decadal variability superimposed on the longer-term trend (Bindoff *et al*. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances (Scheuerell and Williams 2005, Zabel *et al*. 2006, USGCRP 2009). Ocean conditions adverse to salmon and steelhead may be more likely under a warming climate (Zabel *et al*. 2006).

### 2.2.1 Status of the Species

Climate change, as described in section 2.2, is likely to adversely affect the size and distribution of populations of ESA-listed anadromous fish in the Pacific Northwest. The size and distribution of the populations considered in this opinion generally have declined over the past few decades due to natural phenomena and human activity, including the operation of hydropower systems, over-harvest, hatcheries, and habitat degradation. Enlarged populations of terns, seals, sea lions, and other aquatic predators in the Pacific Northwest have been identified as factors that may be limiting the productivity of some Pacific salmon and steelhead populations (Ford *et al*. 2010).

***OC Coho Salmon.*** This species includes populations of OC coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco. The Cow Creek hatchery stock (South Umpqua population) is managed as an integrated program and is included as part of the ESU because the original brood stock was founded from the local natural origin population and natural origin coho salmon have been incorporated into the brood stock on a regular basis. OC coho salmon were first listed in February 2008. As part of a legal settlement agreement in 2008, NMFS completed a new status review for the evolutionary significant unit (ESU). In 2011, NMFS issued a final rule re-promulgating the threatened listing for OC coho salmon (USDC 2011b).

The OC-Technical Review Team (TRT) identified 56 populations: 21 independent and 35 dependent. The dependent populations were dependent on strays from other populations to maintain them over long time periods. The TRT grouped the 21 independent populations into five biogeographic strata (Table 2) (Lawson *et al.* 2007).

**Table 2.** OC coho salmon populations. Dependent populations (D) are populations that historically would not have had a high likelihood of persisting in isolation for 100 years. These populations relied upon periodic immigration from other populations to maintain their abundance. Independent populations are populations that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years and are rated as functionally independent (FI) and potentially independent (PI) (McElhany *et al.* 2000, Lawson *et al.* 2007).

| Stratum | Population | Type | Stratum | Population | Type |
|---|---|---|---|---|---|
| North Coast | Necanicum | PI | Mid-Coast (cont.) | Alsea | FI |
| | Ecola | D | | Big (Alsea) | D |
| | Arch Cape | D | | Vingie | D |
| | Short Sands | D | | Yachats | D |
| | Nehalem | FI | | Cummins | D |
| | Spring | D | | Bob | D |
| | Watseco | D | | Tenmile | D |
| | Tillamook | FI | | Rock | D |
| | Netarts | D | | Big (Siuslaw) | D |
| | Rover | D | | China | D |
| | Sand | D | | Cape | D |
| | Nestucca | FI | | Berry | D |
| | Neskowin | D | | Sutton | D |
| Mid-Coast | Salmon | PI | Lakes | Siuslaw | FI |
| | Devils | D | | Siltcoos | PI |
| | Siletz | FI | | Tahkenitch | PI |
| | Schoolhouse | D | | Tenmile | PI |
| | Fogarty | D | Umpqua | Lower Umpqua | FI |
| | Depoe | D | | Middle Umpqua | FI |
| | Rocky | D | | North Umpqua | FI |
| | Spencer | D | | South Umpqua | FI |
| | Wade | D | Mid-South Coast | Threemile | D |
| | Coal | D | | Coos | FI |
| | Moolack | D | | Coquille | FI |
| | Big (Yaquina) | D | | Johnson | D |
| | Yaquina | FI | | Twomile | D |
| | Theil | D | | Floras | PI |
| | Beaver | PI | | Sixes | PI |

Wainwright *et al.* (2008) determined that the weakest strata of OC coho salmon were in the North Coast and Mid-Coast of Oregon, which had only “low” certainty of being persistent. The strongest strata were the Lakes and Mid-South Coast, which had “high” certainty of being persistent. To increase certainty that the ESU as a whole is persistent, they recommended that restoration work should focus on those populations with low persistence, particularly those in the North Coast, Mid-Coast, and Umpqua strata.

A 2010 Biological Recovery Team (BRT) (Stout *et al.* 2011) noted significant improvements in hatchery and harvest practices have been made. It has not been demonstrated that productivity during periods of poor marine survival is now adequate to sustain the ESU. Recent increases in adult escapement do not provide strong evidence that the century-long downward trend has changed. The ability of the OC coho salmon ESU to survive another prolonged period of poor marine survival remains in question.

Current concerns for spatial structure focus on the Umpqua River. Of the four populations in the Umpqua stratum, two, the North Umpqua and South Umpqua, were of particular concern. The North Umpqua is controlled by Winchester Dam and has historically been dominated by hatchery fish. Hatchery influence has recently been reduced, but the natural productivity of this population remains to be demonstrated. The South Umpqua is a large, warm system with degraded habitat. Spawner distribution appears to be seriously restricted in this population, and it is probably the most vulnerable of any population in this ESU to increased temperatures.

Current status of diversity shows improvement through the waning effects of hatchery fish on populations of OC coho salmon. In addition, recent efforts in several coastal estuaries to restore lost wetlands should be beneficial. However, diversity is lower than it was historically because of the loss of both freshwater and tidal habitat loss coupled with the restriction of diversity from very low returns over the past 20 years.

The BRT concluded that there is a moderate certainty of ESU persistence over the next 100 years and a low-to-moderate certainty that the ESU is sustainable for the foreseeable future, assuming no future trends in factors affecting the ESU. The NMFS issued a final determination to retain the ESA-listing status, effective June 20, 2011. Thus, the February 2008 critical habitat designation and 4(d) regulations remain in effect (USDC 2011b).

Limiting factors and threats to the OC coho salmon ESU include (Stout *et al.* 2011, NOAA Fisheries 2011):

- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, stream flow, and water quality have been degraded as a result of cumulative impacts of agriculture, forestry, instream mining, dams, road crossings, dikes, levees, *etc.*
- Fish passage barriers that limit access to spawning and rearing habitats.
- Adverse climate, altered past ocean/marine productivity, and current ocean ecosystem conditions have favored competitors and predators and reduced salmon survival rates in freshwater rivers and lakes, estuaries, and marine environments.

<u>Coos River population.</u> OC coho salmon occurring in the action area are part of the Coos River population that was identified as a functionally-independent population. An independent population is one that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years (Lawson *et al.* 2007). The Coos River population is part of the Mid-South Coast biogeographic strata defined within the OC coho salmon ESU (Lawson *et al.* 2007).

Annual spawning surveys document the Coos River population's annual abundance varies considerably from year to year (Table 3).[2] The recent trend in this population's abundance is consistent with ESU level abundance trends. (Table 3). The Coos River population has been relatively stable except for the 2007 run year as the abundance fell to just 1,329 fish. The condition of freshwater habitat continues to limit the Coos River population production, especially the loss of winter habitat and stream complexity. This type of habitat is important to juvenile coho salmon looking for refuge during large flood events.

**Table 3.** Annual estimates of OC coho salmon natural spawner abundance in the Coos River system based on monitoring data collected by ODFW (includes Big Creek for 1990-2004).

| **Year** | **Coos River Basin** |
|---|---|
| 1990 | 2,273 |
| 1991 | 3,813 |
| 1992 | 16,545 |
| 1993 | 15,284 |
| 1994 | 14,685 |
| 1995 | 10,351 |
| 1996 | 12,128 |
| 1997 | 1,127 |
| 1998 | 3,167 |
| 1999 | 4,945 |
| 2000 | 5,386 |
| 2001 | 43,301 |
| 2002 | 35,429 |
| 2003 | 29,559 |
| 2004 | 24,116 |
| 2005 | 17,048 |
| 2006 | 11,266 |
| 2007 | 1,329 |
| 2008 | 14,881 |
| 2009 | 26,979 |
| 2010 | 27,658 |
| **1990-2010 Avg.** | **15,298** |

***Southern Green Sturgeon.*** Two distinct population segments (DPS) have been defined for southern green sturgeon, a northern DPS (spawning populations in the Klamath and Rogue rivers) and a southern DPS (spawners in the Sacramento River). Southern green sturgeon includes all naturally-spawned populations of southern green sturgeon that occur south of the Eel River in Humboldt County, California. When not spawning, this anadromous species is broadly distributed in nearshore marine areas from Mexico to the Bering Sea. Although it is commonly observed in bays, estuaries, and sometimes the deep riverine mainstem in lower elevation reaches of non-natal rivers along the west coast of North America, the distribution and timing of estuarine use are poorly understood.

[2] http://oregonstate.edu/dept/ODFW/spawn/pdf%20files/coho/AnnualEstESU1996-2010.pdf

In addition to the Puget Sound recovery domain, southern green sturgeon occur in the Willamette and Lower Columbia, Oregon Coast, and Southern Oregon/Northern California Coasts recovery domains. However, southern green sturgeon habitat in the Puget Sound recovery area was not designated as critical habitat.

The principal factor for the decline of southern green sturgeon is the reduction of its spawning area to a single known population limited to a small portion of the Sacramento River. It is currently at risk of extinction primarily because of human-induced ''takes'' involving elimination of freshwater spawning habitat, degradation of freshwater and estuarine habitat quality, water diversions, fishing, and other causes (USDC 2010). Adequate water flow and temperature are issues of concern. Water diversions pose an unknown but potentially serious threat within the Sacramento and Feather rivers and the Sacramento River Delta. Poaching also poses an unknown but potentially serious threat because of high demand for sturgeon caviar. The effects of contaminants and nonnative species are also unknown but potentially serious threats. As mentioned above, retention of green sturgeon in both recreational and commercial fisheries is now prohibited within the western states, but the effect of capture/release in these fisheries is unknown. There is evidence of fish being retained illegally, although the magnitude of this activity likely is small (NOAA Fisheries 2011).

Southern green sturgeon are known to occupy Coos Bay during the summer months. Southern green sturgeon only spawn in the Sacramento River basin in California, therefore juvenile southern green sturgeon are not present in Coos Bay. However, adult and subadult southern green sturgeon use estuarine areas for foraging and growth and development outside of the natal river system (Moser and Lindley 2007). Data from Washington studies indicate that southern green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007). While in Coos Bay, they likely seek out the deepest habitats to rest during low tides and feed on invertebrates in shallow water during high tides.

***Eulachon.*** The southern distinct population segment of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Core populations for this species include the Fraser River, Columbia River, and (historically) the Klamath River. Eulachon leave saltwater to spawn in their natal streams late winter through early summer, and typically spawn at night in the lower reaches of larger rivers fed by snowmelt. After hatching, larvae are carried downstream and widely dispersed by estuarine and ocean currents. Eulachon movements in the ocean are poorly known although the amount of eulachon bycatch in the pink shrimp fishery seems to indicate that the distribution of these organisms overlap in the ocean.

The viability of this species is under assessment although abrupt and continuing declines in abundance throughout its range and the added vulnerability that a small population size presents for this type of highly fecund, broadcast spawning species are of particular concern. Of the four components of species viability criteria, abundance of the eulachon has declined to historical low levels, productivity is of concern due to climate change, diversity is limited to a single age class, and spatial structure is declining as runs sizes dwindle throughout their range (Drake *et al.* 2008).

In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River with no evidence of returning to their former population levels since then (Drake *et al.* 2008). Persistent low returns and landings of eulachon in the Columbia River from 1993 to 2000 prompted the states of Oregon and Washington to adopt a Joint State Eulachon Management Plan in 2001 that provides for restricted harvest management when parental run strength, juvenile production, and ocean productivity forecast a poor return (WDFW and ODFW 2001). Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings have again declined to the very low levels observed in the mid-1990s (JCRMS 2010), and since 2005, the fishery has operated at the most conservative level allowed in the management plan (JCRMS 2010). Large commercial and recreational fisheries have occurred in the Sandy River in the past. The most recent commercial harvest in the Sandy River was in 2003. No commercial harvest has been recorded for the Grays River from 1990 to the present, but larval sampling has confirmed successful spawning in recent years (USDC 2011a).

There is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuary. In the *Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries* (Monaco *et al*. 1990) it describes eulachon as "rare" in the Coos Bay estuary.

The primary factors responsible for the decline of the southern DPS of eulachon are changes in ocean conditions due to climate change (Gustafson *et al.* 2010, Gustafson *et al*. 2011), particularly in the southern portion of its range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success. Additional factors include climate-induced change to freshwater habitats, dams and water diversions (particularly in the Columbia and Klamath rivers where hydropower generation and flood control are major activities), and bycatch of eulachon in commercial fisheries (NOAA Fisheries 2011).

Other limiting factors include (Gustafson *et al.* 2010, Gustafson *et al*. 2011):

- adverse effects related to dams and water diversions
- artificial fish passage barriers
- increased water temperatures, insufficient streamflow
- altered sediment balances
- water pollution
- over-harvest
- predation

### 2.2.2 Status of the Critical Habitat

Climate change, as described in Section 2.2, is likely to adversely affect the conservation value of designated critical habitats in the Pacific Northwest. The conservation value of critical habitats considered in the opinion generally declined during the era of European settlement due to depletion of cold water habitat and other variations in quality and quantity of spawning, rearing, and migration habitats associated with development of riverine and estuarine areas (Ford *et al*. 2010).

The NMFS reviews the status of designated critical habitat affected by the proposed action by examining the condition and trends of PCEs throughout the designated area. These PCEs vary slightly for some species, due to biological and administrative reasons, but all consist of site types and site attributes associated with life history events.

**Oregon Coast Recovery Domain.** In this recovery domain, critical habitat has been designated for OC coho salmon, eulachon, and southern green sturgeon. Many large and small rivers supporting significant populations of OC coho salmon flow through this domain, including the Nehalem, Nestucca, Siletz, Yaquina, Alsea, Siuslaw, Umpqua, Coos, and Coquille.

The historical disturbance regime in the central Oregon Coast Range was dominated by a mixture of high and low-severity fires, with a natural rotation of approximately 271 years. Old-growth forest coverage in the Oregon Coast Range varied from 25 to 75% during the past 3,000 years, with a mean of 47%, and never fell below 5% (Wimberly *et al.* 2000). Currently, the Coast Range has approximately 5% old-growth, almost all of it on Federal lands. The dominant disturbance now is logging on a cycle of approximately 30 to 100 years, with fires suppressed.

***OC Coho Salmon.*** The state of Oregon (2005) completed an assessment of habitat conditions in the range of OC coho salmon in 2005. Oregon's assessment mapped how streams with high intrinsic potential for OC coho salmon rearing are distributed by land ownership categories. Agricultural lands and private industrial forests have by far the highest percentage of land ownership in high intrinsic potential areas and along all OC coho salmon stream miles. Federal lands have only about 20% of OC coho salmon stream miles and 10% of high intrinsic potential stream reaches. Because of this distribution, activities in lowland agricultural areas are particularly important to the conservation of OC coho salmon.

The OC coho salmon assessment concluded that at the scale of the entire domain, pools are generally abundant, although slow-water and off-channel habitat (which are important refugia for OC coho salmon during high winter flows) are limited in the majority of streams when compared to reference streams in minimally-disturbed areas. Amounts of large wood in streams are low in all four ODFW monitoring areas and land-use types relative to reference conditions. Amounts of fine sediment are high in three of the four monitoring areas, and were comparable to reference conditions only on public lands. Approximately 62 to 91% of tidal wetland acres (depending on estimation procedures) have been lost for functionally and potentially independent populations of OC coho salmon.

As part of the coastal OC coho salmon assessment, the Oregon Department of Environmental Quality analyzed the status and trends of water quality in the range of OC coho salmon using the Oregon water quality index, which is based on a combination of temperature, dissolved oxygen, biological oxygen demand, pH, total solids, nitrogen, total phosphates, and bacteria. Using the index at the species scale, 42% of monitored sites had excellent to good water quality and 29% show poor to very poor water quality. Within the four monitoring areas, the North Coast had the best overall conditions (six sites in excellent or good condition out of nine sites), and the Mid-South coast had the poorest conditions (no excellent condition sites and two out of eight sites in good condition). For the 10-year period monitored between 1992 and 2002, no sites showed a declining trend in water quality. The area with the most improving trends was the North Coast, where 66% of the sites (six out of nine) had a significant improvement in index scores. The Umpqua River basin, with one out of nine sites (11%) showing an improving trend, had the lowest number of improving sites.

The specific unit of OC coho salmon critical habitat that will be affected by the proposed action is the Coos Bay Frontal 5th field HUC (1710030403). The action area comprises only a portion of the 5th field HUC. This portion only contains PCEs necessary for rearing and migration (Table 4). The NMFS Critical Habitat Analytical Review Team (CHART) identified agriculture, forestry, grazing, road building/maintenance, and urbanization as key management activities affecting the PCEs within this watershed. More specifically, the landscape changes are largely from: a loss of large woody debris and forested land cover, dredging and urbanization of lower estuary, and diking and draining of wetlands (mostly for urban development, agriculture and grazing). The CHART considered this watershed and the associated Coos River mainstem as having high conservation value.

**Table 4.** PCEs of critical habitats designated for ESA-listed OC coho salmon and corresponding species life history events.

| Primary Constituent Elements | | Species Life History Event |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Freshwater spawning | Substrate<br>Water quality<br>Water quantity | Adult spawning<br>Embryo incubation<br>Alevin growth and development |
| Freshwater rearing | Floodplain connectivity<br>Forage<br>Natural cover<br>Water quality<br>Water quantity | Fry emergence from gravel<br>Fry/paar/smolt growth and development |
| Freshwater migration | Free of artificial obstruction<br>Natural cover<br>Water quality<br>Water quantity | Adult sexual maturation<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |
| Estuarine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Salinity<br>Water quality<br>Water quantity | Adult sexual maturation and "reverse smoltification"<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |
| Nearshore marine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Water quantity<br>Water quality | Adult growth and sexual maturation<br>Adult spawning migration<br>Nearshore juvenile rearing |
| Offshore marine areas | Forage<br>Water quality | Adult growth and sexual maturation<br>Adult spawning migration<br>Subadult rearing |

***Southern Green Sturgeon.*** For freshwater rivers north of and including the Eel River, the areas upstream of the head of the tide were not considered part of the geographical area occupied by the southern DPS. However, the critical habitat designation recognizes not only the importance of natal habitats, but of habitats throughout their range. Critical habitat has been designated in coastal U.S. marine waters within 60 fathoms depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) and freshwater (USDC 2009). Table 5 delineates PCEs for southern DPS green sturgeon.

The CHART identified several activities that may threaten the PCEs in coastal bays and estuaries and may necessitate the need for special management considerations or protection.

The application of pesticides may adversely affect prey resources and water quality within the bays and estuaries, as well as the growth and reproductive health of southern DPS green sturgeon through bioaccumulation. Other activities of concern include those that may disturb bottom substrates, adversely affect prey resources, or degrade water quality through re-suspension of contaminated sediments. Of particular concern are activities that affect prey resources. Prey resources can be affected by: commercial shipping and activities generating point source pollution and non-point source pollution that can discharge contaminants and result in bioaccumulation of contaminants in southern green sturgeon; disposal of dredged materials that can bury prey resources; and bottom trawl fisheries that can disturb the bottom (but may result in beneficial or adverse effects on prey resources for southern green sturgeon). In addition, petroleum spills from commercial shipping activities and proposed alternative energy hydrokinetic projects may affect water quality or hinder the migration of southern green sturgeon along the coast (USDC 2009).

The southern green sturgeon considered in this opinion migrate through the action area and use it for rearing. Thus, the affected PCEs for estuarine area are adult/subadult rearing and migration.

**Table 5.** PCEs of critical habitat proposed for southern green sturgeon and corresponding species life history events.

| Primary Constituent Elements | | Species Life History Event |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Freshwater riverine system | Food resources<br>Migratory corridor<br>Sediment quality<br>Substrate type or size<br>Water depth<br>Water flow<br>Water quality | Adult spawning<br>Embryo incubation, growth and development<br>Larval emergence, growth and development<br>Juvenile metamorphosis, growth and development |
| Estuarine areas | Food resources<br>Migratory corridor<br>Sediment quality<br>Water flow<br>Water depth<br>Water quality | Juvenile growth, development, seaward migration<br>Subadult growth, development, seasonal holding, and movement between estuarine and marine areas<br>Adult growth, development, seasonal holding, movements between estuarine and marine areas, upstream spawning movement, and seaward post-spawning movement |
| Coastal marine areas | Food resources<br>Migratory corridor<br>Water quality | Subadult growth and development, movement between estuarine and marine areas, and migration between marine areas<br>Adult sexual maturation, growth and development, movements between estuarine and marine areas, migration between marine areas, and spawning migration |

***Eulachon.*** The NMFS designated critical habitat for eulachon in October of 2011. Coos Bay was not designated as critical habitat for eulachon and therefore is not analyzed in this opinion.

## 2.3 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

The action area is located within the Coos Bay estuary, the second largest estuary in Oregon, and includes Isthmus Slough, a bifurcation of the estuary. Coos Bay is approximately 13,300 acres, averaging nearly 0.62 mile wide by 15 miles long (Cortright *et al*. 1987). The bay has nearly 30 tributaries, the major tributary being the Coos River. Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary, reducing an estimated 90% of Coos Bay marshes (Proctor *et al.* 1980). Intense development in and around the estuary has impacted the shoreline and intertidal zone by removing vegetation and habitats.

The Coos Bay estuary is classified as a drowned river mouth-type estuary, where winter flows discharge high volumes of sediment through the estuary. In summer, when discharge is lower, seawater inflow dominates the estuary. Isthmus Slough is listed on the Oregon Department of Environmental Quality 303(d) list for water quality limited streams for temperature, ammonia, chlorophyll, dissolved oxygen, fecal coliform, manganese, and pH (ODEQ 2008).

Tributaries to Coos Bay exhibit evidence of bed degradation and are disconnected with their floodplains. Bank erosion is common throughout their lengths, and bedrock is the predominant substrate. Urban, rural residential, and agriculture uses are impacting Coos Bay and its tributaries. Riparian vegetation is mostly limited to a narrow strip alongside the rivers. Bank erosion has elevated turbidity to levels that injure OC coho salmon and impair their feeding and sheltering. Limiting factors to the OC coho salmon population within the action area include degraded water quality and limited quantity of productive shallow-water habitat such as saltwater marsh and eelgrass beds.

The action area is located in North Bend upstream of the Highway101 bridge. The land use around the project site is primarily commercial and industrial.. The bay is maintained as a deepwater port by the Corps. The shoreline from OTC upstream is industrial property with deep docks and associated shipping traffic. The shoreline remains deep (20 feet or greater) for approximately 3 miles before reaching the confluence of Isthmus Slough. Shallow-water habitat (less than 10 feet) is not available on the western shoreline upstream from the OTC project until after the confluence of Isthmus Slough. The shoreline characteristics include riprap banks, docks located on treated piles, and historic fill. The east bank of the estuary of the action area has several historic dredging disposal spoil islands, contains large, shallow-water mudflats, and is actively farmed for oysters.

The shoreline in the action area contains mudflats with depths ranging from 1 to 7 feet in the fill location behind the sheet pile, and 7 to 36 feet in the location of the existing and proposed docks. The riprap toe for fill placement is estimated at 12 feet deep. The slope shoreline at the proposed sheet pile fill is very flat where as the shoreline at the proposed riprap fill is very steep. The existing banks contain concrete and rock placed for erosion protection. Historic treated piles are located through the shoreline, inside of the existing docks. No vegetation is present in the mud flats throughout the action area, or in the riparian area. Logs are stacked in the riparian area of the mudflats. The area's aquatic habitat is degraded and in poor condition.

## 2.4 Effects of the Action

"Effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

### 2.4.1 Effects on the Environment

The proposed action will affect the ESA-listed fish species by causing physical and biological changes to the environmental baseline, and through direct and indirect effects to these species. The proposed action includes offsite compensatory mitigation to reduce net adverse impacts by improving habitat conditions and survival for aquatic species. The NMFS will evaluate the net combined effects of the proposed action and the offsite compensatory mitigation measures as interrelated actions.

#### Water Quality Degradation

**Total Suspended Solids and Sedimentation.** In-water construction activities such as fill, pile driving, treated pile removal, and ground disturbance are likely to temporarily increase erosion and concentrations of total suspended solids and sedimentation. The OTC is placing a sediment curtain surrounding the placement of fill to minimize some of these impacts.

The largest negative effects to substrate will occur from driving of sheet pile, pile removal, and placement of associated construction fill. Short-term pulses of sediment are likely to occur after removal of the piles and the areas where material was disturbed during construction, driving piles, and during placement of fill behind the sheet pile. Decreasingly small pulses of sediment (re-suspension lasting a few hours to a day) may continue to occur for the next three months until all disturbed materials in the construction area settle into place. This sediment is not likely to move more than 100 feet downstream and upstream from the construction fill, pile driving, and pile removal activities. Some sedimentation of substrates, primarily used by OC coho salmon and southern green sturgeon for migration and rearing, will occur in the bay. Fine, redeposited sediments have the potential to reduce primary and secondary productivity (Spence *et al.* 1996) for juvenile OC coho salmon.

**Chemical Contaminants.** The OTC is also planning to remove 256 treated piles during dock improvements. The existing treated wood piles have been leaching contaminants into the water and the sediment for decades. Long-term beneficial effects include the reduction of predator ambush areas and removal of chemical contaminants. Short-term effects include the potential chemical contamination from broken piles or redistribution of chemicals during pile removal, especially without implementation of best management practices.

Any time machinery is operated in close proximity to a stream; there is some chance a large fuel spill or hydraulic line rupture will occur. The NMFS believes the probability of this occurring is very low, but not discountable. If a spill of this nature were to occur, its volume could likely be as little as a few ounces or as much as 50 gallons. If there is a leak, it is typically small resulting in only a few ounces being released. A small amount of fuel likely could be released from the construction area, where it would be noticeable as much as 100 feet downstream or upstream depending on the tidal cycle before being diluted to immeasurable concentrations, prior to reaching the lower limits of the action area. In the immediate area it could have short-term effects on water quality.

Increased impervious surface and resulting stormwater management will result in discharged stormwater into Coos Bay. The proposed project will add 0.46 acre of dock and adjacent 3.9 acres of fill to the impervious area. The outfall contribution areas are shown in Table 6.

Stormwater runoff delivers a wide variety of pollutants to aquatic ecosystems, such as nutrients, metals, petroleum-related compounds, and sediment washed off the road surface (Driscoll *et al*. 1990, Buckler and Granato 1999, Colman *et al.* 2001, Kayhanian *et al.* 2003). These ubiquitous pollutants are a source of potent adverse effects to ESA-listed OC coho salmon, green sturgeon, and eulachon and, even at ambient levels (Loge *et al*. 2006, Hecht *et al*. 2007, Johnson *et al*. 2007, Sandahl *et al*. 2007, Spromberg and Meador 2006). Aquatic contaminants often travel long distances in solution or attached to suspended sediments, or gather in sediments until they are mobilized and transported by next high flow (Anderson *et al*. 1996, Alpers *et al*. 2000a, 2000b). These contaminants also accumulate in the prey and tissues of juvenile salmon where, depending on the level of exposure, they cause a variety of lethal and sublethal effects on salmon including disrupted behavior, reduced olfactory function, immune suppression, reduced growth, disrupted smoltification, hormone disruption, disrupted reproduction, cellular damage, and physical and developmental abnormalities (Fresh *et al*. 2005, Hecht *et al*. 2007, LCREP 2007).

**Table 6.** Outfall Contribution Areas

| Outfall Designation | Description | Area (Acres) | Impervious Area | |
|---|---|---|---|---|
| | | | Acres | Percent |
| 1 | S. Outlet | 10.48 | 10.48 | 100% |
| 2 | N. Outlet | 3.31 | 3.31 | 100% |
| 3 | Center Outlet | 13.85 | 13.85 | 100% |
| 4 | N. Drain | 1.38 | .07 | 5% |
| Beach | Non-point | 0.75 | .04 | 5% |
| Facility Total | | 29.77 | 27.75 | |

Baldwin *et al*. (2003) exposed juvenile coho salmon to various concentrations of copper to evaluate sublethal effects on sensory physiology, specifically olfaction. These researchers demonstrated that short pulses of dissolved copper at concentrations as low as 2 μg/L over experimental background concentrations of 3 μg/L reduced olfactory sensory responsiveness within 20 minutes such that the response evoked by odorants was reduced by approximately 10%. At 10 µg/L over background, responsiveness was reduced by 67% within 30 minutes. They calculated neurotoxic thresholds sufficient to cause olfactory inhibition at 2.3 to 3.0 µg/L over background. They also referenced three studies that reported copper exposures over four hours cause cell death of olfactory receptor neurons within rainbow trout, Atlantic salmon, and Chinook. The concentrations tested are lower than common concentrations in stormwater outfalls, and thus indicate toxicity even after stormwater has been moderately diluted. The measured exposure times are likewise shorter than typical stormwater outfall discharge times. Inhibiting olfaction is detrimental to salmon because olfaction plays a significant role in the recognition and avoidance of predators and migration back to natal streams to spawn (Baldwin *et al*. 2003). More recent research indicates that the effect of 2 µg/L concentrations over experimental background concentrations of 3 µg/L reduces the survival of individuals (Hecht *et al.* 2007).

A review of zinc toxicity studies reveals effects including reduced growth, behavioral alteration (avoidance), reproduction impairment, increased respiration, decreased swimming ability, increased jaw and bronchial abnormalities, hyperactivity, and hyperglycemia. Juvenile fish are more sensitive. Both avoidance in juveniles and growth in adults exposed to zinc have been documented at 5.6 µg/L and 1,120µg/L, respectively. When making general comparisons between lethal and sublethal endpoints tested on juvenile rainbow trout, the sublethal effects occur at concentrations approximately 75% less (5.6 µg/L) than lethal effects (24 µg/L) (EPA 1980; Hansen *et al*. 2002). Even relatively low concentrations (5.6 µg/L, established for juvenile rainbow trout) resulted in avoidance of the plume. NMFS is certain that similar results for salmon will occur.

Stormwater is a complex mixture of many contaminants originating on roads, landscaping, and other surfaces. Most published literature addresses acute toxicity of single pollutants, although pollutants from stormwater exist in mixtures in waterbodies and interact with each other (*e.g*., Niyogi *et al*. 2004). Rand and Petrocelli (1985) state that in “assessing chemically induced effects (responses), it is important to consider that in the natural aquatic environment organisms may be exposed not to a single chemical but rather to a myriad or mixture of different substances at the same or nearly at the same time. Exposures to mixtures may result in toxicological interactions.” A toxicological interaction is one in which exposure to two or more pollutants results in a biological response quantitatively or qualitatively different from that expected from the action of each chemical alone. Exposure to two or more pollutants simultaneously may produce a response that is simply additive of the individual responses or one that is greater (synergistic) or less (antagonistic) than expected from the addition of their individual responses (Denton *et al*. 2002). For example, mixtures of zinc and copper have greater than additive toxicity to a wide variety of aquatic organisms including freshwater fish (Eisler 1993). Although the large number of pollutants and much larger number of toxicological interactions in urban stormwater make specific mechanisms of toxicological effects difficult to predict, there is ample evidence that the mixture of toxins in urban stormwater can degrade habitat enough to substantially reduce its ability to support spawning, feeding, and growth to maturity.

Sediment contamination from stormwater has also been identified in work by the Puget Sound Ambient Monitoring Program on changes and trends in Puget Sound sediments (Dutch *et al*.

2005). These authors noted an increase in PAHs in sediment since the 1980s, attributable to stormwater conveyance from increasing urbanization and vehicle traffic (Lefkovitz *et al*. 1997, Van Metre *et al*. 2000, both as cited in Dutch *et al*. 2005). Therefore, the accumulation of PAHs and other contaminants in the sediment will affect ESA-listed fish over the long term.

The OTC will achieve some stormwater treatment through construction of oil/water separators in the ten catch basins and filtration through ditch lines located on the western property lines of the OTC facility. However, oil/water separators do not remove heavy metals and not all the water flows through the ditchlines. Therefore, adequate removal of stormwater contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Water quality monitoring at this site has demonstrated inadequate treatment. Stormwater testing for sample site #3 on January 17, 2011, found copper at 26 μg/L and Zinc at 83.7 μg/L.[3] The proposed action will likely result in a small increase in discharge of heavy metals because: (1) It does not treat heavy metals any better than they were treated in 2011; (2) it is increasing the amount of impervious surfaces; and (3) the amount of vehicular use and parking is likely to marginally increase due to the increased capacity of shipping.

The improvements to the dock facility at the OTC terminal will allow 12 additional ships annually. These vessels will intake ballast water for stability of the ship. Ballast water has the opportunity to carry invasive species. The United States Coast Guard now requires these ships to empty their ballast water off-shore at least 200 nautical miles. For fish and invertebrates in the action area, the movement and operation of the vessels while in Port is not likely to create a detectable adverse affect on water quality or individuals because open ocean ballast exchange would have occurred outside of 200 nautical miles minimizing the likelihood of non-native species being introduced into Coos Bay.

**Loss of Shallow-Water Habitats and Forage.** The OTC is planning to use clean sand from the North Spit to fill behind the sheet pile and the riprap toe. The adverse effects include loss of shallow-water habitats, short-term negative water quality effects from sediment pulses (discussed above), reduction of benthic forage, and loss of shallow habitat for aquatic vegetation to recover.

The sheet pile and upstream riprap that provides fill containment can also affect water currents and depositional areas that provide food resources for ESA-listed species. The changing of the substrate on the slope from soft benthic substrate to rock riprap will change characteristics of the shoreline to harder surfaces, with interspatial hiding areas for fish.

Overwater structures and associated activities can impact ecological functions of habitat by altering those controlling factors that support key ecological functions such as rearing, and refugia (Nightingale and Simenstad 2001). It is hypothesized that overwater structures can cause long-term impacts to the biological community and the environment by altering predator/prey relationships, fish behavior, and habitat function.

---

[3] Email from John Craig, OTC consultant, to Jim Muck, NMFS, December 28, 2011 (Transmitting water quality testing results).

Shading, or the loss of ambient light to underwater environments, can reduce the abundance of phytoplankton, benthic macroalgae, and vascular plants such as eelgrass (Nightingale and Simenstad 2001). These primary producers are an important part of the food webs supporting juvenile salmon and other fish in estuarine and nearshore marine environments. However, with the sheet pile extended to 7 feet, much of the rearing area for plant growth is already impacted. Overwater structures can also impact fish migratory behavior by creating sharp underwater light contrasts through the casting of shade under ambient daylight conditions and artificial night lighting changes (Nightingale and Simenstad 2001).

The OTC completed compensatory mitigation in 1997 by breaching a diked pastureland and removing the existing tidegate. Fill from the dike was used to fill existing drainage ditches and construct a dike on the southern property line to prevent flooding of the adjacent land. The compensatory mitigation included 1.4 acres of restoration (1 to 1 credit ratio), and 10.20 acres of enhancement (3 to 1 credit ratio). The goal of the mitigation was the reestablishment of tidal flow to the protected pasture, restoring fish and wildlife functions and to allow low marsh and aquatic communities to reestablish. These mitigation goals are intended to compensate for the loss in shallow-water habitats and forage from the proposed project.

A monitoring report for the site was completed in May 2003 by Wetland Environmental Technologies (Craig 2003). The site is demonstrating anoxic soil conditions and formation of tidal channels. Pasture grasses and other aquatic plants have died as they do not tolerate brackish water. The salinity in the mitigation area was 25 parts per thousand (PPT) during monitoring. Clam holes are present through the mitigation area. The area continues to restore itself to a natural estuarine habitat meeting the goals of the compensatory mitigation plan.

**Hydro Acoustics.** Generally, vibratory hammers are much quieter than impact hammers. The degree to which an individual fish exposed to underwater sound will be affected (from a startle response to immediate mortality) is dependent on the number of variables such as species of fish, size of the fish, presence of a swimbladder, sound pressure intensity and frequency, shape of the sound wave (rise time), depth of the water around the pile and the bottom substrate composition and texture. The OTC proposes to use a vibratory hammer without any proofing for pile installation. Vibratory hammers produce a rounded sound pressure wave with a slower rise time. In contrast, impact hammers produce sharp sound pressure waves with rapid rise times, the equivalent of a punch versus a push in comparison to vibratory hammers. The sharp sound pressure waves associated with impact hammers represent a rapid change in water pressure level. In general, underwater noise affects rapid pressure changes, especially on gas-filled spaces in the body causing the injury and mortality effects to fish. Because the more rounded sound pressure wave produced by vibratory hammers produces a slower increase in pressure, the potential for injury and mortality is reduced. However, sound waves may cause migrating fish to move across the channel to avoid the noise and construction activities.

**Entrainment.** The proposed action will increase shipping in Coos Bay by one vessel per month, or 12 ships annually. NMFS determines the increase in shipping an interrelated effect from the proposed action. Large ships use intakes called a seachest to pull water for cooling and ballast water. Information is limited on intake seachest for ballast water and engine cooling systems for ships entering Coos Bay that are destined for loading at the OTC terminal. The OTC sent an e-mail with typical drawings for OTC ships.[4] The seachests are located at 14.1 feet depth when empty, and 26.9 feet depth when the vessel is full. The orifice area is 1.25 feet by 18.8 feet with 16 bars that are 0.4 inches wide along the longest length. The intake flow is 2.35 cubic feet/second. NMFS fish passage engineering staff reviewed these figures and determined that the screen and required intake flow meet NMFS screening measures, if the ship only used cooling intakes and not combined with ballast water intake.[5] The OTC ships do not require ballast water intake during log loading operations at the OTC terminal.

### 2.4.2 Effects on Listed Species

The in-water timing construction is planned for October 1 to February 15. The habitat in the action area is degraded, composed of concrete blocks, excess bark from log storage, and lacking aquatic or riparian vegetation. NMFS is reasonable certain that juvenile eulachon or OC coho salmon will not use the action area during the in-water work season (Table 7). Adult OC coho salmon migrate through the action area from September through December, with peak migration in October. Juvenile OC coho salmon are not present during construction because they are rearing in upper tributaries (Miller and Sadro 2003, Koski 2009). Adult eulachon are very rare in the Coos Bay estuary (Monaco *et al.* 1990), but may occur in the months of late December through May. Southern green sturgeon are not present during the in-water work period in the Coos Bay estuary (Moser and Lindley 2007).

The proposed action is reasonably likely to have the following direct and indirect effects on OC coho salmon, southern green sturgeon, and eulachon. The duration of the effects will vary from ephemeral (instantaneous to hours) or short-term (days to months), and indirect effects are long-term (years to decades, or the life of the project).

**Table 7.** Life cycle migration and rearing patterns of Eulachon, OC coho salmon, and green sturgeon located in the action area of the Coos Bay estuary. Darker colors represent peak occurrence. Construction window is located at the bottom row.

| Species | Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult OC coho salmon | | | | | | | | | | | | |
| Juveniles OC coho | | | | | | | | | | | | |
| Adult Eulachon | | | | | | | | | | | | |
| Juvenile Eulachon | | | | | | | | | | | | |
| Adult/subadult green sturgeon | | | | | | | | | | | | |
| Construction Window | | | | | | | | | | | | |

[4] E-mail from Lori Nelson (for Jim Lyons), OTC, to Jim Muck NOAA Fisheries, (November 10, 2011) (delivering Seachest drawings and flow for typical OTC vessels).

[5] E-mail from Aaron Beavers, NOAA Fisheries, to Jim Muck, NOAA Fisheries, (November 10, 2011) (reviewing screening and intake for vessels at the OTC terminal.)

**Water Quality Degradation**

**<u>Total Suspended Solids and Sedimentation</u>.** The proposed action will re-suspend sediments during construction fill and pile driving. Consolidated substrate will be loosened and re-suspended either immediately because the activity will occur subtidally, or at a later time once the disturbed area is inundated on the next tide. The turbidity plume will likely persist for a few hours (1 to 3 hours) given that the sediment size is larger grain sand. Short-term pulses are likely to occur from pile driving and removal activities, and may redistribute sediment for several weeks after pile driving and removal activity. Although no estimates were provided for number of piles driven or removed per day, NMFS estimated that to drive and remove 194 piles and drive sheet pile, the project will take at least 2 months of in-water work. That will provide an exposure of at least 2 to possibly 3 months of sediment to ESA-listed species in the action area during construction.

Adult OC coho salmon will likely have exposure to very low levels (if any at all) of turbid water associated with the construction since the pile driving and removal will only disturb a small amount of sediment. Adult OC coho salmon and eulachon are expected to move away from areas where construction is occurring. Sedimentation is not likely to reduce food resources of juvenile OC coho salmon or southern green sturgeon due to the small amount of sediment disturbed, it remaining within 100 feet of the activity, and it matching the existing substrate in the action area. The NMFS is reasonably certain the effects of suspended sediment and sedimentation are insignificant and will not cause a reduction of survival or harm OC coho salmon, southern green sturgeon or eulachon.

**<u>Chemical Contaminants</u>.** Accidental release of fuel, oil, and other contaminants can injure or kill aquatic organisms. Petroleum based contaminants, such as fuel, oil, and some hydraulic fluids, contain polycyclic aromatic hydrocarbons, which can kill salmon at high levels of exposure and can also cause sub-lethal adverse effects at lower concentrations (Neff 1985).

Any spills outside of the contained work area may affect any OC coho salmon or eulachon that are in the immediately area or upstream or downstream from the spill depending on tide cycle. However, few individuals should be in the action area, and there is a very low risk of a spill. Therefore, this should have very little effect on the species. Any spills within the construction area should be cleaned up prior to removal of spill barriers.

OTC will remove approximately 256 treated piles as part of this project. The existing treated wood piles have been leaching contaminants into the water and the sediment for decades. The applicant did not propose conservation measures to reduce contaminants from leaching during pile removal. During removal there is potential for contaminants to be re-suspended in the water column without conservation measures to further minimize leaching of treated wood chemicals. Due to an incoming and outgoing tide, this suspension of contaminants will move up and down in the estuary with tidal flow and eventually resettle into the mud. Although this effect is considered short-term (2 to 3 months), these exposed contaminants have the potential to kill or cause sub-lethal adverse effects to OC coho salmon, green sturgeon, and eulachon. Additionally, future maintenance dredging can further redistribute these chemicals.

After pile removal, long-term water quality should improve with the replacement of concrete and steel piles. In the long-term, removal of treated piles is a benefit to ESA-listed species in the estuary.

Increased impervious surface and resulting stormwater management will result in discharged stormwater into Coos Bay. The proposed project will add 0.46 acre of dock and adjacent 3.9 acres of fill to the impervious area. Despite some stormwater treatment, complete removal of contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Coos Bay estuary maintains high salinity even during high winter rains. This demonstrates the estuary has slow flushing, even with high flows that occur during the winter. Stormwater entering at the OTC site will concentrate near the stormwater outlets at the estuary, but will linger in the estuary with the ongoing tide cycles until eventually flushed downstream. Concentrations of copper and zinc will exceed thresholds causing injury and death of ESA-listed species, as demonstrated by the January 2011 sampling. Given the concentration of contaminants, the volume of the bay, and tidal flushing, NMFS is reasonably certain these thresholds will be exceeded throughout areas within 200 feet of each outfall, with highest concentrations within 100 feet of each outfall.

Quantifying the number of ESA species that death and injury will occur is difficult to estimate, but NMFS is reasonable certain the number of individuals is small. This is due to the exposure of these species being limited because: 1) The habitat is degraded at the OTC site and is not preferable for any life stage of any ESA species; 2) OC coho salmon and eulachon will migrate through the affected area of contamination, but are unlikely to hold or rear, thus minimizing exposure time; and 3) southern green sturgeon are only present in the bay during the summer months when stormwater exposure is at its lowest.

**Loss of Shallow-Water Habitats and Forage*.*** The construction fill will modify 3.9 acre of subtidal and intertidal habitat estuary habitat will result with direct and indirect effects to OC coho salmon, eulachon, and southern green sturgeon. The direct physical effect of placing fill will be covering of the estuary floor, thus increasing the amount of deep subtidal habitat next to shore, making the loss of shallow-water habitat permanent, and steepening the slope of the nearshore areas.

Direct effects will include the potential for adult eulachon to be killed (smothering) during construction fill, although eulachon are at very rare numbers in Coos Bay (Monaco *et al.* 1990). The applicant is not proposing work area isolation. The NMFS is reasonable certain that adult OC coho salmon will swim away from the action area during construction fill *(Sediment and Turbidity are addressed above).* Southern green sturgeon are not expected in the action area during in-water work.

Indirect effects include a loss of intertidal habitat for estuarine invertebrates, less shallow-water habitat for juvenile fish, and a loss of refugia from predators. This can affect the smaller ESA-listed species such as eulachon and juvenile OC coho salmon as they lose the ability to avoid predators. The substrate of the area to be filled includes sand and sandy mud. It provides habitat for a variety of clams, amphipods, and ghost shrimp. The changing of the substrate on the slope from soft benthic substrate to rock riprap will change the species present at the site from mud-colonizing infaunal and epifaunal invertebrates to likely larger, mobile invertebrates and fish. Loss of these prey species will result in a reduction of food available to rearing adult and subadult southern green sturgeon and juvenile OC coho salmon.

As noted above, filling 3.9 acres  will cause reduction in the prey base for threatened species, and reduce the shallow-water habitat needed for smaller fish to escape predators. However, compensatory mitigation will provide beneficial effects to off-set some of these losses. The OTC completed compensatory mitigation in 1997, by breaching a diked pastureland and removing  the existing tidegate The goal of the mitigation was to reestablish tidal flow to the protected pasture, restore fish and wildlife functions such shallow-water habitats, and allow low marsh and aquatic communities to reestablish.

A monitoring report for the off-site mitigation  was completed in May 2003 by Wetland Environmental Technologies (Craig 2003). The site is demonstrating anoxic soil conditions and formation of tidal channels. Pasture grasses and other aquatic plants have died as they do not tolerate brackish water. The salinity in the mitigation area was 25 PPT during monitoring. Clam holes are present through the OTC mitigation area. The area continues to restore itself to a natural estuarine habitat meeting the goals of the compensatory mitigation plan.

The mitigation has been providing benefits to southern green sturgeon, eulachon, and OC coho salmon for 14 years. These benefits are realized prior to the construction and habitat loss due to this project. The beneficial effect for ESA-listed species are as follows:

- The mitigation credits for OTC total 11.60 acres. The removal of the dike and existing tidegate converted 32 acres of upland pastureland to shallow, open water habitat. This area than became an undeclared mitigation bank for other applicants to purchase remaining credits. Under the Corps regulatory programs, OTC was required to use credits on the 11.60 acres (enhancement and restoration combined).
- The OTC Terminal Expansion Project is filling 3.9 acres of intertidal wetlands. The regulatory conversion exceeds the required 3 to 1 enhancement ratio.
- The OTC mitigation credits are adjacent to the Isthmus Slough Channel and provide shallow-water areas for juvenile rearing and escapement from potential predators. The intertidal areas provide “mud flats” that have sand and sediment deposition that provide habitat for clams, amphipods, and ghost shrimp. Ghost shrimp and clams are a major prey item for southern green sturgeon. A NMFS tour of the site showed visible clam holes in large numbers along the shoreline to Isthmus Slough Channel.
- The OTC filled all ditches from the agriculture operations previous occurring at the mitigation site. A major tide channel remained where the existing tidegate was located that runs throughout the length (west to east) of the 32 acre mitigation site. The site is naturally creating additional small channels created by tidal flushing. These areas provide additional rearing for young of the year OC coho salmon, eulachon, and other marine fishes. These channels are watered throughout the tide cycle.

Isthmus Slough is located approximately 2.75 miles upstream from OTC terminal, a tidal slough from the mainstem Coos River estuary. The mitigation site is located 8 miles upstream from the

OTC terminal on Isthmus Slough. The majority of the Coos Bay population of OC coho salmon originates from the mainstem Coos River. Tributaries of Isthmus Slough include Davis Creek and Noble Creek, both of which have OC coho salmon, but in low abundance. OC coho salmon originating from the mainstem of the Coos River may not realize the benefits of the Isthmus Slough mitigation as the distance upstream will more than likely prevent mainstem originating juvenile coho salmon the opportunity to use the shallow water for predatory refuge or benefit from the increase food production. The baseline habitat conditions for the action area are poor with no vegetation such as eel grass. The riparian area also has no vegetation and consists of concrete and stored logs on the shoreline, and the water column has many old treated wood pilings present. Although the location of the mitigation sight is not ideal for OC coho salmon, it does provide some habitat for juvenile rearing.

The mitigation site at Isthmus Slough is providing  habitat for southern green sturgeon, and is recovering quite well from historic log rafting and diking that occurred along the shoreline of the slough. NMFS has determined the mitigation site provides some  benefit to  southern green sturgeon, especially in light of the baseline poor habitat in the action area.

OTC proposes to construct a new 400- by 60-foot dock. The dock is located on piles located about 10 to 15 feet above the water surface and will allow light to enter. The water depth under the dock range from 7 feet to 32 feet, and has a very steep slope. Presently there is no aquatic vegetation in the action area, nor is it predicted after project completion. Juvenile salmonids use the upper layer of the deep water within harbors (Heiser and Finn 1970, Cardwell *et al*. 1980, Pentec 2003). The shoreline upstream of the action area (several miles) is also deep draft docks, with very limited shallow-water habitat. Migrating fish in Coos Bay will either cross the channel to the eastern bank where shallow-water habitat is abundant, or move through surface waters along piers. No evidence has been reported that harbor facilities in marine environments in the action area contain concentrations of predators that might prey on juvenile salmonids.

**Hydro Acoustics.** The OTC is using a vibratory hammer without any proofing for sheet and pile installation. Vibratory hammers produce a rounded sound pressure wave with a slower rise time. In contrast, impact hammers produce sharp sound pressure waves with rapid rise times, the equivalent of a punch versus a push in comparison to vibratory hammers. The sharp sound pressure waves associated with impact hammers represent a rapid change in water pressure level. In general, underwater noise affects rapid pressure changes, especially on gas-filled spaces in the body causing the injury and mortality effects to fish. Because the more rounded sound pressure wave produced by vibratory hammers produces a slower increase in pressure, the potential for injury and mortality is reduced. However, sound waves may cause migrating fish to move across the channel to avoid the noise and construction activities. Sound waves from vibratory hammers will not significantly disrupt their normal behavioral patterns of OC coho salmon and eulachon, and therefore the action has an insignificant response effect. Southern green sturgeon are not present in the action area during the in-water work period and will not be affected by pile driving.

**Entrainment.**

The NMFS is reasonably certain the effects from the intake of engine cooling water are immeasurable to eulachon and OC coho salmon because: (1) The flow rate to cool the engines will allow juvenile OC coho salmon and adult eulachon to swim away from the finger weirs meeting NMFS screening criteria for fish of that size; (2) the intakes are located at least 14.1 feet deep where adult and juvenile eulachon and juvenile OC coho salmon are not present; (3) the habitat surrounding the docking facilities does not attract OC coho salmon or eulachon; (4) the engine noise should move fish away from the seachest intakes; and (5) ballast water intake is not required for ships at the OTC terminal while loading timber, reducing the amount of flow next to the intake seachest. The NMFS has determined the effects to southern green sturgeon are discountable and insignificant because they rear close to the bottom away from the seachest intakes and are large enough to avoid any entrainment risk if in the vicinity.

For fish and invertebrates in the action area, the movement and operation of the vessels while in Port is not likely to create a detectable adverse affect on water quality or individuals because: (1) Open ocean ballast exchange would have occurred outside of 200 nautical miles minimizing the likelihood of non-native species being introduced into Coos Bay; (2) construction of the OTC docks will increase the number of vessels that will be able to be loaded by one ship a month, or 12 ships annually. Substantial boating activity already occurs within Coos Bay thus the expected increase in boat traffic is not anticipated to result in measurable adverse impacts to ESA-listed species in the estuary.

### 2.4.3 Effects on Critical Habitat in the Action Area

The action area is in the Coos Bay Frontal 5th field HUC (1710030403), which is designated as critical habitat for OC coho salmon and southern green sturgeon. OC coho salmon adults and juveniles use the action area for rearing and migration. Additionally, southern green sturgeon adults and subadults use the action area for rearing and migration. Thus, the affected PCEs in the action area are those that are essential for conservation of adult and juvenile OC coho salmon for rearing and migration and for adult and subadult green sturgeon rearing and migration. These PCEs include free passage, water quality, water quantity, natural cover, and forage. The likely effects of the action on these physical and biological features are listed below. The duration of effects will vary from ephemeral (instantaneous to hours) or short-term (days to months), and indirect effects are long-term (years to decades).

OC coho salmon and southern green sturgeon estuary rearing and migration.
*Water quality* – The OTC will achieve some stormwater treatment through construction of oil/water separators in the ten catch basins and filtration through ditch lines located on the western property lines of the OTC facility. However, oil/water separators do not remove heavy metals and not all the water flows through the ditchlines. Therefore, adequate removal of stormwater contaminants will not occur, resulting in copper and other heavy metals entering the bay.

Water quality monitoring at this site has demonstrated inadequate treatment. Stormwater testing for sample site #3 on January 17, 2011, found copper at 26 μg/L and Zinc at 83.7 μg/L.[6] The proposed action will likely result in a small increase in discharge of heavy metals because: (1) It does not treat heavy metals any better than they were treated in 2011; (2) it is increasing the amount of impervious surfaces; and (3) the amount of vehicular use and parking is likely to marginally increase due to the increased capacity of shipping. The tested copper levels are six times greater than threshold levels injuring coho salmon. These chemicals will continue exposure as ongoing maintenance dredging near the facility will re-suspend the heavy metals in the water column. The effects of stormwater are reasonably likely to cause an adverse affect to water quality in Coos Bay.

Suspended sediment levels will be increased due to fine sediment mobilized by construction activities. In the short-term, the proposed action is likely to slightly degrade water quality as disturbed soil from pile removal, pile installation, and the construction fill are exposed to the estuary. However, suspended sediment is expected to decrease over the long-term as disturbed areas settle or are flushed out of the system. Accidental release of fuel, oil, or other contaminants is unlikely, but would degrade water quality from the spill location up to 100 feet downstream and 100 feet upstream. The project is lacking conservation measures to minimize chemical contaminates leaching from wood piles during extraction. These chemicals can cause an adverse short-term effect to any adult OC coho salmon near the action area, and may cause long-term effects by settling into downstream sediments. These sediments then may be re-suspended by dredging or other in-water activity and could potentially directly or indirectly affect OC coho salmon and southern green sturgeon. All other construction activities except pile removal impacts are short-term or discountable, such that the quality and function of this PCE will be maintained within the Coos Bay 5$^{th}$ field HUC.

*Natural cover and Forage* **–** Previous activities have eliminated the majority of the natural cover in the project area, except existing treated piles. Simply stated, the existing site is poor quality habitat. The sheet pile will extend out to a depth of seven feet, reducing the amount of shallow-water habitat by 3.9 acres. Shallow-water habitat is used by juvenile OC coho salmon to avoid predators.

Habitat suitability for macroinvertebrates, clams, and ghost shrimp will be eliminated during the construction fill of 3.9 acres. While the impact on habitat is great enough to result in some OC coho salmon and southern green sturgeon being affected, the scale of this impact is small.

The OTC has performed mitigation for these losses in natural cover and forage by providing 1.4 acres of restoration and 10.2 acres of enhancement. The mitigation was completed in 1997 and benefits are already realized.

*Free passage* – The dock structure that occupies the 1.1 acre of the OTC terminal will present obstacles to the movement and migration of both juvenile and adult OC coho salmon and perhaps a few adult southern green sturgeon. Vessels moving to and from slips well cause ESA-listed species to move out of the way. Thus, southern green sturgeon and OC coho salmon

[6] Email from John Craig, OTC consultant, to Jim Muck, NMFS, December 28, 2011 (Transmitting water quality testing results).

movement in the estuary will be affected by human activities and ship traffic. In contrast, the presence of people can have a positive effect in that few avian predators can be found lurking in harbors. The NMFS is reasonably certain the overall effect to passage is immeasurable for the follow reasons: (1) The shoreline is already a deep dock draft, (2) the dock is located high above the water surface on piles allowing light penetration to occur, and (3) fish can swim in deeper water or cross the channel to a more suitable habitat.

Information presented in the status and baseline sections of this opinion demonstrate that the Coos Bay Frontal 5th field watershed and estuary has been altered, but conditions still support successful rearing and migration. Three PCEs will be affected, but will not be functionally changed because effects will be small-scale, short-term, or unlikely. The adverse effects to water quality from sediment and re-suspension of contaminants from the treated pile removal can create a short-term adverse effect to OC coho salmon and southern green sturgeon. This adverse effect is at the site and reach scale, and short-term, but could be avoided with adequate conservation measures. The natural cover and forage will be adversely affected at the site but already off-set with pre-implementation mitigation. Stormwater will be treated to a level higher than pre-project conditions.

### 2.5 Cumulative Effects

"Cumulative effects" are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

The population of Coos County will grow by approximately 3% over the next 30 years (ODAS 2004). Most of this growth will occur in the county's more populated cities of Coos Bay, North Bend, Bandon, and Coquille. The increase in population growth is likely to cause greater use of the Coos River estuary by recreational and commercial boats. The physical, auditory, and chemical effects of increased non-project boat traffic in the next few decades is likely to reduce the conservation value of the habitat within the action area. Population growth in Coos County associated road and residential development, as well as maintenance and upgrading of the existing infrastructure, are also likely in the foreseeable future for this watershed.

### 2.6 Integration and Synthesis

The Integration and Synthesis section is the final step of NMFS' assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (section 2.4) to the environmental baseline (section 2.3) and the cumulative effects (section 2.5) to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2).

### 2.6.1 Species

**OC Coho Salmon.** The effects of the proposed action, when added to the status of OC coho salmon, the environmental baseline, and cumulative effects, will not appreciably reduce the likelihood of both the survival and recovery of OC coho salmon in the wild by reducing its numbers, reproduction, or distribution. In our analysis above, NMFS determined that the construction related effects from 3.9 acres of fill, the chemical contaminants from lack of best management practices during pile removal, and stormwater contaminants will directly and indirectly injure or kill a small number OC coho salmon. However, the number of individuals injured or killed is far too small to reduce the abundance or productivity of the Coos River population of OC coho salmon. This independent population has average returns of over 15,000 adults over the last 20 years and the effect of losing a small number of juvenile fish would be immeasurable. The proposed action will have no impact on population spatial structure or diversity. Because there would be no measurable effects to the viability of the Coos River population (the only population affected), the proposed action would not reduce the ability of the species as a whole to survive and recover.

**Southern Green Sturgeon.** The effects of the pile removal and associated chemical contaminates when added to the status of southern green sturgeon, the environmental baseline, and cumulative effects, will not appreciably reduce the likelihood of both the survival and recovery of southern green sturgeon by reducing its abundance, reproduction, or distribution. Pile removal will cause indirect and direct effects to southern green sturgeon from chemical leaching that is distributed into the sediment, and redistributed again during dredging or other in-water work activities. Stormwater may add additional copper and metals that may reach adverse effects to green sturgeon, especially during dredging activities that re-suspend the contaminants when sturgeon are rearing in the bay.

The indirect effect from the construction fill of 3.9 acres will reduce shallow-water habitat for prey species such as clams and ghost shrimp. However, this area is much degraded and productivity is low. The compensatory mitigation at the Isthmus Slough site will enhance 1.4 acres from dike removal and the associated removal of the tidegate, and enhancement of 10.2 acres of shallow, intertidal area. Benefits from the site are already realized as clam holes, shrimp, and anaerobic conditions exist in the intertidal wetlands. The construction fill will have no impact on population spatial structure or diversity of green sturgeon.

**Eulachon**. Adult eulachon may be injured during pile removal or during construction fill. Indirect effects may occur during increased contaminates from additional impervious area and the inadequate filtration to remove metals. OTC is planning to remove an estimated 256 treated piles, which without conservation measures, would release chemical contaminants into the estuary. The exposure levels of chemicals may reach high enough levels to kill adults, but will reach levels that can cause sub-lethal adverse effects. Additionally, the construction fill has a probability of killing through smothering eulachon during the in-water work period, especially from January 1 through February 15, although numbers are difficult to quantify. Given the amount of fill and chemical contaminants during pile removal and stormwater contribution, and knowing that eulachon are rare in Coos Bay, NMFS is reasonably certain the number of eulachon injured or killed is extremely small. The effects of the pile removal and associated chemical contaminates, additional stormwater, and smothering from placement of fill when added to the status of eulachon, the environmental baseline, and cumulative effects, are reasonably unlikely to appreciably reduce the likelihood of both the survival and recovery of eulachon by reducing its abundance, reproduction, or distribution.

### 2.6.2 Critical Habitat

Extensive filling and diking of Coos Bay and its sloughs, estuaries, and tributaries have changed the form and function of the estuary, reducing an estimated 90% of Coos Bay marshes (Proctor *et al.* 1980). The construction fill will eliminate an additional 3.9 acres of shallow, intertidal habitat. The 3.9 acres currently is much degraded with concrete, treated piles, bark from the existing log storage facility, and no riparian vegetation.

The compensatory mitigation at the Isthmus Slough site will enhance 1.4 acres from dike removal and the associated removal of the tidegate, and enhancement of 10.2 acres of shallow, intertidal area. Benefits from the site are already realized as clam holes, shrimp, and anaerobic conditions exist in the intertidal wetlands. Isthmus Slough is improving from historical conditions of log rafting and poor water quality. Isthmus Slough has very poor turn-over due to degraded water quality since only Noble and Davis creeks contribute flow, other than tidal infusion into the Bay.

The OTC is proposing to remove an estimated 256 treated piles and replacing the piles with concrete piles and decking. This will improve the long-term water quality in the Coos Bay estuary. However, short-term impacts from treated pile removal may cause adverse conditions for both eulachon and OC coho salmon, and contribute to further chemical contamination of the bay. The additional impervious area and lack of complete treatment of metals such as copper will increase chemical pollutants directly into the Coos Bay estuary creating an adverse effect to water quality. This area extends out 200 feet from the four stormwater outlets.

The effects of the proposed action, when added to the status of range-wide designation of OC coho salmon critical habitat, the environmental baseline, and cumulative effects, will not appreciably reduce the conservation value of designated critical habitat for the survival and recovery of the of OC coho salmon. Adverse effects resulting in degradation to PCEs will occur, but only at the action area scale. The proposed action will not reduce the conservation value of the Lower Coos Bay Frontal fifth-field watershed. Nor will it reduce the conservation value of the range-wide designation of critical habitat for OC coho salmon.

## 2.7 Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of OC coho salmon, southern green sturgeon, or eulachon or to destroy or adversely modify critical habitat designated for those species.

## 2.8. Incidental Take Statement

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For purposes of this consultation, we interpret "harass" to mean an intentional or negligent action that has the potential to injure an animal or disrupt its normal behaviors to a point where such behaviors are abandoned or significantly altered.[7] Section 7(b)(4) and Section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA, if that action is performed in compliance with the terms and conditions of this incidental take statement.

### 2.8.1 Amount or Extent of Take

**OC Coho Salmon.** The effects of the proposed action will occur in areas where adult and juvenile OC coho salmon are likely to be present. The action area is defined as juvenile and adult migration habitat and juvenile rearing habitat in degraded condition, but is essential to these life stages. The project will result in death and injury of adult and juvenile OC coho salmon from increasing chemical contaminants with treated pile removal and lack of adequate stormwater treatment. It will result in death and injury of some juvenile OC coho salmon due to loss of forage opportunity and predation effects from reduced shallow water habitat. This take will occur throughout the area of pile removal and within 200 feet of each outfall. Incidental take within that area meeting the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

The NMFS cannot precisely predict the number of fish reasonably certain to be harmed or killed due to treated pile removal, inadequate stormwater treatment, or loss of shallow water forage. The distribution and abundance of fish occurring within the action area are a function of habitat quality, competition, predation, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, while NMFS is reasonably certain a low number of individuals to be injured or killed, it cannot precisely predict a number of fish.

[7] The NMFS has not adopted a regulatory definition of harassment under the ESA. The World English Dictionary defines harass as "to trouble, torment, or confuse by continual persistent attacks, questions, etc." The U.S. Fish and Wildlife Service defines "harass" in its regulations as "an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering," 50 CFR 17.3. The interpretation we adopt in this consultation is consistent with our understanding of the dictionary definition of harass and is consistent with the U.S. Fish and Wildlife interpretation of the term.

The best available indicator for the extent of take is the number of days required to remove treated wood pilings. In addition, the number of days required to remove pilings is the most practical and feasible indicator to measure. In discussions with the consultant and other piling removal operations, NMFS estimates 10 piles can be removed per day. Thus, piling removal will occur on a maximum of 26 days. Exceeding 26 days of piling removal is a trigger for reinitiating consultation.

**Southern Green Sturgeon.** The effects of the proposed action will occur in areas where adult and subadult southern green sturgeon are likely to be present. The action area is defined as subadult and adult migration habitat and forage habitat in degraded condition, but is essential to these life stages. The project will result in death and injury of adult and subadult southern green sturgeon from chemical contaminants of treated pile removal and lack of adequate stormwater treatment. Incidental take within that area meeting the terms and conditions of this incidental take statement will be exempt from the taking prohibition.

The NMFS cannot precisely predict the number of fish reasonably certain to be harmed or killed due to treated pile removal or inadequate stormwater treatment. The distribution and abundance of fish occurring within the action area are a function of habitat quality, competition, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, while NMFS is reasonably certain a low number of individuals to be injured or killed, it cannot precisely predict a number of fish.

The best available indicator for the extent of take is the number of days required to remove treated wood pilings. In addition, the number of days required to remove pilings is the most practical and feasible indicator to measure. In discussions with the consultant and other piling removal operations, NMFS estimates 10 piles can be removed per day. Thus, piling removal will occur on a maximum of 26 days. Exceeding 26 days of piling removal is a trigger for reinitiating consultation.

**Eulachon.** Eulachon were listed on March 18, 2010 (75 FR 13012) but protective regulations under 4(d) have yet to be promulgated; therefore, no prohibition under section 9 apply. Without the 4(d) regulations, take is not prohibited.

### 2.8.2 Effect of the Take

In the accompanying opinion, NMFS determined that this level of incidental take is not likely to result in jeopardy of the ESA-listed species.

### 2.8.3 Reasonable and Prudent Measures and Terms and Conditions

“Reasonable and prudent measures” are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). “Terms and conditions” implement the reasonable and prudent measures (50 CFR 402.14). These must be carried out for the exemption in section 7(o)(2) to apply.

The following measures are necessary and appropriate to minimize the impact of incidental take of listed species due to the proposed action:

The Corps shall:

1. Minimize incidental take resulting from removal of 256 treated piles by applying measures to avoid or minimize adverse effects to eulachon, OC coho salmon, or their critical habitats.
2. Minimize the incidental take resulting from construction fill by applying measures to avoid or minimize adverse effects to eulachon.
3. Minimize incidental take from stormwater runoff by applying permit conditions that minimize release of chemical contaminants in stormwater.
4. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this ITS are effective in minimizing the impact of incidental take.

The measures described below are non-discretionary, and must be undertaken by the Corps or, if an applicant is involved, must become binding conditions of any permit or grant issued to the applicant, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this ITS. If the Corps (1) fails to assume and implement the terms and conditions or (2) fails to require an applicant to adhere to the terms and conditions of the ITS through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, the Corps or applicant must report the progress of the action and its impact on the species to NMFS as specified in the ITS.

1. To implement reasonable and prudent measure #1 (pile removal measures to minimize chemical contaminants), the Corps shall require the OTC to:

    a. Install a floating surface boom to capture floating surface debris.
    b. Keep all equipment (*e.g.*, bucket, steel cable, vibratory hammer) out of the water, grip piles above waterline, and complete all work during low water and low current conditions.
    c. Dislodge the piling with a vibratory hammer, when possible; never intentionally break a pile by twisting or bending.
    d. Slowly lift the pile from the sediment and through the water column.
    e. Place the pile in a containment basin of a barge deck, pier, or shoreline without attempting to clean or remove any adhering sediment – a containment basin for removed piles and any adhering sediment may be constructed of durable plastic sheeting with sidewalls supported by hale bales or another support structure to contain all sediment and return flow which may otherwise be directed back into the waterway.
    f. Fill the holes left by each piling with clean native sediments immediately upon removal.

g. Dispose of all removed piles, floating surface debris, any sediment spilled on work surfaces, and all containment supplies at a permitted upland disposal site.

h. Make every attempt short of excavation to remove piling, if a pile is intractable, breaks above the surface, or breaks below the surface, cut the pile off at least 3 feet below the surface of the sediment.

i. If the pile is intractable or breaks above the surface, cut the pile at the sediment line.

2. To implement reasonable and prudent measure #2 (minimize incidental take from construction fill), the Corps shall require the OTC to:

   a. Place the construction fill from the upstream area behind the sheet pile first and then work downstream.

   b. Place the fill during the ebbing tide.

   c. Maintain the floating sediment curtain throughout the in-water construction fill, but keep a space at the bottom of the curtain at least one foot for fish to escape.

3. To implement reasonable and prudent measure #3 (stormwater), the Corps shall require OTC to maintain and manage stormwater facilities to ensure that the discharge copper concentration does not exceed 5.0 μg/L at all discharge points.

   a. This can be achieved either with cartridge installation or routing stormwater through swales.

   b. To maximize treatment efficiency prior to discharge to surface or subsurface waters. Implement and maintain one or both of the following specific treatment practices to increase efficacy. (See the Portland 2008 Stormwater Manual for examples).[8]

   c. Submit a maintenance and operations plan within one month following completion of construction:

      i. Provide the inspection timing in the maintenance and operations plan, at a minimum, cartridges need to be checked quarterly and after large rainfall events (greater than 1 inch in 24 hours) during the first year. In subsequent years:

         (1) During erosion events or active construction.

         (2) After the first storm after September 1 with measurable precipitation resulting in stormwater discharge.

         (3) When the flow rate through the cartridges or swales is noticeably diminished.

   d. For swales, use vegetation and soil amended swales designed for infiltration.

      i. Plant species within the swales which will uptake copper and/or zinc metals, *e.g*., rushes or clover. See *e.g.,* Contaminant Removal in Runoff, Research Report WA-RD 404.1. Online at: www.wsdot.wa.gov/research/reports/fullreports/404.1.pdf

---

[8] Operations and Maintenance chapter available online at www.portlandonline.com/bes/index.cfm?c=47954&a=202884

ii. Monitor and replace vegetation within swales in accordance with a maintenance and operations plan, to be submitted within 1 month following construction.
iii. Remove and replace amended soil based on the maintenance and operations plan.
iv. For any vegetation treatments, monitor plantings yearly for 5 years to ensure a minimum of 80% cumulative survival. Dead plants shall be replaced, as necessary, to bring the site into conformance. If plantings fail to meet this standard, the applicant shall plant additional vegetation.

e. For cartridges, apply the following requirements:
i. Minimize the risk of larger concentrations by maintaining the Bayfilter system to design levels with frequent cartridge replacement and vault cleaning.
ii. Reduce the lot debris treated by swales and cartridges by monthly maintenance of oil/water vaults during the dry season.
iii. Stabilize, as necessary, all erodible elements of any conveyance system to minimize erosion.
iv. Sediment and liquid from any catch basin cleaning may only be disposed of in an approved facility.

4. To implement reasonable and prudent measure #4 (monitoring), the Corps shall ensure that OTC shall provide a report to NMFS with the results of the following:

a. Conduct stormwater discharge sampling.
i. The applicant will obtain samples for three (3) years following completion of construction from each outfall pipe or ditch.
ii. Sampling will be timed to capture the "first flush" of material from impervious surfaces, typically occurring during the "first fall storm event," meaning the first storm after September 1 of each year that precipitation occurs and results in a stormwater discharge from the facility.
(1) Collect three discrete samples during within the first 12 hours of the first fall storm event and analyze each sample individually (*e.g.*, do not composite).

b. Record days with no precipitation preceding storm, rainfall duration, and the average storm intensity (rainfall inches per hour).

c. Prepare a Project Completion Report. Prepare and submit a project completion report to NMFS describing the OTC's success in meeting the terms and conditions contained in this opinion. The content of the project completion report will include:
i. Project identification.
(1) Project name.
(2) Type of activity.
(3) Project location by 6th field USGS HUC and by latitude and longitude as determined from the appropriate 7-minute USGS quadrangle map.

(4) OTC contact person(s).
(5) Starting and ending dates for work completed.

ii. Swale plantings. Number, type, and source of plantings.

iii. Photo documentation. Photos of habitat conditions at the project site before, during and after project completion.[9]

(1) Include general views and close-ups showing details of the project and project area, including pre- and post-construction.
(2) Label each photo with date, time, project name, photographer's name, and the subject.

iv. Stormwater management. For swales, structural stormwater facilities, and conveyance systems, provide a maintenance and operations plan the timing of inspections and maintenance activities according to a regular schedule. Provide the plan within 30 days after construction is completed, for NMFS approval. Include a sample log, to be available for inspection on request by the COE or NMFS (see www.portlandonline.com/bes/index.cfm?c=34980&a=54730).

v. Other data. Include the following specific project data in the project completion report:

(1) A summary of pollution and erosion control inspection results, including a description of any erosion control failure, contaminant release, and efforts to correct such incidences.
(2) Any incidence of observed injury or mortality.

d. Provide Notice of any Variance or Exception From Stormwater Management Requirements. The applicant will notify NMFS in the event that it or its assignee, designee, or other successor in interest, if any, grants a variance or exception from any conservation, monitoring or other environmental measure pertaining to storm water management that otherwise would have been required under the applicant's permit.

e. Site Restoration.

i. Finished sheet pile, riprap, and final shoreline configuration.
ii. Final tidal current description.

f. Monitoring for extent of take. Complete treated pile removal within a maximum of 26 days. Report the number of days spent removing piles and total piles removed.

g. Reporting. Prepare and submit a summary of the turbidity monitoring, including a photograph of the baseline and compliance sites; a copy of turbidity measurements or observations with the date and time that each was taken; other relevant sampling conditions; and description of any sediment control failure, sediment release, and correction efforts.

h. Submit Reports. To submit the project completion monitoring report, or to reinitiate consultation, contact:

---

[9] Relevant habitat conditions may include characteristics of stream channels, eroding and stable streambanks in the project area, riparian vegetation, water quality, flows at base, bankfull and over-bankfull stages, and other visually-discernable environmental conditions at the project area, and upstream and downstream from the project.

Oregon State Habitat Office
National Marine Fisheries Service
Attn: 2011/03866
1201 NE Lloyd Blvd., Ste. 1100
Portland, Oregon 97232-1274

i. NOTICE. If a sick, injured or dead specimen of a threatened or endangered species is found in the project area, the finder must notify NMFS through the contact person identified in the transmittal letter for this opinion, or through NMFS Office of Law Enforcement at 1-800-853-1964, and follow any instructions. If the proposed action may worsen the fish's condition before NMFS can be contacted, the finder should attempt to move the fish to a suitable location near the capture site while keeping the fish in the water and reducing its stress as much as possible. Do not disturb the fish after it has been moved. If the fish is dead, or dies while being captured or moved, report the following information: (1) The NMFS consultation number (found on the top left of the transmittal letter for this Opinion), (2) the date, time, and location of discovery, (3) a brief description of circumstances and any information that may show the cause of death, and (4) photographs of the fish and where it was found. The NMFS also suggests that the finder coordinate with local biologists to recover any tags or other relevant research information. If the specimen is not needed by local biologists for tag recovery or by NMFS for analysis, the specimen should be returned to the water in which it was found, or otherwise discarded.

## 2.9. Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following conservation recommendation is a discretionary measure that NMFS believes is consistent with this obligation and therefore should be carried out by the Federal action agency:

1. The Corps should evaluate the success of the Isthmus Slough Mitigation Bank and review the possibility to provide additional enhancement to the site by adding eel grass plantings to the mitigation requirements from all bank users.
2. The Corps should look at opportunities to enhance, restore, and expand estuarine areas.

Please notify NMFS if the Federal action agency carries out any of these recommendations so that we will be kept informed of actions that are intended to improve the conservation of listed species or their designated critical habitats.

## 2.10 Reinitiation of Consultation

As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal action agency involvement or control over the action has been retained, or is authorized by law, and if: (1) The amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action on listed species or designated critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

To reinitiate consultation, contact the Oregon State Habitat Office of NMFS, and refer to the NMFS Number 2011/03866.

## 2.11 "Not Likely to Adversely Affect" Determinations

### Marine Mammal and Sea Turtles

The NMFS' concurrence or finding of the determination, "may affect, not likely to adversely affect" must be based on NMFS finding that the effects are all expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur. Based on best judgment, a person would not: (1) Be able to meaningfully measure, detect, or evaluate insignificant effects; or (2) expect discountable effects to occur. Refer to the biological opinion for a description of the proposed action and action area.

### Species Determinations

**Steller Sea Lions**. Steller sea lions of the eastern DPS can occur in Oregon waters throughout the year, with two breeding rookeries at Rogue Reef and Orford Reef, and haul out locations used along the coast. Steller sea lions infrequently occur in Coos Bay, and there are no consistently used haulouts within 5 miles of Coos Bay (the most proximate haulout is Cape Arago on the outer coast). Given the short-term nature of construction and the infrequent nature of Steller sea lion occurrence in the project vicinity, NMFS concludes that potential effects from the proposed action are discountable. It is extremely unlikely that a Steller sea lion would be present during or exposed to the proposed construction activities in Coos Bay. Therefore, NMFS finds that the proposed action may affect, but is NLAA Steller sea lions.

**Other Marine Mammals and Sea Turtles** (Southern Resident killer whales, humpback whales, fin whales, blue whales, Sei whales, sperm whales, green sea turtles, leatherback sea turtles, loggerhead sea turtles, and olive ridley sea turtles).

The above identified marine mammal and sea turtle species are either not expected or extremely unlikely to occur in the Coos Bay channel or the Bay proper, and therefore the NMFS does not anticipate that adverse effects will result from removal of existing structures, pile installation, dock construction and improvements, and associated fill are discountable.

These species may occur along the Oregon Coast between the Coos Bay breakwater, in the shipping lanes to and from the port, or on a roundtrip between Coos Bay estuary the extent of the U.S. EEZ enroute to China where OTC ships are proposed to travel. Therefore, OTC ship movements to and from the OTC docks in Coos Bay through the marine transit area may affect marine mammal and sea turtle species. Effects are likely to be discountable or insignificant for the reasons described below.

The OTC ship movements through the marine transit area are anticipated to result in a minimal increase in current levels of ship traffic in the area (12 additional ships per year). The NMFS is not able to quantify existing traffic conditions in the marine transit area to provide context for the addition of up to 12 ship trips annually. However, NMFS does not anticipate that the additional 12 trips annually through the marine transit area would result in anything other than insignificant effects. Vessel strikes of marine mammals or sea turtles by OTC ships in the marine transit area are extremely unlikely, as described in more detail below.

ESA-listed marine mammal occurrence in the marine transit area would be infrequent, transitory and if present, at low density, and marine mammals would therefore be unlikely to encounter an OTC ship associated with the proposed project (NMFS 2008 a, b, c, d, e). Sea turtle occurrence through the marine transit area is rare (*i.e*., NMFS and USFWS 2007 a, b, c, d). Because the potential for an encounter between marine mammal or sea turtle species with these 12 additional ships per year is extremely unlikely, NMFS anticipates that the potential for a ship strike or other adverse interaction is discountable.

The proposed action is not likely to adversely affect the quality of marine mammal prey; however, it may affect the quantity of prey available, by take of OC coho salmon and southern green sturgeon. NMFS anticipates that the effects to Chinook salmon are similar to OC coho salmon. Any take of OC coho salmon, Chinook salmon, eulachon, or southern green sturgeon associated with the proposed actions (as described in the incidental take statement) would result in an insignificant reduction in adult equivalent prey resources for marine mammals that may intercept these and other prey species within their range (*i.e*., Southern Resident killer whales and Steller sea lions).

The NMFS finds all effects of the action are expected to be discountable or insignificant, and therefore provides a determination of “may affect, not likely to adversely affect” for Southern Resident killer whales, humpback whales, fin whales, blue whales, Sei whales, sperm whales, green turtles, leatherback turtles, loggerhead turtles, and olive ridley turtles.

## 3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Adverse effects include the direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the Corps and descriptions of EFH contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce for EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999).

### 3.1 Essential Fish Habitat Affected by the Project

The PFMC described and identified EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook salmon and coho salmon (PFMC 1999). The proposed action and action area for this consultation are described in the Introduction to this document. The action area includes areas designated as EFH for various life-history stages of groundfish, coastal pelagics, and Pacific salmon (Appendix A).

### 3.2 Adverse Effects on Essential Fish Habitat

Based on information provided by the action agency and the analysis of effects presented in the ESA portion of this document, NMFS concludes that the proposed action will have the following adverse effects on EFH designated for 49 species of Pacific Coast groundfish, five coastal pelagic species, and OC coho and Chinook salmon:

- Water quality degradation from:
  - Increase in suspended sediment (short-term);
    - construction fill in the intertidal and subtidal
    - jetting, vibrating, and removing treated piles
    - vibrating sheet piles and 194 concrete dock piles

Increased suspended sediment will cause an adverse affect on EFH from these activities. The increase will be short-term but likely high intensity, particularly during the removal of piles and fill during construction activities.

  - Chemical contamination caused by;
    - accidental spills during construction (short-term)

- removal of treated piles
- inadequate stormwater treatment

Removal of treated piles and accidental spills during construction and inadequate stormwater treatment are likely to adversely affect EFH.

- Changes to physical, chemical, and biological habitat including (long-term) from fill of 3.9 acres of estuary:
  - benthic productivity
  - loss of shallow-water habitats
  - predation (increase of and refuge from)
  - disruption of migratory pathways

Of the aforementioned pathways of effect, changes to benthic productivity from the construction fill and placement of riprap will adversely affect EFH.

- Vessel cooling intake seachest:
  - potential for entrainment
  - potential introduction of invasive species

Pelagic and groundfish EFH species are more likely to be entrained on the seachest due to the behavior of the species, and will create an adverse affect.

- Mitigation (long-term):
  - water column
  - intertidal habitat

The mitigation, completed in 1997, is a beneficial effect for EFH species. However, the spatial distance from the mid-estuary located at the action area to the mitigation site at Isthmus Slough may not provide benefit to all the various EFH species. Examples include reduction of salinity at the Isthmus Slough site and distance needed for migration. The Isthmus Slough mitigation does provide off-setting primary and secondary production which are prey species for most EFH species.

### 3.3 Essential Fish Habitat Conservation Recommendations

The NMFS expects that full implementation of these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in section 3.2 above, approximately 3.9 acres of designated EFH for groundfish, coastal pelagics, and Pacific salmon.

The following five conservation measures are necessary to avoid, mitigate, or offset the impact of the proposed action on EFH. These conservation recommendations include the ESA terms and conditions.

1. Juvenile Chinook salmon, young rockfish and flatfish are likely to be in the action area during ground disturbing activities, especially early in the in-water work period. These

life history stages are more susceptible to increased levels of turbidity. Thus, NMFS recommends that the Corps implement a turbidity monitoring plan with sufficient sampling stations to ensure that the turbidity plume is not extending more than 100 feet from the disturbance activity. An upriver and downriver compliance point is likely insufficient given the complex currents, tidal action, and wind-driven surface currents in coastal estuaries. Thus, several compliance points may be necessary to encompass a perimeter around the activity. Background turbidity, location, date, and time must be recorded before pile driving or excavation, and construction fill occurs. Sampling should occur every three hours. If turbidity is exceeding 10% above background for two consecutive sampling periods, NMFS recommends the applicant implement best management practices to minimize the extent of the plume.

2. The NMFS recommends the Corps implement Terms and Conditions #1, #2 and #3 in the ESA portion of this document to offset adverse effects to EFH from fill and pile removal activities.

3. The NMFS recommends that the Corps coordinate with the Coast Guard to develop rules to reduce the entrainment of fish during cooling and ballast water intake.

4. The Corps should evaluate the success of the Isthmus Slough Mitigation Bank and review the possibility to provide additional enhancement to the site by adding eel grass plantings to the mitigation requirements from all bank users.

5. The Corps should look at opportunities to enhance, restore, and expand estuarine areas.

### 3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Federal action agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation from NMFS. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations, unless NMFS and the Federal action agency have agreed to use alternative time frames for the Federal action agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS Conservation Recommendations, the Federal action agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects, 50 CFR 600.920(k)(1).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

### 3.5 Supplemental Consultation

The Corps must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations, 50 CFR 600.920(l).

## 4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

**4.1 Utility:** Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users are the Corps.

An individual copy was provided to the Corps. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

**4.2 Integrity:** This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

**4.3 Objectivity:**

*Information Product Category*: Natural Resource Plan.

*Standards*: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq*., and the MSA implementing regulations regarding EFH, 50 CFR 600.920(j).

*Best Available Information*: This consultation and supporting documents use the best available information, as referenced in the Literature Cited section. The analyses in this opinion/EFH consultation contain more background on information sources and quality.

*Referencing*: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

*Review Process*: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

## 5. LITERATURE CITED


Alpers, C.N., H. E. Taylor, and J.L. Domagalski (editors). 2000a. Metals Transport in the Sacramento River, California, 1996–1997 - Volume 1: Methods and Data. U.S. Geological Survey, Water-Resources Investigations Report 99-4286. Sacramento, California.

Alpers, C.N., R. C. Antweiler, H. E. Taylor, P. D. Dileanis, and J.L. Domagalski. 2000b. Metals Transport in the Sacramento River, California, 1996–1997 – Volume 2: Interpretation of Metal Loads. U.S. Geological Survey, Water-Resources Investigations Report 00-4002. Sacramento, California.

Anderson, C.W., F.A. Rinella and S.A. Rounds. 1996. Occurrence of Selected Trace Elements and Organic Compounds and Their Relation to Land Use in The Willamette River Basin, Oregon, 1992–94. U.S. Geological Survey, Water-Resources Investigations Report 96–4234, Portland, Oregon.

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz. 2003. Sublethal effects of copper on coho salmon: impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22: 2266–2274.

Beamis, W.E., and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. *Environmental Biology of Fishes* 48:167-183.

Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan. 2007. Observations: Oceanic Climate Change and Sea Level. P. 385-432 in: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Buckler, D.R., and G.E. Granato. 1999. Assessing biological effects from highway-runoff constituents: U.S. Geological Survey Open File Report 99-240, Northborough, Massachusetts. 45 p.

Cardwell, R.D., M.I. Carr, and E.W. Sanborn. 1980. Water Quality and Flushing of Five Puget Sound Marinas. Washington Department of Fisheries, Technical Report 56, Olympia.

Colman, J.A., K.C. Rice, and T.C. Willoughby. 2001. Methodology and significance of studies of atmospheric deposition in highway runoff: U.S. Geological Survey Open-File Report 01-259, Northborough, Massachusetts, 63 p.

Cortright, R., J. Weber, and R. Bailey. 1987. The Oregon estuary plan book. Department of Land Conservation and Development. Salem, Ore.

Craig, J. 2003. Wetland Mitigation Monitoring Report. Prepared by Wetland Environmental Technologies, Inc. for Jim Lyons, Ocean Terminal Company.

Denton, D.L., C.E. Wheelock, S.A. Murray, L.A. Deanovic, B.D. Hammock, and D.E. Hinton. 2002. Joint acute toxicity of esfenvalerate and diazinon to larval fathead minnows (*Pimephales promelas*). Environmental Toxicology and Chemistry 22:336-341.

Drake, J., R. Emmett, K. Fresh, R. Gustafson, M. Rowse, D. Teel, M. Wilson, P. Adams, E.A.K. Spangler, and R. Spangler. 2008. Summary of scientific conclusions of the review of the status of eulachon (*Thaleichthys pacificus*) in Washington, Oregon and California. Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington.

Driscoll, E.D., P.E. Shelley, and E.W. Strecher. 1990. Pollutant loadings and impacts from highway runoff, Volume III: Analytical investigation and research report. FHWD-RD-88-0088. Federal Highway Administration, Office of Engineering and Highway Operations Research and Devlepment, McLean, Virginia.

Dutch, M., V. Partridge, S. Aasen, and K. Welch. 2005. Changes and Trends in Puget Sound Sediments: Results of the Puget Sound Ambient Monitoring Program, 1989-2000. Publication No. 05-03-024. http://www.ecy.wa.gov/pubs/0503024.pdf. August 2005.

Eisler, R. 1993. Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Department of the Interior, Fish and Wildlife Service. Biological Report 10. 106 pp.

Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for copper. U.S. Environmental Protection Agency, Publication 440/5-80-036. 162 pp. EPA. 1983. Results of the Nationwide Urban Runoff Program. NTIS No. PB84-185545.

Ford, M.J. (ed.), T. Cooney, P. McElhany, N. Sands, L. Weitkamp, J. Hard, M. McClure, R. Kope, J. Myers, A. Albaugh, K. Barnas, D. Teel, P. Moran, and J. Cowen. 2010. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. Draft U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-XXX.

Fresh, K. L., E. Casillas, L. L. Johnson, D. L. Bottom. 2005. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-69, 105 p.

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-105, 360 p.

Gustafson, R.G., M.J. Ford, P.B. Adams, J.S. Drake, R.L. Emmett, K.L. Fresh, M. Rowse, E.A.K. Spangler, R.E. Spangler, D.J. Teel, and M.T. Wilson. 2011. Conservation status of eulachon in the California Current. Fish and Fisheries. DOI: 10.1111/j.1467-2979.2011.00418.x.

Hansen, J.A., P.G. Welsh, J. Lipton, and P.G. Welsh. 2002. Relative Sensitivity of Bull Trout (*Salvelinus confluentus*) and Rainbow Trout (*Oncorhynchus mykiss*) to Acute Exposures of Cadmium and Zinc. Environmental Toxicology and Chemistry 21(1): 67-75.

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sub-lethal neurobehavioral toxicity. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-83, 39 p.

Heiser, D.W., and E.L. Finn, Jr. 1970. Observations of Juvenile Chum and Pink Salmon in Marina and Bulkhead Areas. Supplemental Progress Report, Puget Sound Studies, Washington Department of Fisheries, Management and Research Division, Olympia.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. ISAB Climate Change Report, ISAB 2007-2, Northwest Power and Conservation Council, Portland, Oregon.

JCRMS (Joint Columbia River Management Staff). 2010 joint staff report concerning stock status and fisheries for sturgeon and smelt. Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife.

Johnson, L.L., G.M. Ylitalo, M.R. Arkoosh, A.N. Kagley, C.L. Stafford, J.L. Bolton, J. Buzitis, B.F. Anulacion, and T.K. Collier. 2007. Contaminant exposure in outmigrant juvenile salmon from Pacific Northwest estuaries. Environmental Monitoring and Assessment. 124:167-194.

Kayhanian, M., A. Singh, C. Suverkropp, and S. Borroum. 2003. Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations. Journal of Environmental Engineering. 129: 975–990.

Koski, K.V. 2009. The fate of Coho Salmon Nomads: The Story of an Estuarine-Rearing Strategy Promoting Resilience. Ecology and Society 14(1):4. http://www.ecologyandsociety.org/vol14/iss1/art4/

Lawson, P.W., E.P. Bjorkstedt, M.W. Chilcote, C.W. Huntington, J.S. Mills, K.M.S. Moore, T.E. Nickelson, G.H. Reeves, H.A. Stout, T.C. Wainwright, and L.A. Weitkamp. 2007. Identification of historical populations of Coho salmon (*Oncorhynchus kisutch*) in the Oregon coast evolutionarily significant unit. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-79, 129 p.

LCREP (Lower Columbia River Estuary Partnership). 2007. Lower Columbia River and estuary ecosystem monitoring: Water quality and salmon sampling report. Lower Columbia River Estuary Partnership. Portland, Oregon.

Loge, F., M.R. Arkoosh, T.R. Ginn, L.L. Johnson, and T.K. Collier. 2006. Impact of Environmental Stressors on the Dynamics of Disease Transmission. Environmental Science & Technology. 39(18):7329-7336.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, Seattle, Washington, 156 p.

Miller, B. A., and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. *Transactions of the American Fisheries Society* 132:546-559.

Monaco, M.E., R.L. Emmett, S.A. Hinton, and D.M. Nelson. 1990. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Vol. I: Data summaries. ELMR Rep. 4. U.S. Dept. Commerce, NOAA, National Ocean Service, Strategic Assessment Branch, Silver Spring, MD.

Moser, M., and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/sl0641-006-9028-1.

Neff, J.M. 1985. Polycyclic aromatic hydrocarbons. *In*: Fundamentals of aquatic toxicology, G.M. Rand, and S.R. Petrocelli (eds.), p. 416-454. Hemisphere Publishing, Washington, D.C.

Nightingale, B., and C. Simenstad. 2001. White Paper, Overwater Structures: Marine Issues. University of Washington, Wetland Ecosystem Team, Seattle.

Niyogi, S., P. Couture, G. Pyle, D.G. McDonald, and C.M. Wood. 2004. Acute cadmium biotic ligand model characteristics of laboratory-reared and wild yellow perch (*Perca flavescens*) relative to rainbow trout (*Oncorhynchus mykiss*). Can. J. Fish. Aquat. Sci. 61: 942–953.

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007a. Green Sea Turtle (*Chelonia mydas*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/greenturtle_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007b. Loggerhead Sea Turtle (*Caretta caretta*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/loggerhead_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007c. Leatherback Sea Turtle (*Chelonia mydas*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/greenturtle_5yearreview.pdf

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). 2007d. Olive Ridley Sea Turtle (*Lepidochelys olivacea*) 5-Year Review: Summary and Evaluation. August 2007. http://www.nmfs.noaa.gov/pr/pdfs/species/oliveridley_5yearreview.pdf

NMFS (National Marine Fisheries Service). 2008a. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Blue Whale (*Balaenoptera musculus*): Eastern North Pacific Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whbl-en.pdf

NMFS (National Marine Fisheries Service). 2008b. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Fin Whale (*Balaenoptera physalus*): California/Oregon/Washington Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whfi-cow.pdf

NMFS (National Marine Fisheries Service). 2008c. Marine Mammal Stock Assessment Reports (SARs) by Species/Stock: Humpback Whale (*Megaptera novaeangliae*): California/Oregon/Washington Stock. Revised 12/15/2008. http://www.nmfs.noaa.gov/pr/pdfs/sars/po2008whhb-cow.pdf

NMFS (National Marine Fisheries Service). 2008d. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). Prepared by National Marine Fisheries Service, Northwest Regional Office. January 17, 2008. 251 pp.

NMFS (National Marine Fisheries Service). 2008e. Recovery Plan for the Steller sea lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD, 325 pgs.

NOAA (National Oceanic and Atmospheric Administration) Fisheries. 2011. Biennial report to Congress on the recovery program for threatened and endangered species October 1, 2008 – September 30, 2010. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

ODAS (Oregon Department of Administrative Services). 2004. Long-term population estimates. Salem, Oregon. http://www.oregon.gov/DAS/OEA/demographic.shtml (Accessed November 2011).

ODEQ (Oregon Department of Environmental Quality). 2008. Oregon's 2004/2006 Integrated 303(d) Report. URL: http://www.deq.state.or.us/wq/assessment/rpt0406.htm.

Pentec (Pentec Environmental). 2003. Movement of Juvenile Salmon through Modified Nearshore Habitats in the Lower Snohomish Estuary. Prepared for Port of Everett, Everett, Washington, by Pentec, Edmonds, Washington.

PFMC (Pacific Fishery Management Council). 1998. The Coastal Pelagic Species Fishery Management Plan: Amendment 8. Pacific Fishery Management Council, Portland, Oregon. December.

PFMC (Pacific Fishery Management Council). 1999. Amendment 14 to the Pacific Coast Salmon Plan. Appendix A: Description and identification of essential fish habitat, adverse impacts and recommended conservation measures for salmon. Pacific Fishery Management Council, Portland, Oregon. March.

PFMC (Pacific Fishery Management Council). 2005. Amendment 19 to the Pacific Coast Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon. November.

Proctor, C.M., C. Garcia, D.V. Galvin, G.B. Lewis, and L.C. Loehr. 1980. An ecological characterization of the Pacific Northwest coastal region. U.S. Fish and Wildlife Service. FWS/OBS-79/15.

Rand, G.M. and S.R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology: Methods and Applications. Editors. Hemisphere Publishing Corporation, Washington, D.C.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science & Technology. 41(8):2998-3004.

Scheuerell, M.D., and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 14:448-457.

Spence, B.C, G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon. *http://www.nwr.noaa.gov/1habcon/habweb/habguide/ManTech/front.htm*

Spromberg, J.A., and J.P. Meador. 2006. Relating chronic toxicity responses to population-level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Ecological Modeling 199(2006):240-252.

State of Oregon. 2005. Coho assessment part 1: Synthesis final report. Salem, Oregon.

Stout, H.A., P.W. Lawson, D. Bottom, T. Cooney, M. Ford, C. Jordan, R. Kope, L. Kruzic, G. Pess, G. Reeves, M. Scheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams, and T. Williams. 2011. Scientific conclusions of the status review for Oregon Coast coho salmon (*Oncorhynchus kisutch*). Draft revised report of the Oregon Coast Coho Salmon Biological Review Team. NOAA/NMFS/NWFSC, Seattle, Washington.

USDC (U.S. Department of Commerce). 2009. Endangered and threatened wildlife and plants: Final rulemaking to designate critical habitat for the threatened southern distinct population segment of North American green sturgeon. National Marine Fisheries Service. Federal Register 74(195):52300-52351.

USDC (U.S. Department of Commerce). 2010. Endangered and threatened wildlife and plants: Final rulemaking to establish take prohibitions for the threatened southern distinct population segment of North American green sturgeon. National Marine Fisheries Service. Federal Register 75(105):30714-30728.

USDC (U.S. Department of Commerce). 2011a. Endangered and threatened species, designation of critical habitat for southern distinct population segment of eulachon. Proposed rule; request for comment. National Marine Fisheries Service. Federal Register 76(3):515-536.

USDC (U.S. Department of Commerce). 2011b. Listing Endangered and Threatened Species: Threatened status for the Oregon Coast coho salmon evolutionarily significant unit. National Marine Fisheries Service. Federal Register 76(118):35755-35771.

USGCRP (U.S. Global Change Research Program). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, New York.

Wainwright, T.C., M.W. Chilcote, P.W. Lawson, T.E. Nickelson, C.W. Huntington, J.S. Mills, K.M.S. Moore, G.H. Reeves, H.A. Stout, and L.A. Weitkamp. 2008. Biological recovery criteria for the Oregon Coast coho salmon evolutionarily significant unit. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-91, 199 p.

WDFW and ODFW (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife). 2001. Joint state eulachon management plan.

Weitkamp, L. A. (2010): Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries, Transactions of the American Fisheries Society, 139:1, 147-170

Wimberly, M.C., T.A. Spies, C.J. Long, and C. Whitlock. 2000. Simulating historical variability in the amount of old forests in the Oregon Coast Range. Conservation Biology 14:167–180.

Zabel, R.W., M.D. Scheuerell, M.M. McLure, and J.G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20:190-200.

# 6. APPENDIX: SPECIES WITH DESIGNATED EFH IN THE ACTION AREA.

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Arrowtooth flounder | *Atheresthes stomias* | Adults | All | Clupeids, gadids, krill, shrimp, Theragra chalcogramma |
| | | Eggs | | |
| | | Larvae | | Copepod eggs, Copepod nauplii, copepods |
| Big skate | *Raja binoculata* | Adults | All | Crustaceans, fish |
| Black rockfish | *Sebastes melanops* | Adults | All | Amphipods, Cephalopods, Clupeids, Euphausiids, Mysids, polychaetes, salps |
| | *Sebastes melanops* | Juveniles | Feeding, Growth to maturity | Amphipods, barnacle cypriots, Copepods, crustacean zoea, fish larvae, Mysids, polychaetes |
| Blue rockfish | *Sebastes mystinus* | Adults | All | algae, crab, fish juveniles, fish larvae, hydroids, jellyfish, krill, salps, tunicates |
| | | Juveniles | All | algae, Copepods, Euphausiids, fish juveniles, hydroids, krill, tunicates, algae, copepods, crab, |
| | | Larvae | Feeding | |
| Bocaccio | *Sebastes paucispinis* | Adults | Feeding, Growth to maturity | Juvenile rockfish, molluscs, small fishes |
| | | Juveniles | Feeding, Growth to maturity | Copepods, euphausiids |
| Flathead sole | *Sebastes auriculatus* | Adults | All | Crabs, fish, isopods, polychaetes, shrimp |
| | | Juveniles | Feeding, Growth to maturity | Amphipods, Copepods, crabs, fish |
| Butter sole | *Isopsetta isolepis* | Adults | | Amphipods, decapod crustaceans, fish, molluscs, polychaetes, sea stars, shrimp |
| Cabezon | *Scorpaenichthys marmoratus* | Adults | | Crabs, fish eggs, lobsters, molluscs, small fishes |
| California skate | *Raja inornata* | Eggs | Unknown | |
| Chilipepper | *Sebastes goodei* | Juveniles | Feeding, Growth to maturity | Copepods, euphausiids |
| Curlfin sole | *Pleuronichthys decurrens* | Adults | All | Crustacean eggs, Echiurid proboscises, nudibranchs, polychaetes |
| Darkblotched rockfish | *Sebastes crameri* | Adults and Juveniles | | Amphipods, Euphausiids, octopi, salps, small fishes |
| | | Larvae | | |
| English sole | *Parophrys vetulus* | Adults | All | Amphipods, crustaceans, cumaceans, mollluscs, ophiuroids, polychaetes |
| | | Juveniles | Feedging, Growth to maturity | Amphipods, copepods, cumaceans, molluscs, mysids, polychaetes |
| Flathead sole | *Hippoglossoides elassodon* | Adults | All | Clupeids, fish, molluscs, mysids, polychaetes, shrimp |
| Greenstriped rockfish | *Sebastes elongatus* | Adults | All | Copepods, euphausiids, shrimp, small fishes, squids, tunicates |
| Kelp greenling | *Hexagrammos decagrammus* | Adults | All | Brittle Stars, crabs, octopi, shrimp, small fishes, snails, worms |
| | | Larvae | | Amphipods, brachyuran, copepod nauplii, copepods, euphausiids, fish larvae |
| Lingcod | *Ophiodon elongatus* | Adults | All | Demersal fish, juvenile crab, octopi, squids |
| | | Larvae | Feeding | Amphipods, copepods eggs, copepod nauplii, copepods, decapod larvae, euphausiids |

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Longnose skate | *Raja rhina* | Adults | All | |
| | | Eggs | | |
| | | Juveniles | Growth to Maturity | |
| Pacific cod | *Gadus macrocephalus* | Adults | All | Amphipods, crabs, mysids, sandlance, shrimp, Theragra chalcogramma |
| | | Juveniles | | Amphipods, copepods, crabs, shrimp |
| | | Larvae | | Copepods |
| Pacific hake | *Merluccius productus* | Adults | All | Amphipods, clupeids, crabs, Merluccius productus, rockfish, squids |
| | | Juveniles | | Euphausiids |
| Pacific ocean perch | *Sebastes alutus* | Adults | All | Copepods, euphausiids, mysids, shrimp, small fishes, squids |
| | | Juveniles | | Copepods, euphausiids |
| Pacific sanddab | *Citharichthys sordidus* | Adults | All | Clupeids, crab larvae, octopi, squids |
| Petrale sole | *Eopsetta jordani* | Adults | All | Eopsetta jordani, Euphausiids, Ophiuroids, pelagic fishes, shrimp |
| Quillback rockfish | *Sebastes maliger* | Adults | all | Amphipods, clupeids, crabs, euphausiids, fish juveniles, molluscs, polychaetes, shrimp |
| Redbanded rockfish | *Sebastes babcocki* | Adults | All | |
| Redstripe rockfish | *Sebastes proriger* | Adults | All | Clupeids, fish juveniles, squids |
| Rex sole | *Glyptocephalus zachirus* | Adults | All | Cumaceans, euphausiids, larvacea, polychaetes |
| Rock sole | *Lepidopsetta bilineata* | Adults | All | echinoderms, echiurans, fish, molluscs, polychaetes, tunicates, |
| Rosethorn rockfish | *Sebastes helvomaculatus* | Adults | All | amphipods, copepods, euphausiids |
| Rosy rockfish | *Sebastes rosaceus* | Adults | All | crabs, shrimp |
| Rougheye rockfish | *Sebastes aleutianus* | Adults | All | |
| | | Juveniles | Growth to Maturity, Feeding | |
| Sablefish | *Anoplopoma fimbria* | Adults | Growth to Maturity | Clupeids, euphausiids, octopi, rockfish, shrimp |
| | | Juveniles | Growth to Maturity | Amphipods, Cephalopods, copepods, demersal fish, Euphausiids, krill, small fishes, squids, tunicates |
| | | Larvae | Feeding | Copepod eggs, Copepod nauplii, copepods |
| Sand sole | *Psettichthys melanostictus* | Adults | All | Clupeids, crabs, fish, molluscs, mysids, polychaetes, shrimp |
| | | Juveniles | Feeding, Growth to maturity | Euphausiids, molluscs, mysids, polychaetes, shrimp |
| Sharpchin rockfish | *Sebastes zacentrus* | Adults | All | Amphipods, copepods, euphausiids, shrimp, small fishes |
| | | Juveniles | Feeding, Growth to maturity | Amphipods, copepods, euphausiids, shrimp, small fishes |
| Shortbelly rockfish | *Sebastes jordani* | Adults | All | Copepods, euphausiids |
| Shortraker rockfish | *Sebastes borealis* | Adults | All | Bathylagids, Cephalopods, Decapod crustaceans, fish, molluscs, myctophids, mysids, shrimp |
| Shortspine thornyhead | *Sebastolobus alascanus* | Adults | All | Amphipods, copepods, crabs, fish, polychaetes, Sebastolobus alascanus, Sebastolobus altivelis, shrimp |

| Groundfish | | | | |
|---|---|---|---|---|
| Common Name | *Scientific Name* | Lifestage | Activity | PreyName |
| Silvergray rockfish | *Sebastes brevispinis* | Adults | All | |
| Soupfin shark | *Galeorhinus galeus* | Adults | All | Fish, invertebrates |
| | | Juveniles | Growth to Maturity | Invertebrates, Fish |
| Spiny dogfish | *Squalus acanthias* | Adults | All | Invertebrates, pelagic fishes, invertebrates, pelagic fishes, |
| Splitnose rockfish | *Sebastes diploproa* | Juveniles | Feeding | Amphipods, cladocerans, copepods |
| | | Larvae | | |
| Spotted ratfish | *Hydrolagus colliei* | Adults | All | algae, Amphipods, Annelids, Brittle Stars, fish, hydrolagus colliei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squids |
| | | Juveniles | Growth to Maturity | algae, Amphipods, Annelids, Brittle Stars, fish, hydrolagus colliei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squids |
| Starry flounder | *Platichthys stellatus* | Adults | Growth to Maturity | Crabs, fish juveniles, molluscs, polychaetes |
| | | Juveniles | Feeding | Amphipods, copepods, polychaetes |
| Stripetail rockfish | *Sebastes saxicola* | Adults | All | Copepods, euphausiids |
| | | Juveniles | Feeding, Growth to maturity | copepods |
| Tiger rockfish | *Sebastes nigrocinctus* | Adults | All | Amphipods, clupeids, crabs, fish juveniles, juvenile rockfish, shrimp |
| Vermilion rockfish | *Sebastes miniatus* | Adults | All | Clupeids, juvenile rockfish, krill, octopi, squids |
| Widow rockfish | *Sebastes entomelas* | Adults | All | Amphipods, Copepods, Euphausiids, Merluccius productus, salps, shrimp, squids |
| | | Juveniles | Feeding, Growth to maturity | Copepod eggs, Copepods, Euphausiid eggs |
| Yelloweye rockfish | *Sebastes ruberrimus* | Adults | All | Clupeids, cottids, crabs, gadids, juvenile rockfish, sea urchin, shrimp, snails |
| Yellowtail rockfish | *Sebastes flavidus* | Adults | All | Clupeids, Euphausiids, krill, Merluccius productus, Mysids, salps, Squids, tunicates |
| **Coastal Pelagic Species** | | | | |
| Common Name | *Scientific Name* | | | |
| Northern Anchovy | *Engraulis mordax* | | | |
| Pacific Sardine | *Sardinops sagax* | | | |
| Pacific (Chub) Mackerel | *Scomber japonicus* | | | |
| Market squid | *Loligo opalescens* | | | |
| Jack Mackerel | *Trachurus symmetricus* | | | |
| **Pacific Salmon** | | | | |
| Common Name | *Scientific Name* | | | |
| Coho Salmon | *Oncorhynchus kisutch* | | | |
| Chinook Salmon | *Oncorhynchus tshawytscha* | | | |

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

**Refer to NMFS No:**
**2012/00604**

June 22, 2012

Cayla D. Morgan
Seattle Airport District Office
Federal Aviation Administration
1601 Lind Avenue SW, Suite 250
Renton, Washington 98055-4056

Re: Endangered Species Act Section 7(a)(2) Concurrence Letter and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Southwest Oregon Airport mitigation site dike repair, Coos Bay (Haynes Inlet 6th field HUC: 171003040304), Coos County, Oregon

Dear Ms. Morgan:

On February 29, 2012, the National Marine Fisheries Service (NMFS) received a request from the Federal Aviation Administration (FAA) for formal consultation under section 7 of the Endangered Species Act (ESA) on the effects of the Southwest Oregon Airport (SWORA) mitigation site dike repair (proposed action). In the request for consultation the FAA determined that the proposed action would likely adversely affect (LAA) Oregon Coast (OC) coho salmon (*Oncorhynchus kisutch*) and southern distinct population segment (DPS) North American green sturgeon (*Acipenser medirostris*) (hereafter referred to as 'green sturgeon'). The FAA also determined that the proposed action is not likely to adversely affect (NLAA) southern DPS Pacific eulachon (*Thaleichthys pacificus*) (hereafter referred to as 'eulachon'), designated critical habitat for OC coho salmon, and designated critical habitat for green sturgeon. After review of the biological assessment and initiation package for the proposed action the NMFS determined that the effects of the proposed action are NLAA OC coho salmon and their designated critical habitat, green sturgeon and their designated critical habitat, and eulachon. This response to your request was prepared by NMFS pursuant section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402, and agency guidance for preparation of letters of concurrence.[1]

The NMFS also reviewed the proposed action for potential effects on essential fish habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), including conservation measures and any determination that you made regarding the potential effects of the action.

[1] Memorandum from D. Robert Lohn, Regional Administrator, to ESA consultation biologists (guidance on informal consultation and preparation of letters of concurrence) (January 30, 2006).

This review was pursuant to section 305(b) of the MSA, implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation.[2] In this case, NMFS concluded that the action would not adversely affect EFH. Thus, consultation under the MSA is not required for this action.

This letter is in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Data Quality Act) (44 U.S.C. 3504 (d) (1) and 3516), and underwent pre-dissemination review using standards for utility, integrity and objectivity.

**Consultation History**

On August 23, 2010, the U.S. Army Corps of Engineers (Corps) contacted NMFS requesting initiation of emergency consultation procedures to install a temporary protective structure at the SWORA mitigation site for protection of the dike. The dike had eroded from wind-wave action, combined with tidal fluctuation was limiting use of an access road needed for the landowner to access part of their property. The emergency proposal consisted of a log boom installed to take the greatest force of the wave action and halt erosion to the dike. The NMFS issued emergency conservation measures on September 7, 2010.

On February 5, 2011, NMFS received an e-mail from the contractor requesting a meeting on-site to discuss a long-term solution for dike stabilization. On February 17, 2011 NMFS met with the contractor, landowner, Oregon Department of Fish and Wildlife, SWORA and their consultants, and the Corps to determine an appropriate method to stabilize the dike.

On September 22, 2011, NMFS received a public notice from the Corps requesting comments on the proposed action. On October 3, 2011, NMFS responded to this public notice by sending the Corps a Fish and Wildlife Coordination Act letter that identified concerns regarding construction activities and the proposed action.

On February 29, 2012, NMFS received from the FAA a biological assessment (BA) and a letter requesting consultation for the effects of the proposed action to ESA-listed species and critical habitats. In the BA, the FAA determined that the proposed action was LAA OC coho salmon and green sturgeon. The FAA also determined that the proposed action was NLAA eulachon, designated critical habitat for OC coho salmon, and designated critical habitat for green sturgeon. The BA also included the FAA's determination that the proposed action would likely adversely affect EFH for Pacific salmon and coastal pelagic species.

On March 28, 2012, NMFS sent a letter requesting the FAA provide additional information required to continue with consultation on the proposed action and its effects to ESA-listed species and critical habitat. The FAA responded to NMFS' request, providing a letter on May 16, 2012. On May 25, 2012, NMFS followed up with the FAA and their consultant to obtain

---

[2] Memorandum from William T. Hogarth, Acting Administrator for Fisheries, to Regional Administrators (national finding for use of Endangered Species Act section 7 consultation process to complete essential fish habitat consultations) (February 28, 2001).

additional information in NMFS' request that was not clearly identified in the FAA's response.[3] After reviewing all information provided by the FAA, NMFS determined that additional information was required to continue with consultation and e-mailed the consultant with the additional information request on June 1, 2012. The consultant responded on June 4, 2012 with the requested information. The NMFS reviewed this information and initiated informal consultation on June 4, 2012.

The NMFS used information provided in the BA, Corps joint permit application (Corps No.: NWP-2006-760/4), and information from meetings and e-mails with the FAA and their consultants to complete this consultation. A complete record of this consultation is on file at the Oregon Coast Branch of the Oregon State Habitat Office in Roseburg, Oregon.

The proposed action does not qualify for programmatic biological opinion coverage (SLOPES) because it is neither a transportation or restoration project, but a project to repair and stabilize a water control structure (dike).

**Description of the Proposed Action and the Action Area**

The proposed action is the FAA's SWORA mitigation site dike repair project (Figure 1). The dike has eroded on the Coos Bay side from wind and wave activity, which has undermined the dike and its function. The proposed action will include: (1) Excavation of two meandering channels on the back side of the existing dike; (2) stabilizing the face (section A in Figure 1) of the existing dike with a rootwad structure that includes anchor logs and large rocks to hold rootwads in place (Figure 2); (3) stabilizing the outside (section B in Figure 1) northern and southern corners of the dike with riprap incorporated with rootwads (Figure 2); and (4) replacing a damaged culvert fitted with a tidegate. The dike consists of fill material and was not historically present in Haynes Inlet of Coos Bay. The dike was constructed in the early 1940s to create pasture land to serve a dairy farm.[4] In 2008, NMFS completed consultation on the SWORA taxiway C relocation and construction of an air traffic control tower (refer to NMFS No.: 2008/03298). The dike constructed in the 1940s was relocated to its current position as mitigation for the aforementioned project to restore tidal channels and tidal marshlands in the action area. During the work to relocate the dike, riprap was installed in section B (Figure 1) on the dike to strengthen these areas. The SWORA proposes to work from June to August.

***Meandering channels***. The SWORA will excavate two meandering channels behind the dike. Construction of one channel (meandering channel 1) will occur along the back side of the dike southwest of the northern side of the restored tidal area. The SWORA will connect this channel to an existing channel that runs to a tidegate that drains to the bay. The other constructed channel's location (meandering channel 2) will be along the back side of the northern stretch of the dike and connect to an existing channel at the northeast corner of the site. The SWORA will

---

[3] Phone conference between Cayla Morgan (FAA), Casey Storey and Rainse Anderson (WHPacific), and Jeff Young (NMFS) discussing conservation measures and potential for fish presence in excavation areas for meandering channels (May 25, 2012).

[4] Biological and EFH assessment for the SWORA proposed parallel taxiway C relocation and air traffic control tower construction (Phase II). 2006. Prepared for SWORA and W&H Pacific by Natural Resource Planning Services, Inc. (See NMFS No.: 2008/03298).

construct the channels to have an ordinary high water line (OHW) at four feet elevation with an active channel width and depth of ten and two feet. Channel construction will occur such that the channel will meander along the back side of the dike. Willow plantings will occur at the OHW and SWORA will place woody debris every 50 feet in the constructed channels (Figure 2).

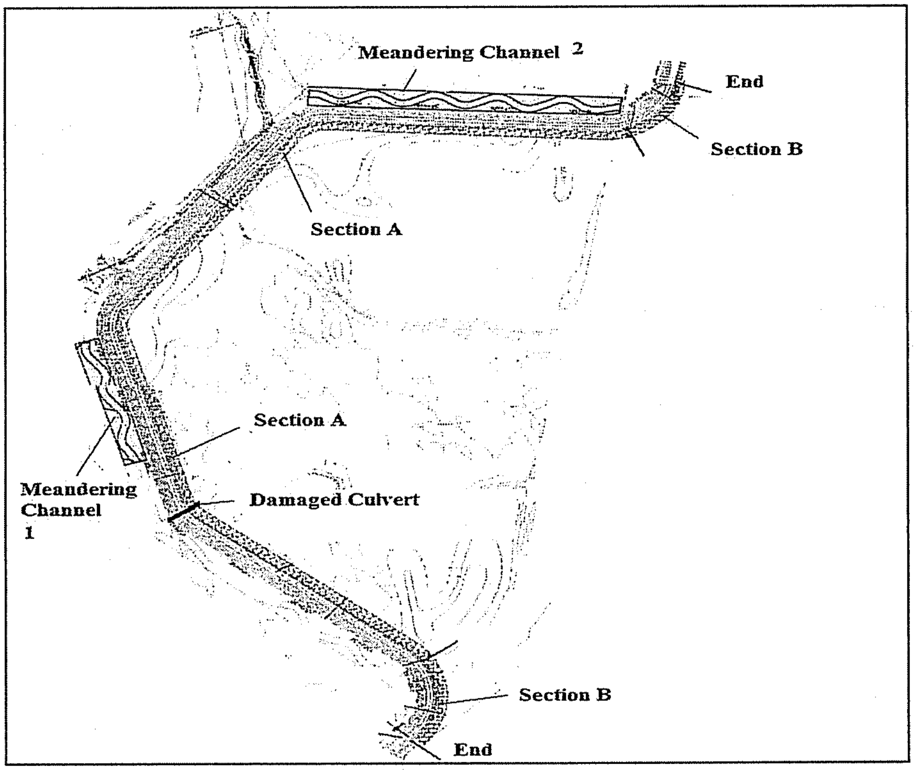



**Figure 1.** Diagram of the SWORA mitigation site dike and locations of project activities associated with the proposed action.

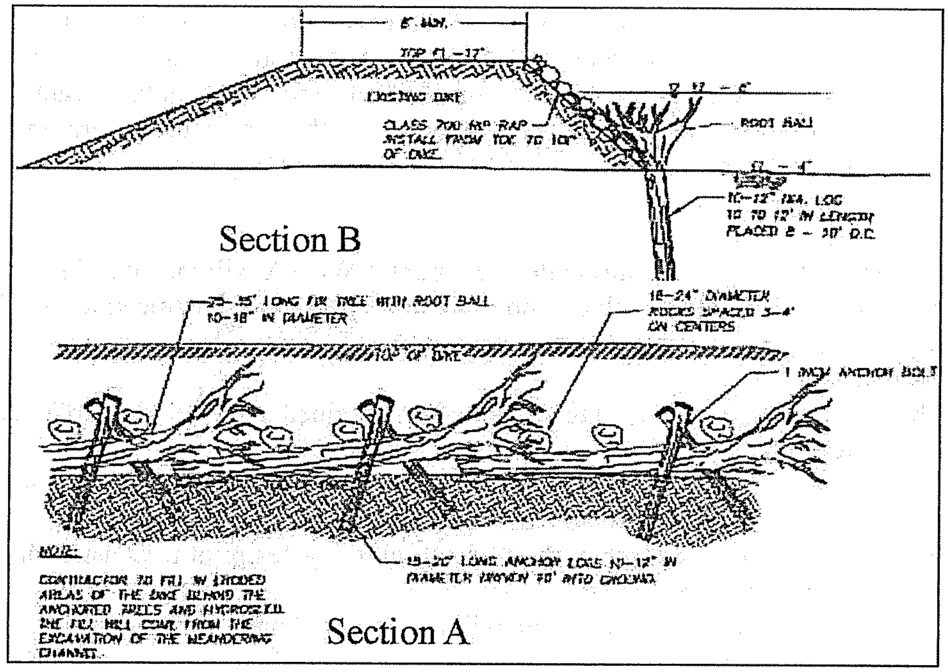



**Figure 2.** Rock riprap and rootwad treatments to stabilize the SWORA mitigation site dike.

***Dike repair and stabilization***. Using the excavated material from the construction of the meandering channels, SWORA will place identified material on the face of the dike. This dike repair will return the dike to its previous width. To stabilize the face of the dike SWORA will use two different stabilization techniques. The first (section A of Figure 2) will consist of 10- to 18-inch diameter tree sections approximately 25 to 35 feet long with rootwads attached. The SWORA will place the trees so that the rootwads overlap the stems to provide a continuous stabilization structure along the dike. To hold the tree sections in place, SWORA will place 18 to 24-inch rocks on top of the trees and pound into the ground 15- to 20-foot log sections to approximately a 10-foot depth. The SWORA will than connect these over the tree sections with a bolt to secure the tree sections in place. The second technique (section B of Figure 2) will consist of placing an approximate total of 200 feet of rock riprap from the toe to the top of the dike. When the dike was relocated to its existing location, riprap was placed in these areas to provide protection of the dike. These areas get the worst of the wind and wave action. The placement of additional riprap will strengthen these areas. The SWORA will then drive 10- to 12-foot long tree sections that are 10 to 12 inches in diameter into the ground at the toe of the riprap leaving the rootwad exposed. These will be placed every 8 to 10 feet.

***Culvert replacement***. The SWORA will replace a damaged culvert (Figure 1) that drains to Coos Bay. This culvert is fitted with a top-hinged tidegate to prevent saltwater intrusion into the pasture behind the dike. The SWORA will excavate the dike down to the culvert and replace it with a new culvert of the same size and length. The new culvert will have the same slope (zero) and will be set at the same elevation. The SWORA will place the existing tidegate on the new culvert.

The SWORA and FAA proposed conservation measures to minimize the effects to ESA-listed species and critical habitats. One of those was fish salvage. If fish were to become stranded in the excavation areas for the proposed meandering channels, then fish would be captured and removed and safely released back to the bay. The only way that fish could be present in the excavation areas is if they are washed over the dike.[3] The remaining conservation measures include the following:

1. To minimize the effects of suspended sediment, SWORA will install sediment fences and floating silt curtains at the culvert and at the ends of the existing meandering channels where constructed channels will be connected to minimize dispersion of suspended sediment.
2. All heavy equipment will be staged, parked, maintained, and fueled in upland areas at least 150 feet from the nearest waterbody and/or wetland.
3. All heavy equipment will be operated from on top of the existing dike or from work mats or platforms to reduce impacts to existing aquatic and wetland resources.
4. Sediment socks will be placed at the outlet of all tidegates prior to construction near waterways draining to each.
5. All vehicles used during construction will be inspected daily for fluid leaks and maintained appropriately.
6. Spill response kits will be on-site during construction in the event of unanticipated discharge of fuel or equipment fluids.
7. All non-work areas will be flagged, staked, or fenced prior to construction.
8. All work will be conducted during periods of dry weather to reduce the introduction of sediment to project area waterways.
9. All work within tidally influenced portions of the project area will be completed when tidal inundation is absent (low tide, low slack and incoming tides).
10. After construction activities are completed, SWORA will hydroseed all exposed soil areas.

The proposed action area is located in Haynes Inlet of the Coos Bay Frontal fifth-field watershed (HUC5: 1710030403). The action area consists of the proposed meandering channel areas (Figure 1) and 40 feet out from the backside of the dike in these areas; 50 linear feet from connection points of proposed meandering channels and existing channels; and the dike and 50 feet out from the dike towards the bay along the entire length of the dike (approximately 1,650 linear feet). The extent of the action area has been determined based on the extent of construction and the likely extent of suspended sediment dispersion.

**Description of Species and Critical Habitat**

The proposed action may affect OC coho salmon, green sturgeon, and eulachon; and designated critical habitats ESA-listed species (Table 1). The action area is designated critical habitat for OC coho salmon and green sturgeon, but not for eulachon. The critical habitat unit affected by the proposed action is the Coos Bay Frontal fifth-field watershed (HUC5: 1710030403).

**Table 1.** Federal Register notices for ESA-listed species referred to in this document.

| Species | Listing Status | Critical Habitat | Protective Regulations |
|---|---|---|---|
| OC coho salmon | T 6/20/11; 76 FR 35755 | 2/11/08; 73 FR 7816 | 2/11/08; 73 FR 7816 |
| Green sturgeon | T 4/07/06; 71 FR 17757 | 10/09/09; 74 FR 52300 | 6/02/10; 75 FR 30714 |
| Eulachon | T 3/18/10; 75 FR 13012 | 10/20/2011; 76 FR 65324 | Not applicable |

***OC coho salmon***. Adult and juvenile OC coho salmon use the action area as a migration corridor and to transition between freshwater and saltwater. Juvenile OC coho salmon also use the action area for rearing during the juvenile outmigration. The action area surrounding the project area is tidally influenced mudflats with tidal channels that provide rearing opportunities for juveniles. The NMFS is reasonably certain that few OC coho salmon juveniles will be present in the action area during project activities. Juvenile outmigration ends by mid-July and does not begin again until mid-February of the next year. Adult OC coho salmon pass by the action area on their way to Palouse and Larson sloughs as spawning begins at the beginning of September and ends in January. Migrating adults would not spend considerable time within the action area. The primary constituent elements (PCEs) of OC coho salmon designated critical habitat in the estuary are those that support migration, rearing, and successful transition between freshwater to saltwater (Table 2).

**Table 2.** PCEs of critical habitat designated for OC coho salmon and potentially affected by the proposed action with corresponding species life history events.

| Primary Constituent Elements | | Species Life History Event |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Estuarine areas | Forage<br>Free of artificial obstruction<br>Natural cover<br>Salinity<br>Water quality<br>Water quantity | Adult sexual maturation and "reverse smoltification"<br>Adult upstream migration and holding<br>Fry/parr/smolt growth, development, and seaward migration |

***Green sturgeon***. The NMFS defined two distinct population segments (DPS) of green sturgeon: a northern DPS with spawning populations in the Klamath and Rogue rivers and a southern DPS that spawns in the Sacramento River. Green sturgeon was listed as threatened in 2006 (71 FR 17757), and includes all spawning populations south of the Eel River in California. Critical habitat for green sturgeon within Coos Bay terminates at head of tide (74 FR 52300) and includes the action area. Subadult and adult green sturgeon use the action area as habitat for growth and development to adulthood and for adult and subadult feeding. Green sturgeon are known to congregate in coastal waters and estuaries, including non-natal estuaries such as Coos

Bay (including South Slough). Beamis and Kynard (1997)[5] suggest that green sturgeon move into estuaries of non-natal rivers to feed. Data from Washington studies indicate that green sturgeon will only be present in estuaries from June until October (Moser and Lindley 2007).[6] The PCEs of designated critical habitat in the estuary are those that support subadult and adult green sturgeon growth and development and movements between estuarine and marine areas.

**Table 3.** PCEs of critical habitat designated for green sturgeon and potentially affected by the proposed action with corresponding species life history events.

| **Primary Constituent Elements** | | **Species Life History Event** |
|---|---|---|
| **Site Type** | **Site Attribute** | |
| Estuarine areas | Food resources<br>Migratory corridor<br>Sediment quality<br>Water flow<br>Water depth<br>Water quality | Adult and subadult growth and development<br>Adult and subadult seasonal holding<br>Adult and subadult movements between estuaries and marine areas |

***Eulachon***. Eulachon range from the Mad River in northern California to the Skeena River in British Columbia, Canada. They inhabit several riverine and estuarine systems along the west coast and population sizes vary between these systems. The Coos Bay population occurs in rare relative abundance. The NMFS listed eulachon as threatened under the ESA, protective regulations were issued on March 18, 2010 (75 FR 13012). The NMFS designated critical habitat for eulachon on October 20, 2011 (76 FR 65324) and the action area is not critical habitat. Eulachon adults return to freshwater from January to May and evidence suggests that adult eulachon may return as early as December to spawn (WDFW and ODFW 2001).[7] Typical spawning for eulachon occurs from January to mid-May, with the peak in February to mid-March, though there is currently little information available about eulachon movement and/or spawning locations in Coos Bay estuarine and near-shore marine areas. When eggs hatch in 30 to 40 days, eulachon larvae immediately wash downstream to estuarine and ocean areas where they feed on phytoplankton and zooplankton. Most larvae will likely be carried past the action area during spring freshets before the proposed work period. By this time remaining larvae will likely have grown to juvenile size, which disperse to the ocean as soon as they are able. Juvenile eulachon potentially occur in the action area, but their presence will likely be migratory in nature.

---

[5] Beamis, W.E., and B. Kynard. 1997. Sturgeon rivers: An introduction to acipensiform biogeography and life history. Environmental Biology of Fishes 48:167-183.

[6] Moser, M., and S. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes DOI 10 1007/s10641-006-9028-1.

[7] WDFW (Washington Department of Fish and Wildlife) and ODFW (Oregon Department of Fish and Wildlife). 2001. Washington and Oregon eulachon management plan. Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife. Online at http://wdfw.wa.gov/fish/creel/smelt/wa-ore_eulachonmgmt.pdf. November.

**Effects of the Action**

For purposes of the ESA, "effects of the action" means the direct and indirect effects of an action on the listed species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action (50 CFR 402.02). The applicable standard to find that a proposed action is NLAA listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial.[8] Beneficial effects are contemporaneous positive effects without any adverse effects to the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur.

The effects of the proposed action are reasonably likely to include: (1) Increased suspended sediments; (2) work area isolation and fish salvage; and (3) modification of nearshore habitat.

**Effects to Species**

***Increased suspended sediment***. Excavation of meandering channels, placement of excavated material to repair the dike, and placement of rock riprap and woody debris structures to stabilize the dike will disturb substrate and temporarily degrade water quality by increasing suspended sediments in the action area. Increased suspended sediments will occur along the entire linear length of the dike (1,650 feet) and extend out 50 feet towards the bay and in the proposed meandering and existing channels 50 downstream of the existing and proposed channels' connection point. The suspended sediment plumes will occur during project implementation and for the first few high tide cycles following project completion. Concentrations of suspended sediment plumes will become lower with each subsequent high tide as sediment is dispersed and stabilized.

Juvenile coho salmon exposed to increases in suspended sediment for periods as short as four hours can experience adverse physiological (as low as 17 milligrams per liter [mg/L]) and behavioral effects (as low as 30 mg/L) (Berg and Northcote 1985).[9] The potential for juvenile OC coho salmon to occur in the action area is low since the majority of individuals would have migrated past the action area to the Pacific Ocean before the proposed work period. OC coho salmon that may occur within the open water portion of the action area are likely to be exposed to concentrations below the threshold of concern. Concentrations of suspended sediments in meandering channels are reasonably unlikely to reach levels that would adversely affect OC coho salmon. Adult OC coho salmon will not be present in the action area during the work period. Therefore, the effects of increased suspended sediments are insignificant and are NLAA OC coho salmon.

Adult and subadult green sturgeon are far less sensitive to suspended sediments than salmonids. Green sturgeon usually inhabit environments with higher suspended sediment concentrations

---

[8] U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. Endangered Species Act consultation handbook: procedures for conducting section 7 consultations and conferences. March. Final. P. 3-12.

[9] Berg, L., and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

than do salmonids. Green sturgeon are likely to occupy deeper areas of Coos Bay than the action area; however, there is a low likelihood that adult and subadult green sturgeon could move into the action area to feed during high tides. Because of their high tolerance for suspended sediments, green sturgeon will not elicit an adverse response. Therefore, the effects of increased suspended sediments are insignificant and are NLAA green sturgeon.

Exposure of eulachon adults and larvae to increased suspended sediments is unlikely to occur. Adults will have migrated past the action area before the proposed work window. Juvenile eulachon occurring in the action area at this time of year would be from Palouse and Larson Sloughs. The potential for occurrence of juvenile eulachon in the action area is low because most individuals will have grown enough by the proposed work period to continue migration towards the ocean. The effects of increased suspended sediments to eulachon are likely similar to those observed in juvenile salmonids by Berg and Northcote (1985).[9] Juvenile eulachon that may occur within the open water portion of the action area are likely to be exposed to concentrations below the threshold of concern. Therefore, the effects of increased suspended sediments are insignificant and are NLAA eulachon.

***Isolation and fish salvage***. Potential for OC coho salmon, green sturgeon, and eulachon presence in the excavation area behind the dike is unlikely. The only way that fish could become present in the excavation and isolation area is from over wash of the dike by bay waters and it would have to be a sustained flow for fish to pass over the dike. Waves may wash up onto the dike during high flow events combined with high tides and significant wind and wave action, but it is unlikely that fish will be carried onto or over the dike into the excavation area. When the dike was constructed it was constructed with an eight foot top width. The top elevation of the dike is 12 feet, which was determined based on the highest measured tide of 10.26 feet.[10] It is unlikely that a sustained flow condition could exist over the dike. Therefore, effects of isolation and fish salvage are reasonably unlikely to occur to OC coho salmon, green sturgeon, and eulachon and are discountable due to the lack of presence of these species in this portion of the action area.

***Nearshore habitat modification***. Nearshore habitat modification along the approximately 1,650-foot long dike will occur. Currently the dike is eroded inside the mitigation site (section A in Figure 1) and riprap has been previously placed at both the northeast and southeast corners of the dike (section B of Figure 1). The dike in both these areas currently provides little habitat benefit for OC coho salmon, green sturgeon, and eulachon due to erosion and presence of riprap. They unlikely use it on a frequent basis. Following placement of the rootwad structure in section A, the nearshore area of this portion of the dike will provide habitat for species that OC coho salmon and eulachon consume as food and cover for OC coho salmon that rear in the action area. This will provide some benefit for rearing OC coho salmon and juvenile eulachon. In section B placement of new riprap over existing riprap will not benefit nor degrade the habitat, but maintain its current condition. The SWORA will also place some rootwads along the toe of the structure.

Green sturgeon are likely to occupy deeper habitats in the action area, but could move into shallow areas during high tide to feed. While in the action area, green sturgeon will be feeding

[10] E-mail from Casey Storey, WHPacific, to Jeff Young, NMFS discussing the constructed height of the dike in relation to the highest measured tide (June 4, 2012).

on invertebrates associated with softer bottom substrate in the tidal mudflats and not along the dike; therefore the modification of nearshore habitat along the dike will not modify the behavior of green sturgeon when present in the action area. Additionally, their forage species are unlikely to be adversely affected by the modifications of the dike face. Therefore, the effects of nearshore habitat modification are insignificant and NLAA green sturgeon.

The potential OC coho salmon and eulachon occurring in the nearshore areas of section B is low, but could occur. However, individuals migrating past the action area will not remain in these areas long enough to elicit an adverse response. Recent studies have shown that juvenile coho salmon smolts rearing in estuaries primarily use tidally inundated marshes (Cornwell *et al.* 2001, Jones *et al.* 2011).[11,12] Rearing juvenile OC coho salmon and juvenile eulachon present in the action area will primarily occupy the tidal mudflats feeding on small invertebrates, but may also occur infrequently in the nearshore area of the dike. Rootwads placed at the base of the riprap will provide some rearing opportunity, but because of other habitat available adjacent to section B and along the dike (nearshore of section A and tidal mudflats) rearing individual OC coho salmon and eulachon behavior will not be modified and they will not remain long enough to elicit an adverse response. Therefore, the effects of nearshore habitat modification are insignificant and NLAA OC coho salmon and eulachon.

**Effects to Critical Habitat**

The critical habitat unit affected by the proposed action is the Coos Bay Frontal fifth-field watershed (HUC: 1710030403). It is designated critical habitat for OC coho salmon and green sturgeon. It is not designated critical habitat for eulachon. The PCEs of OC coho salmon designated critical habitat in the action area include: (1) Forage; (2) free of artificial obstruction; (3) natural cover; (4) salinity; (5) water quality; and (6) water quantity. The PCEs for green sturgeon include: (1) Food resources; (2) migratory corridor; (3) sediment quality; (4) water flow; (5) water depth; and (6) water quality. The proposed action will affect the water quality PCE for both OC coho salmon and green sturgeon critical habitat and natural cover for OC coho salmon critical habitat.

The proposed action will degrade water quality along the length of the dike face (approximately 1,650 feet) and 50 feet into the bay from placement of excavated material to repair the dike and excavation of the dike to replace the damaged culvert. This will occur on high tides and with wind and wave action against the dike. Suspended sediment plumes will be short-term and localized with concentrations that are unlikely to reach adverse levels. Therefore, the effects of suspended sediments to the water quality PCE are NLAA critical habitats for OC coho salmon and green sturgeon. The natural cover PCE for OC coho salmon will be improved after project completion because the rootwad structure at the dike will provide additional shelter for rearing juvenile OC coho salmon. Therefore, the proposed action is NLAA the natural cover PCE of OC coho salmon critical habitat in the action area.

---

[11] Cornwell, T.J., D.L. Bottom, and K.K. Jones. 2001. Rearing of juvenile salmon in recovering wetlands of the Salmon River estuary. Oregon Department of Fish and wildlife, Information Reports 2001-05, Portland, Oregon.

[12] Jones, K.K., T.J. Cornwell, D.L. Bottom, S. Stein, H.K. Wellard, and L.A. Campbell. 2011. Recovery of wild coho salmon in Salmon River Basin, 2008-10. Monitoring Program Report Number OPSW-ODFW-2011-10, Oregon Department of Fish and Wildlife, Salem, Oregon.

**Conclusion**

Based on this analysis, NMFS concludes that all effects of the proposed action are NLAA OC coho salmon, green sturgeon, eulachon, and designated critical habitat for OC coho salmon and green sturgeon.

**Reinitiation of Consultation**

Reinitiation of consultation is required and shall be requested by the Federal agency, or by NMFS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and (1) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (2) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this concurrence letter; or if (3) a new species is listed or critical habitat designated that may be affected by the identified action (50 CFR 402.16). This concludes the ESA portion of this consultation.

Please direct questions regarding this letter to Jeff Young, fisheries biologist in the Oregon Coast Habitat Branch of the Oregon State Habitat Office, at 541.957.3389.

Sincerely,

William W. Stelle, Jr.
Regional Administrator

cc: Theresa Cook, SWORA
Benny Dean, Corps

# APPENDIX Q-8

JCEP Draft Biological Assessment, April 2014

# BIOLOGICAL ASSESSMENT

# and ESSENTIAL FISH HABITAT ASSESSMENT

**for the**

# Jordan Cove Energy and Pacific Connector Gas Pipeline Project

Jordan Cove Energy Project, L.P. Docket Nos. CP13-483-000

Pacific Connector Gas Pipeline Project, L.P. CP13-492-000



**April 2014**

## EXECUTIVE SUMMARY

This draft Biological Assessment (BA) and Essential Fish Habitat (EFH) Assessment for the Jordan Cove Energy and Pacific Connector Gas Pipeline Project (Project) has been prepared by the applicants for the staff of the Federal Energy Regulatory Commission (FERC or Commission) to comply with requirements of the United States (U.S.) Fish and Wildlife Service (FWS) and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS) under section 7 of the Endangered Species Act of 1973 (ESA), and by the NMFS under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The applicants have developed this BA in informal consultation and cooperation with FWS and the applicants remain committed to continue working cooperatively with FERC and FWS to refine the mitigation proposal associated with the BA. The CMP is considered a working document that would be revised throughout the ESA consultation process.

The FERC is the primary federal agency responsible for authorizing applications to construct and operate onshore liquefied natural gas (LNG) export and interstate natural gas transmission facilities. The FERC is also the lead federal agency responsible for complying with the ESA and the MSA for the Project. Other federal agencies with significant authorities over the Project are cooperating with the FERC in the National Environmental Policy Act (NEPA) review.

Each of the cooperating agencies has its own authorities or permitting responsibilities for elements of the Project. The COE has authority to issue dredging and wetland permits for the Project under section 10 of the Rivers and Harbors Act (RHA) and section 404 of the Clean Water Act (CWA). The Coast Guard determines the suitability of the waterway for LNG marine traffic by issuing a Letter of Recommendation. The Bureau of Land Management (BLM), United States Forest Service (USFS), and Bureau of Reclamation (Reclamation) will consider Pacific Connector’s application for a Right-of-Way Grant and Temporary Use Permits for the portions of the Pacific Connector pipeline that would cross federal lands. The USFS will also evaluate whether or not the proposed pipeline would require amending the forest plans of the affected National Forest System (NFS) lands. The Environmental Protection Agency (EPA) has responsibilities to review the proposed action under the Clean Air Act (CAA) and Clean Water Act (CWA). The Department of Transportation (DOT) has authority to enforce safety regulations and standards for the LNG terminal beginning at the last valve immediately before the storage tanks, and the design and operation of the Pacific Connector pipeline.

## PROPOSED ACTION

The purpose of the Jordan Cove Energy and Pacific Connector Gas Pipeline Project is to provide a new access point on the U.S. Pacific Coast where natural gas from supply basins in Western Canada and the Northern Rockies in the U.S. can be delivered through new or existing natural gas pipeline system infrastructure, liquefied, and loaded onto LNG carriers for delivery to Asian and non-coterminous U.S. Pacific markets. In so doing, the project was designed to use a port location with a suitable and maintained depth for deep draft vessels, use a port location with sufficiently sized developable land that meets the requirements for an LNG terminal facility; and use a site location in a port that is consistent with existing industrial land uses, meets all applicable regulations, accommodates industry standard LNG carriers and minimizes community and environmental impacts.

The waterway for LNG marine traffic would begin in the Pacific Ocean at the outer limits of the U.S. territorial waters, 12 nautical miles off the coast of Oregon, and end 7.5 nautical miles up the existing Coos Bay navigation channel at the proposed LNG terminal in Coos Bay. For the analysis in this BA and EFH Assessment specific to species covered by the ESA and MSA, we considered impacts from LNG marine traffic extending out to the limits of the Exclusive Economic Zone (EEZ), 200 nautical miles off shore. The access channel, slip, and LNG terminal would be located in or adjacent to Coos Bay, in Coos County, Oregon. The proposed LNG terminal is located on the north spit of Coos Bay. During construction, approximately 406.8 acres will be disturbed. Following construction, approximately 192.7 acres on the LNG Terminal, South Dunes, and construction worker camp sites (bridge) will be required for the permanent facilities. The new access channel and slip would require dredging about 30 acres within Coos Bay and excavation of another 36 acres of adjacent upland. Dredged and excavated material would be placed on the site of the South Dunes Power Plant. The LNG terminal facilities would include:

- A pipeline gas conditioning facility consisting of two feed gas cleaning and dehydration trains with a combined natural gas throughput of approximately 1 Bscf/d;
- Four natural gas liquefaction trains, each with the export capacity of 1.5 million metric tonnes per annum (MMTPA);
- A refrigerant storage and resupply system;
- An Aerial Cooling System (Fin-Fan);
- An LNG storage system consisting of two full-containment LNG storage tanks, each with a net capacity of 160,000 $m^3$ (1,006,000 barrels), and each equipped with three fully submerged LNG in-tank pumps sized for approximately 11,600 gallons per minute (gpm) each;
- An LNG transfer line consisting of one 2,300-foot-long, 36-inch-diameter line that will connect the shore based storage system with the LNG loading system;
- An LNG carrier cargo loading system designed to load LNG at a rate of 10,000 $m^3$ per hour ($m^3$/hr) with a peak capacity of 12,000 $m^3$/hr, consisting of three 16-inch loading arms and one 16-inch vapor return arm;
- A protected LNG carrier loading berth constructed on an Open Cell® technology sheet pile slip wall and capable of accommodating LNG carriers with a range of capacities;
- The improvement of an existing, on-site unimproved road and utility corridor to become the primary roadway and utility interconnection between the LNG Terminal and South Dunes sites, including between the pipeline gas conditioning units on the South Dunes Power Plant site and the liquefaction trains on the LNG Terminal site;
- A boil off gas (BOG) recovery system used to control the pressure in the LNG storage tanks;
- Electrical, nitrogen, fuel gas, lighting, instrument/plant air and service water facility systems;
- An emergency vent system (ground flare);
- An LNG spill containment system, a fire water system and various other hazard detection, control, and prevention systems; and
- Utilities, buildings, and support facilities.

The following facility, although not jurisdictional to FERC, will also be constructed to support the Project:

- The South Dunes Power Plant, a 420 megawatt (MW) natural gas fired combined-cycle electric power plant inclusive of heat recovery steam generator (HRSG) units for the purpose of powering the refrigeration systems in the natural gas liquefaction process and supplying steam to the conditioning units.

The natural gas pipeline facilities would include:

- a 232-mile-long, 36-inch-diameter, underground high-pressure welded steel pipeline; and
- one natural gas compressor station, three natural gas meter stations, five pig[1] launchers and/or receivers, seventeen mainline block valves, five new communication towers, and additional communications equipment installed at eight existing towers.

The Pacific Connector pipeline would deliver natural gas to the Williams Northwest Pipeline Corporation Grants Pass Lateral interstate pipeline near Clarks Branch, Oregon, and would terminate near the California border, east of Malin, Oregon, with interconnections with the Gas Transmission Northwest (GTN) Corporation and Ruby Pipeline LCC natural gas systems.

In addition to the LNG terminal and natural gas pipeline facilities, the Project would require construction of facilities that do not fall under the Commission's jurisdiction. These include the South Dunes Power Plant and the Southwest Oregon Regional Security Center.

The slip will be constructed on land owned by Fort Chicago LNG II U.S. L.P. Jordan Cove will construct the slip and the LNG carrier and tug berths. Upon completion, Jordan Cove will transfer ownership of the slip to the Port. Under the sell back, long term lease agreement that Jordan Cove will enter into with the Port, Jordan Cove will lease the slip from the Port and Jordan Cove will operate the LNG carrier berth. Jordan Cove will reimburse the Port for operation and maintenance of the slip.

The access channel will be on land owned by the State of Oregon. The Port has submitted an application to the USACE for the slip and access channel. The Port has obtained an easement from the State for the use and maintenance of the access channel. Jordan Cove will construct the access channel. Upon completion of construction and initiation of operation, Jordan Cove will transfer maintenance responsibility to the Port, which will be responsible for maintaining the access channel. Jordan Cove will be responsible for reimbursing the Port for operation and maintenance of the access channel.

Although the Port itself is not under the jurisdiction of the FERC, operation of the access channel and slip are considered interrelated and interdependent actions with those proposed by Jordan Cove and are therefore included in Jordan Cove's application to the FERC, and addressed in this BA and EFH Assessment.

## COORDINATION AND COMMUNICATION

The FERC staff, and Jordan Cove Energy and Pacific Connector Gas Pipeline as the FERC's nonfederal representative for the purpose of conducting consultations under the ESA and MSA, began conferring with the FWS and NMFS in 2005 through a number of meetings, site visits, telephone calls, and electronic mailings. Primary coordination has involved Mr. Chuck Wheeler of the NMFS and Mr. Doug Young of the FWS.

[1] A "pig" is a tool for cleaning and inspecting the inside of a pipeline.

In addition to the interagency meetings, the applicants and FERC representatives met with an Interagency Task Force, which included representatives of the FWS and NMFS, as well as USFS, BLM, ODLCD, ODE, ODSL, COE, ODFW, EPA, and ODEQ, to obtain specific input, guidance, and technical approach reviews. Agencies participating in the Interagency Task Force reviewed information provided by Jordan Cove Energy and Pacific Connector Gas Pipeline. The FERC and Jordan Cove and Pacific Connector have conducted specific studies and analyses associated with comments raised by the FWS and NMFS and these are integral to this assessment.

The presentation of the analysis in this draft BA and EFH Assessment is organized by key activities associated with construction and operation of the Project. Structural and functional elements of the project were grouped into four major components: 1) Waterway for LNG marine traffic; 2) Marine facilities; 3) LNG terminal facilities; and 4) Pipeline and associated facilities. Section 4.0 discusses the potential effects on listed species and critical habitat associated with each of these major components, and includes our determination of effect for each species and designated critical habitat (where present in the action area). Section 6.0 discusses potential effects on EFH.

## MAJOR CONCLUSIONS

Endangered Species Act

The FWS and NMFS were consulted to confirm federally listed species and critical habitat with the potential to occur in the action area. Thirty-one species (including 2 Evoluntionarily Significant Units of the same species) that are federally listed as endangered or threatened (one of which is proposed for delisting), and one species proposed for listing potentially occur in the action area. Of these, critical habitat has been designated or proposed in the action area for 12 species. The findings regarding the effects of the Jordan Cove Energy and Pacific Connector Gas Pipeline Project on listed and proposed species are based on the best scientific and commercial data available, and not on experimental designs of mitigation measures or practices. The Proposed Action may affect, but is not likely to adversely affect 20 species and/or their designated critical habitat: 7 whales, 1 land mammal, 3 birds, 4 sea turtles and 1 amphibian (proposed for listing with proposed critical habitat), collectively classified as herpetofauna, 1 fish (designated critical habitat not likely affected for 2 species only), and 3 plants. Alternatively, the Proposed Action may affect, and is likely to adversely affect 12 species: 2 birds, 5 fish, vernal pool fairy shrimp, and 4 plants and the designated critical habitat for a fifth species are likely to be adversely affected. These determinations as well as a summary of the justification for the determinations are provided in table ES-1.

Since the project began, three species have been removed from the list of threatened and endangered species and are no longer considered in the Biological Assessment. They include the bald eagle (*Haliaeetus leucocephalus*, removed in 2007), brown pelican (*Pelecanus occidentalis*, removed in 2009), and Steller sea lion (*Eumetopias jubatus*, removed in 2013). In addition, the Proposed Action would have no effect on the Canada lynx (*Lynx canadensis*, Contiguous U.S. Distinct Population Segment), North American wolverine (*Gulo gulo luscus*, proposed for listing), bull trout (*Salvelinus confluentus*, Klamath River Distinct Population Segment), or yellow billed cuckoo (*Coccyzus americanus*, Western Distinct Population Segment, proposed for listing) and these four species are not considered in this Biological Assessment.

TABLE ES-1

**Determinations of Effect for Federally Listed Endangered and Threatened Potentially Occurring In the Vicinity of the Project Area**

| Listed Species | Determination of Effect a/ Species | Critical Habitat | Justification |
|---|---|---|---|
| **Mammals** | | | |
| Blue whale<br>*Balaenoptera musculus* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG and fire at sea would not cover a large enough area to affect mammals in the water. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. |
| Fin whale<br>*Balaenoptera physalus* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cover a large enough area to affect mammals in the water. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. |
| Killer whale<br>(Eastern Northern Pacific Southern Resident Stock)<br>*Orcinus orca* | NLAA | NE | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting mammals in the water. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. |
| Humpback whale<br>*Megaptera novaeangliae* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting mammals in the water. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. |
| Sei whale<br>*Balaenoptera borealis* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG and fire at sea would not cool the water column to the point of affecting mammals in the water Ship noise would be detectable but would not exceed NMFS interim noise exposure criteria. |
| Sperm whale<br>*Physeter macrocephalus* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting mammals in the water. Ship noise would be detectable and could exceed NMFS interim noise exposure criteria for Level B non-pulse noise but would not cause injury. |
| North Pacific right whale<br>*Eubalaena japonica* | NLAA | NE | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting mammals in the water. Ship noise would be detectable but would not exceed NMFS interim noise exposure criteria. |
| Gray wolf<br>(Western Washington, Western Oregon, Northern California)<br>*Canis lupus,* | NLAA | N/A | Project would cross the activity area of one solitary wolf, OR-7 that emigrated from the Northern Rocky Mountain DPS in NE Oregon. Construction noise and human presence could affect the animal's north and south movements, if present at the time of construction. |
| **Birds** | | | |
| Short-tailed albatross<br>*Phoebastria albatraus* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting food species in the water. |
| Western snowy plover<br>(Pacific Coast Population)<br>*Charadrius alexandrinus nivosus* | NLAA | NLAA | The primary nesting areas on the North Spit used by western snowy plover are more than 4.5 miles from construction sites for the slip and power plant. Noise at nesting areas and critical habitat due to sheet pile driving and project construction would not be above ambient levels. Avoidance and conservation measures will be in place to decrease the possibility of negative effects to the species and its critical habitat. |

TABLE ES-1

**Determinations of Effect for Federally Listed Endangered and Threatened Potentially Occurring In the Vicinity of the Project Area**

| Listed Species | Determination of Effect a/ Species | Determination of Effect a/ Critical Habitat | Justification |
|---|---|---|---|
| Marbled murrelet *Brachyramphus marmoratus* | LAA | LAA | Construction of the proposed Project would result in modification of suitable habitat. Disturbance due to construction, blasting, and helicopter use could adversely impact this species. The proposed Project would impact critical habitat through removal of PCEs. |
| Northern spotted owl *Strix occidentalis caurina* | LAA | LAA | Construction of the proposed Project would result in modification of suitable habitat. Disturbance due to construction, blasting, and helicopter use could adversely impact this species. The proposed Project would impact critical habitat through removal or potential downgrading of PCE. |
| Streaked horned lark *Eremophila alpestris strigata* | NLAA | NE | Construction and operation of the proposed Project could cause a few individual migrating and/or wintering streak horned larks to locate away and avoid the project location. The nearest critical habitat unit is 80 miles away. |
| **Herpetofauna** | | | |
| Green turtle *Chelonia mydas* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting turtles in the water. Ship noise would be detectable but would not permanently or temporarily impair hearing. |
| Leatherback turtle *Dermochelys coriacea* | NLAA | NLAA | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting turtles in the water. Ship noise would be detectable but would not permanently or temporarily impair hearing. |
| Olive Ridley turtle *Lepidochelys olivacea* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting turtles in the water. Ship noise would be detectable but would not permanently or temporarily impair hearing. |
| Loggerhead turtle *Caretta caretta* | NLAA | N/A | Shipping traffic would be traveling at slow speeds (10 knots or less as detailed in the Ship Strike Avoidance Measures for Whales) making the potential for ship-strike extremely low. Spills or releases of LNG at sea would not cool the water column to the point of affecting turtles in the water. Ship noise would be detectable but would not permanently or temporarily impair hearing. |
| Oregon spotted frog *Rana pretiosa* | (Proposed) NJ | (Proposed) NAM | The possibility that pipeline construction across Spencer Creek could affect Oregon spotted frogs was judged to be discountable because the crossing site is 6,400 feet upstream from occupied habitat and proposed critical habitat in Buck Lake and the frogs and proposed critical habitat are not within the analysis area. If frogs occupy Buck Marsh in the future, sediment mobilized during construction might affect them but that is not foreseeable. |
| **Fish** | | | |
| Green sturgeon (Southern Distinct Population Segment) *Acipenser medirostris* | LAA | LAA | Subadult sturgeon may suffer mortality from burial during discharge of maintenance dredged material at Site F. Maintenance dredging would reduce food supply for rearing fish in Coos Bay. Designated critical habitat would be adversely affected by reduction in food sources from dredging in Coos Bay for construction and discharge of maintenance dredge spoils at ocean dumping Site F. |
| Eulachon (Southern Distinct Population Segment) *Thaleichthys pacificus* | NLAA | NE | While some eulachon may be present in Coos Bay during construction and dredging the mitigation measures in place would reduce the scope and magnitude of area affected so the chance of them being adversely affected from the operations is remote. No critical habitat coincides with the estuarine analysis area. |
| Coho salmon (Southern Oregon/Northern California Coast Evolutionarily Significant Unit) *Oncorhynchus kisutch* | LAA | LAA | Juvenile rearing stages would suffer stress and possibly mortality from elevated turbidity at stream pipeline crossing sites, from fish salvage operations conducted before pipeline stream crossings, and from stream side blasting. Adult spawning success may also suffer from short-term elevated sediment from pipeline stream crossings. Designated critical habitat would be adversely affected by reduced large woody debris (LWD) supply and riparian habitat loss and impedance of fish movement during instream construction. |

TABLE ES-1

**Determinations of Effect for Federally Listed Endangered and Threatened Potentially Occurring In the Vicinity of the Project Area**

| | Determination of Effect a/ | | |
|---|---|---|---|
| **Listed Species** | **Species** | **Critical Habitat** | **Justification** |
| Coho salmon (Oregon Coast Evolutionarily Significant Unit) *Oncorhynchus kisutch* | LAA | LAA | Juvenile rearing stages would suffer stress and possibly mortality from elevated turbidity near stream pipeline crossing sites, from fish salvage operations conducted before pipeline stream crossings, and from stream side blasting. Adult spawning success may also suffer from short-term elevated sediment from pipeline stream crossings. Juvenile loss from entrainment during LNG vessel water intake in Coos Bay may occur. Designated critical habitat would be adversely affected by reduced LWD supply and riparian habitat loss and impedance of fish movement during instream construction. |
| Lost River sucker *Deltistes luxatus* | LAA | NLAA | Juvenile or adult fish may be adversely affected if they are in the region of pipeline stream crossing during construction and may suffer mortality from fish salvage operations. Designated critical habitat would not be adversely affected as the use of horizontal direction drill (HDD) would avoid contact with any in water critical habitat in the stream. |
| Shortnose sucker *Chasmistes brevirostris* | LAA | NLAA | Juvenile or adult fish may be adversely affected if they are in the region of the stream crossing during construction and may suffer mortality from fish salvage operations. Designated critical habitat would not be adversely affected as the use of HDD would avoid contact with any in water critical habitat in the stream. |
| **Invertebrates** | | | |
| Vernal pool fairy shrimp *Branchinecta lynchi* | LAA | LAA | Use of the Medford Industrial Park Yard is expected to indirectly affect fairy shrimp if they are 527 feet away since intact hydrologic connections between the yard and vernal pools could potentially be impacted by surface disturbances and/or soil compaction by heavy machinery. The proposed action could potentially adversely modify PCE 2 through surface disturbances and/or soil compaction by heavy machinery within the Medford industrial Park Yard at least 527 feet away from designated critical habitat unit VERFS 3B. |
| **Plants** | | | |
| Applegate's milk-vetch *Astragalus applegatei* | LAA | N/A | Potential suitable habitat occurs along the proposed pipeline route and comprehensive surveys have not been conducted in that area; therefore it is possible that unidentified plants occur within the proposed pipeline construction right-of-way and work space. |
| Gentner's fritillary *Fritillaria gentneri* | LAA | N/A | Not all potential suitable habitat crossed by the pipeline was surveyed due to landowner access denial. Gentner's fritillary does not flower every year, and has been documented to not flower for several years; therefore, it is possible that this plant is present in the construction right-of-way even though it was not identified during the two years of surveys conducted for this flower. Fritillaria sp. leaves were documented within and adjacent to the proposed project and without flowers, it is nearly impossible to determine if those leaves belong to Gentner's fritillary or another Fritillaria species. |
| Large-flowered woolly meadowfoam *Limnanthes pumila ssp. grandiflora* | LAA | LAA | Use of the Medford Industrial Park Yard, even if it does not support the species, potentially could indirectly affect large-flowered meadowfoam and vernal pools if they are 527 feet away, possibly in proposed critical habitat, since intact hydrologic connections between the yard and vernal pools might be impacted by additional soil compaction by heavy machinery. |
| Cook's lomatium *Lomatium cookie* | NLAA | LAA | Surveyed suitable habitat at proposed pipe storage yards in Jackson County and along the proposed pipeline did not document Cook's lomatium. Unsurveyed habitat is low quality vernal pool habitat located over 0.25 mile from known sites with no apparent hydrologic connectivity. The proposed action could potentially adversely modify critical habitat areas at least 527 feet away that provide sufficient buffer protection from adjacent development and weed sources, continuous non-fragmented habitat and intact hydrology (PCE 1). Effects from surface disturbances and/or soil compaction by heavy machinery within the Medford Industrial park Yard would be at least 527 feet away from proposed critical habitat unit RV6A. |
| Kincaid's lupine *Lupinus sulphureus var. kincaidii* | LAA | N/A | Individual plants would be removed. Indirect impacts to suspected plants outside of the pipeline construction right-of-way and along proposed access roads would be documented. Trenching activities associated with the proposed pipeline could impact below-ground stems and the expected impact to extant plants is unknown. Potential suitable habitat has not been surveyed due to landowner access denial. |

TABLE ES-1

**Determinations of Effect for Federally Listed Endangered and Threatened Potentially Occurring In the Vicinity of the Project Area**

| Listed Species | Determination of Effect a/ Species | Determination of Effect a/ Critical Habitat | Justification |
|---|---|---|---|
| Western lily *Lilium occidentale* | NLAA | N/A | Based on areas surveyed, the species is absent and suitable habitat would not be affected but surveys have not been conducted in all affected locations due to restricted access. There is remote possibility that the species is present on the unsurveyed area but highly unlikely. |
| Rough popcornflower *Plagiobothrys hirtus* | NLAA | N/A | Historically occupied habitat is in the vicinity of two proposed contractor yard sites but project activities at the yards are highly unlikely to affect occupied habitat, if present at those sites. Project effects to the species are currently insignificant and discountable. |

a/ N/A - Not applicable (critical habitat has not been designated or proposed).
NE - No effect.
NLAA - May affect, not likely to adversely affect.
LAA - May affect, likely to adversely affect.
NJ – Not jeopardize continued existence of a proposed species
NAM – Not adversely modify or destroy proposed critical habitat.

## Magnuson-Stevens Fishery Conservation and Management Act

The Pacific Fishery Management Council (PFMC) has developed four Fishery Management Plans (FMPs) that address EFH for managed species in the Project area. The four fisheries managed by the PFMC contain highly migratory species, coastal pelagic species, groundfish, and Pacific Coast salmon.

The MSA describes EFH as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Within the Project area, EFH has been designated for two salmonids (chinook and coho), three pelagic species (northern anchovy, Pacific sardine and Pacific mackerel), and 29 groundfish species known or suspected to occur within Coos Bay. According to the PFMC, all habitat accessible to these managed species, including spawning and incubation, juvenile rearing, juvenile migration corridors, and adult migration corridors, is considered EFH. Highly migratory species defined by the PFMC include tunas (five species), sharks (five species), billfish/swordfish (two species) and the dorado (also called dolphinfish or mahi-mahi). Based on the documentation and analytical results contained herein, the Jordan Cove Energy and Pacific Connector Gas Pipeline Project would have no adverse effect on EFH for highly migratory species, and may adversely affect EFH for coastal pelagic species, groundfish, and Pacific Coast salmon. These determinations as well as a summary of the justification for the determinations are provided in table ES-2.

TABLE ES-2

**Determinations of Effect for Essential Fish Habitat**

| Fishery | Analysis Area | | | Determination of Effect a/ | Justification |
|---|---|---|---|---|---|
| | EEZ | Estuarine | Riverine | | |
| Highly Migratory Species | X | -- | -- | NAE | Accidental spills and releases at sea, if they should occur, would not diminish water quality within the EEZ analysis area. Ship noise would be detectable but would not exceed interim noise exposure criteria. |
| Coastal Pelagic Species | X | X | -- | MAA | Short term loss of estuarine eelgrass habitat following dredging for LNG terminal and pipeline installation within Coos Bay. Disposal of maintenance dredged material at Site F in EEZ would temporarily bury potential food resources. Juvenile larval stages of fish could be entrained or impinged during LNG terminal operation in estuarine area. Accidental spills and releases at sea in EEZ, if they should occur, and Project construction within the Coos Bay estuary are not expected to diminish water quality or substrates. Ship noise and construction noise would be detectable but would not exceed interim noise exposure criteria. |
| Groundfish | X | X | -- | MAA | Short term loss of estuarine eelgrass habitat following dredging for LNG terminal and pipeline installation within Coos Bay. Disposal of maintenance dredged material at Site F in EEZ would temporarily bury potential food resources. Juvenile larval stages of fish could be entrained or impinged during LNG terminal operation in estuarine area. Accidental spills and releases at sea in EEZ, if they should occur, and Project construction within the Coos Bay estuary are not expected to diminish water quality or substrates. Ship noise and construction noise would be detectable but would not exceed interim noise exposure criteria. |
| Pacific Coast Salmon | X | X | X | MAA | Pipeline crossing of riverine habitat would impact substrates and water quality over the short-term and remove riparian vegetation which could affect water quality over the long-term. Short term loss of estuarine eelgrass habitat following dredging for LNG terminal and pipeline installation within Coos Bay. Disposal of maintenance dredged material at Site F in EEZ would temporarily bury potential food resources. Juvenile larval stages of fish could be entrained or impinged during LNG terminal operation in estuarine area, and could be trapped in ocean tailings during disposal of maintenance dredged material at Site F in EEZ. Ship noise and construction would be detectable but would not exceed interim noise exposure criteria. |

a/ -- - Not applicable.
NAE - No adverse effect.
MAA - May adversely affect.

## TABLE OF CONTENTS

## LIST OF APPENDICES
## (provided electronically)

# LIST OF TABLES

# LIST OF FIGURES

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius |
| °F | degrees Fahrenheit |
| $\mu g/m^3$ | micrograms per cubic meter |
| ACEC | Area of Critical Environmental Concern |
| ACFM | actual cubic feet per minute |
| ACHP | Advisory Council on Historic Preservation |
| ACS | Aquatic Conservation Strategy |
| agl | above ground level |
| AIS | Automatic Identification System |
| ANS | Aquatic Nuisance Species |
| ANSTF | Aquatic Nuisance Species Task Force |
| AOCs | Areas of Concern |
| ARPA | Archaeological Resource Protection Act |
| ATVs | all-terrain vehicles |
| BA | biological assessment |
| Bcf/d | billion cubic feet per day |
| BLM | U.S. Department of Interior, Bureau of Land Management |
| BMP | best management practice |
| BO | biological opinion |
| BOG | boil-off gas |
| BPA | Bonneville Power Administration |
| Bscfd | Billion standard cubic feet per day |
| Btu | British thermal units |
| BVA | block valve assembly |
| BWE | ballast water exchange |
| BWM | National Ballast Water Management Program |
| C&H | Coast and Harbor Engineering |
| CAA | Clean Air Act |
| CANCOV | canopy cover |
| CBNBWB | Coos Bay North Bend Water Board |
| CBNS RMA | Coos Bay North Split Recreation Management Area |
| CBR | Coos Bay Rail Link |
| CEQ | Council on Environmental Quality |
| Certificate | Certificate of Public Convenience and Necessity |
| CFR | Code of Federal Regulations |
| CHUs | critical habitat units |
| CM | channel mile |
| CMP | compensatory mitigation program |
| Coast Guard | U.S. Coast Guard |
| COE | U.S. Army Corps of Engineers |
| Commission | Federal Energy Regulatory Commission |
| COTP | Captain of the Port |
| CP | cathodic protection |
| CSA | Conservation Support Areas |
| CWA | Clean Water Act |
| cy | cubic yard |
| CZMA | Coastal Zone Management Act |
| dBA | A-weighted sound level |
| dbh | diameter-at-breast-height |
| DCAs | designated conservation areas |
| DFDE | dual fuel diesel electric |
| DMEF | Dredged Material Evaluation Framework |
| DO | dissolved oxygen |
| DOD | U.S. Department of Defense |
| DOT | U.S. Department of Transportation |
| DP | direct pipe |
| DPS | Distinct Population Segments |
| Dth/d | decatherms per day |
| DTR | Daily Timing Restriction |
| EAR | existing access road |
| ECRP | Pacific Connector's Erosion Control and Revegetation Plan |

| | |
|---|---|
| EEZ | Economic Exclusion Zone |
| EFH | essential fish habitat |
| EFSC | Energy Facility Siting Council |
| EI | Environmental Inspector |
| EIA | Energy Information Administration |
| EIS | environmental impact statement |
| EPA | U.S. Environmental Protection Agency |
| EPAct | Energy Policy Act of 2005 |
| ERP | emergency response plan |
| ESA | Endangered Species Act |
| ESCP | Erosion and Sedimentation Control Plan |
| ESU | Evolutionarily Significant Units |
| FAA | Federal Aviation Administration |
| FERC | Federal Energy Regulatory Commission |
| FMPs | Fishery Management Plans |
| FMSC | Federal Maritime Security Coordinators |
| FOI | Forest Operations Inventory |
| fps | foot per second |
| ft/sec | feet per second |
| FWS | U.S. Department of the Interior, Fish and Wildlife Service |
| g/ml | grams per milliliter |
| GeoBOB | Geographic Biotic Observations Database (BLM) |
| GIS | geographic information system |
| GNN | Gradient Nearest Neighbor |
| gpm | gallons per minute |
| GT | Gross Ton |
| GTN | Gas Transmissions Northwest LLC |
| HDD | horizontal directional drill |
| HDPE | high-density polyethylene |
| hp | horsepower |
| HRSG | heat recovery steam generator |
| HUC | hydrologic unit code |
| I-5 | Interstate 5 |
| IVMP | Interagency Vegetation Mapping Project |
| JCE & PCGP | Jordan Cove Energy and Pacific Connector Gas Pipeline Project |
| Jordan Cove | Jordan Cove Energy Project L.P. |
| Jordan Cove's Plan | Jordan Cove's Upland Erosion Control, Revegetation, and Maintenance Plan |
| Jordan Cove's Procedures | Jordan Cove's Wetland and Waterbody Construction and Mitigation Procedures |
| JPA | Joint Permit Application |
| kJ | kilojoules |
| KOAC | known owl activity centers |
| kV | kilovolt |
| kWh | kilowatt-hour |
| LCM | lost circulation materials |
| LDC | local distribution company |
| LdN | Day-Night Average Sound Level |
| LEMMA | Landscape Ecology, Modeling, Mapping & Analysis |
| Leq | night time energy equivalent sound level |
| LNG | liquefied natural gas |
| LOI | Letter of Intent |
| LOR | Letter of Recommendation |
| LPG | liquid petroleum gas |
| LSR | Late-Successional Reserves |
| LUCS | land use compatibility statement |
| LWD | large woody debris |
| $m^3$ | cubic meters |
| MAMU | marbled murrelet |
| MBTA | Migratory Bird Treaty Act |
| mcy | million cubic yards |
| mg/l | milligram per liter |
| mgd | million gallons per day |
| MHHW | mean higher high water |
| MLLW | mean lower low water |

| | |
|---|---|
| MLV | mainline valve |
| Mm | millimeters |
| MMBtu | million British thermal units |
| MMPA | Marine Mammal Protection Act |
| MOCA | Managed Owl Conservation Area |
| MP | milepost |
| mph | miles per hour |
| MPRSA | Marine Protection, Research, and Sanctuary Act |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| MMscfd | million standard cubic feet per day |
| MMTPA | million metric tonnes per annum |
| MSL | mean sea level |
| MSNO | master site number |
| mt | metric tonnes |
| mt/hr | meters per hour |
| MTBM | microtunnel boring machine |
| MW | megawatt |
| NAISA | National Aquatic Invasive Species Act of 2003 |
| NANPCA | Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 |
| NAVD88 | North American Vertical Datum of 1988 |
| NEPA | National Environmental Policy Act |
| NFPA | National Fire Protection Association |
| NFS | National Forest System |
| NGA | Natural Gas Act |
| NGL | natural gas liquid |
| NHPA | National Historic Preservation Act |
| NISA | National Invasive Species Act of 1996 |
| NMFS | National Oceanic and Atmospheric Administration National Marine Fisheries Service |
| nmi | nautical mile |
| Northwest | Northwest Pipeline |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priorities List |
| NRCS | Natural Resources Conservation Service |
| NRF | nesting, roosting, and foraging |
| NRHP | National Register of Historic Places |
| NRIMP | Natural Resources Information Management Program |
| NSA | Noise-Sensitive Area |
| NSO | northern spotted owl |
| NSOOM | Northern Spotted Owl Occupancy Map |
| NWFP | Northwest Forest Plan |
| NWI | National Wetlands Inventory |
| OAR | Oregon Administrative Record |
| ODA | Oregon Department of Agriculture |
| ODE | Oregon Department of Energy |
| ODEQ | Oregon Department of Environmental Quality |
| ODF | Oregon Department of Forestry |
| ODFW | Oregon Department of Fish and Wildlife |
| ODLCD | Oregon Department of Land Conservation and Development |
| ODOT | Oregon Department of Transportation |
| ODSL | Oregon Department of State Lands |
| ODWR | Oregon Department of Water Resources |
| OEP | FERC's Office of Energy Projects |
| OHV | Off-Highway Vehicle |
| OHWM | ordinary high water mark |
| OIMB | Oregon Institute of Marine Biology |
| OPRD | Oregon Parks and Recreation Department |
| OPUC | Oregon Public Utility Commission |
| ORBIC | Oregon Biodiversity Information Center |
| ORNHIC | Oregon Natural Heritage Information Center |
| ORS | Oregon Revised Statute |
| OSHA | Occupational Safety and Health Administration |
| Pacific Connector | Pacific Connector Gas Pipeline L.P. |
| PAR | permanent access road |
| PCB | polychlorinated biphenyl |

| | |
|---|---|
| PCE | primary constituent element |
| PCGP | Pacific Connector Gas Pipeline |
| PFMC | Pacific Fishery Management Council |
| PG&E | Pacific Gas and Electric Company |
| PHMSA | Pipeline Hazardous Materials Safety Administration |
| PI | point of intersection |
| Plan | FERC staff's Upland Erosion Control, Revegetation, and Maintenance Plan |
| POD | Plan of Development |
| Port | Oregon International Port of Coos Bay |
| PORTS | Physical Oceanographic Real Time System |
| ppm | parts per million |
| Procedures | FERC staff's Wetland and Waterbody Construction and Mitigation Procedures |
| Project | Jordan Cove Energy and Pacific Connector Gas Pipeline Project |
| psig | pounds per square inch gauge |
| PTS | permanent threshold shift |
| Reclamation | U.S. Bureau of Reclamation |
| RFS | Request for Service |
| RHA | Rivers and Harbors Act |
| rms | root mean square |
| ROD | Record of Decision |
| Roseburg | Roseburg Forest Products |
| ROW | right-of-way |
| RSET | Regional Sediment Evaluation Team |
| S&M | Survey and Manage |
| SAP | sampling and analysis plan |
| SBS | Siskiyou BioSurvey |
| SCADA | supervisory control and data acquisition |
| scf | standard cubic feet |
| SCV | submerged combustion vaporizer |
| SEF | Sediment Evaluation Framework |
| SHPO | State Historic Preservation Officer |
| SONCC | Southern Oregon/Northern California Coast |
| SOC | Species of Concern |
| SPCCP | Spill Prevention, Containment, and Countermeasures Plan |
| SSC | Suspended Solids Concentration |
| SQG | Sediment Quality Guidelines |
| SRMA | Special Recreation Management Area |
| STEP | Shipboard Technology Evaluation Program |
| TAR | temporary access road |
| TEWA | temporary extra work area |
| TMMP | Turbidity Monitoring and Management Plan |
| TNC | The Nature Conservancy |
| TPH | total petroleum hydrocarbon |
| TSS | total suspended sediment |
| TTS | temporary threshold shift |
| Tuscarora | Tuscarora gas transmission system |
| TVS | total volatile solid |
| UCSA | uncleared storage area |
| U.S. | United States |
| USACE | U.S. Army Corps of Engineers |
| USC | Unites States Code |
| USDA | U.S. Department of Agriculture |
| USDA-FS | U.S. Department of Agriculture – Forest Service |
| USDI | U.S. Department of the Interior |
| USFS | U.S. Department of Agriculture Forest Service |
| USGS | U.S. Geological Survey |
| VH-LU | Vessel Hydrodynamics Longwave Unsteady |
| VMS | Visual Management System |
| WDNR | Washington Department of Natural Resources |
| WDOE | Washington Department of Ecology |
| WSDOT | Washington State Department of Transportation |
| WSA | Waterway Suitability Assessment |
| WSPA | Western States Petroleum Association |
| WSR | Waterway Suitability Report |

# 1.0 INTRODUCTION

## 1.1 PROJECT BACKGROUND

Jordan Cove Energy Project, L.P. (Jordan Cove) and Pacific Connector Gas Pipeline, LP (Pacific Connector) filed applications with the Federal Energy Regulatory Commission (FERC or Commission) under sections 3 and 7 of the Natural Gas Act (NGA) in May and June 2013, respectively. In Docket No. CP13-483-000, Jordan Cove seeks authorization to construct and operate a new liquefied natural gas (LNG) export terminal on the east side of the North Spit of Coos Bay, in Coos County, Oregon. In Docket No. CP13-492-000, Pacific Connector seeks a Certificate of Public Convenience and Necessity (Certificate) to construct and operate a new 36-inch-diameter natural gas pipeline extending from Jordan Cove's proposed LNG terminal southeast for about 232 miles through Coos, Douglas, Jackson, and Klamath Counties, Oregon. Hereafter in this document, Jordan Cove and Pacific Connector are also referred to as the applicants, and their inter-related proposals are collectively referred to as the Jordan Cove Energy and Pacific Connector Gas Pipeline (JCE & PCGP) Project, or the Project.

On December 17, 2009, Jordan Cove received NGA Section 3 authorization from FERC to site, construct, and operate an LNG import and regasification facility on the bay side of the North Spit of Coos Bay, Oregon. The authorized facilities included: an LNG ship unloading berth, cryogenic service pipelines, two 160,000 cubic meters ($m^3$) (1,006,000 barrels) cryogenic LNG storage tanks, regasification facilities, and facilities to send out natural gas from the terminal. The import facility was authorized by FERC and the Coast Guard to be capable of handling 148,000 $m^3$ capacity LNG carriers (the LNG carrier berth was designed to accommodate LNG carriers up to 217,000 $m^3$). FERC also certificated Pacific Connector to construct and operate a new pipeline to connect the import facility to existing intrastate and interstate pipeline systems.

On February 29, 2012, Jordan Cove advised FERC that, given current natural gas market conditions, Jordan Cove is now proposing to construct and operate a natural gas liquefaction and export facility and does not currently intend to construct the facilities specific to import and regasification of LNG. On April 16, 2012, FERC issued an order vacating the authorizations granted in 2009 for the import facility. Jordan Cove is now seeking authority under Section 3 of the NGA to site, construct and operate a natural gas liquefaction and LNG export facility, located on the bay side of the North Spit of Coos Bay, Oregon. The site of the Project is more than one mile from the nearest residential area and has sufficient area to serve as a buffer from other facilities and activities in the vicinity. The Project also includes the construction of the South Dunes Power Plant, a facility for which the Oregon Energy Facility Siting Council (EFSC) will lead the regulatory permitting.

The Oregon International Port of Coos Bay (Port) would permit the slip and access channel component of the Jordan Cove LNG Terminal Project. The Port has submitted a Joint Permit Application (JPA) under Section 10 of the Rivers and Harbors Act (RHA) and Section 404(b)(1) of the Clean Water Act (CWA) with the U.S. Army Corps of Engineers (COE), Oregon Department of State Lands (ODSL), and Oregon Department of Environmental Quality (ODEQ) to construct the access channel to the LNG terminal slip within Coos Bay and to construct and own the slip at the LNG terminal.

The slip will be constructed on land owned by Fort Chicago LNG II U.S. L.P. Jordan Cove will construct the slip and the LNG carrier and tug berths. Upon completion, Jordan Cove will transfer ownership of the slip to the Port. Under the sell back/long term lease agreement that Jordan Cove will enter into with the Port, Jordan Cove will lease the slip from the Port and Jordan Cove will operate the LNG carrier berth. Jordan Cove will reimburse the Port for operation and maintenance of the slip.

The access channel will be on land owned by the State of Oregon. The Port has obtained an easement from the State for the use and maintenance of the access channel. Jordan Cove will construct the access channel. Upon completion of construction and initiation of operation, Jordan Cove will transfer maintenance responsibility to the Port, which will be responsible for maintaining the access channel. Jordan Cove will be responsible for reimbursing the Port for operation and maintenance of the access channel.

Although the Port itself is not under the jurisdiction of the FERC, construction and operation of the access channel and slip are considered interrelated and interdependent actions with those proposed by Jordan Cove and are therefore included in Jordan Cove's application to the FERC, and addressed in this Biological Assessment (BA) and Essential Fish Habitat (EFH) Assessment.

The FERC is the federal agency responsible for authorizing onshore LNG terminals and interstate natural gas transmission facilities, as specified in section 311(e)(1) of the Energy Policy Act of 2005 (EPAct) and the NGA. For the JCE & Pacific Connector pipeline, in accordance with section 313(b)(1) of the EPAct, the FERC is the lead federal agency for the coordination of all applicable federal authorizations, and is also the lead federal agency for preparation of an environmental impact statement (EIS) in compliance with the requirements of the National Environmental Policy Act of 1969 (NEPA).

The FERC is preparing an EIS. The EIS will provide a detailed description of the Project, and potential environmental impacts on specific resources. It will also discuss measures that would be implemented to avoid, reduce, or mitigate impacts, and will include recommendations from the FERC staff of additional measures that the Commission may choose to attach as enforceable conditions to the Project Order, should it decide to authorize the Project. Several agencies are cooperating agencies in developing the EIS. A cooperating agency has jurisdiction by law or special expertise with respect to environmental impacts involved with the proposal.

Each of the cooperating agencies has their own authorities or permitting responsibilities for elements of the Project. The Coast Guard is responsible for assessing the suitability of the waterway and issuing a Letter of Recommendation (LOR); however, it does not issue a permit or license in this context. The COE has authority to issue dredging and wetland permits for the Project under the River and Harbors Act (RHA) and Clean Water Act (CWA). The EPA has responsibilities under the Clean Air Act (CAA) and CWA. The Department of Transportaion (DOT) has authority to enforce safety regulations and standards for the LNG terminal beginning at the last valve immediately before the storage tanks, and the design and operation of the Pacific Connector pipeline. The Bureau of Land Managemt (BLM) can issue a Right-of-Way Grant for the crossing of federal lands under the Mineral Leasing Act (MLA), and the United States Forest Service (USFS) and Bureau of Reclamation (Reclamation) could concur.

Table 1.1-1 provides a summary of major federal, state, and local permits, approvals, and consultations that would be required for construction and operation of the JCE & PCGP Project. Additional information on permits and approvals that would be required will be included in FERC's EIS for the Project.

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| **FEDERAL** | | | |
| FERC | Sections 3 and 7 of the NGA<br>Section 311 of the EPAct<br>18 CFR 153, 157, 375, and 385<br>Order No. 687 | Issue Approval of Place of Import and Authorization of Siting, Construction, and Operation of LNG Terminal Facilities (section 3a of NGA).<br>Issue Certificate of Public Convenience and Necessity to construct, install, own, operate, and maintain a pipeline (section 7c of NGA). | On May 21, 2013, Jordan Cove filed an application with the FERC.<br>On June 6, 2013, Pacific Connector filed an application with the FERC. |
| | NEPA<br>40 CFR 1500-1508<br>18 CFR 380.12 | Prepare EIS. | |
| Advisory Council on Historic Preservation (ACHP) | Section 106 of the NHPA<br>36 CFR 800 | Has opportunity to comment on the undertaking. | Pending FERC review of final cultural resources reports, after consultations with Oregon State Historic Preservation Officer (SHPO). |
| Federal Communication Commission | License for fixed microwave stations and service | Review proposals for new or additions to existing communication station. | Pending. |
| USDA, Natural Resources Conservation Service (NRCS) | Farmland Protection Policy Act | Determine if the project would result in the permanent conversion of prime farmland. | Pending. |
| USFS | NEPA | Adopt EIS. | Pending. |
| | Special Use Permit | Review Permit. | June 12, 2006 Special Use Survey Permit issued. |
| | Amendments to Forest Plan | Amend Forest Plans. | Analysis incorporated into EIS process. |
| | Timber Sale Agreements | Reach Timber Sale Agreement. | Anticipated 1st Quarter 2015. |
| | Timber Clearing Permits | Issue Timber Clearing Permit. | Anticipated 2nd Quarter 2015. |
| | Road Use Permits | Issue Road Use Permits. | Anticipated 2nd Quarter 2015. |
| | Mineral Sale Permits | Mineral Sale Permit. | Anticipated 1st Quarter 2015. |
| | Fire Season Waivers | Fire Season Waivers. | Apply during construction. |
| | Snow Plow Permit | Permit plowing of access roads | Apply during construction on as-needed basis. |
| | Special Use Permits | Permit use of Staging Areas, Industrial Camping, and Disposal Sites. | Anticipated 2nd Quarter 2015. |
| | Overload/Oversize Permit | Permit oversize loads on NFS roads. | Anticipated 2nd Quarter 2015. |
| | Right-of-Way Easement Grant | Consent to issue Right-of-Way Grant on NFS lands. | Anticipated 2nd Quarter 2015. |
| COE | Section 10 of the RHA<br>33 CFR 320 to 330 | Issue permit for activities that will occupy, fill, or grade land in a floodplain, streambed, or channel of a stream or other waters of the United States. | On June 13, 2013, JCEP and the Port submitted joint permit applications (JPAs). On July 8, 2013, Pacific Connector submitted JPA. |
| | Section 404 of the CWA | Issue permit for the placement of dredged or fill material into waters of the United States, including wetlands. | On June 13, 2013, JCEP and the Port submitted joint permit applications (JPAs). On July 8, |

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| | | | 2013, Pacific Connector submitted JPA. |
| National Marine Fisheries Service (NMFS) | Section 7 of the ESA | Consider lead agency determination of effects on federally listed species and their habitat. Provide a biological opinion (BO) if the project is likely to adversely affect such species or their habitat. | Pending. |
| | Marine Mammal Protection Act (MMPA) 50 CFR 216 | Consult on protected marine mammals. | Pending. |
| | MSA | Provide conservation recommendations for projects that may adversely impact EFH. | Pending. |
| U.S. Department of Defense (DOD) | Section 311(f) of the EPAct and Section 3 of the NGA | Consult with the Secretary of Defense to determine whether an LNG facility would affect the training or activities of an active military installation. | Pending. |
| DOE, Bonneville Power Administration (BPA) | Encroachment Permit for Electric Transmission Line Crossing | Permit review. | Pacific Connector anticipates submitting this permit request 2nd Quarter 2014. |
| EPA | Section 404 of the CWA<br>Section 309 of the CAA | Can veto wetland permits issued by the COE.<br>Review EIS for compliance with CAA and the NEPA. | Pending. |
| Coast Guard | 33 CFR 127 | Captain of the Port issues Letter of Recommendation (LOR)determining the suitability of the waterway for LNG marine traffic. | JCEP submitted Updated Letter of Intent to Coast Guard on December 28, 2012 |
| | 33 CFR 165 | Establish safety and security zones for LNG vessels in transit and while docked. | On July 1, 2008, Coast Guard issued Waterway Suitability Report (WSR). |
| | Ports and Waterway Safety Act | Ensure navigation safety. | Pending. |
| | Maritime Transportation Act 33 CFR 101, 103, 104, 105 | Develop LNG Vessel Management and Emergency Plan. Review and approve Facility Security Plan. | Pending. |
| | Navigation and Vessel Inspection Circular – Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas Marine Traffic (NVIC 05-05) | Validate Waterway Suitability Assessment (WSA) and produce WSR. | On April 10, 2006, Jordan Cove submitted initial draft WSA to Coast Guard, and revised WSA on September 4, 2007.<br>On July 1, 2008, Coast Guard issued WSR. |
| BLM | Section 28 of Mineral Leasing Act of 1920 43 CFR 2880 | Issue Right-of-Way Grant for Pacific Connector pipeline crossing federal lands | On April 17, 2006, Pacific Connector submitted its Right-of-Way Application, which was accepted by the BLM on May 5, 2006. Pacific Connector submitted an amendment to the original application on February 25, 2013. BLM's Record of Decision is pending. |
| | Timber Harvest and Sale Authorization 43 CFR 5400 | Authorize removal and sale of timber and other forest resources associated with land clearing for construction of the pipeline and ancillary facilities (may be authorized in Right-of-Way Grant). | Anticipated 1st Quarter 2015. |
| | Federal Land Policy and Management Act of 1976, as amended 43 CFR 1610 | Land Use Plan Amendments - BLM must offer a 90-day comment period following the draft EIS and a 30-day protest period following issuance of final EIS and resolve | Analysis incorporated into EIS process. Final issuance of the amendments will be part of the ROD. ROD is estimated for 2nd |

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| | | protests prior to issuing the ROD. | Quarter 2015. |
| | Archaeological Resources Protection Act of 1979 (ARPA) 16 USC 470aa-470,, | Cultural Resources Use Permit. | In June 2007, BLM approved survey permits. |
| Reclamation | NEPA<br>Right-of-Way Easement Grant | Adopt EIS or conduct own analysis.<br>Consent to issue Right-of-Way Grant. | Pending. |
| FWS | Section 7 of the ESA | Consider lead agency determination of effects on federally listed species and their habitat. Provide a BO if the project is likely to adversely affect such species or their habitat. | Pending. |
| | Fish and Wildlife Coordination Act | Provide comments to prevent loss of and damage to wildlife resources. | Pending. |
| | Migratory Bird Treaty Act (MBTA) | Consultation regarding compliance with the MBTA. | Pending. |
| DOT, PHMSA | Natural Gas Pipeline Safety Act<br>49 USC 601<br>49 CFR Parts 190-199 | Administer national regulatory program to ensure the safe transportation of natural gas. | Pending. |
| DOT, Federal Aviation Administration (FAA) | 18 CFR Subchapter E FAR Part 77 | Notice of Proposed Construction Possibly Affecting Navigable Air Space. | On May 8, 2007, FAA issued aeronautical study of communication tower at the proposed Jordan Cove Meter Station.<br>On November 1, 2008, FAA issued aeronautical study of the LNG storage tanks at the proposed terminal. |
| U.S. Department of the Treasury, Bureau of Alcohol, Tobacco, and Firearms | Explosives User Permit 27 CFR 555 | Issue permit to purchase, store, and use explosives during project construction. | Permits to be obtained by Jordan Cove and Pacific Connector, as necessary, before construction. |
| **STATE – OREGON** | | | |
| Oregon Department of Agriculture (ODA) | Oregon Endangered Species Act<br>Oregon Senate Bill 533 and Oregon Revised Statute (ORS) 564 | Consult on Oregon listed plant species, and ODA would review botanical survey reports covering non-federal public lands prior to ground-disturbing activities where state listed botanical species are likely to occur. | On September 15, 2006, ODA responded to Jordan Cove that it was in compliance with state laws, and no species should be adversely affected.<br>On July 24, 2006, ODA provided Pacific Connector with a list of state species.<br>In its September 4, 2007 application to the FERC, Pacific Connector included a botanical survey report. In November 2008, Pacific Connector submitted a second botanical report.<br>ODA review of those reports is pending. |
| Oregon Department of Energy (ODE) | Section 311 of the EPAct | Furnish an advisory report on state and local safety and security issues to the FERC, and conduct operational safety inspections. | On October 4, 2007, ODE filed its safety and security report to the FERC. |
| ODEQ | Section 401 of the CWA | Water quality certification. Issue National Pollutant Discharge Elimination System (NPDES) permits for discharge of hydrostatic test water, submerged combustion vaporizer (SCV) condensate, and stormwater. | Pacific Connector submitted JPA to ODEQ on July 8, 2013. |

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| | CAA | Issue air quality permit. | Pacific Connector anticipates submitting an application 1st Quarter 2014. Jordan Cove submitted an application in March 2013. |
| | Water Pollution Control Facility Permit under Oregon Administrative Rule (OAR) 340-045 | Issues permit for the disposal of solid wastes and waste water into public waters. | Pacific Connector anticipates submitting an application 1st Quarter 2015. |
| | ORS 468B.300 et seq. | ODEQ to review and approve LNG vessel and facility spill contingency plans. | Pending. |
| Oregon Department of Fish and Wildlife (ODFW) | Fish and Wildlife Coordination Act and the Oregon Endangered Species Act under ORS 496, 506, and 509 and OAR 635 | Consult on sensitive species and habitats that may be affected by the project and, in general, regarding conservation of fish and wildlife resources.<br>Fish passage approval from ODFW needed for stream crossings. | Pending. |
| | Fish and Wildlife HMP, OAR 345-022-0060 | Consult on and approve fish and wildlife mitigation plan. | Pending. |
| | ORS 509.140, et al | Consider issuance of in-water blasting permits | Applications by Pacific Connector to be submitted prior to and during construction on as-needed basis. |
| | 635-412-0005 through 0040 | Review temporary stream crossing plans consistency with Oregon fish passage law and ODFW fish passage rules | Pending. |
| Oregon Department of Forestry (ODF) | Easement on State lands<br>Oregon Forest Practices Act<br>OAR 629<br>ORS 477<br>ORS 527 | Management of State Forest lands for Greatest Permanent Value, develops Forest Management Plans, stewardship under State's Land Management Classification System, monitors harvests of timber on private lands, and protects non-federal public and private lands from wildfires. | Pacific Connector anticipates submittal of final plans to ODF 1st Quarter 2015. |
| Oregon Department of Land Conservation and Development (ODLCD) | CZMA<br>15 CFR Part 930<br>ORS 196.435 | Determine consistency with CZMA program policies. | Pending. |
| SHPO | Section 106 of the NHPA<br>ORS 338.920 | Review cultural resources reports and comment on recommendations for National Register of Historic Places (NRHP) eligibility and project effects.<br>Issue permits for excavation of archaeological sites on non-federal public and private lands. | Pacific Connector filed updated cultural resource information with FERC on June 6, 2013. Jordan Cove submitted updated information in August 2013. |
| ODSL | Submerged and Submersible Land Easement<br>OAR 141-122 | Grant submerged land easements (e.g., waterbody crossings). | Pacific Connector anticipates this permit application to be submitted 3rd Quarter 2014. |
| | Joint Removal-Fill Permit, ORS 196.795-990<br>OAR 141-85-25-31, 115, 121, 126, 131 136, 141, 151 | Approve removal or fill of material in waters of the state.<br>ODSL must determine that proposed removal and fill activity would not be inconsistent with protection, conservation, and best use of water resources in the state.<br>Compensatory mitigation required for projects that would impact wetlands or waters of the state. | Pacific Connector filed an application on July 15, 2013. |
| | Compensatory Wetland Mitigation Rules<br>OAR 141-085-0121 | Review and approve wetland mitigation plans. | Pending. |
| Oregon Department of | Section 303(c) DOT | Consultation and clearance letter | Pending. |

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| Transportation (ODOT) | Act 49 CFR 303 | regarding recreational land disturbance and construction-related traffic impacts. | |
| | Access Permit ORS 184, OAR 734-051 and 55 | Issue permits to cross state funded roadways. | Applications for ODOT permits will be submitted prior to and during construction on an as-needed basis. |
| Oregon Department of Water Resources (ODWR) | ORS 537, OAR 690-310 | Issue permits to appropriate surface water and groundwater during project operation. | Pacific Connector anticipates submitting permit applications 1st Quarter 2015. Pending for Jordan Cove. |
| | ORS 537, OAR 690-340 | Issue limited licenses for temporary use of surface waters for hydrostatic testing and suction dredging. | Pacific Connector anticipates submitting permit applications 1st Quarter 2015. |
| Oregon Department of Geology and Mineral Industries | Building Code Section 1802.1 and ORS 455.446 | Review per regulations on development in a tsunami inundation zone. | Pending. |
| | OR 517 | Review per regulations on mining and reclamation activities. | Pending. |
| Oregon Public Utilities Commission (OPUC) | OAR 860-031 | Inspect the natural gas facilities for safety. | Pending. |
| **LOCAL** | | | |
| Coos County | Multiple Land-use permits and Land Use Compatibility Statement (LUCS) for other state permits | Review consolidated applications, and issue permits and approvals. | On December 5, 2007, Coos County Board of Commissioners approved Jordan Cove's application for an Administrative Conditional Use Permit for the upland portion of the proposed LNG terminal. On January 2, 2008, Coos County Board approved the Port's application for an access channel and terminal slip. On July 15, 2008 the Oregon Land Use Board of Appeals remanded the terminal application back to Coos County to resolve wetlands and archaeological issues. On August 19, 2009, Coos County Board approved revised permit for terminal. On September 8, 2010 Coos County approved a conditional use permit for the PCGP. Pacific Connector is currently in the process of amending the Conditional Use Permit. |
| | Section 311 of EPAct | Review and provide consultation regarding Jordan Cove's Emergency Response Plan (ERP). | On July 16, 2009, Jordan Cove signed concept agreements with Coos County Sheriff's Office, Emergency Management, and Health Department. |
| | Shoreline Management Act | Issue Shoreline Development Permit to cross waterbodies covered by the Shoreline Management Act. | Pending. |
| Douglas County | Land use permits and LUCS for other state permits | Pacific Connector claims that Douglas County indicated that it would affix a statement to the LUCS about its land use process. | In October 2009, Douglas County made land use decision for Pacific Connector pipeline. Pacific Connector is currently in the process of amending the Conditional Use Permit. |

TABLE 1.1-1

**Major Permits, Approvals, and Consultations for the JCE & PCGP Project**

| Agency | Authority/Regulation/ Permit | Agency Action | Status |
|---|---|---|---|
| Jackson County | Land use permits and LUCS for other state permits | Land use permits necessary for the Shady Cove Meter Station and the Butte Falls Compressor Station. | Jackson County has provided a LUCS for the PCGP Project. |
| Klamath County | Land use permits and LUCS for other state permits | Pacific Connector claims that Klamath County indicated that it would affix a statement to the LUCS about its land use process. | Klamath County has provided a LUCS for the PCGP Project. |
| All Counties | Road Crossing Permits | Review permits to cross county roads. | Pending. |
| | Grading Permits | Review permits for excavation and grading activities. | Pending. |
| | Solid Waste Disposal | Review permits for disposal of solid waste generated by construction. | Pending. |

Section 7 of the Endangered Species Act (ESA), as amended, states that any project authorized, funded, or conducted by a federal agency should not “jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined...to be critical” (16 United States Code [USC] section 1536(a)(2)(1988)). The lead federal agency, or the applicant as a non-federal party, is required to consult with the FWS and the National Marine Fisheries Service (NMFS) to determine whether any federally listed or proposed endangered or threatened species or their designated critical habitat occur in the vicinity of the proposed project. If, upon review of existing data or data provided by the applicant, one (or both) of the two federal agencies determine that these species or habitats may be affected by the proposed project, the FERC is required to prepare a BA to identify the nature and extent of adverse impacts, and to recommend measures that would avoid the habitat and/or species, or would reduce potential impacts to acceptable levels.

In accordance with section 313(b)(1) of the EPAct, the FERC is the lead federal agency responsible for the coordination of all applicable federal authorizations, including consultation under the ESA. If other federal permits are issued for the proposed Project, it would be the responsibility of each issuing agency to ensure federal permits would incorporate the results of the ESA consultation, including any terms and conditions identified by the FWS or NMFS. Each federal permit would likely contain its own set of conditions or mitigation requirements, and it would be the responsibility of each issuing agency, following its own procedures or regulations, to ensure that implementation of permit conditions is done in accordance with any terms and conditions resulting from ESA consultation. In general, the FERC would maintain the lead agency role through construction and complete restoration of areas affected by the Project. The duration of other agency’s jurisdiction over permit conditions would vary depending on the agency and the condition. For example, the Coast Guard would be responsible for safety and security of the LNG terminal for the life of the Project, while COE permit requirements may extend until wetland restoration or mitigation measures are deemed successful. Therefore, it is not possible at this time to identify the full extent of each federal agencies possible overlap with terms and conditions resulting from the ESA process. It would be the responsibility of the FERC, in accordance with section 313(d) of the EPAct, to keep a complete consolidated record of all actions or decisions made by agencies undertaking federal authorizations.

The MSA, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), established procedures designed to identify, conserve, and enhance EFH for those species regulated under a federal fisheries management plan. The MSA requires federal agencies to consult with the NMFS on all actions or proposed actions authorized, funded, or undertaken by the agency that may adversely affect EFH (MSA section 305(b)(2)). Although absolute criteria have not been established for conducting EFH consultations, the NMFS recommends consolidated EFH consultations with interagency coordination procedures required by other statutes, such as the NEPA, the Fish and Wildlife Coordination Act, or the ESA to reduce duplication and improve efficiency (50 CFR 600.920(e)). The EFH Assessment has been consolidated with the draft BA prepared pursuant to the ESA.

## 1.2 PROJECT LOCATION AND ENVIRONMENTAL SETTING

The JCE & PCGP Project is located in southern Oregon. The main components of the Project include:

- Waterway for LNG marine traffic to the proposed LNG terminal, under the authority of the Coast Guard;
- Access channel and slip at the terminal to be permitted, by the Port on land owned by Jordan Cove who will construct the slip and access channel and transfer ownership to the Port;
- Jordan Cove's LNG terminal; and
- Pacific Connector's pipeline and associated facilities.

The waterway would begin in the Pacific Oceans off the coast of Oregon, and end at the proposed LNG terminal in Coos Bay. The access channel, slip, and LNG terminal would be located in or adjacent to Coos Bay, in Coos County, Oregon. The Pacific Connector pipeline would begin at the LNG terminal and cross through Coos, Douglas, Jackson, and Klamath Counties, to its terminus east of the town of Malin. A more detailed description of Project components will be included in the forthcoming EIS.

### 1.2.1 Waterway for LNG Marine Traffic

The Coast Guard defines the waterway for LNG marine traffic for this Project as extending from the outer limits of the U.S. territorial waters, 12 nautical miles off the coast of Oregon, and 7.5 nautical miles up the existing Coos Bay navigation channel to the proposed location of the Jordan Cove LNG import terminal. For the analysis in this BA and EFH Assessment specific to species covered by the ESA and MSA, we considered impacts from LNG marine traffic extending out to the limits of the Exclusive Economic Zone (EEZ), 200 nautical miles offshore.

The characteristics of the waterway (see detailed description in forthcoming EIS) are summarized here. The existing Coos Bay navigation channel extends from the mouth of Coos Bay to the City of Coos Bay Docks at about Channel Mile (CM) 15.1. The channel width at the entrance mark is 1,500 feet, reducing to 700 feet at CM 0 and 300 feet to CM 1. From CM 1 to the proposed LNG terminal the authorized channel width is 300 feet. At the entrance, the water is 47 feet deep, but the remainder of the navigation channel is 37 feet deep at mean lower low water (MLLW). The navigation channel is maintained by the COE.

Coos Bay, and the tributaries that flow into it, lie within the USGS-designated watershed Coos Bay (USGS Cataloging Unit: 17100304). The watershed covers an area of approximately 739 square miles of Oregon's southern coastal range, and is included in the larger South Coast Watershed Basin. The navigation channel is included in the Coos Bay Estuary Management Plan (CBEMP) and is zoned Deep-Draft Navigation Channel (37-foot authorized draft). The navigation channel is bounded by the North Spit on the west and the mainland to the south and east. On the south and east shore of Coos Bay along the waterway are several communities including Charleston, Barview, Empire, and the cities of Coos Bay and North Bend.

The navigation channel does not have to be improved to allow LNG carriers to transit to the proposed Jordan Cove LNG terminal. Jordan Cove had a consultant conduct a carrier simulation study which showed that LNG carriers up to 148,000 $m^3$ in capacity could safely transit up the existing Coos Bay navigation channel under high tide conditions[2] (see forthcoming EIS for a more detailed description of the characteristics of LNG carriers).

There are several instances where LNG carrier traffic through the EEZ and the waterway could have effects on EFH and federally-listed species. First, there is the potential for vessel strikes on marine mammals or sea turtles. This potential impact is discussed for each affected species under section 4 of this BA. Second, noise from LNG carriers transiting the EEZ could cause behavioral distruptions to listed marine mammals although effects of noise on sea turtles are unlikely. Third, a fuel or oil leak from an LNG carrier in transit could affect EFH or federally listed species. Again, this potential impact is discussed under individual species. Lastly, there is the remote possibility that of a leak of LNG from the carrier in transit (see forthcoming EIS for explanation of an LNG leak, and associated pool fire if vapors are ignited).[3] The risk management measures recommended in the Coast Guard's Waterway Suitability Report (WSR), issued on July 1, 2008 (see forthcoming EIS), should protect the public and the environment from accidental or intentional incidents that may result in LNG discharge from a carrier in the waterway.

The Letter of Recommendation (LOR) issued by the Coast Guard on April 24, 2009 found that based on full implementation of the measures outlined in Jordan Cove's Waterway Suitability Assessment (WSA), and the measures recommended in the Coast Guard's WSR, the waterway could be suitable for the type and frequency of LNG marine traffic associated with this Project. The WSR limited LNG carriers calling at the Jordan Cove terminal and using the waterway to not greater than 148,000 $m^3$ in capacity. Jordan Cove expects that as many as 90 LNG carriers may come to call at its terminal in a year. In connection with the export facility proposal, Jordan Cove notified the Captain of the Port that any changes created by the Project would be addressed in the annual WSA update. The Captain of the Port affirmed this approach in February 2012 and requested that the Letter of Intent (LOI), the WSA, and the Emergency Response Plan be amended to reflect the Project. The WSA for the year 2012 was updated on November 12, 2012 to provide for the loading of LNG at the LNG Terminal. The LOI likewise was updated on December 28, 2012.

There are no specific features to be constructed or operated in the waterway, except for the access channel and slip, which are discussed below. Therefore, there is no further discussion of the waterway in this section.



[2] This report, Moffatt and Nichol, *Jordan Cove LNG Terminal Coos Bay, Oregon, 148,000* $m^3$ *Class LNG Carrier Transit and Maneuvering Simulations, March 17-20, 2008*, was filed with the FERC on May 23, 2008.

[3] The Zones of Concern are described in Enclosure 11 of the Coast Guard's NVIC 05-05. These zones are based on the report *Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water*, December 2004 (SAND2004-6258) prepared by the U.S. Department of Energy's Sandia National Laboratories (Sandia Report).

### 1.2.2 Marine Facilities

The proposed access channel, and currently submerged portion of the slip, would be located in Coos Bay, at about CM 7.5 along the existing Coos Bay navigation channel, just past the Jarvis Turn in the navigation channel (in Sections 5 and 8, Township 25 South, Range 13 West) in unincorporated Coos County, just west and north of the corporate limits of the cities of North Bend and Coos Bay. The access channel would encompass approximately 30 acres of open water and shoreline.

The portion of the proposed slip that is currently upland is located on the bay side of the North Spit of Coos Bay (figure 1.2-1). This is currently vacant land that is owned by by Fort Chicago LNG II U.S. L.P., an affiliate of Jordan Cove. The slip would cover about 36 acres: part would be inter-tidal shorelands; part would be relatively flat former dredge deposits covered by grass and brush; and part would be a forested dune.

The LNG terminal slip and access channel are located within the aquatic and shoreline segments of the Coos Bay Estuary Management Plan. The access channel and inter-tidal portion of the slip fall within zoning district 6 – Development Aquatic (6-DA). The purpose of the 6-DA zone is to provide areas for navigation and other water-dependent uses. The slip would include an LNG carrier unloading berth and a tugboat dock (necessary for operation of the LNG terminal). In conjunction with the tugboat dock, a small administration building and small parking lot would be constructed in an upland area.

The volume of material to be excavated and dredged from the slip is 4.3 million cy (2.3 million cy excavated and 2.0 million cy dredged) and the volume to be dredged from the access channel is 1.3 million cy for a total of 5.6 million cy. Current plans for management of the material involve the placement of the 1.9 million cy of excavated material on the LNG Terminal site and the placement of 3.7 million cy on the South Dunes Power Plant site. The bulk of the material required to raise the elevation of these two areas will come from the excavation of the slip and access channel. In light of the fill requirements for the South Dunes Power Plant and the access/utility corridor, there is no longer a need to place material excavated and dredged from the slip and access channel at the Port Commercial Stockpile Site or the Jordan Cove Placement area or to have a hydraulic slurry pipeline to the Port Commercial Stockpile Site. Accordingly, there is no longer the need to ship sand to the San Francisco Bay area and the potential effects due to the hauling of sand by barge from the Project site to the Bay Area is no longer an activity that is part of the Project.

Dredging of the access channel would affect approximately 15.2 acres of currently existing deep subtidal strata below -15.3 feet in depth; about 5.8 acres (3.3 acres of shallow subtidal plus 2.5 acres of eelgrass which is within shallow subtidal) of existing shallow subtidal strata between the mean lower low water (MLLW) line and -15 feet; and about 8.1 acres of existing intertidal strata between the MLLW and the MHHW. Construction and operation of the upland portion slip would disturb about 15 acres of forest, and about 21 acres of grasses or brush.

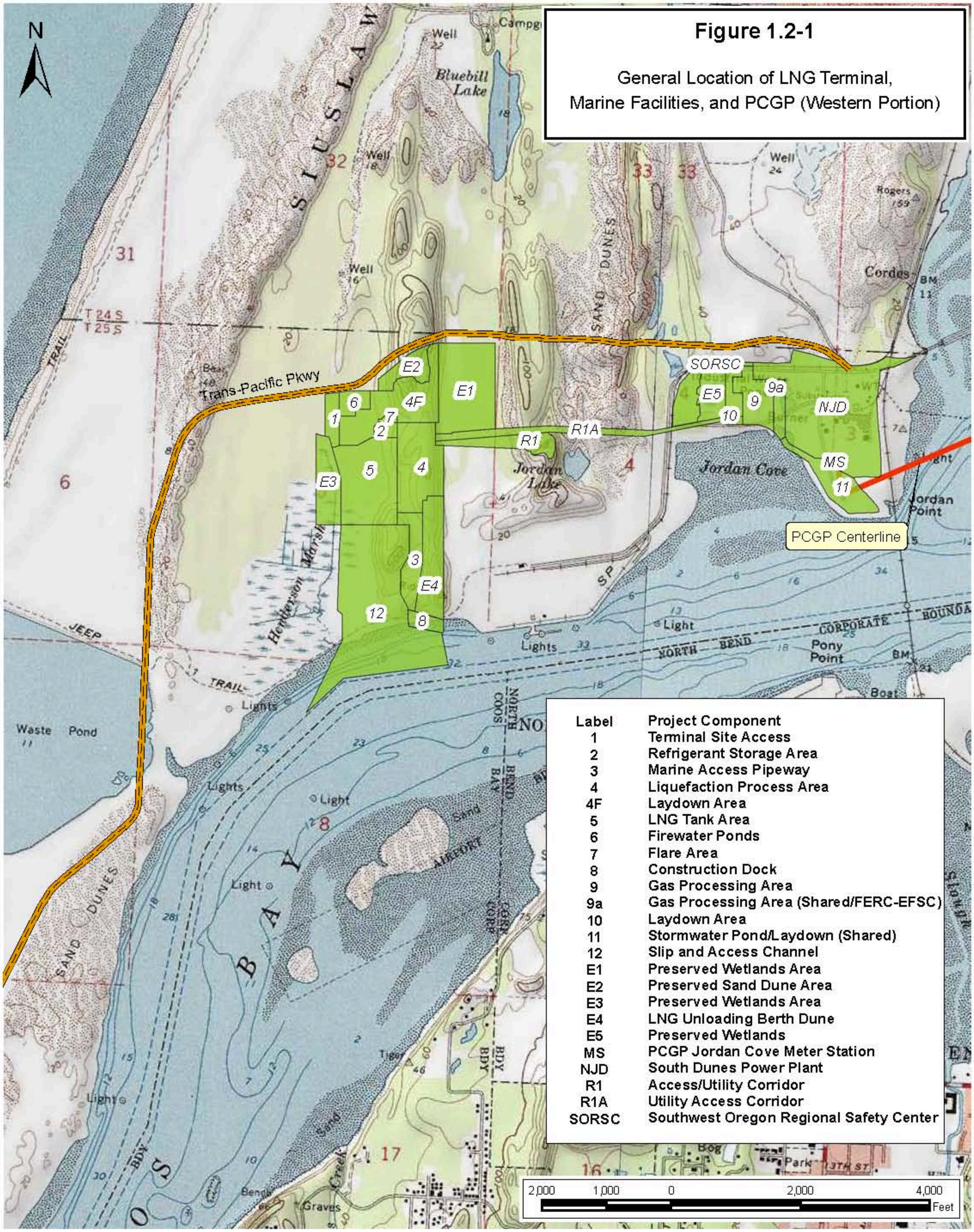



**Figure 1.2-1**

General Location of LNG Terminal, Marine Facilities, and PCGP (Western Portion)

### 1.2.3 LNG Terminal

Jordan Cove's proposed LNG terminal would be located in an upland area on the North Spit adjacent to the location of the slip, on property privately owned by by Fort Chicago LNG II U.S. L.P., an affiliate of Jordan Cove and identified on Coos County Assessor's map as tax lots 100/200/300, within Sections 4 and 5 T25S, R13W (figure 1.2-1). This is currently vacant land located within the Coastal Shorelands Boundary and zoned 6-WD (Segment 6 – Water Dependent). This segment is zoned for water dependent and water related commercial and industrial development, including port and docking facilities. In 2012, the Project received all local Coos County approvals for the LNG Terminal (except the building permit to be obtained when construction is to commence), including some import facility permits that were amended for the Jordan Cove LNG Terminal Project and permits that were obtained anew for the currently proposed Project.

The site of the LNG terminal was the location of a livestock ranch until 1958. After it was acquired as part of the Menasha mill complex in 1961, the tract was occasionally used for log sorting activities. In 1972-1973, the COE spread materials dredged during maintenance of the Coos Bay navigation channel on the site. From the late 1970s through the early 1980s sand, boiler ash, and wood debris from milling operations were placed on the property. Weyerhaeuser, which acquired the mill in 1981, spread decant solids from its wastewater treatment facility at the site between 1985 and 1994.

The construction of the LNG terminal will disturb approximately 406.8 acres. Of the approximately 406.8 acres, 301.5 acres will be within the land owned by Fort Chicago LNG II U.S. L.P., an affiliate of Jordan Cove. The remaining 105.3 acres outside of the land owned by Fort Chicago LNG II U.S. L.P. will be used for temporary construction areas and will be leased from private owners. Specifically, an additional area of 41.1 acres will be leased on the Roseburg Forest Products property and used for temporary construction areas including office, laydown, fabrication, craft break/lunchroom, parking, a heavy equipment truck haul route, and a slurry/decant water pipeline route. An additional 48.9 acres will be leased on the west side of the southern end of the McCullough Bridge for use as a temporary construction work force housing area. In addition, approximately 15.3 acres for the industrial wastewater line and raw water/water line relocation will be in an existing utility easement on land owned by the Port. The western portion of the LNG terminal site is relatively flat, where formerly dredge materials were deposited and are now covered by brush and grasses. The eastern portion includes a forested dune. Jordan Cove would acquire an operational easement over 10.9 acres of Port land to cover the full extent of the LNG terminal thermal radiation and vapor exclusion zones.

Construction and operation of the LNG terminal would disturb about 96 acres of forest and about 109 acres of grasses. About 45 acres of wetlands within the site owned by Fort Chicago LNG II U.S. L.P. would not be affected by terminal construction or operations, and would be retained in its current condition.

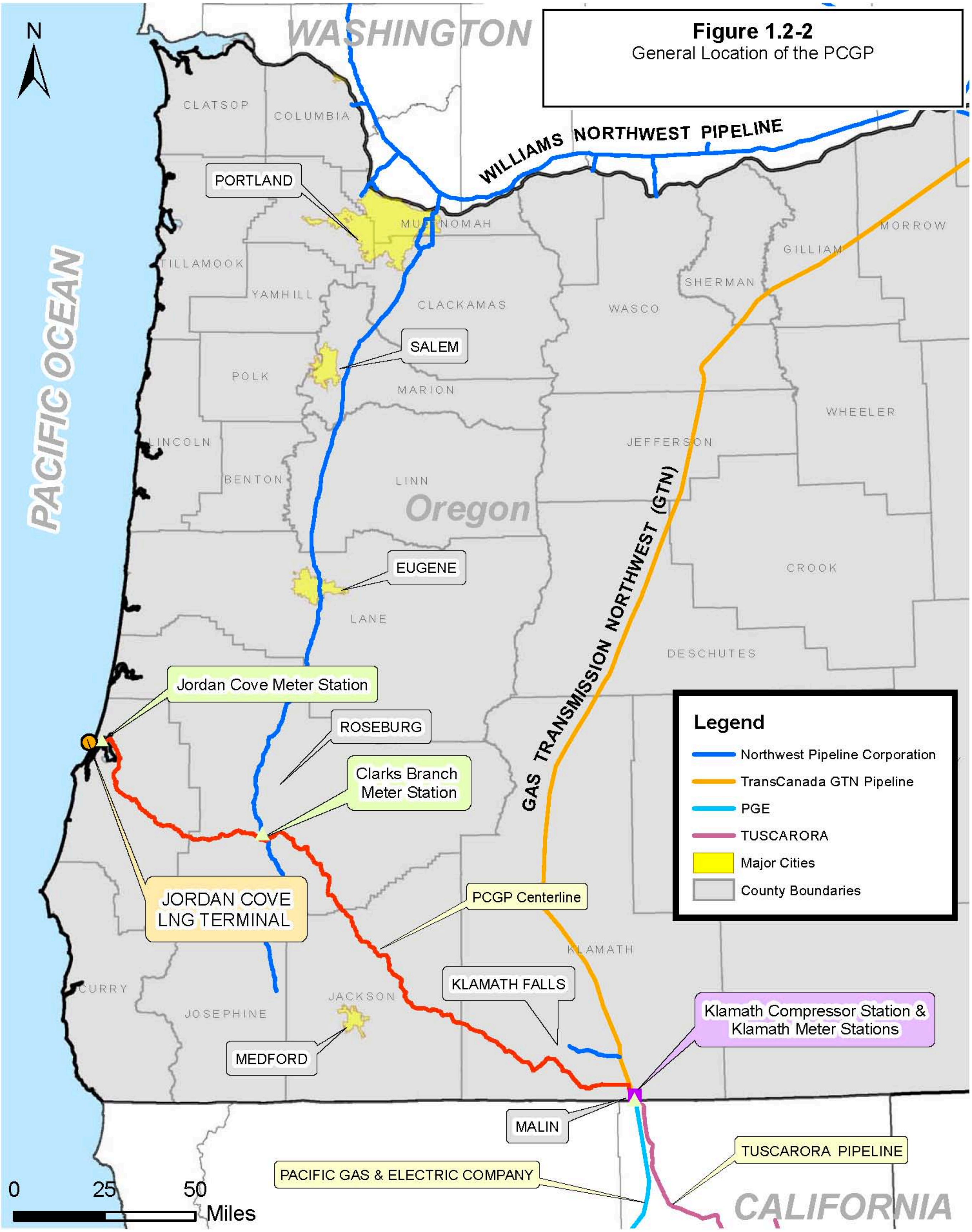


Figure 1.2-2
General Location of the PCGP
WASHINGTON
PACIFIC OCEAN
Oregon
CALIFORNIA
WILLIAMS NORTHWEST PIPELINE
GAS TRANSMISSION NORTHWEST (GTN)
CLATSOP
COLUMBIA
PORTLAND
MULTNOMAH
TILLAMOOK
YAMHILL
CLACKAMAS
SALEM
POLK
MARION
LINCOLN
BENTON
LINN
EUGENE
LANE
SHERMAN
GILLIAM
MORROW
WASCO
WHEELER
JEFFERSON
CROOK
DESCHUTES
Jordan Cove Meter Station
ROSEBURG
Clarks Branch Meter Station
JORDAN COVE LNG TERMINAL
PCGP Centerline
KLAMATH
CURRY
JOSEPHINE
JACKSON
MEDFORD
KLAMATH FALLS
Klamath Compressor Station & Klamath Meter Stations
MALIN
TUSCARORA PIPELINE
PACIFIC GAS & ELECTRIC COMPANY
Legend
Northwest Pipeline Corporation
TransCanada GTN Pipeline
PGE
TUSCARORA
Major Cities
County Boundaries
0
25
50
Miles
N

### 1.2.4 Pacific Connector Gas Pipeline and Associated Facilities

The proposed Pacific Connector pipeline would extend about 232 miles southeast from the LNG terminal, traversing Coos, Douglas, Jackson, and Klamath Counties in Oregon (see figures 1.2-1 and 1.2-2 and Appendix A). The pipeline would be 36-inches in diameter and is designed to transport up to 1.06 billion cubic feet per day (bcf/d) of natural gas at a maximum allowable operating pressure of 1,480 pounds per square inch gage. The pipeline would proceed from Coos Bay, over the Coast Range, through the Camas Valley and Olalla Valley, over the Klamath Mountains and Cascade Range, and then into the Klamath Basin. For about 92 miles the pipeline would be situated adjacent to existing rights-of-way, including powerlines, other pipelines, and roads.

The pipeline would cross 48.8 miles within Coos County, between MPs 1.5 and 45.7; 66.2 miles in Douglas County between MPs 45.7 and 110.0; 55.73 miles within Jackson County between MPs 110.0 and 166.4, and 61.1 miles within Klamath County between MPs 166.4 and 228.1.[4] In Coos County, the pipeline would cross lands zoned predominantly Forest and Exclusive Farm Use, as well as some Rural Residential (RR-5). In Douglas County, the pipeline would cross lands zoned predominantly Timberland Resource, Farm Forest, and Exclusive Farm Use, and to a lesser extent Farm Forest Agriculture and Woodlot and Rural Residential (5R). In Jackson County, the pipeline would cross lands zoned predominantly Forest Resource and a substantial length of Exclusive Farm Use. In Klamath County, the pipeline would cross primarily lands zoned for Forest and Exclusive Farm Use, but also some Residential (R5) and Heavy Industrial.

The pipeline would cross a combined total of about 149.3 miles of forest, include deciduous forest, evergreen forest, mixed forest (containing both deciduous and evergreen trees), clearcut forest, and regenerating forest. About 38.8 miles of agricultural lands would be crossed, including cropland and pasture. The pipeline would cross about 22.4 miles of range, including herbaceous (grassy) rangelands, shrub and brush rangelands, and mixed (both grassy and brush) rangelands.

The standard construction right-of-way would be about 95-feet-wide. When crossing wetlands and certain riparian areas, the construction right-of-way may be reduced to 75 feet wide. Approximately 2,697.5 acres would be required for the construction right-of-way for the pipeline. The permanent easement would be 50 feet wide, except where Pacific Connector is able to negotiate a wider easement with particular land owners.

There would be a number of ancillary use areas associated with construction of the pipeline. Pacific Connector proposes to use 1,676 temporary extra work spaces, totaling about 1,094.5 additional acres. In addition, about 287 uncleared storage areas would be used during pipeline construction, totaling another 673.1 acres. There would be 44 rock source and disposal sites, totaling about 69.8 acres. Pacific Connector would use 38 pipe storage and contractor yards, totaling about 1,339.1 acres. Approximately 646 miles of existing roads would be used to access the pipeline right-of-way during construction. Pacific Connector would have to make improvements to portions of 65 of those existing roads, disturbing about 20.3 acres. Pacific Connector would need to build 14 new temporary access roads, totaling 5 acres, and permanently maintain 13 new access roads for operation of the pipeline, covering about 2.6 acres. Details about temporary extra work areas will be provided in the forthcoming EIS.

[4] Although the total pipeline length is 231.8 miles, due to numerous pipeline reroutes made after MPs were assigned, Pacific Connector attempted to maintain continuity of original MPs and accounted for realignments using equations.

Aboveground facilities associated with the pipeline include 3 meter stations (4 interconnects), a compressor station, 5 pig launchers/receivers, and 17 MLVs. All the pig launchers and receivers would be colocated at meter stations, the compressor station, or with MLVs. The MLVs not located at meter stations or the compressor station would be within the permanent easement of the pipeline.

Pacific Connector would also install communication facilities related to the operation of its proposed pipeline. Pacific Connector intends to use eight existing communication towers, including towers at Blue Ridge and Signal Tree in Coos County; Harness Mountain and Winston in Douglas County; Starveout Creek, Flounce Rock, and Robinson Butte in Jackson County; and Stukel Mountain in Klamath County. In addition, new communication towers would be erected at the proposed meter stations, as discussed below.

The Jordan Cove Meter Station, at MP 1.47R along the Pacific Connector pipeline, in Section 3, T25S, R13W, in Coos County, would be located on about 0.85 acre of property owned by Fort Chicago LNG II U.S. L.P. adjacent to the South Dunes Power Plant facility. It would include an interconnection with the LNG terminal, a pig receiver, MLV, and a 140-foot-tall communication tower.

The Clarks Branch Meter Station would be located at MP 71.5 along the pipeline, in Section 18, T29S, R5W, on private land in Douglas County. It would occupy about 1 acre, which is currently herbaceous rangeland. The meter station would include an interconnection with Williams Northwest Grants Pass Lateral, pig launcher and receiver, MLV, and 26-foot tall communication tower.

The Klamath Meter Stations (Klamth Eagle to connect with Ruby and Klamath Beaver to connect with GTN) would be co-located with the Klamath Compressor Station at the terminus of the pipeline, in Section 11, T41S, R12E, in Klamath County. The site would also include a 26-foot-tall communication tower.

The Klamath Compressor Station would be located at MP 228.13 along the Pacific Connector pipeline, in Section 11, T41S, R12E, in Klamath County. It would occupy about 31 acres of privately owned land that is mostly rangeland. The Klamath Compressor Station would consist of three new Solar Titan 130-20502S turbine-driven centrifugal compressor units (2 operating and 1 backup). It would also include a pig launcher, MLV, and 160-foot-tall communication tower.

## 2.0 ESA CONSULTATION BACKGROUND

## 2.1 SPECIES LISTS

Thirty federally endangered and threatened species and one species proposed for listing occur in the proposed Project area as identified by the FWS (2006a, 2006b, 2007a, and 2007b) and NMFS (Wheeler 2006a and 2006b; NMFS 2009a) and updates from agencies' websites. Table 2.1-1 summarizes these species, including critical habitat and availability of recovery plans, and the general component of the Project where they may occur.

In addition, there are four species, listed or proposed for listing that occur within Oregon but for which the Proposed Action would have no effect. Those species include the Canada lynx (*Lynx canadensis*, Contiguous U.S. Distinct Population Segment), North American wolverine (*Gulo gulo luscus*, proposed for listing), bull trout (*Salvelinus confluentus*, Klamath River Distinct Population Segment), or yellow-billed cuckoo (*Coccyzus americanus*, Western Distinct Population Segment, proposed for listing) and the four species are addressed in Section 4.1.2, below.



TABLE 2.1-1

**Listed Species that May Be Present within the Project Area**

| Listed Species | Federal Status a/ | Potential Occurrence within the Project Area | Critical Habitat within the Project Area | Recovery Plan Drafted |
|---|---|---|---|---|
| **Mammals** | | | | |
| Blue whale<br>*Balaenoptera musculus* | E | Pacific Ocean EEZ | None Designated | Yes |
| Fin whale<br>*Balaenoptera physalus* | E | Pacific Ocean EEZ | None Designated | Yes |
| Killer whale<br>(Eastern Northern Pacific Southern Resident Stock)<br>*Orcinus orca* | E-CH | Pacific Ocean EEZ | Not in Project Area | Yes |
| Humpback whale<br>*Megaptera novaeangliae* | E | Pacific Ocean EEZ | None Designated | Yes |
| Sei whale<br>*Balaenoptera borealis* | E | Pacific Ocean EEZ | None Designated | Yes |
| Sperm whale<br>*Physeter macrocephalus* | E | Pacific Ocean EEZ | None Designated | Yes |
| North Pacific right whale<br>*Eubalaena japonica* | E-CH | Pacific Ocean EEZ | Not in Project Area | Yes |
| Gray wolf<br>*Canis lupus,* | E | Douglas County<br>Jackson County<br>Klamath County | None Designated | None Applicable |
| **Birds** | | | | |
| Short-tailed albatross<br>*Phoebastria albatraus* | E | Pacific Ocean EEZ | None Designated | Yes |
| Western snowy plover<br>(Pacific Coast Population)<br>*Charadrius alexandrinus nivosus* | T-CH | Coos County | Yes – Unit OR-10, Coos Bay North Spit | Yes |
| Marbled murrelet<br>*Brachyramphus marmoratus* | T-CH | Coos County<br>Douglas County | Yes – CHU OR-06-d | Yes |
| Northern spotted owl<br>*Strix occidentalis caurina* | T-CH | Coos County<br>Douglas County<br>Jackson County<br>Klamath County | Yes – CHU OCR-6 (in Unit 2 Oregon Coast Range), KLW-1 (in Unit 9 Klamath West), KLE-1, KLE-2, KLE-3, KLE-4, KLE-5 (in Unit 10 Klamath East), ECS-1 (in Unit 8 East Cascades) | Yes |
| Streaked horned lark<br>*Eremophila alpestris strigata* | T-CH | Coos County | Not in Project Area | No |

TABLE 2.1-1

**Listed Species that May Be Present within the Project Area**

| Listed Species | Federal Status a/ | Potential Occurrence within the Project Area | Critical Habitat within the Project Area | Recovery Plan Drafted |
|---|---|---|---|---|
| **Herpetofauna** | | | | |
| Green turtle<br>*Chelonia mydas* | T-CH | Pacific Ocean EEZ | Not in Project Area | Yes |
| Leatherback turtle<br>*Dermochelys coriacea* | E-CH | Pacific Ocean EEZ | Yes-Pacific Ocean north of Cape Blanco, south of Cape Flattery | Yes |
| Olive Ridley turtle<br>*Lepidochelys olivacea* | T | Pacific Ocean EEZ | None Designated | Yes |
| Loggerhead turtle<br>*Caretta caretta* | T | Pacific Ocean EEZ | None Designated | Yes |
| Oregon spotted frog<br>*Rana pretiosa* | PT -PCH | Buck Lake, Klamath County | Buck Lake, Klamath County | No |
| **Fish** | | | | |
| Green sturgeon<br>(Southern Distinct Population Segment)<br>*Acipenser medirostris* | T-CH | Pacific Ocean EEZ<br>Coos Bay estuary and tributary rivers to Head of Tide | Yes - Coos Bay estuary, tributary rivers to Head of Tide, and Pacific Ocean to 60 fathoms | No |
| Eulachon<br>(Southern Distinct Population Segment)<br>*Thaleichthys pacificus* | T-CH | Coos Bay, Pacific Ocean EEZ | Not in Project Area | No |
| Coho salmon<br>(Southern Oregon/Northern California Coast Evolutionarily Significant Unit)<br>Oncorhynchus kisutch | T-CH | Rogue River | Yes – Upper Rogue HU (17100307) | Yes-draft |
| Coho salmon<br>(Oregon Coast Evolutionarily Significant Unit)<br>*Oncorhynchus kisutch* | T-CH | Coos Bay, and the Coos, Coquille, and South Umpqua, Rivers | Yes – South Umpqua Subbasin (HU 17100302), Coquille Subbasin (HU 17100305), – Coos Subbasin including the Coos Bay Estuary (HU 17100304) | No |
| Lost River sucker<br>*Deltistes luxatus* | E-CH | Klamath River<br>Lost River | Yes – Unit 1, Klamath County | Yes |
| Shortnose sucker<br>*Chasmistes brevirostris* | E-CH | Klamath River<br>Lost River | Yes – Unit 1, Klamath County | Yes |
| **Invertebrates** | | | | |
| Vernal pool fairy shrimp<br>*Branchinecta lynchi* | T-CH | Jackson County | Yes – Eagle Point and Sams Valley quadrangles – CHUs VERFS 3A and 3B | Yes |
| **Plants** | | | | |
| Applegate's milk-vetch<br>*Astragalus applegatei* | E | Klamath County | None Designated | Yes |
| Gentner's fritillary<br>*Fritillaria gentneri* | E | Jackson County | None Designated | Yes |
| Large-flowered woolly meadowfoam<br>*Limnanthes pumila ssp. grandiflora* | E | Jackson County | Yes- Units Rogue Valley-6 and Rogue Valley-8 | Yes |
| Cook's lomatium<br>*Lomatium cookii* | E | Jackson County | Yes - Units Rogue Valley-6 and Rogue Valley-8 | Yes |
| Kincaid's lupine<br>*Lupinus sulphureus var. kincaidii* | T-CH | Douglas County | Not in Project Area | Yes |
| Western lily<br>*Lilium occidentale* | E | Coos County | None Designated | Yes |
| Rough popcornflower<br>*Plagiobothrys hirtus* | E | Douglas County | None Designated | Yes |

a/ Status Key: E = Endangered, T = Threatened, PT = Proposed Threaned, CH = Critical Habitat, PCH = Proposed Critical Habitat.

Species listed under the ESA and under authority of NMFS (Wheeler, 2006a, b) within the Project area include coho salmon – the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU), coho salmon – Oregon Coast (ESU), green sturgeon – the Southern DPS, and eulachon – the Southern DPS all of which are listed as threatened. Critical habitat is designated for Coos Bay and the nearshore ocean area for the green sturgeon – the Southern DPS in the project area. Within the Pacific Connector pipeline project area, federally designated critical habitat for coho (SONCC ESU) occurs in all streams and rivers below longstanding natural barriers and Lost Creek Dam within the Rogue River basin, and for coho salmon – Oregon Coast (ESU) in the Coos, Coquille, and South Umpqua Sub-basins. Designated critical habitat has been finalized for the shortnose sucker and Lost River sucker in the Klamath River which would be crossed by the Pacific Connector pipeline.

In addition, NMFS has jurisdiction over all marine mammals, including pinnipeds (seals, sea lions, walruses) and cetaceans (whales, dolphins, porpoises). All marine mammals are protected under the Marine Mammal Protection Act (MMPA) and some of those species have been listed as endangered or threatened under the ESA. With specific exceptions the MMPA prohibits "take" of marine mammals within waters of the United States and by citizens on the high seas. "Take" under the MMPA includes the following actions: harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect. Marine mammals listed under ESA that may occur off the Oregon coast are the southern resident killer whale, humpback whale, blue whale, fin whale, sei whale, sperm whale, and North Pacific right whale (see table 2.1-1).

Similarly, NMFS has jurisdiction over four species of sea turtles, listed as endangered or threatened, which may occur off the Oregon coast out to the limits of the EEZ which extends 200 nautical miles off shore. Although there are no breeding grounds in the Pacific Northwest and sightings are very rare, the four species include the leatherback sea turtle, loggerhead sea turtle, green sea turtle, and olive Ridley sea turtle (see table 2.1-1). Critical habitat for leatherback sea turtle has been designated along the Oregon Coast north of Cape Blanco.

The FWS has jurisdiction under the ESA for terrestrial federally listed threatened or endangered species, including birds, invertebrates, and plants. The Pacific Connector pipeline route would pass through designated critical habitat units (CHUs) for northern spotted owl (NSO) (CHUs OCR-6, KLW-1, KLE-2, KLE-3, KLE-4, KLE-5, and ECS-1), and marbled murrelet (MAMU) (CHU OR-06-d) (FWS, 2011a and 2012a). Designated critical habitat for the western snowy plover includes 273 acres on the North Spit of Coos Bay, about 2.6 miles southwest of the proposed Jordan Cove LNG terminal and 5.1 miles southwest of the pipeline terminus

Critical habitat for vernal pool fairy shrimp has been designated for 7,500 acres in Jackson County, including the Shady Cove, Eagle Point, Boswell Mountain, Brownsboro, and Sams Valley quadrangles [-]. Two of the yards (Burrell Lumber and Burrell Real Estate) proposed to be used by Pacific Connector would be located in close proximity to CHUs VERFS 3A and 3B.

In 2010, the FWS designated critical habitat for the large-flowered woolly meadowfoam and the Cook's lomatium (Federal Register vol. 75, no. 139: 42490-42570). Eight CHUs for large-flowered woolly meadowfoam were identified in Jackson County, covering a total of about 5,840 acres, while three CHUs were identified in Jackson County for Cooks lomatium, covering a total of about 2,282 acres. Pacific Connector would be located in close proximity to two CHUs, Rogue Valley 6 and Rogue Valley 8.

## 2.2 INFORMATION SOURCES

Information on listed species' distributions, habitat requirements, and potential occurrence in the Project area and vicinity was gathered from many sources including: 1) published scientific literature; 2) agencies' published and unpublished reports; 3) agencies' unpublished raw and/or compiled data; 4) agencies' geo-spatial databases, which document species observations; 5) on-site surveys for species and habitats (as modified during agency review); and 6) personal communications with agency personnel knowledgeable about species ecological status in the Project area and vicinity. The applicants and FERC representatives met with the Interagency Task Force, which included representatives of the FWS and NMFS, as well as USFS, BLM, ODLCD, ODE, ODSL, COE, ODFW, EPA, and ODEQ, to obtain specific input, guidance, and technical approach reviews. Agencies participating in the Interagency Task Force reviewed information provided by the applicants. A subgroup of the task force, the ESA Consultation Subgroup, was established to develop habitat layers, determine extent of analyses, and provide guidance for avoidance and minimization measures for ESA species.

Existing vegetation within the Pacific Connector pipeline project area was classified by the applicants using several reference/data sources: 1) National Wetland Inventory (NWI) maps refined with field delineation surveys conducted in 2006 and 2008; 2) aerial photography of the proposed Pacific Connector pipeline alignment (2006 and 2012); and 3) digital geographic information system (GIS) data coverage and vegetation categories described by the Oregon Gap Analysis Project (Kagan et al., 1999) and current wildlife habitat types described and delineated by the Northwest Habitat Institute in 1999 (Kiilsgaard and Garrett, 1999). Vegetation cover types within the Pacific Connector pipeline project area were digitized by the applicants with GIS from aerial photography (2012) and were delineated based on the predominant vegetation physiognomy (e.g., trees, shrubs, herbaceous vegetation) and the dominant species present.

Fisheries (ESA-listed species and species with EFH) information was gathered from many sources including: 1) NMFS (Wheeler, 2006a and 2006b); 2) FWS (FWS, 2006a and 2006b); 3) ODFW Natural Resources Information Management Program (NRIMP) (ODFW, 2006a), which documents observations of species in the project area; 4) species' population and distribution information available online at StreamNet (StreamNet 2006); and 5) published scientific literature and agency reports. Information on other listed species was gathered from: 1) *Wildlife-Habitat Relationships in Oregon and Washington* (Johnson and O'Neil, 2001), which provides relationships between specific habitats and the wildlife species that may occur in the Pacific Connector pipeline project area; 2) ORNHIC (ORNHIC, 2012), GeoBOB (BLM, 2006), ISMS (BLM, 2006), and NRIS (USFS, 2006) databases; FWS GIS database and NSO demographic database; 3) National Biological Breeding Bird Survey routes and Audubon Christmas Bird Counts; 4) published scientific literature and agency reports; and 5) other state and federal databases and literature available online. Field surveys (below) were conducted prior to formation of the Interagency Task Force, but survey results and survey protocols have been reviewed by members of a Species Survey Subgroup.

### 2.2.1 Species Surveys

Existing vegetation cover types within the LNG terminal were determined from field surveys conducted by consultants to Jordan Cove, including wetland delineations (Stuntzner, 2005) that have been approved by the ODSL and botanical surveys (SHN, 2006) accepted by the ODA. Vegetation (including wetlands) cover type maps were prepared using current aerial photography overlaid with the cover type boundaries determined in the field surveys. Extensive surveys have been conducted at the Project site for botanical resources. The Project site was initially surveyed and evaluated extensively in 2005 and 2006 for the previously proposed LNG import facility. Additional surveys were conducted in 2012 and 2013 to supplement the previous surveys and ensure that all existing botanical resources are included in this evaluation. A preliminary botanical survey of the construction worker camp site across the bay was conducted in April

2013 (see forthcoming EIS for results of these surveys and description of wetlands and vegetation at the LNG terminal).

Jordan Cove also had consultants conduct biological investigations for wildlife and fish at the terminal and slip sites in 2005, 2006, and 2012 (LBJ Enterprises, 2006; Alice Berg & Associates, 2006; SHN, 2013) as well as a biological sampling program in Coos Bay in 2010 (Shanks et al., 2010). The predicted occurrence and status of fish and invertebrate species were based on available literature, which included actual field data from ODFW field sampling programs. Survey methodologies were developed through consultations with the ODFW, BLM, and FWS. The Oregon Institute of Marine Biology (OIMB) conducted studies of zooplankton distribution and water quality parameters in 2009 and 2010. The results of Jordan Cove's 2005 and 2006 biological surveys will be provided in the forthcoming EIS. The results of the first year of the biological sampling program in Coos Bay are included in this draft BA/EFH Assessment.

The Pacific Connecter FERC Certificate application discussed the vegetation and habitat types crossed by the Pacific Connector pipeline, in Resource Report 3. Ellis Ecological Services Inc. (2013) conducted a survey of eelgrass beds in 2013 within Coos Bay. Pacific Connector had Siskiyou BioSurvey, LLC (SBS) conduct botanical and biological surveys for terrestrial sensitive species in 2007 and 2008, and a variety of additional survey efforts from 2009 through 2013. These surveys documented the presence or absence of federally-listed species along the proposed pipeline route. The surveys also sought to identify state listed species, and federal land management agency Survey and Manage and special status species, including the great grey owl, red tree vole, and several mollusks. The results of these surveys were summarized in Pacific Connector's FERC Certificate application and biological survey reports were provided as a stand alone document to Resource Report 3 (see also forthcoming EIS).

## 2.3 MAGNUSON-STEVENS ACT CONSULTATION

The Sustainable Fisheries Act of 1996 amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and requires federal agencies, in part, to consult with the NMFS about activities that may adversely affect EFH (NMFS, 1997a). The MSA established guidelines for Regional Fishery Management Councils to identify and describe EFH in Fishery Management Plans (FMPs) to responsibly manage exploited fish and invertebrate species in federal waters. The Pacific Fishery Management Council (PFMC) has developed four FMPs that address EFH for managed species in the Project area (PFMC, 1998, 1999, 2004). The four fisheries managed by the PFMC are highly migratory species, coastal pelagic species, groundfish, and Pacific Coast salmon.

This BA and EFH Assessment provides information to NMFS on potential effects to EFH, pursuant to Section 305(b) of the MSA. The MSA describes EFH as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity (NMFS, 1997a). Within the Project area, EFH has been designated for two salmonids (Chinook and coho), three pelagic species (northern anchovy, Pacific sardine and Pacific mackerel), and 29 groundfish species known or suspected to occur within Coos Bay. All habitat accessible to these managed species, including spawning and incubation, juvenile rearing, juvenile migration corridors, and adult migration corridors, is considered EFH (PFMC, 1999). Highly migratory species defined by the PFMC include tunas (five species), sharks (five species), billfish/swordfish (two species) and the dorado (also called dolphinfish or mahi-mahi).

# 3.0 PROJECT DESCRIPTION

## 3.1 PROPOSED FACILITIES

### 3.1.1 Waterway for LNG Marine Traffic

Based on the Coast Guard having authorized the 148,000 $m^3$ size of LNG carrier for the Project, it is anticipated that approximately 90 LNG carriers per year will be required to transport the designed 6 MMTPA output of the liquefaction facilities. Ninety ship calls is an increase in 10 carriers per year from the estimated ship calls for the proposed import terminal. The actual number of LNG carriers will be dependent on the capacity of the LNG carriers calling on the Project and the actual output production of the Project. The LNG carrier berth is designed to accommodate LNG carriers up to 217,000 $m^3$ should larger size carriers be authorized by the Coast Guard in the future.

The LNG carriers would transit the waterway from the LNG terminal, enter the EEZ and cross the ocean for delivery to Asian and non-coterminous U.S. Pacific markets. The impact from transoceanic transport of LNG once the carriers leave the EEZ is not analyzed in this document.

A pilot would board the incoming LNG carrier at least 5 nautical miles outside of the sea buoy. From the territorial sea, LNG carriers would be under the pilot's control and would enter the navigational channel and go past the sea buoy. Two 80 metric ton bollard pull tractor tugs would be secured to the LNG carrier at the direction of the pilot at a point either offshore or upon entering the breakwater.

The last point to turn the ship around if conditions are deemed not appropriate to enter is Buoy #1. The the bay is located between two jetties, about 2,100 feet apart that extend about 3,000 feet from the shore. There is a bar in the Entrance Range with a depth of 37 feet, which establishes the minimum depth of the channel. The most favorable time for crossing the bar is on the end of the flood tide. There is usually a southerly current during the summer months off the entrance jetties and a northerly current in the winter after strong southerly winds. The tidal range for Coos Bay is about 7 feet for mean spring range and about 3 feet for mean neap range. Only during high water slack would an LNG carrier transit the waters inside the jetties to minimize the impacts of currents.

After passing the jetties and the southern tip of the North Spit, the LNG carrier would travel approximately 1.8 nautical miles and begin its turn to the north at a speed of approximately 6 knots. Transiting a distance of 1.6 nautical miles up the Coos Bay Range, the speed of an LNG carrier in this area would be determined by steerage and wind conditions, but would be about 6 knots. The LNG carrier would travel in a northerly direction a distance of 2.1 nautical miles when traversing the Empire Range and the Lower Jarvis Range. The speed of an LNG carrier in this area would be between about 4 to 6 knots.

After the Lower Jarvis Range, the LNG carrier would travel a distance of 0.8 nautical mile to reach the northernmost point in its transit, at the beginning of the access channel to the Jordan Cove terminal. A third tug would meet the LNG carrier at the access channel. The carrier would be slowed and turned at the direction of the pilot. With tug assistance, the LNG carrier would back into the berthing dock. Jordan Cove estimated that the maximum transit time for an LNG carrier in the Coos Bay navigation channel would be about 90 minutes.

#### 3.1.1.1 Coast Guard Risk Management Measures

The Coast Guard exercises regulatory authority over LNG facilities that affect the safety and security of port areas and navigable waterways. The Coast Guard is responsible for matters related to navigation safety, LNG carrier engineering and safety standards, and all matters pertaining to the safety of facilities or equipment located in or adjacent to navigable waters up to the last valve immediately before the LNG storage tanks. The Coast Guard also has authority for LNG facility security plan review, approval, compliance verification as provided in 33 CFR 105, and siting as it pertains to the management of carrier traffic in and around the LNG facility. Under 33 CFR 127 the Coast Guard regulates the design, construction, equipment, operations, inspections, maintenance, testing, personnel training, firefighting, and security of LNG waterfront facilities.

On June 14, 2005, the Coast Guard published a Navigation and Carrier Inspection Circular – *Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas (LNG) Marine Traffic* (NVIC 05-05). The purpose of the NVIC 05-05 was to provide the Coast Guard Captain of the Port (COTP), Federal Maritime Security Coordinators (FMSC), members of the LNG industry, and port stakeholders with guidance on assessing the suitability of a waterway for LNG marine traffic. On December 22, 2008, the Coast Guard published a second Navigation and Carrier Inspection Circular – *Guidance Related to Waterfront Liquefied Natural Gas (LNG) Facilities* (NVIC 05-08). The purpose of NVIC 05-08 is to revise the format of the LOR to conform to its intended effect of being a recommendation of the waterway suitability to the FERC. In accordance with this guidance, each LNG project applicant is to submit a WSA to the cognizant COTP. As described in NVIC 05-05, the COTP submits a Water Suitability Report (WSR) to the FERC after review of the Follow-On WSA. The WSR contains the Coast Guard's preliminary determination on the suitability of the waterway for LNG marine traffic.

The LOR issued by the Coast Guard on April 24, 2009 stated that the Coos Bay waterway could be made suitable for LNG marine traffic by implementing the measures outlined in the WSR. Throughout the life of the LNG terminal, Jordan Cove would ensure that the facility and any LNG carrier transiting to and from the facility comply with all requirements set forth by the Coast Guard COTP Sector Portland, including all risk mitigation measures recommended in the WSR.

Jordan Cove has actively participated in the Waterway Suitability Assessment (WSA) process with the Coast Guard to ensure that the Project is in full compliance with all safety and security regulations applicable to LNG vessel transits. In connection with the import facility, Jordan Cove had submitted to the Coast Guard a Letter of Intent (LOI) pursuant to 33 C.F.R. §127.007, and its preliminary WSA, as required by the Commission's regulations (18 C.F.R. § 157.21(a)(1) and (d)(12)). The Coast Guard issued a Waterway Suitability Report (WSR) and a Letter of Recommendation for the Coos Bay navigation channel, finding that the channel can be made suitable for LNG marine traffic if a number of conditions are met. In connection with the export facility proposal, Jordan Cove notified the Captain of the Port that any changes created by the Project would be addressed in the annual WSA update. The Captain of the Port affirmed this approach and requested that the LOI, the WSA, and the Emergency Response Plan be amended to reflect the Project. The WSA for the year 2012 was updated to provide for the loading of LNG at the LNG Terminal. The LOI likewise was updated. The WSA and its transmittal are considered to be Security Sensitive Information and therefore have been submitted solely to the Coast Guard.

Additional resources, such as high bollard pull tractor tugs and pilots, will be required to handle the anticipated number of LNG carriers and support the anticipated growth within the Port. Jordan Cove has committed to provide the following marine resources as identified by the Coast Guard in the current version of the WSR:

- Three, 80 bollard ton tractor tugs with Class 1, fire-fighting capability;
- LNG carrier navigation system for LNG carrier use while in route to the Project;
- Physical Oceanographic Real Time System (PORTS) to provide real time river level, current and weather data;
- Automatic Identification System (AIS) receiver and camera system to monitor the transit of the LNG ships while in Coos Bay;
- Emergency response notification system; and
- Installation of private navigation aids (e.g., targets).

#### 3.1.1.2 Potential for Shoreline Erosion and Wake Stranding

We considered the potential of LNG carrier traffic in the waterway causing shoreline erosion. If there was significant shoreline erosion from LNG carrier traffic in the waterway, this could result in a rise in sedimentation and turbidity in Coos Bay, which could have an effect on aquatic resources. Also, there is the potential the LNG carriers transiting the waterway could create waves that wash aquatic species up onto the shore. The forthcoming EIS will discuss shoreline erosion that may result from LNG carrier traffic in the Coos Bay navigation channel.

The possible impacts on the shoreline along the navigation route to and from the LNG Terminal from the pressure fields generated by passing deep-draft vessels and vessel wakes generated by assisting tug boats were analyzed at selected areas of interest along the route, namely, Pigeon Point, Clam Island, and the airport. A complete description of the modeling and the results are provided in DRAFT Volume 2 of the C&H Technical Report (Coast and Harbor Engineering, 2011). The analysis of possible impact on the shoreline of these selected sensitive areas was accomplished through a combination of numerical modeling and empirical formulae. Pressure effects have been studied using the 2-D Vessel Hydrodynamics Longwave Unsteady (VH-LU) numerical model. Pressure field effects (also known as draw-down or Bernoulli effects) result from the pressure differential that forms along the moving body of the vessel. Low-pressure area develops along the sides, and high-pressure area develops in front of the bow and behind the stern of the vessel. The pressure field moves with the passing vessels, and is projected upon the channel bottom and banks in the form of long-period waves. The VH-LU model simulates pressure field effects and calculates water surface elevations, velocities, and forces on banks and bottom slopes along the waterway. The potential changes in erosion/accretion processes at the sensitive shorelines along the navigation route were determined by comparing pressure field velocities between Post-Project Conditions and Existing Conditions (as defined in the C&H Technical Report).

Two types of comparison analysis were conducted to detect any possible change of pressure field impacts on sensitive areas due to the introduction of LNG vessels to the waterway system:

spatial method and stationary method. The spatial method included comparison of pressure field depth-averaged velocity spatial distribution (plan view) between Existing Conditions and Post-Project Conditions at the same time steps. The stationary method included a comparison of time series of pressure field depth-averaged velocities at selected locations along the sensitive shoreline areas.

The results of the analysis show that hydrodynamic effects from pressure field velocities measured along the sensitive shoreline from existing deep-draft vessels exceed the pressure field velocities that may be generated by future LNG carriers. The reason for this is that the Coast Guard has mandated that all LNG carriers be escorted by a minimum of two tractor tugs each with 80 tonne bollard pull capacity. The use of these tugs allows the LNG carrier to transit at a lower speed than the existing vessels which transit without tug assist. Vessel velocity, rather than its size has a much greater impact on the amplitude of the pressure wave. The conclusion of this finding is that the potential impact from the proposed LNG carrier on coastal processes at the sensitive shoreline would be smaller than that from the existing deep-draft vessels.

Vessel wake effects have been studied using the 2-D spectral wave model SWAN (SWAN) for waves/wakes generation and propagation and empirical formulation for evaluation of swash sediment transport. The potential vessel wake impact at the sensitive areas was determined by comparing swash sediment transport for Post-Project Conditions relative to Existing Conditions. The possible impact on sensitive shoreline from increased vessel wake energy along the navigation route was evaluated using calculations of swash sediment transport. Swash sediment transport indicates the potential for shoreline response to waves/wakes energy delivered to the shoreline itself.

Swash sediment transport at the sensitive areas for Existing Conditions was assumed to be formed from two different contributing factors:

- Swash sediment transport generated by wind waves.
- Swash sediment transport generated by present traffic of tug-boat wakes.

Swash sediment transport at the sensitive areas for Post-Project Conditions was assumed to be formed from three different contributing factors:

- Swash sediment transport generated by wind waves.
- Swash sediment transport generated by present traffic of tug-boat wakes.
- Swash sediment transport generated by future traffic of tug-boat wakes.

SWAN was applied to generate wind-waves and propagate them to the sensitive shorelines from different directions at various tide elevations. A total of 1,080 modeling scenarios, combinations of wind speed, directions, and tide elevations were simulated with SWAN.

The results of the swash transport calculations show a small increase in wake-generated swash sediment transport at the areas of interest due to LNG carriers. The results show that the increase in swash sediment transport from combined inbound and outbound carrier traffic would not exceed six percent at Pigeon Point, eight percent at Clam Island, and five percent at the airport sensitive shorelines. The total sediment transport for future inbound and outbound LNG carrier traffic will be less than eight percent of the existing and future wind-wave swash sediment transport. The estimated increase in swash sediment transport due to the LNG carrier traffic is a small fraction of the swash sediment transport due to the natural wind-wave conditions. This increase most likely would not be detected in a general balance of swash sediment transport due to yearly variability of wind-wave conditions and swash sediment transport.

**Slip**

The possible effects of propwash of vessels operating in the slip on the dredged slope and bottom of the slip were determined by numerical modeling and analytical methods. The LNG carriers will not use a thruster or ship's power in docking or undocking operations. LNG carrier maneuvering will be conducted with the assistance of tug-boats. A tractor tug-boat was selected as a design vessel for this analysis, and propwash modeling was conducted using tug-boat positions in the Project area as provided by the simulations for docking and undocking LNG carriers. Extreme docking and undocking conditions were used for tractor tug-boat propwash modeling to simulate the most conservative situation (highest propeller current velocities) that may occur in the future. These conditions are represented by a tractor tug-boat applying up to 75 percent of available power for up to 60 seconds while pushing the LNG carrier. The potential for bottom scour was analyzed by simulating the near-bottom velocity that would be generated by a propeller during extreme conditions, and relating the velocity through engineering relationships to sediment movement and scour depth. The methodology for evaluating the potential for bottom scour consisted of two steps:

- Step 1 – Compute propwash velocities and resulting hydrodynamic forces developed at the bottom surface.
- Step 2 – Compare these velocities and forces to bottom sediment stability criteria, and estimate areas and depth of scour where propeller-induced hydrodynamic force exceeds bottom sediment stability.

The velocity field created aft of a propeller was computed using the 2-D numerical model JETWASH. Sediment stability criteria are assumed to be equivalent to sediment critical shear stress (threshold) criteria. Shear stress is computed using modeled velocity at a specified height above the bottom, and assumes that a logarithmic velocity profile develops in the propwash flow near the bottom. Depth of scour on a dredged slope was estimated by the method in which larger particles in the size distribution can armor a surface after a sufficient volume of finer material is winnowed away, and further scour is halted. For modeling purposes only, berthing an LNG carrier was assumed to occur at a tide elevation of no lower than four feet above MLLW. Propeller effects on the bottom and slide slope are modeled with a tide elevation of four feet, because at higher tides the propeller effects will be less. Water depth in the basin during numerical modeling was kept at 49 feet MLLW.

Based on the modeling results of propwash impact on dredged slope, it was determined that the location of maximum near-bottom velocity of 2.0 feet per second (ft/sec) is on the slip bottom, about 30 feet from the toe of the side slope. This velocity (2.0 ft/sec) corresponds to the threshold velocity for initiation of motion of medium sand. This implies that the exposed west slope of the slip would not be subject to propwash erosion if the size of material present on the bottom and on the side slope is larger than medium sand (e.g., coarse sand, gravel, etc.). The computed propwash velocity is below the threshold velocity for initiating suspension of sediment for these types of material and larger. The proposed design of the dredged slope exposed to propwash is armoring with large rock. In this case, propwash will have no effect on scouring and damage of the armored material placed on the dredged side slope.

Analysis of propwash impact on the bottom and side slope in the slip was conducted using model output in a 2-D horizontal plane located 0.85 feet above the actual bottom. The modeling result show that maximum near-bottom velocity produced by the tug-boat is 2.16 ft/sec, and occurs at a distance of 240 feet horizontally from the propeller. Near-bottom velocity is the velocity at a position in the flow at 0.85 feet above the bottom. Bottom sediment exposed by excavation of the slip is expected to have a median diameter of 0.27 millimeters (mm). Analysis indicates that the bottom sediment may be eroded during the design extreme propwash event. Possible depth of scour will depend on the duration and repetition of this velocity at the same location in the slip. It is unlikely that this velocity will last long, and it is even more unlikely that this velocity may occur at the same spot during a long period of operation. Under this conservative approach, computed scour depth resulting from the volume of loss to attain bottom stability is less than two inches. This amount of conservatively estimated scour is not expected to be a factor in bottom stability or water quality, and mobilized material will not be distributed far from where it would be scoured. Over time, what material is displaced at one time may be moved again in subsequent docking maneuvers. The pattern of movement in the long-term is expected to be intermittent reworking of the same bottom surface material. At any one time, an area on the bottom is expected to be scoured to a maximum depth of less than two inches.

The modeling results indicated that for final design, rock armoring be eliminated on the west slope, if this armoring is not required for other than tug-boat propwash scour protection. Consequently, the design was modified to incorporate the formation of the west side of the slip with the Open Cell® sheet pile technology.

**Coos Bay Navigation Channel Bottom**

The possible impacts on the bottom of the navigation channel from propeller wash (propwash) due to LNG carriers navigating to and from the LNG Terminal was investigated using JETWASH. Propwash of tugs moving with the LNG carrier was not included in this analysis because the tug-boats would operate at low power, and the tug-boat's propeller diameter is less than a third the diameter of the LNG carrier's propeller. Further the vertical distance between the tug-boat propeller tip and the bottom is so large (about 35 feet) that tug-boat effects on the channel bottom in this operation are insignificant. The turbulent force that might be experienced at the channel bottom and suspension of bottom sediment by the LNG carrier motion and propeller wash will be additional to the turbulence and sediment suspension caused by the vessels that currently navigate the channel. Displacement of bottom material by fluid forces without replacement by deposition is defined as bottom scour.

The potential increase in bottom scour was analyzed by comparing the effects of a 148,000 $m^3$ capacity LNG carrier with the effects of a vessel representative of the vessels that currently transit the navigation channel. The comparison of vessel effects is based on vessel propwash bottom sediment scour, suspension, and dispersal by each of the two vessel types, along with their respective proportions of re-deposition of sediment outside the limits of the 300-foot-wide navigation channel in the area of interest.

Bottom sediment may be disturbed by flow created by the hull passing over the bottom. The potential exists for sediment suspended from the bottom of the navigation channel to be dispersed in the flow laterally outside the channel limits to the areas that may have habitat value. Suspended material falling back to the bottom within the navigation channel limits may be disturbed or dredged at some future time. The relative amount dispersed beyond the navigation channel limits, compared to that returning to the bottom within the channel, is a measure of the physical impact by propwash on the channel bottom.

Analysis of propwash modeling results showed that no bottom scour outside of the navigation channel boundaries would occur during passage of the design LNG carrier. The modeling results also showed that a greater level of turbulence, and thus suspended sediment dispersion, will occur in the transit of a typical bulk carrier than with an LNG carrier. Near bottom velocity created by passage of the bulk carrier is greater than that of the LNG carrier for the design conditions of tide level and vessel speed and draft.

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds have been observed to cause occasional stranding of juvenile salmon (Pearson et al., 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al.) to cause stranding. In models and research conducted by Jordan Cove, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute to fish stranding within Coos Bay.

#### 3.1.1.3 Ballast Water Disposal

If the LNG Terminal operates at LNG production design capacity of approximately six MMTPA (0.8 Bscf/d of natural gas) for the entire year, a total of 90 vessel calls (assuming on average 148,000 m$^3$ vessels) will be needed to export the LNG from the LNG Terminal. These shipments would, of necessity, need to be scheduled for ratable delivery with one 148,000 m$^3$ vessel (carrying the equivalent of 3.4 billion cubic feet of natural gas) departing every four days. Each LNG vessel will discharge approximately 9.2 million gallons of ballast water during the loading cycle to compensate for 50 percent of the mass of LNG cargo loaded.

LNG ships will discharge ballast concurrently with the LNG cargo loading. The amount of ballast water discharged must, at a minimum, be adequate to maintain the LNG ship in a positive stability condition and with an adequate operating draft while the LNG cargo is loaded. The ballast water discharged will be that from 200 miles out in the open sea as occurred as part of the mandated ballast water exchange (BWE) process.

Typically, the amount of ballast water discharged by the LNG ship at the berth will be approximately 50 percent of the weight of the LNG loaded. One cubic meter of LNG is 0.46 metric tonnes (mt), which for the maximum size of LNG carrier authorized to call on the LNG Terminal (148,000 $m^3$) would be 68,080 mt of LNG per ship. Assuming one metric tonne of seawater is 1.027 $m^3$, the amount of seawater ballast discharged (50 percent of the weight of the LNG loaded) would be approximately 34,959 $m^3$ (approximately 9.2 million gallons). In the event that a 217,000 $m^3$ ship is used, the amount of water discharged would be on the order of 12.9 million gallons.

The LNG loading rate is designed to be 10,000 $m^3$/hr (with a peak capacity of 12,000 $m^3$/hr), or 4,600 meters per hour (mt/hr) (5,520 mt/hr peak), consequently the ballast water discharge rate would be approximately 20,250 gpm. The typical LNG ship has an upper and a lower ballast water discharge on each side of the hull, referred to as sea chests. The lower unit is just above the keel of the ship, approximately 10 meters (33 feet) below the water line. Typical LNG ships also have three ballast water pumps, each capable of 3,000 $m^3$/hr (13,210 gpm) rated capacity.

The ballast water discharge port or sea chest is approximately 3.5 to 4.2 square meters covered by a screen with 4.5 mm bars, spaced every 20-25 mm. The discharge velocities for the ballast water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be adversely affected by the ballast discharge. Some smaller organisms may be temporarily displaced by the discharge flow, but the displacement should be insignificant in the confines of the slip.

Ballast water that is likely to be introduced into the slip at the LNG Terminal will be composed mainly of open ocean water retrieved during BWE activities during trans-ocean shipping (200 miles off shore). The physio-chemical composition of this water would be very similar to that which occurs within Coos Bay and the slip depending on hydrologic conditions.

Seawater on average, in the world's oceans has a salinity of about 3.5 percent. This means that every kilogram, or every liter, of seawater has approximately 35 grams (1.2 ounces) of dissolved salts (mostly, but not entirely, the ions of sodium chloride. The average density of seawater at the ocean surface is 1.025 grams per milliliter (g/ml); seawater is denser than freshwater (which reaches a maximum density of 1.000 g/ml at a temperature of four degrees Celsius (°C) (39 °F)) because of the salt’s added mass. Although the vast majority of seawater has a salinity of between 3.1 percent and 3.8 percent, seawater is not uniformly saline throughout the world. Where mixing occurs with fresh water runoff from river mouths or near melting glaciers, seawater can be substantially less saline.

A potentially notable difference that may be observed in water quality could be salinity. Since the LNG Terminal is approximately seven miles from the open Pacific Ocean, potential differences in salinity may not be perceptible. The issue of a potential salt wedge up into the Coos and Millicoma Rivers has been raised. The findings of the sampling conducted by OIMB in the bay indicated a wide range in physical oceanographic data (including salinity) between seasons and tidal cycles and the modeling conducted by C&H predicted that there would be imperceptible changes in the tidal velocities, etc. due to the construction and operation of the Project. The results of the modeling also concluded that the potential changes due to the Project would be less significant than the naturally occurring changes and, as such, there is no predicted perceptible change to the existing conditions that would occur as a result of the Project.

Another physio-chemical water quality parameter that may be influenced by the introduction of ballast water is the dissolved oxygen level. Dissolved oxygen levels are a critical component for the respiration of aquatic marine organisms. Among many other factors, dissolved oxygen levels in water can be influenced by water temperature, water depth, phytoplankton, wind and current. All of these constituents in some way influence the amount of oxygen in the water. Typical water column profiles indicate a decrease in dissolved oxygen with an increase in depth. Some factors that often influence this stratification include sunlight attenuation for photosynthetic organisms that can produce oxygen, wind, wave, and current that results in mixing.

Water that is collected within the ballast tanks of a ship would lack many of these important influences and could suppress dissolved oxygen levels. However, ballast water that is discharged is not expected to be anoxic (i.e., lacking all oxygen), just lower than what levels would likely be at the surface. In addition, ballast water will be discharged near the bottom of the slip where dissolved oxygen levels may already be lower. Therefore no significant impacts are likely to occur as a result of discharging ocean water with potentially suppressed dissolved oxygen levels.

Water temperatures and pH are not likely to be altered as a result of introducing ballast water. Since ballast water is stored in the ship's hull below the waterline, water temperatures are not expected to deviate much from ambient temperatures of the surrounding sea water. The pH of the ballast water (reflective of open ocean conditions) may be slightly higher as compared to that of freshwater estuaries. However, this slight variation is not expected to have any impacts on existing marine organisms.

An assessment of potential impacts suggests that the primary potential impact to the slip will be a periodic influx of higher salinity seawater associated with ballast discharge. However, the amount of ballast water discharged into the system relative to Coos Bay as a whole system would represent a very minor influence on the system during each ballast water discharge event. The proposed slip design indicates that the slip, exclusive of the access channel, will create approximately 50 million cubic feet of additional water volume from land that is currently upland. The total number of gallons in the slip is approximately 374 million gallons. The discharge of 9.2 million gallons of ballast water from the 148,000 $m^3$ LNG carrier would represent 2.4 percent of the volume of the slip and in comparison to the rest of the bay is an infinitesimal percent change. Since the ballast water was collected from the Pacific Ocean, although some 200 miles from the bay, the ballast water discharged will not result in a net change.

Due to the volumes of ballast water often collected by ships, there remains the possibility of living aquatic organisms entering ballast tanks. Some of the larger macro organisms that may be collected will often die; however, some of the smaller planktonic organisms can often survive. An environmental concern associated with this procedure is the risk of introducing exotic species in coastal freshwater and marine ecosystems. Loaded with water from the surrounding ports and coastal waters throughout the world, ships can carry a diverse assemblage of marine organisms in ballast water that may be foreign and exotic to the ship's port of destination. The transfer of water from port-to-port can result in aquatic biological invasions. Invasive species threaten to outcompete and exclude native species and the overall health of an ecosystem, causing algal blooms and hypoxic conditions and affecting all trophic levels resulting in a decline in biodiversity. This concern has long been recognized and is addressed in *Coast Guard*

*Regulation Navigation and Vessel Inspection Circular 07-04*, Change 1 that governs ballast water operations in US ports.

Jordan Cove will continue to require that the ballast water of all LNG carriers be discharged in accordance with Federal oversight and the regulations listed below:

- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) – established a broad federal program "to prevent introduction of and to control the spread of introduced aquatic nuisance species…The U.S. Fish and Wildlife Service, the U.S. Coast Guard, the Environmental Protection Agency, the Army Corps of Engineers, and the National Oceanic and Atmospheric Administration all were assigned … responsibilities, including membership on an Aquatic Nuisance Species Task Force…" (ANSTF, 2005).
- National Invasive Species Act of 1996 (NISA) – reauthorizes and amends the NANPCA 1990. "Nonindigenous invasive species have become established throughout the waters of the U.S. and are causing economic and ecological degradation to the affected near shore regions." The Secretary of Transportation was charged to develop national guidelines to prevent invasive species via ballast water of commercial vessels; the primary means of which is through mid-ocean BWE, unless the exchange threatens the safety or stability of the vessel, its crew, or its passengers (NEMW, 2007).
- National Aquatic Invasive Species Act of 2003 (NAISA) – amended in 2005 and again in 2007. The 2003 act established a mandatory National Ballast Water Management Program. The primary requirements established under NAISA are: 1) all ships operating in U.S. waters are required to have on board an Aquatic Invasive Species Management Plan, 2) the development of standards by the Coast Guard for mid-ocean BWE and BWT for vessels operating outside of the exclusive economic zone, 3) implementing the best management practices and available technology related to BWTs (NEMW, 2007).
- National Ballast Water Management Program (BWM) – originally established by NANPCA 1990 and further amended by NISA 1996 and NAISA 2003 resulting in the ballast water management program being made mandatory and to include BWE and reporting to the Coast Guard (AAPA, 2006).
- Shipboard Technology Evaluation Program (STEP) – a program authorized under the Coast Guard's BWM. STEP is designed to facilitate the development of "effective ballast water treatment (BWT) technologies, through experimental systems, thus creating more options for vessel owners seeking alternatives to ballast water exchange.
- Navigation and Vessel Inspection Circular 07-04, Change 1 - a program developed by the Coast Guard for the management and enforcement of ballast water discharge into U.S. ports and harbors (33 CFR Part 151, 69 FR 44952, July 28, 2004)

Jordan Cove will continue to rely upon the federal oversight and regulations that govern ballast water discharge into US waters.

#### 3.1.1.4 Cooling Water

**Impingement or Entrainment**

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The power requirements for loading LNG in the export mode are less than those for unloading LNG in the import mode because the LNG carrier does not have to use on board LNG pumps to handle LNG cargo; hence both the LNG carrier engine requirement and the required amount of cooling water flow are reduced. The amount of cooling water to be re-circulated is a function of the propulsion system of the LNG ship and, once the LNG ship fleet has been identified, the issue of cooling water circulation requirements can be further addressed. For purposes of this analysis, typical cooling water flow rates were used. Cooling water flows while at the berth are approximately 1,300 $m^3$/hr (343,421 gallons per hour or 5,723 gpm). For a 148,000 $m^3$ ship this would total approximately 4.3 million gallons while loading LNG cargo. In the event that a 217,000 $m^3$ ship is used, the amount of water required would be on the order of six million gallons. The intake port for this cooling water is approximately the same size and at the same location as the ballast water intake port, 3.5 to 4.2 square meters covered by a screen with 4.5 mm bars, spaced every 25 mm and approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG ship. The velocity across this port is approximately 0.28 ft/sec with a temperature differential of three degrees centigrade. It is likely that some organisms that are small enough to pass through the screens covering the ship's intake port will be drawn in with the cooling water and will be lost from the population in the slip area. It is anticipated that the effect associated with the intake of cooling water will be minimal. The intake velocities for the cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be impinged on the intake screen.

**Temperature Effects**

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The engines will be running to provide power for standard hotelling activities as well as running the ballast water pumps. The activities that will require LNG carrier power and the assumptions used to develop the cooling water flow requirements are as follows:

- Hotelling operations require the generation of 1.9 MW of power during the entire time that the LNG carrier remains in the slip. The vessel is anticipated to be within the slip for a total of 17.5 hours.
- A typical auxiliary power unit for an LNG carrier is the Wartsila 34DF. This is a dual fuel (liquid and natural gas) unit that is a complete primary driver/generator package capable of being sized upwards to 6.9 MW output. Fuel to power conversion is 7,700 kilojoules (kJ) per kilowatt-hour (kWh) (kJ/kWh) (7,305 British thermal units (Btu) per kWh (Btu/kWh)). This system has an overall fuel to power efficiency of 46.7 percent, thereby resulting in the rejection of 3,893 Btu of heat into the cooling water for each kWh of power generated.
- All calculations that follow are based upon the transfer of 148,000 $m^3$ of LNG from the LNG storage tanks to the LNG carrier. The 148,000 $m^3$ carrier is set as the basis because it represents the largest vessel authorized to call on the LNG Terminal.

The total gross waste heat discharged into the slip from the cooling water stream will be due primarily from the hotelling operations (including the power required to run the ballast water discharge pumps) as the shore side LNG pumps will be used to transfer the LNG from the LNG storage tanks to the LNG carrier. The hotelling operations were assumed to be as follows:

Hotelling Operations -17.5 total hours x 1,900 kW x 3,983 Btu/kWh = 132.5 million Btu (MMBtu)

The total amount of heat discharged into the slip during each vessel call is approximately 132.5 MMBtu.

Because of the extreme differential of the temperature of the cargo in the LNG carrier (-260$^{o}$F) and that of the surrounding air and water (nominally 45$^{o}$F) there is a constant uptake of heat by the LNG carrier from its surroundings. This heat uptake is manifested by the amount of LNG cargo that changes state from liquid to vapor on a daily basis. The typical LNG carrier sees 0.25 percent of its liquid cargo converted to the gaseous state each 24 hours. In this process 219 Btu of heat is absorbed for each pound of LNG converted to vapor. This results in a total of 53 MMBtu absorbed by a typical 148,0000 m$^3$ LNG carrier during the 17.5 hours it is within the slip. Given the distribution of vessel surfaces between those surfaces in contact with water as opposed to those surfaces in contact with air it is reasonable to assume that 50 percent or more of the heat take up by the vessel is extracted from the water. This assumption is further reinforced by the fact that the heat transfer coefficient between water and steel is significantly higher than the heat transfer coefficient between air and steel. Applying this allocation of heat absorption sources results in having 26.5 MMBtu being removed from the slip by the LNG vessel during its stay. Thus a portion of the 132.5 MMBtu of thermal energy discharged into the slip from the cooling water is offset by the uptake of 26 MMBtu by the LNG vessel itself, resulting in a net heat input to the slip of 106.5 MMBtu per 148,000 m$^3$ LNG carrier call.

Analysis and numerical modeling were performed to identify potential impacts of LNG carrier cooling water discharge on water quality in the slip and adjacent area of Coos Bay. The modeling was initially performed with two different numerical models: the 3-D UM3 model and the DKHW model. The models simulate hydrodynamic mixing processes of submerged discharges and predict temperature fields and dispersion of non-conserved substances in ambient water bodies. Cooling water numerical modeling requires input of steady-state flow velocity in the modeling domain. The results of tidal flowing modeling using the SELFE model showed that ambient current velocities inside the LNG Terminal area vary, depending on tidal stage. Peak current speeds in the berth only exceed approximately 0.32 ft/sec less than two percent of the time. Therefore, for cooling water modeling, two steady state ambient flow velocities were assumed and used further in the analysis: high velocity = 0.32 ft/sec and typical velocity = 0.16 ft/sec.

The following conservative assumptions were used in the analysis. The assumptions are conservative in that a steam powered ship was used. The steam powered ships tend to be older than the newer more modern dual fuel diesel electric ships that require lower quantities of cooling water.

- LNG carriers are steam-powered with a cargo capacity of 148,000 m$^3$.
- Maximum pump capacity for main condenser cooling is 10,000 m$^3$/hr (44,030 gpm) and maximum pump capacity for LNG carrier's equipment cooling is 3,000 m$^3$/hr (13,209 gpm). Total capacity being used at a given time is typically in the range of 6,300 m$^3$/hr (27,739 gpm). For the analysis, 6,300 m$^3$/hr (27,739 gpm) was used.

- Diameter of the horizontal discharge port is 1.1 meters (3.6 feet).
- Depth of discharge port below still water is 10.0 meters (32.8 feet).
- Maximum heating of cooling water at time of discharge is 3 ºC (5.4 ºF) above ambient temperature.

Results of the modeling showed that for typical ambient flow conditions at a distance of 50 feet from the discharge point (LNG carrier sea chest), temperatures will not exceed 0.3 ºC (0.54 ºF) above the ambient temperature. This difference will decrease with further distance.

### 3.1.2 Marine Facilities

#### 3.1.2.1 Construction of Marine Facilities

**Access Channel and Slip**

A slip and an access channel connecting the slip to the Coos Bay Navigation Channel at approximate Channel Mile 7.3 will be constructed. Jordan Cove will utilize the east side of the slip for the LNG ship berth. Tug-assist berths will be located on the north side of the slip. There is no berth on the west side of the slip. The area above the sheet pile wall on the west side of the slip will be used to create a berm as a location for the placement of dredge material.

The new slip will be created from an existing upland area. The inside dimensions at the toe of the slope of the slip measure approximately 800 feet along the north boundary and approximately 1,500 feet and 1,200 feet along the western and eastern boundaries, respectively. The minimum water depth within the slip is -45 feet NAVD88 (North American Vertical Datum of 1988). The northern side slope is anticipated to be initially constructed at 3 feet horizontal (H): 1 foot vertical (V), and the top of the slope is proposed at elevation +25 feet NAVD88. The eastern side of the slip will be used for an LNG berth and the northern end will be used for a tractor tug dock.

The access channel will connect the slip to the navigation channel. The access channel is approximately 2,300 feet in length at the intersection with the navigation channel (taking into account the bend in the navigation channel at this point of intersection) and is approximately 800 feet in width at the mouth of the slip. The distance from the closest edge (north edge) of the navigation channel to the mouth of the slip is approximately 700 feet. The walls of the access channel would be sloped to meet the existing bottom contours at an angle of 3 feet H: 1 foot V. The access channel would cover approximately 30 acres below the mean higher high water (MHHW) line. Dredging of the access channel would affect approximately 15.2 acres of currently existing deep subtidal strata below -15.3 feet in depth; about 5.8 acres (3.3 acres of shallow subtidal plus 2.5 acres of eelgrass which is within shallow subtidal) of existing shallow subtidal strata between the mean lower low water (MLLW) line and -15 feet, and about 8.1 acres of existing intertidal strata between the MLLW and the MHHW.

The east and west side of the slip will be formed by the Open Cell® Sheet Pile Technology developed and patented by PND Engineers, Inc. Open Cell® technology sheet pile is being used at the Sabine Pass LNG Terminal. Unlike conventional sheet pile retaining walls that maintain a clean linear berth face, the Open Cell® Sheet Pile structure face is designed to uniformly deform into a scalloped face as the land side static loads are applied. The engineering advantage of this technology is that the structural integrity of the sheet pile wall is created by the post-construction stressing of the wall by driving the sheet piles, including the tie-back walls first, then excavating the material from the waterside area. This approach results in the upland load stretching out the wall to reach its final scalloped face. When the sheets are driven the wall is a perfectly straight line. It is only after the material on the waterside is excavated that equalizing load on the waterside is removed thereby forcing the shore side load to stretch the piled walls and lock them into place. This creates a very stable structure.

The Open Cell® Sheet Piling will allow the LNG carriers to be moored approximately one meter from the side of the slip. The LNG carrier loading arm/docking platform slab deck will be constructed of concrete behind the Open Cell® Sheet Pile wall. The LNG carrier mooring dolphins, breasting dolphins and loading arm platform and structures will be constructed on the upland area behind the Open Cell® Sheet Piles. Four breasting structures and six mooring structures will be provided for berthing the LNG ship. The breasting dolphins will be attached to the front of the concrete loading arm/docking platform and will be equipped with fenders sized to safely berth and moor the full range of LNG carriers authorized to call on the LNG Terminal. The mooring dolphins will be located onshore and will also be constructed from concrete on pile supported foundations. The mooring structures will be provided with suitable access, quick release hooks and lighting. The loading arm/docking platform will be a reinforced concrete slab/beam structure, approximately 115 feet wide by 60 feet deep supported on piles.

Four marine loading arms will be installed on the concrete base of the loading arm/docking platform slab deck. A mezzanine type elevated platform above the concrete support deck will be constructed of steel for maintenance of the triple swivel assembly of the arms. LNG spill containment will be addressed at the main concrete lower platform level where a concrete curbed and sloped area will contain LNG spillage. Drainage from this point will be via the LNG spill collection trough to the marine area impoundment basin.

Construction of the slip will require the excavation and dredging of approximately 4.3 million cubic yards (cy) of material (2.3 million cy excavated and 2.0 million cy dredged) and construction of the access channel will require the dredging of approximately 1.3 million cy for a total of 5.6 million cy.

In order to minimize the impacts of construction of the marine facilities on fisheries, reduce the total period of estuary turbidity, and extend the time available for construction, a two phase construction methodology will be used to construct the slip. The basic concept of the two phase construction methodology is to excavate (either wet or dry) the majority of the slip area and construct the structures while maintaining a natural physical barrier between the excavated/dredged slip and Coos Bay. This will be accomplished by retaining a natural earthen berm to provide a physical partition between Coos Bay and the Phase 1 marine facilities construction activities. This construction methodology will allow year-round work on Phase 1 (the northern portion of the slip) without being in contact with or causing an impact to the waters of Coos Bay. Phase 2 work will include excavation/dredging of the berm and the access channel and in-water construction. Phase 2 will be constructed during period(s) when fisheries considerations allow in-water work between October 1 and February 15 (window may be modified by agencies having jurisdiction). Details of each of the steps involved during both of Phases 1 and 2 are outlined below. It should be noted that there are numerous scenarios for constructing these facilities to honor the intent of minimizing the impact of construction on the waters of Coos Bay. The sequence that follows is one such scenario. The actual means and methods employed by the contractor for performing the work behind the berm quite likely will vary to some minor degree from this description.

**Phase 1 Construction Details**

Clearing and Grubbing - The slip area consists of two types of topography; (1) natural sand dunes forested with a small amount of harvestable timber and scrub brush and (2) a level area, which was created from dredge material placed on the site by the USACE during 1972 and 1973, covered with low scrubs and grasses. The merchantable timber will be salvage logged and sold while the unmerchantable timber, timber slash and brush will be pulverized in a tub grinder and stockpiled as mulch. The mulch will be saved for future erosion control of recontoured sand dunes created during the construction process. Only surfaces that need to be recontoured to accommodate the slip or supporting structures will be grubbed and cleared. All areas where the existing topography can be maintained will be kept in the current, natural state. Efforts will be made to minimize the surface area to be grubbed and cleared.

Dry Excavation - The existing natural ground surface is at an elevation of approximately +20 feet NAVD88. The water table across the slip occurs at an elevation of approximately +10 feet NAVD88. All excavated material above an elevation of approximately +10 feet NAVD88 will be removed by conventional earthmoving equipment such as scrapers, bulldozers, and front-end loaders. A berm will be maintained as a barrier to the bay during this construction phase. In all areas other than where the Open Cell® Sheet Pile is installed, a side slope of 3H:1V will be maintained on the slip side to preserve the integrity of the berm during excavation and dredging. Excavation during this step will remove only material essential for creating the slip and constructing upland structures. Contouring of the slip perimeter above +10 feet NAVD88 will be performed during this step. Side slopes of 3H:1V where the Open Cell® Sheet piling is not used will be maintained around the perimeter of the slip to maintain slope stability. The materials stockpiled for future mulching operations will be applied as ground cover to the newly exposed sandy slopes to prevent erosion upon completion of the site contouring of elevations above +10 feet NAVD88.

The volume of material to be excavated and dredged from the slip is 4.3 million cy (2.3 million cy excavated and 2.0 million cy dredged) and the volume to be dredged from the access channel is 1.3 million cy for a total of 5.6 million cy. Current plans for management of the material involve the placement of the 1.9 million cy of excavated material on the LNG Terminal site and the placement of 3.7 million cy on the South Dunes Power Plant site.

Excavated material will be hauled by trucks to the South Dunes Power Plant site. The excavated material truck haul route will go to the north of the slip through the LNG Terminal site and then follow the route of the access/utility corridor to the South Dunes Power Plant site. The route will not cross the Trans-Pacific Parkway at any time and the only potential conflict will be with chip truck traffic to the Roseburg wood chip facility. Wood chip truck traffic will be given the right-of-way over haul truck traffic by using flag men to halt haul truck traffic until vehicles have passed the intersection. The excavated material truck haul route will be on Jordan Cove-owned land and the hauling activities will not cause any additional effects other than those associated with the access/utility corridor.

Excavation of Dredge Launch Pond – Several wide-tread excavators will be used to remove material down to elevation 0.0 feet NAVD88, thereby creating a 300 foot long by 200 foot wide by 10 foot deep launch pond. Preferably, the launch pond will be located near the slip perimeter and road access. The material will be moved to the upland disposal sites by trucks as described in the previous section.

The launch pond will receive the dredging equipment that will be used to complete the Phase 1 dredging of the slip. All the material to be excavated that is located at or below the level of the water table will be removed by means of hydraulic dredging and transported to the South Dunes site.

The slurry pipeline used for hydraulic transportation of excavated materials (including the decant water return line) will follow the shoreline of the Roseburg property until the point where it follows the route of the future access/utility corridor. The route will be approximately 8,650 feet in length with an approximate construction right-of-way width of eight feet, and the portion on the Roseburg property will require an incremental 1.2 acres. The pipelines will not result in additional land disturbance. From the slip site across the Roseburg property, they will be placed directly on the ground surface. From the point where they follow the route of the access/utility corridor, the pipelines will be covered with the fill used to develop the access/utility corridor. No excavation of the existing ground surface will occur to install the pipelines as the pipelines will be placed on fill material and temporarily covered by additional fill material. Where not covered, the pipelines will be held in place by cross bracing anchored into the soil. In the area of the Roseburg chip ship berth the pipeline will be placed on the rip-rap along the shore line so as not to affect the docking and loading of the chip ships. The pipelines will be able to span any affected wetlands or waterbodies without the need to place any structures in the wetlands or waterbodies. At all points along the pipeline route where the slurry pipeline could rupture and the contents could potentially enter the waters of the bay, secondary containment will be provided around the slurry pipeline.

The slurry pipeline and decant water return pipelines will be a 20-inch-diameter fused polypropylene (seamless) pipeline and will be provided with secondary containment at any wetland and waterbody crossings to ensure that those bodies will not be affected by any breaks or leaks. The decant water return pipeline will be placed along, and directly adjacent to, the slurry pipeline (no spacing between the two pipelines). The decant water pipeline will be used to convey the decanted water from the settling areas back to the dredge pond. When the hydraulic transport has been completed the pipelines will be drained, flushed with clean water, and cut apart only in those areas where any residual material in the pipeline could not potentially be released into the bay, wetlands, or other water bodies. The pipeline will be removed by the contractor and taken off site for reuse, recycle, or disposal in a permitted landfill. Since the pipelines will be on existing developed surfaces (grassed, paved, graveled, and rip-rap area of the Roseburg property) and areas to be developed for the Project (access/utility corridor), no post construction restoration will be required other than reseeding of grassed areas that were disturbed by the location of the pipelines on the grassed area. It is anticipated that since there will be no actual ground disturbance, the grassed areas will restore naturally, and require minimal seeding.

Slip Dredging – One or more disassembled hydraulic dredge plants will be transported to the slip site by truck. The hydraulic dredge plants may be in the 18-inch to 24-inch size range, since this is the maximum size range for transportability and the minimum size range capable of dredging to an elevation of minus 45 feet NAVD88. The plants will be assembled on site and lifted by crane into the dredge launch pond. A hydraulic transport pipeline will connect the dredge(s) to the South Dunes site and a decant water return pipeline will return the water to the dredge pocket (see detailed description above).

The hydraulic dredges, capable of transporting a slurry of 30 percent solids by weight at a flow rate of 6,000 gpm or greater will create an ever increasing dredge prism that will, in the end, create the fully defined slip within the confines of the berm. The hydraulic dredges are capable of dredging to the final slip depth of minus 45 feet NAVD88, while creating side slopes for the slip at a ratio of 3H:1V where the Open Cell® Sheet piling is not used. Dredging of the slip prism will be conducted outside of the normal Coos Bay dredging window because the slip will be isolated from the waters of Coos Bay by the berm.

Driving of Piling for Marine Structures – All of the mooring dolphins will be constructed "in-the-dry" and as such piles can be driven prior to or concurrent with the dredging of the slip. Land based mobile cranes with pile driving equipment will be located on the land-side of the Open Cell® Sheet Pile walls. All piles required for the LNG loading structure as well as for all of the mooring dolphins will be driven on dry land and no open water pile driving will be required.

Slope Armoring – The northern slip face will be armored. The south slip face created by the berm will remain unarmored as it will be removed during Phase 2 to create the final configuration of the slip and the access channel. The sequence for pile driving, slope dressing and armoring may vary depending upon the means and methods chosen by the contractor performing the work.

**Phase 2 Construction Details**

Breaching and Removing the Berm – Once all Phase 1 construction is complete, work will begin on breaching and removing the berm (500,000 cy) and the remaining area of the slip. Dredging may be conducted from both the Coos Bay side and the slip side to reduce the duration of the breaching and removal activity. Material removed by the hydraulic dredges will be used to rebuild the dune between the eastern edge of the slip and the Roseburg property (area E4 on figure 1.2-1). During construction, this dune area will be graded to allow the hauling of heavy pieces of equipment from the construction dock to the Project site. Once the heavy hauling is completed, this haul route will no longer be needed and the former dune area will be restored. The material to restore the dune area will be hydraulically conveyed to this area where a series of settling ponds will be used to decant the dredged material with the water ultimately being discharged into the slip once all turbidity has settled.

Final Contouring and Slope Armoring – Removing the berm will open the slip to Coos Bay. Additional dredging to contour the access channel will complete the construction dredging activities. Armoring of the remaining unarmored slip side slopes will be completed. Although not anticipated, any additional in-water structures required to complete the slip and associated in-water structures will be installed. In-water work will be performed during the allowable construction window between October 1 and February 15.

Dredging Access Channel – The access channel connecting the slip to the Coos Bay Navigation Channel will be dredged either before or after the berm is removed. This work, along with all in-water removal activities performed from the Coos Bay (southerly) side of the berm will be performed during an allowable in-water construction window between October 1 and February 15.

Restoration – Following the dredging activities, all disturbed areas, including exposed slopes will be stabilized with a seed mixture specified by the Natural Resources Conservation Service

(NRCS) as being capable of surviving in highly permeable, xeric regimes, binding loose sand, and withstanding burial and deflation from aeolian processes. Native species will be used and if any non-native species are required for specific problem areas, species will be selected that will not become nuisance species to the surrounding areas. The slurry and decant water return pipelines will be removed as described above. The portion of the excavated material haul truck and the slurry and decant water return pipelines route on the east side of Jordan Cove Road will become part of the access/utility corridor. The excavated material haul road on the west side of Jordan Cove Road will also become part of the access/utility corridor. As such, no areas disturbed by the excavated material haul truck road and pipelines will require restoration. However, should there be any areas disturbed by the haul truck or pipelines route that do not become part of the access/utility corridor, they will be restored to pre-construction condition.

The slurry/decant water return pipelines route on the developed Roseburg property will not require restoration as the pipelines will be placed on areas that are graveled, concrete, or rip-rapped. Should there be any areas of the route where ground disturbance occurs, these areas will be returned to pre-construction conditions.

**LNG Carrier Loading Facilities**

The LNG carrier loading facilities will be constructed once the eastern side of the slip is formed using the Open Cell® Sheet Pile Technology. All of the loading facilities will be on the shore side of the slip, with no facilities located in the water of the slip. The platform with the loading arms (inclusive of the loading and vapor return arms) will be constructed on a concrete pad located at the edge of the slip. The foundation of the pad will contain a number of piles that will be tied into the concrete pad to provide a stable foundation for the breasting dolphins and the loading arm platform. Separate piles will be driven for the breasting dolphin and the loading arm platform. The loading arm platform will be constructed on columns raised from the concrete pad and accessed through stairways. The LNG transfer piping will be located over LNG troughs that will contain any spills and divert the LNG to a containment basin.

The LNG carrier loading facilities will be constructed using land based equipment to install the required structural elements for the loading platform and mooring dolphins. Actual installation of berth piping and equipment, and hookup and commissioning of the loading system, and utilities will follow.

### 3.1.2.2 Operations and Maintenance – Marine Facilities

**Maintenance Dredging**

The COE would be responsible for maintenance dredging of the Coos Bay navigation channel, and the Port would be responsible for maintenance dredging of the access channel and slip at the LNG terminal.

The volume of maintenance dredged material from the slip and access channel was preliminarily estimated to be approximately 350,000 cy every two years. At the time that the original estimate was developed, there was limited information on coastal geomorphological changes for Coos Bay. Once additional information was available, Jordan Cove requested Coast and Harbor Engineering (C&H) to review the previous modeling predictions and update the modeling. The studies described in DRAFT Volume 1 of the C&H Technical Report determined that the bottom slope of the navigation channel reach adjacent to the LNG Terminal was getting deeper on the north side, mostly due to the meandering of the thalweg of the tidal channel. The bottom deepening would progressively reduce the depth differences between the natural bottom slope and the dredging cut, minimizing trapping effects for sediment transport. This implies that sedimentation rates in the terminal area and the access channel would reduce in time with progression of natural bottom deepening.

In DRAFT Volume 3 of the C&H Technical Report, C&H determined (and or reviewed previous predictions of) sedimentation rates in the LNG Terminal slip area and in the access channel for the current geomorphologic conditions and extrapolated the predictions to the future, accounting for long-term geomorphologic trends. Once long-term sedimentation rates were estimated, maintenance dredging requirements, including dredging volumes and schedules were developed. Sedimentation rates in areas of the LNG Terminal slip were estimated using a combination of three methods: prototype analysis, empirical methods, and numerical modeling. Based on evaluation of all different estimates, the design sedimentation rate for the LNG Terminal slip and the access channel dredging are 0.16 feet per year and 0.56 feet per year, respectively. This translates to approximately 8,500 cy per year and 29,200 cy per year, respectively.

Sedimentation and maintenance dredging requirements would likely be reduced at the access channel area over time due to natural stabilization and adjustment processes. Predicted volumes for maintenance dredging in the access channel are 26,100 cy per year after 10 years, 21,900 cy per year after 25 years, and 14,800 cy per year after 50 years.

Approximately 37,700 cy is the total maintenance dredging volume expected at year 1 and 34,600 cy is the total maintenance dredging volume expected at year 10. In the first 10 years, an approximate total of 360,000 cy would be removed and in the next 10 years approximately 330,000 cy would be removed for an approximate total of 690,000 cy in comparison to the earlier prediction of 1.75 million cy. This is a substantial reduction in volume which in turn will reduce the demand for disposal space.

The original estimate for the frequency of dredging was every two years. Now, with the additional information from the modeling, the recommended future maintenance dredging requirements are approximately 115,000 cy would need to be dredged every 3 years for the first 9-12 years (10 years approximately) and after 10 years it would be safe to reduce the volume of dredging to some values in the range of 115,000 to 160,000 cy for a frequency of 5 years between dredging events.

With the exception of the material from the maintenance dredging, all 5.6 million cy will be used beneficially by the Project in raising both the LNG Terminal site and the South Dunes site to elevations above the tsunami inundation zone. A total of 1.9 million cy will be placed on the LNG Terminal site while the remaining 3.7 million cy will be placed on the South Dunes site.

The 37,700 cy of material per year from the maintenance dredging will be placed in the Coos Bay Site F (figure 3.1-1) as is current maintenance dredge practice. On the basis of detailed sediment transport modeling conducted in Coos Bay, it was determined that the material to be removed during maintenance dredging is largely the same material that is currently removed during the existing every two year maintenance dredging of the navigation channel. Due to the development of the slip, the material that is currently removed during maintenance dredging will now collect in the slip due to the hydraulics of the bay system as modeled. The model demonstrated that over time the amount of material to be removed will gradually decrease. A copy of DRAFT Volume 3 of the C&H Technical Report was provided to FERC as Appendix E.1 to Jordan Cove's Resource Report 1, submitted as part of the FERC Certificate application.

Future maintenance dredging of the slip and access channel would be conducted using a suction dredge, which consists of two suction arms that are dragged along the area to be dredged. The COE ship Yaquina is the dredge most likely to be used as it is currently used along the northwest coast to maintain the harbor entrances. The maintenance dredging would be combined with other COE existing maintenance dredging in the Port.

The material removed by suction arms would be deposited in a hopper in the center of the ship. Once the hopper is full, the ship would sail out to the Site F disposal site and dump the dredged material. Site F is approximately 9 nautical miles from the LNG terminal. Conservation measures (see appendix N) would be followed to reduce the potential for water quality effects from suction dredging and disposal activities on sensitive or listed fish and wildlife species. No dewatering of dredge material would occur in Coos Bay.

<u>Coos Bay Site F</u>

Coos Bay Site F is located in the Pacific Ocean, about 1.75 miles north-northwest of the north jetty at the mouth of Coos Bay (figure 3.1-1). The site is owned by the State of Oregon out to the 3-mile territorial limit, and the remainder by the COE. This is an existing EPA-approved offshore placement site, used by the COE since 1986 to dispose of materials dredged during maintenance of the Coos Bay navigation channel, in accordance with section 103 of the Marine Protection, Research, and Sanctuary Act (MPRSA). The site was expanded in 1989, 1995, and 2006, so that it now encompasses about 3,075 acres, with water depths ranging from 20 to 160 feet. The COE has indicated to the Port that this site has the capacity to take in the operational maintenance dredging of the LNG terminal access channel and slip. Dumping of the Jordan Cove LNG terminal maintenance dredge material would occur during in-water work windows established by the ODFW.

A more detailed description of the proposed use of offshore disposal Site F is provided in Moffatt and Nichol (2007). Site F has had all NEPA analyses and consultations completed prior to the last round of expansions.

The EPA has expressed concerns about the use of Site F by the Port to deposit materials dredged during maintenance of the Jordan Cove LNG terminal access channel and slip.[5] In particular, EPA is concerned that the capacity of Site F may be impacted by the disposal of maintenance dredged materials from the Jordan Cove terminal. EPA recommended that Jordan Cove's proposed Maintenance Dredging Plan be consistent with the Site Management and Monitoring Plan developed by the COE. Further, EPA recommended that a hopper dredge with multiple bottom dump doors be utilized whenever feasible. Jordan Cove's export proposal includes substantially less maintenance dredging than the proposal on which the EPA commented.

#### 3.1.2.3 Future Plans and Abandonment – Marine Facilities

Jordan Cove understands that the Port is considering potential future development plans for the uplands it controls adjacent to the west side of the slip. According to David Koch, the Chief Executive Officer of the Port, the Port is pursuing multiple marine terminal development projects

[5] See letter from Richard Parkin, Acting Director of the Office of Ecoysystem, Tribal and Public Affairs of EPA Region 10 to Kimberly Bose, Secretary of the FERC, dated June 8, 2009.

along the North Spit of lower Coos Bay, referred to collectively as the Oregon Gateway Marine Terminal complex. While the Jordan Cove LNG Terminal Project will utilize the Oregon Gateway vessel slip east berth, the Port is pursuing long-term development of a General Purpose Cargo Terminal for the west berth, with access to freight rail and the regional highway system. Port planning activities envision a versatile facility better able to capitalize on market shifts and adaptable for the import and export of a variety of commodities. Potential uses of the west berth include movement of dry bulk and break-bulk cargoes, in addition to serving as a staging, assembly and deployment area for offshore wind energy platforms.

Potential projects that might be located on the North Spit in the future would need a deeper and wider navigation channel. In July 2007, the Port and the U.S. Army Corps of Engineers (USACE) entered into an agreement under Section 203 of the Rivers and Harbors Act of 1899 to study the deepening and widening of the channel to accommodate future generations of container ships. The activities conducted to date include detailed technical studies that analyzed a range of alternatives, including a study to characterize the affected environmental resources and the environmental consequences of each alternative, engineering studies to develop preliminary design and cost estimates for each alternative, and an economic benefit cost analysis, which is a Section 203 requirement to determine which alternatives would result in economic benefits to the nation.

At this time, no commitment has been made by any company to locate on the North Spit, and no letter of intent or other agreements to occupy the site have been signed. No environmental studies have begun or been planned or scoped for such projects other than the Section 203 review. For this reason, there is no berth proposed along the west side of the slip. Instead, a berm will be constructed between the edge of the slip and Henderson Marsh. This berm will effectively preclude any immediate development of the west side of the slip. In addition, Jordan Cove will enter into an exclusive lease with the Port for the water surface on the west side of the slip effectively requiring any project developer to seek permission from Jordan Cove for any use of the west side of the slip. No request for such a use has been received by Jordan Cove to date. In sum, there are no Oregon Gateway Marine Terminal or other facilities that can be considered "reasonably expected" to locate on the North Spit.

Under the sell back, long term lease agreement that Jordan Cove will enter into with the Port, Jordan Cove will remove the LNG component facilities and return the site to a clear and level condition. Jordan Cove is required to provide sufficient surety to cover the estimated cost of this termination provision.

Both the expansion and abandonment of the LNG terminal facilities are speculative, and are not part of the proposed action. Consequently, there are no activities related to the expansion or abandonment of the Port component that would affect threatened or endangered species addressed in this BA. If Jordan Cove decided to expand or abandon the LNG terminal, it must seek authorization for those actions in a new application with the FERC, and this would be considered a new undertaking, requiring separate consultations under the ESA.

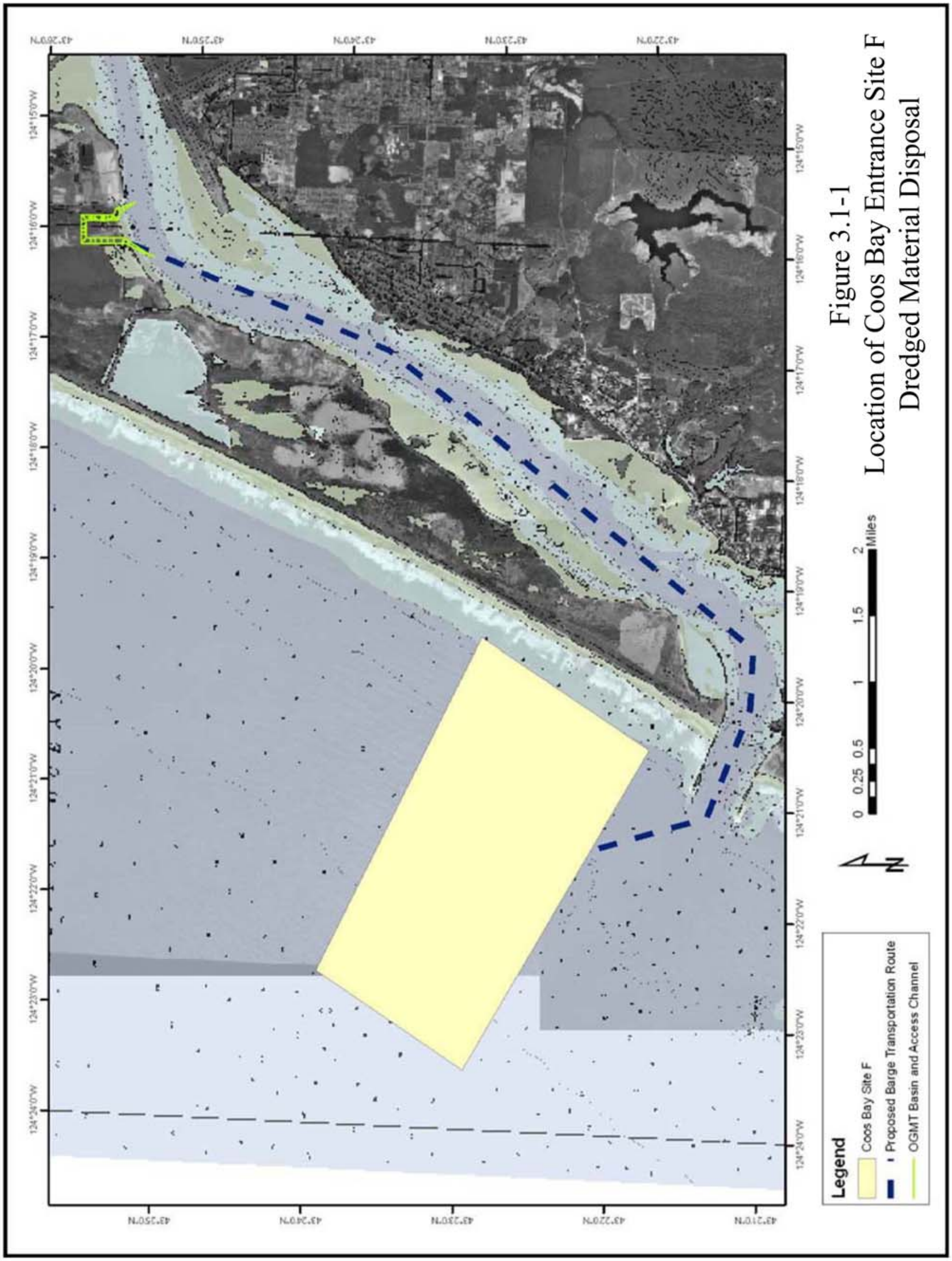



Figure 3.1-1
Location of Coos Bay Entrance Site F
Dredged Material Disposal

### 3.1.3 Jordan Cove LNG Terminal

Jordan Cove would construct its LNG terminal facilities in accordance with its project-specific Upland Erosion Control, Revegetation, and Maintenance Plan (Jordan Cove's Plan) and Wetland and Waterbody Construction and Mitigation Procedures (Jordan Cove's Procedures). Jordan Cove's Plan and Procedures are modified from the FERC staff's Upland Erosion Control, Revegetation, and Maintenance Plan (FERC staff's Plan, May 2013 Version), and our Wetland and Waterbody Construction and Mitigation Procedures (FERC staff's Procedures, May 2013 Version, see appendix C to this BA/EFH Assessment). The intent of the FERC staff's Plan and Procedures is to assist applicants by identifying baseline mitigation measures for minimizing the extent and duration of disturbances on soils, wetlands, and waterbodies associated with projects under the FERC's jurisdiction throughout the country. As general guidelines, the FERC staff's Plan and Procedures may be less stringent than state and local guidelines that are based on state or local concerns, issues, and/or regulations. Most of Jordan Cove's modifications to the FERC staff's Plan and Procedures relate to measures that apply to linear pipeline construction that would not be applicable to the project- and site-specific conditions at the LNG terminal.

Jordan Cove submitted a preliminary draft Spill Prevention, Control, and Countermeasure Plan (SPCCP) with its application to the FERC (see forthcoming EIS). Also included with its application to the FERC (included with Appendix I.2 of Resource Report 2 – Water Use and Quality), was a preliminary Erosion and Sediment Control Plan (ESCP) that was part of Jordan Cove's application for a stormwater general permit from the ODEQ.

#### 3.1.3.1 Construction of LNG Terminal Facilities

The LNG terminal facilities that would be constructed include the following:

- A pipeline gas conditioning facility consisting of two feed gas cleaning and dehydration trains with a combined natural gas throughput of approximately 1 Bscf/d;
- Four natural gas liquefaction trains, each with the export capacity of 1.5 MMTPA;
- A refrigerant storage and resupply system;
- An Aerial Cooling System (Fin-Fan);
- An LNG storage system consisting of two full-containment LNG storage tanks, each with a net capacity of 160,000 $m^3$ (1,006,000 barrels), and each equipped with three fully submerged LNG in-tank pumps sized for approximately 11,600 gallons per minute (gpm) each;
- An LNG transfer line consisting of one 2,300-foot-long, 36-inch-diameter line that will connect the shore based storage system with the LNG loading system;
- An LNG carrier cargo loading system designed to load LNG at a rate of 10,000 $m^3$ per hour ($m^3$/hr) with a peak capacity of 12,000 $m^3$/hr, consisting of three 16-inch loading arms and one 16-inch vapor return arm;
- A protected LNG carrier loading berth constructed on an Open Cell® technology sheet pile slip wall and capable of accommodating LNG carriers with a range of capacities;
- The improvement of an existing, on-site unimproved road and utility corridor to become the primary roadway and utility interconnection between the LNG Terminal and South Dunes sites, including between the pipeline gas conditioning units on the South Dunes Power Plant site and the liquefaction trains on the LNG Terminal site;

- Within the utility corridor, a proposed transmission line is designed for two bottom 13.8 kV conductors (one on each side of a pole), a 115 kV double circuit with six phase conductors (three on a side), and two top shield or static wires, one on each side extending for 6,370 feet between the South Dunes Power Plant and the LNG Terminal, using single poles between 76 and 111 feet tall, depending on terrain elevation;
- A boil off gas (BOG) recovery system used to control the pressure in the LNG storage tanks;
- Electrical, nitrogen, fuel gas, lighting, instrument/plant air and service water facility systems;
- An emergency vent system (ground flare);
- An LNG spill containment system, a fire water system and various other hazard detection, control, and prevention systems; and
- Utilities, buildings and support facilities.

The following facility, although not jurisdictional to FERC, will also be constructed to support the Project:

- The South Dunes Power Plant, a 420 megawatt (MW) natural gas fired combined-cycle electric power plant inclusive of heat recovery steam generator (HRSG) units for the purpose of powering the refrigeration systems in the natural gas liquefaction process and supplying steam to the conditioning units.

A more detailed description of the components of Jordan Cove's LNG terminal will be found in the forthcoming EIS. All facilities and components would be constructed in accordance with governing regulations, including 33 CFR Part 127 for the marine facilities, 49 CFR Part 193, and National Fire Protection Association (NFPA) Standard 59A for LNG facilities and the codes and standards referenced therein. A summary of the land areas affected by the construction and operation of the various LNG terminal facilities is provided in table 3.1.3.1-1 and shown on figure 1.2-1.

Final transportation to the Project site will be undertaken by road, rail, and possibly marine transport. An existing rail line is located adjacent to the Project site. The kinds of materials and the mode of delivery to the site will depend on the origin, size, and weight of the material. It is anticipated that the larger and heavier pieces of equipment will arrive by marine transport.

Jordan Cove is reviewing the transportation of the large pieces of equipment and is proposing to develop a temporary construction dock to be used for material or equipment shipment during construction. This construction dock will be placed at the eastern corner of the slip utilizing the area dredged for the slip and access channel and the berth area behind the Open Cell® sheet pile walls as the dock surface. Heavy equipment haul roads will be constructed from the construction dock face to the process area of the site and to the South Dunes site.

Jordan Cove further envisions some bulk materials, such as insulation, will be shipped in standardized containers. Fabrication shops will be used to fabricate pipe spool pieces and other prefabricated units of equipment and skid mounted process equipment modules with delivery to the site in accordance with the construction schedule. Where practical, skid mounted equipment will be used to minimize the pieces that must be delivered and installed at the site.

TABLE 3.1.3.1-1

**Total Project Land Requirements for Construction and Operation of the LNG Terminal and Port Slip**

| Facility | Area (acres) | Temporarily Affected by Construction (acres) | Permanently Affected by Operation (acres) |
|---|---|---|---|
| Terminal Site Access | 3.9 | 3.9 | 3.9 |
| Refrigerant Storage Area | 1.9 | 1.9 | 1.9 |
| Marine Access/Pipeway | 8.8 | 8.8 | 8.8 |
| Liquefaction Process Area | 20.2 | 20.2 | 20.2 |
| Laydown Area | 21.3 | 21.3 | 0.0 |
| LNG Tank Area | 27.3 | 27.3 | 27.3 |
| Firewater Ponds | 3.7 | 3.7 | 3.7 |
| Flare Area | 1.0 | 1.0 | 1.0 |
| Construction Dock | 2.9 | 2.9 | 2.9 |
| Gas Process Area | 9.0 | 9.0 | 9.0 |
| Gas Processing Area (Shared Jurisdiction between FERC and EFSC) | 4.3 | 4.3 | 4.3 |
| Laydown Area | 3.8 | 3.8 | 0.0 |
| Stormwater Pond/Laydown | 11.1 | 11.1 | 11.1 |
| PCGP Meter Station | 0.85 | 0.85 | 0.85 |
| Slip and Access Channel | 66.0 | 66.0 | 66.0 |
| Access/Utility Corridor | 10.9 | 10.9 | 10.9 |
| Control Builidng/Plant Warehouse/Maintenance Building | 8.1 | 8.1 | 8.1 |
| Sand Dune Area | 6.5 | 6.5 | 0.0 |
| LNG Loading Berth Dune | 15.0 | 15.0 | 0.0 |
| Industrial Wastewater Pipeline Relocation | 12.8 | 12.8 | 4.7 |
| Water/Raw Water Line | 2.5 | 2.5 | 1.1 |
| Undisturbed Areas | 45.4 | 0.0 | 0.0 |
| Temporary Construction Areas | 89.4 | 89.4 | 0.0 |
| South Dunes Power Plant | 57.5 | 57.5 | 57.5 |
| Southwest Oregon Regional Safety Center | 8.2 | 8.2 | 8.2 |

The existing rail line has been acquired by the Port and is now called the Coos Bay Rail Link (CBR) with the majority of the necessary repairs and upgrades completed. The other improvements, repairs and additions along the rail line route have been completed and the rail line is suitable for delivery of materials to the Project.

## Construction Activities

Construction site preparation will require clearing, filling and grading of the site to an approximate elevation of +30 feet for the base of the LNG storage tank area and approximately +46 feet for the process areas. Temporary ditches, sediment fences and silt traps will be installed as necessary. Individual excavations will then be made for equipment foundations. Following completion of foundations, the site will be brought up to final grade. Final grading and landscaping will consist of gravel surfaced areas, asphalt surfaced areas, concrete paved surfaces, grass areas, and construction of the storm surge barrier.

Grading of the areas to be occupied by the Project facilities will entail approximately 2.5 million cy of cut and fill. Any material remaining from that work, including final grading and landscaping, will be used to raise the South Dunes site utilized for the pipeline gas conditioning facility and raise the access/utility corridor between the LNG Terminal and the South Dunes site. Approximately 3.5 million cy of material will be available for the South Dunes site and access/utility corridor to raise the existing elevation to approximately +46 to +48 feet. The material available to raise the elevation of these areas will come from the excavation of the slip and access channel. In light of the fill requirements for the South Dunes site and the access/utility corridor, there is no longer a need to place material excavated and dredged from the slip and access channel at the Port Commercial Stockpile Site or the Jordan Cove Placement area or to have a hydraulic slurry pipeline to the Port Commercial Stockpile Site (and accordingly no need to consider potential environmental effects associated with these now superseded plans).

The foundations for all equipment and structures, including the LNG storage tanks, process equipment, and pipe racks, will be mat type. Foundations for all critical process equipment and structures located outside of the storm surge barrier will be installed at an elevation of +46 feet.

Construction of the LNG storage tanks would be the most time-consuming element in the development of the LNG terminal. General steps taken during construction of each LNG storage tank would include installation of the foundations and tank bottom slab, construction of the outer concrete container wall, insertion of the bottom carbon steel vapor liner, construction of the steel dome roof and suspended deck, installation of the 9 percent nickel steel inner tank, installation of the internal tank accessories (pump columns, instrumentation, and piping), installation of external tank accessories, installation of insulation, and installation of LNG pumps. Following a successful inner container hydrotest (see below), the tank would be washed down and cleaned. After installation of the LNG pumps, the tank would be closed and purged with nitrogen to a positive gauge pressure. At this point in the construction process, the tank would be ready for cooldown with LNG.

The Roseburg chip terminal currently uses two one-million-gallon water tanks supplied from wells to charge their firewater system. Both of these obsolete tanks will be decommissioned once the Project is placed in-service. In order to maintain the water supply to the Roseburg Fire Water System, a new 12-inch-diameter tap from the existing Coos Bay North Bend Water Board (CBNBWB) water line will be made and connected to the Roseburg fire water system.

The inner container of the LNG storage tanks will be hydraulically tested (hydrotested) in accordance with the requirements of API 620. The hydrotest water source will be potable and raw water from the existing CBNBWB water lines. The potable water line runs along Trans-Pacific Parkway from the point that is crosses under Coos Bay. The raw water line runs along Trans-Pacific Parkway from the South Dunes site to the CBNBWB North Spit treatment plant located one-mile west of Ingram Yard.

The CBNBWB has indicated that it has the capability to provide the necessary quantities of water from its water supply system consisting of wells and reservoirs (Appendix A.2 of Resource Report 2 - Water Quality and Use). The existing 12-inch potable water line has the necessary pressure and capacity to deliver 20 million gallons over a two to three week period during the months of September through May and a three to four week period during the months of June through August.

The approximate 5.3 million gallon fire water pond will be filled with water from the CBNBWB potable water line. For the hydrotesting of the LNG storage tanks, water will be supplied from three sources to fill the tanks at a rate of approximately 2,000 gallons per minute (gpm). The water will be withdrawn from the firewater pond, the raw water line, and the potable water line. Water withdrawn from either the raw water line or the potable water line will be limited to 1,000 gpm so as not to put undue strain on the CBNBWB line. It will take approximately 10 days to fill the first tank with the 28 million gallons required for the hydrotest. No biocides or chemicals will be added to the hydrostatic test water, since it is essentially potable water that has already been treated by the CBNBWB and the raw water meets all hydrotest specifications without treatment or additives.

In advance of filling the tanks, the hydrotest water source will be tested to ensure that the water will meet all applicable code requirements. If the construction sequence allows, the two tanks will be hydrotested with the same water by transferring the water at the conclusion of the hydrotesting of one tank to the other tank. Water will be introduced into the inner tank container through a manhole in the outer container concrete roof at a rate that will not exceed the limitations specified in API 620. The duration that the water remains in the tanks will be strictly controlled, therefore it is not expected that any contamination or discoloration will be present on discharge. However, the water will be tested to confirm composition prior to the water being discharged from the tank. In each case the small amount of water that remains in the tank after the bulk transfer/emptying operation has taken place will be treated as appropriate to meet discharge water quality criteria prior to discharge.

The quantity of water required for hydrotesting one tank is estimated to be approximately 28 million gallons. If the construction sequence allows, the tanks will be tested in succession. The water will be transferred to the next tank, once the testing of the previous tank is completed. Due to the inability to transfer the residual heel in each tank at the conclusion of the hydrotest, it is estimated that approximately 0.25 million gallons of additional water will be required for testing the second tank. Therefore, the total required volume of hydrotest water is estimated to be 28.25 million gallons. The total duration of the hydrotest of the first tank from start of filling to emptying is expected to be approximately 34 days, with the second tank taking approximately three weeks.

On completion of hydrotesting, the water will be pumped from inside the inner tank using electrically driven submersible pumps suitably sized for the required lift height out of the tank as there are no bottom or side outlets on the LNG tanks. The temporary piping used to initially fill and transfer water between the tanks will be modified to enable the water to be pumped to the point of disposal. The planned discharge point of the hydrotest water is the firewater pond. The rate of discharge is expected to be approximately 1.8 million gallons per day (mgd) for the bulk pumping operation with substantially lower rates being achieved when removing the final amounts of water from the tank bottom. From the firewater pond, the hydrotest water will be discharged into the industrial wastewater pipeline via an overflow, which connects to a previously existing, permitted ocean discharge. Approximately five of the 28.25 million gallons used to hydrotest the LNG storage tanks will be retained in the fire water pond, effectively using that quantity of water a second time and reducing the amount of water required from the CBNBWB.

**Construction Workers and Traffic**

Jordan Cove, together with its contractors Kiewit and Black & Veatch, conducted a modularization exercise to identify the optimal number of workers for each specific construction phase of the Project in an effort to minimize the potential effects from a large influx of construction workers into the Project area. Current estimates of the total construction staffing on the LNG Terminal and South Dunes sites have been built from the bottom up, craft by craft, over the 42-month construction period commencing in October 2014. Underlying the new estimates is a 50-hour, rather than a 40-hour, workweek, a change that reduces total staffing numbers and makes Project jobs more attractive to skilled workers seeking to maximize their paychecks. The result is an anticipated total workforce that will range from 100 to 300 in the first year, ramp up slowly in the second year, climb more steeply in the third year, reach a peak level construction workforce in month 30 of approximately 2,100 personnel that will be sustained about four months before dropping down gradually for the remainder of the construction period. This results in an average workforce for the duration of the 42-month construction period of approximately 900 personnel and a construction-period total of 8.3 million man-hours.

Applying the ECONorthwest analysis to the total peak workforce of 2,937 (the sum of the current peak construction workforce estimate for the Project of 2100 and the estimated average pipeline workforce of 837), at the peak in months 30-33, the Project would employ about 1,076 local residents and a total of 1,862 itinerant workers: 1,156 from Oregon and Washington and 705 from elsewhere.

Access for transporting equipment, materials, and personnel to the Project site will be provided by existing roads. Access to the LNG Terminal will be provided by the Trans-Pacific Parkway which interconnects with US 101. Site traffic originating from the south will pass through the intersection of US 101 and the Trans-Pacific Parkway. US 101 connects to Interstate 5 through Highway 38 in Reedsport to the north or through Highway 42 to the south.

Construction supervisor parking and equipment storage will be provided in the temporary construction areas located on the Roseburg Forest Products Company wood chip facility site adjacent to the LNG Terminal site. It is estimated that an average of 75 vehicle trips will be made per day over the 42-month construction period for these personnel. Construction worker parking is proposed for several off-site locations, all of which would have the capability for worker transport to the Project site by bus or rail. The potential off-site areas are existing paved areas suitable for parking and include the proposed worker camp on the south end of the McCullough Bridge, the Mill Casino parking lot located to the north of the existing RV Park, and possibly some areas to the north of the McCullough Bridge where there are existing paved parking areas.

Material deliveries to the site will occur throughout the 42-month construction phase, peaking in months 21-24. The use of an onsite concrete batch plant will lessen the traffic and congestion impacts on the local infrastructure, with deliveries of bulk materials required only for the production of the necessary concrete required for the facility. The site can anticipate, on average, 21 material deliveries per day throughout the construction period.

The land based deliveries to the Project will be scheduled to typically occur outside the peak traffic periods, if possible, and will not affect existing traffic. A traffic survey addressing the key intersections and access routes to the Project site for the construction traffic (workers and deliveries) was conducted.

The traffic impact analysis, which addressed the key intersections and access routes to the Project site for the construction traffic (workers and deliveries) included several recommendations to ensure that the roads and intersections in the Project site areas remain at an acceptable level of service. The recommendations included:

- Temporary signalization of US 101/Trans-Pacific Parkway;
- Manual flagging control at Trans-Pacific Parkway/Horsfall Beach Road;
- Temporary speed reduction on US 101 in the vicinity of Trans-Pacific Parkway;

- Staggered work shift start and end times (e.g., 6:20 AM to 4:50 PM, 7:00 AM to 5:30 PM, and 7:40 AM to 6:10 PM) allowing the arrivals and departures to be spread over a two hour interval in both the morning and afternoon peak periods;
- Construction of a dedicated southbound left-turn lane at US 101/East Bay Drive; and
- Other possible safety enhancements, subject to approval by the Oregon Department of Transportation (ODOT), such as the installation of "Congestion Ahead" signs on US 101 in advance of the Trans-Pacific Parkway intersection.

ODOT has reviewed these recommendations and has agreed in principal but also believes that if major schedule changes take place that these measures may not be enough. Conversely if different construction techniques or scheduling are imposed, not all the mitigation may be necessary. ODOT in its review of the study, lists the following mitigations offered in the study that will become part of the agreement between Jordan Cove, the county, and state.

- Three staggered work shifts with both start and end times that distribute the arriving and departing traffic throughout a two-hour period;
- Manual flagging control at Trans-Pacific Parkway/Horsfall Beach Road during weekday PM peak hour whenever construction employees are at or above 1,700 people per day;
- Construction of a dedicated eastbound right-turn lane at the intersection of US 101 at Trans-Pacific Parkway;
- Temporary signalization of US 101 at Trans-Pacific Parkway;
- Temporary variable speed reduction on US 101 in the vicinity of Trans-Pacific Parkway; and
- Use of a Visual Management System (VMS) to notify motorists of peak period traffic conditions or traffic control change at US 101/Trans-Pacific Parkway.

The conclusion of the traffic impact analysis for the operational phase of the Project was that once regular operations of the LNG Terminal begin, traffic generated by the Project will be very low and will have little impact on traffic operations in the area.

#### 3.1.3.2 Operations and Maintenance – LNG Terminal

#### LNG Carrier Operations at the Berth

If the LNG Terminal operates at LNG production design capacity of approximately six MMTPA (0.8 Bscf/d of natural gas) for the entire year, a total of 90 vessel calls (assuming on average 148,000 $m^3$ vessels) will be needed to export the LNG from the LNG Terminal. These shipments would, of necessity, need to be scheduled for ratable delivery with one 148,000 $m^3$ vessel (carrying the equivalent of 3.4 billion cubic feet of natural gas) departing every four days. Each LNG vessel will discharge approximately 9.2 million gallons of ballast water during the loading cycle to compensate for 50 percent of the mass of LNG cargo loaded.

LNG ships will discharge ballast concurrently with the LNG cargo loading. The amount of ballast water discharged must, at a minimum, be adequate to maintain the LNG ship in a positive stability condition and with an adequate operating draft while the LNG cargo is loaded. The ballast water discharged will be that from 200 miles out in the open sea as occurred as part of the mandated ballast water exchange (BWE) process.

Typically, the amount of ballast water discharged by the LNG ship at the berth will be approximately 50 percent of the weight of the LNG loaded. One cubic meter of LNG is 0.46 metric tonnes (mt), which for the maximum size of LNG carrier authorized to call on the LNG Terminal (148,000 $m^3$) would be 68,080 mt of LNG per ship. Assuming one metric tonne of seawater is 1.027 $m^3$, the amount of seawater ballast discharged (50 percent of the weight of the LNG loaded) would be approximately 34,959 $m^3$ (approximately 9.2 million gallons). In the event that a 217,000 $m^3$ ship is used, the amount of water discharged would be on the order of 12.9 million gallons.

The LNG loading rate is designed to be 10,000 $m^3$/hr (with a peak capacity of 12,000 $m^3$/hr), or 4,600 meters per hour (mt/hr) (5,520 mt/hr peak), consequently the ballast water discharge rate would be approximately 20,250 gpm. The typical LNG ship has an upper and a lower ballast water discharge on each side of the hull, referred to as sea chests. The lower unit is just above the keel of the ship, approximately 10 meters (33 feet) below the water line. Typical LNG ships also have three ballast water pumps, each capable of 3,000 $m^3$/hr (13,210 gpm) rated capacity.

The ballast water discharge port or sea chest is approximately 3.5 to 4.2 square meters covered by a screen with 4.5 mm bars, spaced every 20-25 mm. The discharge velocities for the ballast water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be adversely affected by the ballast discharge. Some smaller organisms may be temporarily displaced by the discharge flow, but the displacement should be insignificant in the confines of the slip.

Ballast water that is likely to be introduced into the slip at the LNG Terminal will be composed mainly of open ocean water retrieved during BWE activities during trans-ocean shipping (200 miles off shore). The physio-chemical composition of this water would be very similar to that which occurs within Coos Bay and the slip depending on hydrologic conditions.

Seawater on average, in the world's oceans has a salinity of about 3.5 percent. This means that every kilogram, or every liter, of seawater has approximately 35 grams (1.2 ounces) of dissolved salts (mostly, but not entirely, the ions of sodium chloride. The average density of seawater at the ocean surface is 1.025 grams per milliliter (g/ml); seawater is denser than freshwater (which reaches a maximum density of 1.000 g/ml at a temperature of four degrees Celsius (°C) (39 °F)) because of the salt’s added mass. Although the vast majority of seawater has a salinity of between 3.1 percent and 3.8 percent, seawater is not uniformly saline throughout the world. Where mixing occurs with fresh water runoff from river mouths or near melting glaciers, seawater can be substantially less saline.

A potentially notable difference that may be observed in water quality could be salinity. Since the LNG Terminal is approximately seven miles from the open Pacific Ocean, potential differences in salinity may not be perceptible. The issue of a potential salt wedge up into the Coos and Millicoma Rivers has been raised. The findings of the sampling conducted by OIMB in the bay indicated a wide range in physical oceanographic data (including salinity) between seasons and tidal cycles and the modeling conducted by C&H predicted that there would be imperceptible changes in the tidal velocities, etc. due to construction and operation. The results of the modeling also concluded that the potential changes would be less significant than the naturally occurring changes and, as such, there is no predicted perceptible change to the existing conditions that would occur as a result of the construction and operation.

Another physio-chemical water quality parameter that may be influenced by the introduction of ballast water is the dissolved oxygen level. Dissolved oxygen levels are a critical component for the respiration of aquatic marine organisms. Among many other factors, dissolved oxygen levels in water can be influenced by water temperature, water depth, phytoplankton, wind and current. All of these constituents in some way influence the amount of oxygen in the water. Typical water column profiles indicate a decrease in dissolved oxygen with an increase in depth. Some factors that often influence this stratification include sunlight attenuation for photosynthetic organisms that can produce oxygen, wind, wave, and current that results in mixing.

Water that is collected within the ballast tanks of a ship would lack many of these important influences and could suppress dissolved oxygen levels. However, ballast water that is discharged is not expected to be anoxic (i.e., lacking all oxygen), just lower than what levels would likely be at the surface. In addition, ballast water will be discharged near the bottom of the slip where dissolved oxygen levels may already be lower. Therefore no significant impacts are likely to occur as a result of discharging ocean water with potentially suppressed dissolved oxygen levels.

Water temperatures and pH are not likely to be altered as a result of introducing ballast water. Since ballast water is stored in the ship's hull below the waterline, water temperatures are not expected to deviate much from ambient temperatures of the surrounding sea water. The pH of the ballast water (reflective of open ocean conditions) may be slightly higher as compared to that of freshwater estuaries. However, this slight variation is not expected to have any impacts on existing marine organisms.

An assessment of potential impacts suggests that the primary potential impact to the slip will be a periodic influx of higher salinity seawater associated with ballast discharge. However, the amount of ballast water discharged into the system relative to Coos Bay as a whole system would represent a very minor influence on the system during each ballast water discharge event. The proposed slip design indicates that the slip, exclusive of the access channel, will create approximately 50 million cubic feet of additional water volume from land that is currently upland. The total number of gallons in the slip is approximately 374 million gallons. The discharge of 9.2 million gallons of ballast water from the 148,000 $m^3$ LNG carrier would represent 2.4 percent of the volume of the slip and in comparison to the rest of the bay is an infinitesimal percent change. Since the ballast water was collected from the Pacific Ocean, although some 200 miles from the bay, the ballast water discharged will not result in a net change.

Due to the volumes of ballast water often collected by ships, there remains the possibility of living aquatic organisms entering ballast tanks. Some of the larger macro organisms that may be collected will often die; however, some of the smaller planktonic organisms can often survive. An environmental concern associated with this procedure is the risk of introducing exotic species in coastal freshwater and marine ecosystems. Loaded with water from the surrounding ports and coastal waters throughout the world, ships can carry a diverse assemblage of marine organisms in ballast water that may be foreign and exotic to the ship's port of destination. The transfer of water from port-to-port can result in aquatic biological invasions. Invasive species threaten to outcompete and exclude native species and the overall health of an ecosystem, causing algal blooms and hypoxic conditions and affecting all trophic levels resulting in a decline in biodiversity. This concern has long been recognized and is addressed in Coast Guard Regulation Navigation and Vessel Inspection Circular 07-04, Change 1 that governs ballast water operations in US ports.

Jordan Cove will continue to require that the ballast water of all LNG carriers be discharged in accordance with Federal oversight and the regulations listed below:

- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) – established a broad federal program "to prevent introduction of and to control the spread of introduced aquatic nuisance species…The U.S. Fish and Wildlife Service, the U.S. Coast Guard, the Environmental Protection Agency, the Army Corps of Engineers, and the National Oceanic and Atmospheric Administration all were assigned … responsibilities, including membership on an Aquatic Nuisance Species Task Force…" (ANSTF, 2005). The Act can be found at: http://www.anstaskforce.gov/ Documents/nanpca90.pdf.

- National Invasive Species Act of 1996 (NISA) – reauthorizes and amends the NANPCA 1990. "Nonindigenous invasive species have become established throughout the waters of the U.S. and are causing economic and ecological degradation to the affected near shore regions." The Secretary of Transportation was charged to develop national guidelines to prevent invasive species via ballast water of commercial vessels; the primary means of which is through mid-ocean BWE, unless the exchange threatens the safety or stability of the vessel, its crew, or its passengers (NEMW, 2007). A summary of the Act can be found at: http://www.nemw.org/ nisa_summary.htm.

- National Aquatic Invasive Species Act of 2003 (NAISA) – amended in 2005 and again in 2007. The 2003 act established a mandatory National Ballast Water Management Program. The primary requirements established under NAISA are: 1) all ships operating in U.S. waters are required to have on board an Aquatic Invasive Species Management Plan, 2) the development of standards by the Coast Guard for mid-ocean BWE and BWT for vessels operating outside of the exclusive economic zone, 3) implementing the best management practices and available technology related to BWTs (NEMW, 2007). Summaries of the Acts can be found at: http://www.nemw.org/NAISA%202003%20Summary.pdf (2003); http://www.nemw.org /NAISA%202005%20Summary.pdf (2005); and http://www.nemw.org/NAISA_07_ Summary.pdf?d110:s.00725 (2007).

- National Ballast Water Management Program (BWM) – originally established by NANPCA 1990 and further amended by NISA 1996 and NAISA 2003 resulting in the ballast water management program being made mandatory and to include BWE and reporting to the Coast Guard (AAPA, 2006).

- Shipboard Technology Evaluation Program (STEP) – a program authorized under the Coast Guard's BWM. STEP is designed to facilitate the development of "effective ballast water treatment (BWT) technologies, through experimental systems, thus creating more options for vessel owners seeking alternatives to ballast water exchange." Applications to participate in the STEP program can be found on the Coast Guard website under "STEP Application Instructions," at: http://www.uscg.mil/hq/cg5/cg522/cg5224/step.asp

- Navigation and Vessel Inspection Circular 07-04, Change 1 - a program developed by the Coast Guard for the management and enforcement of ballast water discharge into U.S. ports and harbors (33 CFR Part 151, 69 FR 44952, July 28, 2004)

Jordan Cove will continue to rely upon the federal oversight and regulations that govern ballast water discharge into US waters.

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The power requirements for loading LNG in the export mode are less than those for unloading LNG in the import mode because the LNG carrier does not have to use on board LNG pumps to handle LNG cargo; hence both the LNG carrier engine requirement and the required amount of cooling water flow are reduced. The amount of cooling water to be re-circulated is a function of the propulsion system of the LNG ship and, once the LNG ship fleet has been identified, the issue of cooling water circulation requirements can be further addressed. For purposes of this analysis, typical cooling water flow rates were used. Cooling water flows while at the berth are approximately 1,300 $m^3$/hr (343,421 gallons per hour or 5,723 gpm). For a 148,000 $m^3$ ship this would total approximately 4.3 million gallons while loading LNG cargo. In the event that a 217,000 $m^3$ ship is used, the amount of water required would be on the order of six million gallons. The intake port for this cooling water is approximately the same size and at the same location as the ballast water intake port, 3.5 to 4.2 square meters covered by a screen with 4.5 mm bars, spaced every 25 mm and approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG ship. The velocity across this port is approximately 0.28 ft/sec with a temperature differential of three degrees centigrade. It is likely that some organisms that are small enough to pass through the screens covering the ship's intake port will be drawn in with the cooling water and will be lost from the population in the slip area. It is anticipated that the effect associated with the intake of cooling water will be minimal. The intake velocities for the cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be impinged on the intake screen.

**Temperature Effects**

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The engines will be running to provide power for standard hotelling activities as well as running the ballast water pumps. The activities that will require LNG carrier power and the assumptions used to develop the cooling water flow requirements are as follows:

- Hotelling operations require the generation of 1.9 MW of power during the entire time that the LNG carrier remains in the slip. The vessel is anticipated to be within the slip for a total of 17.5 hours.
- A typical auxiliary power unit for an LNG carrier is the Wartsila 34DF. This is a dual fuel (liquid and natural gas) unit that is a complete primary driver/generator package capable of being sized upwards to 6.9 MW output. Fuel to power conversion is 7,700 kilojoules (kJ) per kilowatt-hour (kWh) (kJ/kWh) (7,305 British thermal units (Btu) per kWh (Btu/kWh)). This system has an overall fuel to power efficiency of 46.7 percent, thereby resulting in the rejection of 3,893 Btu of heat into the cooling water for each kWh of power generated.

- All calculations that follow are based upon the transfer of 148,000 $m^3$ of LNG from the LNG storage tanks to the LNG carrier. The 148,000 $m^3$ carrier is set as the basis because it represents the largest vessel authorized to call on the LNG Terminal.

The total gross waste heat discharged into the slip from the cooling water stream will be due primarily from the hotelling operations (including the power required to run the ballast water discharge pumps) as the shore side LNG pumps will be used to transfer the LNG from the LNG storage tanks to the LNG carrier. The hotelling operations were assumed to be as follows:

Hotelling Operations -17.5 total hours x 1,900 kW x 3,983 Btu/kWh = 132.5 million Btu (MMBtu)

The total amount of heat discharged into the slip during each vessel call is approximately 132.5 MMBtu.

Because of the extreme differential of the temperature of the cargo in the LNG carrier (-260°F) and that of the surrounding air and water (nominally 45°F) there is a constant uptake of heat by the LNG carrier from its surroundings. This heat uptake is manifested by the amount of LNG cargo that changes state from liquid to vapor on a daily basis. The typical LNG carrier sees 0.25 percent of its liquid cargo converted to the gaseous state each 24 hours. In this process 219 Btu of heat is absorbed for each pound of LNG converted to vapor. This results in a total of 53 MMBtu absorbed by a typical 148,0000 $m^3$ LNG carrier during the 17.5 hours it is within the slip. Given the distribution of vessel surfaces between those surfaces in contact with water as opposed to those surfaces in contact with air it is reasonable to assume that 50 percent or more of the heat take up by the vessel is extracted from the water. This assumption is further reinforced by the fact that the heat transfer coefficient between water and steel is significantly higher than the heat transfer coefficient between air and steel. Applying this allocation of heat absorption sources results in having 26.5 MMBtu being removed from the slip by the LNG vessel during its stay. Thus a portion of the 132.5 MMBtu of thermal energy discharged into the slip from the cooling water is offset by the uptake of 26 MMBtu by the LNG vessel itself, resulting in a net heat input to the slip of 106.5 MMBtu per 148,000 $m^3$ LNG carrier call.

Analysis and numerical modeling were performed to identify potential impacts of LNG carrier cooling water discharge on water quality in the slip and adjacent area of Coos Bay. The modeling was initially performed with two different numerical models: the 3-D UM3 model and the DKHW model. The models simulate hydrodynamic mixing processes of submerged discharges and predict temperature fields and dispersion of non-conserved substances in ambient water bodies. Cooling water numerical modeling requires input of steady-state flow velocity in the modeling domain. The results of tidal flowing modeling using the SELFE model showed that ambient current velocities inside the LNG Terminal area vary, depending on tidal stage. Peak current speeds in the berth only exceed approximately 0.32 ft/sec less than two percent of the time. Therefore, for cooling water modeling, two steady state ambient flow velocities were assumed and used further in the analysis: high velocity = 0.32 ft/sec and typical velocity = 0.16 ft/sec.

The following conservative assumptions were used in the analysis. The assumptions are conservative in that a steam powered ship was used. The steam powered ships tend to be older than the newer more modern dual fuel diesel electric ships that require lower quantities of cooling water.

- LNG carriers are steam-powered with a cargo capacity of 148,000 $m^3$.
- Maximum pump capacity for main condenser cooling is 10,000 $m^3$/hr (44,030 gpm) and maximum pump capacity for LNG carrier's equipment cooling is 3,000 $m^3$/hr (13,209 gpm). Total capacity being used at a given time is typically in the range of 6,300 $m^3$/hr (27,739 gpm). For the analysis, 6,300 $m^3$/hr (27,739 gpm) was used.
- Diameter of the horizontal discharge port is 1.1 meters (3.6 feet).
- Depth of discharge port below still water is 10.0 meters (32.8 feet).
- Maximum heating of cooling water at time of discharge is 3 ºC (5.4 ºF) above ambient temperature.

Results of the modeling showed that for typical ambient flow conditions at a distance of 50 feet from the discharge point (LNG carrier sea chest), temperatures will not exceed 0.3 ºC (0.54 ºF) above the ambient temperature. This difference will decrease with further distance.

**LNG Terminal Operations**

The storage and transfer of LNG from the storage tanks to an LNG carrier at the berth would not likely have any affect on federally listed species (see forthcoming EIS for discussion of terminal operation and its potential impact on water quality).

There are no process water discharges from the liquefaction process, unlike the regassification of LNG with submerged combustion vaporizers which results in the discharge of some water produced during the vaporization process. There will be some waste water discharges from the oily water separators that will be directed to the industrial wastewater pipeline. Following standard treatment in the oily water separators, the discharge will meet water quality standards. The quantity of the discharge will be dependent on the amount of stormwater received by the Project site and the amount of wash water used that requires treatment in the oily water separator.

Following construction of the LNG Terminal facilities, approximately 34.3 acres of the 192.7 acre site (land area permanently affected by operation) will consist of impervious surface area. This 18 percent reduction should not have an adverse effect on the recharge ability of the Project site area. The stormwater management system is designed and constructed to accommodate this increase in runoff volume and to direct any flow that does not come into contact with any equipment containing potential contaminants to the slip. During operations, stormwater flows that could come into contact with equipment containing potential contaminants would be directed to oily water separators and ultimately discharged through the NPDES permitted discharge.

There could be indirect effects on wildlife because of increased human presence resulting from the Project. During operation of the LNG terminal, about 150 people would be employed. The current number of people employed at facilities operating on the North Spit is approximately 110 (Southport – 70, Roseburg – 20, DB Western – 20). This increase in people in the area could potentially lead to indirect effects such as increased snowy plover predators in the area due to trash. During operation, the facility would be kept clear of food wastes that could attract predators. Covered, animal proof receptacles would be provided in eating and break areas, parking lots, and at appropriate locations around the terminal. During operations the facility and grounds would be regularly inspected to ensure that no garbage is allowed to accumulate.

Additionally, all employees would be trained on current snowy plover regulations and recreational use restrictions.

### 3.1.3.3 Non-Juridictional Facilities and Interrelated Activities

South Dunes Power Plant

JCEP will obtain authorization from the EFSC to construct and operate the South Dunes Power Plant, a natural gas fueled combined cycle generating plant that will provide electrical power to the Project. The South Dunes site is on the site of the former Weyerhaeuser linerboard mill, closed in 2003 and since demolished. Access to the site will be from US-101 then west on the Trans-Pacific Parkway, two miles north of North Bend.

The South Dunes Power Plant is capable of producing 420 MW of electrical power for the Project, as well as process steam that will be used in conditioning gas prior to its delivery for liquefaction at the LNG Terminal. It will consist of two 170 MW blocks of high-efficiency combined cycle combustion turbine generation. Three combustion turbine generators (CTG), three heat recovery steam generators (HRSG), and one steam turbine generator (STG), will collectively compose each power block, adding approximately 40 MW to each 170 MW block for a total output of 420 MW.

Each CTG will produce electricity, with the exhaust gases from the CTG(s) supplying heat to the HRSG(s). Steam produced in the HRSG(s) will be used to power the STG(s) to produce additional electricity and process steam. Duct burners fueled by natural gas in the HRSG(s) will allow for production of additional steam and additional electricity from the STG(s) when needed. Steam exhausted from the STG(s) will be condensed in air-cooled condensers, with the resultant condensate returned to the HRSG(s) to remake steam.

Fuel will be supplied primarily in the form of BOG from the Project. Some additional natural gas will be supplied from the PCGP which will connect to a metering station to be located in the southern portion of the South Dunes Power Plant site. The pipeline and metering station will be installed, owned and operated by others. Water will be supplied by the Coos Bay-North Bend Water Board (CBNBWB) through an existing pipeline that connects to the South Dunes Power Plant site.

One new switchyard with generator transformers will be constructed onsite to switch/direct the power produced by both power blocks. The voltage will be stepped up to 115 kV for transmission to the LNG Terminal.

The CTG(s), HRSG(s), and STG(s) will be outdoor units, given the relatively moderate ambient conditions of the area. A control and administrative building will provide space for plant controls and offices for plant personnel. A separate water treatment area will provide a location for the equipment necessary to purify the raw water, producing demineralized water for use in the power plant steam cycle and amine solution for $CO_2$ removal. The site will also support metering and conditioning facilities for the natural gas supply used by both the South Dunes Power Plant and the LNG Terminal.

Southwest Oregon Regional Safety Center

The Southwest Oregon Regional Safety Center (SORSC) is a non-jurisdictional building located on an approximate 8.3 acre parcel of land within the southeast quadrant of the intersection of the Jordan Cove Road and Trans Pacific Parkway. The primary purpose of the SORSC is to provide the physical plant that would house the Jordan Cove Fire Company, the primary first responder for LNG incidents occurring either on an LNG carrier within the Coos Bay Federal Navigation Channel or at the JCEP facility. In addition to being the base of operations for the Jordan Cove Fire Company and the JCEP Fire Brigade, the SORSC will provide office and training space for the Coos County Sheriff's Department and Southwestern Oregon Community College. Office space has also been offered to the U.S. Coast Guard and the Oregon International Port of Coos Bay.

The SORSC facility will be constructed by a yet to be named contractor and the building will be owned by JCEP with individual facility users in control of office or training space allocated to their organization. Local zoning allows for the construction and operation of the SORSC and a Coos County building permit will be required. Although the SORSC building and operation is not deemed to be a FERC jurisdictional activity the SORSC site has been included in all of the environmental analyses provided to FERC, other federal agencies and the State of Oregon. Wetland delineations of the SORSC site have been conducted and accepted by the Oregon Department of State Lands. Any removal/fill activities necessary to prepare the SORSC site involving U.S. jurisdictional wetlands are identified and included in the Section 404 permit application submitted to the USACOE in early July. Likewise any removal/fill activities necessary to prepare the SORSC site involving Oregon jurisdictional wetlands are identified and included in the Removal/Fill application submitted to the Oregon Department of State Lands.

### 3.1.3.4 Future Plans and Abandonment – LNG Terminal

Jordan Cove has retained the capability within the Project design and set aside the space within the LNG Terminal to add the equipment necessary for import of LNG; should natural gas market conditions change in the future, Jordan Cove would add the equipment necessary for import of LNG provided that it has the necessary FERC authorization. Other than the possibility of adding vaporization facilities to the Project, there are no current plans which will result in the future expansion of the Project.

As evidenced by the operating histories at existing LNG terminals, robust construction techniques and proper maintenance and operating procedures have resulted in the useful life of these facilities far surpassing their 25 plus year design life. Based on this solid history, Jordan Cove does not anticipate abandonment of the Project in the foreseeable future. In the event it becomes necessary, Jordan Cove has signed an agreement with the ODOE that details the procedures to be followed for the proper abandonment of the Project. That agreement is part of the existing Memorandum of Understanding with ODOE, which is in the process of being updated. Until it is amended, Jordan Cove is operating under the existing Memorandum of Understanding and the decommission agreement contained therein.

As stated above, if Jordan Cove decided to expand or abandon the LNG terminal, it must seek authorization for those actions in a new application with the FERC, and this would be considered a new undertaking, requiring separate consultations under the ESA

### 3.1.4 Pacific Connector Pipeline and Associated Facilities

Pacific Connector would construct and operate the following facilities:

- 232-mile-long, 36-inch-diameter welded steel underground natural gas pipeline (Pacific Connector pipeline), with a maximum Maximum Allowable Operating Pressure (MAOP) of 1,480 psig;
- natural gas compressor station (Klamath Compressor Station), at about milepost (MP) 228.13 along the route of the Pacific Connector pipeline, in Klamath County, Oregon, consisting of an operational 41,000 ISO horsepower (hp) of new compression;
- three natural gas meter station locations, including the Jordan Cove Meter Station at MP 1.47R in Coos County; the Clarks Branch Meter Station at about MP 71.5 in Douglas County; and the Klamath-Eagle and Klamath-Beaver at MP 228.13 in Klamath County;
- gas control communication system, consisting of new radio towers at each meter station and the compressor station, use of an existing communication site owned by Williams Northwest, and leased space on seven other existing communication towers;
- 17 mainline valves (MLVs), 3 of which are co-located at meter stations and the compressor station; and
- 5 pig launchers and receivers, 3 co-located with meter stations and the compressor station, and the other 2 co-located with MLVs.

Figure 1.2-2 provides a general overview of the locations of the proposed facilities. Maps of the pipeline route, based on 7.5-minute topographic quadrangles, are also included in appendix A.

#### 3.1.4.1 Pipeline Routing Considerations

The Pacific Connector pipeline route was developed with consideration of the construction requirements for a large-diameter, high-pressure natural gas transmission pipeline. The pipeline has to start at the Jordan Cove LNG terminal and end at the Oregon/California border near Malin, at the terminus of the Gas Transmission Northwest LLC (GTN) and Ruby pipeline systems. FERC's forthcoming EIS will explain routing considerations. To the extent possible, Pacific Connector wanted to follow existing rights-of-way, such as other pipelines, power lines, and roads. Constructability/stability requirements were of primary consideration for routing the pipeline, and major geological hazards were mostly avoided. Pacific Connector also sought to reduce potential impacts on sensitive resources, such as minimizing the number of waterbody crossings, minimizing crossings of old growth forest, avoiding habitat for federally listed species, and reducing landowner encumbrances, where feasible. Avoidance of wilderness areas, known cultural resources, national parks and monuments, as well as scenic waterways and byways was also a factor in development of the proposed alignment. Table 3.1.4.1-1 lists considerations made during pipeline routing at specific locations. A number of alternative pipeline routes were evaluated by Pacific Connector during initial route selection, and will be evaluated in the forthcoming EIS. This BA/EFH Assessment is based on the proposed pipeline route submitted by Pacific Connector in June 2013.

TABLE 3.1.4.1-1

**Pacific Connector Pipeline Proposed Route Alignment**

| MP Location | Route Alignment Feature | Route Rationale | Map Sheet Number (Appendix A) |
|---|---|---|---|
| 1.5R to 1.7R | Around geographic Jordan Cove through former Weyerhaeuser mill property | Avoids population of Point Reyes bird's-beak plants and cultural resource | 1 |
| 1.7R to 4.1R | In-water route across Haynes Inlet | For geotechnical reasons, Pacific Connector cannot use an HDD to cross under Haynes Inlet. A Direct Pipe crossing method was considered but rejected. The proposed route shortened the distance in Coos Bay compared to the September 2007 alternative route, and minimizes impacts on eelgrass, oyster beds, and cultural resources. | 1 |
| 9.4R to 12.4R | Brunschmid Wetland Reserve | Avoids the NRCS' permanent conservation easement. | 2 and 3 |
| 11.1R | HDD under the Coos River | Avoids direct impacts on the Coos River, avoids archaeological site at Graveyard Point; avoids State Highway 241 (Coos River Highway) and direct impacts such as subsidence under this road. | 2 |
| 9.7 to 10.3 | Stock Slough | Avoids 2 crossings of Stock Slough, and problematic road crossing, and 1st crossing of Stock Slough with limited workspace. | 2 |
| 12.8 to 21.6 | Route aligns with BPA powerline corridor | Several deviations to minimize unstable conditions incorporated | 3 through 4 |
| 15.3 to 16.1 | Boone Creek | Minimizes steep side slope construction, unstable slope | 3 |
| 21.6 | Route deviates from BPA powerline corridor | Avoids side slopes, avoids an existing electric substation, and provides for a better crossing of the North Fork Coquille River | 4 |
| 25.1 to 26.1 | Re-enters then exits BPA powerline corridor | Avoids Cherry Creek and Coos County pipeline | 5 and 7 |
| 29.1 to 29.5 | Lone Rock Timberland parcel | Avoids planned sub-division development within this parcel | 7 |
| 29.8 | Crosses East Fork Coquille River | Avoids MAMU habitat; route modification to provide perpendicular river crossing | 7 |
| 30.3 to 30.7 | MAMU Stand G50 | Reduces impacts on MAMU stand | 7 |
| 31.4 to 32.35 | Hardwood study plot on BLM land | Avoids Oregon State University Red Alder Test Plot and reduces impacts on MAMU stand | 7through 9 |
| 36.1 to 36.3 | MAMU Stand B07 | Reduces impacts on MAMU stand | 9 |
| 43.0 to 44.7 | BLM land | Avoids Rock Creek ACEC | 13 |
| 45.2 to 45.7 | MAMU Stand C3070 | Reduces impacts on MAMU stand | 13 |
| 46.51 to 48.0 | Incorporated Weaver Ridge Alternative | Incorporated Weaver Ridge alternative to minimize MAMU stand impacts and to avoid problematic descent of Weaver Ridge on 2009 FERC FEIS Route | 18 and 19 |
| 48.0 to 49.5 | Deep Creek | Avoids multiple crossings of Deep and Wildcat Creeks | 18 and 19 |
| 49.5 to 49.8 | Rust Parcel Sub-division | Reduces impacts on planned development | 18 and 19 |
| 51.5 to 52.1 | Camas Valley east of the Middle Fork Coquille River | Avoids MAMU stand | 18 |
| 51.5 to 52.5 | Standlely reroute | Alignment accommodates landowner request and mimimizes quarry effects | 18 |
| 53.5-54.3 | MAMU Stand B13 | Alignment considered MAMU stand and habitat on BLM lands | 22 |
| 57.8 to 57.9 | Kincaide's lupine | Avoids population of Kincaide's lupine | 22 |
| 60 to 68 | Crosses timberlands on ridgelines through Olalla Valley to Dillard | Mostly avoids residential areas, minimizes impacts on agricultural land, and domestic water supplies | 23 through 24 |
| 67.5 to 74 | Incorporated Southern Route Alternative | Alignment allows crossing of I-5, South Umpqua River, Dole Road and a Railroad with a single Direct Pipe | 24 |
| 75.5 to 75.9 | Mariposa Lily | In-road alignment to minimize effects to Mariposa Lily | 25 |
| 81.4 to 83 | Avoided NSO (0361B) nest patch | Incorporated a reroute to utilize new logging roads and recent clear cuts to avoid NSO Nest Patch and Core Area | 29 |
| 83 to 94 | Wood Creek to Days Creek -route follows forested ridgelines | Avoids water supply springs near Woods Springs; avoids steep dissected topography; avoids rural residences and pasture in the Woods Creek and Days Creek valley floors; and better crossing of St. John's Creek | 29 through 30 |
| 85 to 87 | Oregon Women's Land Trust OWL Farm | Avoids guest residence and stream crossings | 29 |

TABLE 3.1.4.1-1

**Pacific Connector Pipeline Proposed Route Alignment**

| MP Location | Route Alignment Feature | Route Rationale | Map Sheet Number (Appendix A) |
|---|---|---|---|
| 95.0 to 95.6 | NSO Patch 094-8 | Reduces impacts on old growth forest and NSO nest patch | 30 through 31 |
| 105 to 111 | Wildcat Ridge-FS Road 3200 Compromise Route | Avoids Peavine Quarry; avoids Long Prairie; avoids NSO nest patches; Minimizes steep side slope construction; avoids one mercury mine; and has a better crossing of East Fork Cow Creek | 34 through 35 |
| 118.7 to 119.1 | Gagnon property | Route adjusted to edge of pasture to address landowner concerns | 37 |
| 122.6 | Crosses under Rogue River by HDD | Avoids direct impacts on the Rogue River; and avoids direct impacts on Highway 62 | 37 |
| 123.0 to 123.3 | Laudani property | Route adjusted to increase distance from residences and minimize steep side slope construction | 38 through 38 |
| 128.4 to 130.5 | Crosses Indian Creek and south of Mucky Flat | Route influenced by landowner concerns, including reducing impacts on pasture and avoidance of private airfield at Mucky Flat | 40 |
| 132.6 to 133.0 | Crosses Mitchell Creek Ranch | Avoids a planned new home site | 41 |
| 135.0 to 137.0 | Route is to west side of Obenchain Mountain | Avoids drainage, springs, wet pasture lands | 41 |
| 143.7 to 148 | Crosses C2 Ranch | Aligned for minimum effects to conservation easements held by Southern Oregon Land Conservancy; and reduces impacts on irrigation facilities | 42 through 43 |
| 150.3 to 150.7 | Medford BLM District | Aligned to reduce impacts on Heppsie Mountain rock quarry | 43 |
| 155 to 169 | Robinson Butte to Burton Butte Compromise Route would mostly follow existing FS Roads | Minimizes impacts on Late Successional Reserves; minimizes steep side slope construction; and avoids a wetland. Several minor route modifications incorporated to avoid rare S&M species. | 44 and 49 |
| 162.1 to 161.5 | South of Big Elk Meadow | Avoids NSO patch | 46 |
| 167.7 to 168.2 | Pacific Crest Trail crossing | Minimizes visual impacts on trail | 49 |
| 171 to 187.3 | Route aligned to parallel Clover Creek Road | Minimum “dead zone” between pipeline and road from MPs 169.5 to 170.9; avoids steep slopes between MPs 171,1 and 187.4; and avoids Buck Lake, wet meadow, and Spencer Creek. Several minor alignment modifications incorporated to avoid rare S&M species. | 49 through 53 |
| 187.3 to 191 | Incorporated McLaughlin Lane Alternative | Reroute avoids residences and avoids town of Keno | 53 through 55 |
| 192.6 to 197.0 | Parallels existing road and GTN pipeline | Avoids FWS Klamath Basin Wildlife Refuge | 55 |
| 194.1 to 194.4 | Archaeological site | Avoids archaeological site | 55 |
| 195.4 to 196.5 | Deviates from existing rights-of-way | Avoids population of Applegate milk vetch | 55 |
| 197.0 to 198.3 | Adjacent to former Weyerhaeuser industrial facility near West Klamath, Oregon | Avoids structures at this historic mill complex | 55 through 56 |
| 199.2 to 200.1 | HDD under Klamath River | Avoids direct impacts on Klamath River; avoids direct impacts on Highway 97 and Southern Pacific Railroad; and avoids archaeological site | 56 |
| 200.0 to 204.2 | Route within BPA powerline corridor | Minimizes impacts on hay fields | 56 |
| 204.2 to 206.0 | Deviates from powerline corridor | Avoids a lake at MP 204.20 | 56 through 57 |
| 206.0 to 208.8 | Aligned with State Highway 39, transmission line, and Southern Pacific Railroad | Avoids structures near MP 207.70 and 208.10 | 57 |
| 208.8 to 211.6 | Crosses over powerline, highway, railroad corridor, alignment stays adjacent to existing rights-of-way | Avoids residences, better crossings of canals and roads | 57 through 58 |
| 211.6 to 215.0 | Deviates from powerline | Avoids area of geotechnical and cultural concerns | 59 |
| 215.0 to 225.5 | Rejoins BPA powerline corridor | Avoids potential landslide areas and fault on west side of Stukel Mountain | 59 through 61 |
| 225.5 to 228 | Follows propertly lines | Follows property lines, fencelines; considers irrigation lines to connect to GTN pipeline and compressor station location | 62 |

## Aboveground Facilities

Proposed aboveground facilities that would be associated with the Pacific Connector pipeline include meter stations, mainline valves, pig launchers/receivers, and one compressor station. Aboveground facilities are listed in table 3.1.4.1-2 and described below. The locations of aboveground facilities are shown on the maps in appendix A.

TABLE 3.1.4.1-2

**Summary of Disturbance Associated with Aboveground Facilities**

| **Facility** | **MP** | **Acres Disturbed During Construction**[1] | **Acres Disturbed – for Permanent Operations**[3] | **Jurisdiction** |
|---|---|---|---|---|
| Jordan Cove MS, BVA #1, and Receiver [2,4] | 1.47R | 0.85 | 0.85 | Private |
| BVA#2 (Boone Creek Road | 15.69 | 0.06 | 0.06 | Private |
| BVA #3 (Myrtle Point Sitkum Road) | 29.48 | 0.06 | 0.06 | Private |
| BVA #4 (Deep Creek Spur) | 48.41 | 0.06 | 0.06 | BLM |
| BVA #5 (South of Olalla Creek) | 59.58 | 0.06 | 0.06 | Private |
| Clarks Branch Meter Station, BVA#6, Launcher/Receiver & Communications Tower [4] | 71.46 | 0.97 | 0.97 | Private |
| BVA #7 (Pack Saddle Road) | 80.03 | 0.06 | 0.06 | BLM |
| BVA #8 (Hwy 227) | 94.66 | 0.06 | 0.06 | Private |
| BVA #9 (BLM Road 33-2-12) | 112.10 | 0.06 | 0.06 | Forest Service |
| BVA #10 (Shady Cove) | 122.18 | 0.06 | 0.06 | Private |
| BVA #11, Launcher/Receiver (Butte Falls) | 132.03 | 0.44 | 0.44 | Private |
| BVA #12 (Heppsie Mtn Quarry Spur) | 150.70 | 0.06 | 0.06 | BLM |
| BVA #13 (Clover Creek Road) | 169.48 | 0.06 | 0.06 | Private |
| BVA #14 and Launcher/Receiver Site | 187.43 | 0.44 | 0.44 | Private |
| BVA #15 (Klamath River) | 197.77 | 0.06 | 0.06 | Private |
| BVA #16 (Hill Road) | 214.28 | 0.06 | 0.06 | Private |
| Klamath Compressor Station, Klamath-Beaver and Klamath-Eagle Meter Stations, BVA #17, Launcher & Communications Tower [4] | 228.13 | 30.86 | 30.86 | Private |
| | **Total** | **34.28** | **34.28** | |
| Blue Ridge Communication Site – Coos County [5] | ~ 20 | 0.23 | 0.23 | BLM |
| Signal Tree Communication Site – Coos County [5] | ~45.0 | 0.23 | 0.23 | BLM |
| Flounce Rock Communication Site – Jackson County [5] | ~123.0 | 0.23 | 0.23 | BLM |
| Robinson Butte Communication Site – Jackson County [5] | ~159.0 | 0.23 | 0.23 | Forest Service |
| Stukel Mountain Communication Site – Klamath County [5] | ~209 | 0.23 | 0.23 | BLM |
| | **Total** | **1.15** | **1.15** | |
| | **Grand Total** | **35.43** | **35.43** | |

1 Temporary construction disturbance associated with the aboveground facilities is included within the pipeline construction right-of-way, and is not double counted in total project disturbance estimates.
2 The Jordan Cove Meter Station will be located entirely within the proposed South Dunes Power Plant.
3 The 17 mainline block valves will be located within areas disturbed by the construction right-of way or within associated aboveground facility footprints (i.e., meter stations and the compressor station); however, the permanent operation acres provided will remain as permanent disturbance associated with these graded, graveled and fenced facilities.
4 Communication facilities are included in the disturbed areas associated with the meter stations and compressor station.
5 Communication facilities will utilize existing towers and equipment buildings, where space is available for lease, with no associated disturbance. If construction of new facilities is required, Pacific Connector will obtain an approximate 100 x 100 foot (0.23 acre) area in the immediate area of the existing communication tower facilities.

*Jordan Cove Meter Station*

Gas would be delivered to the proposed LNG terminal via the Jordan Cove Meter Station located at MP 1.47R of the Pacific Connector pipeline, in Coos County (see Appendix A). The meter station would be on property owned by Fort Chicago LNG II U.S. L.P. and would be adjacent to the South Dunes Power Plant facility, in a current industrial setting. Construction and operation of the meter station would affect 0.85 of Industrial land (table 3.1.4.1-2 and 3.1.4.3-1). There are no waterbodies or wetlands at the meter station.

The meter station would be graveled and enclosed by a 7-foot-high chain-link fence. Existing power and phone service for gas control communication equipment is available. A pig receiver and block valve would be located within the meter station facilities. Access to the site would be from an existing road within the South Dunes Power Plant. A building would be installed to house the gas and sulfur chromatographs, moisture analyzer, communications equipment, and flow computer. A building would also be required to house the control valves and ultrasonic meters. A 140-foot tall, steel communications tower would be installed to provide a link with gas control monitoring system in Salt Lake City, UT. The tower would stand without support of guy wires. Lighting at the meter station would be down-shielded to keep light within the boundaries of the site, which would minimize attracting nocturnally flying birds to the vicinity of the tower (Manville, 2000).

*Clarks Branch Meter Station*

The Clarks Branch Meter Station would be located in Douglas County, at MP 71.46 along the Pacific Connector pipeline (see appendix A). No waterbodies or wetlands are within the meter station tract. The meter station would occupy a site of 0.97 acre of privately owned land covered by agriculture and grassland-shrublands habitat types (table 3.1.4.1-.2 and table 3.1.4.3-1).

The meter station would provide an interconnect to deliver gas to the existing Williams interstate natural gas system known as Northwest Pipeline LLC Grants Pass Lateral. A pig launcher/receiver would be located within the meter station. The yard would be graveled, and the station enclosed by a 7-foot-high chain-link fence. The meter station would be located east of Dole Road. Existing power is available nearby the location. A building would be installed to house a BTU chromatograph, communications equipment, and flow computer. A building would be required for control valves and meters to reduce noise emissions for the station. A 26-foot-tall, self-supported, steel communications tower would be installed at the meter station to provide a link with gas control monitoring system in Salt Lake City, UT. The facility would be equipped with outside lighting, if necessary, for night work activities; however, these lights would only be utilized when the station is manned. During operations, nighttime work or maintenance activities would generally not be scheduled; therefore, these lights would only be used periodically and possibly for short periods during the winter when daylight hours are shorter.

*Klamath Meter Stations*

The Klamath-Eagle and Klamath-Beaver meter stations would be located at the terminus of the pipeline at MP 228.13 (see appendix A). The meter stations would be within the 31-acre Klamath Compressor Station tract that is currently sagebrush steppe vegetation (table 3.1.4.1-2 and table 3.1.4.3-1). No wetlands or waterbodies are within this tract.

Each meter station would be capable of receiving up to 100 percent of the system design capacity of 1 Bcf/d. The Klamath-Eagle Meter Station would serve as the interconnect with Ruby, and the Klamath-Beaver Meter Station would serve as the interconnect with GTN. The meter station complex would include a pig launcher.

*Klamath Compressor Station*

The Pacific Connector pipeline would require approximately 41,000 ISO horsepower of new compression (with one additional standby unit of 20,500 ISO horsepower) at the proposed new Klamath Compressor Station located at MP 228.13, in Klamath County (see appendix A) at the terminus of the pipeline. The compressor station would consist of turbine-driven centrifugal compressor units. The compressor station is located approximately 1.75 miles northeast of Malin, Oregon. The location is accessed on the south from Malin Loop Road and on the west from Morelock Road. The site is located adjacent to the supply interconnects with GTN Malin/Tuscarora Meter Station and the Ruby Turquoise Flats facility. It would occupy a site of approximately 31 acres of privately owned land that is relatively flat and currently sagebrush steppe vegetation type with a few scattered juniper trees (table 3.1.4.1-2 and table 3.1.4.3-1). Adjacent lands support croplands and rangelands. The Klamath Compressor Station would not affect any waterbodies or wetlands.

The 31-acre site would be secured by a 7-foot high chain-link fence. To minimize visual intrusions, a security fence around the perimeter of the station would be installed with screening slates and landscaping along appropriate sides of the station to reduce potential visual effects to area residences. The entire site would be graveled. The southern edge of the site is adjacent to Malin Loop Road, which would provide primary access to the site. The nearest residential dwelling is within 1,000 feet of the center of the site. Two other residences are within 1,500 feet of the center of the site.

The new compression units would be installed in a new Class 1 Division 2 rated compressor building. Other facilities would include an inlet filter/separator, lube oil cooler, inlet air silencer/cleaner, exhaust system, and gas coolers. The compressor building would include skid-mounted fuel gas conditioning, measuring, and regulation equipment. Related suction and discharge headers and piping would be installed between the pipeline and the compressor units. Other buildings inside the station would include a new control room/ancillary equipment building and unit valve skid buildings. The ancillary equipment building would include an air compressor system, hot water boiler, and back-up generator. A high pressure vent system with a silencer would be installed in order to allow the station to be blown down. Near the northwest corner of the station, where the pipeline leaves the station boundaries, aboveground pig launcher/receiver equipment and a mainline block valve would be installed.

There would be a small office in one of the buildings with phone and computer access. The station would also be utilized as a maintenance base for operation of the pipeline facilities. The station would not be manned 24 hours per day, but would have emergency pipe, spare parts, portable equipment such as blow-down silencers, and small hand tools stored on site. The facility would be equipped with outside lighting to support night work activities; however, these lights would only be utilized when operations personnel are working at the station. During operations, nighttime work or maintenance activities would generally not be scheduled; therefore, these lights would only be used periodically and possibly for short periods during the winter when daylight hours are shorter.

Residences within a 1-mile radius of the compressor station location were provided in Pacific Connector's FERC Certificate application (see figure 9.8-1 in Resource Report 9). Noise details will be provided in the forthcoming EIS. It is estimated that for the 5 closest Noise Sensitive Areas (NSAs) (between 1,000 feet and 2,500 feet away from the compressor station), operational noise should vary from the estimated night time energy equivalent sound level (Leq) noise levels at the NSAs due to the compressor station operation range between 41.1 A-weighted sound level (dBA) and 49.7 dBA and the day-night average sound level (Ldn) noise levels range between 47.5 dBA and 56.1 dBA. The estimated contribution at NSA #1 exceeds the FERC Ldn limit of 55 dBA by just over one decibel. Additional noise control measures are being developed and will be included in final design to reduce the contribution below the FERC limit.

No effects to federally listed species are expected from construction or operation of the Klamath Falls Compressor Station.

*Gas Control Communications*

Pacific Connector would have its parent company, Williams, design, construct, operate, maintain, and manage the everyday business affairs of the pipeline. This includes general communications, and remote operations of meter stations and other related facilities (including MLVs). Pacific Connector would need to use a total of 11 radio communication towers to link the pipeline with Williams' headquarters in Salt Lake City, UT. Radio towers would be required at each meter station and the compressor station to provide a link with Williams' gas control monitoring system. As part of the communication system, Pacific Connector would also need to lease space on existing mountaintop radio communications towers.

Three new communication towers would be erected at the Jordan Cove Meter Station, Clarks Branch Meter Station, and the Klamath Compressor Station. Pacific Connector has conducted initial communications studies and determined that in addition to the three proposed new towers that would be installed at the meter stations and compressor station, leased space on existing communication towers as well as new towers would be needed. Pacific Connector would prefer to lease space on existing tower sites at the time of construction. If leased space is not available on existing facilities, and construction of new facilities is required, Pacific Connector would seek to obtain an approximate 100 foot by 100 foot (0.23 acre) area for each of the new facility installations in the immediate vicinity of the existing communication tower facilities. The new towers and communication buildings would be enclosed within a 50 foot by 50 foot (0.06 acre) fenced footprint located within the larger 100 foot by 100 foot area.

In addition to the proposed communication sites, Pacific Connector would utilize the existing Northwest Pipeline Harness Mountain Communications Site in Douglas County, which serves the Grants Pass Lateral. In the case of the existing tower at Robinson Butte, on National Forest System (NFS) lands, the USFS may require the modification of the current special use permit in order to allow the addition of new communication equipment. Table 3.1.4.1-3 provides the locations and heights of the proposed communication system required for the Pacific Connector pipeline.

TABLE 3.1.4.1-3

**Location of Proposed and Existing Gas Control Communication Towers**

| Site Name | Location | | | | | | | Tower Height (feet) | Jurisdiction |
|---|---|---|---|---|---|---|---|---|---|
| | Latitude | | | Longitude | | | County | | |
| **Proposed New Towers** | | | | | | | | | |
| Jordan Cove Meter Station [1] | 43 | 25 | 58.1 | 124 | 14 | 27.8 | Coos | 140 | Private |
| Clarks Branch Meter Station | 43 | 3 | 16.9 | 123 | 19 | 41.2 | Douglas | 26 | Private |
| Klamath Compressor and Meter Stations | 41 | 59 | 46.9 | 121 | 21 | 27.3 | Klamath | 26 | Private |
| **Existing Williams Northwest Pipeline Communication Tower Site** | | | | | | | | | |
| Harness Mountain | 43 | 31 | 27.4 | 123 | 5 | 39.2 | Douglas | 150 | Private |
| **Existing Communication Tower Sites (space to be leased)** | | | | | | | | | |
| Blue Ridge | 43 | 16 | 16 | 124 | 5 | 9 | Coos | 170 | BLM[2, 3] |
| Signal Tree | 43 | 0 | 7.4 | 123 | 46 | 44.3 | Coos | 120 | BLM[2, 3] |
| Winston | 43 | 5 | 53.6 | 123 | 23 | 31.3 | Douglas | 250 | Private |
| Starveout Creek | 42 | 42 | 48.4 | 123 | 12 | 11.2 | Jackson | 60 | Private |
| Flounce Rock | 42 | 43 | 40.4 | 122 | 36 | 33.1 | Jackson | 120 | BLM[2, 3] |
| Robinson Butte | 42 | 21 | 51.4 | 122 | 22 | 54.1 | Jackson | 125 | Forest Service[2, 3] |
| Stukel Mountain | 42 | 5 | 46.0 | 121 | 38 | 1.0 | Klamath | 100 | BLM[2, 3] |

1 A tower at this site would only be necessary if Pacific Connector is unable to mount an antenna on one of the structures within the Jordan Cove site.
2 The Communication Facilities Plan provides more detail on the communication tower sites located on federally-managed lands.
3 New towers and equipment buildings may be necessary at these locations if lease space is unavailable at the time of construction. Table 3.1.4.1-2 includes the potential disturbance for these sites.

For use of the Robinson Butte communication site, Pacific Connector would only require light utility four-wheel drive vehicles to travel 2.2 miles on FS Road 3730 from Big Elk Road (paved) to access the tower. A cable and winch system would be used to hoist the microwave antenna communication systems from the vehicle to the tower. No maintenance and/or improvements are expected along FS Road 3730 because only light utility vehicles are required to access the site. The Robinson Butte communication tower is located within northern spotted owl designated critical habitat (Unit KLE-4). Currently known NSO sites are farther than one-quarter mile from activity associated with this communication tower. Also, no suitable habitat for listed plants occurs along this road or at the communications site.

Construction or operation of the communication towers are not expected to affect state and/or federal threatened or endangered species since existing facilities would be used, or construction of new facilities would occur immediately adjacent to existing communication facilities. No waterbodies are expected to be affected by construction of the communication towers or use of existing communications towers. Therefore, no adverse impacts to federally listed species are expected.

Gas control communications towers would not affect any waterbodies. New communications towers would be free-standing; none would utilize guy wires, to minimize potential bird collisions. Security lighting at these sites would be down-shielded to keep light within the boundaries of the site, which would minimize attracting nocturnally flying birds to the vicinities of the towers (Manville, 2000).

*Launchers/Receivers and Mainline Block Valves*

MLVs would be located along the pipeline according to DOT's spacing requirements (CFR 192.179). There would be a total of 17 MLVs along the proposed pipeline route, of which 3 would be co-located at meter stations and the compressor station (see table 3.1.4.1-2). Each MLV would occupy a site 50 x 50 feet (0.06 acre) and would be enclosed by a 7-foot high chain-link fence. Each MLV would require a permanent access road, and Pacific Connector has attempted to locate final placement of block valves adjacent to existing roads to minimize the length of new permanent access roads. Pacific Connector would paint the aboveground piping in the block valve locations green unless otherwise dictated by permit conditions. Locations of mainline block valves are depicted on the USGS quad-based general location maps in appendix A.

Remotely operated pipe inspection and cleaning tools (known as "pigs") would be used to inspect and maintain the inside of the pipeline. Pig launchers/receivers would be located at each end of the pipeline (Jordan Cove Meter Station and Klamath Compressor Station). Due to battery and data storage limitations, there would also be a pig launcher and receiver at the Clarks Branch Meter Station as well as co-located with MLVs #11 at MP 132.03 and #14 at MP 187.43. At the two co-located MLV locations, the block valve and pig launcher/receiver assembly sites would be 95 by 200 feet (0.44 acre). Pigging facilities would be located inside the fenced areas at all locations.

Launchers/receivers and mainline block valves would be located within the permanent pipeline easement or within the footprints of the aboveground facilities, which have been discussed above. Areas of existing wildlife habitats associated with each block valve are included in the discussion of the pipeline construction right-of-way. Areas of wildlife habitat that would be affected by operation of each mainline block valve are included in table 3.1.4.4-1.

### 3.1.4.2 Land Requirements – Pacific Connector Pipeline

Construction of the pipeline would require acquisition of temporary construction rights-of-way, temporary extra work areas (TEWAs), and permanent easements which are described in this section. Table 3.1.4.2-1 summarizes the construction and operation land requirements for the Pacific Connector pipeline. The pipeline project area is considered as areas of disturbance (i.e., construction right-of-way, TEWAs, uncleared storage areas [UCSAs], yards, disposal areas, etc.).

There are no plans to undertake any work outside of the identified pipeline project areas (construction right-of-way, TEWAs, UCSAs) for equipment tie-offs on steep slopes during clearing activities. The proposed construction right-of-way and TEWAs have been designed to provide the necessary workspace and support areas for constructing the pipeline.

TABLE 3.1.4.2-1

**Total Project Land Requirements for Construction and Operation**

| Project Component | Length (miles) or Number of Sites | Land Affected During Construction (acres) | Land Affected During Operation (acres) |
|---|---|---|---|
| Pipeline Facilities | 231.82 * | 2,697.49 | 1,404.56[1] / 842.83[2] |
| Temporary Extra Work Areas [3] | 1,676 | 1,094.47 | (98.61) [8] |
| Uncleared Storage Areas | 287 | 673.14 | 0.00 |
| Quarries & Disposal Sites | 44 | 69.78 | (69.78) [8] |
| Contractor and Pipe Storage Yards | 38 | 1,339.08 | 0.00 |
| Existing Roads Needing Improvements in Limited Locations [4] | 65 | 20.26 | (20.26) [9] |
| Temporary Access Roads | 14 | 5.01 | 0.00 |
| Permanent Access Roads | 13 | 2.57 [5] | 2.57 [5] |
| Aboveground Facilities | 17 | 32.01 [6] | 35.43 [7] |
| Hydrostatic Discharge Locations Outside the ROW | 6 | 1.10 [10] | 0.00 |
| **Total** | | **5,934.91** | **1,442.56 [8, 9]** |

* Because of changes in the centerline and associated MP equations, the ending MP no longer represents the actual centerline length.

1 New permanent easement is 50-feet on private and federal lands.

2 Acreage affected by the 30-foot corridor where brush control will be performed during operation of the pipeline.

3 TEWAs are shown on the Environmental Alignment Sheets provided under separate cover to FERC's Staff.

4 Includes those existing roads requiring widening in specific locations; does not include limbing/brush clearing or blading/grading for potholes.

5 Portions of the PARs are within the construction right-of-way and permanent easement.

6 Construction impacts associated with the aboveground facilities are included in the construction impacts for the pipeline facilities except the 5 potential communication tower sites and the Klamath Compressor Station, which are included here (1.15 acres and 30.86 acres, respectively).

7 Portions of the operational impacts of the aboveground facilities are included within the permanent easement acreage.

8 Represents TEWAs, existing quarries, and rock source and disposal sites provided in appendix G that may be used as permanent storage areas. The acreages are not included in the overall operational total (1,442.56 acres) because the storage areas will not be used during operation of the pipeline.

9 While the improvements will not be reclaimed, these roads will not be used for operations and the acres are not included in the total operational acreage.

10 Small brush or trees may be cleared by a rubber-tired rotary or flail motor (brush hog) or by hand with machetes/chainsaws. No soil disturbance will occur. A rubber-tired or track hoe will be utilized to lay the discharge line and to remove the saturated haybales or filter bags upon completion of hydrostatic discharge.

## Construction Right-of-Way

Temporary Construction Right-of-Way

Pacific Connector proposes to utilize a standard 95-foot-wide temporary construction right-of-way with a 50-foot permanent easement. Construction-related effects in the temporary construction right-of-way and operation-related effects in the permanent easement to wildlife habitats are included in table 3.1.4.3-1. The temporary construction right-of-way configuration is required to accommodate the necessary clearing and grading activities to prepare the right-of-way, temporarily store spoil materials for construction, and to provide a passing lane during construction for equipment movement up and down the right-of-way. The temporary construction right-of-way would be used as the primary transportation corridor during construction. Eliminating the passing lane by narrowing the right-of-way width would significantly restrict traffic flow along the right-of-way. Proper traffic flow minimizes pipeline project impacts by reducing the number of access roads that may need to be constructed and by minimizing construction duration. The proposed 95-foot right-of-way configuration would accommodate many of the necessary cuts and spoil storage area requirements along the proposed alignment, thereby reducing the number of additional TEWAs that would be required to safely construct the pipeline, and would minimize the total overall pipeline project disturbance. Typically, large-diameter pipeline projects (i.e., 30-inch diameter or greater) utilize at least a 100-foot or wider temporary construction right-of-way. For example, the 712-mile, 42-inch diameter Rockies Express Pipeline (West) Project (FERC Docket CP05-31-000) utilized a 125-foot wide construction right-of-way to construct the project across the Rocky Mountain and Plains States.

Where feasible (i.e., where topographic conditions allow), at palustrine forested and scrub shrub wetland crossings, the construction right-of-way would be reduced to 75 feet in width to minimize impacts to these resources. The reduced construction right-of-way, or "neckdown," is consistent with the FERC staff's Procedures (Section VI. A.3). Because TEWAs are typically required on either side of neckdowns, neckdowns within emergent wetlands were determined on a case-by-case basis depending on the quality of the wetland and the quality of the adjacent vegetation that would be disturbed by the TEWAs.

Steep slope or side slope areas would require the construction right-of-way to be greater than 95 feet in width. These conditions require unique construction techniques such as a "two-tone" right-of-way (see Drawing 3430.34-X-0019 in the ECRP provided in appendix F). Additional TEWAs are necessary for adequate spoil storage/staging and to ensure a safe working plan during construction. Sharp angles or points-of-intersection (PIs) along the alignment also require TEWAs on the working side of the right-of-way to provide adequate space to install pipeline field bends or "factory" bends and to ensure that stringing trucks (which would be greater than 100 feet in length) have the necessary turning radius to navigate the corner and stay within the "certificated construction limits."

In total, construction of the Pacific Connector pipeline would result in 4,595.8 acres of disturbance (excludes acres associated with contractor yards). Approximately 92.2 miles or 40 percent would be constructed within or adjacent to existing utility and transportation corridors (powerlines, pipelines, and roads).

<u>Temporary Extra Work Areas</u>

In addition to the 95-foot wide construction right-of-way, TEWAs would also be required at numerous locations to provide additional work space during construction. The TEWAs are listed in appendix G. Generally, these TEWAs are required for (but not limited to) the following:

- steep slopes and side sloping areas to accommodate cuts and spoil storage requirements;
- bore pits and spoil storage at road and railroad crossings;
- spoil storage, staging, and construction of drag sections such as at wetland crossings, residential/industrial areas, and road crossings, etc.;
- waterbody and wetland crossings;
- pipe and equipment staging;
- additional spoil storage areas where the topography requires cut and fills or where side slopes are traversed;

- areas where tie-ins or factory bends require additional trench widths to allow workers to enter the trench and perform welds and to ensure Occupational Safety and Health Administration (OSHA) trench safety requirements;
- sharp angles or PIs where additional area is required to account for the wide turning radius of stringing trucks (which would be greater than 100 feet in length);
- topsoil segregation areas to ensure topsoil and subsoils are not mixed;
- off right-of-way dewatering areas; and
- timber staging/decking.

Where the pipeline would be installed in Haynes Inlet across Coos Bay, between about MPs 1.7R and 4.1R, Pacific Connector indicated it would use about a 250-foot-wide construction right-of-way. This large construction right-of-way in the bay would be necessary to accommodate work boats needed to support the pipeline lay barges.

Road and stream crossings and tie-in locations are typically conducted with a separate construction crew to fabricate and install the pipeline across these features. To conduct these crossings, additional work area is required to stage or accommodate the equipment, crew vehicles, pipeline materials, dig the trench, store the spoil and safely install the pipeline. Consequently, additional TEWAs are required at these locations.

A total of 1,094.5 acres of TEWAs would be disturbed during construction of the pipeline. Construction-related effects in the TEWAs to wildlife habitats are included in table 3.1.4.3-1. All of these areas are considered temporary disturbance and would be restored upon completion of construction (see appendix F). During right-of-way cleanup and restoration, TEWAs would be restored in a similar manner as other areas disturbed during pipeline construction. The areas would be regraded and a seedbed prepared as necessary, then seeded with a seedmix developed in consultation with affected landowners. All TEWAs that were forested prior to construction would be replanted with trees.

The FERC staff's Procedures contain a number of specifications regarding the location of TEWAs in proximity to waterbodies and wetlands. Pacific Connector would comply with most of these specifications, including:

- TEWAs have been located at least 50 feet away from waterbody and wetland boundaries unless a site-specific modification has been requested;
- Vegetation clearing between the TEWA and the edge of the waterbody would be limited to the width of the construction right-of-way; and
- TEWAs have been sized to the minimum necessary to safely complete construction.

Because of the rugged terrain, there are numerous areas where site-specific conditions prevent compliance with the specifications provided in the FERC staff's Procedures. These areas have been identified, described, and requested as modifications in appendix H. The BLM and USFS have requested additional TEWA setbacks within riparian reserves that are greater than the 50-foot setbacks specified in the FERC staff's Procedures. Pacific Connector has determined that these increased setbacks in riparian reserves would not be practical and would render the necessary TEWAs unusable. Therefore, Pacific Connector would follow the FERC staff's Procedures to minimize the extent and duration of pipeline project-related impacts on wetland and waterbodies.

There are 519 TEWAs within riparian zones that are within 1 site potential tree height of a waterbody. There are 54 TEWAs that would directly affect waterbodies. These include TEWAs associated with the Coos Bay estuary crossing where additional workspaces are required in areas, where deeper cover has been designed, where substrate materials may require a wider trench, or where lay barges would be anchored during the crossing.

Several other TEWAs are located at the second crossing of the South Umpqua River, which would be crossed using a diverted open-cut method. The crossing would require TEWAs to be placed in the waterbody to install the diversion dams and to complete the crossing.

Most of the TEWAs that would directly affect waterbodies are located in the Klamath Basin where an additional 5 feet of TEWA is required for topsoil segregation in agricultural areas. The agricultural fields/pastures that are traversed are extensive and are bisected by numerous small ditches and canals. During design of the TEWAs, the TEWAs often were not cutoff or divided across these ditch and canal waterbodies because of their minor size. In addition, there are numerous extensive wetlands and drainage ditches within these agricultural fields where TEWAs have been placed across the ditches for access to the right-of-way or for dewatering purposes in high groundwater areas.

Another area where TEWAs are required to cross waterbodies include the HDD pullback areas for the Coos and Rogue Rivers, where the HDD pipe string would be prefabricated prior to completing the HDDs. In these areas, the prefabricated pipe string would be set on rollers and the pipe string would span over minor waterbodies located within the pullback areas.

Uncleared Storage Areas

During design of the construction footprint for the Pacific Connector pipeline, Pacific Connector identified the need for additional temporary work areas in various locations such as in dense, mature forested areas; in areas of steep slopes; and in areas where the route follows steep, narrow ridgelines. However, to minimize overall pipeline project disturbance, Pacific Connector has specifically designated some temporary work areas as UCSAs rather than TEWAs (see appendix G). Unlike the TEWAs, the UCSAs would not be cleared of trees during construction. These areas would be used to store forest slash, stumps, and dead and downed log materials removed from the construction right-of-way prior to construction; these materials would be scattered back across the right-of-way after construction. The amount of this type of material is expected to be large enough to hinder construction activities if it were stored within the construction right-of-way. Construction-related effects in the UCSAs to wildlife habitats are included in table 3.1.4.3-1. Therefore, these UCSAs would be important construction footprint features. Some forested areas crossed by the pipeline on NFS lands are designated as Late-Successional Reserves (LSR) and are also designated as critical habitat for the NSO or MAMU. In these areas, forested habitat alteration is restricted, and use of UCSAs rather than TEWAs would minimize forested habitat removal while still providing important work areas to facilitate pipeline construction.

In some locations, the UCSAs may be used to store spoil or to temporarily park equipment between the mature trees. However, storage and temporary parking of equipment/vehicles would not occur immediately adjacent to the tree so as to minimize impacts (soil compaction or tree damage). In extremely steep and side sloping topography, the UCSAs may be required as a contingency location to contain rock that rolls beyond the construction limits. Along extremely steep and narrow ridgeline areas, logs, slash, and dead and downed material may be used as cribbing to contain excavated materials during construction (right-of-way grading and trenching activities). During restoration, some of the materials that are pulled out of the cribbing may roll beyond the construction limits. Where feasible, Pacific Connector would retrieve materials that have rolled downhill using cables and chokers attached to standard on-site restoration equipment (i.e., bulldozers and trackhoes) to winch the material back to the right-of-way. There may be some cases where retrieval of the lost cribbing material may cause more harm to resources than allowing it to remain where it settled to naturally decompose. In these areas, it would be infeasible and impractical to retrieve all of the overcast materials because additional tree clearing and grading would be required to reach the materials.

Pacific Connector has identified 673.1 acres of UCSAs that would be used during construction. There are 64 UCSAs within riparian zones that are within 1 site potential tree height of a waterbody. There are 11 UCSAs that would directly affect waterbodies.

The amount of spoil or woody debris that would be stored within UCSAs, or which pieces of equipment may be temporarily parked within UCSAs is not possible to estimate at this time, but would be determined as construction progresses. The UCSAs are considered temporary disturbance because they would not be cleared and the materials (i.e., slash, stumps and downed and dead material, etc.) stored within them would be removed during restoration activities, with the exception of unrecoverable materials on steep slopes as described above.

The temporary use of UCSAs to store slash is not expected to present a wildfire hazard. Slash materials would only be temporarily stored in the UCSAs, generally only during the period between construction and restoration, which is expected to be one year or less. As indicated by the USFS (see Forest Slash Treatment, Section 10.2 of the ECRP – appendix F), dead and downed woody debris greater than 16 inches in diameter do not contribute to fire hazard. Pacific Connector expects that most material stored in the UCSAs would be large-size materials (16 inches or greater), such as stumps removed from the trenchline or existing downed logs and larger slash materials that would not contribute to a fire hazard. During restoration, the slash material temporally stored in the UCSAs would be removed from the UCSAs and redistributed over the right-of-way according to the fuel loading limits as specified in Section 10.2 of the ECRP (see appendix F).

The UCSAs were conceived as a design criterion to reduce forest clearing (reduce a typical 125-foot-wide construction right-of-way to 95 feet). They are expected to function to allow the construction of the pipeline in rugged terrain by allowing the limited use of the uncut forest adjacent to the right-of-way for materials placement so that pipeline construction equipment can utilize the narrower 95-foot-wide corridor. The cost/benefit analysis could not be completed without the use of UCSAs and it would not be possible to “assembly line and move” materials along the right-of-way, thereby requiring additional clearing.

Pacific Connector has not provided a “worst-case analysis” of effects to the interior forest habitat measured from the edges of UCSAs. The effects to interior forest habitat are those effects created by a deforested “edge” created by the removal of all trees from a portion of the forest as is proposed for the construction right-of-way and TEWAs. The UCSAs are proposed simply for the temporary placement of material (logs, slash, rocks, equipment). These activities would not result in the removal of the forest. In many cases, the use of UCSAs would have impacts on the forest understory, but temporary reduction of understory shrub cover does not produce the effects of an “edge.” After removal of the materials stored in the UCSAs, the understory would recover. Even if in a few instances an individual tree were damaged and lost from use of the UCSAs, the loss of individual trees within a forested habitat does not create an "edge." Pacific Connector has prepared the Leave Tree Protection Plan (Appendix P to the POD, available upon request) detailing how it would protect live trees within the UCSAs.

Off-Right-of-Way Hydrostatic Discharge Sites

Pacific Connector has identified six potential hydrostatic test water discharge locations that would be outside of the construction right-of-way, TEWAs, or UCSAs (see table 3.1.4.3-8 below). In these six locations, small brush or trees may be cleared by a rubber-tired rotary or flail motor (brush hog), or by hand with machetes/chainsaws. No soil disturbance would occur. A rubber-tired or track hoe would be utilized to lay the discharge line and to remove the saturated hay bales or filter bags upon completion of hydrostatic test water discharge. The six hydrostatic test water discharge locations would affect a total of about 1.1 acres. Construction-related effects within the hydrostatic discharge sites to wildlife habitats are included in table 3.1.4.3-1.

Project Contractor and Pipe Storage Yards

Pacific Connector has identified 38 temporary pipe storage and contractor yards and rail ports (see table 3.1.4.2-2 and appendix A) that may be used during construction to off-load and store pipe and stage contractor equipment. These sites are generally not along or immediately adjacent to the proposed pipeline. The yards would also be used to stage equipment and store materials used during construction. Stored materials may include: construction mats, fencing materials, fuel and lubricants, stormwater control materials (straw bales, erosion control fabric, silt fence materials, etc.) and other materials. The yards would also be used for contractor office trailers and employee parking facilities. The yards which are available for project use would be secured during the easement acquisition phase, which is anticipated to begin prior to construction. Figures of the proposed yards are provided in appendix I. The yards total about 1,339.1 acres.

In general, Pacific Connector selected yard locations because they are existing industrial sites that have been previously graded and graveled, are proximate to the pipeline project area, and can be accessed by railroad or roads. All of the currently identified sites are privately owned.

Of the 38 yards, 31 were surveyed for wetlands and access was denied to 7. No wetland features are present on 19 of the surveyed yards. Twelve yards contain wetland features or drainage ditches, which would be protected during construction. Wildlife habitats within contractor and pipe storage yards are not included in table 3.1.4.3-1. Because most of the yards are existing industrial facilities, they do not contain high quality wildlife habitat.

TABLE 3.1.4.2-2

**Privately-Owned Contractor and Pipe Storage Yards that may be used during Construction of the PCGP Project**

| Name | County | Size (acres) | Description |
|---|---|---|---|
| North Spit Dock Yard | Coos | 4.79 | Old industrial dock; gravel and grassy surface |
| Weyerhaeuser Cove [1] | Coos | N/A [1] | Old industrial; half is paved [1] |
| Coquille Sawmill Yard | Coos | 7.47 | Old industrial; abandoned sawmill; previously utilized as a contractor's yard |
| Fairview Yard | Coos | 2.24 | Old industrial; graveled and dirt surfaces |
| Coquille Yard | Coos | 21.84 | Old industrial, vacant lot |

TABLE 3.1.4.2-2

**Privately-Owned Contractor and Pipe Storage Yards that may be used during Construction of the PCGP Project**

| Name | County | Size (acres) | Description |
|---|---|---|---|
| Georgia Pacific-Coos Bay | Coos | 107.08 | Active sawmill & lumber yard |
| Glendale#1 | Douglas | 4.43 | Vacant lot/old industrial |
| Glendale#2 | Douglas | 6.80 | Vacant lot/old industrial |
| Old Highway 99 Yard | Douglas | 8.76 | Gravel-surfaced vacant lot |
| Sutherlin John Murphy Yard | Douglas | 85.48 | Old industrial, formerly John Murphy Plywood Mill; a portion has an asphalt surface |
| Sutherlin Central Avenue | Douglas | 0.18 | Old industrial; formerly Gerretsen Building Supply Co. |
| Gravel Pit South Winston | Douglas | 128.93 | Operational gravel pit |
| Green #1 Yard | Douglas | 9.37 | Old industrial, vacant lot |
| Green District Yard | Douglas | 7.05 | Old industrial log yard, gravel-surfaced parking lot |
| Days Creek Yard | Douglas | 176.67 | Pasture |
| Riddle Pasture | Douglas | 22.69 | Crop/pasture |
| Riddle Main Street | Douglas | 8.78 | Old industrial; vacant lot |
| Green Diamond Pipe | Douglas | 67.28 | Abandoned mining operation |
| Milo Yard [2] | Douglas | N/A [2] | Former quarry [2] |
| Highway 99 Hayfield Yard | Douglas | 96.36 | Agriculture (hayfield) |
| Weaver Road Yard | Douglas | 7.75 | Old industrial log storage yard |
| Hult Chip Yard (Pipe) | Douglas | 13.31 | Old industrial; paved |
| Hult Chip Yard (Parking) | Douglas | 2.65 | Old industrial; gravel surface |
| Hult Chip Yard (Roll) | Douglas | 8.90 | Old industrial; paved |
| Burrill Lumber | Jackson | 64.11 | Old lumber mill/log yard |
| Burrill Real Estate – Medford Industrial Park | Jackson | 92.05 | Existing industrial park |
| Avenue F and 11th Street | Jackson | 26.16 | Industrial business and vacant leveled lot |
| Oregon Opportunities | Jackson | 5.18 | Developed industrial lot within industrial park |
| Avenue C and 7th Street – Elite Cabinet and Doors | Jackson | 26.40 | Undeveloped land within industrial park |
| Rogue Aggregates | Jackson | 111.02 | Active aggregate quarry and processing facility and undeveloped land |
| Collins Pacific [3] | Klamath | N/A [3] | Active wood products plant [3] |
| Klamath Falls Amuchastegui Building | Klamath | 25.43 | Existing commercial site |
| Klamath Falls Industrial Oil | Klamath | 39.47 | Undeveloped site |
| Klamath Falls Memorial Drive | Klamath | 48.01 | Undeveloped site |
| Klamath Falls Memorial Drive Pipe Yard | Klamath | 24.72 | Old industrial/vacant lot |
| Klamath Falls North of Cross Road East | Klamath | 30.56 | Farmland |
| Klamath Falls North of Cross Road West | Klamath | 37.38 | Farmland |
| Merrill Siding | Klamath | 9.78 | Railroad siding |
| | **Total** | **1,339.08** | |

[1] This yard is incorporated in the construction footprint as TEWA 1.46. The area (acres) of this yard is included in the TEWA impacts for the project.

[2] This yard is incorporated in the construction footprint as TEWA 94.52-W. The area (acres) of this yard is included in the TEWA impacts for the project.

[3] This yard is incorporated in the construction footprint as TEWAs 198.22-W, 198.42-W, 198.43-N, and 198.72-N. The area (acres) of this yard is included in TEWA impacts for the project.

Rock Source and Permanent Disposal Sites

Permanent disposal sites may be required to handle excess rock, spoil, or drilling mud that are generated during construction. Prime disposal sites for these materials include existing rock/gravel quarries and pits near the pipeline route. Where existing quarries or pits are not available, Pacific Connector has identified stable sites along the right-of-way as permanent disposal sites. Pacific Connector has identified 44 rock source/disposal sites which total 168.4 acres (see appendix G). Of these 44 rock source/disposal sites, 26 sites are existing quarries/gravel pits or abandoned quarries/gravel pits. Although some of the existing/abandoned sites appear to have land use types other than quarries/gravel pits, it is not Pacific Connector's intent to expand these sites beyond the existing or previously disturbed footprints. Construction-related effects within rock source and permanent disposal sites to wildlife habitats are included in table 3.1.4.3-1.

*Permanent Easement*

A permanent easement is needed for long-term operation and maintenance of the pipeline. The permanent easement would be 50 feet wide (unless landowners agree to a larger width) and would be centered over the pipe. The permanent easement for the pipeline would consist of approximately 1,404.6 acres. Within the permanent easement, long-term effects to wildlife habitats are based on the 30-foot maintenance corridor (842.8 acres) that is kept clear of large trees. The 30-foot strip centered on the pipeline would be maintained in herbaceous cover, with no trees larger than 15 feet high allowed due to operational considerations.

*Construction Access Roads*

Approximately 646 miles of existing roads would be used to access the pipeline right-of-way during construction. Existing egress and ingress points to and from the construction right-of-way have been identified in the table in appendix J as well as on the USGS quad-based maps in appendix A. These points have been identified to allow for safe, efficient construction and movement of equipment and materials.

In some areas, it would be necessary to grade or widen existing roads (to allow large equipment a turning radius) to access the construction right-of-way. Pacific Connector has estimated that 65 existing roads would need to be modified to handle construction traffic. These roads have been identified with footnotes in appendix J. The stringing trucks would be hauling 40- to 80-foot joints of pipe. The total length of these vehicles would be more than 100 feet, and therefore these vehicles would travel outside the existing road footprint, especially on corners and with oncoming traffic. Widening access roads in the identified constricted locations is necessary to accommodate the potential for the stringing trucks to "walk" outside of the existing road footprint. In some circumstances, it may also be necessary for oncoming traffic to "pull out" of the existing road footprint for passing purposes.

During use of existing roads for construction, paved surfaces would be kept clear of large accumulations of mud and other debris. Dirt roads may be maintained by grading, or covered by gravel. Appropriate sediment and erosion control devices would be installed along dirt roads used during wet weather or the rainy season to contain potential impacts to the road surface.

Minor improvements (i.e., filling potholes, grading to remove ruts, and/or limbing to remove overgrowth) may be needed in some areas to accommodate oversized and heavy construction equipment (see footnotes in appendix J). In general, roadway improvements would require a minimal amount of site disturbance and earthwork necessary to make the roads useable for access to the construction right-of-way. All maintenance would conform to BLM, USFS, state, county, and landowner requirements. No maintenance or improvements would be allowed on any road not authorized for use and approved for improvements.

Table 2 in appendix J lists access roads needing improvement that are within 100 feet of waterbodies. With implementation of the procedures in the ECRP (see appendix F), Pacific Connector does not anticipate that improvement of these existing roads would have any significant impacts on nearby waterbodies, as erosion and sedimentation would be controlled and minimized. Therefore, there would be no adverse impacts from road improvements on federally listed aquatic species in those waterbodies.

*New Temporary Access Roads*

Pacific Connector has identified 14 locations, totaling approximately 2 miles, where it would be necessary to construct new temporary access roads (TARs) (see appendix A). Construction of the TARs would temporarily impact 5.0 acres. After installation of the pipeline, the TARs would be restored to their previous condition and land use.

The potential increase in surface runoff from the pipeline project's temporary or permanent access roads is expected to be insignificant. Most of the TARs would require minor grading to access the right-of-way from existing roads because they are located in pastures, along gentle terrain, or along existing two-track roads.

Only four of the TARs would be located within 100 feet of a wetland or waterbody (see table 2 in Appendix J). Of the TARs to be constructed, five are adjacent to or within 50 feet of fish-bearing waterbodies and one is adjacent to or within 50 feet of non-fish-bearing ditches. No waterbodies or riparian reserves on federal lands would be affected by TARs. Moreover, appropriate BMPs outlined in Pacific Connector's ECRP (see appendix F) would be utilized to ensure that potential surface runoff and potential sedimentation impacts on waterbodies and wetlands from use of these roads would be avoided or minimized.

*Permanent Access Roads*

Pacific Connector would need to construct 13 new permanent access roads (PARs) for access to the right-of-way and aboveground facilities (see appendix A). These roads, totaling about 1 mile in distance, would provide access during operations and maintenance activities while the pipeline is in service. Most of the PARs would be located within Pacific Connector's permanent easement. Construction of the PARs would permanently impact 2.57 acres.

Most of the disturbance associated with these PARs would occur within disturbed areas associated with the pipeline's construction right-of-way or along existing two-track roads. Three of the permanent access roads would be located within 100 feet of a wetland or waterbody (see table 2 in appendix J). Pacific Connector would ensure that the roads are appropriately stabilized using gravel and appropriate BMPs, as outlined in the ECRP (see appendix F), to minimize potential surface water runoff and to avoid potential sedimentation impacts.

No waterbodies or riparian reserves on federal lands would be affected by PARs. Wildlife habitats that would be permanently affected by PARs are included in table 3.1.4.2-3.

| Table 3.1.4.2-3<br><br>**Temporary and Permanent Access Roads for the PCGP Project** | | | | |
|---|---|---|---|---|
| **Access Road (TAR/PAR-MP)** | **Dimension (feet)** | **Impact (acres)** [1] | **Jurisdiction** | **Purpose** |
| TAR-27.06 | 20x1,427 | 0.66 | BLM – Coos Bay | Access to TEWA 27.06N |
| TAR-29.88 | 16x3,035 | 1.10 | Private | Access to East Bank East Fork Coquille River |
| TAR-71.10 | 20x518 | 0.24 | Private | Access to South Umpqua TEWA 71.06N |
| TAR-81.37 | 20x653 | 0.18 | Private | Access to right-of-way |
| TAR-88.63 | 20x985 | 0.45 | Private | Access between TEWA 88.52-W&88.62-W |
| TAR-88.67 | 20x275 | 0.12 | Private | Access to TEWA 88.62-N |
| TAR-94.81 | 20x114 | 0.05 | Private | Access to S. Umpqua River |
| TAR-128.69 | 25x650 | 0.37 | Private | Access to ROW |
| TAR-141.10 | 25x471 | 0.27 | Private | Access to TEWA-140.98 |
| TAR-204.32 | 20x922 | 0.42 | Private | Access to road on levee |
| TAR-208.72 | 20x287 | 0.13 | Private | Access to TEWA-208.67-W |
| TAR-212.50 | 14x2,124 | 0.68 | Private | Access to Lost River |
| TAR-215.72 | 14x728 | 0.23 | Private | Access from Taylor Road |
| TAR-225.46 | 20x259 | 0.11 | Private | Access to ROW |
| | **Total TAR** | **5.01** | | |
| PAR-29.48 | 25x85 | 0.05 | Private | Access to BVA#3 |
| PAR-48.41 | 25x70 | 0.04 | BLM | Access to BVA#4 |
| PAR-59.58 | 25x86 | 0.05 | Private | Access to BVA#5 |
| PAR-71.46 | 25x1,226 | 0.57 | Private | Access to Clarks Branch MS & BVA#6 |
| PAR-80.03 | 25x92 | 0.05 | BLM | Access to BVA #7 |
| PAR-94.66 | 25x183 | 0.10 | Private | Access to BVA#8 |
| PAR-112.10 | 25x107 | 0.06 | Forest Service | Access to BVA#9 |
| PAR-122.18 | 25x171 | 0.10 | Private | Access to BVA#10 |
| PAR-132.03 | 25x2,047 | 0.89 | Private | Access to BVA#11 Launcher/Receiver |
| PAR-150.70 | 25x260 | 0.15 | BLM | Access to BVA#12 |
| PAR-169.48 | 25x342 | 0.20 | Private | Access to BVA#13 |
| PAR-187.46 | 25x228 | 0.25 | Private | Access to BVA#14/ Launcher/Receiver |
| PAR-214.28 | 25x106 | 0.06 | Private | Access to BVA#16 |
| | **Total PAR** | **2.57** | | |
| | **Total TAR & PAR** | **7.58** | | |
| [1] All or portions of the PARs are located within the permanent pipeline easement. | | | | |

### 3.1.4.3 Construction – Pacific Connector Pipeline

All pipeline facilities would be designed, constructed, tested, operated, and maintained to conform with or exceed DOT requirements found in Title 49 CFR, Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Safety Standards; 18 CFR 380.15, Site and Maintenance Requirements; and other applicable federal and state regulations. Pacific Connector would follow its ECRP while constructing the pipeline and associated facilities. This plan was modeled on the FERC staff's Plan and Procedures, with project-specific modifications, and other changes based on reviews by the BLM and USFS. Table 3.1.4.3-1 lists habitats affected by Project construction activities. During activities associated with constructing the pipeline and associated facilities (survey, timber clearing, construction, and revegetation), Pacific Connector would ensure that construction contracts include stipulations to ensure that all trash, food waste, debris, and other items attractive to corvids and other potential predators are picked up and removed from the Project area on a daily basis. Pacific Connector's EIs and FERC's third-party Environmental Monitors would be responsible for overseeing that the construction contractor is adequately following these stipulations.

TABLE 3.1.4.3-1

**Summary of Construction-Related Disturbance to Habitat (acres)**

| General Habitat Type | Mapped Habitat Category Type | Forest Stand by Age | Pipeline Facilities | | | | | | | | Subtotals | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction Right-of-Way | Hydrostatic Discharge Sites [4] | Temporary Extra Work Areas | Uncleared Storage Areas | Rock Source/ Disposal | Access Roads (TARs/PARs/ Improvements) [5] | Pipe Yards | Aboveground Facilities - Klamath Compressor Station | Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type |
| Forest-Woodland | Westside Lowland Conifer-Hardwood Forest | L-O [1] | 107.36 | 0 | 23.33 | 111.86 | 0 | 0.01 | 0 | | 242.56 | 459.00 | 734.53 | 1436.09 | 48.6 |
| | | M-S [2] | 265.11 | 0 | 67.81 | 114.79 | 3.77 | 0.17 | 7.35 | | | | | | |
| | | C-R [3] | 373.85 | 0.13 | 183.53 | 135.46 | 5.49 | 0 | 36.07 | | | | | | |
| | Montane Mixed Conifer Forest | L-O [1] | 17.72 | 0 | 1.24 | 7.03 | 0 | 0 | 0 | | 25.99 | 14.1 | 77.76 | 117.85 | 4 |
| | | M-S [2] | 9.14 | 0 | 0.47 | 4.49 | 0 | 0 | 0 | | | | | | |
| | | C-R [3] | 45.07 | 0 | 16.56 | 15.93 | 0 | 0.2 | 0 | | | | | | |
| | Southwest Oregon Mixed Conifer-Hardwood Forest | L-O [1] | 286.90 | 0 | 56.15 | 122.13 | 1.49 | 0.03 | 0 | 0 | 466.70 | 194.94 | 269.30 | 930.94 | 31.50 |
| | | M-S [2] | 115.64 | 0 | 32.64 | 46.66 | 0 | 0 | 0 | 0 | | | | | |
| | | C-R [3] | 160.72 | 0 | 43.92 | 59.07 | 5.55 | 0.04 | 0 | 0 | | | | | |
| | Ponderosa Pine Forest and Woodlands | L-O [1] | 51.77 | 0 | 18.72 | 4.32 | 0 | 0 | 0 | 0 | 74.81 | 70.71 | 102.94 | 248.46 | 8.50 |
| | | M-S [2] | 59.58 | 0.05 | 10.15 | 0.93 | 0 | 0 | 0 | 0 | | | | | |
| | | C-R [3] | 79.06 | 0 | 16.03 | 6.92 | 0.93 | 0 | 0 | 0 | | | | | |
| | Westside Oak and Dry Douglas-fir Forest and Woodlands | L-O [1] | 32.04 | 0 | 11.22 | 4.48 | 0 | 0 | 0 | 0 | 47.74 | 48.57 | 0 | 96.31 | 3.3 |
| | | M-S [2] | 33.62 | 0 | 9.83 | 4.74 | 0 | 0.38 | 0 | 0 | | | | | |
| | | C-R [3] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Western Juniper and Mountain Mahogany Woodlands | L-O [1] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66.95 | 52.61 | 119.56 | 4.00 |
| | | M-S [2] | 56.38 | 0 | 10.44 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | C-R [3] | 48.11 | 0 | 4.34 | 0 | 0 | 0 | 0 | 0 | | | | | |

TABLE 3.1.4.3-1

**Summary of Construction-Related Disturbance to Habitat (acres)**

| General Habitat Type | Mapped Habitat Category Type | Forest Stand by Age | Pipeline Facilities: Construction Right-of-Way | Hydrostatic Discharge Sites [4] | Temporary Extra Work Areas | Uncleared Storage Areas | Rock Source/ Disposal | Access Roads (TARs/PARs/ Improvements)[5] | Pipe Yards | Aboveground Facilities - Klamath Compressor Station | Subtotals: Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Subtotal Forest-Woodland** | ***1742.07*** | ***0.18*** | ***506.38*** | ***638.81*** | ***17.25*** | ***1.10*** | ***43.42*** | ***0.00*** | ***857.8*** | ***854.3*** | ***1237.1*** | ***2949.2*** | |
| | | ***Percent of All Forest-Woodland*** | ***59.1*** | ***0.0*** | ***17.2*** | ***21.7*** | ***0.6*** | ***0.0*** | ***1.5*** | ***0.0*** | ***29.1*** | ***29.0*** | ***41.9*** | ***100.0*** | |
| Grasslands-Shrubland | Sagebrush Steppe | | 63.61 | 0 | 16.6 | 0 | 7.25 | 0.08 | 0 | 30.86 | | | | 118.4 | *20.6* |
| | Shrublands | | 74.96 | 0.08 | 30.03 | 7.45 | 0 | 0.12 | 0 | 0 | | | | 112.64 | *19.6* |
| | Westside Grasslands | | 111.27 | 0.13 | 91.98 | 6.64 | 0.89 | 1.57 | 46.94 | 0 | | | | 259.42 | *45.1* |
| | Eastside Grasslands | | 18.07 | 0 | 3.41 | 0 | 1.4 | 0 | 93.34 | 0 | | | | 116.22 | *20.2* |
| | | **Subtotal Grasslands-Shrubland** | **267.91** | **0.21** | **142.02** | **14.09** | **9.54** | **1.77** | **140.28** | **30.86** | | | | **606.68** | *105.4* |
| Wetland / Riparian | Westside Riparian-Wetlands/Eastside Riparian-Wetlands | L-O [1] | 0.04 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0.89 | 2.58 | 3.54 | *3.2* |
| | | M-S [2] | 0.81 | 0 | 0.08 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | C-R [3] | 2.1 | 0 | 0.48 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | Shrub | 0.93 | 0 | 0.12 | 0 | 0 | 0 | 0 | 0 | | | | 1.05 | *0.9* |
| | Herbaceous Wetlands | | 67.57 | 0 | 38.35 | 0.02 | 0 | 0.01 | 0 | 0 | | | | 105.95 | *95.8* |
| | | **Subtotal Wetland / Riparian** | **71.45** | **0** | **39.06** | **0.02** | **0** | **0.01** | **0** | **0** | **0.07** | **0.89** | **2.58** | **110.54** | ***100*** |
| Agriculture | Agriculture, Pastures, and Mixed Environs | | 379.05 | 0.71 | 221.43 | 2.65 | 3.01 | 4.33 | 325.28 | 0 | | | | 936.46 | *100* |
| | | **Subtotal Agriculture** | **379.05** | **0.71** | **221.43** | **2.65** | **3.01** | **4.33** | **325.28** | **0** | | | | **936.46** | ***100*** |
| Developed / Barren | Urban and Mixed Environs | | 21.59 | 0 | 101.20 | 0.20 | 37.38 | 0.10 | 813.76 | 0 | | | | 974.23 | 80.3 |
| | Roads | | 129.99 | 0 | 69.91 | 15.81 | 2.46 | 0.21 | 14.68 | 0 | | | | 233.06 | *19.2* |
| | Beaches | | 0.16 | 0 | 5.93 | 0 | 0 | 0 | 0 | 0 | | | | 6.09 | *0.5* |

TABLE 3.1.4.3-1

**Summary of Construction-Related Disturbance to Habitat (acres)**

| General Habitat Type | Mapped Habitat Category Type | Forest Stand by Age | Pipeline Facilities: Construction Right-of-Way | Hydrostatic Discharge Sites [4] | Temporary Extra Work Areas | Uncleared Storage Areas | Rock Source/ Disposal | Access Roads (TARs/PARs/ Improvements) [5] | Pipe Yards | Aboveground Facilities - Klamath Compressor Station | Subtotals: Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type | Percent of Total Habitat | Subtotal by Habitat Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subtotal Developed / Barren** | | | **151.74** | **0** | **177.04** | **16.01** | **39.84** | **0.31** | **828.44** | **0** | | | | **1213.38** | ***100*** |
| Open Water | Open Water - Lakes, Rivers, Streams | | 11.10 | 0 | 6.51 | 1.56 | 0.14 | 0.06 | 1.66 | 0 | | | | 21.03 | 21.70 |
| | Bays and Estuaries | | 74.17 | 0 | 2.03 | 0 | 0 | 0 | 0 | 0 | | | | 76.2 | *78.4* |
| **Subtotal Open Water** | | | **85.27** | **0** | **8.54** | **1.56** | **0.14** | **0.06** | **1.66** | **0** | | | | | |
| **Subtotal Non-Forest** | | | **955.42** | **0.92** | **588.09** | **34.33** | **52.53** | **6.48** | **1295.66** | **30.86** | **0.07** | **0.89** | **2.58** | **2964.29** | |
| ***Percent of All Non-Forest*** | | | ***32.2*** | ***0*** | ***19.8*** | ***1.2*** | ***1.8*** | ***0.2*** | ***43.7*** | ***1*** | ***0*** | ***0*** | ***0.1*** | ***100*** | |
| **Project Total** | | | **2697.49** | **1.1** | **1094.47** | **673.14** | **69.78** | **7.58** | **1339.08** | **30.86** | **857.87** | **855.16** | **1239.72** | **5913.5** | |
| **Percent of Pipeline Facilities** | | | ***45.6*** | ***0*** | ***18.5*** | ***11.4*** | ***1.2*** | ***0.1*** | ***22.6*** | ***0.5*** | ***14.5*** | ***14.5*** | ***21*** | ***100*** | |

[1] The "Late Successional and Old-Growth" category (L-O) describes those forest areas with a majority of trees over 80 years of age. Forests with stands greater than 175 years are considered to have old-growth characteristics.

[2] The "Mid-Seral" category (M-S) describes those forest areas with a majority of trees over 40 years of age but less than 80 years of age.

[3] The "Grass-shrub-sapling or Regenerating Young Forest" category (C-R) describes those forest areas that are either clear-cut (tree age 0-5 years) or regenerating (tree age 5 to 40 years). Forest areas in this category are divided into forest vegetation types based on their potential to become those types of forests.

[4] Small brush or trees may be cleared by a rubber-tired rotary or flail motor (brush hog) or by hand with machetes/chainsaws. No soil disturbance would occur. A rubber-tired hoe would be utilized to lay the discharge line and to remove the saturated hay bales or filter bags upon completion of hydrostatic discharge.

[5] Portions of some of the PARs are located within the construction right-of-way and, therefore, there is some duplication in the acreage calculations.

The Pacific Connector pipeline would be divided into five construction spreads to allow for mainline pipeline construction in two construction seasons. Each spread would require approximately 240 to 300 construction personnel at peak. It is estimated that there would be approximately 30 to 50 construction inspectors per spread at peak. The three HDDs (Coos, Rogue, and Klamath rivers) and Direct Pipe crossings (Interstate 5 and the South Umpqua River) would require an estimated workforce of 15 to 20 construction and support staff and 2 to 4 construction and environmental inspectors (EIs) per drill site. Construction of the Klamath Compressor Station would require approximately 40 to 50 construction personnel at peak and 5 to 7 construction inspectors. The three proposed meter station sites (four interconnects) would require an estimated 100 to 140 construction personnel at peak and another 10 to 14 construction inspectors.

**Construction Spreads**

Standard pipeline construction proceeds in the manner of an outdoor assembly line composed of specific activities that make up the linear construction sequence. These operations collectively include survey and staking of the right-of-way, clearing and grading, trenching, pipe stringing and bending, welding and coating, lowering-in and backfilling, hydrostatic testing, right-of-way cleanup, and restoration. Pacific Connector has determined that to efficiently construct the pipeline, construction would be divided into at least five separate construction spreads. The construction spreads would include all construction/restoration activities within a specific milepost range along the pipeline.

Preliminary locations of construction spreads identified by Pacific Connector include the following:

- Spread One - MPs 1.47R-49.7
- Spread Two – MPs 49.7-94.7
- Spread Three – MPs 94.7-132.1
- Spread Four – MPs 132.1-188.0
- Spread Five – MPs 188.0-228.1

Table 3.1.4.3-2 provides an estimate of the noise and noise attenuation at specified distances associated with equipment used along a typical pipeline construction spread during the assembly line process.

Certificated Work Areas

Consistent with Section IV.A.1 of the FERC staff's Plan, Pacific Connector would confine pipeline project-related disturbance to the FERC-Certificated work areas. No disturbance would be allowed to occur outside of these areas without appropriate surveys (cultural, threatened and endangered species, residential, etc.), other federal, state, or local permits, and prior written approval from the FERC.

TABLE 3.1.4.3-2

**Estimated Noise Associated with Equipment and Noise Attenuation at Specified Distances During a Typical Pipeline Construction Sequence**

| Drawing Number a/ | Pipeline Construction Sequence a/ | Equipment Expected b/ | Estimated Cumulative Noise (dBA) At 50 feet c/ | Estimated Noise (dBA) at 200 feet d/ | | Estimated Noise (dBA) at 0.25 mile d/ | | Attenuation Distance (feet) to Background f/ | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | No Trees | With Trees (100 feet) e/ | No Trees | With Trees (100 feet) e/ | No Trees | With Trees (100 feet) e/ |
| 1 | Right-of-Way Acquisition and Survey | Pickup Truck, Chain Saw | 88 | 73 | 68 | 53 | 48 | 4,222 | 2,660 |
| 2 | Clearing and Grading | Pickup Truck, Chain Saw, Excavator, Dozer, Flatbed Truck, Loader, Shovel, Logger-Cutter, Skidder, Crawler-Chipper | 93 | 78 | 73 | 58 | 53 | 6,745 | 4,249 |
| 3 | Fencing | Pickup Truck, Auger Drill Rig | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,211 |
| 4 | Centerline Survey of Ditch | Pickup Truck | 80 | 63 | 58 | 45 | 40 | 2,016 | 1,270 |
| 5 | Ditching (Rock-Free) | Pickup Truck, Backhoe, Excavator, Dozer, Flatbed Truck, Dump Truck, Tracked Ditcher | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,211 |
| **OR** | | | | | | | | | |
| 6 | Ditching (Rock) | Pickup Truck, Backhoe, Excavator, Dozer, Flatbed Truck, Auger Drill Rig, Mounted Impact Hammer, Rock Drill, Blasting (Mitigated rock fracturing), Dump Truck | 99 | 84 | 79 | 64 | 58 | 11,670 | 7,352 |
| 7 | Padding Ditch Bottom | Pickup Truck, Backhoe, Excavator, Dump Truck | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,211 |
| 8 | Stringing | Pickup Truck, Excavator, Flatbed Truck, Crane | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,211 |
| 9 | Bending | Pickup Truck, Excavator, Dozer | 87 | 72 | 67 | 52 | 47 | 3,850 | 2,425 |
| 10 | Line Up, Stringer Bead and Hot Pass | Pickup Truck, Excavator, Dozer, Side-Boom, Welder/Torch | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,211 |
| 11 | Fill and Cap Weld | Pickup Truck, Welder/Torch | 81 | 66 | 61 | 46 | 41 | 2,211 | 1,393 |
| 12 | As-Built Footage | Pickup Truck, Welder/Torch | 82 | 67 | 62 | 47 | 42 | 2,425 | 1,528 |
| 13 | X-Ray and Weld Repair | Pickup Truck, Welder/Torch | 82 | 67 | 62 | 47 | 42 | 2,425 | 1,528 |
| 14 | Coating Field and Factory Welds | Pickup Truck, Welder/Torch | 82 | 67 | 62 | 47 | 42 | 2,425 | 1,528 |
| 15 | Inspection (Jeeping) and Repair of Coating | Pickup Truck | 80 | 65 | 60 | 45 | 40 | 2,016 | 1,270 |
| 16 | Lowering In and Tie-Ins | Pickup Truck, Backhoe, Excavator, Dozer | 87 | 72 | 67 | 52 | 47 | 3,850 | 2,425 |
| 17 | As-Built Survey | Pickup Truck | 80 | 65 | 60 | 45 | 40 | 2,016 | 1,270 |
| 18 | Pad and Backfill | Pickup Truck, Backhoe, Excavator, Dozer, Dump Truck | 87 | 72 | 67 | 52 | 47 | 3,850 | 2,425 |
| 19 | Test and Final Tie-In | Pickup Truck, Backhoe, Pumps | 86 | 71 | 66 | 51 | 46 | 3,510 | 2,221 |
| 20 | Replace Topsoil and Cleanup | Pickup Truck, Backhoe, Excavator, Dozer, Tractor | 88 | 73 | 68 | 53 | 48 | 4,222 | 2,660 |

a/ Drawing Number and Pipeline Construction Sequence are shown in figure x in the draft EIS.
b/ Equipment expected, based on "typical" pipeline construction requirements at a given location.
c/ Estimated Cumulative Noise at 50 feet is based on equipment-specific noise values (WSDOT 2008; de Hoop and Lalonde 1998) and rules for decibel addition specified by WSDOT 2008.
d/ Noise attenuation assumes "soft site" (absorptive ground) conditions and point-source noise reduction of 7.5 decibels (dB) for every doubling of distance (WSDOT 2008).
e/ In these estimates, a buffer of 100 feet of dense vegetation is present in line of sight between noise source and receptor. If 200 feet of dense vegetation is present, noise would be reduced by an additional 5 dB.
f/ Background noise assumed to be 40 dB during daylight hours, when construction would occur.
Source: de Hoop and Lalonde 2003; WSDOT 2011.

Surveying and Staking

Prior to the start of construction, the exterior right-of-way limits and the boundaries of TEWAs shown on the Environmental Alignment Sheets would be civil surveyed and clearly staked. The survey stakes would be maintained throughout construction, and monitored by Pacific Connector's EIs. Any pre-existing property line or survey monuments that occur within the construction right-of-way would be protected where possible, and if damage occurs during construction, these monuments would be replaced according to state and federal standards. Civil surveys on federal lands would adhere to guidelines established by the BLM, Reclamation, and USFS that were provided to Pacific Connector during the pre-filing review period. Civil survey is generally performed on foot or using all-terrain vehicles (ATVs) or off-highway vehicles (OHVs) from existing access points to the pipeline right-of-way. An EI would verify the limits of the staked right-of-way and TEWAs and these survey stakes would be maintained throughout construction.

Construction Right-of-Way Egress and Ingress/Equipment Mobilization

Access roads that would be used during construction or crossed by the pipeline have been identified and are provided in appendix J and shown on maps in appendix A. This table lists roads that would be used to access the construction right-of-way and identifies roads that would require improvement (i.e., brush clearing, grading, widening, etc). Equipment involved in pipeline construction would be moved onto the right-of-way using approved access roads, and once on the right-of-way would then generally proceed down the right-of-way performing their job tasks. No roads would be widened or otherwise improved to accommodate construction traffic without first completing an environmental analysis and obtaining the appropriate federal, state, and local approvals, including written authorization from the FERC. Equipment involved in pipeline construction would be moved onto the right-of-way using the roads listed in appendix J.

Vegetation Clearing and Grading

During tree and brush clearing, all operations and tree falling would occur within the certificated construction limits. On lands supporting taller shrub-type vegetation cover (sagebrush communities), Pacific Connector would clear the right-of-way by mowing or scalping off the tops of the shrubs with a motor-grader or a bulldozer. This material would be salvaged on the edge of the construction right-of-way and scattered across the right-of-way after seeding during final cleanup. Hayfields and vegetation cover types such as grass, low shrubs, or other low-growth vegetation would not be cleared except in areas directly over the trench or where grading would be required.

The cleared vegetation material would be stored on the edge of the right-of-way and spread back over disturbed areas during final restoration. This material would increase moisture retention and reduce wind and water erosion and is considered by Pacific Connector to be the functional equivalent of mulch and a source of native seed (see Section 10.15 in Appendix F for further details). Vegetation clearing in and adjacent to wetlands and at waterbody crossings would be consistent with the FERC staff's Procedures.

*Timber Removal*

The construction right-of-way would be cleared of all timber using standard logging practices in forested areas, in accordance with landowner and land management agency requirements.

Pacific Connector expects that all logging methods may be necessary to efficiently remove timber from the right-of-way, depending on the specific location. The forthcoming EIS will discuss in more detail Pacific Connector's proposed logging methods. Pacific Connector has developed a Right-of-Way Clearing Plan in consultation with the appropriate resource and/or regulatory agencies.

Most of the pipeline route in forested areas is expected to be logged by mechanical cutting and ground skidding equipment. Hand-felling would likely occur on steep slopes, and skidding patterns would be laid out to minimize erosion. The USFS recommends that no tractor logging occur on slopes exceeding 35 percent on federal lands, and that other yarding methods including cable systems and helicopter logging be utilized. Cable and helicopter logging would minimize impacts on soils. Where log skidding would be done using mechanical methods, Pacific Connector proposes to employ the following methods where feasible to reduce the potential for soil compaction:

- low-ground weight (pressure) vehicles would be used as much as possible;
- removal of duff would be avoided, if possible, so that it remains as a cushion between equipment, felled logs, and soils;
- designated skid trails, preferably over the proposed pipeline trench location, would be used as much as possible to limit the footprint of logging disturbance on soils within the construction right-of-way; and
- landings, yarding, and load-out areas used for timber harvesting would be scarified after use and prior to the rainy season where the potential for sediment delivery to waterbodies is possible. Scarification would promote infiltration and minimize runoff.

Pacific Connector indicated that it may use helicopters for logging and pipe stringing within the following locations where there are steep slopes and limited access to the right-of-way:

| Begin MP | End MP | Helicopter Staging |
|---|---|---|
| 18.10 | 19.30 | TEWAs 17.77-W, 19.06-W |
| 37.10 | 38.42 | TEWAs 36.63-W, 36.97-W, 37.14-N, 38.29-W & 38.29-N |
| 46.70R | 47.20R | TEWA-46.76-N, 46.79-N, 47.53-N & 47.52-W |
| 60.50 | 61.50 | TEWAs 60.52-N, 60.54-W, 60.59-N, 60.87-W, 60.88-N, 61.27-N, 61.29-W, 61.35-W, 61.41-N |
| 77.80 | 79.90 | TEWA 77.72-N, 77.95W, 78.99-W, & 79.85-N |
| 92.46 | 94.50 | TEWA 92.62, 92.63-N, 92.63-W, 93.01, 93.01-N, & 94.52-W |
| 95.10 | 97.05 | TEWA 94.52-W, 96.25-N, 96.25-W 97.02-N, 97.04-W |
| 97.7 | 98.00 | TEWA 97.63-N, 97.79-N, & 97.92-W |
| 101.3 | 102.30 | TEWA 101.63-N, 101.77-N,<br>& 102.19-N |
| 108.5 | 110.40 | TEWA 109.10-W, & 110.34-W<br>TEWA 110.73 Helicopter landing Peavine Quarry |
| 116.30 | 117.85 | TEWA-116.59-W, & 117.68-N |
| 123.30 | 125.15 | TEWAs 123.53-W, 123.71-N, 124.30-N, 124.54-W, 124.99-W, & 124.95-N |

Prior to clearing operations, Pacific Connector would flag existing snags in forested areas on the edges of the construction right-of-way or TEWAs, to protect those snags from removal during timber cutting, where feasible. These snags would be saved to benefit primary and secondary cavity-nesting birds, mammals, reptiles, and amphibians. During this process, other large-diameter trees on the edges of the construction right-of-way and TEWAs would also be flagged and saved as green recruitment or habitat trees, where possible. Some of these trees would be girdled to create snags to benefit wildlife. Snags and habitat trees would be retained if they do not pose a safety hazard to construction activities, as per the regulations outlined by OSHA.

During forest clearing, all operations and tree falling would occur within the authorized construction work areas. Some TEWAs that are already vacant areas adjacent to existing roads, have been identified for log storage and decking. In addition, some slash and other debris from clearing activities may be temporarily stored in UCSAs.

Trees would be felled or sheared in a manner that would not impact adjacent forest or structures outside of the right-of-way. Trees would also be felled away from wetlands, waterbodies, and riparian reserves. Pacific Connector would not remove stumps or root systems from wetlands, except along the trench line, unless necessary for safety reasons during construction. In upland forest, Pacific Connector would also limit stump removal to the trench line and areas where grading would be necessary to create a level working surface. Any debris as a result of tree cutting that falls into a waterbody would be removed, if practical. Logs and slash would not be yarded across perennial streams unless fully suspended. Existing logs firmly embedded into the bed or banks of streams would not be disturbed, unless their removal is necessary for clearing the right-of-way, trenching, or fluming or other waterbody crossing methods. Any existing logs removed from waterbodies during installation of the pipeline would be returned during restoration (if occurring on federally-managed lands, approval would be obtained from the land-managing agency). Landings for clearing operations would not be located in wetlands or riparian reserves. Where feasible, logs yarded out of wetlands or riparian zones would be skidded with at least one end suspended from the ground so as to minimize soil disturbance. Any cut timber designated for in-stream or upland wildlife habitant enhancements would be stored at the edge of the right-of-way or in TEWAs for later use during restoration activities. Where LWD is acquired for project in-stream habitat use, this material would only be obtained from the certified construction limits and would be collected outside riparian zones to maintain root structure within the riparian zone. An exception to this is where the LWD can be obtained from the trenchline or right-of-way cut areas where root systems would be removed during trench excavation or grading operations.

Trees to be cleared in forested areas along the pipeline route are typically considered too large by Pacific Connector to be taken whole for yarding. Therefore, trees would be cut, topped, limbed, and bucked on site where they have fallen. Generally, only the logs would be yarded to a landing for decking, loadout, and transport. The remainder of the wood debris from clearing (i.e., tree tops and limbs) would remain on the ground within the construction right-of-way where the trees were cut. During logging, tree tops and limbs would be broken or crushed creating a volume of small slash that would be impractical to remove from the right-of-way. Some of the slash on the ground would act as erosion control between the time the right-of-way is cleared and the pipeline is installed.

Pacific Connector's ECRP (see appendix F) describes the BMPs that would be applied during timber clearing, including the measures that would be used where these activities occur during the late fall or winter. As described in the Forest/Timber Clearing Section of the ECRP (see section 3.3.2 of appendix F), the slash generated during timber clearing operations in PCGP Year One would remain on the ground and in place to provide cover to minimize erosion over the winter of PCGP Year One/Year Two. Additionally, during and after timber clearing operations, the EI would determine appropriate temporary BMPs that would be installed to minimize potential erosion and sedimentation impacts. These measures may include:

- scarification of compacted surface, where appropriate, to promote infiltration and reduce runoff;
- use of slash/brush piles at appropriate locations to prevent off-site runoff and sedimentation;
- installation of temporary slope breakers at appropriate locations and at spacings to shorten slope lengths, prevent concentrated flow and to divert runoff to stabilized areas;
- installation of silt fences or straw bale sediment barriers;
- temporary seeding (using appropriate quick-germinating cover crops such as annual ryegrass or other appropriate quick-growing temporary cover species; this measure would not occur on federal lands where introduced species are restricted); and/or
- mulching of areas that do not have sufficient cover to ensure effective surface cover.

The EI would also utilize other effective BMPs as discussed in the ECRP to prevent sedimentation beyond the approved construction right-of-way and associated TEWAs or into waterbodies or wetlands. As stated in the ECRP, effective ground cover is considered to be the amount of cover necessary for maintaining a disturbed site in a low hazard category for erosion. Table 10.15-1 of the ECRP (see appendix F) provides effective ground cover requirements based on potential erosion hazard. Pacific Connector assumes that the soils within the construction right-of-way would be categorized within the high to very high erosion hazard classes and would apply the appropriate mulching cover requirements for these erosion hazards classes.

Specific hazard trees have not yet been identified. The presence of any existing hazard trees along existing roads should be addressed by USFS as an obligation unrelated to the proposed action. The extent or existence of hazard trees would only be identified following the creation of the construction right-of-way, TEWAs, or new access roads by Pacific Connector. Danger trees would be designated by qualified federal representatives, or third-party personnel that have been approved by the agencies. Danger trees would be felled in advance of logging, pipeline construction, road construction/reconstruction, and road maintenance. Danger trees would be directionally felled, using chainsaws, away from the permanent right-of-way if trees are to be left and towards the right-of-way if trees are to be removed. Compliance monitors in the field could review and approve as appropriate requests to remove danger trees outside the approved construction area. Prior to right-of-way easement acquisition, Pacific Connector would conduct timber cruises to verify timber volumes and species composition on forested lands to determine timber values. Timber cruises would be completed according to industry and/or federal agency standards. The timber cruises would identify the feasible logging systems that would be practical along the pipeline easement based on the pipeline alignment, construction right-of-way configuration (i.e., temporary construction right-of-way and TEWAs), topographic conditions and constraints, existing access, timber types and volumes to be removed, and the various logging system limitations. If necessary, the Right-of-Way Clearing Plan will be amended based on information from the timber cruises.

Merchantable timber would be removed and sold according to landowner/land-managing agency stipulations; however, it is Pacific Connector's preference to cut and remove all timber from the right-of-way and TEWAs to ensure that these areas are cleared prior to construction. In very limited areas, TEWAs have been identified for log storage and decking. These are existing cleared areas adjacent to existing roads where log storage could occur for extended periods. The construction right-of-way has been designed to minimize additional TEWAs to minimize overall pipeline project disturbance. The construction footprint is currently not large enough in many areas to accommodate log clearing and efficient construction activities simultaneously. Therefore, cut timber must be removed from the construction right-of-way to avoid pipeline project delays.

Pacific Connector filed with the FERC in June 2013, a draft Right-of-Way Clearing Plan developed in consultation with the BLM and USFS. That plan estimated acres of forests to be cleared, net volume of clearing, and available harvesting methods. However, as timber cruises have not been conducted yet, the Plan still requires additional information such as the dollar value of timber, logging system(s) to be used for each harvest segment, yarding locations, the location of landings and decks, etc.

*Treatment of Forest Slash*

Slash from timber clearing would be salvaged on or at the edge of the right-of-way and scattered/redistributed across the right-of-way during final cleanup and reclamation according to BLM and USFS fuel loading specifications to minimize fire hazard risks. This material would be pulled back onto the right-of-way during final cleanup after seeding. Where it is not feasible to pull the slash back onto the right-of-way after seeding, seeding in these areas (broadcast or hydroseeding) would occur with specifications to ensure adequate seed coverage. Scattering the slash across the right-of-way would hinder OHV traffic on the right-of-way and would act as a natural mulch to minimize erosion (see appendix F).

Because more than 1 ton per acre of woody material (logs, slash and chips) may be scattered across the right-of-way during final cleanup in many areas, Pacific Connector requested a modification from Section IV.F.4.e. of the FERC staff's Plan. Pacific Connector would utilize the fuel loading standards of the BLM and the USFS as the limit for the quantity of woody debris that would be distributed across the right-of-way to minimize fire hazard risks for this variance request. Section IV.F.4.e of the FERC staff's Plan states that if wood chips are used as mulch to not use more than 1 ton per acre of chips and to add an equivalent of 11 pounds of available nitrogen where chips are used as mulch.

The purpose of Section IV.F.4.e of the FERC staff's Plan is to ensure that revegetation efforts are not hindered due to the decaying process of large amounts of wood chips, which can bind up soil nitrogen and impede revegetation. Pacific Connector requested this modification because it would be impractical and infeasible to remove this material from the right-of-way and it is a typical silvicultural practice in the pipeline project area (i.e., forest slash left in logged areas). Furthermore, it is expected that the woody slash material would not deplete soil nitrogen in the short term, during revegetation establishment, because the size of the woody material that would be scattered on the right-of-way would be large and would not readily decay in the short-term. However, as proposed in Section 10.8 of the ECRP (see appendix F), Pacific Connector would apply a standard fertilization rate of 200 pounds per acre bulk triple-16 fertilizer (16:16:16 - nitrogen, potassium and phosphorus) on all disturbed areas to be reseeded, except in wetlands and in federally designated riparian reserves. This fertilization rate would apply 32 pounds per acre of elemental nitrogen, potassium, and phosphorus. The elemental nitrogen rate would also satisfy the FERC staff's requirement to add nitrogen where wood chips are used as mulch (see Section IV.F.4.e).

As stated in Section 10.8 of Pacific Connector's ECRP (see appendix F), to protect riparian reserves, fertilizers would not be applied within buffers at least 100 feet wide along all flowing streams that have domestic use or support fisheries. Application of fertilizers would also be avoided during heavy rain or when wind speed could cause drift. All fertilizers would be stored and equipment loaded away from streams and outside riparian reserves. Pacific Connector would also incorporate fertilizer into the top 2 inches of soil as soon as possible after application, which is a practice that minimizes the potential transport of nutrients and is a BMP specified in Section V. D. 2. of the FERC staff's Plan (see appendix C). These BMPs would be applied to minimize potential nutrient input to aquatic systems.

Slash would be distributed back on the right-of-way according to appropriate fuel loading size classes. On NFS lands, the maximum amount of slash that would be scattered across the right-of-way would be 12 tons per acre (see table 3.1.4.3-3), and on BLM and private lands the maximum would be 15 tons per acre (table 3.1.4.3-4).

As provided by the USFS, dead and downed woody debris greater than 16 inches in diameter does not contribute to fire hazard and would be maintained on site. Slash may be chipped and scattered across the right-of-way, provided that the average depth of wood chips covering the area does not exceed 1 inch following application. This chip depth along with other site-specific erosion control BMPs as outlined in the pipeline project's ECRP (see appendix F) would be sufficient to stabilize the soil surface from erosion while allowing grass seed to germinate and seedlings to develop. It is not expected to significantly increase fuel hazards as long as the maximum tonnage for fuel loading does not exceed 12 tons per acre.

TABLE 3.1.4.3-3

**Fuel Loading Specification by Size Class on NFS Lands**

| Size Class (diameter) | tons/acre |
|---|---|
| 0 to 1/4 inch | < 1 |
| 1/4 to 3 inches | 4 to 8 |
| 3 to 8 inches | 7 to 12 |
| Maximum Total Loading | 12 |

TABLE 3.1.4.3-4

**Fuel Loading Specification by Size Class on BLM and Private Lands**

| Size Class (diameter) | tons/acre |
|---|---|
| 0 to 1/4 inch | < 1 a/ |
| 1/4 to 8 inches | 5 to 8 a/ |
| >8 inches | 10 to 15 |

a/ Adapted from USFS Fuel Loading Standards

In areas where the fuel loading exceeds these standards, Pacific Connector would machine or hand pile and burn the excess material, depending on the site location, according to the requirement of the landowner. Burning would occur during the appropriate burning season and according to the conditions permitted by the BLM, the USFS, and the ODF (OAR 629-615-300). A prescribed burning plan for these activities is included in the POD (available upon request).

The burning describes the measures to be implemented by Pacific Connector, to conduct this activity in a safe manner and reduce the potential for a wildfire, including:

- Slash piles to be burned would be located within the construction right-of-way but separated away from surrounding vegetation to prevent potential ignition;
- The slash burn pile would be limited in height and size so the burn can be controlled;
- The area surrounding the slash burn pile would be kept free of flammable debris;
- Pacific Connector would have fire suppression tools available at the site of the prescribed burns;
- Pacific Connector would use fire watchmen, as appropriate, during burning operations; and
- Pacific Connector would not conduct slash burning within one-quarter mile of an occupied MAMU stand or occupied NSO next patch during the critical breeding season.

On BLM and NFS lands, larger slash pieces (more than 8 inches in diameter), may be removed from the pipeline project area and decked in designated storage sites, as stipulated by these agencies, or on the right-of-way at road crossings. This material would be made available to the public through the agencies' firewood programs. Some large woody debris would be left on the right-of-way, as determined by the BLM and USFS, as retained down wood for wildlife habitat and to aid in soil productivity.

Temporary Erosion Control Structures

Temporary erosion controls would be installed immediately after vegetation clearing and would be properly maintained throughout construction and reinstalled as necessary until replaced by permanent erosion controls or until restoration is complete. Temporary erosion control structures and procedures are discussed in detail in Pacific Connector's ECRP (see appendix F).

Topsoiling

The FERC staff's Plan (Section IV.B.1) requires topsoil segregation in: 1) all residential areas; 2) annually cultivated or rotated agricultural lands and pasture; 3) hayfields; and 4) other areas at the landowner's request. In these areas, the FERC staff's Plan requires either full work area or trenchline and subsoil storage area stripping. The FERC staff's Procedures (Section VI.B.2.h) address topsoiling in wetlands. In wetland areas, the FERC generally requires the top 12 inches over the trenchline to be salvaged, except in areas where standing water or saturated soils are present. Areas that would require topsoiling will be provided in the forthcoming EIS and are shown on the Environmental Alignment Sheets (available upon request).

Along the alignment where topsoil segregation is proposed, Pacific Connector has requested 10 feet of TEWA in addition to the 95-foot construction right-of-way. The purpose of this TEWA is to ensure that the stockpiled topsoil is kept separate from the trench subsoil throughout construction.

Blasting

Section 5.0 in the Geologic Hazards and Mineral Resources Report,[6] filed as part of Pacific Connector's application with the FERC, provides the locations along the proposed alignment where blasting may be necessary. A summary of blasting potential, by MP, is also included in table 3.1.4.3-5. During trenching activities, in areas where hard shallow bedrock is encountered, Pacific Connector would first attempt to utilize specialized excavation methods to reach the

[6] This report, produced by GeoEngineers (2013), was substituted by Pacific Connector as Resource Report 6 in the Environmental Report attached to its application to the FERC.

required pipeline design burial depth. These excavation methods may include ripping using hydraulic hammers or rock saws. However, if these methods prove to be ineffective or inefficient, blasting may be necessary to achieve the required trench depth. Where blasting is necessary, mitigation measures would be incorporated into the blasting program to minimize potential adverse impacts to the environment including nearby water sources, structures, and utilities. If blasting is required, all applicable federal, state, and local regulations would be observed and all necessary permits would be obtained. All blasting activities would be conducted by licensed blasting contractors in accordance with all applicable regulatory requirements.

Where blasting is required in streambeds, Pacific Connector proposes to utilize the dam-and-pump crossing method so that blasting activities can be completed in the dry to avoid potential impacts to aquatic species during in-water blasting. If a dam-and-pump crossing method cannot be used and in-water blasting is required, Pacific Connector would implement other techniques such as scare charges to temporarily clear aquatic organisms from the area. It is anticipated that the preparation of the rock for blasting (drilling shot holes) would cause enough disturbance to displace most aquatic organisms from the immediate vicinity of the blast. Immediately following blasting, equipment would remove any shot rock that could impede stream flow. Appropriate federal, state, and local permits would be acquired and agencies would be notified according to permit requirements.

TABLE 3.1.4.3-5

**Summary of Blasting Potential Along the Proposed Pacific Connector Pipeline**

| From MP | To MP | Blasting Potential | Material |
|---|---|---|---|
| 1.47R | 60.0 | None to Low | Soil, sediments, sedimentary rocks and valley fill |
| 60.0 | 70.1 | None to Moderate | Sedimentary and metamorphic rocks with local valley fill |
| 70.1 | 78.1 | Low to Moderate | Sedimentary and metamorphic rocks |
| 78.1 | 88.6 | High | Igneous rocks with sedimentary rocks and local valley fill |
| 88.6 | 89.2 | None to Low | Sedimentary rocks with local valley fill |
| 89.2 | 89.6 | High | Igneous rocks |
| 89.6 | 90.8 | Moderate | Sedimentary rocks |
| 90.8 | 94.5 | Low | Sedimentary rocks |
| 94.5 | 109.4 | High | Sedimentary and igneous rocks with local valley fill |
| 109.0 | 109.5 | Low | Landslide deposit |
| 110.9 | 112.1 | Low | Soft igneous rock |
| 112.1 | 135.4 | Moderate to High | Igneous and locally tuffaceous rock and local valley fill |
| 135.4 | 136.3 | Low | Landslide deposit |
| 136.3 | 136.8 | High | Igneous and locally tuffaceous rock |
| 136.8 | 138.7 | Low | Landslide deposit |
| 138.7 | 159.9 | Moderate to High | Igneous rock, tuffs, breccias, conglomerates, lahar deposits, local valley fill |
| 159.9 | 172.0 | High | Igneous rock and locally tuffaceous rock with local valley fill |
| 172.0 | 174.4 | None | Thick soil |
| 174.4 | 181.1 | High | Lava flows |
| 181.1 | 182.9 | Low | Unconsolidated volcanic deposits |
| 182.9 | 191.7 | Moderate to High | Igneous rocks with local soil and sediment |
| 191.7 | 218.9 | None to Moderate | Soft igneous rocks with local sediment and valley fill |
| 218.9 | 221.8 | High | Igneous rocks |
| 221.8 | 227.7 | None to Moderate | Soil, soft igneous rocks valley fill |
| 227.7 | 228.1 | High | Igneous rocks |

Blasting in uplands during pipeline construction is not expected to generate noise levels in excess of 92 dBA, with appropriate mitigation measures applied. Under worst-case conditions, the distance for noise from blasting to attenuate to 92 dBA is 175 to 200 feet away from the pipeline trench (see Pacific Connector Blasting and Helicopter Noise Analysis & Mitigation Plan, appendix P).

If blasting is determined to be required during pipeline construction in areas that have not been identified for ESA consultation, Pacific Connector would require the contractor to 1) continue to use other trenching methods until successful trench depths can be achieved; or 2) require the contractor to "skip" the blasting segment and return to the location after the MAMU/NSO/GGO seasonal constraint has passed; or 3) to inform FERC that reinitiation of formal consultation is necessary and to provide the appropriate rationale, information, and data to FERC.

Explosives detonated near water produces shock waves that can be lethal to fish, eggs, and larvae by rupturing swim bladders and addling egg sacs (British Columbia Ministry of Transportation, 2000). Explosive detonated underground produce two modes of seismic wave (Alaska Department of Fish and Game, 1991): 1) body waves that are propagated as compressional primary (P) waves and shear secondary (S) waves, and 2) surface waves produced when a body wave travels to the earth surface and is reflected back. Shock waves propagated from ground to water are less lethal to fish than in-water explosions since some energy is reflected or lost at ground-water interface (Alaska Department of Fish and Game, 1991). Peak overpressures as low as 7.2 pounds psig produced by blasting on a gravel/boulder beach caused 40 percent mortality in coho smolts and other studies revealed 50 percent mortality in smolts with peak overpressures ranging from 19.3 to 21.0 psig (Alaska Department of Fish and Game, 1991).

Alaska Department of Fish and Game (1991) concluded that fish would be sufficiently protected from blasting on land by limiting overpressures to 2.7 psig. Typical trench blasting scenarios use multiple 1 to 2 pound charges separated by an 8-milisecond delay. With use of 1- to 2-pound charges in rock, the set back distance (at which 2.7 psig would occur) from the pipeline trench to the fish habitat is between 34 and 49 feet (Alaska Department of Fish and Game, 1991). When using the dam-and-pump stream crossing methodology, the typical right-of-way distribution of an isolated streambed (dry open-cut) would be no less than 25 feet on one side of the pipe trench and 50+ feet on the opposite side of the pipe trench, depending on whether it's a 75- or 95-foot width crossing. Therefore, when blasting is used during a waterbody crossing, an area within the crossing equivalent to length of the trench and approximately 25-feet wide (in the worst-case scenario) would be exposed to instantaneous hydrostatic pressure changes above 2.7 psig. Pacific Connector intends to protect fish from blasting within waterbodies by mostly using dry crossing techniques (such as dam-and-pump), removing or excluding fish temporarily from the dry portion of the crossing during construction, and preventing them from re-entering isolated portions within waterbodies crossed for distances sufficient to avoid or minimize adverse effects by blasting within streambeds. The Fish Salvage Plan, provided in appendix T, outlines the measures Pacific Connector would use for accomplishing this, and minimizing impacts from blasting when crossing fish-bearing streams.

<u>Trenching and Backfilling</u>

The depth of the trench would be sufficient to allow for a minimum depth of cover over the pipeline of 30 inches in normal soil and 18 inches in consolidated rock for Class 1 locations.

Pacific Connector would exceed these DOT regulations provided in 49 CFR Part 192 where feasible and would achieve 36 inches of cover in Class I locations with normal soils and up to 24 inches of cover in consolidated rock areas. A rotary trenching machine, rock trencher, track-mounted backhoe, or similar equipment would be used to excavate a trench to a sufficient depth to provide the necessary minimum depth of cover. For class II, III, and IV locations, as well as drainage ditches of paved county, city, and state road and railroad crossings, DOT regulations provided in 49 CFR Part 192 require a minimum cover of 36 inches in normal soil and 24 inches in consolidated rock.

Spoil material excavated during trenching operations would be temporarily piled to one side of the right-of-way adjacent to the trench. In areas where topsoil stripping is required, the topsoil and subsoil would be stored in separate windrows or piles on the construction right-of-way and would not be allowed to mix.

After trenching is complete, the pipe sections would be strung along the trench, bent to fit the contour of the trench bottom, aligned, welded together, and placed on temporary supports along the edge of the trench. All welds would be visually and radiographically inspected and repaired, if necessary. Line pipe, normally mill-coated prior to stringing, would require field applied coating at the welded joints prior to final inspection. The entire pipeline coating would be inspected and tested to locate and repair any faults or voids. The pipe assembly would then be lowered into the trench by side-boom tractors, and the trench would be backfilled using a backfilling machine or bladed equipment. No foreign substance, including skids, welding rods, containers, brush, trees, or refuse of any kind, would be permitted in the backfill.

Pacific Connector would install trench plugs (see Drawing 3430.34-X-0011 in the ERCP in appendix F) consistent with the requirements of the FERC staff's Plan (see Section V.B.1). Trench plugs would be installed at the base of slopes adjacent to wetlands and waterbodies and where needed to avoid draining of wetlands (springs). Trench plugs may be constructed from sandbags, foam, or bentonite. Topsoil would not be used to fill the bags. Trench plugs would be installed on slopes to minimize water flow down the trenchline to prevent potential subsurface erosion and to maximize stability.

<u>Hydrostatic Testing</u>

After backfilling, the pipeline would be hydrostatically tested in accordance with DOT regulations to ensure that the system is capable of operating at the maximum operating pressure. If a leak is identified during hydrostatic testing, the line would be repaired and retested until the specifications are achieved.

Pacific Connector's Hydrostatic Testing Plan (see appendix U) was developed in consultation with the USFS and includes measures to prevent the transfer of aquatic invasive species and disease. Pipeline contractors would develop the final hydrostatic test plan and drawings that would include anticipated flow rates, and intake and discharge volumes and water discharge locations and procedures. Ramping rates would be submitted to ODFW for review prior to hydrostatic testing. Approximately 62 million gallons of water would be required to test the pipeline although much less water is expected to be used due to the ability to reuse test water by cascading water between test sections.

Water for hydrostatic testing would be obtained from commercial or municipal sources, private supply wells, or surface water right owners (see table 3.1.4.3-6). Pacific Connector would negotiate water appropriations with private owners in the year prior to construction. If water for hydrostatic testing is acquired from surface water sources, Pacific Connector would obtain all necessary appropriations and withdrawal permits, including permits through the ODWR. As part of this process, ODWR would have the applications reviewed by ODEQ and ODFW to determine if there are concerns about the impact water withdrawals may have on water quality, and fish and wildlife and their habitats. The review includes volume, timing, and duration of the withdrawal. The withdrawal permit ensures that the proposed withdrawal does not impact existing water rights or beneficial uses of the waterbody. The review process ensures that proposed withdrawals do not contribute to inadequate flow or other flow conditions that inhibit the development and survival of salmonids. Low flows may decrease survival by limiting delivery of nutrients and dissolved oxygen to incubating eggs. As required by ODFW, pumps used to withdraw surface water would be screened according to NMFS standards to prevent entrainment of aquatic species. Pacific Connector would not add unapproved chemicals to the hydrostatic test water.

The Hydrostatic Test Plan (see Appendix U) provides extensive detail regarding water use, and management. In particular, Section 7.0 outlines the measures for the protection of aquatic and terrestrial resources. The BMPs listed in Section 7.2.4 are intended to ensure the prevention of invasive species and pathogen transfer between watershed drainages. Pacific Connector has developed the Hydrostatic Test Plan (see Appendix U) in consultation with appropriate resource and/or regulatory agencies, outlining methods to ensure that invasive species and pathogens would not be transferred between hydrologic basins during hydrostatic testing. These agencies will be provided the opportunity to review the final Hydrostatic Test Plan prior to the start of construction.

The pipeline would be tested in approximately 75 sections; each with varying lengths and water volume requirements (see table 3.1.4.3-7). The required test pressure ranges, pipe strength topography (specifically elevation changes), and the availability of test water are used to determine the length of each test segment. During the test, it may be necessary to discharge water at each of the section breaks; however, Pacific Connector would conserve water as much as practical and minimize discharge where feasible by cascading, or transferring, water between test sections. After the test is complete, hydrostatic test water would be discharged to an upland area through a filter bag or straw bale structure to remove particulates and prevent the potential for sediment transport and ground surface erosion. In addition to the 75 test header section breaks located within the construction right-of-way or TEWAs, Pacific Connector has identified six potential hydrostatic discharge locations outside of the construction right-of-way and TEWAs (see table 3.1.4.3-8). In these six locations, small brush or trees may be cleared by a rubber-tired rotary or flail motor (brush hog) or by hand with machetes/chainsaws. No soil disturbance would occur. A rubber-tired or track hoe would be utilized to lay the discharge line and to remove the saturated haybales or filter bags upon completion of hydrostatic discharge.

TABLE 3.1.4.3-6

|

**Potential Hydrostatic Source Locations**

| County | MP | Source | | Owner | Volume (gal) |
|---|---|---|---|---|---|
| Coos Bay Frontal Pacific Ocean (1710030403) | | | | | |
| Coos | 1.47R | Coos Bay - North Bend Water Board | | Coos Bay - North Bend Water Board | 14,204,643 |
| M. F. Coquille River (1710030501) | | | | | |
| Douglas | 50.20 | Water Impoundment | Kinnan Lake | 5-J Limited Partnership, Donald R. Johnson 29080601300 | 2,098,651 |
| Olalla Creek-Lookingglass Creek (1710030212) | | | | | |
| Douglas | 55.90 | Water Impoundment | Ben Irving Reservoir | Douglas County Public Works/ Looking Glass Olalla Water District/ Winston-Dillard Water District | 1,390,902 |
| Douglas | 58.75 | Looking Glass Olalla Water District (Olalla Creek Crossing) | | Looking Glass Olalla Water District | 2,098,699 |
| Clark Branch-South Umpqua River (1710030211) | | | | | |
| Douglas | 71.30 | S. Umpqua River Crossing #1 | | Oregon Department of Water Resources | 5,572,843 |
| Days Creek-South Umpqua River (1710030205) | | | | | |
| Jackson | 94.73 | S. Umpqua River Crossing #2 | | Oregon Department of Water Resources | 6,695,648 |
| Shady Cove-Rogue River (1710030707) | | | | | |
| Jackson | 122.5 | Rogue River Crossing | | Oregon Department of Water Resources | 8,770,257 |
| Little Butte Creek (1710030708) | | | | | |
| Jackson | 146.70 | N. Fork Little Butte Creek Crossing | | Medford Irrigation District/ Rogue River Valley Irrigation District | 1,883,276 |
| Jackson | | | | | |
| Jackson | 161.40 | Water Impoundment | Fish Lake | | 3,420,951 |
| Fourmile Creek (1801020302) | | | | | |
| Klamath | 168.90 | Water Impoundment | Lake Of The Woods National Forest Lake | United States (Rogue River-Siskiyou NF) | 4,102,136 |
| John C Boyle Reservoir-Klamath River (1801020602) | | | | | |
| Klamath | 184.30 | Water Impoundment | John C. Boyle Reservoir | Oregon Department of Water Resources | 2,282,231 |
| Lake Ewauna-Klamath River (1801020412) | | | | | |
| Klamath | 189.00 | Water Impoundment | Keno Reservoir | Oregon Department of Water Resources | 3,359,703 |
| Klamath | 199.20 | Klamath River | | | 3,308,134 |
| Mills Creek–Lost River (1801020409) | | | | | |
| Klamath | 228.1 | High Line Canal | | Malin Irrigation District | 2,923,230 |
| | | | | **Total** | **62,111,304 (190.61)** |

TABLE 3.1.4.3-7

**Potential Hydrostatic Discharge (Test Header) Locations within the Construction Right-of-Way**

| Test Section [1] | HUC (Begin MP) | HUC (Ending MP) | Begin MP [2] | End MP | Section Length [3] (feet) | Volume [4, 5] (gallons) (acre feet) | Jurisdiction [6] |
|---|---|---|---|---|---|---|---|
| 1 | Coos Bay Frontal Pacific Ocean 1710030403 | Coos Bay Frontal Pacific Ocean 1710030403 | 1.47R | 4.17R | 14,045 | 694,074 (2.13) | Private |
| 1a | Coos Bay Frontal Pacific Ocean 1710030403 | Coos Bay Frontal Pacific Ocean 1710030403 | 4.17R | 8.33R | 23,443 | 1,158,530 (3.56) | Private |
| 1b | Coos Bay Frontal Pacific Ocean 1710030403 | Coos Bay Frontal Pacific Ocean 1710030403 | 8.33R | 11.34R | 14,626 | 722,776 (2.22) | Private |
| 1c | Coos Bay Frontal Pacific Ocean 1710030403 | Coos Bay Frontal Pacific Ocean 1710030403 | 11.34R | 12.79 | 15,840 | 782,790 (2.40) | Private |
| 3 | Coos Bay Frontal Pacific Ocean 1710030403 | N. F. Coquille River 1710030504 | 12.79 | 21.08 | 43,771.20 | 2,133,712 (6.55) | Private |
| 4 | N. F. Coquille River 1710030504 | E. F. Coquille River 1710030503 | 21.08 | 28.31 | 38,174.40 | 1,896,299 (5.82) | Private |
| 5 | E. F. Coquille River 1710030503 | E. F. Coquille River 1710030503 | 28.31 | 30.91 | 13,728.00 | 718,249 (2.20) | Private |
| 6 | E. F. Coquille River 1710030503 | M. F. Coquille River 1710030501 | 30.91 | 35.81 | 25,872.00 | 1,252,178 (3.84) | Private |
| 7 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 35.81 | 37.80 | 10,507.20 | 535,932 (1.64) | BLM-Coos |
| 8 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 37.80 | 38.40 | 3,168.00 | 130,878 (0.40) | BLM-Coos |
| 9 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 38.40 | 43.92 | 29,145.60 | 1,502,964 (4.61) | BLM-Coos |
| 10 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 43.92 | 45.00 | 5,702.40 | 294,512 (0.90) | Private |
| 11 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 45.00 | 46.74 | 9,240.00 | 444,774 (1.36) | BLM-Coos |
| 12 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 46.74 | 47.08 | 1,584.00 | 81,141 (0.25) | Private |
| 13 | M. F. Coquille River 1710030501 | M. F. Coquille River 1710030501 | 47.08 | 47.75 | 2,956.80 | 160,279 (0.49) | BLM-Roseburg |
| 14 | M. F. Coquille River 1710030501 | Olalla / Lookingglass Creek 1710030212 | 47.75 | 52.67 | 26,611 | 1,315,088 (4.04) | BLM-Roseburg |

TABLE 3.1.4.3-7

**Potential Hydrostatic Discharge (Test Header) Locations within the Construction Right-of-Way**

| Test Section [1] | HUC (Begin MP) | HUC (Ending MP) | Begin MP [2] | End MP | Section Length [3] (feet) | Volume [4, 5] (gallons) (acre feet) | Jurisdiction [6] |
|---|---|---|---|---|---|---|---|
| 15 | Olalla / Lookingglass Creek 1710030212 | Olalla / Lookingglass Creek 1710030212 | 52.67 | 53.74R | 5,755 | 284,414 (0.87) | BLM-Roseburg |
| 16 | Olalla / Lookingglass Creek 1710030212 | Olalla / Lookingglass Creek 1710030212 | 53.74R | 55.70 | 10,348.80 | 472,622 (1.45) | Private |
| 17 | Olalla / Lookingglass Creek 1710030212 | Olalla / Lookingglass Creek 1710030212 | 55.70 | 57.78R | 10,982 | 542,735 (1.67) | Private |
| 18 | Olalla / Lookingglass Creek 1710030212 | Olalla / Lookingglass Creek 1710030212 | 57.78R | 60.89 | 16,421 | 811,493 (2.49) | Private |
| 19 | Olalla / Lookingglass Creek 1710030212 | Clark Branch – South Umpqua 1710030211 | 60.89 | 63.75 | 15,100.80 | 779,356 (2.39) | BLM-Roseburg |
| 20 | Clark Branch – South Umpqua 1710030211 | Clark Branch – South Umpqua 1710030211 | 63.75 | 65.60 | 9,768.00 | 467,814 (1.44) | Private |
| 21 | Clark Branch – South Umpqua 1710030211 | Clark Branch – South Umpqua 1710030211 | 65.60 | 69.12 | 19,536.00 | 851,481 (2.61) | Private |
| 22 | Clark Branch – South Umpqua 1710030211 | Clark Branch – South Umpqua 1710030211 | 69.12 | 70.80 | 7,920.00 | 493,006 (1.51) | Private |
| 23 | Clark Branch – South Umpqua 1710030211 | Myrtle Creek 1710030210 | 70.80 | 73.41 | 13,780.80 | 731,272 (2.24) | Private |
| 24 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 73.41 | 73.54 | 686.40 | 33,921 (0.10) | Private |
| 25 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 73.54 | 75.99 | 12,936.00 | 395,688 (1.21) | Private |
| 26 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 75.99 | 76.21 | 1,161.60 | 93,162 (0.29) | Private |
| 27 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 76.21 | 77.94 | 9,134.40 | 447,779 (1.37) | Private |
| 28 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 77.94 | 79.01 | 5,649.60 | 290,505 (0.89) | Private |
| 29 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 79.01 | 79.80 | 4,171.20 | 206,135 (0.63) | Private |
| 30 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 79.80 | 80.71 | 4,804.80 | 275,479 (0.85) | BLM-Roseburg |
| 31 | Myrtle Creek 1710030210 | Myrtle Creek 1710030210 | 80.71 | 81.62 | 7,867.20 | 420,732 (1.29) | Private |
| 32 | Myrtle Creek 1710030210 | Days Creek-South Umpqua River | 81.62 | 83.80 | 8,448.00 | 433,755 (1.33) | BLM-Roseburg |

TABLE 3.1.4.3-7

**Potential Hydrostatic Discharge (Test Header) Locations within the Construction Right-of-Way**

| **Test Section** [1] | **HUC (Begin MP)** | **HUC (Ending MP)** | **Begin MP** [2] | **End MP** | **Section Length** [3] **(feet)** | **Volume** [4, 5] **(gallons) (acre feet)** | **Jurisdiction** [6] |
|---|---|---|---|---|---|---|---|
| | | 1710030205 | | | | | |
| 33 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 83.80 | 88.11 | 22,756.80 | 1,108,929 (3.40) | Private |
| 34 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 88.11 | 89.17 | 5,596.80 | 320,558 (0.98) | Private |
| 35 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 89.17 | 90.01 | 4,435.20 | 219,181 (0.67) | Private |
| 36 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 90.01 | 92.27 | 11,932.80 | 620,079 (1.90) | BLM-Roseburg |
| 37 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 92.27 | 92.75 | 2,534.40 | 125,246 (0.38) | Private |
| 38 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 92.75 | 93.09 | 1,795.20 | 120,209 (0.37) | Private |
| 39 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 93.09 | 93.91 | 4,329.60 | 279,486 (0.86) | Private |
| 40 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 93.91 | 95.52R | 8,659 | 427,925 (1.31) | BLM-Roseburg |
| 41 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 95.52R | 96.27 | 4,066 | 200,916 (0.62) | BLM-Roseburg |
| 42 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 96.27 | 100.71 | 23,443.20 | 1,169,034 (3.59) | Private |
| 43 | Days Creek-South Umpqua River 1710030205 | Days Creek-South Umpqua River 1710030205 | 100.71 | 101.50 | 4,171.20 | 206,135 (0.63) | Private |
| 44 | Days Creek-South Umpqua River 1710030205 | Upper Cow Creek 1710030206 | 101.50 | 103.95 | 12,936.00 | 716,246 (2.20) | USFS-Umpqua |
| 45 | Upper Cow Creek 1710030206 | Elk Creek / S. Umpqua 1710030204 | 103.95 | 107.09 | 16,579.20 | 836,455 (2.57) | Private |
| 46 | Elk Creek / S. Umpqua | Upper Cow Creek | 107.09 | 110.36R | 17,266 | 853,241 (2.62) | USFS-Umpqua |

TABLE 3.1.4.3-7

**Potential Hydrostatic Discharge (Test Header) Locations within the Construction Right-of-Way**

| Test Section [1] | HUC (Begin MP) | HUC (Ending MP) | Begin MP [2] | End MP | Section Length [3] (feet) | Volume [4, 5] (gallons) (acre feet) | Jurisdiction [6] |
|---|---|---|---|---|---|---|---|
| | 1710030204 | 1710030206 | | | | | |
| 47 | Upper Cow Creek 1710030206 | Trail Creek 1710030706 | 110.36R | 112.54 | 11,510 | 568,828 (1.75) | USFS-Umpqua |
| 48 | Trail Creek 1710030706 | Trail Creek 1710030706 | 112.54 | 115.13 | 13,675.20 | 716,246 (2.20) | USFS-Umpqua |
| 49 | Trail Creek 1710030706 | Trail Creek 1710030706 | 115.13 | 117.68 | 13,464.00 | 639,112 (1.96) | BLM-Medford |
| 50 | Trail Creek 1710030706 | Shady Cove - Rogue River 1710030707 | 117.68 | 122.23 | 24,024.00 | 1,231,142 (3.80) | BLM-Medford |
| 51 | Shady Cove - Rogue River 1710030707 | Shady Cove - Rogue River 1710030707 | 122.23 | 123.73 | 7,920.00 | 343,598 (1.05) | Private |
| 52 | Shady Cove - Rogue River 1710030707 | Shady Cove - Rogue River 1710030707 | 123.73 | 127.36 | 19,166.40 | 996,734 (3.06) | BLM-Medford |
| 53 | Shady Cove - Rogue River 1710030707 | Big Butte Creek 1710030704 | 127.36 | 132.05 | 24,763.20 | 1,223,762 (3.76) | Private |
| 54 | Big Butte Creek 1710030704 | Big Butte Creek 1710030704 | 132.05 | 133.85 | 9,504.00 | 480,836 (1.48) | Private |
| 55 | Big Butte Creek 1710030704 | Little Butte Creek 1710030708 | 133.85 | 141.00 | 37,752.00 | 1,898,302 (5.83) | Private |
| 56 | Little Butte Creek 1710030708 | Little Butte Creek 1710030708 | 141.00 | 147.74 | 38,385.60 | 1,896,962 (5.82) | BLM-Medford |
| 57 | Little Butte Creek 1710030708 | Little Butte Creek 1710030708 | 147.74 | 148.93 | 3,484.80 | 172,214 (0.53) | Private |
| 58 | Little Butte Creek 1710030708 | Little Butte Creek 1710030708 | 148.93 | 151.40 | 13,041.60 | 644,497 (1.98) | BLM-Medford |
| 59 | Little Butte Creek 1710030708 | Little Butte Creek 1710030708 | 151.40 | 155.44 | 21,331.20 | 1,054,158 (3.24) | BLM-Medford |
| 60 | Little Butte Creek 1710030708 | Little Butte Creek 1710030708 | 155.44 | 160.12 | 24,710.40 | 1,071,865 (3.29) | Private |
| 61 | Little Butte Creek 1710030708 | Spencer Creek 1801020601 | 160.12 | 168.60 | 44,774.40 | 2,212,687 (6.79) | USFS-Rogue River |
| 62 | Spencer Creek 1801020601 | Spencer Creek 1801020601 | 168.60 | 173.10R | 23,760 | 1,174,185 (3.60) | USFS-Winema |
| 63 | Spencer Creek 1801020601 | Spencer Creek 1801020601 | 173.10R | 177.09 | 21,067 | 1,041,111 (3.20) | USFS-Winema/ Private |
| 64 | Spencer Creek 1801020601 | Lake Ewauna / Upper Klamath River 1801020412 | 177.16R | 188.89 | 68,218 | 3,371,217 (10.35) | Private |
| 65 | Lake Ewauna / | Lake Ewauna / | 188.89 | 194.05 | 20,961.60 | 1,035,892 | Private |

TABLE 3.1.4.3-7

**Potential Hydrostatic Discharge (Test Header) Locations within the Construction Right-of-Way**

| **Test Section [1]** | **HUC (Begin MP)** | **HUC (Ending MP)** | **Begin MP [2]** | **End MP** | **Section Length [3] (feet)** | **Volume [4, 5] (gallons) (acre feet)** | **Jurisdiction [6]** |
|---|---|---|---|---|---|---|---|
| | Upper Klamath River 1801020412 | Upper Klamath River 1801020412 | | | | (3.18) | |
| 66 | Lake Ewauna / Upper Klamath River 1801020412 | Lake Ewauna / Upper Klamath River 1801020412 | 194.05 | 194.50 | 2,376.00 | 1,099,913 (3.38) | Private |
| 67 | Lake Ewauna / Upper Klamath River 1801020412 | Lake Ewauna / Upper Klamath River 1801020412 | 194.50 | 197.40 | 15,312.00 | 756,697 (2.32) | Private |
| 68 | Lake Ewauna / Upper Klamath River 1801020412 | Lake Ewauna / Upper Klamath River 1801020412 | 197.40 | 199.70 | 12,144.00 | 766,333 (2.35) | Private |
| 69 | Lake Ewauna / Upper Klamath River 1801020412 | Lake Ewauna / Upper Klamath River 1801020412 | 199.70 | 203.91 | 22,228.80 | 1,098,516 (3.37) | Private |
| 70 | Lake Ewauna / Upper Klamath River 1801020412 | Mills Creek - Lower Lost River 1801020409 | 203.91 | 208.25 | 22,915 | 1,132,437 (3.48) | Private |
| 71 | Mills Creek - Lower Lost River 1801020409 | Mills Creek - Lower Lost River 1801020409 | 208.25 | 218.31 | 53,117 | 2,624,957 (8.06) | Private |
| 72 | Mills Creek - Lower Lost River 1801020409 | Mills Creek - Lower Lost River 1801020409 | 218.31 | 228.13 | 51,850 | 2,562,333 (7.86) | Private<br>Private [5] |
| | | | | | **Total [6]** | **62,111,304 (190.61)** | |

[1] Test section locations will be finalized after final engineering design and the construction contractors have been selected for the project.

[2] Beginning and end mileposts were extrapolated from environmental alignment sheets. Mileposts were not calculated from engineering stationing and may not provide a direct correlation between milepost and engineering stationing. "R" represents a revised milepost location based on the incorporation of reroutes into the proposed route.

[3] Section length reflects actual footage calculated directly from engineering stationing.

[4] Section volumes were calculated using section length directly from engineering stationing.

[5] Estimated discharge volume – based on previous test section volume. Water will be cascaded between test sections, where practical, to fill each section to minimize test water requirements.

[6] Jurisdiction corresponds with each test section's beginning MP except Test Section 72 where jurisdiction is provided for both the beginning and ending MPs.

| TABLE 3.1.4.3-8<br><br>**Potential Hydrostatic Discharge Locations Outside of the Construction Right-of-Way** | | | | |
|---|---|---|---|---|
| **MP (Watershed/ HUC)** | **Size (acre)** [1] | **Corresponding Test Section(s)** | **Volume** [2] **(gallons) (acre feet)** | **Jurisdiction** |
| 11.36R (Coos Bay-Frontal Pacific Ocean) | 0.13 | 1c, 2 | 782,790 (2.40) | Private |
| 57.72 (Olalla / Lookingglass Creek 1710030212) | 0.13 | 17, 18 | 542,735 (1.67) | Private |
| 69.13 (Clark Branch – South Umpqua 1710030211) | 0.13 | 21, 22 | 851,481 (2.61) | Private |
| 88.09 (Days Creek-South Umpqua River 1710030205) | 0.44 | 33, 34 | 1,108,929 (3.40) | Private |
| 127.39 (Shady Cove-Rogue River 1710030707) | 0.13 | 52, 53 | 996,734 (3.06) | Private/BLM |
| 208.29 (Mills Creek - Lower Lost River 1801020409) | 0.14 | 70, 71 | 1,132,437 (3.48) | Private |
| **Total** | **1.10** | | **5,415,106 (16.62)** | |

[1] Small brush or trees may be cleared by a rubber-tired rotary or flail motor (brush hog) or by hand with machetes/chainsaws. No soil disturbance will occur. A rubber-tired or track hoe will be utilized to lay the discharge line and to remove the saturated hay bales or filter bags upon completion of hydrostatic discharge.

[2] These volumes are included in Table 3.1.3.3-6; they are NOT additional volumes. Estimated discharge volume – based on previous test section volume. Water will be cascaded between test sections, where practical, to fill each section to minimize test water requirements.

Permission to discharge the hydrostatic test water would be applied for concurrently with the request for coverage under the ODEQ General Stormwater Discharge Permit and permitted through a separate letter of approval. Hydrostatic test water would be discharged into upland areas at a rate to prevent scour, erosion, and sediment migration to sensitive resources such as wetlands and waterbodies (see Pacific Connector's ECRP in appendix F). Discharge rates would range from several hundred gallons per minute to several thousand gallons per minute, depending on the length of the test section, profile, topography, vegetation cover, and soil type, and as reviewed by the contractor and the EI.

The hydrostatic testing discharge would be conducted utilizing discharge structures that dissipate velocity of the discharge and filter out any potentially present dirt, grit, or oxidation that would be present collectively as total dissolved solids. The discharge structure is placed in an upland location that is topographically appropriate to allow the flow to "pool" and discharge uniformly through the structure to promote infiltration of the discharge water. Flow rates to the discharge structure can be controlled by controlling the discharge valve to ensure the discharged flows do not flow above the carrying capacity of the structure(s). Additionally, as shown in the ECRP (see attachment C to appendix F, Drawing 3430.34-X-0012) water discharge can be controlled by discharging into a central tank and then pumping to multiple discharge structures concurrently or successively (one then the other) to control discharge rates/volumes to promote infiltration, minimize overland flow and to prevent overland flow to waterbodies (for more detail see the Hydrostatic Testing Plan in appendix U). Pacific Connector's EIs would be responsible for monitoring discharge activities and making appropriate adjustments to facilitate proper infiltration through the discharge structures.

The hydrostatic discharge would be filtered on uptake and again upon discharge, and this filtering would prevent the transport of seeds or vegetative matter through the hydrostatic testing process. Where possible, Pacific Connector would release water within the same basin from which it was withdrawn. However, cascading water from one test section to another to minimize water withdrawal requirements may make it impractical to release water within the same basin where the water was withdrawn. Where water is withdrawn from surface waters, pump screening would meet both NMFS and ODFW screening criteria, which would minimize the potential of invasive species transmission from the hydrostatic testing process. Prior to water withdrawal, Pacific Connector would also review U.S. Geological Survey (USGS) biological research division data to determine where known locations of invasive species and pathogen infestation exist along the pipeline project area and at proposed water source locations (see Appendix U).

Hydrostatic test water would be discharged at a rate to prevent scour, erosion, and sediment migration to sensitive resources such as wetlands and waterbodies. When discharged, the test water would be released into a dewatering device such as a straw bale structure or sediment bag to minimize possible peak flow effects by dissipating the energy of the test water flow, filter the test water to avoid sedimentation, and by allowing release of the test water as sheet flow back into the ground (see appendix U, attachment A, Drawing 3430.34-X-0012 and Drawing 3430.34-X-0013). The discharge would occur to an appropriately sized discharge structure based on the expected quantity of water to be discharged. Hydrostatic test water would be released in upland areas through a discharge structure prior to entering the ground at least 150 feet from wetlands and waterbodies. The hydrotest water would not be allowed to discharge directly to wetlands or waterbodies. Pacific Connector would ensure, as stated in the FERC staff's Procedures (VII.D.2), that discharge into state-designated exceptional value waters, waterbodies that provide habitat for federally listed threatened or endangered species, or waterbodies designated as public water supplies would not occur unless appropriate federal, state, and local permitting agencies grant written permission.

Generally, water quality of discharged water from hydrostatic testing is similar to the quality of water when filled, especially test water discharged from new pipes (Tallon et al., 1992). Tallon et al. (1992) recognized that "concentrations of constituents found in the discharge waters did not significantly change from those observed in the fill waters. Exceptions to this observation include oil and grease." But, the excess oil and grease reported was only from one of the three pipelines studied. If not for that one sample, there would not have been a significant change in oil and grease between fill and discharge water, consistent with the other constituents analyzed. Tallon et al. (1992) further explain, "as would be expected, existing pipelines were reported to have higher constituent levels than new pipelines." In any case, hydrostatic test water would not be discharged into aquatic environments. Tallon's discharge water analysis was from hydrostatic testing of pipelines that had been in service from 34 to 43 years, not for water discharged from newly constructed pipelines.

Pacific Connector has data from a 2006 pipeline construction project in Washington that installed a new 36-inch-diameter natural gas pipe. The results of the hydrostatic discharge test from this project are more comparable to the expected discharge quality that would occur from testing of the Pacific Connector pipeline. The 2006 project discharged 17,034,047 gallons of test water from multiple discharge points over a 4-month period. The 2006 project was under a state permit that had a permit discharge limitation for oil and grease at 10 mg/L (ppm). This is identical to the NPDES discharge limits issued by ODEQ for discharges to waters of the United States and state of Oregon. The 2006 project discharge water was analyzed for oil and grease as total petroleum hydrocarbons (TPH) in the range of diesel or oil organic compounds using methods NWTPH-D and NWTPH-Dx, again the same methodology recognized by ODEQ. The 2006 project analyzed only the discharge water, not the source water, so it would be assumed that the source water oil and grease levels are “Non Detect.”

For the 2006 project in Washington, almost all of the discharged hydrostatic test water (99.99 percent) contained levels of oil and grease below the permit limit. To break out concentrations of oil and grease from testing new pipe installations, the following data analysis is provided.

- 9,494,054 gallons (56 percent) of the test water discharged by the 2006 project was reported to have oil and grease at “Non Detect” levels or no greater than the source water;
- 4,459,460 gallons (26 percent) of test water discharge contained reported oil and grease at levels above “Non Detect” but less than 1 ppm for either range;
- 3,076,033 gallons (18 percent) of test water discharge contained reported oil and grease at levels above 1ppm but less than 3 ppm for either range;
- 1,200 gallons (0.01 percent) of test water exceeded the oil and grease permit limit of 10 ppm (discharge reported at 21ppm diesel range/11 ppm oil range organic compounds, the source of which was identified to be a greased fitting on the discharge valve controller that extended into the water flow).

Considering that water is essentially a non-compressible material, temperature increases from pressurization during hydrostatic testing is negligible. During the hydrostatic testing phase of the project, the pipeline is buried, except for a small area (approximately 200 feet) immediately at the hydrostatic test header location and is not exposed to potential solar heating. Therefore, the test water is at ground temperature and the potential to increase water temperatures during hydrostatic testing is inconsequential.

It is projected that pipeline construction would be completed in late summer to early fall of the pipeline construction season, which would also minimize potential adverse impacts to terrestrial and aquatic ecosystems. The pipeline must be tested immediately following completion of construction so that any failures could be repaired and retested while the construction phase is still active. Intentionally delaying hydrostatic testing until late fall or winter would result in unnecessarily extending the entire construction duration of the project, extending the length the construction contractor remains on site, continued right-of-way and access disturbance, as well as delaying final cleanup and restoration of the right-of-way. Winter testing would be particularly problematic in that much of the right-of-way would be under snow and in wet/muddy condition.

Dust and Fire Control Water

During pipeline construction, Pacific Connector would need to obtain water for dust and fire control purposes. Control of construction-generated fugitive dust may be necessary during dry periods, such as the summer. The EI would direct dust control efforts to places deemed necessary, including residential areas and other locations along the pipeline route where dust is considered a safety or public nuisance, including access roads. Typically, water trucks would fill up with water at designated sources, and spray selected areas along the construction right-of-way and access roads, to keep dust down. The water trucks would spray only enough water to control dust or reach an optimum soil moisture content, and not enough to create a problem with water runoff, erosion, and sedimentation.

Additionally, Pacific Connector has indicated it may utilize a synthetic product such as Dustlock®, in addition to water, for dust control. Dustlock® is a naturally occurring by-product of the vegetable oil refining process. Dustlock® penetrates into the bed of the material and bonds to make a barrier that is naturally biodegradable, ensuring that the surrounding ground and water are not contaminated, and minimizing any potential effects to fish and wildlife. While there are no known health risks by the use of Dustlock® to fish and wildlife resources, Pacific Connector would not use Dustlock® within riparian areas.

Cleanup and Permanent Erosion Control Devices

*Cleanup*

Pacific Connector would make every effort to complete final cleanup of an area within 20 days after backfilling the trench. Final cleanup would include final grading and installation of permanent erosion control structures. In no case would Pacific Connector delay final cleanup beyond the end of the next recommended seeding season. During final cleanup, Pacific Connector would remove all construction debris and grade disturbed areas to approximate preconstruction grade to the extent practicable. During final cleanup and initial restoration, fences, gates, drainage ditches, culverts, and other structures that may have been temporarily removed or damaged during construction would be permanently repaired, returned to their preconstruction condition, or replaced. All drain tiles crossed by the pipeline would be checked, and if damaged, they would be repaired before backfilling. All areas disturbed by construction activities would be re-graded during restoration, with contours matching the surrounding landscape, and pre-construction natural drainage patterns re-established. Pacific Connector would install erosion control fabric (such as jute or excelsior) to stabilize streambanks during restoration.

However, if it appears that construction may continue into the winter because of unforeseen delays and cleanup and reseeding is delayed until the spring, Pacific Connector would implement the winterization plan (see attachment E to the ECRP in appendix F). This plan describes the procedures that would be implemented to minimize potential impacts associated with delayed cleanup (i.e., temporary erosion controls procedures, topsoil stabilization, reseeding, etc.).

*Permanent Erosion Control Devices*

Pacific Connector would install permanent erosion control devices or BMPs consistent with the requirements of Section V.B. of the FERC staff's Plan and as described in the pipeline project-specific ECRP provided in appendix F. These BMPs would consist predominantly of trench breakers, slope breakers or waterbars, and revegetation measures to permanently stabilize disturbed areas. Pacific Connector would utilize the spacing for these structures as specified in FERC staff's Plan (Section V.B.1.b, and V.B.2.b) or as recommended by the BLM, USFS, or NRCS. Because the recommendations from these agencies varied, Pacific Connector developed specifications that are consistent across the pipeline project based on slope and soil characteristics, and that utilize the agency recommendations as much as practical.

Revegetation

As required by the FERC staff's Plan, Pacific Connector consulted with the NRCS, the BLM, and the USFS regarding specific seeding dates and recommended seed mixtures for the pipeline project area. The recommendations have been incorporated into the pipeline project-specific ECRP (see appendix F). The ECRP describes the procedures that would be implemented to minimize erosion and enhance revegetation success for the entire pipeline project. The ECRP describes the procedures that would be utilized to minimize the spread of noxious weeds as a result of pipeline project construction. The ECRP describes the silvicultural prescriptions that would be implemented in areas that are outside the permanent easement.

All areas disturbed by construction, including the construction right-of-way, TEWAs, UCSAs, and contractor yards as necessary, would be restored and revegetated in accordance with Pacific Connector's ECRP. Prior to seeding, the disturbed areas would be prepared as a seedbed approximately 3 to 4 inches deep using appropriate equipment, as necessary in certain areas, as determined by the EI. This could include chisel plowing or disking. In most areas, typical regrading and contouring during restoration would create a suitable rough, yet firm, seedbed, conducive to capturing seeds and retaining soil moisture. In residential and cropland areas, additional cleanup activities prior to the preparation of a proper seedbed may include rock removal.

Pacific Connector would work with individual landowners in agricultural areas to determine how the right-of-way would be restored where the pipeline would cross croplands. Usually, in agricultural areas, the landowner determines whether or not Pacific Connector would be responsible for seeding. In some situations, the owner of agricultural land may do the final restoration and seeding and Pacific Connector would compensate the landowner for those efforts.

In residential areas, Pacific Connector would restore disturbed lawns, ornamental shrubs, gardens, and other landscape features in accordance with their agreement with the landowner. The restoration work in residential areas would be done by a contractor familiar with local horticultural or landscape practices, or Pacific Connector may choose to compensate a landowner to restore their property.

Based on Oregon State University Extension Service recommendations for fertilization rates for nitrogen fertilizer on new pasture seedlings, Pacific Connector intends to use a standard fertilization rate of 200 pounds per acre bulk triple-16 fertilizer on disturbed areas to be seeded. The NRCS did not recommend the addition of lime or other soil pH modifiers. Fertilizer would not be used in wetlands, unless required by the land-managing agencies, and would not be applied within 100 feet of streams. The fertilizer would be stored outside of riparian reserves and away from streams, and would not be applied during heavy rains or high wind conditions. It could be either broadcast, or incorporated in the slurry for hydroseeding.

Prior to construction, Pacific Connector would submit a Request for Service (RFS) to native seed vendors and growers to provide the necessary quantity of native seed that would be required for pipeline project restoration and erosion control. In the RFS, Pacific Connector would provide the estimated quantity of native grass seed required by species and by ecozone according to the Seed Mixtures specified in Tables 10.9-1, 10.9-2 and 10.9-3 of the ECRP (see appendix F). Pacific Connector has had discussions with various local native seed vendors in Oregon during the prefiling process regarding availability of native seed and ability to provide/produce the necessary quantity of seed for the pipeline project. Pacific Connector contacted Heritage Seedlings, Inc. Oregon Wholesale Seed Company, Pacific NW Natives, and Callahan Seed, among others. These vendors indicated that they could provide the various native seed species required for the pipeline project over the 2-year collection/growing season that would occur between the beginning of construction and restoration. Further, the Native Seed Network (http://www.nativeseednetwork.org/index) provides a useful tool to search for available native seed and seed vendors.

Pacific Connector also visited the J. Herbert Stone Nursery, at the direction of the USFS and BLM, because the nursery produces native seed for these agencies' projects and for fire restoration. Under a cooperative agreement the nursery could produce seed for the pipeline project. The nursery also stores surplus native seed for the various agencies and this surplus seed could also be available through agreements with the agencies based their need.

It is expected that seeding would be timed to begin in August and could extend into the winter months at lower elevations. Seeding may be done by broadcast methods, drilling, or hydroseeding. Broadcast seeding, using a mechanical broadcaster seeder, is the preferred method of seeding on steep slopes. After broadcast, the seedbed would be dragged by chains or other appropriate harrows to cover the seeds thinly with soil. Hydroseeding would be done in accessible upland areas. Hydroseeding equipment would include tanks, pumps, nozzles, and other devices for mixing the seed hydraulically with wood fiber mulch and tackifier. A built-in agitator would keep the seed, mulch, tackifier, and water mixed together homogeneously until pumped from the tank. A drill seeder pulled by a tractor may be used in gently sloping areas.

The seed mixtures were determined in consultations with the land-managing agencies and the NRCS. The seed mixtures on BLM land were developed based on BLM Instruction Memo-2001-014, which specifies the use of native species, if possible. During right-of-way easement negotiations, private landowners may select their own seed mixtures other than those proposed for elsewhere along the pipeline route. The seed mixture seeding rates are based on Pure Live Seed. The seed mixture should be free of noxious weeds.

Mulch would be applied on slopes were necessary to stabilize the right-of-way after seeding. Mulch would consist of native wood chips, wood fiber mulch mixed with the hydroseed, bonded fiber matrix to be used on slopes steeper than 40 percent grade (greater than 2.5 to 1), and certified weed-free straw.

Waterbody Crossings

The Pacific Connector pipeline would affect 400 waterbodies. Of the 400 waterbodies that would be affected, 101 are perennial, 164 are intermittent, 128 are ditches, 6 are stock ponds, and 1 is an estuary (Coos Bay). Waterbodies would be crossed in accordance with the FERC staff's Procedures and applicable permits from other agencies. It is expected that the intermittent waterbodies and the ditches would be dry during construction. Excluding the ditches, the table in appendix M lists the waterbodies affected by the Pacific Connector pipeline and provides the proposed crossing method for each, the rationale for the proposed method, whether federally listed species are present, the ODFW-recommended in-water work window, and whether a crossing bridge is required.

The list of waterbodies crossed by the pipeline is based on field investigations that were conducted during 2006 and 2008; review of USGS topographic maps; review of GIS data from the Oregon/Washington Hydrography Framework Partnership (August 29, 2005) published by the BLM in Oregon providing geographic hydrology information; and review of recent low level and high resolution aerial photography (2012) and LiDAR data developed for the pipeline project during 2006. Pacific Connector would cross waterbodies using conventional crossing techniques within the ODFW suggested in-water construction windows.

Pacific Connector plans to cross intermittent flowing streams, and irrigation canals and ditches when they are dry, using standard upland, cross-country pipeline construction methods. If water is flowing at the time of the crossing, a dry crossing method would be used (i.e., flume or dam-and-pump, see below). The standard depth of cover would be 5 feet below intermittent flowing streams and ditches.

Pacific Connector proposes to use an HDD to go under three rivers (Coos River, Rogue River, and Klamath River) and a Direct Pipe to go under the first crossing of the South Umpqua River. Three waterbodies (Kentuck Slough, Catching Slough, and the Medford Canal) would be bored under. The crossing of Coos Bay would be a wet open cut. The second crossing of the South Umpqua River would be done using a diverted open cut. All other waterbodies would be crossed with dry open cut methods.

Forty-five streams crossed or adjacent to the pipeline route are known to support anadromous salmon and/or steelhead, and 33 streams are assumed to support anadromous salmon and/or steelhead. There are 48 streams crossed or adjacent to the pipeline route that are known to support resident fish, and 69 that are assumed to support resident fish. In all, there are 116 waterbodies known or assumed to be fish-bearing and one estuarine waterbody that is fish-bearing. Of that total, EFH species and habitat have been documented in 40 waterbodies and are assumed to be present in 36 more (see appendix M).

Pipeline crossings of perennial waterbodies would be made nearly perpendicular to the axis of the waterbody channel, where feasible. The pipeline route would avoid paralleling a waterbody within 15 feet or less, where feasible. Where possible, Pacific Connector has located TEWAs so that they are no closer than 50 feet from waterbody boundaries. However, where topographic conditions or other constraints prevent the 50-foot waterbody setback, these areas have been noted and described in appendix H. Consistent with Section V. B. 2. a. of the FERC staff's Procedures, where the uplands adjacent to a waterbody consist of actively cultivated or rotated cropland or other disturbed land, the TEWAs have been located adjacent to the waterbody.

Pacific Connector, in a response to comments from NMFS during ESA Subgroup meetings of the Interagency Task Force, has agreed to a 150-foot set back from streams for refueling activities under the pipeline project SPCCP. Relative to construction rights-of-way and TEWAs, the location, size and spacing of TEWAs have been established for construction of the pipeline facilities factoring in safety, topography, and pipeline construction progressions using the FERC staff's Wetland and Waterbody Procedures allowance of a 50-foot setback from waterbodies. The TEWA placement nearer to the waterbody than 50 feet is due to the use of these areas by contractors to ensure that all of the waterbody crossing limitations (within the necked down right-of-way) can be performed. To further limit the placement of TEWAs would result in increasing risk of failure of the construction right-of-way to serve for safe and environmentally-sound construction. The conservation and control measures (e.g., BMPs) are specifically designed to minimize potential impacts to waterbodies associated with construction of a linear facility that crosses the waterbodies. Pacific Connector continues to recognize the need for a variance procedure for overnight "parking" and/or fueling of equipment where necessary as a variance from this setback. The required BMPs and approval of the EI for any such variance is delineated in the project SPCCP. Pacific Connector agrees that on BLM and NFS lands, the authorized BLM or USFS representative would be informed of the EI's determination. The representative can evaluate the situation and the decision of the EI.

The proposed pipeline would cross numerous irrigation canals and ditches in agricultural fields in Klamath County. Some of the irrigation canals and ditches in this area are part of Reclamation's Klamath Project. Reclamation would require that the pipeline be installed at least 3 feet below the bed of facilities over which it has jurisdiction. To minimize agricultural impacts and to schedule the crossings of the majority of the canals and ditches when they are dry and not in use, Pacific Connector is proposing to install its pipeline through the Klamath Basin between about MPs 188 and 228, during the winter. This would correspond with the ODFW recommended crossing window for the Lost River. The winter construction schedule would also minimize the crossing of high groundwater areas in the Klamath Basin, which are caused from irrigation and canal leakage or drainage. Reclamation would require that irrigation canals and ditches under its jurisdiction be crossed between October 15 and March 15, outside of the irrigation season.

Pacific Connector would work with Reclamation, the appropriate irrigation districts, and individual landowners to develop site-specific procedures to minimize disruption of irrigation canals and ditches during construction. If these features are in use at the time of construction, Pacific Connector would utilize a dry crossing technique, such as fluming, boring, or dam-and-pump methods to prevent disruption of downstream flows and to minimize any downstream impacts. Pacific Connector would maintain water flow in all crop irrigation systems, unless shutoff is coordinated with affected landowners. Pacific Connector would negotiate with the landowners at these locations to minimize impacts to their agricultural operations and would compensate the landowners for any crop loss/damage resulting from pipeline construction.

*Major Waterbodies*

Major waterbodies as defined by the FERC are those greater than 100 feet wide. Pacific Connector has completed geotechnical studies at these waterbodies to determine feasible crossing methods. Pacific Connector has prepared detailed, site-specific construction drawings with construction details for each of these waterbody crossings that identify the areas that would be disturbed by the proposed construction method including the areas necessary to fabricate the pipeline for the crossing, stage equipment, store spoil, and construct the crossing (see appendix W). Sediment control structures at these crossings are shown in the site-specific construction drawings. During development of the crossing methods, Pacific Connector consulted with all appropriate federal and state agencies. The crossing methods are described below.

*Coos Bay and Haynes Inlet*

A wet open-cut crossing construction technique would be used to cross approximately 2.4 miles of Coos Bay and Haynes Inlet, a tidal waterbody that has substantial flows and fluctuating water levels. A construction plan for the Coos Bay estuary crossing is provided in appendix D.

Construction in Coos Bay would use several different pipeline installation methods. A Shallow Water Lay Barge would be used to install the pipeline in water between 0 feet to 20 feet deep. The pipeline would be installed at shore approaches using open-cut trench methods, with shore based equipment where possible. From the barge a combination of the conventional S-lay method and "pipe push" method would be used. To make certain that the pipe is buried at least 5 feet deep, a pre-lay trench would be dug.

*Coos River, Rogue River, and Klamath River*

Pacific Connector is proposing to use the HDD method for the crossing of the Coos River (MP 11.13R), the Rogue River (MP 122.65), and the Klamath River (MP 199.38). Pacific Connector plans to HDD the Coos, Rogue, and Klamath River crossings during the first year of pipeline construction (Project Year Two or BA Year 3 – see figures 3.2-1 and 3.2-3) to allow sufficient time to pursue permits for an alternative crossing location or method in the unlikely event the proposed HDDs are unsuccessful. The alternate crossing method or a HDD at an alternate location would then be completed during the second year of pipeline construction (Project Year Three or BA Year 4 – see figures 3.2-1 and 3.2-3) during mainline construction and would be constructed within the ODFW-recommended in-water work window to protect aquatic species. appendix E provides HDD crossing plans for each river as well as a Drilling Fluid Contingency Plan and a Failure Mode Plan.

The HDD method involves boring under a feature and pulling the pipeline into place through the borehole that has been reamed to accommodate the diameter of the pipeline. This procedure involves three main phases, pilot hole drilling, subsequent reaming passes, and pipe pullback. HDD typically is used for the crossing of major waterbodies (greater than 100 feet wide).

<u>Pilot Hole</u>

The pilot hole establishes the ultimate position of the installed pipeline. For this operation, an initial hole is drilled from the entry point to the exit point on the opposite side of the crossing. The head of the pilot drill string contains a pivot joint to provide directional control of the drill string. By altering or steering the drill head, the operator can control the direction as the drill progresses. Thus, the pilot hole can be directed downward at an angle until the proper depth is achieved, then turned and directed horizontally for the required distance, and finally angled upward to the surface. Tracking and steering of the HDD drill head is generally guided using a two-wire system. The system consists of two insulated wires (approximately 0.25-inch in diameter) that are laid on the ground and are charged with an electrical current. A magnetometer accelerometer probe located behind the drill bit detects the electric current to triangulate the drill bit for steering.

As the pilot drill string is advanced, additional sections of drill pipe are added at the drill rig located at the entry point. High-pressure jetting of drilling fluid at the drill head and, in harder soil formations, rotation of the drill bit, facilitates advancement of the drill string. The drilling fluid (mud) is typically a non-toxic bentonite clay mixed with freshwater to make a slurry. Once the pilot hole exits in an acceptable location, the reaming operation is initiated.

*Reaming*

During the reaming phase, a reaming head is attached to the drill pipe and pulled back through the pilot hole to enlarge it. Several reaming passes may be made with incrementally larger reaming heads to enlarge the hole to approximately 1.5 times the diameter of the pipeline. Various reaming heads can be utilized, depending on the substrate encountered. High-pressure drilling fluid is jetted through the reaming head to float out drill cuttings and debris, to cool the drilling head, and to provide a cake wall to stabilize the hole. Once the drill hole is enlarged to the proper diameter, the pipe is pulled back through the reamed hole.

*Pullback*

The last step to complete a successful installation is the pullback of the pre-fabricated product pipe into the enlarged hole. The pullback process is the most critical step of the HDD process. A reinforced pullhead is welded to the leading end of the product pipe and to a swivel connected to the end of the drill pipe. The swivel is placed between the drill rig and the product pipe to reduce torsion and prevent rotation from being passed to the product pipe

During pullback, the pull section is supported with a combination of roller stands and/or product pipe handling equipment to direct the product pipe into the hole at the correct angle, reduce tension during pullback, and prevent the product pipe from being damaged. After the product pipe is in place, the installed crossing is hydrostatically tested, pigged (optional), and tie-in welds on each side of the crossing are completed.

*South Umpqua River – MP 71.30*

Pacific Connector is proposing a Direct Pipe (DP) crossing of the South Umpqua River at MP 71.30 during the first year of pipeline construction (Project Year Two or BA Year 3 – see figures 3.2-1 and 3.2-3) to allow sufficient time to pursue permits for an alternative crossing location or method in the unlikely event the proposed DP is unsuccessful. The alternate crossing method or crossing at an alternate location would then be completed during the second year of pipeline construction (Project Year Three or BA Year 4 – see figures 3.2-1 and 3.2-3) and would be constructed within the ODFW-recommended in-water work window to protect aquatic species. DP is a trenchless construction method to install pipelines beneath rivers, highways, railroads, levees, wetlands and other features that require special attention to environmental and logistical concerns. DP is, in its simplest definition, a combination of the traditional microtunneling process and HDD. DPs are completed using an articulated, steerable microtunnel boring machine (MTBM) mounted on the leading end of the product pipe or casing which is jacked into position using a pipe thrusting machine mounted at or near the ground surface (see appendix E).

Internal instrumentation is typically used to survey the progress of the MTBM so that its location can be compared to the design requirements. A gyroscope mounted within the MTBM locates the orientation and a precision manometer is used to locate the elevation of the MTBM.

The MTBM exerts continuous and controllable pressure at the excavation face and is capable of excavating a wide variety of soils under significant groundwater pressures. Soil and rock are excavated by the cutting head and removed through pressurized slurry pipes to the launching pit at a rate that is balanced with the advance rate of the machine, as the MTBM and pipe are jacked through the formation. A pipe thrusting machine located in or near the launching pit provides the necessary force to advance the product pipe and provide the face pressure required for excavation. The product pipe is typically pre-fabricated in a continuous section or in smaller sections, typically 300 to 500 feet. The smaller sections are welded to the back of subsequent sections after each section is advanced.

Friction between the pipe and surrounding soil can create significant resistance during DP installation. To reduce the frictional resistance, over cutting is employed to create a small annular space between the pipe and external soil. The over cut is typically on the order of 1 to 2 inches. The use of bentonite slurry helps reduce the frictional resistance between the pipe and soil as well as reducing the risk of collapse of the annulus around the pipe. Bentonite lubrication is typically added from the launch seal and from a specialized lubrication ring located behind the MTBM and in front of the jacking pipe.

Following completion of the tunneling process, the MTBM is retrieved from the receiving pit. If the DP-installed pipe is to be used as casing, after completion of the grouting the product pipe may be installed within the casing using centralizers or resting on the bottom of the casing if the product pipe is concrete coated. After the product pipe is installed and tested, the interior annular space between the casing and product pipes may be filled with cement grout.

*South Umpqua River – MP 94.73*

The second crossing of the South Umpqua River at MP 94.73 is planned for the ODFW recommended in-water work window between July 1 and August 31 during the first year of pipeline construction (Project Year Two or BA Year 3 – see figures 3.2-1 and 3.2-3). The South Umpqua River channel at MP 94.73 is sufficiently flat, wide, and shallow to divert all of the river flow to one side or bank of the river while work is proceeding in the dry on the opposite bank. Typically in August water levels at the crossing have been sufficiently low that a diverted open-cut crossing method could easily have been utilized at this crossing location.

This crossing method would require TEWAs to be located in the river and would require equipment to work in the river to place the diversion structures or dams to divert the river flow from one side of the river and then to the other. The diversion could be constructed using imported riprap, concrete jersey barriers, water bladder portadams, and/or sand bags to divert the river's flow temporarily away from the work area in order to minimize contact between stream flow and the excavation and backfill activities. This would require Pacific Connector to place equipment within the stream to install, maintain, and ultimately remove the diversion structures. The crossing would take a minimum of 14 days to complete including 3 to 4 days of in-stream work to install, rearrange, and remove the diversion structures. Some turbidity would result during in-stream activities and when the water is diverted to the backfilled areas.

The diverted open-cut crossing method at this location would require an in-stream tie-in, but it would be made in the dry behind the diversion structure. During the crossing, initial trenching would first occur on the dry side of the river; however, depending on the water levels during the season, it may be necessary to install a diversion to push or divert the flow to at least the middle of the river. Once the construction right-of-way has been isolated by the diversions and/or sediment control devices, trenching would proceed to approximately the middle of the river. Trench spoil would be stored within the stream channel behind the diversion or sediment control structures to ensure that sedimentation from saturated materials does not flow back into the river. After the trench has been completed, a section of pipe would be placed in the trench. Trench boxes or another marker form would be placed at the end of the pipe section in the middle of the riverbed for the tie-in. The trench would be backfilled and the streambed restored to the original contour configuration, except for the immediate area around the tie-in.

The diversion structure would then be removed and rearranged to divert the flow temporarily to the other side or dry side of the river in order to minimize contact between stream flow and the excavation and backfill activities. This would again require Pacific Connector to place equipment within the stream in order to rearrange the diversion structures. Once the diversion structures have been properly reconfigured and extended beyond the tie-in location and the river flow diverted to the opposite side of the river, excavation for the other section of pipe would begin. Trenching would proceed across the river bed to the tie-in point in the middle of the river where it would be uncovered. Once the excavation is complete, the second pipe section would be carried in and tied-into the first section. After the tie-in has been made, the streambed would be restored to its original contours and configuration and the diversions structures would be removed. Streambanks would be reestablished and stabilized.

During the diverted open cut, multiple discharge pumps would be required to keep the tie-in area dry while the welds are being made and to control any flow seepage in the work areas. The discharge from this activity would occur to a straw bale discharge structure located in an upland area as far away from the river as possible to prevent any silt-laden water from flowing into the river.

*Kentuck Slough (MP 6.28R), Catching Slough (MP 11.11), and Medford Aqueduct (MP 133.38)*

Conventional bores of waterbodies are proposed at Kentuck Slough (MP 6.28R), Catching Slough (MP 11.11), and the Medford Aqueduct (MP 133.38). The specific type of bore (i.e., jack and bore, slick bore, hammer, etc.) that would be utilized would be determined during the design phase of the pipeline project and depends on construction characteristics, the type of soils present, and the contractor's familiarity with the method. The hammer is typically utilized in difficult soils containing consolidated rock, and the slick bore is used in soils with fewer frictional characteristics. Although each type of bore is somewhat different, the requirements and risks associated with each are similar. In all cases, the bore must be completed along a straight pathway requiring excavation of a bore pit on either side of the crossing (called launching and receiving pits). The depth of the bore pits must be several feet deeper than the bottom of the pipeline and can be quite deep when accounting for the depth of the feature to be crossed and the depth of cover between the bottom of the feature (e.g. stream bed) and the top of the pipeline. Welders and other laborers must work within the confined space of the bore pit; and the presence of water can be problematic.

During a standard boring operation, the spoil material is passed into the bore pit. Trackhoes then remove this spoil from the bore pit. Pipe is welded up and eventually pulled through the bore hole. Each section of the pipe is joined using full-penetration welding procedures and 100 percent of the welds are inspected using non-destructive testing procedures (x-ray) to form a continuous pipeline segment. This is a difficult operation, requiring the welders to work in the confined space of the bore pit. Because conventional boring does not limit water migrating into the bore, an important factor in the design of launching and receiving pits is groundwater control.

Dewatering systems using deep wells or well points are frequently used. Trench boxes or sheet piling are often used to support the pit walls and to cut off groundwater inflows.

*Minor and Intermediate Waterbodies*

If water is present in the streambed at the time of construction, Pacific Connector would utilize a dry-ditch crossing method (flume or dam-and-pump) to cross all minor and intermediate waterbodies consistent with the requirements of Section V.B.6 of the FERC staff's Procedures. Fluming and dam-and-pump procedures that would be utilized to cross these waterbodies are provided in appendix K.

<u>*Storage of Hazardous Materials*</u>

Hazardous materials, chemicals, fuels, and lubricating oils would be stored in upland areas at least 150 feet from waterbodies and wetlands or in accordance with FERC's Procedures (see appendices C and L). Restricted areas for storage of these materials would be clearly marked in the field. Concrete coating, refueling, and equipment maintenance activities would be conducted according to FERC's Procedures. Concrete trucks would not be washed on the right-of-way. All hazardous materials would be handled in accordance with the SPCCP (see appendix L). If any unanticipated spill occurs during construction, Pacific Connector would implement the procedures outlined in the SPCCP.

<u>*Temporary Bridges*</u>

If water is present in any streambeds at the time of construction, Pacific Connector would utilize temporary construction bridges during all phases of construction to cross these waterbodies. Equipment bridges would not be installed on intermittent waterbodies, which are dry at the time of construction. However, if a storm occurs that results in water in the streambed of the otherwise intermittent waterbody, no equipment would cross the waterbody until the streambed dries up or until a bridge is installed. Although FERC's Procedures (see Section V. B. 5. a.) allow clearing equipment and equipment necessary for installation of the temporary bridges to cross waterbodies prior to bridge installation, Pacific Connector would not allow clearing equipment to cross waterbodies prior to bridge placement. Where feasible, Pacific Connector's contractors would attempt to lift, span, and set the bridges from the streambanks. However, where it is not feasible to install or safely set the temporary bridges from the streambanks, only the equipment necessary to install the bridge or temporary support pier would cross the waterbody.

The temporary equipment bridges would be constructed to maintain unrestricted flow and to prevent soil from entering the waterbody. Soil would not be used to stabilize equipment bridges. Bridges would be designed according to the FERC staff's Procedures (Section V.B.5.B) and would be maintained to withstand and pass the highest flow expected to occur while the bridge is in place. The highest flow expected would be determined during the season of construction and would take into account an evaluation of regional climate and physical conditions as well as existing historical streamflow data and peak discharge statistics from nearby USGS gauging stations.

Where feasible, bridges would be designed to span the entire ordinary high water mark (OHWM) of the waterbody. If it is not possible to span the OHWM with a bridge, a temporary culvert or pier may be required. These culverts/piers would be installed to minimize flow restrictions that may deflect stream flow to banks to prevent streambank erosion or scour.

The ECRP (appendix F - see Drawing 3430.34-X-0010) provides additional details for temporary bridges. These structures would meet the requirements attached to permits or approvals issued by the COE, ODSL, ODEQ, and ODFW for this project. To allow for the delivery of materials and equipment up and down the construction right-of-way, it may be necessary to install some bridges outside the ODFW recommended in-water construction windows.

Temporary bridges would be set during clearing operations in the first year of pipeline construction (Project Year Two or BA Years 2 and 3 – see figures 3.2-1 and 3.2-3) as well as during mainline construction the following year. The temporary bridges set during clearing operations would be temporarily removed after clearing is complete and would not be left in place across a waterbody over the winter. During mainline construction in the second year of pipeline construction (Project Year Three or BA Years 3 and 4 – see figures 3.2-1 and 3.2-3), the temporary bridges would be reset and would be removed as soon as possible after permanent seeding. If there would be more than one month between final cleanup and the beginning of permanent seeding and reasonable alternate access to the right-of-way is available, equipment bridges would be removed as soon as possible after final cleanup as required by the FERC staff's Procedures (Section V. B. 5. f.).

Sediment barriers would be installed immediately after initial disturbance of the waterbody or adjacent upland as shown on Drawings 3430.34-X-0005 and 3430.34-X-0007 in the pipeline project-specific ECRP (see appendix F). Sediment barriers would be properly maintained throughout construction and reinstalled as necessary (such as after backfilling of the trench) until replaced by permanent erosion controls or restoration of adjacent upland areas is complete.

All waterbodies supporting fisheries would be backfilled with material removed from the trench with the upper 1-foot of the trench backfilled with clean gravel or native cobbles. The bottom and banks would be returned to preconstruction contours; banks would be stabilized; and temporary sediment barriers would be installed before returning flow to the waterbody channel.

Pacific Connector requested a modification from Section V.C.1. of the FERC's Procedures in fish-bearing streams that do not have gravel, cobble, or other rock substrates (see appendix H). This modification was requested because many of the streams to be crossed by the pipeline are remote and are located in steep valley or ravine bottoms; therefore, hauling rock to these steams is impractical especially where these streams do not have these substrate characteristics.

#### 3.1.4.4 Operations, Maintenance, and Monitoring – Pacific Connector Pipeline

Pacific Connector would test, operate, and maintain the proposed pipeline facilities in accordance with DOT regulations provided in 49 CFR Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards, FERC's guidance at 18 CFR 380.15, and maintenance provisions of the FERC staff's Plan and Procedures. The pipeline right-of-way would be clearly marked where it crosses public roads, waterbodies, fenced property lines, and other locations as necessary. Table 3.1.4.4-1 lists the habitat types affected by operation of the pipeline facilities.

TABLE 3.1.4.4-1

**Summary of Operation-Related Disturbance to Habitat by the Proposed Pacific Connector Pipeline (acres a/)**

| General Vegetation Type | Mapped Vegetation Category Type | Forest Stand by Age | Pipeline Facilities | | | | | | | Aboveground Facilities | | | | | | | | | | | | | | | | | | Total Operation Impacts by Habitat Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *30-foot Maintenance Corridor* | Permanent Access Roads | Subtotal Late Successional Old-Growth Forest | Subtotal Mid-Seral Forest | Subtotal Clearcut / Regenerating Forest | Subtotal By Habitat Type | Permanent Easement (50-foot) | Jordan Cove MS & BVA #1 [5] | BVA #2 | BVA #3 | BVA #4 | BVA #5 | BVA #6 Clarks Branch MS | BVA #7 | BVA #8 | BVA #9 | BVA #10 | BVA #11 | BVA #12 | BVA #13 | BVA #14 | BVA #15 | BVA #16 | Klamath CS, BVA #17, MS | Subtotal Aboveground Facilities [6] | |
| Forest-Woodland | Westside Lowland Conifer-Hardwood Forest | L-O [1] | 33.48 | 0.01 | | | | | 56.55 | | | | | | | 0.06 | | | | | | | | | | | | |
| | | M-S [2] | 81.55 | 0 | 33.49 | 81.55 | 115.97 | 231.01 | 136.15 | | 0.06 | | | | | | | | | | | | | | | | 0.12 | **231.13** |
| | | C-R [3] | 115.97 | 0 | | | | | 194.57 | | | | | | | | | | | | | | | | | | | |
| | Montane Mixed Conifer Forest | L-O [1] | 5.81 | 0 | | | | | 9.58 | | | | | | | | | | | | | | | | | | | |
| | | M-S [2] | 3.23 | 0 | 5.81 | 3.23 | 14.57 | 23.61 | 5.3 | | | | | | | | | | | | | | | | | | 0.06 | 23.67 |
| | | C-R [3] | 14.37 | 0.2 | | | | | 23.93 | | | | | | | | | | | | | 0.06 | | | | | | |
| | Southwest Oregon Mixed Conifer-Hardwood Forest | L-O [1] | 89.08 | 0.03 | | | | | 148.94 | | | | | | | | | 0.06 | | | | | | | | | | |
| | | M-S [2] | 36.39 | 0 | 89.11 | 36.39 | 52.02 | 177.52 | 60.80 | | | | | | | | | | | | | | | | | | 0.12 | 177.64 |
| | | C-R [3] | 51.98 | 0.04 | | | | | 86.14 | | | | 0.06 | | | | | | | | | | | | | | | |
| | Ponderosa Pine Forest and Woodlands | L-O [1] | 16.18 | 0 | | | | | 26.93 | | | | | | | | | | | | | | | | | | | |
| | | M-S [2] | 18.57 | 0 | 16.18 | 18.57 | 24.85 | 59.60 | 31.00 | | | | | | | | | | | | | | | | | | 0 | 59.60 |
| | | C-R [3] | 24.85 | 0 | | | | | 41.44 | | | | | | | | | | | | | | | | | | | |
| | Westside Oak and Dry Douglas-fir Forest and Woodlands | L-O [1] | 9.87 | 0 | | | | | 16.42 | | | | | | | | | | | | | | | | | | | |
| | | M-S [2] | 10.34 | 0.38 | 9.87 | 10.72 | 0 | 20.59 | 17.22 | | | | | | | | | | | 0.13 | | | | | | | 0.13 | 20.72 |
| | | C-R [3] | 0 | 0 | | | | | 0 | | | | | | | | | | | | | | | | | | | |
| | Western Juniper and Mountain Mahogany Woodlands | L-O [1] | 0 | 0 | | | | | 0 | | | | | | | | | | | | | | | | | | | |
| | | M-S [2] | 18.09 | 0 | 0 | 18.09 | 15.37 | 33.46 | 29.70 | | | | | | | | | | | | | | | | | | 0.44 | 33.90 |
| | | C-R [3] | 15.22 | 0 | | | | | 25.37 | | | | | | | | | | | | | | 0.44 | | | | | |
| **Subtotal Forest-Woodland** | | | **544.98** | **0.81** | **154.46** | **168.55** | **222.78** | **545.79** | **910.04** | **0** | **0.06** | **0** | **0.06** | **0** | **0** | **0.06** | **0** | **0.06** | **0** | **0.13** | **0** | **0.06** | **0.44** | **0** | **0** | **0** | **0.87** | **546.66** |
| Grasslands-Shrubland | Sagebrush Steppe | | 19.44 | 0 | | | | 19.44 | *32.86* | | | | | | | | | | | | | | | | | 30.86 | 30.86 | **50.3** |
| | Shrublands | | 24.01 | 0.12 | | | | 24.13 | *39.69* | | | | | | | | | | | | 0.06 | | | | | | 0.06 | **24.19** |
| | Westside Grasslands | | 35.21 | 1.04 | | | | 36.25 | *58.85* | | | | | | 0.4 | | 0.06 | | 0.06 | 0.27 | | | | | | | 0.79 | **37.04** |
| | Eastside Grasslands | | 5.71 | 0 | | | | 5.71 | *9.5* | | | | | | | | | | | | | | | | | | 0 | **5.71** |
| **Subtotal Grasslands-Shrubland** | | | **84.37** | **1.16** | | | | **85.53** | ***140.9*** | **0** | **0** | **0** | **0** | **0** | **0.4** | **0** | **0.06** | **0** | **0.06** | **0.27** | **0.06** | **0** | **0** | **0** | **0** | **30.86** | **31.71** | **117.24** |
| Wetland/ Riparian | Westside Riparian-Wetlands/Eastside Riparian-Wetlands | L-O [1] | 0.01 | 0 | | | | | *0.02* | | | | | | | | | | | | | | | | | | | |
| | | M-S [2] | 0.26 | 0 | 0.01 | 0.26 | 0.76 | 1.03 | *0.45* | | | | | | | | | | | | | | | | | | 0 | **1.03** |
| | | C-R [3] | 0.76 | 0 | | | | | *1.28* | | | | | | | | | | | | | | | | | | | |
| | | Shrub | 0.36 | 0 | | | | 0.36 | *0.58* | | | | | | | | | | | | | | | | | | 0 | **0.36** |
| | Herbaceous Wetlands | | 21.61 | 0 | | | | 21.61 | *35.92* | | | | | | | | | | | | | | | | | | 0 | **21.61** |
| **Subtotal Wetland/Riparian** | | | **23.00** | **0** | | | | **23.00** | ***38.25*** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **23.00** |
| Agriculture | Agriculture, Pastures, and Mixed Environs | | 120.86 | 0.32 | | | | 121.18 | *201.22* | | | 0.06 | | 0.06 | 0.57 | | | | | 0.02 | | | | 0.06 | 0.06 | | 0.83 | **122.01** |

TABLE 3.1.4.4-1

**Summary of Operation-Related Disturbance to Habitat by the Proposed Pacific Connector Pipeline (acres a/)**

| General Vegetation Type | Mapped Vegetation Category Type | Forest Stand by Age | Pipeline Facilities: 30-foot Maintenance Corridor | Permanent Access Roads | Subtotal Late Successional Old-Growth Forest | Subtotal Mid-Seral Forest | Subtotal Clearcut / Regenerating Forest | Subtotal By Habitat Type | Permanent Easement (50-foot) | Aboveground Facilities: Jordan Cove MS & BVA #1 [5] | BVA #2 | BVA #3 | BVA #4 | BVA #5 | BVA #6 Clarks Branch MS | BVA #7 | BVA #8 | BVA #9 | BVA #10 | BVA #11 | BVA #12 | BVA #13 | BVA #14 | BVA #15 | BVA #16 | Klamath CS, BVA #17, MS | Subtotal Aboveground Facilities [6] | Total Operation Impacts by Habitat Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subtotal Agriculture** | | | **120.86** | **0.32** | | | | **121.18** | ***201.22*** | **0** | **0** | **0.06** | **0** | **0.06** | **0.57** | **0** | **0** | **0** | **0** | **0.02** | **0** | **0** | **0** | **0.06** | **0.06** | **0** | **0.83** | **122.01** |
| Developed / Barren | Urban and Mixed Environs | | 6.74 | 0.06 | | | | 6.8 | 11.38 | 0.85 | | | | | | | | | | | | | | | | | 0.85 | 7.65 |
| | Roads | | 47.45 | 0.19 | | | | 47.64 | *76.64* | | | | | | | | | | | | | | | | | | 0 | **47.64** |
| | Beaches | | 0.05 | 0 | | | | 0.05 | *0.08* | | | | | | | | | | | | | | | | | | 0 | **0.05** |
| **Subtotal Developed / Barren** | | | **54.24** | **0.25** | | | | **54.49** | ***88.1*** | **0.85** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0.85** | **55.34** |
| Open Water | Open Water - Lakes, Rivers, and Streams | | 2.25 | 0.03 | | | | 3.43 | 5.64 | | | | | | | | | | | 0.02 | | | | | | | 0.02 | 3.45 |
| | Bays and Estuaries | | 8.93 | 0 | | | | 8.93 | *14.88* | | | | | | | | | | | | | | | | | | 0 | **8.93** |
| **Subtotal Open Water** | | | **11.18** | **0.03** | | | | **12.36** | ***20.52*** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0.02** | **0** | **0** | **0** | **0** | **0** | **0** | **0.02** | **12.38** |
| **Subtotal Non-Forest** | | | **294.8** | **1.76** | **0.01** | **0.26** | **0.76** | **296.56** | ***488.99*** | **0.85** | **0** | **0.06** | **0** | **0.06** | **0.97** | **0** | **0.06** | **0** | **0.06** | **0.31** | **0.06** | **0** | **0** | **0.06** | **0.06** | **30.86** | **33.41** | **329.97** |
| **Project Total** | | | **839.78** | **2.57** | **154.47** | **168.81** | **223.54** | **842.35** | ***1399.03*** | **0.85** | **0.06** | **0.06** | **0.06** | **0.06** | **0.97** | **0.06** | **0.06** | **0.06** | **0.06** | **0.44** | **0.06** | **0.06** | **0.44** | **0.06** | **0.06** | **30.86** | **34.28** | **876.63** |

[1] Acres disturbed were evaluated using GIS; footprints for each component (aboveground facilities, permanent easement, and 30-foot maintenance corridor) were overlaid on the digitized vegetation coverage.

[2] The "Late Successional and Old-Growth" category (L-O) describes those forest areas with a majority of trees over 80 years of age. Forests with stands greater than 175 years are considered to have old-growth characteristics.

[3] The "Mid-Seral" category (M-S) describes those forest areas with a majority of trees over 40 years of age but less than 80 years of age.

[4] The "Grass-shrub-sapling or Regenerating Young Forest" category (C-R) describes those forest areas that are either clear-cut (tree age 0-5 years) or regenerating (tree age 5 to 40 years).

[5] CT = Communications tower

[6] Subtotal by Habitat Type includes the 30-foot maintenance corridor, permanent access roads, and only aboveground facilities with a meter station or compressor station (mainline block valves located within the 30-foot maintenance corridor).

General: If percentages were less than 1/100ths, they were not included in the table.

-Columns and rows do not necessarily sum correctly due to rounding.

Acres of impacts to non-vegetated areas are included within this table for consistency in values reported within this Resource Report.

The pipeline would be inspected regularly by aerial patrols or on-the-ground personnel to observe general right-of-way conditions and to identify any indications of soil erosion that may expose the pipe, stressed vegetation that may indicate a leak in the line, damage to erosion control structures, unauthorized encroachment onto the right-of-way, and other conditions that could present a safety hazard or require preventive maintenance or repairs. All inspections would be in accordance with DOT standards. Generally, repair of erosion control structures, drain tiles, and the need for additional fill may be required in the first year or two following construction in areas where the trench may have settled. Areas susceptible to damage from large storm events would be inspected and repaired as appropriate depending on the nature of damage. Waterbody crossings would be inspected periodically. Any areas of concern (AOCs) that are brought to the attention of the pipeline operator would be assessed and repaired as necessary. A supply of replacement pipe, leak clamps, sleeves, and related materials would be stored at local district offices for use during repair activities.

Vegetation maintenance would be a required periodic use of the federal or private lands crossed by the pipeline, and would be covered in lease agreements for each individual affected property. No herbicides would be used to control vegetation (i.e., brush and trees) on the permanent pipeline easement unless approved or required by the landowner. Herbicides would not be used in or within 100 feet of a waterbody's mean high water mark. Vegetation at aboveground facilities would be periodically maintained using mowing, cutting, trimming, and herbicides (selectively). Vegetation within the permanent easement would be periodically maintained by mowing, cutting, and trimming (either by mechanical or hand methods). In upland areas, the permanent easement would be maintained in a condition where trees or shrubs greater than 6 feet tall would be controlled (cut or trimmed) within 15 feet either side of the centerline (for a total of 30 cleared feet). Maintenance activities are expected to occur approximately every 3 to 5 years depending on the growth rate of vegetation. During maintenance, vegetation would be cut/trimmed in 4- to 6-foot lengths and scattered across the permanent easement to naturally decompose, discourage OHV traffic, and benefit wildlife habitat. Occasionally where site conditions allow, chipping of this material may also occur. Pacific Connector believes that the slash materials generated and scattered across the permanent easement during maintenance activities would not exceed the fuel loading specifications discussed above. To facilitate periodic corrosion and leak surveys, a corridor not exceeding 10 feet in width centered on the pipeline may be maintained annually in a herbaceous state, if required.

In forested and shrub wetland areas, vegetation maintenance would be as described above except trees and shrubs would be selectively removed as necessary to minimize equipment operating within the wetland. Where the pipeline crosses a waterbody, vegetation maintenance would be limited to allow a riparian strip at least 25 feet wide, measured from the waterbody's OHWM, to permanently revegetate with native species, with the exception of maintenance required to maintain vegetation no greater than 6 feet tall within 15 feet of the centerline of the pipe.

On federal lands where riparian reserves are affected, a 100-foot riparian strip (or less if the pre-construction riparian vegetation did not extend to 100 feet) would be planted perpendicular to the waterbody on both sides of the waterbody. However, to facilitate periodic pipeline corrosion/leak surveys, a corridor centered on the pipeline and up to 10 feet wide would be maintained in an herbaceous state in this riparian strip with no vegetation greater than 6 feet in height. Herbicides would not be used in or within 100 feet of a waterbody's mean high water mark. Herbicides would only be used on NFS lands if needed to control invasive species, in accordance with each National Forest's management plans.

In addition to DOT-required surveys, Pacific Connector would monitor the pipeline system using a supervisory control and data acquisition (SCADA) system. SCADA systems are used to monitor and control facilities or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining, and transportation. A SCADA system gathers information; transfers the information back to a control center; carries out necessary analysis and control; and displays the information in a logical and organized fashion 24 hours a day, 7 days per week. The control center for the Pacific Connector pipeline would be provided by Williams Pacific Operator and would be located in Salt Lake City, Utah.

If noxious weed infestation occurs on the permanent easement, selective use of herbicides would be used to control these species. All use of herbicides at aboveground facilities or on the permanent easement would be in accordance with federal, state, and local regulations and land managing agency requirements as well as landowner approval and would be consistent with FERC's Plan and Procedures. The Noxious Weed Control Plan, provided in the ECRP in Appendix F provides additional details regarding noxious weed control on the permanent easement.

Generally, repair of erosion control structures and the need for additional fill may be required in the first year or two following construction in areas where the trench may have settled or any other areas disturbed by construction activities. Depending on the location of the trench settlement or AOC, minor repairs of waterbars or drain tiles may be necessary because the settlement could affect the drainage or proper function of these features and regrading and/or addition of fill material may be necessary. Erosion control structures and the need for additional fill would be assessed by operations personnel along the right-of-way during routine inspections. Areas susceptible to damage from large storm events would be inspected and repaired as appropriate depending on the nature of damage. All areas disturbed by construction activities would be restored and monitored and appropriate repairs would be made as necessary. A supply of emergency replacement pipe, leak repair clamps, sleeves, and related materials would be stored at the local district office for repair activities.

Waterbody crossings would be inspected periodically by Pacific Connector's operations personnel. Operation and maintenance activities, including aerial inspection of the pipeline, would be conducted only within the permanent easement. Aerial inspections would be conducted by helicopter and/or small fixed-wing aircraft to examine the pipeline right-of-way once per year during the life of the pipeline.

**Cathodic Protection System**

The pipeline would be protected from external corrosion using a low voltage impressed current electrical system, referred to as a cathodic protection (CP) system, which would be installed about one year following construction, to allow for collection of post-construction data of electroconductivity soil potentials, which is required before the CP system can be designed and installed. This system would input a low-voltage electrical charge into the pipeline underground. Permitting for the CP system is not applied for in the FERC Certificate application because the system design would be conducted after the pipeline is installed. The CP system cannot be designed properly until the ground is settled and there is good soil contact with the new pipe following pipeline construction. Pacific Connector would consult with federal, state, and local agencies regarding permitting of the CP system following pipeline construction. Pacific Connector anticipates that it would need to install approximately 12 rectifiers for the CP system at separate locations along the 232-mile length of the pipeline, typically spaced about 15 to 20 miles apart and generally located near existing access roads and existing power distribution lines. The exact locations of the rectifiers is not known at this time because the system would be designed after the pipeline is completed. If a vertical deep well anode bed were to be installed, it would require a trunk-mounted drill rig to drill a 10-inch diameter well 300 feet deep. A horizontal anode bed would require the use of a standard backhoe for installation within an area approximately 300 feet long, 2 feet wide, and 5 feet deep. Approximately 2 acres of ground surface would be disturbed during the installation of the CP system.

Pacific Connector intends to install the CP system in full compliance with any seasonal restriction or daily timing restriction for any federally listed avian species should any of the CP sites be located within an area (e.g., MAMU stand or NSO Core area). To the extent that the CP system design allows flexibility of placement of sites, all specified avoidance and minimization efforts would be followed to locate CP sites outside of such areas. CP sites are typically installed in the operational right-of-way or immediately adjacent in the construction right-of-way, so it is not expected that additional timber removal would be required. Systems are usually designed to utilize existing permanent access roads, so crossing of streams or waterbodies by temporary bridging is not anticipated. CP sites would not be installed in riparian zones.

**Maintenance and New Operational Facilities**

In Docket No. CP13-492-000, Pacific Connector also applied for a blanket certificate under Part 157, subpart F of the Commission's regulations and requested issuance of a blanket certificate under Subpart G of Part 284, respectively. According to the FERC's regulations at 18 CFR Part 380.4, these requests for blanket authorities are categorically excluded from environmental review. The currently unknown and unspecified future actions that may take place under the blanket certificate issued under Part 157 that may result in ground disturbance or changes in operational air or noise emissions, reported to the Commission by the applicants as prior notices or annual reports, would be subject to individual environmental reviews in accordance with Part 157.206 of the FERC regulations.

Pacific Connector would be able to replace facilities and build new minor facilities under the blanket certificate programs. The regulations covering operational activities that could result in new and additional construction disturbance are found at 18 CFR Part 2, Part 157 and Part 380. The regulatory framework is outlined below:

**2.55(a) Auxiliary Installations**

A project classified as a 2.55(a) project represents installation of auxiliary installations to existing facilities. Examples of such installations are valves, drips, pig launchers/receivers, yard and station piping, CP systems, gas cleaning cooling and dehydration equipment, residual refining equipment, water pumping treatment and cooling equipment, electrical and communication equipment, and buildings. Such auxiliary facilities are virtually always placed within the footprint of the existing right-of-way or construction disturbance area. Although no specific FERC reporting requirements apply to this type of project, alternate reporting requirements may be dictated by other approvals (i.e. wetlands, stormwater, etc.).

**2.55(b) Like-Kind Replacement Project (with ground disturbance)**

Projects classified as 2.55(b) are reportable projects to FERC in annual reporting documents. However, the project is required to consist of like-kind replacement (e.g., replacement of one or more pipe joints) such that all work is limited to the easement or previously disturbed construction right-of-way. Should the project scope change, requiring additional workspace or operational right-of-way, the classification of the project and its subsequent reporting requirements change to a Blanket Authorization activity or may require the filing of an Application pursuant to section 7(c) of the NGA.

**Automatic Blanket Authorization 157.208(a)**

Construction, acquisition, operation, replacement, and miscellaneous rearrangement of eligible facilities. Projects may be classified as blanket certificate projects pursuant to section 157.208 under the automatic authorization provisions. For such projects, the following reporting requirements are necessary prior to any construction activity. For environmental compliance, informal consultation must be initiated and completed with the FWS relative to any issues pursuant to the ESA and with NMFS pursuant to the ESA and MSA. Other federal clearances must also be obtained. The pipeline operator is formally the non-federal designee to conduct the informal consultation with the agencies on behalf of FERC. Such projects may involve construction outside of the original project's construction disturbance area, but they may not commence until the applicable federal resource agencies concur that the projects would not likely adversely affect a listed species or its critical habitat or adversely affect EFH in the case of MSA. Additionally, the total project cost must be below the dollar amount limit in 157.208(d). If the project exceeds this cost; it is elevated to a Prior Notice Project.

**Blanket Certificate Project – Prior Notice 157.208(b)**

Projects classified as construction, acquisition, operation, replacement, and miscellaneous rearrangement of eligible facilities with prior notice to FERC. The pipeline operator is formally the non-federal designee to conduct the informal consultation with the agencies on behalf of FERC. Such projects may involve construction outside of the original project's construction disturbance area, but they may not commence until the federal resource agencies concur that the project would not likely adversely affect a listed species or its critical habitat or adversely affect EFH in the case of MSA. Prior Notice projects require the preparation of a notice application to FERC and require Commission approval prior to commencing. Approval occurs at the end of a 10-day notice period and 60-day comment period if not protested.

#### 3.1.4.5 NonJurisdictional Facilities and Interrelated Activities

In addition to the facilities discussed, the Pacific Connector pipeline project would require construction of facilities that do not fall under the FERC's jurisdiction. Although these facilities are not regulated by the FERC, they are related to the Project and their potential environmental impacts are considered in this BA and EFH Assessment.

Utility Connections

Electrical power and phone service would also be required for each of Pacific Connector's proposed meter and compressor stations. Installation of the utility connections is not regulated by the FERC. These actions may be regulated by the counties or the state or Oregon.

Because the compressor station and the meter stations would either be installed adjacent to the proposed South Dunes Power Plant or adjacent to existing roads and utility service, no additional disturbance beyond what is evaluated for construction of the compressor station and the meter stations themselves would result from the utility connections.

### 3.1.4.6 Future Plans and Abandonment – Pacific Connector Pipeline

At this time, Pacific Connector has no foreseeable plans for future expansion or modifications of the facilities. Expansion or modification activities are authorized under the regulatory framework for operations and maintenance of the pipeline that is granted by the FERC Certificate.

**Expansion Projects Requiring an Application Pursuant to Section 7(c) of the NGA and Compliance with Part 380 NEPA Regulations**

The pipeline operator cannot proceed with any expansion project without filing a new application for a Certificate for Public Convenience and Necessity pursuant to Section 7(c) of the NGA. All applications must include the environmental data required under 18 CFR Part 380.12. In accordance with Part 380.13, the applicant must assist the FERC with compliance with the ESA, by entering into informal consultations with the FWS and NMFS. If the project could affect listed species, the applicant must conduct appropriate surveys and produce a draft BA. The FERC would consider an expansion to be a new undertaking and, if necessary, would enter into separate formal consultations with the Services.

**Abandonment of Facilities**

The pipeline operator has no plans for abandonment of the proposed facilities and at such time abandonment is necessary, the operator would be required to file an application with the FERC to abandon any of the facilities. Abandonment or deactivation of facilities would comply with Williams Pacific Gas Operator's Operations and Maintenance Manual and DOT 49 CFR 192.727 Abandonment or Deactivation of Facilities. The pipeline would be abandoned in place, where necessary, and would be disconnected from all sources and supplies of gas, purged of gas and have the ends sealed. Regarding aboveground facilities, when service is permanently discontinued to a customer, one of the following would be completed:

- The valve that is closed to prevent flow of gas would be fitted with a locking device or other means to prevent gas flow;
- a mechanical device or fitting would be installed to prevent the flow of gas in the service line or meter assembly; or
- physical disconnection of the customer piping from the gas supply source and sealing the pipe ends.

Typically, Pacific Connector would attempt to maintain abandonment and deactivation procedures within the existing right-of-way. There may be circumstances that require Williams Pacific Gas Operator to work outside of the existing right of way in limited areas in order to complete necessary excavations to seal or cap the pipe ends, e.g. block valve removal may require a 50 x 50 foot extra workspace. Prior to conducting any abandonment activities, Pacific Connector would apply for permits/authorizations with all applicable federal, state and local agencies to ensure compliance with all policies and regulations.

In order to abandon facilities, a company must file an application with the FERC under section 7(b) of the NGA. Again, as with an expansion, this application would be considered a new, separate undertaking. The applicant would assist the FERC in complying with the ESA by having informal consultations with the Services about its proposed action. If the abandonment activities have the potential to adversely affect a federally listed species, the FERC would initiate formal consultations with the Services.

## 3.2 SCHEDULE

Prior to the FERC providing written permission to begin construction, Jordan Cove and Pacific Connector must each have received all authorizations required by federal law.

Some of the actions that must be completed prior to construction include:

- The FERC must complete formal consultations under the ESA with the FWS and NMFS.
- The FERC must complete the process required under the Advisory Council on Historic Preservation's (ACHP's) regulations (36 CFR 800) for complying with section 106 of the National Historic Preservation Act (NHPA).
- The BLM must issue a Right-of-Way Grant for the pipeline over federal lands, with the concurrence of the USFS and Reclamation;
- The applicants must obtain other necessary federal and federally-delegated permits and authorizations, including permits from the COE under the RHA and CWA, permits from the ODEQ under the CWA and CAA, and a consistency determination from the ODLCD under the Coastal Zone Management Act (CZMA); and
- Jordan Cove must satisfy the conditions of the Coast Guard WSR.

At this time it is unknown when all necessary state and federal permits and approvals would be obtained. Therefore, the project schedule below discusses construction in terms of calendar years and Project Years without strict calendar dates. Project Years begin in the 4$^{th}$ quarter (October); "BA Years" are calendar years (see figure 3.2-1).

In general, construction of the proposed LNG terminal and the pipeline would take about 3.5 years. The first year of construction would be for the beginning of work at Jordan Cove's LNG terminal. The construction of the pipeline would actually begin during the second year of LNG terminal construction. Therefore, the first and second year of pipeline construction would actually correspond to Project Years Two and Three.

### 3.2.1 Jordan Cove LNG Terminal and Marine Facilities

Construction of Jordan Cove's LNG terminal and the marine components (access channel and slip) is expected to take approximately 42 months as shown on the general schedule for the major Project construction activities in figure 3.2-2. During Project Year One, Jordan Cove would conduct the following activities:

- Mobilize;
- Begin final engineering design;
- Prepare site;
- Start cut and fill activities;
- Excavate upland portion of the slip and haul soils to power plant site;
- Excavate dredge pocket behind berm, and begin to hydraulically convey dredged materials to power plant site;
- Conduct dredging of access channel in the bay during the first in-water work window;
- Start installation of piles in the portion of the slip behind the berm; and
- Start foundations for LNG storage tanks.

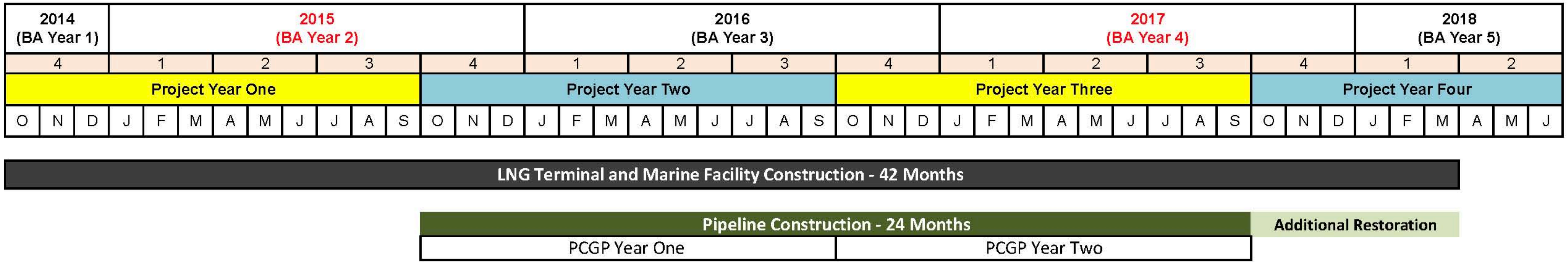



**Figure 3.2-1.** Project Schedule for LNG Terminal and Marine Facilities and Pacific Connector Pipeline

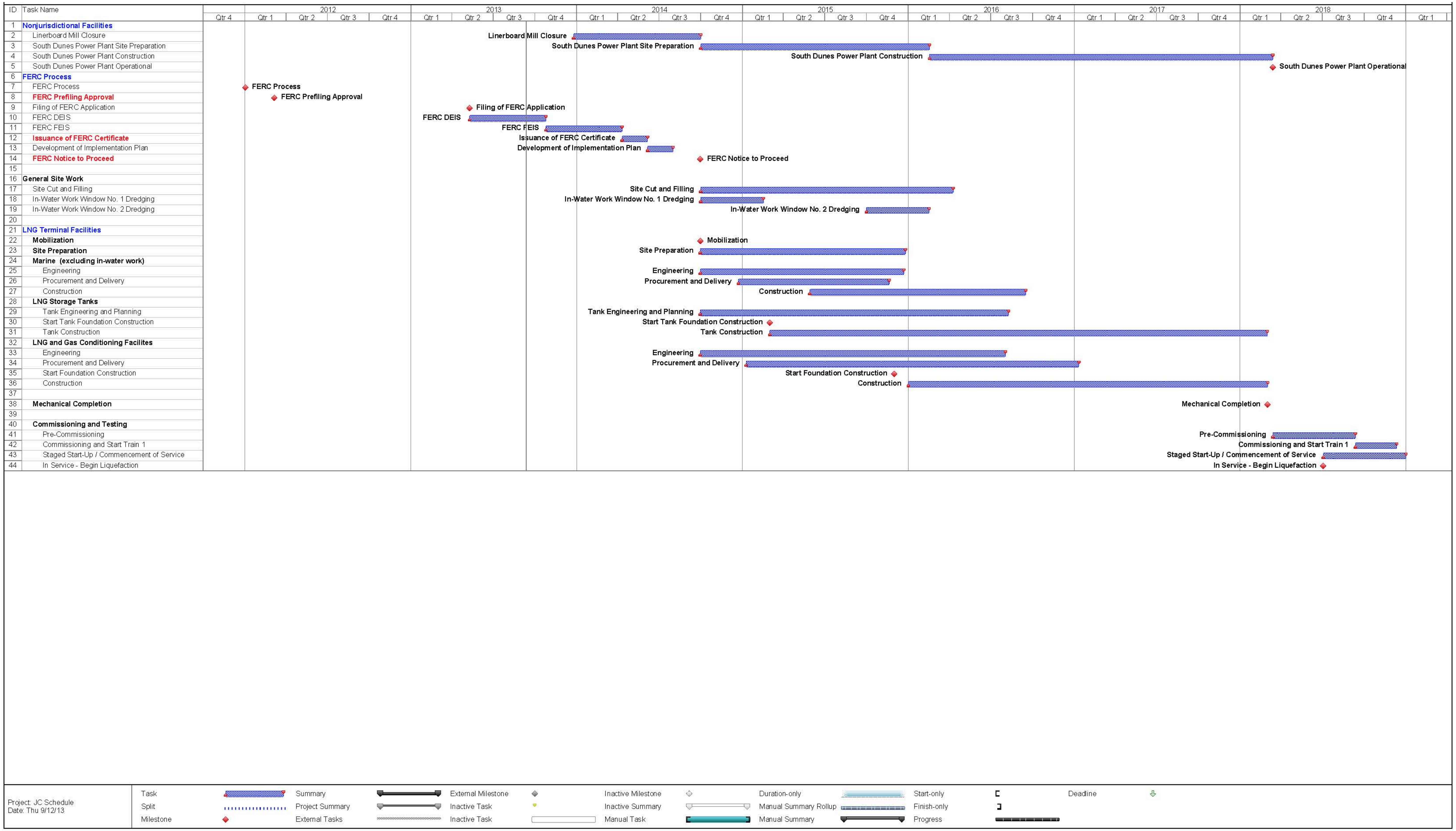



**Figure 3.2-2.** Schedule for LNG Terminal and Marine Facilities

During Project Year Two, the following activities would be conducted:

- Complete excavation of dredge pocket behind the berm, and hydraulically transport materials to power plant site;
- Complete installation of piles in the portion of the slip behind the berm;
- Construction of the LNG berth facilities;
- Complete final engineering design;
- Start foundation construction in liquefaction area;
- Start mechanical installations;
- Conduct additional dredging in the bay during the second in-water work window;
- Continue construction of the LNG storage tanks.

During Project Year Three, the following activities would be conducted:

- Complete structural foundations;
- Complete erecting buildings;
- Start electrical installations;
- Complete the berth and LNG loading facilities;
- Complete construction of LNG storage tanks;
- Continue construction of liquefaction facilities and gas processing.

During Project Year Four, the following activities would be conducted:

- Complete LNG storage tank construction;
- Commission and start Train 1;
- Staged Start-up and Commencement of Service; and
- Begin liquefaction.

All construction within Coos Bay would occur during the allowable in-water work window recommended by the ODFW (October 1 through February 15).

### 3.2.2 Pacific Connector Pipeline Facilities

Pacific Connector anticipates starting construction on the Pacific Connector pipeline in Project Year Two and continuing through Project Year Three. Restoration of construction disturbance is expected to begin in the fall of Project Year Three and be completed by the end of the winter season in the early part of Project Year Four when forest, wetland, and riparian revegetation – trees and shrubs – would be planted. Depending on site-specific conditions, it may be necessary to continue restoration and revegetation through spring of Project Year Four.

During the first year of pipeline construction (Project Year Two or BA Year 3), Pacific Connector plans to conduct the HDDs at the Coos, Rogue and Klamath Rivers and the Direct Pipe method at the first South Umpqua River crossing to allow sufficient time to pursue permits for alternate crossing locations or methods in the unlikely event the proposed HDDs/DP are unsuccessful. An alternate crossing method or an HDD at an alternate location would then be completed in the second year of pipeline construction (Project Year Three or BA Year 4) during mainline construction, if the original HDD/DP could not be completed in Project Year Two. Also in Project Year Two, Pacific Connector plans to clear forest along the pipeline route to minimize overall construction workspace requirements. Additionally, Pacific Connector anticipates starting pipeline construction in Project Year Two for: 1) the Coos Bay water route segment (MPs 1.7R to 4.1R) to allow pipeline installation to occur during the recommended in-water work period established by ODFW; 2) portions of the Klamath Basin (MPs 188 to 228) to minimize agriculture impacts and to allow the crossing of most irrigation canals when they are dry; 3) areas identified during biological surveys to have MAMU presence or occupied stands and/or NSO activity to minimize disturbance to those federally-listed species, except where identified in sections 4.3.3 and 4.3.4 of this BA; and 4) some areas of severe slopes.

Pacific Connector intends to construct the pipeline using five geographic spreads as previously mentioned. The construction spreads would include all timber clearing, construction, and restoration activities within a specific milepost range along the pipeline. The location of each construction spread is provided in table 3.2.2-1.

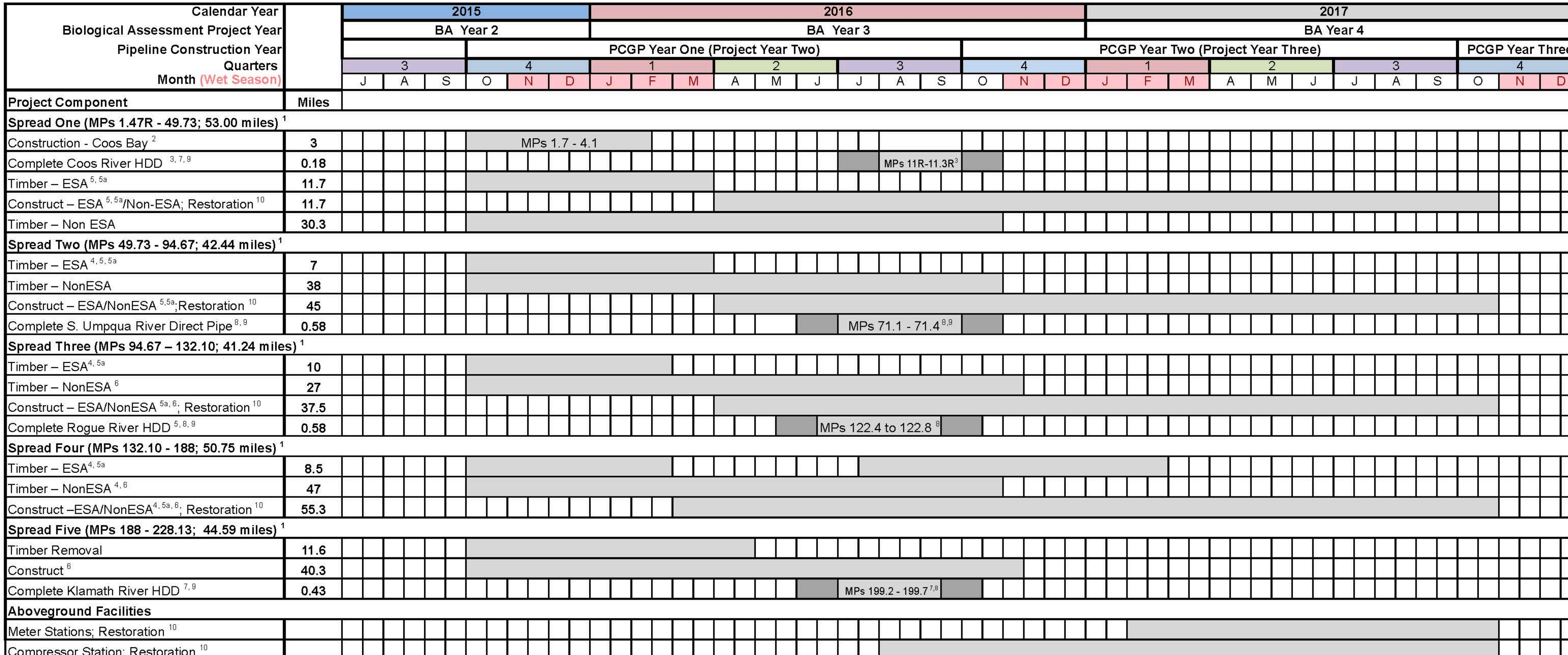
TABLE 3.2.2-1

**Pacific Connector Pipeline Construction Spread Locations**

| Spread | Milepost Range [1] | Length (miles) a/ |
|---|---|---|
| 1 | 1.47R to 49.73 | 53.00 |
| 2 | 49.73 to 94.67 | 42.44 |
| 3 | 94.67 to 132.10 | 41.24 |
| 4 | 132.10 to 188.00 | 50.75 |
| 5 | 188.00 to 228.13 | 44.59 |

a/ Mileposts remain the same (through the use of equations), although reroutes have been incorporated into the alignment and the actual spread lengths have been adjusted.

A schedule has been developed for each spread for Project Years Two, Three, and Four (PCGP Years One and Two), taking into consideration seasonal construction constraints (timing windows) stipulated to protect biological resources (NSO, MAMU, in-stream construction/fisheries, and big game wintering habitats). The schedule allows for reasonable time requirements to remove timber and construct the Pacific Connector pipeline to reduce potential environmental impacts and construction safety risks associated with winter construction. If stipulated timing windows for two or more resources conflict with each other or cannot be considered for environmental and safety reasons, efforts have been taken to reduce the seasonal constraints near the ends of recommended in-stream construction windows (ODFW 2000a) and/or NSO and MAMU breeding seasons. Except where noted below, construction across waterbodies would occur within the ODFW-recommended in-stream construction timing windows, although the majority of bridges, where required, would be installed prior to and removed after the in-stream timing window. General timing of activities for each of the five construction spreads is discussed below and shown schematically in figure 3.2-3. A more comprehensive Project description specific to each listed species is included below in section 4.0 of this BA.




[1] Because of the various reroutes incorporated into the Proposed Project alignment and the incorporation of engineering station equations, milepost ranges cannot be subtracted to calculate the spread length.

[2] Construction within ODFW-recommended in-water work window (October 1 through February 15).

[3] ODFW-recommended in-water work window is from October 1 through February 15. Because of the extensive wetland location on the south side of the Coos River, Pacific Connector has scheduled the HDD during the dry season outside the in-water work window between August 1 and September 30 to minimize surface impacts within the saturated floodplain wetland.

[4] This segment of pipeline may require helicopter use for timber removal and pipeline construction.

[5] Timber clearing is scheduled to be completed between 9/16 and 3/31 within 300 feet of marbled murrelet (MAMU) stands; construction within 0.25 mile of MAMU stands is scheduled to adhere to daily timing restrictions (DTRs) from April 1 through August 5.

[5a] Timber clearing is scheduled to be completed between 10/1 and 2/28 within 0.25 mile of northern spotted owl (NSO) nests; construction within 0.25 mile of NSO nests is scheduled not to occur between March 1 and July 15.

[6] Within designated big game range, timber removal and construction is scheduled to be conducted between May 1 through November 15.

[7] ODFW-recommended in-water construction window is July 1 through January 31; construction would precede the window by 1 to 2 weeks based on ODFW input.

[8] Construction is aligned, to the extent feasible based on drilling requirements and interagency discussions, with the ODFW-recommended fish windows, which are July 1 through August 31 for the South Umpqua River and June 15 through August 31 for the Rogue River.

[9] For all HDDs and Direct Pipe, upland rig-up and preparation can occur outside the fish window (dark shaded area). Actual drilling under waterbody is denoted by lighter shading. Frac-out risk is highest during initial drilling period; the risk becomes lower as drilling operations proceed and is lowest during pipe pullback. The schedules presented anticipate a reasonable drilling schedule (shown in lighter gray) without major delays due to potential issues such as stuck drill or reaming tools or pipe installation problems. If such issues create delay, the HDD duration, actual drilling, and pipe installation, as denoted by the lighter gray duration periods in the schedule, could extend into the darker gray durations at the end of the HDD/DP or beyond.

[10] Restoration is expected to begin in the fall of Year Two and be completed by the end of the winter season the following year when the forest, wetland, and riparian plantings would be completed.

**Figure 3.2-3.** General Construction Schedule for the Pacific Connector Pipeline

#### 3.2.2.1 Construction Spread One (MPs 1.47R to 49.73)

Pacific Connector considered the following biological concerns when determining the schedule for construction of Spread One:

- Coos Bay/Haynes Inlet crossing October 1 to February 15 (ODFW work window);
- Coos River HDD August 1 to September 30 (ODFW work window is October 1 to February 15, but crossing is scheduled during dry portion of the year due to the extensive wetland on the south side of the river);
- All other perennial/intermittent waterbody crossings July 1 to September 15 (ODFW work window);
- Possible bald eagle nest near MPs 4.4 to 4.9 - Pacific Connector would not construct within 0.25 mile of the nest if it is occupied during the breeding season between January 1 and August 31.
- Timber removal October 1 through February 28 [0.25 mile from NSO nests]/March 31 [300 feet from MAMU stands] – Project Year Two and Year Three.

#### 3.2.2.2 Construction Spread Two (MPs 49.73 to 94.67)

Pacific Connector considered the following biological concerns when determining the schedule for construction of Spread Two:

- South Umpqua River (MP 71.3) Direct Pipe crossing July 1 to September 30 (ODFW work window is July 1 to August 31);
- All other perennial/intermittent waterbody crossings July 1 to September 15 (ODFW work window);
- Timber removal October 1 through February 28 [0.25 mile from NSO nests]/March 31 [300 feet from MAMU stands] – Project Year Two and Year Three.

#### 3.2.2.3 Construction Spread Three (MPs 94.67 to 132.10)

Pacific Connector considered the following biological concerns when determining the schedule for construction of Spread Three:

- South Umpqua River (MP 94.7) Diverted Open Cut crossing July 1 to August 31 (ODFW work window);
- Rogue River HDD June 15 to September 15 (ODFW work window is June 15 to August 31);
- Perennial/intermittent waterbody crossings between MPs 94.85 and 110.98 July 1 to September 15 (ODFW work window);
- All other perennial/intermittent waterbody crossings June 15 to September 15 (ODFW work window);
- Timber removal October 1 through February 28 [0.25 mile from NSO nests] – Project Year Two and Year Three;
- A 1.5-mile-recommended no disturbance buffer from February 1 through August 31 of a known and productive peregrine falcon nest located on Umpqua National Forest.
- Timber removal and construction within designated big game range May 1 to November 15 unless within a 0.25 mile of an NSO activity center.

#### 3.2.2.4 Construction Spread Four (MPs 132.10 to 188.00)

Pacific Connector considered the following biological concerns when determining the schedule for construction of Spread Four:

- Perennial/intermittent waterbody crossings between MPs 132.10 and 166.21 June 15 to September 15 (ODFW work window);
- Perennial/intermittent waterbody crossings between MPs 166.21 and 177.76 August 1 to September 30 (ODFW work window);
- All other perennial/intermittent waterbody crossings July 1 to January 31 (ODFW work window);
- Timber removal October 1 through February 28 [0.25 mile from NSO nests] – Project Year Two and Year Three;
- Timber removal and construction within designated big game range May 1 to November 15 unless within a 0.25 mile of an NSO activity center.

#### 3.2.2.5 Construction Spread Five (MPs 188.00 to 228.13)

Pacific Connector considered the following biological concerns when determining the schedule for construction of Spread Five:

- Klamath River HDD July 15 to September 15 (ODFW work window is July 15 to January 31);
- Perennial/intermittent waterbody crossings between MPs 188.0 and 199.38 July 1 to January 31 (ODFW work window);
- Bureau of Reclamation features October 15 to March 15;
- Irrigation canals/ditches during the winter/non-irrigation season;
- All other perennial/intermittent waterbody crossings July 1 to March 31 (ODFW work window);
- Timber removal and construction within designated big game range May 1 to November 15.

## 3.3 PROPOSED CONSERVATION MEASURES

### 3.3.1 Proposed Conservation Plan

The applicants have developed a program of conservation measures for the Project that they believe would mitigate adverse impacts to proposed or listed species and their habitats, including proposed or designated critical habitats. Each of the applicants' proposed conservation measures has been categorized into one of five "mitigation" applications, described by the CEQ (43 FR 55990 §1508.20, 1978):

1. Avoiding the impact altogether by not taking a certain action or parts of an action;
2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; or

5. Compensating for the impact by replacing or providing substitute resources or environments.

The goal of the proposed conservation measures is to compensate for unavoidable impacts to listed species and their habitats, intended to improve the status of the species within the context of their listing or proposal for listing under the ESA. The Proponents recognize that two factors will be key to achieving that goal – the same factors that FWS and NMFS would consider when evaluating conservation efforts in decisions whether or not to list species under ESA (FWS and NMFS, 2003). Those two factors include 1) some level of certainty that the conservation measure (or effort) will be implemented, and 2) some level of certainty that the conservation measure (or effort) will be effective.

In general, mitigation or conservation efforts (measures) that avoid impact to proposed and/or listed species and critical habitats have been developed by all Proponents during project design. Measures that minimize impact will be primarily applied on-site at the time of project construction while conservation measures that rectify impact by repair, rehabilitation, or restoration and those that involve impact reduction (by preservation and/or maintenance) are planned for implementation immediately after construction and final site preparation prior to restoration being completed. Compensatory mitigation will be implemented after approval and/or initiation of the project.

The effectiveness of individual conservation measures in improving the status of listed species will be difficult to predict. However, many of the conservation measures can be classified as "best management practices" that have been published by FERC in its *Upland Erosion Control, Revegetation, and Maintenance Plan* and *Wetland and Waterbody Construction and Mitigation Procedures* and are the current standards applied by the natural gas pipeline industry. FERC's BMPs have been subject to the public scoping process with extensive review by the pipeline industry, knowledgeable public, and state and federal regulators nationwide. Reference to a specific section in FERC's Plan and/or Procedures is made in the following sections when relevant to an individual conservation measure.

Other agencies with jurisdictions affected by the Project (BLM and Forest Service) also have BMPs within their respective land management plans that have been promulgated to conserve the natural resources under their authority. However, those agencies' BMPs, by necessity, are more general than FERC's BMPs because they apply to a wide variety of actions, not specifically to pipeline construction.

The Mitigation Policy developed by FWS (1981) specifically excluded any application to listed threatened or endangered species or their critical habitats. Nonetheless, FWS specifically stated that the most desirable sequence of mitigation begins with avoidance, with minimization as the next preferred, then followed by restoration and reduction of impact, and finally compensation. Considering compensatory mitigation in *Guidance for the Establishment, Use, and Operation of Conservation Banks*, FWS (2003a) emphasized that "off-site conservation banks may be the only mitigation option when on-site conservation measures are not practicable for a project or when the use of the bank is environmentally preferable to on-site measures" (FWS, 2003, page 1).

ODFW (2005a) has likewise prioritized impact mitigation actions in the following order: 1) avoid the impact, 2) minimize the impact, 3) repair, rehabilitate or restore the affected area, and 4) replace or provide comparable habitats.

### 3.3.1.1 Avoiding Impact

In CEQ's definition of mitigation by avoidance, an impact does not occur because the action or parts of the action do not occur. Implied in that definition is some knowledge about the action that otherwise would have occurred and analysis of effects to the potentially impacted resource. No such analyses have been conducted for the instances where impacts have been avoided by one or more Project components.

No federally listed species were identified in the upland portions of Jordan Cove's proposed LNG terminal. However, there are federally-listed fish species in Coos Bay that may be affected by proposed dredging for the access channel and slip, and by LNG carrier cooling water and discharges of ballast water. Those acquatic species, impacts, and mitigation are discussed elsewhere in this BA.

Jordan Cove would avoid direct impacts on western snowy plovers and their designated critical habitat since all material excavated and dredged from the slip will be placed at the South Dunes Power Plant site which is not utilized for nesting by snowy plovers. Since all the material to be excavated and dredged from the slip can be used in the development of the South Dunes Power Plant site, other disposal or placement alternatives were dismissed as not being environmentally preferable because use of those sites had the potential for adverse impacts on snowy plover habitat on the North Spit.

Similarly, Pacific Connector would avoid direct impacts on some federally listed species by how it designed the route for its pipeline at specific locations (see Appendix V). Some of the locations are listed below:

- MP 11.13R – HDD under the Coos River avoids direct impacts on Coho salmon;
- MPs 29.8 to 30.1 – route avoids MAMU habitat and an occupied stands;
- MPs 51.5 to 52.1 – route avoids MAMU stands;
- MPs 57.8 to 57.9 – route avoids population of Kincaide's lupine;
- MPs 110.2 to 110.4 – route avoids NSO nest patches;
- MP 122.6 – HDD under the Rogue River avoids direct impacts on Coho salmon;
- MPs 161.2 to 161.4 – route avoids NSO nest patch;
- MPs 195.4 to 196.5 – route avoids population of Applegate milk vetch; and
- MP 199.4 – HDD under Klamath River avoids direct impacts on Lost River and shortnose suckers.

Pacific Connector would be able to avoid impacts on specific populations and critical habitat for vernal pool fairy shrimp, large-flowered woolly meadowfoam, and Cook's lomatium within the Burril Lumber and Medford Industrial Park proposed contractor/pipe storage yards (Jackson County) by not using portions of those yards which contain individuals or habitat.

### 3.3.1.2 Minimizing Impact

In CEQ's definition of mitigation by minimization, impact occurs, but effects (magnitude of impacts) are limited by different means, including 1) design of the proposed action and its components, and 2) application of specific conservation measures (including BMPs) during implementation of the proposed action that minimize impact. Many of the conservation measures associated with the proposed Project that would reduce impacts on federally listed species can be classified as BMPs. These BMPs have been incorporated into Jordan Cove's Plan and Procedures and Pacific Connector's ECRP. The project-specific applicant-prepared plans and procedures and ECRP are based upon the FERC staff's Plan and Procedures, which are the current standards applied by the natural gas pipeline industry. The FERC staff's Plan and Procedures have been subject to public scrutiny for many years, including extensive review by state and federal resource agencies and/or regulators nationwide. Reference to a specific section in the FERC staff's Plan and/or Procedures is made in the following sections when relevant to an individual conservation measure.

Other agencies with jurisdictions affected by the Project (BLM, USFS, and Reclamation) also have BMPs within their respective land management plans that have been promulgated to conserve the natural resources under their authority. However, those agencies' BMPs, by necessity, are more general than the FERC staff's Plan and Procedures because they apply to a wide variety of actions, not specifically to pipeline construction.

Jordan Cove has also developed a plan to reduce the chance for LNG carriers to collide with federally listed marine mammals and sea turtles within the EEZ. Jordan Cove would request all LNG carriers calling on the LNG terminal to reduce speeds to 10 knots or less within 30 nautical miles of the entrance to Coos Bay during the whale migratory period. During the 96-hour pre-notification process to be followed by all LNG carriers calling on the terminal, Jordan Cove would check with the NMFS for information on the migratory patterns of whales within the route of the LNG carrier and would inform the ship's master of the patterns reported by NMFS. Jordan Cove would request that all LNG carrier operators consult current whale sighting information prior to calling on the LNG terminal and be aware of the reported locations of whales and plan their operations accordingly. LNG carriers would be requested to route around and maintain a 100-yard distance from the whales observed and to avoid crossing in front of the whales and maintain a parallel route, if possible.

Jordan Cove would provide a ship strike avoidance measures package to shippers exporting LNG cargo from the Jordan Cove LNG terminal. This package would include the measures proposed by NMFS for avoidance of marine mammals to further reduce the likelihood of adverse effects on these species. Some of the suggested measures include the following:

- Provide training to LNG carrier crews, including the use of a reference guide such as the Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska by Pieter Folkens. This is a pamphlet that would be provided to LNG carriers calling on the terminal and would be included as part of the terminal use agreement to the shippers.
- Provide a copy of the NMFS CD-rom-based training program entitled A Prudent Mariner's Guide to Right Whale Protection as part of a ship strike avoidance measures package to all LNG carriers calling on the terminal. While this CD-rom-based training program is specific to right whales, NMFS has stated that the guidance and avoidance measures are also applicable to fin, humpback, and sperm whales.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the ship to 10 knots or less to avoid striking protected species.

- When whales are sighted, maintain a distance of 90 meters (or 100 yards) or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce ship speed to 10 knots or less when pods or large assemblages of cetaceans are observed near an underway ship.
- When whales are sighted in a ship's path or in proximity to a moving ship, reduce speed to 10 knots or less or shift the engine to neutral until whales are clear of the area or path of the ship.

LNG carrier crews would be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the ship. If the injury or death is caused by collision with the ship, appropriate regulatory agencies (FERC or NMFS) would be notified within 24 hours of the incident. Information to be provided would include the date and location (latitude/longitude) of the strike, the ship name, the species or a description of the animal, if possible.

LNG carrier masters would be requested to provide reports of sightings of marine mammal while in the EEZ action area and to provide the report upon docking at the LNG terminal. This reporting request would be included in the Ship Strike Avoidance Measures Package provided to each LNG carrier calling on the terminal and compliance with the measures and the reporting would be included in all terminal service agreements with shippers.

Conservation measures that have been proposed to minimize impacts during construction and operation are provided in table 2A in Appendix N for the marine facilities, in table 2B in Appendix N for the Jordan Cove LNG Terminal, and in table 2C in appendix N for the Pacific Connector pipeline. The diverse array of conservation measures provided in those tables has been organized along several hierarchal categories that have been formulated to provide for focus and evaluation of how each measure would contribute to minimizing impact. First, project locations have been included where each measure is most likely to be applied. In all but a few instances, locations are broadly identified (for example, waterbodies crossed or the construction right-of-way along the Pacific Connector pipeline route) because measures are likely to be applied in all or most of those locations.

In each of the three tables in Appendix N, multiple conservation measures may apply to the same resource. Resources have also been broadly identified by relevance to proposed and listed species and their habitats overall, not just proposed or designated critical habitats. As examples, "water quality" and "soils" are resources relevant to aquatic and terrestrial species in very broad terms, whereas the resource identified as "EFH-pelagic, groundfish, salmon, other fish and invertebrate species" is specific to those species within the Coos Bay estuary while "EFH-freshwater salmon, fisheries and aquatic resources" applies to species in fresh waterbodies affected by pipeline construction.

In many instances, while multiple conservation measures apply to the same general location and same general resource, specific conservation measures are likely to minimize impact to the resource differently, depending on how the impact potentially affects the resource. To account for the different ways that conservation measures are likely to minimize impact, impact pathways have been schematically described to further categorize the potential utility of each measure. To illustrate, Jordan Cove (table 2A in Appendix N) has proposed to install all piles while the slip is isolated from the bay. That measure virtually eliminates impact along the following schematic pathway in which arrows indicate likely cause-and-effect relationship: "acoustic shock → physiological damage, displacement from habitat → mortality of fish and other aquatic species." That conservation measure and pathway apply to the "EFH-pelagic, groundfish, salmon, other fish and invertebrate species" resource.

Jordan Cove would reduce impacts on western snowy plovers through implementation of 1) BMPs and 2) education and outreach programs. During construction of the LNG terminal, the facility would be kept clear of debris and food wastes that could attract snowy plover predators. Covered, animal-proof receptacles would be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. The site would be policed on a daily basis during construction to remove any food or other debris left by workers.

Jordan Cove would train all construction and operations staff on the need for snowy plover conservation; current snowy plover regulations and recreational use restrictions; and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on-leash, and remaining on established roads and trails. The training program would be developed based on guidance provided in Appendix K of the 2007 Plover Recovery Plan, or would be contracted for through state/local agencies or organizations (such as the Oregon Coast Aquarium, National Park Service, Western Snowy Plover Working Team, or Oregon Coast Community College) who may have pre-existing plover education and outreach programs. Prior to implementation, the training program would be submitted for comment to members of the Western Snowy Plover Working Team.

The training would be administered concurrently with safety training provided to all staff at the beginning of their employment. Environmental training would also be provided to operational personnel, to ensure that all personnel are aware of and comply with the management tools in place to affect the recovery and maintenance of the snowy plover population on the North Spit. Printed educational materials would be posted at the proposed facilities for the life of the LNG terminal. The types of educational materials may vary, but could include posters, table tents, maps, brochures, or fact sheets. Numerous sources for existing educational materials are provided in Appendix K of the Plover Recovery Plan (FWS, 2007c).

Some examples of conservation measures for Pacific Connector's pipeline include modifications incorporated into the proposed route that would reduce impacts on some federally listed species. In general, these route or TEWA modifications reduced the amount of old growth forest that would need to be cleared at specific locations, thus reducing impacts on species that inhabit that forest. In some cases, the proposed pipeline route or TEWA was moved to locations where the forest was previously harvested, or the pipeline was co-located with an existing right-of-way. Places where the pipeline route was modified or TEWAs changed to reduce impacts are detailed in Appendix V:

Pacific Connector can also reduce impacts on federally listed species through the timing and duration of construction activities. For example, all waterbodies would be crossed during the ODFW recommended in-water work windows, thus minimizing impacts on federally listed fish species. Similarly, impacts on MAMU can be minimized if tree clearing activities within

MAMU nesting habitats are conducted between September 16 and March 31, outside of the MAMU critical breeding period that lasts from April 1 through August 5.

#### 3.3.1.3 Restoration and Monitoring

CEQ distinguished between mitigation of impact by repairing, rehabilitating, or restoring the affected environment (restoration), and reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action (reduction). In practice, these two approaches are often combined or the distinction between the two approaches becomes blurred.

Restoration of the affected environment is a key element of the FERC staff's Procedures for affected waterbodies (Section V.C.1-8) and wetlands (Section VI.C.1-7). The FERC staff's Procedures also require monitoring for restoration success (Section VI.D.3 and 4) as follows:

- Monitor and record the success of wetland revegetation annually for the first 3 years after construction or until wetland revegetation is successful. At the end of 3 years after construction, file a report with the Secretary identifying the status of the wetland revegetation efforts. Include the percent cover achieved and problem areas (weed invasion issues, poor revegetation, etc.). Continue to file a report annually until wetland revegetation is successful.
- Wetland revegetation shall be considered successful if the cover of herbaceous and/or woody species is at least 80 percent of the type, density, and distribution of the vegetation in adjacent wetland areas that were not disturbed by construction. If revegetation is not successful at the end of 3 years, develop and implement (in consultation with a professional wetland ecologist) a remedial revegetation plan to actively revegetate the wetland. Continue revegetation efforts until wetland revegetation is successful.

Likewise, Section VII in the FERC staff's Plan specifies the following monitoring requirements (Section VII.A):

1. Conduct follow-up inspections of all disturbed areas after the first and second growing seasons to determine the success of revegetation.
2. Revegetation in non-agricultural areas shall be considered successful if upon visual survey the density and cover of non-nuisance vegetation are similar in density and cover to adjacent undisturbed lands. In agricultural area, revegetation shall be considered successful if crop yields are similar to adjacent undisturbed portions of the same field.
3. Continue revegetation efforts until revegetation is successful.
4. Monitor and correct problems with drainage and irrigation systems resulting from pipeline construction in active agricultural areas until restoration is successful.
5. Restoration shall be considered successful if the right-of-way surface condition is similar to adjacent undisturbed lands, construction debris is removed (unless requested otherwise by the landowner or land managing agency), revegetation is successful, and proper drainage has been restored.

Reporting requirements (the FERC staff's Plan Section VII.B) include:

1. The project sponsor shall maintain records that identify by milepost:

    a. method of application, application rate, and type of fertilizer, pH modifying agent, seed, and mulch used;
    b. acreage treated;
    c. dates of backfilling and seeding;
    d. names of landowners requesting special seeding treatment and a description of the follow-up actions; and
    e. any problem areas and how they were addressed.
2. The project sponsor shall file with the Secretary quarterly activity reports documenting problems, including those identified by the landowner, and corrective actions taken for at least 2 years following construction.

These FERC requirements form the basis for Project monitoring and response to less-than-satisfactory restoration progress.

Conservation measures that have been proposed to rectify, repair, and rehabilitate the affected environment or reduce and eliminate impacts after construction are provided in table 3A in Appendix N for the Jordan Cove Terminal and Marine Facilities and in table 3C in Appendix N for the Pacific Connector pipeline. Conservation measures provided in those tables have been organized by the same hierarchal categories that were described above for tables 2A, 2B, and 2C in Appendix N. As before, Project locations have been included where each measure is most likely to be applied. Also, resources have also been broadly identified by relevance to proposed and listed species and their habitats overall. And, impact pathways have been schematically described to further categorize the potential utility of each measure as they were in tables 2A, 2B, and 2C in Appendix N.

During operation of its proposed LNG terminal, Jordan Cove would conduct the following monitoring activities to reduce impacts on western snowy plovers. The facility and grounds would be regularly inspected to assure that no garbage is allowed to accumulate. Structures associated with the LNG terminal and the LNG loading berth would be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the Migratory Bird Treaty Act.

In the event that a clearly demonstrable and sustained decrease in snowy plover productivity is detected by the ongoing ORNHIC monitoring, Jordan Cove would coordinate with ORNHIC, BLM, OPRD, Wildlife Services, ODFW, FWS and other interested parties to identify adaptive management strategies, as appropriate, to help reverse any such trend.

In the case of the Kincaid's lupine, a federally listed plant, as part of its conservation measures, Pacific Connector has recommended the translocation and replanting of individuals that cannot be avoided during pipeline construction. Pacific Connector proposes that locations for these species be monitored for three years following replanting, to check for germination and successful establishment of the plantings. Pacific Connector has suggested that monitoring should be conducted by a third-party botanical contractor with appropriate credentials to perform the monitoring. Monitoring reports would be provided to FWS, NMFS, FERC and other relevant agencies that request copies of the reports.

### 3.3.2 Compensatory Mitigation Program

Impacts and effects that cannot be otherwise mitigated would be primarily addressed through the applicants' Compensatory Mitigation Plan (CMP) (see Appendix O). The overarching goal of the CMP is to compensate for unavoidable impacts to listed species and their habitats through substitute habitat and/or habitat stewardship.

The applicants have developed this BA in informal consultation and cooperation with FWS and the applicants remain committed to continue working cooperatively with FERC and FWS to refine the mitigation proposal associated with the BA. The CMP is considered a working document that would be revised throughout the ESA consultation process. The following sections are summaries of the compensatory mitigation proposed for each of the Project components.

#### 3.3.2.1 LNG Terminal Components

There are no threatened or endangered species that would be directly affected by the construction of the upland portion of the slip or by construction or operation of the LNG terminal. Operation of the slip (berthing and unloading of LNG carriers) could have some potential direct effects on marine ESA species that make their way into the slip over time. Transit of the LNG carriers could result in potential effects to marine organisms and marine mammals, birds, and reptiles through accidental contact with the ships.

There are potential indirect effects associated with the conversion or removal of upland habitat, placement of dredged materials, and offsite construction worker effects that would be minimized by management practices and oversight of construction activities and personnel. Compensatory mitigation is proposed for those species, such as the snowy plover, where management practices alone may not be sufficient to avoid potentially adverse effects (see section 4.3.3.3 of this BA).

The natural habitats that would be affected most heavily by the construction of the slip and access channel are open-water habitat, and dune forest, with lesser impacts to shoreline habitat. The relatively natural habitat that would be affected most by construction of the upland portions of Jordan Cove's terminal is dune forest, with lesser impacts to grasslands and herbaceous associations. The mitigation strategy that has been proposed for the upland habitat affected by the slip and LNG terminal involves the restoration/enhancement of approximately 48 additional acres in the proposed mitigation area for intertidal habitat.

The approximately 37 acres of upland ODFW Habitat Category 4 affected by the construction of the slip would be converted to approximately 37 acres of open water Habitat Category 5 following construction. The 3.9 acres of the intertidal unvegetated sand-mud flat (Habitat Category 4), the 4.2 acres of intertidal algal flat (Habitat Category 4), and 2.48 acres of eelgrass (Habitat Category 3) affected by the construction of the slip would be mitigated by Jordan Cove (see Attachment 9 to Appendix O).

To mitigate for loss of intertidal unvegetated sand-mud flats and algal flat, Jordan Cove proposes to create new wetlands at a former golf course adjacent the south bank of Kentuck Slough.

Approximately 35 acres disturbed by the construction and operation of the golf course would be restored to a mud-flat condition by re-establishing tidal connections with Kentuck Inlet. This would be accomplished through the removal of tidegates and dikes.

Restoration effort at the Kentuck Slough mitigation site would result in some impacts; however, they would be temporary short term impacts as they would be limited in scope and would only exist during the actual restoration process. Potential impacts include a temporary reduction in water quality due to an increase in sedimentation during dike/tidegate removal, temporary disturbances to adjacent wildlife, and a temporary impact to vegetation removed during restoration activities. As the site is currently utilized as a golf course, these impacts would be less than significant.

To mitigate for impacts on eelgrass, Jordan Cove proposes to create new eelgrass habitat at a shallow unvegetated island approximately 900 feet southwest of the Coos-Bay North Bend Airport runway. This site is adjacent to a successful eelgrass restoration site owned by the State of Oregon and managed by the ODSL. The 2-acre eelgrass mitigation site would be dredged/excavated to the appropriate elevation and then revegetated with eelgrass during summer months (the optimal time for eelgrass transplantation). The proposed success criteria for this eelgrass mitigation site would be the successful establishment of new eelgrass habitat. The COE, NMFS, and EPA have expressed concern regarding the mitigation ratio proposed.

Another element of the CMP for the JCE & PCGP Project is having the applicants fund various projects that would generally benefit species. Jordan Cove reviewed a list of mitigation measures provided by the FWS, BLM, USFS, and ODFW through the Sediment Placement subgroup of the Interagency Task Force and agreed to provide funding as enumerated below. The funding would be provided to the entity as defined by the agencies and it would be the responsibility of the particular entity to administer the funding. Jordan Cove is also requesting that the funding of these conservation measures be used in part to contribute to other habitat mitigation requirements imposed by the ODFW.

Year 1 (when construction begins) – provide $60,000 for:

- fencing (~$30,000)
- signage
- application of shell hash
- tree removal
- one year of maintenance – $10,000

Years 2 and 3 – provide $30,000 (each year) for:

- annual maintenance – $10,000
- beach grass elimination grant (minimum of $10,000)
- shell hash

Years 4 to 2020 – provide $10,000 for:

- annual maintenance

Jordan Cove would fund one additional entry-level wildlife services position dedicated to snowy plover predator monitoring and control during the 42-month construction period.  This staff member would be employed by Oregon Wildlife Services, which is administered by the U.S. Department of Agriculture and Animal and Plant Health Inspection Services.  The specific duties of this additional staff member would be determined by Wildlife Services based on Coos Bay North Spit management needs, but would concentrate on predator management.  This additional position would allow Wildlife Services to better evaluate predator densities and more quickly and effectively respond in the unlikely event that predator pressure on the CBNS increases during Project construction.

#### 3.3.2.2 Pacific Connector Pipeline Component

Appendix O provides Pacific Connector's draft compensatory mitigation plan for effects to ESA species and/or critical habitat as well as Pacific Connector's proposed compensatory mitigation for in-stream and riparian habitat modifications.

# 4.0 SPECIES ACCOUNTS, CRITICAL HABITAT, PROJECT EFFECTS, AND DETERMINATIONS OF EFFECT

This section describes the current status of the species and critical habitat (if applicable) analyzed in this BA. Information provided includes descriptions of species' range and/or critical habitat that may be affected by construction, operation, and maintenance activities of the LNG terminal, Port component, and pipeline and any information relevant to a species' current status.

As applicable, the *Endangered Species Consultation Handbook* (FWS and NMFS, 1998) was used for guidance to analyze the potential Project effects to plant and animal species listed under ESA, their proposed or designated critical habitats, and their recovery. Information on listed species' distributions, habitat requirements, and potential occurrence in the Project area and vicinity was gathered from many sources including 1) published scientific literature; 2) agencies' published and unpublished reports including proposed and final actions published by FWS and NMFS in the Federal Register; 3) agencies' unpublished raw and/or compiled data; 4) agencies' geo-spatial databases, which document species observations; 5) on-site surveys for species and habitats; and 6) personal communications with agency personnel knowledgeable about species ecological status in the Project area and vicinity.

## 4.1 INTRODUCTION

The following subsections describe how the species accounts, critical habitat, project effects, and determinations of effect were developed or determined for the species addressed in this section. Also included are rationales used to exclude four species that are listed or proposed for listing under ESA from consideration in this BA, based on the stepped procedure outlined in Section 4.1.1 which would conclude in a **no effect** determination for the species.

### 4.1.1 Determination of Effects

The FWS (1998) utilized a four-step dichotomous key to make one of the following determinations under the ESA: **No effect**, **Likely to adversely affect**, or **Not likely to adversely affect**. The key was used for evaluating bull trout, but is sufficiently general and rigorous to be used, with modification, to evaluate Project effects on the other listed species considered in this BA.

1) Is the proposed/listed species and/or proposed/designated critical habitat present in the Project area?

   NO - **No effect**.
   YES - Go to step 2.

2) Will the proposed action have any affect whatsoever on the species; designated or proposed critical habitat; seasonally or permanently occupied habitat; or unoccupied habitat necessary for the species' survival? (Any affect whatsoever includes small effects, effects that are unlikely to occur, and beneficial effects)

   NO - **No effect.**
   YES - May affect; Go to step 3.

3) Does the proposed action have potential to result in "take" of any proposed/listed species? ("Take" is defined as "to harass, harm, pursue, hunt, shoot, wound, trap,

capture, collect, or attempt to engage in any such conduct." "Harm" is further defined as "significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering", and "harass" as "actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering".)

NO - Go to step 4
YES - **Likely to adversely affect**.

4) Does the proposed action have potential to cause an adverse effect to any proposed/listed species' habitats, such as: adverse effects to critical habitat constituent elements or segments; impairing the suitability of seasonally or permanently occupied habitat; or impairing or degrading unoccupied habitat necessary for the survival of the species locally?

NO - **Not likely to adversely affect.**
YES - **Likely to adversely affect** (including adverse effects to critical habitat).

### 4.1.2 Determinations of No Effect

There are four species, listed or proposed for listing that occur within Oregon but would not be affected by the Proposed Action. Those species include the Canada lynx - Contiguous U.S. Distinct Population Segment, North American wolverine - proposed for listing, bull trout - Klamath River Distinct Population Segment, and yellow-billed cuckoo - Western Distinct Population Segment, proposed for listing. Brief synopses of the rationales to exclude the species from consideration in this BA are provided below.

Canada lynx. When FWS (2000a) listed Canada lynx as threatened in a final rule, Oregon was included in the species' range based on 12 verified lynx records (see McKelvey et al., 1999) in the state during the previous 100 years. The records (in museum collections) were from the 1800s and early 1900s including one in the U.S. National Museum from the east side of the Cascade Range at Fort Klamath (pre-1900) in Klamath County (Verts and Carraway, 1998). Recent lynx documented in the state were from Wallowa County (1964), Benton County (1974), and Harney County (1993), all in atypical habitats suggesting animals were dispersing from Canadian population centers (Verts and Carraway, 1998; McKelvey et al., 1999). Currently, northeast Oregon/southeast Washington is recognized as a peripheral area in the lynx recovery plan (FWS, 2005a) which could, sustain short-term survival during lynx dispersal. There appears to be an extremely remote chance of a lynx dispersing into southwest Oregon but that is not foreseeable during the construction of the Proposed Action and Canada lynx are not considered in this BA.

North American wolverine. The FWS (2013a) proposed listing the North American wolverine subspecies (*Gulo gulo luscus*) under the ESA. Wolverines in the Sierra Nevada and North Cascades Range are separated by an area in southern Oregon and northern California where there are no historic records of the species. The distribution of wolverines in this area is probably of two disjunct populations, separated for 2000 years prior to the extirpation of the Sierra Nevada population (FWS, 2013a). Currently, there is a small population in the Northern Cascades, sustained by colonizing individuals from Canada. The California wolverine subspecies (*Gulo gulo luteus*) was an Oregon state-threatened species although the subspecies designation is in question (Stone, 2007). One male wolverine recently immigrated to the Sierra Nevada and apparently still survives (FWS, 2013a). Wolverines were thought to have been extirpated in Oregon but since 1965 wolverines have been found in Linn County, on Steens Mountain in Harney County, in Wheeler County, in Hood County, in the Wallowa Mountains of northeastern Oregon (Grant County), and in 2011 one was confirmed in Wallowa County (ODFW, 2011a). The proposed listing under ESA includes wolverines in northeastern Oregon (FWS, 2013a). Due to their large home ranges and habitat preferences, a wolverine may occur in the project area, but none are expected in the foreseeable future. There have been no verified historical or recent records of the species occurring in the PCGP Project vicinity (ORBIC, 2012; Stone, 2007; Verts and Carraway, 1998), and the species would not be affected by the Proposed Action.

Bull trout. Bull trout in the Klamath River DPS inhabit seven isolated stream areas in the Klamath River Basin (FWS, 1998a). Critical habitat for bull trout in the coterminous United States includes Critical Haitat Unit 9, Klamath River Basin. Unit 9 inlcudes three subunits: Upper Klamath Lake, Sycan River, and upper Sprague River subunit (FWS, 2010a). The Upper Klamath Lake subunit is within the Long Lake Valley-Upper Klamath Lake fifth field watershed which is not crossed by the PCGP Project. Agency Lake is the only waterbody in Unit 9 with hydrologic connectivity to the Klamath River (within the Lake Ewauna-Klamath River fifth field watershed); connectivity is through Agency Straits, Upper Klamath Lake, and Link River. As of 2010, Agency Lake was not occupied by bull trout (FWS, 2010b) and no bull trout are present in the PCGP project area. Neither the species nor potentially occupied habitat would be affected by the Proposed Action.

Yellow-billed cuckoo. FWS (2013c) proposed listing the yellow-billed cuckoo, western DPS that nests west of the Continental Divide, for listing as threatened under ESA. In Oregon, the western DPS included birds that nested along the Willammette River and Columbia River although the last confirmed nesting records are from the 1940s and the birds dissappeard in Oregon by 1945 (Wiggins, 2005). Although ORBIC (2013) includes Klamath County within the range of yellow-billed cuckoo, surveys conducted during 1988 in Klamath County did not find any cuckoos (FWS, 2013c). There are recent records (1990 to 2009) from Deschutes, Malheur, and Harney counties (FWS, 2013c). Yellow-billed cuckoos are considered a riparian obligate species and are usually found in large tracts of cottonwood/willow habitats with dense sub-canopies, but may also be found in urban areas with tall trees (FWS, 2007c). No suitable habitats are present within the project area and the species would not be affected by the Proposed Action.

#### 4.1.2.1 Format

There are 30 species listed as threatened or endangered under the ESA and 1 species proposed for listing, totaling 31 species considered in this section. Included are 7 marine mammals, 5 birds, 5 herpetofauna (4 reptiles and 1 amphibian), 6 fish, 1 invertebrate, and 7 plants. This section was organized to address similar information and environmental analyses consistently among the diversity of organisms that could be affected by the proposed action. The following five sections are included for each species:

1. Species Account and Critical Habitat in which the current status under the ESA is identified, past threats that lead to listing and current threats to continued existence, recovery plan components if available, abbreviated species' life history, population estimates and/or trends, and critical habitat that has been designated or proposed;

2. Environmental Baseline in which the species analysis area (portions of the Project action area where species are affected by the proposed action) relevant to each species is described, as well as the species' presence within the action area, species' habitat within the action area, and species' critical habitat present within the action area are described and evaluated;
3. Effects by the Proposed Action in which direct and indirect effects to the species and critical habitats are evaluated in each action area component;
4. Conservation Measures that have been proposed by the applicants in addition to those defined in Section 3.3; and
5. Determination of Effects in which the action agency evaluates how the proposed action would affect the species and critical habitat.

### 4.1.3 Action Area

The action area includes all areas that would be affected directly or indirectly by the proposed action and not just the immediate area involved in the action. Because the proposed action potentially can affect such a variety of species inhabiting diverse habitats within marine, estuarine, riverine, and various terrestrial locations, there are multiple components of the action area that have been defined as species' analysis areas, the areas where individual or groups of listed species are affected by the proposed action. Species' analysis areas are described in detail in each species' environmental baselines. For some species there may be more than one analysis area if the listed species utilizes multiple habitats in diverse locations. Analysis areas and associated species include:

- The EEZ analysis area, which applies to all listed marine mammals), some birds (short-tailed albatross, MAMU), green sturgeon, eulachon, and listed sea turtles;
- The gray wolf analysis area only applies to a solitary gray wolf, OR-7, that has an area of known activity in Jackson, Klamath, and Douglas counties.
- The estuarine analysis area, which applies MAMU, green sturgeon, eulachon, and coho salmon (Oregon Coast ESU);
- The LNG terminal analysis area, which applies to western snowy plovers and streaked horned larks;
- Terrestrial nesting analysis area, which applies only to MAMU;
- Provincial analysis area, which applies only to NSO;
- Several riverine analysis areas that are in specific geographic locations each in the respective ranges of coho salmon in the Oregon Coast ESU and in the SO/NCC ESU, listed suckers, and Oregon spotted frogs; and
- Botanical analysis areas that include vernal pool-associated species (fairy shrimp and two listed plants) and other listed plant species.

## 4.2 MAMMALS

### 4.2.1 Blue Whale

#### 4.2.1.1 Species Account and Critical Habitat

**Status**

The blue whale was listed as endangered throughout its range under the Endangered Species Conservation Act on December 2, 1970 (FWS, 1970) and has been listed under the ESA since its implementation in 1973. Blue whales off the U.S. West Coast are in the Eastern North Pacific stock. Blue whales are classified as depleted throughout its range under the Marine Mammal Protection Act (MMPA) of 1972. Depleted stocks are managed to not fall below their optimum sustainable population levels.

**Threats**

Hunting (whaling) played a large role in the decrease of the blue whale population (Sears and Perrin, 2009). At least 9,500 blue whales were taken by commercial whalers in the North Pacific Ocean from 1910-1965 and at least 11,000 were taken in the North Atlantic from the 1890s-1960s (NOAA Fisheries, 2013a).

There is an ongoing threat of ship strikes to blue whales. Between 2007 and 2011 there were 10 blue whales killed or injured by vessel strikes along the Pacific west coast, 9 of them off the California coast and one off the Oregon coast (Carretta et al., 2013a). Five of the deaths occurred in 2007, the highest number recorded for any year. . Injured whales do not always strand or if they do, they do not always have obvious signs of trauma. Consequently, additional mortality from ship strikes probably goes unreported (Carretta et al., 2013b). Anthropogenic noise is a habitat concern, identified by NMFS (Reeves et al., 1998) as a factor influencing the distribution of blue whales. Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009).

Hybridization between blue whales and fin whales has been documented, and may decrease the fitness of the blue and fin whales that hybridize (Berube and Aguilar, 1998). Entanglement with commercial fishing gear remains a threat to blue whales and some whales swim off while still entangled in fishing gear, so the number and extent of injury and death from entanglement is not fully known (Reeves et al., 1998).

Blue whale food sources may be damaged and they may gain new stressors with certain climate-changing processes such as global warming. The impacts from climate change could affect everything from phytoplankton to organisms at higher trophic levels. Stressors from metabolic demands with warmer oceans may impact the health of animals. Shifts of marine populations either towards the poles or in the ocean depths they use are expected (Fogarty and Powell, 2002). Increased stratification from an increased temperature, and/or increased freshwater inputs may affect nutrient exchange and primary production. There may be reductions in the available nutrient levels and possible changes in the timing and intensity of phytoplankton blooms. There may also be reductions of upwelling and downwelling, thereby limiting the nutrient availability to marine life in specific stratified levels of the ocean. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures, which led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

**Species Recovery**

A recovery plan was drafted in July 1998 for the blue whale. The goals of the recovery plan (NMFS 1998a) are to downlist and delist the species. The stepdown outline to achieve the goal includes the following steps:

- Determine stock structure of blue whale populations occurring in U.S. waters and elsewhere.
- Estimate the size and monitor trends in abundance of blue whale populations.
- Identify and protect habitat essential to the survival and recovery of blue whale populations.
- Reduce or eliminate human-caused injury and mortality of blue whales.
- Minimize detrimental effects of directed vessel interactions with blue whales.
- Maximize efforts to acquire scientific information from dead, stranded, and entangled blue whales.
- Coordinate state, federal, and international efforts to implement recovery actions for blue whales.
- Establish criteria for deciding whether to delist or downlist blue whales.

**Life History, Habitat Requirements, and Distribution**

Blue whales, the largest mammals on earth, are baleen whales known to occur in oceans worldwide. Three separate populations of blue whale are recognized today: Northern Atlantic, Northern Pacific, and Southern Hemisphere. Blue whales are migratory animals known to feed in northern waters during spring and summer. Southern migrations towards subtropical winter breeding grounds begin in the fall (Carretta et al., 2013b). Blue whales inhabit the Gulf of California and offshore waters of Central America during late fall to spring. They migrate north along the west coast of North America durng April and May. Many blue whales occur off the California coast although some migrate to Canadian waters while other groups disperse north to the Gulf of Alaska or west toward the Aleutian Islands (Sears and Perrin, 2009).

The blue whale inhabits and feeds in both coastal and pelagic environments and, as a result, is frequently found on the continental shelf and far offshore in deep waters. They prey mainly on two krill (euphausiid) species, *Euphausia pacifica* and *Thysanoessa spinifera* (Reeves et al., 1998a). *E. pacifica* is an offshore euphausiid that is smaller than the more neritic euphausiid *T. spinifera*. Recent studies have shown a shift in the distribution of blue whales closer to the coast of California due to a shift in feeding more on *T. spinifera* (Reeves et al., 1998a). Blue whales typically travel alone or in pairs, and sometimes they can be found in loose aggregations in better feeding areas. They generally dive between 5 and 20 minutes and between 150 and 200 meters deep, although shallow dives are frequent (Shirihai and Jarrett, 2006).

Blue whales are thought to reach sexual maturity between 5 and 15 years of age. Females are thought to produce young every other year during the winter season in warmer waters (NMFS 1998a). The gestation period for blue whales is between 10 and 12 months, and the calves are weaned between 6 and 8 months. Not much is known about longevity and natural mortality of blue whales, but the lifespan is estimated at up to 90 years (Shirihai and Jarrett 2006). Ice entrapment is not a known factor of natural mortality for the Pacific population of blue whales, but there has been documentation of killer whale attacks on this population (NMFS 1998a).

**Population Status**

Blue whales along the mainland Pacific Coast are part of the Eastern Northern Pacific stock. The best estimate of the Eastern Northern Pacific blue whale population is 1,647 whales, based on mark-recapture estimates (Calambokidis, 2013, cited in Carretta et al., 2013b). The minimum population is estimated at 1,551 whales (Carretta et al., 2013b). The potential biological removal, is the maximum number of animals killed (not including natural deaths), that would still allow for the population to achieve its optimum sustainable population (Barlow et al., 1995). The overall potential biological removal for this blue whale population is 9.3 whales per year, but because this population spends one-quarter of its time in United States waters, the potential biological removal for blue whales is 2.3 whales per year in U.S. waters (Carretta et al., 2013b). The abundance of blue whales off of the West Coast, from Baja California to Washington, has not increased over the past two decades (Carretta et al., 2013b).

**Critical Habitat**

Critical habitat for this species has not been designated.

#### 4.2.1.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to blue whales is the EEZ, extending 200 nautical miles (nmi) offshore from the Coos Bay Head (figure 4.2-1) and within the EEZ from San Diego, California, to Cape Flattery, Washington. Under the 1982 United Nations Convention on the Law of the Sea (LOS Convention), the United States has limited sovereign rights within the EEZ (U.S. Commission on Ocean Policy, 2004) and all analyses of effects by the proposed action are confined to the U.S. Pacific coast EEZ. Within the EEZ analysis area, effects to blue whales would be associated with LNG carriers inbound and outbound from the LNG terminal. To date, sources of LNG that would be shipped from the LNG terminal have not been identified. Potential markets for exported LNG, including Hawaii and the Cook Inlet region of Alaska, have been identified (see Resource Report 1, JCEP LNG Terminal Project). However, the main global LNG markets are currently in Korea and Japan (International Gas Union, 2012).

Alternatively, JCEP has retained the capability within the LNG Terminal design to add import and regasification facilities if market conditions were to change in the future (see Resource Report 1, JCEP LNG Terminal Project). Consequently, destinations and/or sources of LNG are not foreseeable and have been assumed in order to conduct the analyses of direct, indirect, and cumulative effects on blue whales and other species within the EEZ analysis area.

For reasons described in detail below, LNG carriers transiting to LNG destination ports near the equator are assumed to traverse the EEZ perpendicular to the coast. Other LNG carriers bound to or passing Central and South America are expected to parallel the coast from California to Coos Bay and are assumed to follow a north-south course 50 nmi offshore.

**Species Presence**

While exact dates vary each year, long-term acoustic data offshore from Oregon indicates that blue whales are present, at least on a seasonal basis, from late July until January when they migrate to southern waters (Stafford et al., 1999). As they migrate north along the west coast of North America, blue whale call intensities off the Oregon coast peak during October and steadily diminish through January (Burtenshaw et al., 2004). The blue whales off the Oregon coast were typically found farther from shore than where they were found in California where they fed closer to the coast. However, based on records spanning a 72-year period from 1930 to 2002, blue whales are the least frequent of five balaenopterid species found stranded on Oregon and Washington coasts; only one female had been reported stranded in Washington (Norman et al., 2004).

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the Mean Population Estimate divided by the area in the surveyed stratum, 819,470 $km^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of blue whales in the California stratum is 0.157 whale per 100 $km^2$ or 0.046 whale per 100 $nmi^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of blue whales in the Oregon-Washington stratum is 0.030 whales per 100 $km^2$ or 0.009 whale per 100 $nmi^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for blue whales in the California stratum is 0.2125 whale per 100 km or 0.1147 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for blue whales in the Oregon-Washington stratum is 0.0870 whale per 100 km or 0.0470 whale per 100 nmi of ship transect.

### Habitat

The U.S. West Coast is one of the most important feeding areas during summer and fall; blue whales migrate to highly productive areas south in winter off Baja California and the Gulf of California (Carretta et al., 2013b). They are found in coastal waters but are generally more offshore than other whales. Blue whales are occasionally heard or seen off Oregon; as primary production blooms (phytoplankton) and associated euphausiid biomass increase, advancing along the west coast from south to north, aggregations of blue whales move through Oregon offshore waters between October and January en route to foraging areas off the coast of Vancouver Island (Burtenshaw et al., 2004). It is estimated that blue whales spend approximately 75 percent of their time outside the 200 nmi wide EEZ (Carretta et al., 2013b). However, this stock of blue whales may occur within the EEZ analysis area.

### Critical Habitat

Critical habitat for this species has not been designated.

Figure 4.2-1
Location of
Exclusive Economic Zone (EEZ)
Analysis Area Associated with LNG
Ship Transits to and from the LNG Terminal
Strait of Juan Fuca
Grays Harbor
Columbia River
Exclusive Economic Zone Limits (200 Nautical Miles)
Coos Bay
Proposed PCGP Project
Cresent City
Humboldt Bay
Pacific Ocean
Washington
Oregon
California
0 25 50 75 100 200 Miles
N

### 4.2.1.3 Effects by the Proposed Action

#### Direct and Indirect Effects

Direct effects of the proposed action include injury and/or mortality due to ship strikes, adverse effects from vessel underwater noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect blue whales by impacting forage species. These effects are addressed below.

<u>Ship Strikes by LNG Carriers</u>

There is an ongoing threat of ship strikes to large cetaceans, causing mortality or serious injury. From available accounts (Laist et al., 2001; Jensen and Silber, 2003; Douglas et al., 2008; Carretta et al., 2013a), cetaceans collide with ships fairly infrequently. The rate of ship-strikes to blue whales and other large cetaceans is assumed to be the product of ship traffic and the cetacean population density within the EEZ. From 2007 to 2011 ship strikes of blue whales averaged 1.8 death or injury per year in California and 0.2 death or injury per year off the Oregon-Washington coast (Carretta et al., 2013a). Those estimates are undoubtedly minimal since many ship strikes with cetaceans are unknown and unreported.

**Ship Traffic**. A considerable amount of shipping traffic currently occurs within the EEZ analysis area. Along the coastal portion from Coos Bay north to the Columbia River, vessel traffic averaged 3,694 transits annually (see table 4.2.1-1), while from Coos Bay south to Humboldt Bay (California) vessel traffic averaged 3,658 transits per year, based on data compiled during 1998-1999 (Pacific States/British Columbia Oil Spill Task Force, 2002).

**Table 4.2.1-1**
**Lengths (nautical miles, nmi), Annual Ship Transits, and Annual Ship-Miles within Identified Coastal Sections from San Diego, California, to the Strait of Juan de Fuca, Washington during 1998-1999**

| Coastal Section | | Section Length (nmi) [1] | Annual Coastal Ship Transits [2] | Ship Miles (nmi) per Year in Section |
|---|---|---|---|---|
| **From** | **To** | | | |
| San Diego, CA | Los Angeles, CA | 95 | 2,615 | 248,425 |
| Los Angeles, CA | San Francisco, CA | 371 | 4,604 | 1,708,084 |
| San Francisco, CA | Humboldt Bay (Eureka), CA | 232 | 3,668 | 850,976 |
| Humboldt Bay (Eureka),CA | Crescent City, CA | 64 | 3,658 | 234,112 |
| Crescent City, CA | Coos Bay, OR | 125 | | 457,250 |
| Coos Bay, OR | Columbia River (Astoria), OR | 201 | 3694 | 742,494 |
| Columbia River (Astoria), OR | Grays Harbor (Aberdeen), WA | 75 | 4188 | 314,100 |
| Grays Harbor (Aberdeen), WA | Strait of Juan de Fuca, WA | 117 | 4221 | 493,857 |
| Total from Crescent City, CA to Cape Flattery, WA | | | | 2,007,701 |
| Total from San Diego, CA to Cape Flattery, WA | | | | 5,049,298 |

[1] Distances between ports from Appendix B, Coast Pilot 7 (NOAA, 2008)
[2] Annual Coastal Ship Transits from Appendix D, Pacific States/British Columbia Oil Spill Task Force (2002)

Ships traveling to and from the southern hemisphere would most likely parallel the coastline, transiting the EEZ from San Diego north to Coos Bay. In 1999, the estimated total coastal vessel traffic within California, Oregon, and Washington is more than 5 million ship-miles per year, of which more than 3 million ship-miles occur within California waters annually (see table 4.2.1-1). LNG carriers would transit 887 nmi between San Diego and Coos Bay and 90 ships per year (180 annual transits) would generate an additional 159,660 ship-miles per year (assuming that all LNG carriers would return to ports of origin along the West Coast). Potential shipment of LNG to Cook Inlet, Alaska (see Resource Report 1, JCEP LNG Terminal Project) would require transit of 393 nmi within the EEZ between Coos Bay and Cape Flattery; 90 ships per year (180 annual transits) would generate an additional 70,740 ship-miles per year within that segment en route to Alaska.

There is no single authority defining shipping lanes along the Pacific Coast. Typical West Coast vessel traffic patterns reported by Pacific States/British Columbia Oil Spill Task Force (2002) include the following:

- Tank ships operated by Western States Petroleum Association (WSPA) members that carry crude oil transit at distances of ≥50 nmi off the U.S. West Coast except when they enter port or enter a traffic separation scheme around a port;
- Crude oil and refined petroleum tankers not operated by WSPA members may or may not transit closer to shore;
- In general, tank barges hauling crude oil and refined petroleum transit ≥25 nmi offshore except when they enter port or enter a traffic separation scheme around a port;
- Dry cargo and bulk carriers vary from 3 to 30 nmi or more during offshore transits, and avoidance of heavy weather is a factor during all vessel transits; and
- In general, preferred offshore tracks are 25 nmi in northern waters and 30 nmi along southern tracks; seldom are north or south transits outside of the EEZ (Pacific States/British Columbia Oil Spill Task Force, 2002).

From these vessel traffic patterns, which are mostly voluntary, LNG carriers transiting to and from the south or north would be expected to parallel the West Coast a distance of 50 nmi offshore, entirely within the EEZ.

Recent information indicates that ship traffic to U.S. West Coast ports was increasing between 2002 and 2007 but deviated from the established trajectory in 2008, at the onset of the global financial crisis (see figure 4.2-2). Data from the U.S. Department of Transportation, Maritime Administration (MARAD, 2013) through 2011 indicates a progressive return to the pre-2008 trend which had been increasing by constant amount of 435 vessels per year between 2002 and 2007. Based on that observed constant amount of annual increase, the pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. The annual percent change in vessel calls, however, would be 2.1 percent in 2018, lower than the percent change in 2007 which is 2.7 percent, based on the regression model in figure 4.2-2 (note: the annual percent change in vessel calls is a negative exponential function if there is a constant increase in the number of vessels each year).

Applying the yearly percent change in Total Annual Vessel Calls at all West Coast ports based on the regression model in figure 4.2-2 to the total ship-miles along the West Coast beginning in 1999 (5,049,298 ship-miles in table 4.2.1-1), there would be an estimated 8,199,320 ship-miles along the West Coast, expected in 2018.

Similarly, the data from MARAD (2013) were used to estimate ship-miles along the California Coast and along the Oregon-Washington Coast in 2018 from the data in table 4.2.1-1 from 1999 provided by Pacific States/British Columbia Oil Spill Task Force (2002).

- From 2002 to 2007, total vessel calls to California ports increased by a constant number of 251 vessel calls per year (regression model y = 250.74x – 492,585, $r^2$ = 0.78, P=0.019). There were 3,041,597 ship-miles in 1999 within California waters (see table 4.2.1-1); 4,717,894 ship-miles are expected in 2018.
- From 2002 to 2007, total vessel calls to Oregon-Washington ports increased by a constant number of 185 vessel calls per year (regression model y = 184.6x – 364,401, $r^2$ = 0.56, P=0.086). There were 2,007,701 ship-miles in 1999 within Oregon-Washington waters (see table 4.2.1-1); 3,533,752 ship-miles are expected in 2018.

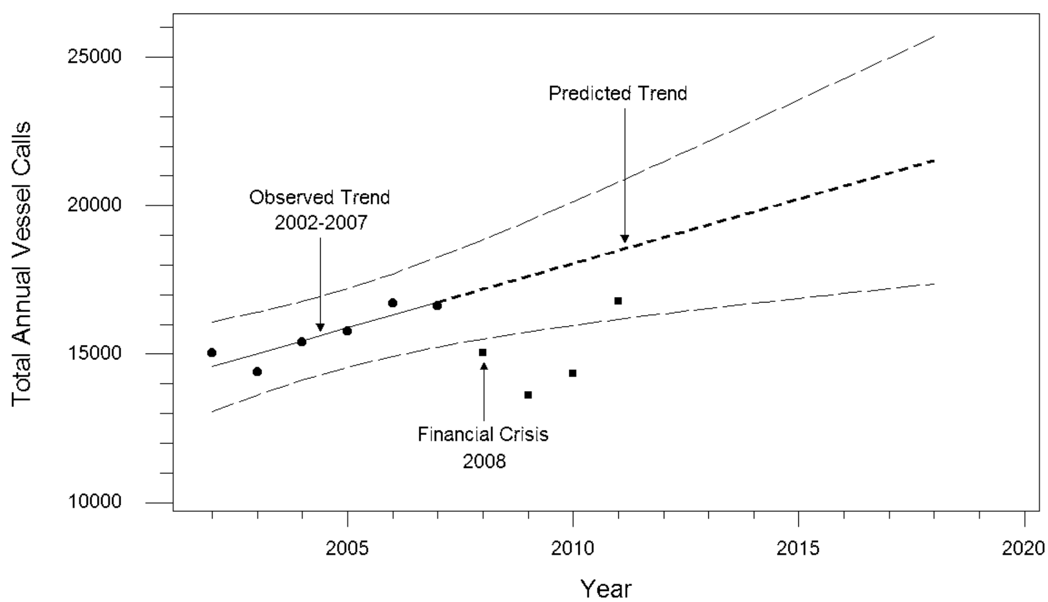



**Figure 4.2-2**
**Total Annual Vessel Calls at All U.S. West Coast Ports from 2002 to 2011. The Observed Increasing Trend from 2002 to 2007 (solid line) is Significant ($r^2$ = 0.81, P=0.015). The Predicted Trend (heavy dashed line) and 95% Prediction Intervals (light dashed lines) through 2018 are Based on the 2002-2007 Observed Trend (y = 435.3 x – 856,986). (Source: MARAD, 2013).**

According to Lloyd's (2013), over 80 percent of global LNG carrier imports are to the Far East, 5.9 percent are to Southern Europe, 5.8 percent are to South America (Atlantic Coast), 5.1 percent are to Northern Europe, and 3.0 percent are to the Indian Subcontenent. LNG carriers from and to the Far East and Indian ports are assumed to traverse the EEZ perpendicularly - east and west - as they depart and approach Coos Bay because most existing shipping traffic between Asia and the United States West Coast travels a "Great Circle route." Similarly, LNG carriers supplying fuel to Hawaii (see Resource Report 1, JCEP LNG Terminal Project) would likely traverse the EEZ perpendicularly. Ships traveling Great Circle routes are usually not considered components of north-south coastal shipping traffic (Pacific States/British Columbia Oil Spill Task Force, 2002).

The Project is designed to accommodate 90 LNG tankers a year. If all LNG tankers approach the Jordan Cove terminal by perpendicular transits through the EEZ, they will contribute 36,000 ship miles annually to vessel traffic in the Oregon-Washington stratum in 2018. If all LNG tankers approach the terminal by parallel transits along the California coast, they will contribute 137,160 ship-miles annually to vessel traffic within the California stratum in 2018. Observed and predicted vessel traffic within both strata in 1999, 2007, 2008, and 2018 are provided in table 4.2.1-2, including the addition of project-related LNG tanker traffic in 2018. During the life of the project, there may be years of mixed LNG tanker traffic, some transiting the EEZ perpendicular and other traffic paralleling the coast but such variability can not be estimated.

**Table 4.2.1-2**
**Estimates of Vessel Traffic, Blue Whale Encounter Rates, Relative Ship-Strike Risk, and Estimates of Blue Whales Struck per Year (with Percent Change from the Previous Estimate) in the California and Oregon-Washington Strata of the Project Activity Area**

| | California Stratum | | | | Oregon-Washington Stratum | | | |
|---|---|---|---|---|---|---|---|---|
| Year and Event | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] |
| 1999 [1] Baseline Annual Ship Transits | 3,041,597 | N/A | N/A | N/A | 2,007,701 | N/A | N/A | N/A |
| 2007 [2] Predicted Trend with 2002-2007 data | 3,747,406 (+23.2%) | N/A | N/A | N/A | 2,650,249 (+32.0%) | N/A | N/A | N/A |
| 2008 [3] Most Recent Cetacean Survey | 3,316,554 (-11.5%) | 0.115 | 3,806 | 1.80 | 2,495,278 (-5.8%) | 0.047 | 1,172 | 0.20 |
| 2018 [2] Ambient Predicted Ship Traffic | 4,717,894 (+42.3%) | 0.171 (+49.1%) | 8,077 (+112.2%) | 3.820 (+112.2%) | 3,533,752 (+41.6%) | 0.070 (+49.1%) | 2,476 (+111.3%) | 0.420 (+111.3%) |
| 2018 [4] Ambient Traffic with LNG Tanker Traffic | 4,855,054 (+2.9%) | 0.171 (0%) | 8,311 (+2.9%) | 3.931 (+2.9%) | 3,569,752 (+1.0%) | 0.070 (0%) | 2,501 (+1.0%) | 0.424 +1.0%) |

[1] Estimated in table 4.2.1-1 with data from Pacific States/British Columbia Oil Spill Task Force, 2002.
[2] Estimated from linear regression of total vessel calls to California ports and Oregon-Washington port from 2002 to 2007. Source: MARAD, 2013
[3] Estimated total vessel calls to California ports and Oregon-Washington ports in 2008 (see Figure 4.2.1-1, above). Source: MARAD, 2013.
[4] Assume 90 LNG tankers with perpendicular transits through West Coast EEZ in Oregon-Washington stratum (36,000 ship-miles per year) or parallel transits through EEZ in California stratum (137,160 ship-miles per year).
[5] Estimates of Whales Struck derived from data reported by Carretta et al., 2013a for ship-strikes in the California and Oregon-Washington EEZ strata.

**Ship-Strike Risk**. An index of relative ship-strike risk within an explicitly defined gridded study area was described by Williams and O'Hara (2009). They multiplied whale density estimates at each grid point by the nearest value of shipping intensity using regular-interval ship locations on the grid from agencies' remote monitoring of shipping in Canadian waters. Regrettably, no such fine-scale data for whales or ships are available within the West Coast EEZ activity area but the approach by Williams and O'Hara (2009) was adapted to the coarse-scale analysis area and two strata by using mean whale encounter rates, described above for blue whales, and shipping intensity as indicated by the total annual ship-miles derived from vessel transits along the West Coast (see table 4.2.1-2) in the California and Oregon-Washington strata.

The encounter rate for blue whales in both EEZ strata combined is significantly ( $P< 0.01$) related to the species' density, based on data collected during surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010), shown in figure 4.2-3. The relationship supports predictions, below, that future encounter rates (eg, in 2018) would be expected to increase as the blue whale population increases.

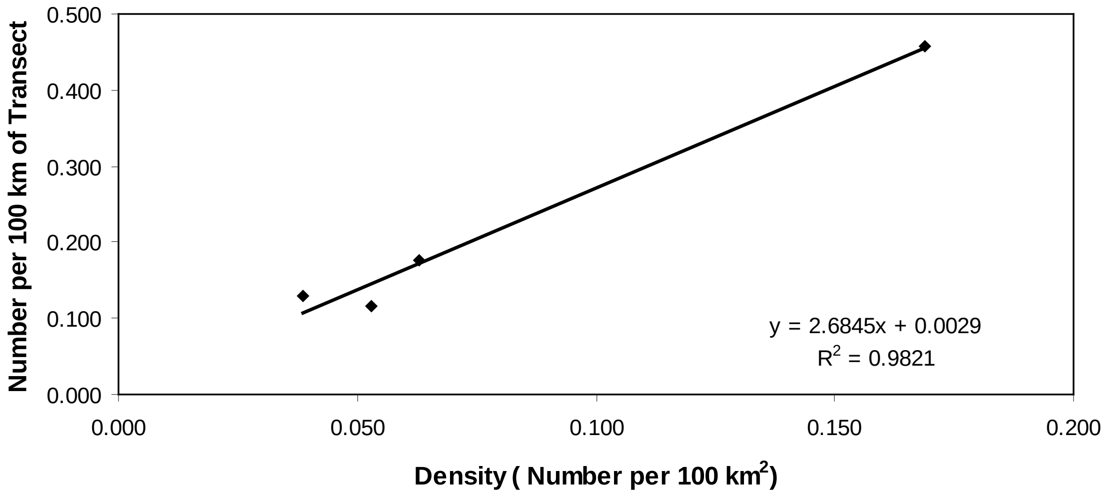



**Figure 4.2-3**

**Relationship of Ship-Transect Encounter Rate with Blue Whales (Number per 100 km) to Blue Whale Density (Number per $km^2$ ) in the California and Oregon-Washington EEZ Strata, Combined. Data were Collected in 1996, 2001, 2005, and 2008. The Relationship is Significant ($P < 0.01$)**

Relative ship-strike risks during 2008 and 2018 (see table 4.2.1-2) are the products of cetacean species' encounter rates and total ship miles expected in each stratum during the two years. The encounter rate for blue whales in 2008 was discussed in Section 4.2.1.2, above. An estimate of the encounter rate in 2018 (beginning of the project operation) is directly proportional to blue whale population and density in that year.. The logistic equation for exponential population growth in discrete generations or time periods, is $N_{t+1} = N_t + r_{max} N_t ((K – N_t)/K)$ where $N_{t+1}$ is the number of animals in the next generation or year, $N_t$ is the number of animals in the current generation or year, $R_{MAX}$ or $r_{max}$ is the maximum value of the per capita growth rate for a species and K is the environmental carrying capacity for the species. If $N_t$ is very small relative to K, as it is for many marine mammal species that are slowly recovering from past overharvesting (Carretta et al., 2013a), the term $((K - N_t)/ K)$ is nearly equal to K/K or 1 and the population is expected to grow exponentially. If exponential growth is assumed, the population size ($N_t$) at time = t is $N_t = N_0 e^{r t}$ where $N_0$ = the initial population size at t = 0 and r is assumed to be $R_{MAX}$. NMFS established default values for $R_{MAX} = 0.04$ if stock-specific measured values were unavailable (Barlow et al., 1995; Wade, 1998).

This approach was used with the default value for $R_{MAX}$ to estimate blue whale encounter rates (as indices of population) in 2018, given the encounter rates of blue whales within the California and Oregon-Washington strata in 2008. In 2008, the blue whale encounter rate in the California stratum was 0.115 whale per 100 nmi and 0.047 whale per 100 nmi in the Oregon-Washington stratum. Based on assumed population growth between 2008 and 2018, the blue whale encounter rate in California in 2018 is estimated at 0.171 whale per 100 nmi and 0.070 whale per 100 nmi in the Oregon-Washington stratum, an increase of 49 percent from the 2008 encounter rates (see table 4.2.1-2).

In 2008, the relative ship-strike risk in the Califonia stratum would be 0.115 whale per 100 nmi multiplied by 3,316,554 ship-miles = 3,806. In 2018, the assumed growth of the blue whale population increases the encounter rate proportionately to 0.171 whale per 100 nmi. Between 2008 and 2018 ship traffic is also be expected to increase to 4,717,894 ship-miles. The relative ship-strike risk in 2018 would be 8,077 which is 112.2 percent of the 2008 encounter rate (table 4.2.1-2). If all 90 LNG tanker transits occur in the California stratum, the total expeced vessel traffic would be 4,855,054 ship miles in 2018 and the ship-strike risk would increase to 8,311, an estimated increase of 2.9 percent. Similar calculations woud apply to the blue whale population growth, encounter rate, relative ship-strike risk in the Oregon-Washington stratum, provided in table 4.2.1-2.

**Estimated Ship-Strikes to Blue Whales**. Data provided by Carretta et al. (2013a) indicated 9 blue whales were struck in the California EEZ between 2007 and 2011 (1.8 whales per year) and 1 blue whale was struck in the Oregon-Washington EEZ during the same period (0.20 whale per year). Jensen and Silber (2003) reported 0.31 blue whale struck per year between 1987 and 2002 along the U.S. Pacific Coast. Using recent ship-strike data from Carretta et al. (2013a), the increased ship-strike risk in 2018 is assumed to increase the annual rate of blue whales struck proportionately in the California stratum to 3.820 per year and to 0.420 per year in the Oregon-Washington stratum (Table 4.2.1-2). The additional project-related LNG tanker traffic would increase the annual rate in California to 3.931 whales per year, an increase of 0.111 ship-strike per year (one injury or death in 9 years) and would increase the annual rate in Oregon-Washington waters to 0.424 whale per year, and increase of 0.004 ship-strike per year (one injury or death in 250 years). Ship-strikes to blue whales by project-related LNG tankers are more likely in California than in the Oregon-Washington EEZ stratum but in both areas, death or injury of blue whales is insignificant and discountable.

<u>Underwater Noise</u>

All vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. Propellers creat more noise if damaged, if operating asynchronously, or operating without nozzles. Engines and auxiliary machinery can also radiate noise during operation which is related to ship size (larger ships are noisier than small ones), speed (noise increases with ship speed), and mode of operation (ships underway with full loads, towing or pushing loads, are noisier than unladen ships) (Greene and Moore, 1995). In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. When whales are exposed to low-level sounds from distant or stationary vessels, they appear to ignore the sounds. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). However, radiated ship noise of oncoming ships may not be immediately detected by whales near the surface due to bow null-effect acoustic shadow zones (Allen et al., 2012). Because of acoustic shadow zones, whales may not hear approaching ships to allow time for their avoidance response even though whale auditory ranges overlaps with peak intensities of ship noise.

Steam turbine power has been replaced by dual fuel diesel electric (DFDE) power plants adapted to utilizing LNG gas boil-off and diesel fuel to power electric drives in many recently constructed LNG vessels. The DFDE propulsion system is more fuel efficient with less engine noise and vibration (Gilmore et al., 2005). Whether or not lower noise-producing propulsion systems will cause increased ship-strikes with marine mammals is unknown.

Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades. Comparisons of ambient noise from the 1990s with noise measurements take during the 1960s indicate ambient noise increased by about 10 dB (Andrew et al., 2002). Recently measured ambient noise are only slightly increasing, decreasing, or showing no trend (Andrew et al., 2011). Low frequency noise especially, generated by commercial vessel traffic, has been estimated at 10 to 12 dB higher in the early 2000s compared to the 1960s (McDonald et al., 2006). In addition to ships, ambient ocean noise is a product of wind, precipitation, wave noise, and sounds generated by cetaceans and fish (McDonald et al., 2008). The low frequencies generated by ships overlap sounds generated by large baleen whales, including the fin whale (Würsig and Richardson, 2009).

Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Exposure of dolphins to intense underwater noise caused significant increases in neural-immune parameters with higher levels of norepinephrine, epinephrine, and dopamine levels, but with decreased aldosterone and monocytes after exposure compared to before exposure (Romano et al., 2004). Anthropogenic noise and vessel disturbance may affect blue whales but there is little evidence available to describe or quantify the impacts of these threats on the species. While anthropogenic noise may threaten other cetaceans, little is known about whether, or how, vessel noise affects blue whales (NOAA Fisheries, 2013a). One blue whale that had been calling prior to nearby passage of a merchant ship continued to call during the passage even though the ship noise at the whale's position exceeded the ambient sound level by as much as 26 dB (McDonald et al., 1995). Vessel disturbance (like whale-watching boats) may affect blue whales, but there is no direct evidence to demonstrate that persistent close approaches by vessels such as tour boats has a negative effect on them.

Noise can cause hearing loss in cetaceans which may be temporary (abbreviated TTS for temporary threshold shift or permanent (abbreviated PTS for permanent threshold shift). Repeated TTS may lead to PTS in which sensory hair cells in the inner ear are destroyed with damage to the cochlea (Nordmann et al., 2000).

NOAA Fisheries is developing comprehensive guidance on sound characteristics likely to cause injury and behavioral disruption based on known causes of TTS. At the present, NOAA has provided interim guidance for thresholds of received sound pressure levels from broad band sounds that may cause behavioral disturbance and injury to marine mammals which are conservative until formal guidance as been developed. The conservative thresholds are applied in MMPA permits and Endangered Species Act Section 7 consultations for marine mammals to evaluate the potential for sound effects. The criterion levels specified in table 4.2.1-3 are specific to the levels of harassment permitted under the MMPA.

**Table 4.2.1-3**
**NOAA Fisheries Current In-water Acoustic Thresholds**

| Criterion | Criterion Definition | Threshold [1] |
|---|---|---|
| Level A | PTS (injury) conservatively based on TTS | 190 $dB_{rms}$ for pinnipeds<br>180 $dB_{rms}$ for cetaceans |
| Level B | Behavioral disruption for impulsive noise (e.g., impact pile driving) | 160 $dB_{rms}$ |
| Level B | Behavioral disruption for non-pulse noise (e.g., vibratory pile driving, drilling) | 120 $dB_{rms}$ [2] |
| [1] All decibels referenced to 1 micro Pascal (re: 1uPa). Note all thresholds are based off root mean square (rms) levels.<br>[2] The 120 dB threshold may be slightly adjusted if background noise levels are at or above this level.<br>Source:NOAA Fisheries, 2013b. | | |

Southall (2004) provided the following descriptions of impulsive noise and non-pulse noise, based on characteristics at the noise source:

- **Single Pulse:** Single sound of short duration, fast rise time generated by a single explosion, single airgun, watergun, or sparker pulse, single ping of certain sonars/depth sounders.
- **Single Non-Pulse:** Single sound of long duration, slow rise time generated by a single vessel pass, drilling event, aircraft overflight, single ping of certain sonars.
- **Multiple Pulse:** Multiple sounds each of short duration, fast rise time generated by airguns, some sonar/depth sounder systems, waterguns, sparkers, pile driving, serial explosions.
- **Multiple Non-Pulse:** Multiple sounds of long duration, slow rise time generated by multiple vessel/aircraft passes, certain sonar systems, tomography sources.

In the following analysis, noises generated by LNG tankers transiting the West Coast EEZ activity area are assumed to be single non-pulse sources during each transit and would be expected to cause behavioral disruption, including masking detection of important sounds (intraspecific communication, prey and/or predator detection, eminent ship-strike), for species within distances at which tanker noise attenuates to 120 dB or more. However, occurrences of single pulse sounds by LNG tankers cannot be completely ruled out (depth or echo sounders, single or serial explosions).

A review of LNG carriers in service during 2013 (Colton, 2013; MarineTraffic, 2013) revealed there are 267 vessels with capacities of 148,000 $m^3$ or less, the current size limit for LNG carriers utilizing the Jordan Cove terminal (although the LNG carrier berth was designed to accommodate LNG carriers up to 217,000 $m^3$). Hatch et al. (2008) determined underwater noise levels from various commercial ships while transiting the Stillwagen Bank National Marine Sanctuary off the Massachusetts coast. Estimates of sound levels from one ship, an LNG Taker (the Berge Everett also known as the BW Suez Everett) built in 2003 with 138,028 $m^3$ capacity (93,844 gross tonnage), are used here to estimate exposure of marine mammals to project-related shipping noise. The reported noise levels from that tanker serves as the standard for the following analysis of noise effects on blue whales within the West Coast EEZ analysis area.

The LNG tanker in the Hatch et al. (2008) study produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 nmi$^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 nmi$^2$.

Based on population growth between 2008 and 2018 described above for blue whale encounter rates, the predicted density of blue whales is 0.068 whale per 100 nmi$^2$ in the California stratum in 2018 and is 0.013 whale per 100 nmi$^2$ in the Oregon-Washington stratum in 2018. Assuming an LNG tanker transit distance of 762 nmi within the California stratum, the number of blue whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.068 whale per 100 nmi$^2$) multiplied by the total area of noise effects (15.6 nmi$^2$), equal to 0.01 whale affected.

The number of blue whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.068 whale per 100 nmi$^2$) multiplied by the total area of noise effects (7,176 nmi$^2$), equal to 5 whales (an estimate between 2 and 8 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) affected by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Similar calculations have been done for blue whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of blue whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.013 whale per 100 nmi$^2$) multiplied by the total area of noise effects (4.08 nmi$^2$), equal to <0.001 whale affected. The number of blue whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.013 whale per 100 nmi$^2$) multiplied by the total area of noise effects 1,883 nmi$^2$), equal to 0.244 whale affected by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on blue whales are possible in the in California EEZ stratum but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 µPa2 (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause behavioral disruptions to blue whales.

<u>Releases and Fire at Sea</u>

The density of LNG is approximately 42 percent of sea water density so LNG accidentally released from a tanker would float on the water, spreading sideways while exposing the LNG fuel to air over an increasing surface area (Fay, 2003). The density of liquid LNG is 450 $kg/m^3$ and the density of LNG vapor is 1.74 $kg/m^3$ (Luketa et al., 2008), both of which are denser than air (density ≈ 1.2 $kg/m^3$ for dry air at sea level and at 20°C) and would remain at the ocean surface until it evaborated. Spreading of an LNG pool over water would be influenced by the following factors (Hightower et al., 2004):

1. The spreading speed of the leading edge of the LNG pool.
2. The variable thickness of the LNG pool as it spreads.
3. Friction between the LNG pool and water.
4. The evaporation rate of LNG on water.

The evaporation rate over water would be dependent on the thickness of the LNG pool (increasing evaporation rate with increasing thickness) and the surface turbulence intensity of the water (increasing evaporation rate with increasing turbulence) (Morse and Kytomaa, 2010). At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

If the vapor from an LNG spill were to come in contact with an ignition source, the resulting fire would burn back to the spill source and could affect species at the water surface within some distance with the fire. Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet.[1] Ignition could cause a fire to burn for 20 minutes with severe thermal

[1] Intentional releases due to terrorism, maliciousness, or other human acts could cause more LNG to be released than accidental releases and provide a simultaneous ignition source (Hightower et al., 2004).

injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of blue whales in the California EEZ stratum during 2018 would be 0.068 whale per 100 $nmi^2$ and 0.013 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire could cause second degree burns would extend to an area of 0.563 $nmi^2$. Considerably fewer than one blue whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to blue whales due to LNG release and fire would be insignificant and discountable.

LNG carriers have been operating commercially since 1959. Since then there have been more than 38,000 LNG carrier voyages, covering more than 60 million miles and transporting a total of 1.5 billion cubic meters of LNG. Currently, approximately 352 LNG carriers safely transport more than 51,975,000 million cubic meters of LNG annually to ports around the world (Lloyd's, 2013). There have been approximately 11 reportable incidents between 1979 and 2006, worldwide. Because LNG has not been transported to the Pacific Northwest, no data are available. However, due to the double hulls of LNG carriers, none of the incidents that have occurred with LNG carriers have resulted in the loss of LNG cargo or other significant petroleum-based spills.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

Analysis of direct and indirect effects to blue whales focused on death or injury due to ship strikes. Future incidence of ship strikes to whales is assumed to be related to the whale population size and volume of vessel traffic within the EEZ analysis area. Available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. Most calls to the Port have been by dry bulk vessels (most or all were wood-chip carriers) with occasional calls by general cargo vessels. In 2002, there were 60 vessel calls but only 25 vessel calls in 2011 (see figure 4.2-4). The observed declining linear trend in annual vessel traffic is significant ($r^2 = 0.836$, $P < 0.001$) and the regression analysis model ($y = 7385 – 3.66 x$) was used to predict numbers of vessel calls to Coos Bay in the future. When the LNG terminal is expected to begin operation in 2018, no vessels are forecast with a 95 percent prediction interval between 0 and 17.6 vessels (see figure 4.2-4).

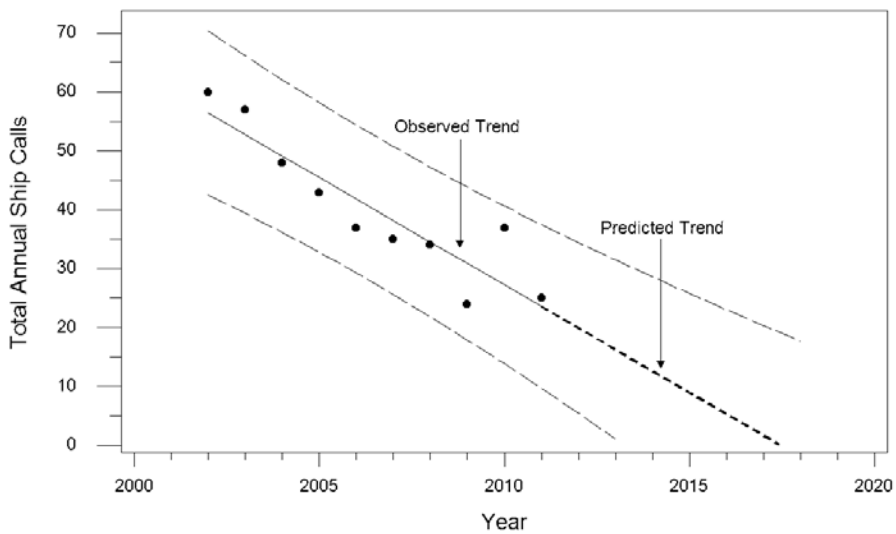



**Figure 4.2-4**
**Annual Calls to Coos Bay by All Vessel Types, 2002-2011 and Predictions (with 95 percent prediction intervals) through 2018, given the Observed Trend (y = 7385 – 3.66 x; $r^2$ = 0.836, P<0.001). Source: MARAD, 2013**

Releases of diesel fuel and/or gasoline are possible in the foreseeable future. According to annual reports published by the Pacific States/British Columbia Oil Spill Task Force, ODEQ reported 34 spills from fishing vessels or other harbor craft in 2002, 38 spills in 2003, and 7 spills from fishing vessels, plus spills from 27 other vessel types in 2004. Those relatively consistent incidences apparently increased in 2005 with 18 spills from fishing vessels, 20 from recreational vessels, and 27 spills by other vessel types. By contrast in 2006, there were 3 spills from fishing vessels, 6 spills from recreational vessels, and only 6 spills from other vessel types. Though not known, it appears that the background rate of spills off the Oregon coast (incidence of spills in proportion to total vessel operation) by fishing vessels, recreation vessels, and other vessel types is generally low and expected to continue at low frequencies in the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2017 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay. Consequently, cumulative effects to blue whales would likely be less than the estimate of direct effects discussed in the previous sections. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with such uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future, by 2018, although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to blue whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect critical habitat; none has been designated.

#### 4.2.1.4 Conservation Measures

Included in the Jordan Cove LNG Terminal Conservation Measures (see appendix N) is development of a plan to minimize potential ship strikes to cetaceans, and possibly other listed (sea turtles) and non-listed marine species by LNG carriers. LNG carriers would transit to the slip at slow speeds (between 4 to 6 knots once inside the Coos Bay navigation channel) and would result in minimal wakes, such that marine mammals would not be affected by the wakes of passing LNG carriers.

Jordan Cove would request all LNG carriers calling on the LNG terminal to reduce speeds to 10 knots or less within 30 nautical miles of the entrance to Coos Bay during the whale migratory period. During the 96-hour pre-notification process to be followed by all LNG carriers calling on the terminal, Jordan Cove would check with the NMFS for information on the migratory patterns of whales within the route of the LNG carrier and would inform the ship's master of the patterns reported by NMFS. Jordan Cove would request that all LNG carrier operators consult current whale sighting information prior to calling on the LNG terminal and be aware of the reported locations of whales and plan their operations accordingly. LNG carriers would be requested to reduce their speed to 10 knots or less when mother and calf pairs, groups or large assemblages are observed near an underway LNG carrier. LNG carriers would be requested to route around and maintain a 100-yard distance from the whales observed and to avoid crossing in front of the whales and maintain a parallel route, if possible.

Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. This package would include the measures proposed by NMFS for avoidance of marine mammals to further reduce the likelihood of adverse effects on these species. Some of the suggested measures include the following:

- Provide training to LNG carrier crews, including the use of a reference guide such as the *Marine Mammals of the Pacific Northwest, including Oregon, Washington, British Columbia and South Alaska* by Pieter Folkens. This is a pamphlet that would be provided to LNG carriers calling on the terminal and would be included as part of the terminal use agreement to the shippers.
- Provide a copy of the NMFS CD-rom-based training program entitled *A Prudent Mariner's Guide to Right Whale Protection* as part of a ship strike avoidance measures package to all LNG carriers calling on the terminal. While this CD-rom-based training program is specific to right whales, NMFS has stated that the guidance and avoidance measures are also applicable to fin, humpback, and sperm whales.
- Require LNG carrier crews to maintain a watch for marine mammals and slow the ship to 10 knots or less to avoid striking protected species.

- When whales are sighted maintain a distance of 90 meters (or 100 yards) or greater from the whale.
- Attempt to maintain a parallel course to the animal and avoid excessive speed or abrupt changes in direction until the animal has left the area.
- Reduce ship speed to 10 knots or less when pods or large assemblages of cetaceans are observed near an underway ship.
- When whales are sighted in a ship's path or in proximity to a moving ship, reduce speed to 10 knots or less or shift the engine to neutral until whales are clear of the area or path of the ship.

LNG carrier masters would be requested to provide reports of sightings of marine mammals while in the EEZ analysis area and to provide the report upon docking at the LNG terminal. This reporting request would be included in the Ship Strike Avoidance Measures Package provided to each LNG carrier calling on the terminal and compliance with the measures and the reporting would be included in all terminal service agreements with shippers.

LNG carrier crews would be asked to report sightings of any injured or dead protected species immediately, regardless of whether the injury or death is caused by the ship. If the injury or death is caused by collision with the ship, appropriate regulatory agencies (FERC or NMFS) would be notified within 24 hours of the incident. Information to be provided would include the date and location (latitude/longitude) of the strike, the ship name, the species or a description of the animal, if possible.

Jordan Cove has been working with the Coast Guard and ODE in the development of an LNG Management Plan. The LNG Management Plan is the primary process used in reducing risk through proper mitigation measures. The interagency group has been given a step by step process in how risk is mitigated in both safety and security issues.

As part of the LNG Management Plan, Jordan Cove is proposing that LNG carriers would not be allowed to move past the 50-mile voluntary traffic lanes offshore unless it is acceptable for them to continue into the LNG terminal. In addition, Jordan Cove is also proposing that LNG carriers would not be allowed to anchor offshore the Oregon coast. The New Carissa incident occurred when a ship inappropriately anchored in heavy seas just off the coast. LNG carriers would only be allowed to enter closer than 50 miles when all conditions are suitable to enter the port. Further, JCEP has committed to providing tractor tugs to escort each LNG into the port and to the berth. This type of tug has not been previously available in the port. These tugs have the capability to fully maneuver the LNG carriers even without ship power.

#### 4.2.1.5 Determination of Effects

**Species Effects**

The Project **may affect** blue whales because:

- Blue whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the project is **not likely to adversely affect** blue whales because:

- Existing information indicates ship strikes to blue whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to blue whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ while en route to the Port of Coos Bay and effects of ship noise on blue whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected blue whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effect to blue whales if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for blue whales.

### 4.2.2 Fin Whale

#### 4.2.2.1 Species Account and Critical Habitat

**Status**

Fin whales were listed as endangered under the Endangered Species Conservation Act on June 2, 1970 (FWS, 1970) and have been listed as endangered throughout its range under the ESA since its implementation in 1973. Two stocks of fin whales are recognized in the North Pacific, and there may be additional subpopulations (NOAA Fisheries, 2012a). The MMPA stock assessment recognizes three stocks of fin whales in the North Pacific, including the California, Oregon, and Washington stock (NOAA Fisheries, 2012a). Fin whales are classified as depleted throughout its range under the MMPA

**Threats**

Commercial whaling was the primary reason for the depletion of the fin whale population; commercial whaling in the North Pacific ended in 1976 (NOAA Fisheries, 2012a). Hybridization between blue whales and fin whales has been documented, and may decrease the fitness of the blue and fin whales that hybridize (Berube and Aguilar, 1998). Ship strikes and disturbance created by vessels and tourism are other threats to fin whales (NMFS, 2010a). From available accounts (Laist et al., 2001; Jensen and Silber, 2003) fin whales collide with ships relatively often, more frequently than 10 other species known to be struck off the U.S. East Coast (Laist et al., 2001) and relatively often on the West Coast (Jensen and Silber, 2003). Between 2007 and 2011 there were eight fin whales killed or injured by vessel strikes along the Pacific west coast, 7 of them off the California coast and one off the Oregon coast (Carretta et al., 2013a). Those estimates are undoubtedly low since many ship strikes with cetaceans are unknown and unreported.

Anthropogenic noise is a habitat concern, identified by NMFS (2010a) as a factor influencing the distribution of fin whales. Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Coastal development and its associated anthropogenic noise may compromise the migration routes and seasonal areas used by fin whales (NMFS, 2010a). Concerns about the future related to global warming and climate change may impact habitats, the availability of food, breeding behavior, and associated migration patterns (NMFS, 2010a).

Fin whale food sources may be damaged and may be stressed by certain climate changing processes such as global warming. The impacts from climate change could affect everything from phytoplankton up the trophic levels of the ecosystem. The potential impacts from global warming are being studied in an ongoing process from the United States GLOBEC program (Fogarty and Powell, 2002). Stressors from metabolic demands with warmer oceans may impact the health of animals. Shifts of marine populations either towards the poles or in the ocean depths they use are expected. Increased stratification from an increased temperature, and/or increased freshwater inputs may affect nutrient exchange and primary production. There may be reductions in the available nutrient levels and possible changes in the timing and intensity of phytoplankton blooms. There may also be reductions of upwelling and downwelling, thereby limiting the nutrient availability to marine life in specific stratified levels of the ocean. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures which led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

**Species Recovery**

A recovery plan was finalized in 2010 (NMFS, 2010a) and a 5-year status review was completed in December 2011 (NMFS, 2011a). The goals of the recovery plan (NMFS, 2010a) are to downlist and delist the species by maintaining stable populations in each ocean basin and ensuring that each population satisfies the risk analysis standard for threatened status and that factors which limit population growth have been identified and addressed.

The recovery plan identifies the following necessary actions:

1. Coordinate state, federal, and international actions to implement recovery efforts;
2. Determine population discreteness and stock structure;
3. Develop and apply methods to estimate population size and monitor trends in abundance;
4. Conduct risk analyses;
5. Identify and protect habitat essential to fin whale survival and recovery;
6. Identify causes of and minimize human-caused injury and mortality;
7. Determine and minimize any detrimental effects of anthropogenic noise in the oceans;
8. Maximize efforts to acquire scientific information from dead, stranded, and entangled or entrapped fin whales;
9. Develop a post-delisting monitoring plan.

**Life History, Habitat Requirements, and Distribution**

Fin whales are a baleen whale and the second-longest whale species. They are widely distributed throughout the world's oceans. The gestation period is assumed to be somewhat less than a year, and fin whale calves are nursed for 6 to 7 months. Most mating and calving takes place in winter. In the North Pacific, fin whales appear to prefer a diet of euphausiids and large copepods, followed by schooling fish such as herring, walleye pollock, and capelin (NMFS, 2010a).

Fin whales can be found in groups of three to seven, with records of groups between 50 and 100 in rich feeding grounds. They typically dive between 3 and 15 minutes to between 100 and 230 meters. A series of two to five shallow dives for between 10 and 20 seconds is common (Shirihai and Jarrett, 2006).

The reproductive age of fin whales is believed to have decreased from 12 to 6 years for females and 11 to 4 for males from the 1950s to the mid 1970s as a result of heavy commercial whaling targeting their populations. They are believed to reproduce every 2 to 3 years upon reaching sexual maturity. An estimated average of 0.36 to 0.47 of sexually mature females are pregnant annually (NMFS, 1998a). Fin whales live to be between 85 to 90 years old (Shirihai and Jarrett, 2006).

Migratory patterns of fin whales in the North Pacific are complex since whales occur in many different locations and latitudes in any season. Aggregations of fin whales occur year-round in southern and central California and the Gulf of California and off Oregon during summer. Vocalizations have been detected year-round off northern California, Oregon, and Washington with concentrations from September through February (Carretta et al., 2013b). Concentrations in the North Pacific form along mixing zones between coastal and oceanic waters associated with the continental shelf.

**Population Status**

Data from surveys of fin whale abundance in California, Oregon, and Washington (out to 300 nmi from the coast) indicatde an increasing population trend for fin whales in that stock (Caretta et al., 2013b). The best estimate of the California/Oregon/Washington Stock of fin whales is 3,051 whales (Carretta et al., 2013b). The minimum population is estimated at 2,598 whales (Carretta et al., 2013b). The overall potential biological removal for this fin whale stock is 16 whales per year (Carretta et al., 2013b). The abundance of fin whales off of the West Coast, from Baja California to Washington, has increased between 1991 and 2008 (Carretta et al., 2013b). The survey data include: 2,042 whales in 1996, 2,118 whales in 2001, 3,281 whales in 2005, and 2,825 whales in 2008 (Carretta et al., 2013b).

**Critical Habitat**

Critical habitat for this species has not been designated.

#### 4.2.2.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to fin whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, Washington, the same as described above for blue whales (see figure 4.2-1).

**Species Presence**

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-

Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the mean population estimate divided by the area in the surveyed stratum, 819,470 km$^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of fin whales in the California stratum is 0.227 whale per 100 km$^2$ or 0.066 whale per 100 nmi$^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of fin whales in the Oregon-Washington stratum is 0.129 whale per 100 km$^2$ or 0.038 whale per 100 nmi$^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for fin whales in the California stratum in 2008 is 0.383 whale per 100 km or 0.207 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for fin whales in the Oregon-Washington stratum in 2008 is 0.334 whale per 100 km or 0.180 whale per 100 nmi of ship transect.

**Habitat**

Recent observations show fin whales to be present year-round in central and Southern California; year-round in the Gulf of California; and in summer in Oregon. Acoustic signals from fin whales are detected year-round off northern California, Oregon, and Washington, with a concentration of vocal activity between September and February (NMFS, 2010a). Since fin whales feed on euphausiids, similar to blue whales, they may likewise follow primary production blooms of phytoplankton and associated euphausiid biomass increases off the Oregon coast as the blooms advace from south to north (Burtenshaw et al., 2004). Therefore, fin whales are expected to occur in the EEZ analysis area at least during some portions of the year.

**Critical Habitat**

Critical habitat for this species has not been designated.

### 4.2.2.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, anthropogenic underwater noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect fin whales by impacting forage species. These effects are addressed below.

Ship Strikes by LNG Carriers

As discussed above for blue whales, there is an ongoing threat of ship strikes to fin whales. Reduction of human-caused injury and mortality to fin whales is a principal objective for the species' recovery (NMFS, 2010a). From available accounts (Laist et al., 2001; Jensen and Silber, 2003) fin whales collide with ships relatively often, more frequently than ten other species known to be struck off the U.S. East Coast (Laist et al., 2001) and relatively often on the West Coast (Jensen and Silber, 2003). The rate of ship-strikes to fin whales and other large cetaceans is assumed to be the product of ship traffic and the cetacean population density within the EEZ. From 2007 to 2011 ship strikes of fin whales averaged 1.4 death or injury per year in California and 0.2 death or injury per year off the Oregon-Washington coast (Carretta et al., 2013a). Jensen and Silber (2003) reported a rate of 0.5 fin whale struck per year off the coasts of California and Washington from 1991 through 2002. Likewise, Douglas et al. (2008) compiled records of ship-stikes of fin whales in Washington State from 1980 to 2006 with an average of 0.07 whale struck per year. Those estimates are undoubtedly minimal since many ship strikes with cetaceans are unknown and unreported.

**Ship Traffic**. A considerable amount of shipping traffic currently occurs within the EEZ analysis area. Past, present, and reasonably foreseeable ship traffic within the EEZ analysis area was discussed for blue whales, above. Ship traffic to U.S. West Coast ports was increasing between 2002 and 2007 but deviated from the established trajectory in 2008, at the onset of the global financial crisis (see figure 4.2-2). The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service.

Applying the yearly percent change in Total Annual Vessel Calls at all West Coast ports based on the regression model in figure 4.2-2 to the total ship-miles along the West Coast beginning in 1999 (5,049,298 ship-miles in table 4.2.1-1), there would be an estimated 8,199,320 ship-miles along the West Coast, expected in 2018.

Similarly, the data from MARAD (2013) were used to estimate ship-miles along the California Coast and along the Oregon-Washington Coast in 2018 from the data in table 4.2.1-1 (under blue whales, above) from 1999 provided by Pacific States/British Columbia Oil Spill Task Force (2002).

- From 2002 to 2007, total vessel calls to California ports increased by a constant number of 251 vessel calls per year (regression model $y = 250.74x - 492{,}585$, $r^2 = 0.78$, $P=0.019$). There were 3,041,597 ship-miles in 1999 within California waters (see table 4.2.1-1); 4,717,894 ship-miles are expected in 2018.
- From 2002 to 2007, total vessel calls to Oregon-Washington ports increased by a constant number of 185 vessel calls per year (regression model $y = 184.6x - 364{,}401$, $r^2 = 0.56$, $P=0.086$). There were 2,007,701 ship-miles in 1999 within Oregon-Washington waters (see table 4.2.1-1); 3,533,752 ship-miles are expected in 2018.

The Project is designed to accommodate 90 LNG tankers a year. If all LNG tankers approach the Jordan Cove terminal by perpendicular transits through the EEZ, they will contribute 36,000 ship miles annually to vessel traffic in the Oregon-Washington stratum in 2018. If all LNG tankers approach the terminal by parallel transits along the California coast, they will contribute 137,160 ship-miles annually to vessel traffic within the California stratum in 2018. Observed and predicted vessel traffic within both strata in 1999, 2007, 2008, and 2018 are provided in table 4.2.2-1, including the addition of project-related LNG tanker traffic in 2018. During the life of the project, there may be years of mixed LNG tanker traffic, some transiting the EEZ perpendicular and other traffic paralleling the coast but such variability can not be estimated.

**Table 4.2.2-1**
**Estimates of Vessel Traffic, Fin Whale Encounter Rates, Relative Ship-Strike Risk, and Estimates of Fin Whales Struck per Year (with Percent Change from the Previous Estimate) in the California and Oregon-Washington Strata of the Project Activity Area.**

| | California Stratum | | | | Oregon-Washington Stratum | | | |
|---|---|---|---|---|---|---|---|---|
| Year and Event | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] |
| 1999 [1] Baseline Annual Ship Transits | 3,041,597 | N/A | N/A | N/A | 2,007,701 | N/A | N/A | N/A |
| 2007 [2] Predicted Trend with 2002-2007 data | 3,747,406 (+23.2%) | N/A | N/A | N/A | 2,650,249 (+32.0%) | N/A | N/A | N/A |
| 2008 [3] Most Recent Cetacean Survey | 3,316,554 (-11.5%) | 0.207 | 6,860 | 1.40 | 2,495,278 (-5.8%) | 0.180 | 4,495 | 0.20 |
| 2018 [2] Ambient Predicted Ship Traffic | 4,717,894 (+42.3%) | 0.308 (+49.1%) | 14,559 (+112.2%) | 2.971 (+112.2%) | 3,533,752 (+41.6%) | 0.269 (+49.1%) | 9,496 (+111.3%) | 0.420 (+111.3%) |
| 2018 [4] Ambient Traffic with LNG Tanker Traffic | 4,855,054 (+2.9%) | 0.308 (0%) | 14,982 (+2.9%) | 3.057 (+2.9%) | 3,569,752 (+1.0%) | 0.070 (0%) | 9,592 (+1.0%) | 0.424 +1.0%) |

[1] Estimated in table 4.2.1-1 with data from Pacific States/British Columbia Oil Spill Task Force, 2002.
[2] Estimated from linear regression of total vessel calls to California ports and Oregon-Washington port from 2002 to 2007. Source: MARAD, 2013
[3] Estimated total vessel calls to California ports and Oregon-Washington ports in 2008 (see Figure 4.2.1-1, above). Source: MARAD, 2013.
[4] Assume 90 LNG tankers with perpendicular transits through West Coast EEZ in Oregon-Washington stratum (36,000 ship-miles per year) or parallel transits through EEZ in California stratum (137,160 ship-miles per year).
[5] Estimates of Whales Struck derived from data reported by Carretta et al., 2013a for ship-strikes in the California and Oregon-Washington EEZ strata.

**Ship-Strike Risk.** An index of relative ship-strike risk within an explicitly defined gridded study area was described by Williams and O'Hara (2009). The approach was adapted to the coarse-scale analysis area by using mean whale encounter rates, described above for fin whales, and shipping intensity as indicated by the total annual ship-miles derived from vessel transits along the West Coast (see table 4.2.2-1) in the California and Oregon-Washington strata.

The encounter rate for fin whales in the California EEZ stratum is significantly ($P < 0.05$) related to the species' density, based on data collected during surveys conducted in in 1991, 1993, 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (Barlow, 2010). Likewise, the encounter rate for fin whales in the Oregon-Washington EEZ stratum is significantly ($P < 0.05$) related to density based on data collected in 1996, 2001, 2005 (data from

Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010), shown in figure 4.2-5. The relationships supports predictions, below, that future encounter rates (eg, in 2018) would be expected to increase as the fin whale population increases.

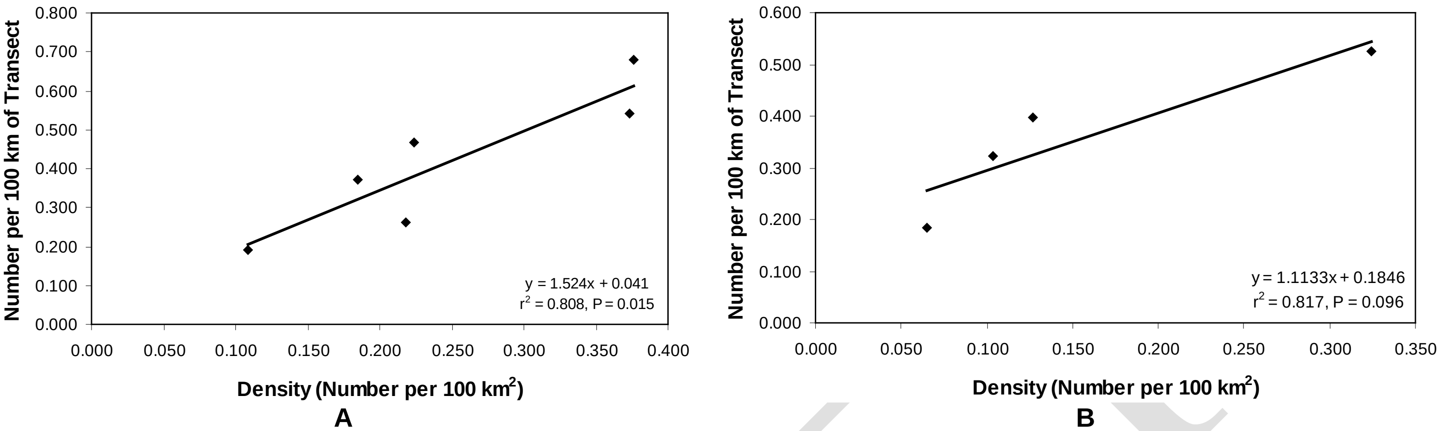



**Figure 4.2-5**
**Relationships of Fin Whale Encounter Rate (Number per 100 km of line-transect) to Density (Number per 100 km$^2$) From Shipboard Surveys Conducted off the Coasts of California (A) and Oregon-Washington (B).**

Relative ship-strike risks during 2008 and 2018 (see table 4.2.2-1) are the products of cetacean species' encounter rates and total ship miles expected in each stratum during the two years. An estimate of the encounter rate in 2018 (beginning of the project operation) is directly proportional to fin whale population and density in that year. Assuming exponential population growth, the population size ($N_t$) at time = t is $N_t = N_0 e^{r t}$ where $N_0$ = the initial population size at t = 0 and r is assumed to be $R_{MAX}$. This approach was used with the default value for $R_{MAX}$ = 0.04 to estimate fin whale encounter rates (as indices of population) in 2018 given the encounter rates of fin whales within the California and Oregon-Washington strata in 2008. In 2008, the fin whale encounter rate in the California stratum was 0.2007 whale per 100 nmi and 0.180 whale per 100 nmi in the Oregon-Washington stratum. Based on assumed population growth between 2008 and 2018, the fin whale encounter rate in California in 2018 is estimated at 0.308 whale per 100 nmi and 0.269 whale per 100 nmi in the Oregon-Washington stratum, an increase of 49 percent from the 2008 encounter rates (see table 4.2.2-1).

In 2008, the relative ship-strike risk in the Califonia stratum would be 0.207 whale per 100 nmi multiplied by 3,316,554 ship-miles = 6,860. In 2018, the assumed growth of the fin whale population increases the encounter rate proportionately to 0.308 whale per 100 nmi. Between 2008 and 2018 ship traffic is also be expected to increase to 4,717,894 ship-miles. The relative ship-strike risk in 2018 would be 14,559 which is 112.2 percent of the 2008 encounter rate (table 4.2.2-1). If all 90 LNG tanker transits occur in the California stratum, the total expeced vessel traffic would be 4,855,054 ship miles in 2018 and the ship-strike risk would increase to 14,982, an estimated increase of 2.9 percent. Similar calculations woud apply to the fin whale population growth, encounter rate, relative ship-strike risk in the Oregon-Washington stratum, provided in table 4.2.2-1.

**Estimated Ship-Strikes to Fin Whales**. Data provided by Carretta et al. (2013a) indicated 7 fin whales were struck in the California EEZ between 2007 and 2011 (1.4 whales per year) and 1 fin whale was struck in the Oregon-Washington EEZ during the same period (0.20 whale per year). Jensen and Silber (2003) reported 6 fin whales struck between 1991 and 2002 along the U.S. Pacific Coast and Douglas et al. (2008) reported 2 strikes off Washington between 1980 and 2006. Using recent ship-strike data from Carretta et al. (2013a), the increased ship-strike risk in 2018 is assumed to increase the annual rate of fin whales struck proportionately in the California stratum to 2.971 per year and to 0.420 per year in the Oregon-Washington stratum (see table 4.2.2-1). The additional project-related LNG tanker traffic would increase the annual rate in California to 3.057 whales per year, an increase of 0.086 ship-strike per year (one injury or death in 12 years) and would increase the annual rate in Oregon-Washington waters to 0.424 whale per year, and increase of 0.004 ship-strike per year (one injury or death in 250 years). Ship-strikes to fin whales by project-related LNG tankers are more likely in California than in the Oregon-Washington EEZ stratum but in both areas, death or injury of fin whales is insignificant and discountable.

<u>Underwater Noise</u>

Determining and minimizing any detrimental effects of anthropogenic underwater noise on fin whales is a principal objective for the species' recovery (NMFS, 2010a). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. When whales are exposed to low-level sounds from distant or stationary vessels, they appear to ignore the sounds. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). However, radiated ship noise of oncoming ships may not be immediately detected by whales near the surface due to bow null-effect acoustic shadow zones (Allen et al., 2012). Because of acoustic shadow zones, whales may not hear approaching ships to allow time for their avoidance response even though whale auditory ranges overlaps with peak intensities of ship noise.

Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades. The low frequencies generated by ships overlap frequencies of sounds generated by large baleen whales, including the fin whale (Würsig and Richardson, 2009). Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Anthropogenic noise and vessel disturbance may affect fin whales but there is little evidence available to describe or quantify the impacts of these threats on the species. While anthropogenic noise may threaten other cetaceans, little is known about whether, or how, vessel noise affects fin whales (NMFS, 2010).

The risk of ship noise causing PTS or TTS (see NMFS' interim acoustic thresholds in table 4.2.1-3, under blue whales) for fin whales would be similar to that described for blue whales, above. Noise from a LNG tanker in the Hatch et al. (2008) study produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 nmi$^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 $nmi^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 $nmi^2$.

Based on population growth between 2008 and 2018 described above for fin whale encounter rates, the predicted density of fin whales is 0.099 whale per 100 $nmi^2$ in the California stratum in 2018 and is 0.056 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum in 2018. Assuming an LNG tanker transit distance of 762 nmi within the California stratum, the number of fin whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.099 whale per 100 $nmi^2$) multiplied by the total area of noise effects (15.6 $nmi^2$), equal to 0.015 whale affected (an estimate between 0.006 and 0.025 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008).

The number of fin whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.099 whale per 100 $nmi^2$) multiplied by the total area of noise effects (7,176 $nmi^2$), equal to 7 whales affected (an estimate between 2 and 12 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3 under blue whales, above).

Similar calculations have been done for fin whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of fin whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.056 whale per 100 $nmi^2$) multiplied by the total area of noise effects (4.08 $nmi^2$), equal to 0.002 whale affected. The number of fin whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.056 whale per 100 $nmi^2$) multiplied by the total area of noise effects 1,883 $nmi^2$), equal to 1 whale affected (an estimate between 0 and 2 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 μPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 μPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on fin whales are possible in the in California EEZ stratum but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 $\mu Pa^2$ (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause behavioral disruptions to fin whales.

<u>Releases and Fire at Sea</u>

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of fin whales in the California EEZ stratum during 2018 would be 0.099 whale per 100 $nmi^2$ and 0.056 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire coul cause second degree burns would extend to an area of 0.563 $nmi^2$. Considerably fewer than one fin whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to fin whales due to LNG release and fire would be insignificant and discountable

Oil spills at sea or off shore might harm fin whales, although effects of oil spills on fin whales have not been reported (NMFS, 2006b). Effects to food resources including krill, copepods, and various schooling fish such as anchovies (NMFS, 2006b) could occur. However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers.

### Cumulative Effects

FWS and NMFS describe cumulative effects (50 CFR. § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of total vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whales). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated total vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay. Consequently, cumulative effects to fin whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4 under blue whales) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to fin whales may be more or may be less than the estimate of direct effects discussed above.

### Critical Habitat

The proposed action would not affect critical habitat; none has been designated.

#### 4.2.2.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (blue whales) apply to fin whales.

#### 4.2.2.5 Determination of Effects

**Species Effects**

The Project **may affect** fin whales because:

- Fin whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** fin whales because:

- Existing information indicates ship strikes to fin whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to fin whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on fin whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury..
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected fin whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to fin whales if they emerged during a fire.

**Critical Habitat Effects**. No critical habitat has been designated or proposed for fin whales.

### 4.2.3 Killer Whale

#### 4.2.3.1 Species Account and Critical Habitat

**Status**

Five killer whale stocks are recognized within Pacific United States waters:

1. Eastern North Pacific Northern Resident stock - occurring from British Columbia through Alaska (unlisted);
2. Eastern North Pacific Southern Resident stock - occurring within the inland waters of Washington and southern British Columbia, listed as endangered under the ESA November, 18, 2005 (NMFS 2005a). The Southern Resident population is classified as depleted under the MMPA; ;

3. Eastern North Pacific Transient stock – occurring from Alaska through California (unlisted);
4. Eastern North Pacific Offshore stock - occurring from Southeast Alaska through California (unlisted); and
5. Hawaiian stock (unlisted).

A status review of Southern Resident killer whales conducted in 2002 concluded that listing as threatened or endangered was not warranted because Southern Resident killer whales were not a species or Distinct Population Segment (DPS) for ESA application (NMFS, 2005a). The status review recognized, however, that the Southern Resident killer whale was a depleted stock under the MMPA. A challenge to NMFS' decision to not the list the species ("not warranted") and subsequent judicial intervention resulted in an updated status review, which found that the Southern Resident killer whale stock is discrete and significant with respect to other resident stocks and should be considered a DPS for listing under ESA (NMFS, 2005a).

NMFS (2012) published a 90-day finding on a petition to remove (delist) the Southern Resident killer whale DPS from the ESA list. The finding determined that the petitioned action might be warranted and NMFS announced their initiation of a status review to determine if the petitioned action is warranted. In 2011, NMFS completed a 5-year review of the status of Southern Residents killer whales and concluded that no change was needed in the species' ESA listing status; the Southern Resident killer whale DPS would remain listed as endangered (NMFS, 2011d).

**Threats**

The Southern Resident killer whale DPS primarily occurs in the inland transboundary waters of British Columbia and Washington in the summer and fall and in outer coastal waters in winter. The NMFS (2008) identified the factors that currently pose a risk for Southern Residents including 1) reductions in quantity or quality of prey, (2) high levels of organochlorine contaminants and increasing levels of many "emerging" contaminants (e.g., brominated flame retardants), putting Southern Residents at risk for serious chronic effects similar to those demonstrated for other marine mammals (e.g., immune and reproductive system dysfunction), (3) sound and disturbance from vessel traffic, and (4) oil spills. Reductions in prey availability, primarily that of salmon, over the past 150 years has limited the carrying capacity for the Eastern North Pacific Southern Resident stock (NMFS, 2008a). Other reasons for the reduction in Southern Resident stock numbers include the live-capture of whales for aquariums, and shooting of whales that were common before 1960 (NOAA Fisheries, 2013c).

Three primary threats to the Southern Resident stock include contaminants, prey availability, and vessel traffic (NMFS, 2008a). High levels of polychlorinated biphenyls (PCBs) have been found in the Southern Resident stock, and increasing levels of polybrominated diphenyl ethers and other contaminants are being found in ocean habitats with increasing frequency (NMFS, 2008a). Ross et al., (2000) found that the Southern Resident stock was one of the most contaminated cetaceans worldwide, and noted that fish-eating marine mammals that are found along industrialized coastal waters are generally high in PCB concentration levels.

Killer whale food sources may be damaged and they may gain new stressors with certain climate changing processes such as global warming. The impacts from climate change could affect everything from phytoplankton up the trophic levels of the ecosystem to keystone predators such as killer whales. Stressors from metabolic demands with warmer oceans may impact the health of animals. Shifts of marine populations either towards the poles or in the ocean depths they use are expected. Increased stratification from an increased temperature, and/or increased freshwater inputs may affect nutrient exchange and primary production. There may be reductions in the available nutrient levels and possible changes in the timing and intensity of phytoplankton blooms. There may also be reductions of upwelling and downwelling, thereby limiting the nutrients available to marine life in specific stratified levels of the ocean. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures, which has led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

Commercial and recreational vessel traffic, ferries, and whale watching have increased considerably during the past decades. Studies have revealed that whale-watch vessel operations affect killer whale behaviors including foraging, communication, movements and energy expenditures, and increase underwater noise (NMFS, 2008a). Whale-watch vessels also strike and cause injury to killer whales and possibly increase susceptibility to ship strikes by other types of vessels (NMFS, 2011d).

**Species Recovery**

A proposed recovery plan was prepared in 2006 by the NMFS for the Southern Resident killer whales (NMFS, 2006c) and a final plan was published in 2008 (NMFS, 2008a). The goal of the final recovery plan is to remove the species from ESA-listed status. The interim goal is to reclassify the Southern Resident killer whale DPS from endangered to threatened. The following is a list of recovery measures needed to achieve the goals and objectives provided in the recovery plan (NMFS, 2008a):

- Protect the Southern Resident killer whale population from factors that may be contributing to its decline or reducing its ability to recover (salmon stock, pollution, vessel disturbance).
- Protect Southern Resident killer whales from additional threats that may cause disturbance, injury, or mortality, or impact habitat (oil spills, acoustic effects, disease, invasive species).
- Develop public information and education programs.
- Respond to killer whales that are stranded, sick, injured, isolated, pose a threat to the public, or exhibit nuisance behaviors.
- Encourage transboundary and interagency coordination and cooperation.
- Monitor status and trends of the Southern Resident killer whale population.
- Conduct research to facilitate and enhance recovery efforts for Southern Resident killer whales.

**Life History, Habitat Requirements, and Distribution**

The killer whale, or orca, is found in all oceans. These whales can adapt to a wide variety of conditions, and appear to be at home in both open seas and coastal waters. Orcas are toothed whales, and the largest of the dolphins. They have a widely varied diet including salmon, pinnipeds, and even large baleen whales; the diet is often geographic specific. They often hunt in groups using pack-like behavior (Carretta et al., 2013b). Pods for mammal-eating killer whales are generally between 5 and 10 animals, while pods of fish-eating killer whales consist of larger groups. The groups generally include a mixture of age and sex. They generally breathe every 10 to 35 seconds during approximately 12 short dives, and can deep dive for up to 17 minutes (Shirihai and Jarrett, 2006).

Sexual maturity of female killer whales is size dependent and occurs when the whales reach lengths of approximately 15 to 18 feet. Mating appears to occur at any time, with no identified breeding season (American Cetacean Society, 2004). The female Southern Resident killer whales average births every 4.9 to 7.7 years, and are polygamous. Females reproduce throughout their lives upon reaching sexual maturity, and can live up to 40 or 50 years of age. Males tend to have death rates that increase by 18 percent each year after reaching 30 years old (American Cetacean Society, 2004).

**Population Status**

In 1993 there were 96 individual killer whales in the three pods that comprise the Eastern North Pacific Southern Resident stock. The population increased to 99 whales in 1995, then declined to 79 whales in 2001, and most recently numbered 85 whales in 2012 (Carretta et al., 2013b).

It is believed that the entire population is identified and accounted for each year, and so the minimum population estimate is also 85 animals. The recent analysis of long-term population growth, from 1979 to 2011, for the Southern Resident killer whale DPS indicates the maximum annual growth rate is $R_{MAX}$ = 3.2 percent (Carretta et al. 2013b). The potential biological removal, is the maximum number of animals killed (not including natural deaths), that would still allow for the population to achieve its optimum sustainable population (NMFS, 1997b). The potential biological removal for these whales is calculated at 0.14 whale per year and appears to be approaching a rate of zero for human-related mortality and serious injury (Carretta et al. 2013b).

Observations of Southern Resident killer whales in Oregon have been restricted to offshore areas near Depoe Bay (1999 and 2000), near Yaquina Bay (2000), and near the Columbia River (2006) (NMFS, 2006d). The nearest sightings of Southern Resident killer whales in California have been off Point Reyes, 30 miles north of San Francisco (NMFS, 2006c). Therefore, the federally listed Southern Resident killer whale stock may occur in, or travel through the EEZ on an infrequent basis. Killer whales occasionally enter lower Coos Bay in search of prey resources, but rarely occur as far upstream as the LNG terminal (U.S. Army Corps of Engineers, 1994). Since the Eastern North Pacific Southern Resident killer whale stock has been sighted along the Oregon coast and as far south as Monterey Bay, California (Carretta et al., 2013b), individuals entering Coos Bay and within the EEZ off the Oregon and Washington coasts are likely to belong to that DPS.

**Critical Habitat**

Critical habitat for the Eastern North Pacific Southern Resident stock of killer whales was designated on November 28, 2006 (NMFS, 2006c). Three specific areas were designated: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca. None of the Critical Habitat Units (CHUs) for the Eastern North Pacific Southern Resident stock occurs within the EEZ analysis area off the Oregon coast or off the Washington coast.

Primary constituent elements of the designated critical habitat are (NMFS, 2006c): 1) Water quality to support growth and development; 2) Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and 3) Passage conditions to allow for migration, resting, and foraging. Fish are the major dietary component of resident killer whales in the northeastern Pacific. Salmon are the preferred prey for the DPS (NMFS, 2006c). Sufficient prey abundance is necessary to support individual growth to reach sexual maturity and reproduction, including lactation and successful rearing of calves. Because of their long life span, position at the top of the food chain, and their blubber stores, killer whales accumulate high concentrations of contaminants including PCBs, DDT, polychlorinated napthalenes, brominated flame retardants, PAHs, dioxins, furans, and heavy metals. Those and others may cause mortality or reproductive failure in Southern Resident killer whales (NMFS, 2006c). Southern Resident killer whales require open waterways that are free from obstruction. In-water structures that block passage, for example, could affect Southern Resident killer whale movement. (NMFS, 2006c).

#### 4.2.3.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to killer whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, Washington, the same as described above for blue whales (see figure 4.2-1).

**Species Presence**

Killer whales are known to occur off the Oregon Coast. Most sightings of the ESA-listed Southern Resident killer whales have occurred during summer within inland waters of Washington and southern British Columbia. However, pods belonging to this stock have also been sighted in coastal waters off southern Vancouver Island and Washington and the location of their complete winter range is uncertain (Carretta et al., 2013b). Two of the three pods comprising this stock have been sighted as far south as Monterey Bay and central California in recent years. Observations of Southern Resident killer whales in Oregon have been restricted to offshore areas near Depoe Bay (1999 and 2000), near Yaquina Bay (2000) and near the Columbia River (2006) (NMFS, 2006c). Therefore, Southern Resident killer whales may occur in or travel through the EEZ analysis area on an infrequent basis. Killer whales occasionally enter lower Coos Bay in search of prey resources (U.S. Army Corps of Engineers, 1994).

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the mean population estimate divided by the area in the surveyed stratum, 819,470 km$^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of killer whales in the California stratum is 0.036 whale per 100 km$^2$ or 0.010 whale per 100 nmi$^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of killer whales in the Oregon-Washington stratum is 0.166 whale per 100 km$^2$ or 0.048 whale per 100 nmi$^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for killer whales in the California stratum is 0.023 whale per 100 km or 0.012 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for killer whales in the Oregon-Washington stratum is 0.076 whale per 100 km or 0.041 whale per 100 nmi of ship transect.

**Habitat**

Killer whales are less restrained by depth, temperature, and salinity of the water than other whales (NMFS 2008a). The Southern Resident stock tends to spend more time in deeper water or waters where there is more salmon abundance. Documented occurrences off of Oregon have led to the belief that the California Current ecosystem is used by this stock, and so the Southern Resident stock may be expected to be found in the EEZ (NMFS 2008a).

**Critical Habitat**

None of the CHUs for the Eastern North Pacific Southern Resident stock occurs within the EEZ analysis area off the Oregon coast.

### 4.2.3.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, effects due to ship noise, and potential adverse effects from a ship spill and/or release of LNG at sea. Spills and/or released LNG could indirectly affect killer whales by impacting forage species. These effects are addressed below.

<u>Ship Strikes by LNG Carriers</u>

As discussed above for blue whales, there is an ongoing threat of ship strikes to killer whales. Of ten whale species studied by Jensen and Silber (2003), killer whales were the least likely to be struck by ships: they found one documented occurrence of a killer whale calf being struck by a ship. One vessel strike on a killer whale from the Southern Resident Stock occurred in 2006, but noted that the particular whale (L98) that was struck had become habituated to vessel interaction while it resided in Nootka Sound. In the 5-year period, 2007-2011, no killer whales had been struck by vessels (Carretta et al., 2013a). Douglas et al. (2008) reported one killer whale stranded in Washington during the period from 1980 to 2006 but the cause of death was likely not related to a ship-stike. The available information indicates that killer whales are not susceptible to ship-strike, at least carcasses indicating trauma and/or wounds from boat propellers have not been reported along the Oregon and Washington coasts (Norman et al., 2004). From 1995 to 2006, 10 killer whales were injured (8) or killed (2) with the inland waterways of British Columbia (including killer whale number L98 killed in 2006, see Williams and O'Hara, 2009) but none of the records were from whales struck in the open ocean.

Therefore, there are no data available to estimate risk of ship-strikes in 2018 and possible death or injury due to project-related LNG traffic in the West Coast EEZ analysis area.

<u>Underwater Noise</u>

Determining and minimizing any detrimental effects of anthropogenic underwater noise on killer whales is a principal objective for the species' recovery (NMFS, 2008a). Killer whales are highly vocal, producing a variety of clicks, whistles, and and pulsed calls used for echolocation and social communication (Ford, 2009). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. Southern Resident killer whales inhabit Puget Sound near Seattle where a large variety of motorized vessels and production of associated underwater noise are prevalent. Studies have shown that killer whales in the DPS increased their call amplitude by 1 dB for every 1 dB increase in background, ambient noise levels (Holt et al., 2008). Boats approaching killer whales causes them to abandon foraging group foraging behaviors (Lusseau et al., 2009) and boat noise could impair communication and cooperative foraging between killer whales over a range of 1–14 km (Foote et al., 2004).

The risk of ship noise causing PTS or TTS (see NMFS' interim acoustic thresholds in table 4.2.1-2) for killer whales would be similar to that described for blue whales, above. LNG ship noise of 182 ± 2 dB dB re 1 µPa @ 1 m would decrease to 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 nmi$^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 nmi$^2$.

Based on population growth between 2008 and 2018, the predicted density of killer whales is 0.016 whale per 100 nmi$^2$ in the California stratum and 0.072 whale per 100 nmi$^2$ in the Oregon-Washington stratum in 2018. Assuming an LNG tanker transit distance of 762 nmi within the California stratum, the number of killer whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.016 whale per 100 nmi$^2$) multiplied by the total area of noise effects (15.6 nmi$^2$), equal to 0.002 whale affected.

The number of killer whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.016 whale per 100 nmi$^2$) multiplied by the total area of noise effects (7,176 nmi$^2$), equal to 1.1 whale affected (an estimate between 0.4 and 1.9 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Similar calculations have been done for killer whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of killer whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.072 whale per 100 nmi$^2$) multiplied by the total area of noise effects (4.08 nmi$^2$), equal to 0.003 whale affected (an estimate between 0.001 and 0.005 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008). The number of killer whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.072 whale per 100 nmi$^2$) multiplied by the total area of noise effects 1,883 nmi$^2$), equal to 1.4 whale affected (an estimate between 0.5 and 2.3 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 dB$_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on killer whales are possible in the in California and Oregon-Washington EEZ strata but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 µPa$^2$ (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause behavioral disruptions to blue whales.

Vessel traffic in habitats occupied by Southern Resident killer whales significantly increase noise above ambient levels which can affect whale behavior (Holt, 2008). However, it is unlikely that LNG carriers transiting the EEZ north from Coos Bay would produce noise at levels that could affect Southern Resident killer whales. Also, LNG carriers are not expected to transit designated critical habitat.

<u>Releases and Fire at Sea</u>

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of killer whales in the California EEZ stratum during 2018 would be 0.016 whale per 100 $nmi^2$ and 0.072 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire coul cause second degree burns would extend to an area of 0.563 $nmi^2$. Considerably fewer than one killer whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to killer whales due to LNG release and fire would be insignificant and discountable

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR. § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-3). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated vessel traffic in Coos Bay in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay. Consequently, cumulative effects to killer whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4 under blue whales) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to killer whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect designated critical habitat the inland transboundary waters of British Columbia and Washington.

#### 4.2.3.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (blue whale) apply to killer whales.

#### 4.2.3.5 Determination of Effects

**Species Effects**

The Project **may affect** killer whales because:

- Killer whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** killer whales because:

- Existing information indicates ship strikes to killer whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to killer whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.

- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on killer whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected killer whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to killer whales if they emerged during a fire.

**Critical Habitat Effects**

The Project would have **no effect** on designated CHUs for the Eastern North Pacific Southern Resident stock because:

- None of the designated CHUs occur within the EEZ analysis area off the Oregon or California coasts.
- The nearest critical habitat unit to Coos Bay is the Strait of Juan de Fuca, Washington, more than 390 nmi north.
- No LNG carriers are expected to transit designated critical habitat.

### 4.2.4 Humpback Whale

#### 4.2.4.1 Species Account and Critical Habitat

**Status**

Humpback whales were listed as endangered under the Endangered Species Conservation Act on December 2, 1970 (FWS, 1970) and have been listed as endangered throughout its range under the ESA since its implementation in 1973. Humpback whales are classified as depleted throughout its range under the MMPA. Recent evidence suggests that there are multiple populations of humpback whales in the North Pacific, including:

1. Winter/spring populations in coastal Central America and Mexico, which migrate to the coast of California to southern British Columbia in summer/fall - referred to as the California/Oregon/Washington stock (formerly the Eastern North Pacific stock), and the stock likely to be present off the Oregon coast during migration;
2. Winter/spring populations of the Hawaiian Islands, which migrate to northern British Columbia/Southeast Alaska and Prince William Sound west to Kodiak - referred to as the Central North Pacific stock; and
3. Winter/spring populations of Japan, which likely migrate to waters west of the Kodiak Archipelago, known as the Western North Pacific stock (Carretta et al., 2013b).

**Threats**

Commercial whaling operations were the primary contributor to the decline in humpback whale populations (NMFS, 1991). The primary ongoing threat to humpback whales is entanglement in fishing gear (NMFS, 1991), especially drift gill-nets (Carretta et al., 2013a and 2013b). Whales that use low-frequency sounds may be at an increased risk for disturbance from anthropogenic noise. This noise is listed as a habitat concern for humpback whales (NMFS, 1991; Carretta et al., 2007).

Humpback whale food sources may be damaged and they may gain new stressors with certain climate changing processes such as global warming. Stressors from metabolic demands with warmer oceans may impact the health of animals. Shifts of marine populations either towards the poles or in the ocean depths they use are expected. Increased stratification from an increased temperature, and/or increased freshwater inputs may affect nutrient exchange and primary production (Fogarty and Powell, 2002).

There may be reductions in the available nutrient levels and possible changes in the timing and intensity of phytoplankton blooms. There may also be reductions of upwelling and downwelling, thereby limiting the nutrient availability to marine life in specific stratified levels of the ocean. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures which led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

**Species Recovery**

A recovery plan was prepared in 1991 by the humpback whale recovery team for the NMFS (NMFS, 1991). The goal of the plan is to be "biologically successful", meaning that humpback whales occupy all of their former range in sufficient numbers to buffer their populations against normal environmental fluctuations or anthropogenic environmental catastrophes. The plan states that the best estimator of biological success would be if the plan is "numerically successful," meaning that populations grow to levels where their population dynamic responses indicate density dependent reductions in productivity. The plan defines "political success" as the time when populations are abundant enough that the species can be downlisted or delisted. The plan's four objectives are:

- Maintain and enhance habitats used by humpback whales currently or historically.
- Identify and reduce direct human-related injury and mortality.
- Measure and monitor key population parameters.
- Improve administration and coordination or recovery program for humpback whales.

**Life History, Habitat Requirements, and Distribution**

The humpback whale is a large baleen whale occupying all ocean basins. Migration and reproduction is tied to seasonal progression (NMFS, 1991). The Pacific humpback whales over-winter in temperate and tropical waters and migrate in summer to waters of high biological productivity in higher latitudes (NMFS, 1991). Breeding and birth likely take place in wintering areas, and it is believed that little feeding takes place in wintering grounds. The humpback whale diet consists of krill, along with fish including cod, pollock, anchovies, and mackerel.

Humpbacks generally travel alone or in pairs consisting of mother and calf. They may be found in groups between 12 and 15 animals. They generally dive between 3 and 15 minutes, but they can dive for up to 40 minutes. They can reach depths of 150 meters, and they display cooperative hunting behavior in what is termed "bubble netting" of their prey (Shirihai and Jarrett, 2006).

Sexual maturity for humpback whales is generally reached between 4 and 6 years of age. Once mature, females tend to give birth every 2 to 3 years with some annual or multi-year intervals beyond 3 years being recorded (NMFS, 1991). The gestation period is between 11 and 12 months, and the calves are weaned at between 6 and 12 months. Calves may continue to associate with their mothers for 1 to 2 years. Information is lacking on lifespan and natural mortality but humpbacks are known to live to be at least 50 years old (Shirihai and Jarrett, 2006).

**Population Status**

The total abundance for humpback whales in the North Pacific has recently been estimated at 21,063 whales, based on mark-recapture estimation using fluke photographs (Barlow et al., 2011). The population has been increasing and may exceed estimates of pre-whaling abundance.

One recent estimate for the California/Oregon/Washington stock was 1,918 whales and the minimum population estimate was calculated to be 1,876 in 2007-2008 (Carretta et al., 2013b). Population estimates for humpback whales in the North Pacific increased from 1,200 in 1966 to 18,000-20,000 whales in 2006. The long-term population increase has been estimated at 7.5 percent per year (Calambokidis et al., 2010). The observed growth rate of the California/Oregon/Washington stock is estimated at 6 to 7 percent per year (Carretta et al., 2013b).

The current calculated potential biological removal for humpback whales is 11 whales per year occurring within the U.S, EEZ (Carretta et al., 2013).

The average number of documented humpback whale deaths by ship strikes for 2007 to 2011 is 1.1 whale per year (Carretta et al., 2013b). That estimate is undoubtedly low since many ship strikes with cetaceans are unknown and unreported.

**Critical Habitat**

Critical habitat for this species has not been designated.

### 4.2.4.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to humpback whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, the same as described above for blue whales (see figure 4.2-1 under blue whale).

**Species Presence**

The California/Oregon/Washington stock of humpback whales is separated out from other populations based upon the feeding area off the mainland West Coast of the United States. The northern boundary of this population is the border of Washington and British Columbia, with humpbacks being found throughout the West Coast feeding area and concentrated primarily off of California (Carretta et al. 2007). Four humpbacks were documented to have been stranded in Oregon from 1930 to 2002, and two were stranded in Washington for the same time period (Norman et al., 2004).

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the mean population estimate divided by the area in the surveyed stratum, 819,470 $km^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of humpback whales in the California stratum is 0.083 whale per 100 $km^2$ or 0.024 whale per 100 $nmi^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of humpback whales in the Oregon-Washington stratum is 0.081 whale per 100 $km^2$ or 0.024 whale per 100 $nmi^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for humpback whales in the California stratum in 2008 is 0.194 whale per 100 km or 0.105 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for humpback whales in the Oregon-Washington stratum in 2008 is 0.172 whale per 100 km or 0.093 whale per 100 nmi of ship transect.

**Habitat**

Humpback whales are present primarily during summer months in the EEZ of the western United States (NMFS, 1991). They are present off the coast of the United States in feeding grounds where they search alone or in groups for krill and small fish, and employ “bubble netting” to corral and trap their prey (Shirihai and Jarrett, 2006). Modeled habitat use indicates that humpback whales are strongly associated with latitude and bathymetric features (including depth, slope and distance to the 100-m isobath). Distance to sea-surface-temperature fronts and salinity (climatology) were also constantly selected, and higher numbers of whales seemed to be associated with higher primary productivity for some models (Della Rosa et al., 2012).

**Critical Habitat**

Critical habitat for this species has not been designated.

#### 4.2.4.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, adverse effects from vessel underwater noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect humpback whales by impacting forage species. These effects are addressed below.

<u>Ship Strikes by LNG Carriers</u>

As discussed above for blue whales, there is an ongoing threat of ship strikes to humpback whales. From available accounts (Laist et al., 2001; Jensen and Silber, 2003) humpback whales collide with ships relatively often, with calves being particularly vulnerable to ship strikes (Laist et al., 2001). Jensen and Silber (2003) found that humpbacks were second most likely behind fin whales to be struck by ships. Ship strikes of humpback whales averaged 0.2 death per year along the Pacific Coast between 2000 and 2004 (Carretta et al. 2007) and 0.17 death per year within Oregon and Washington waters, combined. From 2007 to 2011 ship strikes of humpback whales averaged 0.6 death or injury per year in California and 0.2 death or injury per year off the Oregon-Washington coast (Carretta et al., 2013a). Jensen and Silber (2003) reported a rate of 0.33 humpback whales struck per year off the coast of California from 1995 through 2000. Likewise, Douglas et al. (2008) compiled records of ship-stikes of humpback whales in Washington State from 1980 to 2006 with an average of 0.04 whale struck per year. Those estimates are undoubtedly minimal since many ship strikes with cetaceans are unknown and unreported.

**Ship Traffic**. A considerable amount of shipping traffic currently occurs within the EEZ analysis area. Past, present, and reasonably foreseeable ship traffic within the EEZ analysis area was discussed for blue whales, above. Ship traffic to U.S. West Coast ports was increasing between 2002 and 2007 but deviated from the established trajectory in 2008, at the onset of the global financial crisis (see figure 4.2-2 under blue whale). The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service.

Applying the yearly percent change in Total Annual Vessel Calls at all West Coast ports based on the regression model in figure 4.2-2 to the total ship-miles along the West Coast beginning in 1999 (5,049,298 ship-miles in table 4.2.1-1 under blue whales, above), there would be an estimated 8,199,320 ship-miles along the West Coast, expected in 2018.

Similarly, the data from MARAD (2013) were used to estimate ship-miles along the California Coast and along the Oregon-Washington Coast in 2018 from the data in table 4.2.1-1 from 1999 provided by Pacific States/British Columbia Oil Spill Task Force (2002).

- From 2002 to 2007, total vessel calls to California ports increased by a constant number of 251 vessel calls per year (regression model y = 250.74x – 492,585, $r^2$ = 0.78, P=0.019). There were 3,041,597 ship-miles in 1999 within California waters (see table 4.2.1-1); 4,717,894 ship-miles are expected in 2018.
- From 2002 to 2007, total vessel calls to Oregon-Washington ports increased by a constant number of 185 vessel calls per year (regression model y = 184.6x – 364,401, $r^2$ = 0.56, P=0.086). There were 2,007,701 ship-miles in 1999 within Oregon-Washington waters (see table 4.2.1-1); 3,533,752 ship-miles are expected in 2018.

The Project is designed to accommodate 90 LNG tankers a year. If all LNG tankers approach the Jordan Cove terminal by perpendicular transits through the EEZ, they will contribute 36,000 ship miles annually to vessel traffic in the Oregon-Washington stratum in 2018. If all LNG tankers approach the terminal by parallel transits along the California coast, they will contribute 137,160 ship-miles annually to vessel traffic within the California stratum in 2018. Observed and predicted vessel traffic within both strata in 1999, 2007, 2008, and 2018 are provided in table 4.2.4-1, including the addition of project-related LNG tanker traffic in 2018. During the life of the project, there may be years of mixed LNG tanker traffic, some transiting the EEZ perpendicular and other traffic paralleling the coast but such variability can not be estimated.

**Table 4.2.4-1**
**Estimates of Vessel Traffic, Humpback Whale Encounter Rates, Relative Ship-Strike Risk, and Estimates of Humpback Whales Struck per Year (with Percent Change from the Previous Estimate) in the California and Oregon-Washington Strata of the Project Activity Area**

| | California Stratum | | | | Oregon-Washington Stratum | | | |
|---|---|---|---|---|---|---|---|---|
| Year and Event | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] |
| 1999 [1] Baseline Annual Ship Transits | 3,041,597 | N/A | N/A | N/A | 2,007,701 | N/A | N/A | N/A |
| 2007 [2] Predicted Trend with 2002-2007 data | 3,747,406 (+23.2%) | N/A | N/A | N/A | 2,650,249 (+32.0%) | N/A | N/A | N/A |
| 2008 [3] Most Recent Cetacean Survey | 3,316,554 (-11.5%) | 0.105 | 3,481 | 0.60 | 2,495,278 (-5.8%) | 0.093 | 2,312 | 0.20 |
| 2018 [2] Ambient Predicted Ship Traffic | 4,717,894 (+42.3%) | 0.157 (+49.1%) | 7,387 (+112.2%) | 1.273 (+112.2%) | 3,533,752 (+41.6%) | 0.138 (+49.1%) | 4,884 (+111.3%) | 0.423 (+111.3%) |
| 2018 [4] Ambient Traffic with LNG Tanker Traffic | 4,855,054 (+2.9%) | 0.157 (0%) | 7,601 (+2.9%) | 1.310 (+2.9%) | 3,569,752 (+1.0%) | 0.138 (0%) | 4,934 (+1.0%) | 0.427 +1.0%) |

[1] Estimated in Table 4.2.1-1 with data from Pacific States/British Columbia Oil Spill Task Force, 2002.
[2] Estimated from linear regression of total vessel calls to California ports and Oregon-Washington port from 2002 to 2007. Source: MARAD, 2013
[3] Estimated total vessel calls to California ports and Oregon-Washington ports in 2008 (see Figure 4.2.1-1, above). Source: MARAD, 2013.
[4] Assume 90 LNG tankers with perpendicular transits through West Coast EEZ in Oregon-Washington stratum (36,000 ship-miles per year) or parallel transits through EEZ in California stratum (137,160 ship-miles per year).
[5] Estimates of Whales Struck derived from data reported by Carretta et al., 2013a for ship-strikes in the California and Oregon-Washington EEZ strata.

**Ship-Strike Risk.** An index of relative ship-strike risk within an explicitly defined gridded study area was described by Williams and O'Hara (2009). The approach was adapted to the coarse-scale analysis area by using mean whale encounter rates, described above for humpback whales, and shipping intensity as indicated by the total annual ship-miles derived from vessel transits along the West Coast (table 4.2.4-1) in the California and Oregon-Washington strata.

The encounter rate for humpack whales in the California EEZ stratum is significantly ($P < 0.05$) related to the species' density, based on data collected during surveys conducted in in 1991, 1993, 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (Barlow, 2010), shown in figure 4.2-6. The relationship supports predictions, below, that future encounter rates (eg, in 2018) would be expected to increase as the humpback whale population increases.

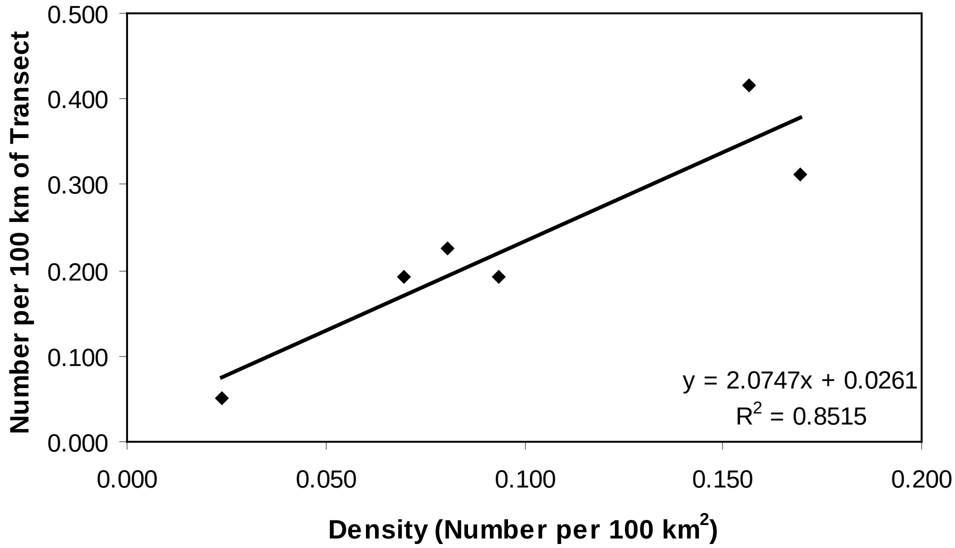



**Figure 4.2-6**
**Relationship of Ship-Transect Encounter Rate with Humpback Whales (Number per 100 km) to Humpack Whale Density (Number per km$^2$ ) in the California EEZ Stratum. Data were Collected in 1991, 1993, 1996, 2001, 2005, and 2008. The Relationship is Significant ($P < 0.01$)**

Relative ship-strike risks during 2008 and 2018 (see table 4.2.4-1) are the products of cetacean species' encounter rates and total ship miles expected in each stratum during the two years. An estimate of the encounter rate in 2018 (beginning of the project operation) is directly proportional to humpback whale population and density in that year. Assuming exponential population growth, the population size ($N_t$) at time = t is $N_t = N_0 e^{r t}$ where $N_0$ = the initial population size at t = 0 and r is assumed to be $R_{MAX}$. This approach was used with the default value for $R_{MAX} = 0.04$ to estimate humpback whale encounter rates (as indices of population) in 2018 given the encounter rates of humpback whales within the California and Oregon-Washington strata in 2008. In 2008, the humpback whale encounter rate in the California stratum was 0.2007 whale per 100 nmi and 0.180 whale per 100 nmi in the Oregon-Washington stratum. Based on assumed population growth between 2008 and 2018, the humpback whale encounter rate in California in 2018 is estimated at 0.308 whale per 100 nmi and 0.269 whale per 100 nmi in the Oregon-Washington stratum, an increase of 49 percent from the 2008 encounter rates (see table 4.2.2-1, above).

In 2008, the relative ship-strike risk in the Califonia stratum would be 0.105 whale per 100 nmi multiplied by 3,316,554 ship-miles = 3,481. In 2018, the assumed growth of the humpback whale population increases the encounter rate proportionately to 0.157 whale per 100 nmi. Between 2008 and 2018 ship traffic is also be expected to increase to 4,717,894 ship-miles. The relative ship-strike risk in 2018 would be 7,387 which is 112.2 percent of the 2008 encounter rate (table 4.2.4-1). If all 90 LNG tanker transits occur in the California stratum, the total expeced vessel traffic would be 4,855,054 ship miles in 2018 and the ship-strike risk would increase to 7,601, an estimated increase of 2.9 percent. Similar calculations woud apply to the humpback whale population growth, encounter rate, relative ship-strike risk in the Oregon-Washington stratum, provided in table 4.2.4-1.

**Estimated Ship-Strikes to Humpback Whales**. Data provided by Carretta et al. (2013a) indicated 3 humpback whales were struck in the California EEZ between 2007 and 2011 (0.60 whale per year) and 1 humpback whale was struck in the Oregon-Washington EEZ during the same period (0.20 whale per year). Jensen and Silber (2003) reported 2 humpback whales struck between 1995 and 2000 along the U.S. Pacific Coast and Douglas et al. (2008) reported 1 strike off Washington between 1980 and 2006. Using recent ship-strike data from Carretta et al. (2013a), the increased ship-strike risk in 2018 is assumed to increase the annual rate of humpback whales struck proportionately in the California stratum to 1.273 per year and to 0.423 per year in the Oregon-Washington stratum (see table 4.2.4-1). The additional project-related LNG tanker traffic would increase the annual rate in California to 1.310 whale per year, an increase of 0.037 ship-strike per year (one injury or death in 27 years) and would increase the annual rate in Oregon-Washington waters to 0.423 whale per year, an increase of 0.004 ship-strike per year (one injury or death in 250 years). Ship-strikes to humpback whales by project-related LNG tankers are more likely in California than in the Oregon-Washington EEZ stratum but in both areas, death or injury of humpack whales is insignificant and discountable.

<u>Underwater Noise</u>

Humpback whales are well known for their vocalizations. Male humpback whales sing long, complex songs that function to attract females and may play roles in establishing dominance hierarchies or cooperative behavior among males (Clapham, 2009). Studies have found that low frequency sounds, whether generated by sonar or ships, cause singing humpback whales to lengthen their singing, perhaps as compensation for the acoustic interference (Miller et al., 2000). Alternatively, humpback whales ceased vocalizing when low-frequency pulses were produced 200 km away from the whales which increased underwater noise levels above ambient levels (Risch et al., 2012). Characteristics of humpback whale songs (duration, tempo or pace, frequency structure) indicated masking of songs by noise from large boats (Norris, 1995).

Determining and minimizing any detrimental effects of anthropogenic underwater noise on humpback whales is a principal objective for the species' recovery (NMFS, 1991). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. When whales are exposed to low-level sounds from distant or stationary vessels, they appear to ignore the sounds. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). However, radiated ship noise of oncoming ships may not be immediately detected by whales near the surface due to bow null-effect acoustic shadow zones (Allen et al., 2012). Because of acoustic shadow zones, whales may not hear approaching ships to allow time for their avoidance response even though whale auditory ranges overlaps with peak intensities of ship noise.

Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades. The low frequencies generated by ships overlap frequencies of sounds generated by large baleen whales, including the humpback whale (Würsig and Richardson, 2009). Changes in vocal behavior may lead to reductions in foraging efficiency and/or mating opportunities (Weilgart, 2007). Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009; Weilgart, 2007).

Noise from a LNG tanker in a study by Hatch et al. (2008) produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 nmi$^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 nmi$^2$.

Based on population growth between 2008 and 2018 described above for humpback whale encounter rates, the predicted density of humpback whales is 0.044 whale per 100 nmi$^2$ in the California stratum in 2018 and is 0.043 whale per 100 nmi$^2$ in the Oregon-Washington EEZ stratum in 2018. Assuming an LNG tanker transit distance of 762 nmi within the California stratum, the number of humpback whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.044 whale per 100 nmi$^2$) multiplied by the total area of noise effects (15.6 nmi$^2$), equal to 0.007 whale affected (an estimate between 0.003 and 0.011 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008).

The number of humpback whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.044 whale per 100 nmi$^2$) multiplied by the total area of noise effects (7,176 nmi$^2$), equal to 3.1 whales affected (an estimate between 1.1 and 5.3 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3 under blue whales, above).

Similar calculations have been done for humpback whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of humpback whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.043 whale per 100 nmi$^2$) multiplied by the total area of noise effects (4.08 nmi$^2$), equal to 0.002 whale affected (an estimate between 0.001 and 0.003 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008). The number of humpback whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.043 whale per 100 nmi$^2$) multiplied by the total area of noise effects (1,883 nmi$^2$), equal to 0.81 whale affected (an estimate between 0.27 and 1.35 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3, blue whales).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of

188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on humpback whales are possible in the in California and Oregon-Washington EEZ strata but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 $\mu Pa^2$ (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause injury to humpback whales.

<u>Releases and Fire at Sea</u>

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of humpback whales in the California EEZ stratum during 2018 would be 0.044 whale per 100 $nmi^2$ and 0.043 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 nmi$^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 nmi$^2$ and the area where fire could cause second degree burns would extend to an area of 0.563 nmi$^2$. Considerably fewer than one humpack whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to humpback whales due to LNG release and fire would be insignificant and discountable

Oil spills at sea or off shore might adversely affect food resources in the immediate area including krill, copepods, and various schooling fish such as anchovies (NMFS, 2006b) could occur. However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4). And, as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated vessel traffic in 2018 would be less than effects based on past levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2 (under blue whales). Consequently, cumulative effects to humpback whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls),, the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to humpback whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect critical habitat; none has been designated.

#### 4.2.4.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (Blue Whale) apply to humpback whales.

#### 4.2.4.5 Determination of Effects

**Species Effects**

The Project **may affect** humpback whales because:

- Humpback whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** humpback whales because:

- Existing information indicates ship strikes to humpback whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to humpback whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on humpback whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected humpback whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to humpback whales if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for humpback whales.

### 4.2.5 Sei Whale

#### 4.2.5.1 Species Account and Critical Habitat

**Status**

Sei whales were listed as endangered under the Endangered Species Conservation Act on December 2, 1970 (FWS, 1970) and have been listed as endangered throughout its range under the ESA since its implementation in 1973. Sei whales off the U.S. West Coast are in the Eastern North Pacific stock. Sei whales are classified as depleted throughout their range under the MMPA.

**Threats**

Commercial whaling operations were the primary reason for the reduction in numbers of sei whales (Carretta et al., 2013b). An ongoing threat to sei whales is ship strikes although the current rate of ship strike deaths and serious injuries is zero (Carretta et al., 2013a). Another ongoing threat is offshore gill-net commercial fishing operations, although they accounted for no recorded deaths from 2000 to 2004 (Carretta et al., 2007) or from 2004 to 2008 (Carretta et al., 2013b). Anthropogenic noise in ocean environments has been suggested to be a concern for whales, especially for baleen whales that communicate using low-frequency sound (Carretta et al., 2013b).

Sei whale food sources may be damaged and they may gain new stressors with certain climate changing processes such as global warming similar to those discussed above for blue whales (Fogarty and Powell, 2002). Those impacts include: 1) changes in nutrient exchange and primary production with effects to all trophic levels in the ecosystem, 2) health effects due to metabolic demands from warmer oceans, 3) shifts of marine populations towards the poles or ocean depths, and 4) with changes in available nutrient levels there may be changes in the timing and intensity of phytoplankton blooms. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures, which led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

**Species Recovery**

A draft plan for recovery the sei whale (and fin whale) was issued in 1998 (NMFS, 1998a) and the plan was finalized in 2011 (NMFS, 2011c). The goal of the recovery plan is to promote recovery of the species in order to eventually downlist and then delist it. The recovery plan (NMFS, 2011c) lists the following tasks as those necessary to achieve the goal:

- Coordinate state, federal, and international actions to maintain international regulation of whaling for sei whales.
- Develop and apply methods to collect sei whale data.
- Support existing studies to investigate population discreteness and population structure of sei whales using genetic analysis.
- Continue to collect data on "unknown" threats to sei whales.
- Initiate new studies to determine population discreteness and population structure of sei whales.
- Estimate population size and monitor trends in abundance.

- Maximize efforts to acquire scientific information from dead, stranded, and entangled sei whales.
- Conduct risk analyses.
- Identify, characterize, protect, and monitor habitat important to sei whale populations in U.S. waters and elsewhere.
- Investigate human-caused threats, and, should they be determined to be medium or high, reduce frequency and severity
- Develop a post-delisting monitoring plan.

**Life History, Habitat Requirements, and Distribution**

The sei whale is a large baleen whale found in both the northern and southern hemispheres. Their diet includes copepods and other small prey types including fish. Calving occurs in midwinter, in low latitude portions of the species' range (OBIS-SEAMAP 2007). Sei whales are generally found alone or in pairs, although sometimes they may be found in groups of up to five. They generally dive between 5 and 20 minutes relatively close to the surface (Shirihai and Jarrett 2006).

Females reach reproductive age when 10 years old. Once mature, females give birth every 2 to 3 years to one calf. The gestation time is between 11 and 13 months, and calves are weaned between 6 and 9 months. It is expected that sei whales live up to 70 years (Shirihai and Jarrett 2006).

**Population Status**

The best abundance estimate of sei whales in California, Oregon, and Washington waters to 300 nautical miles offshore is 126 whales, with a minimum population estimate of 83 whales (Carretta et al., 2013c). There are no estimates for the growth rate of sei whale populations in the North Pacific although the population is expected to have grown since protection was initiation in 1976 (Carretta et al., 2013c).

The only documented occurrence of ship strike mortality of sei whales occurred in Washington in 2003 (Douglas et al., 2008). The average observed annual mortality during the period 2004 to 2008 due to ship strike is zero sei whales per year (Carretta et al., 2013c). The current calculated potential biological removal for sei whales from California to Washington is 0.17 whale per year. There were 0.2 death per year recorded from 2000 to 2004 which exceeded that amount (Carretta et al., 2007), but that rate has apparently not occurred since then.

**Critical Habitat**

Critical habitat for this species has not been designated.

#### 4.2.5.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to sei whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, the same as described above for blue whales (see figure 4.2-1).

## Species Presence

Sei whales are found a great distance from shore in temperate waters and do not appear to approach coastal areas. Nine confirmed sightings of sei whales were made in California, Oregon, and Washington waters during extensive ship and aerial surveys between 1991 and 2008 (Carretta et al., 2013). Two of the reported sightings were within the EEZ off the coast of Oregon, and so the sei whale may be present in the EEZ analysis area (Carretta et al., 2007).

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the mean population estimate divided by the area in the surveyed stratum, 819,470 $km^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of sei whales in the California stratum is 0.013 whale per 100 $km^2$ or 0.004 whale per 100 $nmi^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of sei whales in the Oregon-Washington stratum is 0.024 whale per 100 $km^2$ or 0.007 whale per 100 $nmi^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for sei whales in the California stratum in 2008 is 0.012 whale per 100 km or 0.006 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for sei whales in the Oregon-Washington stratum in 2008 is 0.035 whale per 100 km or 0.019 whale per 100 nmi of ship transect.

## Habitat

Sei whales tend to use temperate waters, and do not associate with specific coastal features (Carretta et al., 2007) and are uncommonly associated with waters of continental shelves (Horwood, 2009). Consequently, they are seldom observed within the EEZ. They are known for shying away from boats, and being one of the fastest swimming large whales, capable of speeds up to 26 knots (Laist et al., 2001). They feed in temperate waters on zooplankton (especially copepods and euphausiids), small schooling fish, and squid (Shirihai and Jarrett, 2006).

## Critical Habitat

Critical habitat for this species has not been designated.

### 4.2.5.3 Effects by the Proposed Action

#### Direct and Indirect Effects

Direct effects of the proposed action include injury and/or mortality due to ship strikes, effects from anthropogenic underwater noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect sei whales by impacting forage species. These effects are addressed below.

Ship Strikes by LNG Carriers

As discussed above for blue whales, there is an ongoing threat of ship strikes to sei whales. Ship strikes of sei whales averaged 0.2 deaths per year along the Pacific Coast between 2000 and 2004 (Carretta et al., 2007). Recent accounts (Laist et al., 2001; Jensen and Silber, 2003) found that fast-swimming sei whales are struck by ships less often than most other whales, with the exception of killer whales (Jensen and Silber, 2003). Currently, the average observed annual mortality during the period 2004 to 2008 due to ship strike is zero sei whales per year (Carretta et al., 2013c). With so few documented ship strikes, there is insufficient information to estimate how many sei whales might be struck by LNG carriers transiting to and from Coos Bay in 2018 and possible death or injury due to project-related LNG traffic in the West Coast EEZ analysis area.

Underwater Noise

Determining and minimizing any detrimental effects of anthropogenic underwater noise on sei whales is a principal objective for the species' recovery (NMFS, 2011b). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. When whales are exposed to low-level sounds from distant or stationary vessels, they appear to ignore the sounds. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). However, radiated ship noise of oncoming ships may not be immediately detected by whales near the surface due to bow null-effect acoustic shadow zones (Allen et al., 2012). Because of acoustic shadow zones, whales may not hear approaching ships to allow time for their avoidance response even though whale auditory ranges overlaps with peak intensities of ship noise. Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades.

The low frequencies generated by ships overlap frequencies of sounds generated by large baleen whales, including the sei whale (Würsig and Richardson, 2009). Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Anthropogenic noise and vessel disturbance may affect sei whales but there is little evidence available to describe or quantify the impacts of these threats on the species. While anthropogenic noise may threaten other cetaceans, little is known about whether, or how, vessel noise affects sei whales (NMFS, 2011c).

The risk of ship noise causing PTS or TTS (see NMFS' interim acoustic thresholds in table 4.2.1-2 under blue whales) for sei whales would be similar to that described for blue whales, above. Noise from a LNG tanker in a study by Hatch et al. (2008) produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 nmi$^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 nmi$^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 nmi$^2$.

Based on population growth between 2008 and 2018 of sei whales, the predicted density of sei whales is 0.006 whale per 100 nmi$^2$ in the California stratum in 2018 and is 0.010 whale per 100 nmi$^2$ in the Oregon-Washington EEZ stratum in 2018. Assuming an LNG tanker transit distance of 762 nmi within the California stratum, the number of sei whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.006 whale per 100 nmi$^2$) multiplied by the total area of noise effects (15.6 nmi$^2$), equal to 0.001 whale affected (an estimate between 0.000 and 0.001 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) .

The number of fin whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.006 whale per 100 nmi$^2$) multiplied by the total area of noise effects (7,176 nmi$^2$), equal to 0.403 whale affected (an estimate between 0.137 and 0.672 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3 under blue whales, above).

Similar calculations have been done for sei whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of sei whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.010 whale per 100 nmi$^2$) multiplied by the total area of noise effects (4.08 nmi$^2$), equal to <0.001 whale affected (an estimate between 0.000 and 0.001 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008). The number of sei whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.010 whale per 100 nmi$^2$) multiplied by the total area of noise effects 1,883 nmi$^2$), equal to 0.194 whale affected (an estimate between 0.066 and 0.032 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on sei whales are possible in the in West Coast EEZ analysis area but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 $\mu Pa^2$ (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause behavioral disruptions to fin whales.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of sei whales in the California EEZ stratum during 2018 would be 0.006 whale per 100 $nmi^2$ and 0.010 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire could cause second degree burns would extend to an area of 0.563 $nmi^2$. Considerably fewer than one sei whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to fin whales due to LNG release and fire would be insignificant and discountable

Oil spills at sea or off shore might harm sei whales, although effects of oil spills on sei whales have not been reported (NMFS, 2006a). Effects to food resources including krill, copepods, and various schooling fish such as anchovies (NMFS, 2006a) could occur. However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-3 under blue whales). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated vessel traffic in 2018 would be less than effects based on past of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2 (under blue whales). Consequently, cumulative effects to sei whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-3) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to sei whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect critical habitat; none has been designated.

#### 4.2.5.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in section 4.2.1.4 (Blue Whale) apply to sei whales.

#### 4.2.5.5 Determination of Effects

**Species Effects**

The Project **may affect** sei whales because:

- Sei whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** sei whales because:

- Existing information indicates ship strikes to sei whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to sei whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on sei whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected sei whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to sei whales if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for sei whales.

### 4.2.6 Sperm Whale

#### 4.2.6.1 Species Account and Critical Habitat

**Status**

Sperm whales were listed as endangered under the Endangered Species Conservation Act on December 2, 1970 (FWS 1970) and have been listed as endangered throughout their range under the ESA since its implementation in 1973. For the MMPA stock assessment reports, sperm whales within the Pacific United States EEZ are divided into three discrete, non-contiguous areas: 1) California, Oregon, and Washington waters; 2) waters around Hawaii; and 3) Alaskan waters. Sperm whales are classified as depleted throughout their range under the MMPA.

**Threats**

Commercial whaling operations were the primary reason for listing sperm whales as an endangered species (NOAA Fisheries, 2012b). The offshore drift gill-net fishery is the primary ongoing threat to sperm whales (Carretta et al. 2007). Another threat is ship strikes, although no ship strikes were reported for sperm whales along the Pacific Coast from 2000 to 2004 (Carretta et al. 2007).

Sperm whales are typically found farther offshore and are deep divers for food; they may be susceptible to increased anthropogenic noise (Carretta et al. 2007). Sperm whale food sources may be damaged and they may be stressed by certain climate changing processes such as global warming, similar to those discussed above for blue whales (Fogarty and Powell, 2002). Those impacts include 1) changes in nutrient exchange and primary production with effects to all trophic levels in the ecosystem, 2) health effects due to metabolic demands from warmer oceans, 3) shifts of marine populations towards the poles or ocean depths, and 4) with changes in available nutrient levels there may be changes in the timing and intensity of phytoplankton blooms. Changes in the California Current have reduced the zooplankton populations, primarily as a result of increased water temperatures which led to intensified stratification and a lowering of mixing and nutrient regeneration in the water column (Fogarty and Powell, 2002).

**Species Recovery**

A draft recovery plan was released in June 2006 (NMFS, 2006e) and a 5-year status review was initiated on January 22, 2007 (NMFS, 2007a). The recovery plan was finalized in 2010 (NMFS, 2010b). The goal of the recovery plan is to eventually downlist and then delist the species. To that end, the final recovery plan lists the following recovery measures:

- Coordinate state, federal, and international actions to implement recovery actions and maintain international regulation of whaling for sperm whales.
- Determine population discreteness and population structure of sperm whales.
- Develop and apply methods to estimate population size and monitor trends in abundance.
- Conduct risk analyses.
- Identify and protect habitat essential to the survival and recovery of sperm whale populations in U.S. waters and elsewhere.
- Investigate causes and reduce the frequency and severity of human-caused injury and mortality.
- Determine and minimize any detrimental effects of anthropogenic noise in the oceans.

- Maximize efforts to acquire scientific information from dead, stranded, and entangled or entrapped sperm whales.
- Develop post-delisting monitoring plan.

### Life History, Habitat Requirements, and Distribution

Sperm whales are the largest of the toothed whales and exhibit significant sexual dimorphism. They are a deep water species, and as such, their diet consists of large species that also occur in deep water – primarily squid, but also sharks, skates, and fishes. They are deep divers, with the average dive depth greater than 1,300 feet (NMFS, 2007a). Dives can last for longer than 2 hours. Cows, calves and juveniles can be found in groups of between 10 and 50 animals, and bachelor schools of young males can be found separately (Shirihai and Jarrett, 2006).

The peak breeding season for sperm whales occurs from March or April to May, with some breeding activity earlier and later (December to August). Gestation likely ranges from 15 months to more than a year and a half (NMFS, 2010b). Most sperm whales fully sexually mature in their twenties, although females begin ovulation between the ages of seven and thirteen. Females give birth every 4 to 6 years once sexually mature, with that time period increasing after they reach the age of 40. Sperm whales have a low reproductive rate of increase, with a maximum of no more than two percent per year. They are also unique in that the killing of larger and older sexually mature males has been a significant reason for the reduction of reproductive rates, meaning that both large and older males and females are needed to increase the rate of reproduction (NMFS, 2010).

Sperm whales have been documented to live in excess of 60 years of age. Known natural reasons for mortality include predation, competition, and disease. Calves are susceptible to both killer whales and sharks. Diseases that are believed to have an impact on sperm whales include myocardial infarction, gastric ulceration, and a type of cumulative bone necrosis that is believed to be caused by deep dives and resulting nitrogen bubbles during ascents (NMFS, 2010b).

### Population Status

The most recent abundance estimates are from 2005 and 2008 with 971 sperm whales in the California, Oregon and Washington stock derived ship surveys (Carretta et al., 2013b). The minimum population estimate is 751 sperm whales for this population. The most recent estimate from 2008 is the lowest to date, in sharp contrast to the highest abundance estimates obtained from 2001 and 2005 surveys but the different estimates indicate the species' variability in abundance rather than a significant population trend (Carretta et al., 2013b). Most populations were depleted by modern whaling, and commercial whaling ended in 1988 with a moratorium issued by the International Whaling Commission (NMFS, 2010b). However, Japan continues to take a small number of sperm whales each year (NMFS, 2010b). The only commercial fishery that is considered to likely incidentally take sperm whales is the offshore drift gill-net fishery. From 2000 to 2004, the California and Oregon thresher shark and swordfish drift gill-net fishery accounted for no deaths, but an unknown fishery was found to have caused one death (Carretta et al. 2007). A total of 18 sperm whales were stranded in Washington and Oregon from 1930 to 2002, with seven in Oregon and 11 in Washington (Norman et al., 2004).

### Critical Habitat

Critical habitat for this species has not been designated.

### 4.2.6.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to sperm whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, the same as described above for blue whales (see figure 4.2-1).

**Species Presence**

Sperm whales are widely distributed across the entire North Pacific and into the southern Bering Sea in summer, but the majority are thought to be south of latitude 40º N in winter (Carretta et al. 2007). They have been seen in every season except winter (December-February) in Washington and Oregon.

Line-transect ship surveys conducted off the coasts of California, Oregon, and Washington in summer and fall of 1991, 1993, 1996, 2001, 2005, and 2008 (Barlow and Forney, 2007; Forney, 2007; Barlow, 2010) have been used to estimate populations within the California and Oregon-Washington strata and to estimate populations for specific stocks. During each of those years (only California waters were surveyed in 1991 and 1993), line-transect locations were pre-determined to survey for pelagic cetaceans within approximately 300 nmi of the West Coast.

The mean density estimates for species in the California stratum are computed as the mean population estimate divided by the area in the surveyed stratum, 819,470 $km^2$ (Barlow, 2010) which is assumed to be the same in all of the years surveyed. The mean density of sperm whales in the California stratum is 0.146 whale per 100 $km^2$ or 0.043 whale per 100 $nmi^2$. Similarly, mean population estimates for species in the Oregon-Washington stratum are the geometric means of population estimates derived from surveys conducted in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010). The mean density of sperm whales in the Oregon-Washington stratum is 0.102 whale per 100 $km^2$ or 0.030 whale per 100 $nmi^2$.

The mean encounter rate (number observed per linear distance of transect) for each cetacean species is the geometric mean of the number of animals counted along line transects in the California stratum during each survey year (1991 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). If no individuals were sighted in one or more years, the arithmetic mean was used. The mean encounter rate for sperm whales in the California stratum in 2008 is 0.093 whale per 100 km or 0.050 whale per 100 nmi of ship transect. Likewise, the mean encounter rate (number observed per linear distance) for cetaceans observed in the Oregon-Washington stratum is the geometric mean of the number of animals counted along line transects during each survey year (1996 through 2008, see above) divided by total transect length in the stratum for each survey year (data from Barlow and Forney, 2007; Forney, 2007; Barlow, 2010). The mean encounter rate for sperm whales in the Oregon-Washington stratum in 2008 is 0.081 whale per 100 km or 0.044 whale per 100 nmi of ship transect.

**Habitat**

Sperm whales are considered to be almost cosmopolitan, preferring areas along the continental shelf where water is as deep as 1,000 to 3,000 meters (Shirihai and Jarrett, 2006). They are present off of Oregon in all times of the year except mid-winter, and can feed and use all sections of the water column. However, they prefer to feed on or near the bottom in deep water, show a preference for squid, and they feed throughout the year (NMFS, 2010b).

### Critical Habitat

Critical habitat for this species has not been designated

### 4.2.6.3 Effects by the Proposed Action

### Direct and Indirect Effects

Direct effects of the proposed action include injury and/or mortality due to ship strikes, effects due to anthropogenic underwater noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect sperm whales by impacting forage species. These effects are addressed below.

Ship Strikes by LNG Carriers

As discussed above for blue whales, there is an ongoing threat of ship strikes to sperm whales. From available accounts, a one sperm whale was struck by ships in 1967 (Jensen and Silber, 2003), one was killed by ship. However, one sperm whale was reported injured by an apparent ship strike (propeller injury) off the Oregon coast and another was reported as a possible ship-strike in Washington State between 1980 and 2006 (Douglas et al., 2008). During the period from 2007 to 2011, a sperm whale was struck and killed off the Oregon coast and another was injured offshore from Washington, both during 2007 (Caretta et al., 2013a) for an average rate of 0.40 strikes per year..

**Ship Traffic**. A considerable amount of shipping traffic currently occurs within the EEZ analysis area. Past, present, and reasonably foreseeable ship traffic within the EEZ analysis area was discussed for blue whales, above. Ship traffic to U.S. West Coast ports was increasing between 2002 and 2007 but deviated from the established trajectory in 2008, at the onset of the global financial crisis (see figure 4.2-2 under blue whales, above). The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service.

Applying the yearly percent change in Total Annual Vessel Calls at all West Coast ports based on the regression model in figure 4.2-2 to the total ship-miles along the West Coast beginning in 1999 (5,049,298 ship-miles in table 4.2.1-1, under blue whales), there would be an estimated 8,199,320 ship-miles along the West Coast, expected in 2018.

Similarly, the data from MARAD (2013) were used to estimate ship-miles along the California Coast and along the Oregon-Washington Coast in 2018 from the data in table 4.2.1-1 (under blue whales, above) from 1999 provided by Pacific States/British Columbia Oil Spill Task Force (2002).

- From 2002 to 2007, total vessel calls to California ports increased by a constant number of 251 vessel calls per year (regression model $y = 250.74x - 492{,}585$, $r^2 = 0.78$, $P=0.019$). There were 3,041,597 ship-miles in 1999 within California waters (see table 4.2.1-1); 4,717,894 ship-miles are expected in 2018.

- From 2002 to 2007, total vessel calls to Oregon-Washington ports increased by a constant number of 185 vessel calls per year (regression model $y = 184.6x - 364{,}401$, $r^2 = 0.56$, P=0.086). There were 2,007,701 ship-miles in 1999 within Oregon-Washington waters (see table 4.2.1-1); 3,533,752 ship-miles are expected in 2018.

The Project is designed to accommodate 90 LNG tankers a year. If all LNG tankers approach the Jordan Cove terminal by perpendicular transits through the EEZ, they will contribute 36,000 ship miles annually to vessel traffic in the Oregon-Washington stratum in 2018. If all LNG tankers approach the terminal by parallel transits along the California coast, they will contribute 137,160 ship-miles annually to vessel traffic within the California stratum in 2018. Observed and predicted vessel traffic within both strata in 1999, 2007, 2008, and 2018 are provided in table 4.2.6-1, including the addition of project-related LNG tanker traffic in 2018. During the life of the project, there may be years of mixed LNG tanker traffic, some transiting the EEZ perpendicular and other traffic paralleling the coast but such variability cannot be estimated.

**Table 4.2.6-1**
**Estimates of Vessel Traffic, Sperm Whale Encounter Rates, Relative Ship-Strike Risk, and Estimates of Sperm Whales Struck per Year (with Percent Change from the Previous Estimate) in the California and Oregon-Washington Strata of the Project Activity Area**

| | California Stratum | | | | Oregon-Washington Stratum | | | |
|---|---|---|---|---|---|---|---|---|
| Year and Event | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] | Ship-Miles (nmi) | Whale Encounter Rate (N/100 nmi) | Relative Ship-Stike Risk | Estimate of Whales Struck per Year [5] |
| 1999 [1] Baseline Annual Ship Transits | 3,041,597 | N/A | N/A | N/A | 2,007,701 | N/A | N/A | N/A |
| 2007 [2] Predicted Trend with 2002-2007 data | 3,747,406 (+23.2%) | N/A | N/A | N/A | 2,650,249 (+32.0%) | N/A | N/A | N/A |
| 2008 [3] Most Recent Cetacean Survey | 3,316,554 (-11.5%) | 0.050 | 1,660 | 0 | 2,495,278 (-5.8%) | 0.044 | 1,019 | 0.40 |
| 2018 [2] Ambient Predicted Ship Traffic | 4,717,894 (+42.3%) | 0.075 (+49.1%) | 3,524 (+112.2%) | 0 (N/A) | 3,533,752 (+41.6%) | 0.065 (+49.1%) | 2,314 (+111.3%) | 0.845 (+111.3%) |
| 2018 [4] Ambient Traffic with LNG Tanker Traffic | 4,855,054 (+2.9%) | 0.075 (0%) | 3,626 (+2.9%) | 0 (N.A) | 3,569,752 (+1.0%) | 0.065 (0%) | 2,338 (+1.0%) | 0.854 +1.0%) |

[1] Estimated in table 4.2.1-1 with data from Pacific States/British Columbia Oil Spill Task Force, 2002.
[2] Estimated from linear regression of total vessel calls to California ports and Oregon-Washington port from 2002 to 2007. Source: MARAD, 2013
[3] Estimated total vessel calls to California ports and Oregon-Washington ports in 2008 (see Figure 4.2.1-1, above). Source: MARAD, 2013.
[4] Assume 90 LNG tankers with perpendicular transits through West Coast EEZ in Oregon-Washington stratum (36,000 ship-miles per year) or parallel transits through EEZ in California stratum (137,160 ship-miles per year).
[5] Estimates of Whales Struck derived from data reported by Carretta et al., 2013a for ship-strikes in the California and Oregon-Washington EEZ strata.

**Ship-Strike Risk.** An index of relative ship-strike risk within an explicitly defined gridded study area was described by Williams and O'Hara (2009). The approach was adapted to the coarse-scale analysis area by using mean whale encounter rates, described above for sperm whales, and shipping intensity as indicated by the total annual ship-miles derived from vessel transits along the West Coast (see table 4.2.6-1) in the California and Oregon-Washington strata.

The encounter rate for sperm whales in the California EEZ stratum is significantly ($P< 0.01$) related to the species' density, based on data collected during surveys conducted in in 1991, 1993, 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (Barlow, 2010). Likewise, the encounter rate for sperm whales in the Oregon-Washington EEZ stratum is significantly ($P< 0.05$) related to density based on data collected in 1996, 2001, 2005 (data from Barlow and Forney, 2007; Forney, 2007) and 2008 (data from Barlow, 2010), shown in figure 4.2-7. The relationships support predictions, below, that future encounter rates (eg, in 2018) would be expected to increase as the sperm whale population increases.

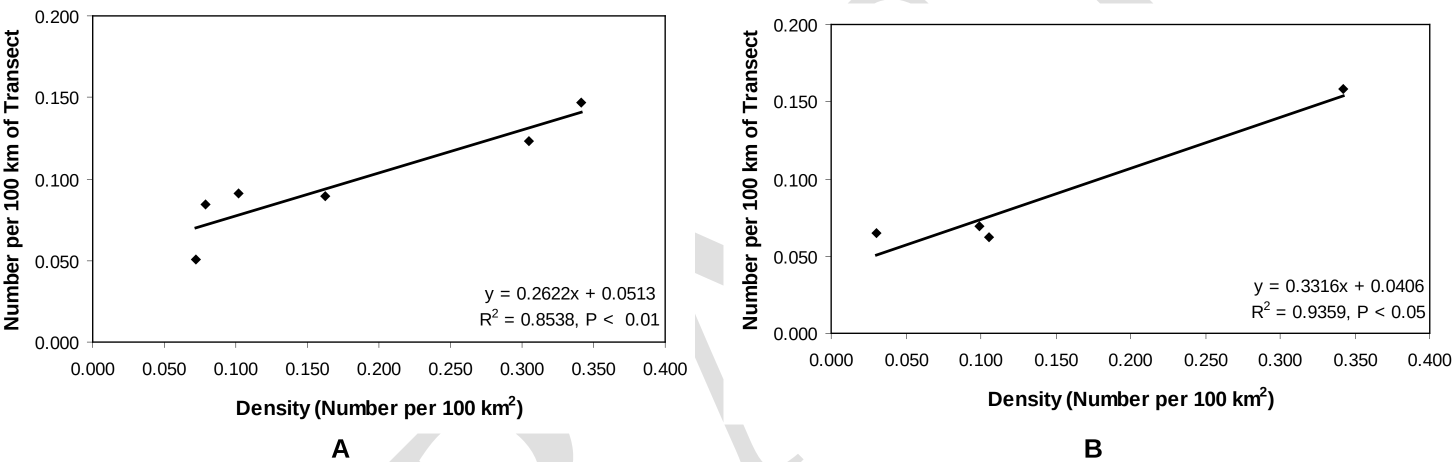



**Figure 4.2-7**
**Relationships of Sperm Whale Encounter Rate (Number per 100 km of line-transect) to Density (Number per 100 km$^2$) From Shipboard Surveys Conducted off the Coasts of California (A) and Oregon-Washington (B).**

Relative ship-strike risks during 2008 and 2018 (see table 4.2.6-1) are the products of cetacean species' encounter rates and total ship miles expected in each stratum during the two years. An estimate of the encounter rate in 2018 (beginning of the project operation) is directly proportional to fin whale population and density in that year. Assuming exponential population growth, the population size ($N_t$) at time = t is $N_t = N_0 e^{r t}$ where $N_0$ = the initial population size at t = 0 and r is assumed to be $R_{MAX}$. This approach was used with the default value for $R_{MAX}$ = 0.04 to estimate sperm whale encounter rates (as indices of population) in 2018 given the encounter rates of sperm whales within the California and Oregon-Washington strata in 2008. In 2008, the sperm whale encounter rate in the California stratum was 0.050 whale per 100 nmi and 0.044 whale per 100 nmi in the Oregon-Washington stratum. Based on assumed population growth between 2008 and 2018, the sperm whale encounter rate in California in 2018 is estimated at 0.075 whale per 100 nmi and 0.065 whale per 100 nmi in the Oregon-Washington stratum, an increase of 49 percent from the 2008 encounter rates (see table 4.2.6-1).

In 2008, the relative ship-strike risk in the Califonia stratum would be 0.050 whale per 100 nmi multiplied by 3,316,554 ship-miles = 1,660. In 2018, the assumed growth of the sperm whale population increases the encounter rate proportionately to 0.075 whale per 100 nmi. Between 2008 and 2018 ship traffic is also be expected to increase to 4,717,894 ship-miles. The relative ship-strike risk in 2018 would be 3,524 which is 112.2 percent of the 2008 encounter rate (table 4.2.6-1). If all 90 LNG tanker transits occur in the California stratum, the total expeced vessel traffic would be 4,855,054 ship miles in 2018 and the ship-strike risk would increase to 3,626, an estimated increase of 2.9 percent. Similar calculations woud apply to the sperm whale population growth, encounter rate, relative ship-strike risk in the Oregon-Washington stratum, provided in table 4.2.6-1.

**Estimated Ship-Strikes to Sperm Whales**. Data provided by Carretta et al. (2013a) indicated that no sperm fin whales were struck in the California EEZ between 2007 and 2011. However, 2 sperm whales were struck in the Oregon-Washington EEZ during that 5-year period (0.40 whale per year). Using recent ship-strike data from Carretta et al. (2013a), the increased ship-strike risk in 2018 is assumed to increase the annual rate of sperm whales struck proportionately in the Oregon-Washington stratum to 0.845 per year but no estimates can be made for increase ship strikes in the California stratum (see table 4.2.6-1). The additional project-related LNG tanker traffic would increase the annual rate in Oregon-Washington waters to 0.854 whales per year, an increase of 0.009 ship-strike per year (one injury or death in 111 years). Ship-strikes to sperm whales by project-related LNG tankers are most likely in the Oregon-Washington EEZ stratum but death or injury of sperm whales is insignificant and discountable.

Underwater Noise

Determining and minimizing any detrimental effects of anthropogenic underwater noise on sperm whales is a principal objective for the species' recovery (NMFS, 2010b). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. Reduced calling or cessation of vocalizations by sperm whales have been documented in response to pingers and military sonar signals, in response to low-frequency ATOC-like sounds, and in response to seismic surveys (Weilgart, 2007). However, sperm whales and other cetaceans have been documented remaining in or returning to high noise environments, probably motivated by forage and/or availability of mates (Weilgart, 2007). In those cases, individual's hearing could be damaged. For example, two sperm whales killed by collision with a ferry in waters off the Canary Islands never responded behaviorally to low frequency sounds generated to test repelling sperm whales from ferry routes. Histological analyses of the inner ears of both animals showed nerve degeneration and fibrous growth in response to low frequency inner ear damage, consistent with prolonged exposure to noise from heavy maritime traffic (André and Degollada, 2003).

When whales are exposed to low-level sounds from distant or stationary vessels, they appear to ignore the sounds. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). However, radiated ship noise of oncoming ships may not be immediately detected by whales near the surface due to bow null-effect acoustic shadow zones (Allen et al., 2012). Because of acoustic shadow zones, whales may not hear approaching ships to allow time for their avoidance response even though whale auditory ranges overlaps with peak intensities of ship noise.

Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades. The low frequencies generated by ships overlap frequencies of sounds generated by large baleen whales, including the spermn whale (Würsig and Richardson, 2009). Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Anthropogenic noise and vessel disturbance may affect sperm whales but there is little evidence available to describe or quantify the impacts of these threats on the species. While anthropogenic noise may threaten other cetaceans, little is known about whether, or how, vessel noise affects sperm whales (NMFS, 2010).

The risk of ship noise causing PTS or TTS (see NMFS' interim acoustic thresholds in table 4.2.1-3 under blue whales) for sperm whales would be similar to that described for blue whales, above. Noise from a LNG tanker in study conducted by Hatch et al. (2008) produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 $nmi^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 $nmi^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 $nmi^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 $nmi^2$.

Based on population growth between 2008 and 2018 described above for sperm whale encounter rates, the predicted density of sperm whales is 0.064 whale per 100 $nmi^2$ in the California stratum in 2018 and is 0.044 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum in 2018. Assuming a LNG tanker transit distance of 762 nmi within the California stratum, the number of sperm whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.064 whale per 100 $nmi^2$) multiplied by the total area of noise effects (15.6 $nmi^2$), equal to 0.010 whale affected (an estimate between 0.004 and0.016 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008).

The number of sperm whales within range of noise levels of 120 dB (radius of 16,185 m or 4.72 nmi) produced by a single LNG tanker transit through the stratum would be equal to the density (0.064 whale per 100 $nmi^2$) multiplied by the total area of noise effects (7,176 $nmi^2$), equal to 4.6 whales affected (an estimate between 1.5 and 7.6 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3 under blue whales, above).

Similar calculations have been done for sperm whales in the Oregon-Washington stratum. Assuming an LNG tanker transit distance of 200 nmi across the Oregon-Washing stratum, the number of fin whales within range of noise levels of 160 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.044 whale per 100 $nmi^2$) multiplied by the total area of noise effects (4.08 $nmi^2$), equal to 0.002 whale affected (an estimate between 0.001 and 0.003 whale based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008). The number of sperm whales within range of noise levels of 120 dB produced by a single LNG tanker transit through the stratum would be equal to the density (0.044 whale per 100 $nmi^2$) multiplied by the total area of noise effects 1,883 $nmi^2$), equal to 0.84 whale affected (an estimate between 0.28 and 1.39 whales based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 120 dB, from Hatch et al., 2008) by noise levels that could cause behavioral disruptions (see table 4.2.1-3).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on sperm whales are possible in the in California EEZ stratum but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Two tractor tugs would guide the LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Unlike LNG tankers, project-related tug traffic would only occur in the Oregon-Washington stratum. LNG ship noise and noise from tugs would exceed the ambient noise levels within the West Coast EEZ activity area assuming those range from 64 dB to 72 dB re 1 $\mu Pa^2$ (at 62 Hz, similar to the ocean noise 7 nmi west of San Diego reported by McDonald et al., 2008) but would not cause behavioral disruptions to fin whales.

<u>Releases and Fire at Sea</u>

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of sperm whales in the California EEZ stratum during 2018 would be 0.064 whale per 100 $nmi^2$ and 0.044 whale per 100 $nmi^2$ in the Oregon-Washington EEZ stratum, the same densities that were used in the analysis of effects due to ship noise, above. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire coul cause second degree burns would extend to an area of 0.563 $nmi^2$. Considerably fewer than one sperm whale would be expected to be present within any of those areas in either of the two EEZ strata during 2018 and injuries to fin whales due to LNG release and fire would be insignificant and discountable

Oil spills at sea or off shore might harm sperm whales, although effects of oil spills on fin whales have not been reported (NMFS, 2006d). Effects to food resources including krill, copepods, and various schooling fish such as anchovies (NMFS, 2006d) could occur. However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-3 under blue whales). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2 (under blue whales). Consequently, cumulative effects to sperm whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-3, under blue whales) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to sperm whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect critical habitat; none has been designated.

#### 4.2.6.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1 (Blue Whale) apply to sperm whales.

#### 4.2.6.5 Determination of Effects

**Species Effects**

The Project **may affect** sperm whales because:

- Sperm whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** sperm whales because:

- Existing information indicates ship strikes to sperm whales within the EEZ analysis area are infrequent.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to sperm whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.

- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on sperm whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected sperm whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to sperm whales if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for sperm whales.

### 4.2.7 North Pacific Right Whale

#### 4.2.7.1 Species Account and Critical Habitat

**Status**

North Pacific right whales were listed as endangered under the Endangered Species Conservation Act (35 FR 18319, Dec. 2, 1970) (FWS 1970) and remained endangered throughout its range on the list of endangered species when the Endangered Species Act was passed in 1973 (NMFS 2013a). The North Pacific right whale is also listed as depleted under the MMPA. The National Marine Fisheries Service established the North Pacific right whale and North Atlantic right whale as distinct species in 2008. The North Pacific population has then been further divided into a western population and an eastern population, with the eastern population located in the U.S. Exclusive Economic Zone (NMFS, 2013a).

**Threats**

Little is known about the North Pacific right whale, including threats to the species. Likely threats include ship strikes and entanglements. However, the magnitude of these threats cannot be assessed due to the rarity and scattered distribution (NOAA Fisheries, 2013d). North Pacific right whales are also susceptible to anthropogenic noise generated from ship noise, oil and gas activities and military sonar and explosives (NMFS, 2013a). Impacts from direct hunts as well as loss of prey due to climate change are also largely unknown (NMFS, 2013a).

**Species Recovery**

A recovery plan for the North Pacific right whale was published in June 2013 (NMFS 2013a). Ultimately, the recovery plan was designed to outline methods and strategies to gain more understanding of the right whale through an increase of data collection. First and foremost, information regarding population and potential threats must be obtained. Commercial whaling is currently the greatest known threat to right whales, and this was outlawed in 1949. However, despite this protection it is thought that illegal whaling in the 1960's has greatly reduced the potential recovery of this species. The goals of the recovery plan are to first downlist the right whale from endangered to threatened and then eventually de-list the species all together. These goals are attained through two objectives:

1.) Achieve sufficient and viable populations throughout the ocean basin;
2.) Ensure significant threats are addressed

The recovery plan describes the criterion for determining when the objectives are met, which includes descriptions of factors that may interfere with population growth. The outline for Recovery Action includes:

- Coordinate state, federal, and international actions to maintain international regulation of whaling for North Pacific right whales
- Determine right whale occurrence, distribution, and range
- Identify, characterize, protect, and monitor important to North Pacific right whale populations
- Estimate population size and monitor trends in abundance
- Investigate human-caused threats, and should they be determined to be medium or high, reduce frequency and severity.

The recovery plan includes an assessment that indicates which threats have a known impact on the population growth, but the impacts are low. However, there are several potential threats that require further investigation (NMFS, 2013a).

**Life History, Habitat Requirements, and Distribution**

North Pacific right whales are large, black toothless baleen whales with a stocky body. Not only do these whales lack teeth, but they also lack a dorsal fin. Further distinguishing characteristics include a broad, deeply notched tail and callosities on the head. The few data gathered indicates that right whales generally live for about 50 years with females having their first calf at 9-10 years. Right whales feed on zooplankton; however, their feeding method differs than that of most baleen whales. This species moves through the water open-mouthed and removes prey from patches of zooplankton – a method known as skimming (NMFS, 2013a).

The International Whaling Commission has identified four different habitat categories for the right whale based upon the different purposes they serve. These categories are feeding, calving, nursery, and breeding. Breeding habitats are not known, however, right whales are primarily found in shallow coastal waters. Calving takes place in the winter and during this time right whales can often be found in lower latitudes, whereas in spring and summer they are found in higher latitudes (NMFS, 2013b).

Historic populations of North Pacific right whales occupied the Gulf of Alaska, eastern Aleutian Islands, south central Bering Sea, Sea of Okhotsk, and Sea of Japan. Right whales have been regularly spotted in Bristol Bay, south Bering Sea since 1996 and as far south as Hawaii in the central North Pacific and California in the eastern North Pacific. Sightings of this species are rare due to commercial whaling through the 1960s (NMFS, 2013b).

**Population Status**

The rarity of sightings and few individuals see in any one year indicate the eastern North Pacific population is very small. The most individuals detected in a single year were 17 whales from multiple ship surveys in 2004. An estimate of 31 individuals was made for the population using mark-recapture data from the Bering Sea and Aleutian Islands (NMFS, 2012a). A minimum population estimate of 25.7 was made for the North Pacific right whale in the year 2008 (Allen and Angliss 2011). However, there are no current and reliable population estimates for this species (NMFS, 2013a). There are no data on population trends and calf sightings are extremely rare. Historically this stock exceeded 11,000 whales.

**Critical Habitat**

Two areas have been designated as critical habitat for the North Pacific right whale. One area is within the Gulf of Alaska and the other area is within the Bering Sea (NMFS, 2013a).

### 4.2.7.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to North Pacific right whales is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, the same as described above for blue whales (see figure 4.2-1).

**Species Presence**

There are historical records of right whales in southern California but those were vagrant individuals; since 1950, there have been at least three sightings from Washington, 12 from California, and two from Baja California, Mexico (NMFS, 2012a). No abundance or density estimates are available for California, Oregon, or Washington (Forney, 2007). Right whales have been sighted off the California coast and coastal Baja California during winter (January to early April) and spring (April to June)

**Habitat**

The global distribution of North Pacific right whales includes the U.S. West Coast extending south along the Baja California Pacific Coast (NOAA Fisheries, 2013d). Right whales have been sighted off the California coast and coastal Baja California during winter (January to early April) and spring (April to June) and may indicate a seasonal pattern of migration to southwestern coast during winter (Gendron et al., 1999). Based on habitat preferences during calving in the Atlantic Ocean, the Southern Califonia Coast and Baja Penninsula were judged to provide suitable calving habitat for North Pacific right whales (Good and Johnston, 2009) but no evidence of calving is present in historical records (Gendron et al., 1999).

**Critical Habitat**

Two areas have been designated as critical habitat for the North Pacific right whale, one within the Gulf of Alaska, the other within the Bering Sea (NMFS, 2013a).

### 4.2.7.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, effects due to ship noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect North Pacific right whale by impacting forage species. These effects are addressed below.

<u>Ship Strikes by LNG Carriers</u>

As discussed above for blue whales, there is an ongoing threat of ship strikes to North Pacific right whales but no data (NMFS, 2013a) exists to estimate how many right whales might be struck by LNG carriers transiting to and from Coos Bay in 2018, the year when the proposed project is expected to be operational.

Underwater Noise

Determining and minimizing any detrimental effects of anthropogenic underwater noise on right whales is a principal objective for the species' recovery (NMFS, 2013a). As described for blue whales, above, all vessels produce noise; propeller cavitation produces most of the broadband noise with dominant tones derived from the propeller blade rate. In general, rorquals including blue, fin and minke whales move away, abruptly change direction, or dive to avoid close approach by vessels. Baleen whales will interrupt normal behavior and swim away from strong or rapidly changing vessel noise, especially if a vessel is headed directly toward the whale (Richardson, 1995). Existing data indicates that right whale response to noise disturbance and vessel activities depends on their behavior at the time; feeding or courting right whales may be relatively unresponsive to loud sounds and slow to react to approaching vessels (NMFS, 2013a).

Ambient noise in the Northeast Pacific Ocean has increased in nearshore and deep ocean environments over the past several decades. The low frequencies generated by ships overlap frequencies of sounds generated by large baleen whales, including the right whale whale (Würsig and Richardson, 2009). Noise from ships and boats may interfere and mask cetacean communication, finding prey, avoiding predators, and possibly navigation (Würsig and Richardson, 2009). Anthropogenic noise and vessel disturbance may affect right whales but there is little evidence available to describe or quantify the impacts of these threats on the species.

The risk of ship noise causing PTS or TTS (see NMFS' interim acoustic thresholds in table 4.2.1-2) for right whales would be similar to that described for blue whales, above. Noise from a LNG tanker in a study by Hatch et al. (2008) produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Using those attenuation distances, one LNG tanker transit across the length of the California EEZ stratum for 762 nmi would produce sound levels of ≥160 dB within an area 15.6 ± 4.9 $nmi^2$ and would produce sound levels ≥120 dB but <160 dB within an area 7,175.9 ± 2,376.3 $nmi^2$. Likewise, one LNG tanker transit across the width of the Oregon-Washington EEZ stratum for 200 nmi would produce sound levels of ≥160 dB within an area 4.1 ± 2.6 $nmi^2$ and would produce sound levels ≥120 dB but <160 dB within an area 1,883.4 ± 1,247.4 $nmi^2$.

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). For example, a 54,000 Gross Ton (GT) container ship generated the highest acoustic source level of 188 dB re: 1 µPa @ 1 meter while a 26,000 GT chemical tanker had the lowest at 177 dB re: 1 µPa @ 1 meter (McKenna et al., 2012). Noise levels from the vessels examined in that study are assumed to be typical of ship noise in the California and Oregon-Washington EEZ strata and would produce radiated noise levels through the two strata that would exceed the threshold for Level B single non-pulse noise of 120 $dB_{rms}$ (see table 4.2.1-3, above). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on North Pacific right whales are possible in the in California

EEZ stratum but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

The extremely low densities of right whales off the combined Oregon/Washington coast (too few for density estimation), right whales in the EEZ analysis area are not expected to be exposed to ship noise that would cause PTS or TTS (see table 4.2.1-2) although right whales,if present, would likely detect LNG carriers transiting the EEZ.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marine mammal surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for marine mammals. Because the estimated densities of marine mammals are generally low within the California and Oregon-Washington strata of EEZ, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing cetaceans within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of North Pacific right whales in the California and Oregon-Washington EEZ strata during 2018 are expected to be so low that the chance of a right whale surfacing in an area of pooled LNG or close enough to a fire to be injured is insignificant and discountable.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6

vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whales). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2. Consequently, cumulative effects to right whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to North Pacific right whales may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

The proposed action would not affect critical habitat; none has been designated within the EEZ analysis area.

#### 4.2.7.4 Conservation Measures

The same Ship-Strike Reduction Plan to minimize potential ship strikes to cetaceans by LNG carriers and LNG Management Plan to minimize risk of spills and releases at sea that were described in section 4.2.1 (Blue Whale) apply to right whales.

#### 4.2.7.5 Determination of Effects

**Species Effects**

The Project **may affect** North Pacific right whales because:

- Right whales may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** right whales because:

- There is no existing information to indicate that ship strikes to right whales occur within the EEZ analysis area.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase in ship strikes to right whales over known frequencies of incidents.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on right whales could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected right whale presence (based on estimated densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to right whales if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated within the EEZ analysis area.

### 4.2.8 Gray Wolf

#### 4.2.8.1 Species Account and Critical Habitat

**Status**

The gray wolf was listed as endangered in 1974 (FWS, 1974). FWS delisted the gray wolf within the Northern Rocky Mountain (NRM) DPS on May 5, 2011, including wolves in the eastern one-third of Oregon (FWS, 2011b). However, some gray wolves in the Pacific Northwest, including western Washington, western Oregon, and northern California, are not included in the NRM DPS and are still listed as endangered. New information on gray wolf taxonomy, cited by FWS (2013b), indicates that the gray wolf subspecies in the contiguous United States does not warrant listing under the ESA and FWS (2013) published a proposed rule to remove the gray wolf from the list of endangered and threatened wildlife.

**Threats**

Wolves in the Pacific Northwest (Oregon and Washington) were pursued and killed by humans through the 1940s and were primarily restricted to remote mountanouse areas, primarily in National Forests of the Cascades, before they were completely extirpated from the region (FWS, 2012b).

**Recovery**

FWS released a recovery plan for gray wolves in the NRM DPS in 1987. The plan focused on recovery in Montana, Wyoming, and Idaho. Although eastern Oregon and eastern Washington coincided with the historical distribution of wolves in the NRM DPS, no recovery areas were designated for either state. However, recovery goals of the NRM DPS of equitably distributed wolf population containing at least 300 wolves and 30 breeding pairs in 3 recovery areas within Montana, Idaho, and Wyoming for at least 3 consecutive years were reached in 2002 (FWS et al., 2013). By 2012, the entire NRM DPS was delisted and wolves were managed under State authority in Montana, Idaho, Wyoming eastern one-third of Washington and Oregon, and a small part of north central Utah (FWS et al., 2013).

No recovery plan has been developed for ESA-listed gray wolves in western Oregon. Wolves are classified as endangered under the Oregon State Endangered Species Acts (ORS 496.171 to 496.192 and 498.026). ODFW (2010) has developed a Wolf Conservation and Management Plan (OWP) to achieve recovery of the species and manage wolves in the state once they became de-listed from the ESA.

The OWP established recovery goals to protect wolves from overutilization for commercial, recreational, scientific, and educational purposes. The plan would serve as a deterrent to illegal killing of wolves by the public in the absence of Federal protections. With the de-listing of the NRM DPS in 2011, the OWP applies to wolves in the eastern one-third of the state. The boundary between east and west wolf management zones is defined by U.S. Highway 97 from the Columbia River to the junction of U.S. Highway 20, southeast on U.S. Highway 20 to the junction with U.S. Highway 395, and south on U.S. Highway 395 to the California border (ODFW, 2010). Wolves west of that boundary are still under federal protection.

**Life History, Habitat Requirements, and Distribution.**

Gray wolves are predators of large ungulates and occasionally of other, smaller prey. Wolves are highly social and their formation of packs, centered on male-female pair bonding, is essential to successful reproduction, survival of offspring, and predation (FWS, 1987). Most packs produce one litter per year ranging from one to nine pups. Wolf pairs (packs) establish home ranges/territories, centered on the den location, and are defended against other wolves (ODFW, 2013a). Habitats supporting wolves historically varied considerably, but extant populations in the NRM DPS and British Columbia utilize forest habitats adjacent to open habitats (meadows, prairies, tundra) but prey availability and minimal human presence and/or harassment are important components of suitable habitat (WDFW, 2009).

Because of the proximity of northeastern Oregon to Idaho packs, dispersing wolves initially occupied areas in northeastern Oregon. Wolf breeding pairs in these areas could be considered more secure and stable because of their proximity and connectivity to the wolves in Idaho. Wolf movement and dispersal between the two populations would allow gene flow between the populations. Oregon's close proximity to the Idaho and Greater Yellowstone populations that number more than 840 wolves provides certainty that dispersing wolves will continue to enter Oregon at an unknown rate (ODFW, 2010).

**Population Status**

Oregon's wolf population increased in both distribution and abundance in 2013. In December, the minimum wolf population was 64 wolves in eight packs. This represents a 33 percent increase from the previous year in total wolves, and two new pacts. 2013 also marks the second consecutive year that the conservation population objective number was reached, as defined in the OWP which sets a population objective of four breeding pairs for three consecutive years in eastern Oregon before delisting from the state's endangered species act can be considered (ODFW, 2014a). A breeding pair of wolves is defined as an adult male and an adult female with at least two pups surviving to the end of December.

The Imnaha Pack was first documented in 2009 and is one of Oregon's oldest contemporary packs (ODFW, 2014b). The first wolves of the pack migrated from Idaho. GPS radio collaring shows a use area of approximately 740 square miles in the Imnaha River drainage (ODFW, 2014a). During winter and spring, the Imnaha pack tends to occupy lower-elevation areas consisting of a mix of private and public lands. In summer and fall, the wolves spend most of their time on public lands at higher elevations (CDFW, 2014).

The minimum population for the pack in 2009 was 10, 15 in 2010, 5 in 2011, 8 in 2012, and 6 in 2013 (ODFW, 2014b). Four radio-collared wolves (including OR-7) have dispersed from the pack since December 2010. The locations and fates of five uncollared pack members are currently unknown. It is likely that some or all of these wolves may have dispersed from the pack. The dispersal of younger individuals from a pack is common. Dispersing wolves generally attempt to join other packs, create new territories within occupied habitat, or form their own pack in unoccupied habitat. In addition to OR-7, known dispersers from the Imnaha pack include OR-5, OR-9 and OR-3 (CDFW, 2014).

The pack produced seven pups in 2013. However, none were documented in the last few months of the year despite multiple observations of the pack. Therefore the pack was not counted as a breeding pair (ODFW, 2014a). The pack has had three breeding-pair years in the past (2009, 2010, and 2012) (ODFW, 2014b). Two GPS radio-collars remain in the pack, the breeding male and a sub-adult female. During 2013, 32 percent of the pack's location data points occurred on private land, an increase from 15 percent in 2012 and 29 percent in 2011 (ODFW, 2014a).

### Critical Habitat

Critical habitat for the gray wolf has not been designated in Oregon.

## 4.2.8.2 Environmental Baseline

### Analysis Area

The action area includes all areas that would be affected directly or indirectly by the proposed action and not just the immediate area involved in the action. Because the proposed action potentially can affect such a variety of species inhabiting diverse habitats within marine, estuarine, riverine, and various terrestrial locations, there are multiple components of the action area that have been defined as species' analysis areas, the areas where individual or groups of listed species are affected by the proposed action. The gray wolf analysis area is specific to a solitary gray wolf, OR-7, that has an area of known activity in Jackson, Klamath, and Douglas counties. The analysis area for OR-7 extends as far as project-related noise attenuates to ambient noise, assumed to be 40 dB on both sides of the construction right-of-way distance of

### Species Presence

A 4-year old male gray wolf (known as OR-7) currently occupies portions of southwestern Oregon and northwestern California. The wolf was born in northeastern Oregon in spring 2009, a member of the Imnaha pack that inhabits the Imnaha River drainage in Wallowa County, Oregon (CDFW, 2013a). OR-7 dispersed from the Imnaha pack in September 2011 and was located (via radio telemetry) within Baker, Grant, Harney, Deschutes, Lake, Klamath, and Douglas counties during its migration. OR-7 traveled more than 373 miles in a straight line distance from where he was born to northern California (FWS, 2013b). The wolf has been living in the southern Cascades in Jackson, Klamath, and Douglas counties, Oregon (ODFW, 2013b) and in Siskiyou, Modoc, Shasta, Lassen, Tehama, Butte, and Plumas counties, California (CDFW, 2013b).

ODFW (2013b) has defined an Area of Known Wolf Activity for OR-7 which extends north from the Oregon-California border for almost 95 miles into Douglas County, Oregon. At present, OR-7 is solitary (ODFW, 2013b).

**Habitat**

Black-tailed deer and Rooseveldt elk occur within the Area of Known Wolf Activity for OR-7. Those big game species are likely to provide a prey base for OR-7, especially during winter when animals are concentrated and old, sick individuals are more easily preyed on and/or carrion is more readily available. Often, big game will remain on or near winter ranges during parturition which also would provide OR-7 with accessible prey (neo-nates). The Known Wolf Activity Area coincides with multiple big game winter ranges:

- Elk and deer winter range in the Keno Wildlife Management Area.
- Very Sensitive Wildlife Areas (big game winter ranges) in the Rogue Wildlife Management Area.
- Very Sensitive Wildlife Areas (big game winter ranges) and Sensitive Big Game Ranges in the Dixon Wildlife Management Area.
- Sensitive Big Game Ranges in the Indigo Wildlife Management Area.

The PCGP pipeline right-of-way crosses the OR-7 Known Wolf Activity Area for 33.07 miles, from MP 147.66 to MP 180.73. The pipeline will cross Very Sensitive Wildlife Areas in the Rogue Wildlife Management Area for 8.11 miles from MP 147.66 to MP 155.77.

Based on ODFW population index data, black-tailed deer in the Rogue Wildlife Management Area Unit have been significantly increasing ($P<0.01$) between 1998 and 2012. In western Oregon, black-tailed deer are found in heavy brush areas at the edges of forests and chaparral thickets, but not in dense forests. Black-tailed deer prefer early successional stages created by clear-cuts or burns, providing grasses, forbs, and shrubs (ODFW, 2006b; Csuti et al. 2001). Most black-tailed deer that summer in the high Cascades winter at lower elevations on the west slope, although some may winter east of the Cascade crest (ODFW, 2006b).

**Critical Habitat**

Critical habitat for the gray wolf has not been designated in Oregon.

#### 4.2.8.3 Effects by the Proposed Action

The portion of the PCGP Project that coincides with wolf OR-7 Known Activity Area is construction Spread 4. In some areas, timber clearing would only be conducted between October and March if within 0.25 mile of northern spotted owl nests, otherwise timber would be cleared from October in one year through October the following year. Construction along Spread 4 would extend from April one year through September the following year. Construction of the PCGP Project will produce noise, will cause locally concentrated human activities, and will remove forested habitat that might be used by some species that are preyed on by OR-7.

Specific impacts to the gray wolf from noise generated from construction of a pipeline have not been conducted; however, it is expected that construction noise in remote areas that are relatively free from noise would have a greater potential to disturb wildlife. Ambient sound levels in much of the PCGP Project area probably would be similar to the Washington Fish and Wildlife Office's determination (FWS, 2003e) of 40 dB in the Olympic National Forest. Considering ambient sound as a base, noise levels associated with some common machines and activities which would be present during pipeline construction are included in table 4.2.8-1. Distances at which noise would attenuate to ambient levels would depend on local conditions such as tree cover and density, topography, weather (humidity), and wind, all of which can alter background noise conditions.

**Table 4.2-8-1**
**Common Sound Levels for Equipment/Activities Potentially Associated with the PCGP Project**

| Measured Sound Source | Range of Reported dB Values (at Distance Measured 50ft) | Relative Sound Level [1] |
|---|---|---|
| Chain Saw (various types/conditions) | 61 – 93 | Low - Very High |
| Pickup Truck (idle to driving) | 55 – 71 | Very Low - Moderate |
| Mowers | 68 – 85 | Low - High |
| Log Truck | 77 – 97 | Moderate - Very High |
| Dump Truck | 84 – 98 | High - Very High |
| Rock Drills | 82 – 98 | High - Very High |
| Pumps, Generators, Compressors | 87 | High |
| Drill Rig | 88 | High |
| General Construction | 84 – 96 | High - Very High |
| Track Hoe | 91 – 106 | Very High - Extreme |
| Helicopter or Airplane (various types/conditions) | 96 – 112 | Very High - Extreme |
| Rock Blast | 112 [2] | Extreme |

Source: FWS, 2006.
1 A general, subjective ranking of noise levels created by the sources considered when used for analysis of relative noise effects on species.
2 Blasting required for the PCGP Project would be underground and muffled which should result in a lower dB value at 50 feet.

These project-related noises could disturb OR-7 if close enough to detect the noise above ambient levels, assumed to be 40 dB. If noise due to helicopter or blasting is the highest level produced during construction (112 db), those noise levels would be expected to attenuate to ambient levels as far as 38,800 feet away (assuming no intervening topography or vegetation and a noise reduction rate of 7.5 dB for every doubling of distance from the source). On the other hand, noise from a pickup truck generating 70 dB while driving would attenuate to ambient levels 800 feet away (with the same assumptions as above). Response of OR-7 to project-related noise would probably be similar as response to other anthropogenic noise including noise related to recreation, hunting, and logging that already occur within the Known Wolf Activity Area. There is no information, however, about OR-7's response to existing anthropogenic noise.

The portion of the PCGP Project that coincides with wolf OR-7 Known Activity Area passes through several types of forested habitats including Southwest Oregon Mixed Conifer-Hardwood Forest for15.28 miles; Westside Oak and Dry Douglas-fir Forest and Woodlands for 0.29 mile; Ponderosa Pine Forest and Woodland for 6.90 miles; and Montane Mixed Conifer Forest for 6.46 miles (habitat categories follow Johnson and O'Neil, 2001). Most of the Project passes through forested habitats that are regenerating (11.52 miles), clearcut (0.50 miles), mid-seral (5.09 miles), late successional (6.37 miles) or old growth (5.46 miles). The Proposed Action would remove

124.47 acres of old growth. Across the OR-7 Known Activity Area, the Project will remove 124. 47 acres of old-growth forest (more than 175 years old), 118.00 acres of late successional forest (80 to 175 years old), 94.33 acres of mid-seral forests (40 to 80 years old), 303.14 acres of regenerating forest (5 to 40 years old) , and 10.88 acres of recent clear-cut forest (0 to 5 years old). The project would create a corridor through those forest-woodland types and seral stages.

Corridors created within forested habitats are used for movement and foraging by big game species. A study conducted in Alberta by Brusnyk and Westworth (1985) focused on forage and browse production on a 17-year old pipeline right-of-way and on a 2-year old right-of-way and big game use. Deer appeared to utilize browse in the 17-year old corridor but returned to adjacent undisturbed forest, probably utilizing available hiding or thermal cover. Deer utilized the corridors for travel in early winter prior to limiting snow depths. Elk utilized forage on the 2-year old right-of-way primarily where portions were adjacent to forested habitats. The principal conclusion of this study was that pipeline corridors increased local habitat diversity and that diversity – juxtapositions of browse or forage to undisturbed forested habitat – influenced use of the corridors by ungulates, not necessarily due to increased vegetative production, *per se*, within pipeline rights-of-way. Increased herbivore density provides a food source for predators (Forman, 1995), so predator density can be increased along the edge created by the corridor as well.

Food enticements associated with human presence during construction activities could also increase predator populations within the vicinity of the Pacific Connector pipeline. In addition, some wildlife species may be directly impacted by construction of the PCGP Project if they are killed by vehicles traveling to and from construction sites. Species most susceptible to vehicle-related mortality include those that are more active at dusk and dawn such as deer (Leedy, 1975; Bennett, 1991; Forman and Alexander, 1998; Trombulak and Frissel, 2000). OR-7 could be drawn to conflict situations brought about by construction of the PCGP Project if attracted to garbage at the workplace and/or drawn to roadside carrion killed by project vehicles. However, carcasses of prey species (e.g., deer and elk) naturally occur on the landscape usually associated with road kills or wildlife killed by natural causes (ODFW, 2010).

**Cumulative Effects**

No specific foreseeable state or private actions have been identified within the gray wolf analysis area. OR-7 was born in spring 2009. By the time the proposed action would be initiated in 2017, OR-7 would be eight years old and, if still alive, would have exceeded the average life span of 4 years for wolves in the Northern Rocky Mountains (FWS, 2010). If OR-7 remains alive and solitary through 2017, there would likely be no future state or private actions that would constitute a cumulative effect past the duration of pipeline construction.

**Critical Habitat**

Critical habitat for the gray wolf has not been designated in Oregon.

#### 4.2.8.4 Conservation Measures

All trash, food waste, and other items attractive to predators and scavengers would be picked up and removed from the project area on a daily basis to minimize potential attraction of predators, including the gray wolf.

#### 4.2.8.5 Determination of Effects

**Species Effects**

The Project **may affect** the gray wolf because:

- One gray wolf's Known Activity Area coincides with the PGCP Project
- That solitary wolf is currently protected as endangered under ESA.

However, the Project is **not likely to adversely affect** the gray wolf because:

- Noises generated during constructions may be detected and would disturb OR-7, but project-related noises are not likely to be substantially different form noises produced by existing recreation, hunting, and logging land uses.
- The pipeline corridor is likely to increase local habitat diversity, forage, and be used for movements by ungulates, possibility increase habitat suitability for gray wolves
- On-site trash and carrion caused by animal-vehicle collisions could attract the gray wolf to the project area and create conflict situations but trash would be removed on a daily basis and roadside carrion is expected to be present as an existing condition. Project-related effects to the gray wolf would be insignificant and discountable.

**Critical Habitat Effects**

Critical habitat for the gray wolf has not been designated in Oregon.

## 4.3 BIRDS

### 4.3.1 Short-tailed Albatross

#### 4.3.1.1 Species Account and Critical Habitat

**Status**

The short-tailed albatross was designated as endangered in Japan under Appendix A of the Endangered Species Conservation Act of 1969 in October 1970 (FWS, 2000b). The species was proposed for listing in the United States in 1980 under the ESA and was listed as endangered throughout its range in the United States on July 31, 2000 (FWS, 2000b).

**Threats**

Factors responsible for the species' decline were not described in the original listing document (FWS 1970). The primary threat leading to the species' decline and ultimate listing was over-harvest for their feathers in the early 1900s (FWS 2000b), but that threat is no longer present. Another major threat to the short-tailed albatross is their small population size and the existence of only two breeding populations, one of which is threatened by volcanic activity on Torishima Island (Japan) as well as by mudslides and erosion (FWS, 2005a and 2008). Petroleum development occurs in many parts of the short-tailed albatross' marine range, and oil spills are a threat to conservation and recovery.

Possibility of volcanic eruption on Torishima remains the primary ongoing threat to short-tailed albatross because 80 to 85 percent of the breeding population nests there (FWS, 2005b). Typhoons and monsoon rains generating erosion slides threaten extant nesting colonies on a regular basis. Secondary threats include adverse effects related to global climate change (oceanic circulation and patterns of upwelling, incidental take by commercial fisheries (longline fisheries trawl fishing in the North Pacific), ingestion of plastic debris (especially beverage bottle caps), contamination by oil and other pollutants (metals, pesticides, PCBs), vulnerability to predation by non-native species, and other human actions including collisions with airplanes (FWS, 2005a). When populations are small and confined to only a few locations such as the known breeding colonies for short-tailed albatrosses, there is a heightened risk of catastrophic loss from random or unpredictable events (environmental stochasticity).

**Species Recovery**

The FWS drafted a recovery plan for the short-tailed albatross in October 2005 (FWS, 2005b), describing actions necessary to achieve conservation and survival of the species. Human harvest of the short-tailed albatross no longer is a threat to the species existence, nor are human-related limitations. Therefore, focus for recovery is on protection and creation of safe breeding colonies (i.e., without potential for volcanic eruption or massive erosion) on remote islands in the Pacific Ocean (FWS, 2008a). The goal of the plan is to recover the species to the point that protection of the ESA is no longer required. The plan listed the following recovery tasks:

- Support ongoing population monitoring and habitat management on Torishima.
- Monitor Senkaku population.
- Conduct telemetry studies.
- Establish one or more nesting colonies on non-volcanic islands.
- Continue research on fisheries operations and mitigation measures.
- Conduct other research.
- Conduct other management-related activities.
- Conduct outreach and international negotiations as appropriate.
- Develop models and protocols for all aspects of recovery work.

**Life History, Habitat Requirements, and Distribution**

The short-tailed albatross nests on flat or sloped sites with sparse or full vegetation on isolated windswept offshore islands with limited human access (FWS, 2000b). It requires remote islands for breeding (FWS, 2005b). The only terrestrial area within U.S. jurisdiction where the short-tailed albatross is currently nesting is the Midway Atoll. After a courtship of nearly three years, a pair of adult short-tailed albatross successfully raised and fledged a juvenile from a nest site within the Midway Atoll National Wildlife Refuge (Papahānaumokuākea Marine National Monument) in spring 2012 (FWS, 2012c).

In the North Pacific, the coastal habitat for the short-tailed albatross is in high-productivity areas with expansive deep water beyond the continental shelf. Short-tailed albatrosses eat squid, fish, eggs of flying fish, shrimp, and other crustaceans (FWS, 2000b). Short-tailed albatross foraging areas are closely associated with shelf-edge habitats where tidal currents and steep bottom topography generate strong vertical mixing of ocean waters. Areas are most prominent along the Aleutian Archipelago but also include several locations along the US west coast inlong the Santa Barbara Channel and Montery Bay Canyon in California and the Juan de Fuca Canyon near Vancouver Island (Piatt et al., 2006).

**Population Status**

Prior to the publication of the Final Rule, FWS (2000b) estimated a worldwide population of 600 breeding age birds and 600 immature birds (younger than 6 years old) for a total of 1,200 individuals. In 2005-06, there were an estimated 500 breeding pairs and approximately 2,000 individual short-tailed albatrosses (FWS, 2005b). Recent (2008-2009) population estimates incicate 418 breeding pairs (836 breeding adults) on Torishima with a total adult population of 1,045 and an estimated adult population on Minami-kojima of 200 during the 2008-2009 nesting season. The worldwide total adults of breeding age in 2008-2009 was 1,245 birds and 1,327 birds of sub-breeding age (under age 5 or 6) (FWS, 2009a).

**Critical Habitat**

Critical habitat has not been designated for the short-tailed albatross. Designation of critical habitat is "not prudent" given, overall, the lack of habitat-related threats to the species within the United States and its territories and absence of specific areas under U.S. jurisdiction that could serve as critical habitat (FWS, 2005b).

### 4.3.1.2 Environmental Baseline

**Analysis Area**

The analysis area within which the proposed action could affect the short-tailed albatross is the EEZ, which extends 200 nautical miles offshore. Within the analysis area, effects to the short-tailed albatross would be associated with LNG carriers which are assumed to transect the EEZ perpendicularly - east and west - as they approach and depart from Coos Bay (see the discussion above under Section 4.2.1.3, Blue Whale).

**Species Presence**

The short-tailed albatross has not been documented within 25 miles of the proposed JCEP LNG project or Pacific Connector pipeline (ORBIC, 2012) and the nearest known nesting population is within the Hawaiian Islands, on the Midway Atoll. Three percent of locations for sub-adult short-tailed albatrosses tagged with satellite transmitters in Alaskan waters were along the continental shelf margin, within the EEZ, of the U.S. Pacific west coast (Suryan et al., 2007). Most recent records for the species in Oregon have been at sea in the vicinity of Perpetua Bank which is 32 miles west of Yachats, Lincoln County (Marshall et al. 2006). Short-tailed albatrosses have also been observed at Heceta Bank (Audubon Society of Portland, 2013), 15-30 miles off th central Oregon coast, part of the same seamount ridge formation as Perpetua Bank, promoting upwelling of ocean currents interacting with seafloor topography with concomitant primary production.

**Habitat**

Short-tailed albatrosses spend much of their time feeding in nutrient-rich areas of ocean upwelling which often occur at continental shelf breaks (FWS, 2005b). In Oregon, the continental shelf extends from 10 miles off the coast at Cape Blanco to 46 miles from the Oregon central coast (Oregon Ocean-Coastal Management Program, 2008). The Perpetua Bank and Heceta Bank are within the continental shelf break zone and ocean upwelling presumably occurs in the vicinity to support foraging by short-tailed albatross. Similar habitat is expected within the EEZ analysis area.

**Critical Habitat**

Critical habitat has not been designated for the short-tailed albatross.

#### 4.3.1.3 Effects by the Proposed Action

**Direct and Indirect Effects**

None of the factors that have threatened the short-tailed albatross in the past or that are ongoing threats to the species would be produced by any components of the proposed action.

However, Laysan or black-footed albatross (but not short-tailed albatross) may have been killed by colliding with airplanes on Midway Atoll (FWS, 2008a). Seabirds collide with fishing trawlers in the North Pacific although take of short-tailed albatross has not been reported (FWS, 2009). Collisions of seabirds with stationary objects (including off-shore wind energy turbines) are possible, either by collisions of ships with birds on the ocean surface or collisions of birds in flight with ship structures although empirical data are limited (Wilson et al., 2007). Collisions between short-tailed albatrosses and LNG carriers are possible but not likely within the EEZ analysis area.

Oil spills at sea or offshore can harm short-tailed albatrosses (FWS, 2009a). However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers. Unlike oil tankers, LNG carriers are double hulled, such that a grounding would not rupture the cargo tanks. In addition, LNG is not like oil, in that it would vaporize as soon as it hits the warmer water. The effects by the proposed action to short-tailed albatrosses are insignificant and discountable (FWS and NMFS, 1998).

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, 1.6 vessels are predicted to enter Coos Bay in 2017 with between 0 and 20.3 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2017 (see figure 4.2-3).

The foreseeable cumulative effect of 90 LNG carriers per year would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2. Consequently, cumulative effects to short-tailed albatross would likely be less than the estimate of direct effects discussed in the previous section.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-3) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,100 vessel calls to West Coast ports in 2017 (with 95% prediction intervals ranging from 17,200 to 25,000 vessel calls), the year the JCEP and PCGP projects are expected to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2017) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to short-tailed albatross may be more or may be less than the estimate of direct effects discussed above.

Releases of diesel fuel and/or gasoline by commercial and recreational vessels are possible. According to annual reports published by the Pacific States/British Columbia Oil Spill Task Force (2002), ODEQ reported 34 spills from fishing vessels or other harbor craft in 2002, 38 spills in 2003, and 7 spills from fishing vessels plus spills from 27 other vessel types in 2004. Those relatively consistent incidences apparently increased in 2005 with 18 spills from fishing vessels, 20 from recreational vessels, and 27 spills by other vessel types. By contrast in 2006, there were 3 spills from fishing vessels, 6 spills from recreational vessels, and only 6 spills from other vessel types. Though not known, it appears that the background rate of spills off the Oregon coast (incidence of spills in proportion to total vessel operation) by fishing vessels, recreation vessels, and other vessel types is generally low. Based on existing information, future rates of offshore releases are also expected to be low and potential for short-tailed albatross to be affected by contamination by oil and other pollutants is not expected to increase above existing levels.

**Critical Habitat**

No critical habitat would be affected by the proposed action; none has been designated.

#### 4.3.1.4 Conservation Measures

No measures have been included in the proposed action to specifically conserve short-tailed albatross. However, the same Ship-Strike Reduction Plan that was described in Section 4.2.1.4 (Blue Whale) to minimize potential ship strikes to cetaceans by LNG carriers could benefit short-tailed albatross within the EEZ analysis area.

#### 4.3.1.5 Determination of Effects

**Species Effects**

The Project **may affect** short-tailed albatross because:

- Short-tailed albatross may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** short-tailed albatross because:

- Short-tailed albatross have infrequently collided with airplanes in flight but collisions with ships are unknown and are expected to be highly unlikely.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase for potential ship strikes to short-tailed albatrosses.

- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting the potential food species (squid, fish, eggs of flying fish, shrimp, and other crustaceans) in the water. Ignited LNG would affect species on the water but not species submerged in the water. Short-tailed albatrosses are expected to avoid ignited LNG.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for the short-tailed albatross.

### 4.3.2 Western Snowy Plover

#### 4.3.2.1 Species Account and Critical Habitat

**Status**

The Pacific Coast population of western snowy plover has been listed as a threatened species under the ESA since March 5, 1993 (FWS, 1993a). In March 2004, FWS issued an initial 90-day review in response to a petition to de-list the western snowy plover. However, in April 2006 after further review, the de-listing petition was found to be unwarranted (FWS, 2006c).

**Threats**

Historic records indicate that western snowy plovers nested in at least 29 locations on the Oregon coast (FWS, 2009b). At the time of the species' listing Final Rule, there were only six (FWS, 1993a). The breeding population in Oregon declined from 139 adults in 1983 to 30 adults in 1992. Similar declines within wintering habitats were also reported in Southern California (FWS, 1993a). Active nesting areas and breeding and wintering populations declined due to habitat degradation caused by urban development (industrial, residential, recreational facilities including homes, parking lots, and commercial establishments), introduced beachgrasses used to stabilize sand dunes, expanding predator populations particularly corvids (crows, ravens), and non-native red foxes, and human disturbance (beach walking and jogging, ORV use, horseback riding, beach raking, pet walking – FWS, 2001). Nesting from mid-March through mid-September corresponds with the period of intensive human use of beaches during summer, which has been documented to adversely affect adult survival as well as reproduction and fledging success. Western snowy plovers in Oregon are designated as threatened under state statute though habitat and birds have not been adequately protected (FWS, 1993a).

Habitat destruction and degradation continue as the primary threats to western snowy plovers along the Pacific coast (FWS, 2007f). Beach stabilization efforts have continued with permanent habitat losses due to homes, resorts, parking lots, and increased human recreational use of beaches. Other human-related threats include sand mining, disposal of dredged materials that also alter beach habitat dynamics and increase recreational access to habitats, driftwood removal (for firewood, decoration), camping and campfires, reduction in sand delivery to beach by water diversions or waterbody impoundments, and maintenance of salt ponds. Non-native beachgrasses continue to degrade the landscape along the Oregon coast by changing patterns of dune stabilization, making beach habitats less suitable for nesting and brood-rearing snowy plovers (FWS, 2007d).

**Species Recovery**

In 2001, the FWS drafted a recovery plan for the western snowy plover, Pacific Coast population, with the primary objectives to increase the numbers and productivity of breeding adults throughout the Pacific Coast and to provide for long-term protection of breeding and winter plovers and their habitat. The recovery plan provides management goals for six recovery units established within the breeding range of the Pacific Coast population in Washington, Oregon, and California. Recovery Unit 1, specifically population OR-10 (Coos Bay North Spit), is near the proposed action. The management goal for this unit is 54 breeding plovers (FWS, 2001 and 2005c). There were 61 total nests within OR-10 reported during the 2012 nesting season (Lauten et al., 2012). A final recovery plan was released in 2007 (FWS, 2007d). The recovery plan's primary objective is to remove the species from the List of Endangered and Threatened Wildlife and Plants by:

- Increasing population numbers distributed across the range of the Pacific coast population.
- Conducting intensive ongoing management for the species and its habitat and developing management mechanisms.
- Monitoring western snowy plover populations and threats to determine success and refine management actions.

The recovery plan lists the following necessary actions:

- Monitor breeding and wintering populations and habitats of the Pacific coast population of the western snowy plover to determine progress of recovery actions to maximize survival and productivity.
- Manage breeding and wintering habitat of the Pacific coast population of the western snowy plover to ameliorate or eliminate threats and maximize survival and productivity.
- Develop mechanisms for long-term management and protection of western snowy plovers and their breeding and wintering habitat.
- Conduct scientific investigations that facilitate the recovery of the western snowy plover.
- Conduct public information and education programs about the western snowy plover.
- Review progress towards recovery of the western snowy plover and revise recovery efforts, as appropriate.
- Dedicate FWS staff to allow the Arcata Fish and Wildlife Office to coordinate western snowy plover recovery implementation.
- Establish an international conservation program with the government of Mexico to protect western snowy plovers and their breeding and wintering locations in Mexico.
- Coordinate with other survey, assessment, and recovery efforts for the western snowy plover throughout North America.

**Life History, Habitat Requirements, and Distribution**

The Pacific Coast breeding population of the western snowy plover includes Oregon. Coastal populations, including those in Oregon, typically consist of resident and migratory birds. Large concentrations of migratory snowy plovers winter primarily in coastal California, Baja California, and along the coastal mainland of Mexico (FWS, 1993a). The Pacific coast population of the western snowy plover includes the birds which nest adjacent to tidal waters, including all nesting birds on the mainland coast, peninsulas, offshore islands, adjacent bays, estuaries, and coastal rivers (FWS, 1993a). They breed on coastal beaches from southern Washington to southern Baja California, Mexico, from early March through late September (FWS, 1993a and 2001). This habitat is often unstable because of unconsolidated soils, high winds, storms, wave action, and colonization by plants. Preferred nesting sites include sand spits, dune-backed beaches, beaches at creek and river mouths, and salt pans at lagoons and estuaries (Wilson, 1980; Stenzel et al., 1981). Less frequently, western snowy plovers nest on bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars (FWS, 2001). In 1990, one western snowy plover nest was documented at Menasha dredge spoils along the east side of Pony Slough at its confluence with Coos Bay (ORBIC, 2012). The nest failed in 1990 and was not reinitiated in 1991.

Nesting in Oregon may occur as early as mid March but peak nest initiation occurs from mid-April through mid-July (Wilson-Jacobs and Meslow, 1984). Nests typically occur in flat, open areas with sandy or saline substrates; vegetation and driftwood are usually sparse or absent (Wilson, 1980). Nests consist of a shallow scrape or depression lined with beach debris (e.g., small pebbles, shell fragments, plant debris, and mud chips); nest lining progresses as incubation progresses.

Usual clutch size is three eggs but can vary from two to six. Both males and females incubate the eggs. After losing a clutch or brood (i.e., group of chicks) or successfully hatching a nest, western snowy plovers may re-nest at the same site or move substantial distances to nest at other sites (Wilson, 1980; Warriner et al., 1986).

Eggs hatch within 30 days. Young are very precocial and ready to leave the nest within 1 to 3 hours of emergence at which point the attending parent would lead them to suitable feeding grounds. Broods rarely remain in the nesting area and have been observed on the North Spit as far as three miles north of the jetty at the mouth of the bay (Todd, 2007). Chicks are able to fly approximately one month after hatching (FWS, 2007d). Plovers feed on small invertebrates in wet sand areas of the intertidal zone, along the wrack line, in dry sandy areas above the high tide line and along surf-cast driftwood and kelp.

**Population Status**

Along the Oregon Coast there are eight main nesting areas though several other areas may be utilized in some years (FWS, 2007f). Lowest population estimates for nesting plovers on the Oregon Coast averaged 33 individuals annually between 1991 and 1993. Since 1993, the Oregon Coast population of adults has significantly increased to 206 birds following an exponential trend (see figure 4.3-1). In 2012, nesting success for those breeding sites was the highest recorded since monitoring began in 1990, with 173 birds fledging in 2012 compared to only three birds that fledged in 1990 (Lauten et al., 2012).

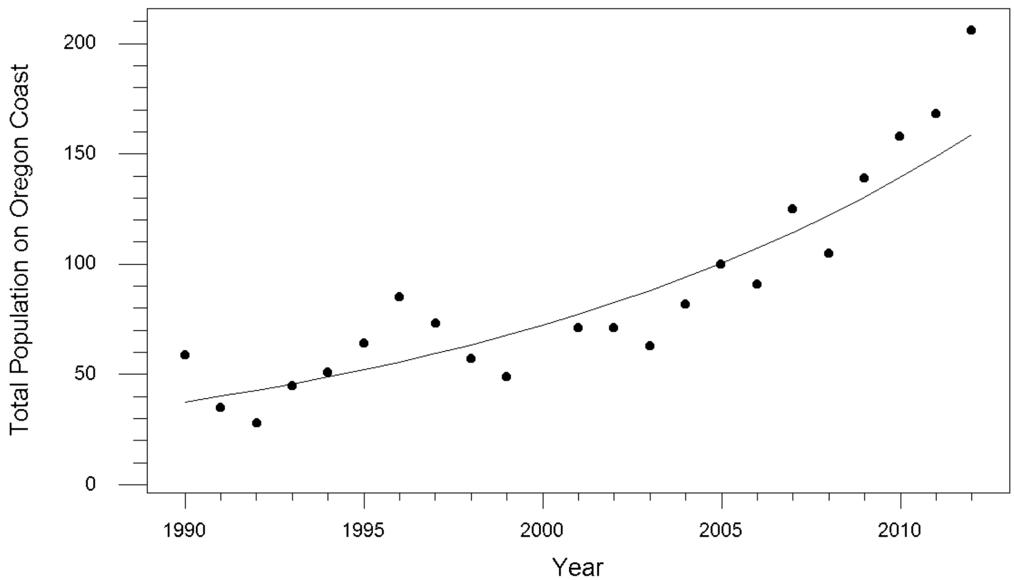



**Figure 4.3-1**
**Number of Adult Western Snowy Plovers Observed During the Breeding Season on the Oregon Coast, 1990 to 2012. The exponential relationship is significant ($r^2$ = 0.79, P<0.001). Source: Lauten et al., 2012**

In 2008, the estimate of total fledglings on the Oregon Coast was only 71, possibly due to 1) cool, wet weather during the early breeding period, 2) a relatively large proportion of young inexperienced birds in the breeding population, and/or 3) increased predation on young (BLM, 2008a). Nevertheless, production of fledglings on the Coos Bay North Spit was 40, over 50 percent of the Oregon Coast total (BLM, 2008a).

**Critical Habitat**

Critical habitat for the western snowy plover was designated on January 6, 2000 (FWS, 1999a), including 278 acres in Coos Bay, and re-designated in 2005 (FWS, 2005c). The most recent revised designation of critical habitat for the western snowy plover was in June 2012 (FWS, 2012d). The closest critical habitat to the PCGP Project is Unit OR-10 which occupies 273 acres on the Coos Bay North Spit, approximately 5.1 miles southwest of MP 1.47R of the PCGP Project. A second critical habitat Unit OR-9, at the mouth of Tenmile Creek on the Siuslaw Nation Forest, is 6.9 miles northwest of MP 3.51R. Both critical habitat units were occupied by western snowy plovers at the time of listing (1993) and in 2012. Approximately 25 breeding adults occupied Unit OR-9 in 2011, while 59 breeding snowy plovers were documented with Unit OR-10 on the North Spit in 2011 (FWS, 2012d). Both units include features essential to the conservation of the species, including expansive sparsely vegetated interdune flats (used for nesting and foraging), areas of sandy beach above and below the high tide line with occasional surf-cast wrack supporting small invertebrates (for nesting and foraging), and close proximity to tidally influence estuarine areas (for foraging).

Based on the Pacific Coast western snowy plover's requirements for reproduction, feeding, forage and shelter, the FWS (2012d) identified the following essential physical and biological features of designated critical habitat: 1) sparsely vegetated areas above daily high tides that are relatively undisturbed by the presence of humans, pets, vehicles or human-attracted predators; 2) sparsely vegetated sandy beach, mud flats, gravel bars or artificial salt ponds subject to daily tidal inundation, but not under water, that support small invertebrates; and, 3) surf or tide-cast organic debris such as seaweed or driftwood located on open substrates. Critical habitat in the vicinity of the project area (Unit OR 9, Coos Bay North Spit), contains expansive, sparsely vegetated interdune flats, areas of sandy beach above and below the high tide line with occasional surf-cast wrack supporting small invertebrates, and close proximity to tidally influenced estuarine areas (FWS, 2012d).

Threats that may require special management in this unit are introduced European beachgrass that encroaches on the available nesting and foraging habitat; disturbance from humans, dogs and off-highway vehicles (OHVs) in important foraging and nesting areas; and predators such as the American crow and common raven (FWS, 2005c).

#### 4.3.2.2 Environmental Baseline

**Analysis Area**

The LNG terminal analysis area extends for 1.7 miles beyond the perimeter of the LNG terminal project area (see figure 4.3-2) to include western snowy plover nesting habitat on the North Spit.

**Species Presence**

Western snowy plovers have been recorded on the National Audubon Society's Christmas Bird Counts in the Coos Bay count circle every year since 2000, and sporadically in earlier surveys. Since 2000, an average of 5.4 snowy plovers have been counted per year; the most reported in any annual survey were 10 counted during 160 observation hours (0.06 counted per hour of observation) in 2005. Western snowy plovers are known to nest at the upper edge of the beach below the foredunes, on bare spits at small estuary mouths and on old dredge spoils (Marshall et al., 2006). No western snowy plovers were detected during field surveys of the Jordan Cove Project site (LBJ Enterprises, 2006).

In summer 2012, 16 total adults (8 males, 8 females) were documented by the Forest Service on the Tenmile Creek Unit OR-9 and 52 adults (35 males, 17 females) were documented by personnel with BLM and Army Corps of Engineers on the Coos Bay North Spit, critical habitat unit OR-10. In 2012, the nest success rate on the North Spit was 87 percent, similar to 2011, and the highest rate on the Oregon Coast since predator management was implemented in 2002 (Lauten et al., 2012). Nesting success at the Tenmile Creek unit has been very poor; only 13 percent of nests were successful in 2012, mostly due to depredations by corvids (common ravens) and great horned owls (Lauten et al., 2012). The total number of nests documented on the North Spit has significantly increased between 1998 and 2012 (see figure 4.3-3).

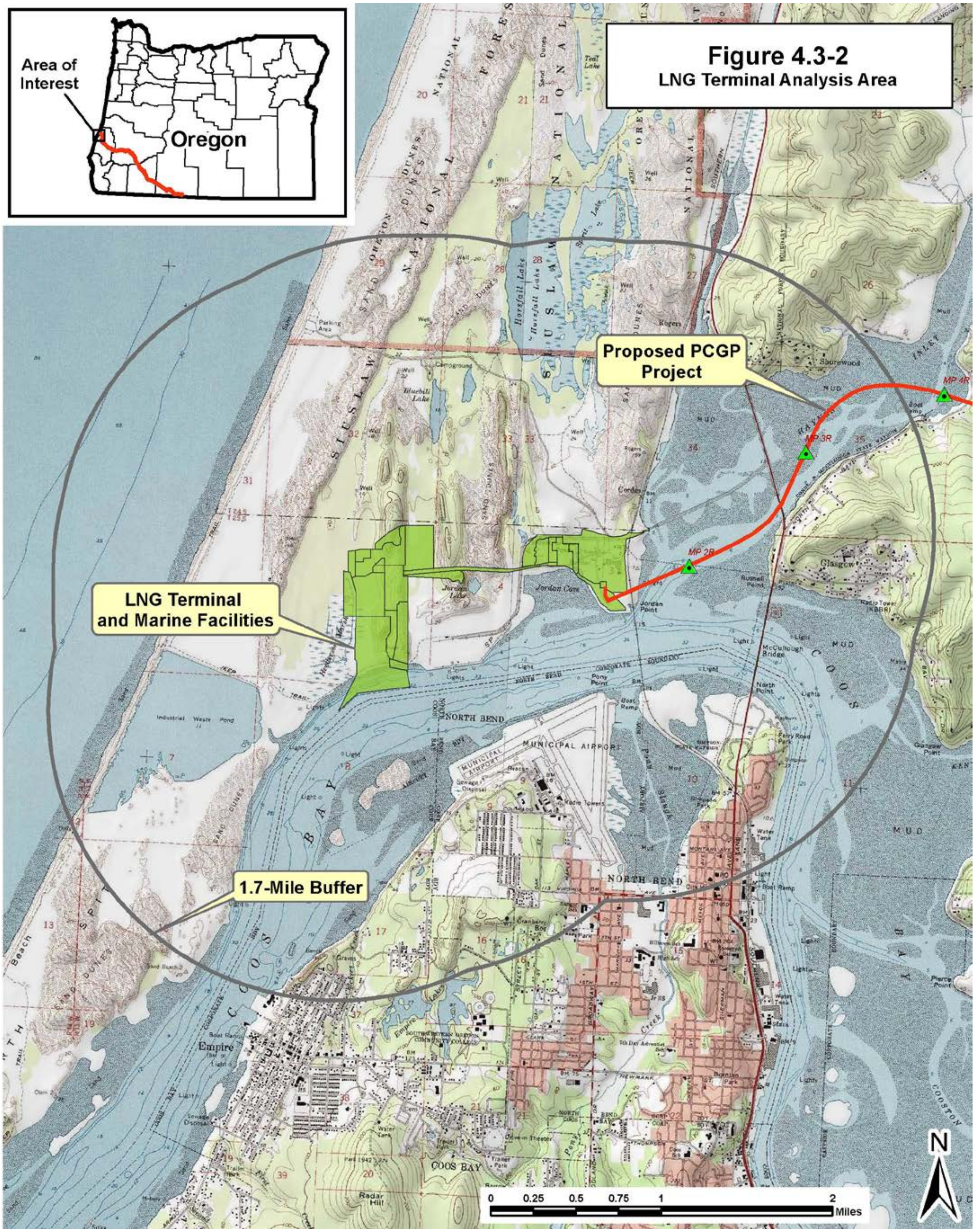


Figure 4.3-2
LNG Terminal Analysis Area
Area of Interest
Oregon
Proposed PCGP Project
LNG Terminal and Marine Facilities
1.7-Mile Buffer
MP 2R
MP 3R
MP 4R
0
0.25
0.5
0.75
1
2
Miles
N

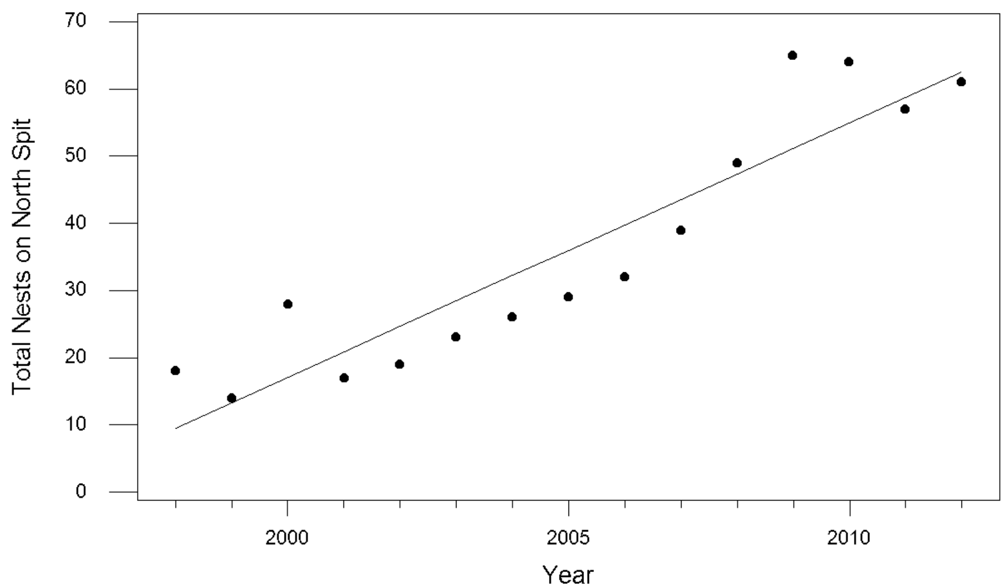



**Figure 4.3-3**
**Total Number of Western Snowy Plover Nests Observed on the Coos Bay North Spit from 1998 to 2012. The increasing linear trend is significant ($r^2 = 0.85$, $P<0.001$).**
**Source: Lauten et al., 2012**

### Habitat

The northern end of critical habitat on the North Spit is approximately 2.6 miles from the LNG terminal site. Nesting habitat, reported by ORBIC (2012), extends north of the North Spit designated critical habitat for nearly 2 miles along the beach. The northern end of that nesting habitat is approximately 1.1 miles from the LNG project area boundary.

The Pacific Connector pipeline terminus is approximately 2.6 miles east of the largest and most consistent western snowy plover nesting areas (ORBIC, 2012) and 4.0 miles northeast of the designated critical habitat on Coos Bay North Spit (FWS, 2012d). In 1990, one western snowy plover nest was documented at Menasha Spoils at the mouth and along the east side of Pony Slough at its confluence with Coos Bay (ORBIC, 2012), approximately 0.6 mile south of MP 1.72R. Since 1990, vegetation has invaded the Menasha Spoils site and the site may no longer be suitable as snowy plover nesting habitat since it is no longer an expanse of sparsely vegetated interdune flats. The nest was unsuccessful and there have been no nest sites documented within the Coos Bay estuary since 1990.

The existing land use of the LNG project area site is open. It has been disturbed by past and present activities. The site area has been filled in the past as evidenced by deposits of clamshells and wood chips. Other disturbances have and are presently occurring from recreational off road vehicle usage. Elevation ranges from near sea level to an approximate elevation of 67 feet. Topography is variable, ranging from low lying deflation basins to semi-stable dunes. Existing vegetation is comprised of upland coniferous dune forests and upland herbaceous dominated areas.

**Critical Habitat**

No designated critical habitat for western snowy plover is present in the LNG terminal analysis area. The northern end of critical habitat (OR-10) on the North Spit is located approximately 2.6 miles from the LNG project area.

### 4.3.2.3 Effects by the Proposed Action

**Direct Effects**

Direct effects of the proposed action include increased noise associated with construction of the LNG terminal and operation activities associated with shipping.

Noise

Noise associated with construction and operation of the facility is the only direct effect to plovers associated with the proposed action. The 2007 western snowy plover recovery plan states that: "sources of noise that would disturb snowy plovers should be avoided," but the levels of noise likely to disturb plovers are not provided. The recovery plan identifies noise associated with dredging as having a potentially negative effect on breeding and wintering western snowy plovers; noise associated with driftwood removal, especially if chainsaws and vehicles are used, can disrupt nesting; noise from beach cleaning machinery, from beach pyrotechnics, and from aircraft overflights (especially helicopters) can also cause adverse effects (FWS, 2007d).

Ambient noise levels in the vicinity of the LNG terminal were measured continuously for 24 hours between August 31 and September 1, 2005 at two residences (noise sensitive areas), one of which was 1.4 miles south of the terminal and the other 2.3 miles east. Ambient noise levels at the terminal site or on the Coos Bay North Spit were not reported (Resource Report 9, JCEP LNG Terminal Project). Average noise levels ranged from 35 dBA (night) to 54 dBA (day) south of the terminal site and from 49 dBA (night) to 66 dBA (day) east of the site. Local conditions such as aircraft, vehicle traffic, vegetation, topography, breaking waves, and winds characteristic of the location can alter background noise conditions. Sound levels (decibels – dB) at outdoor rural residential locations of about 40 dB, averaged for day and night periods (see for example, EPA, 1974) have been accepted as standard. More than likely, ambient noise levels on the North Spit, near breaking waves, will be higher than 40 dB; noise generated by breaking wavecreses in the surf zone can be 15 dB higher than background levels (Dean, 1999). Daytime ambient noise is typically 10 dB higher that night levels (EPA, 1974).

Construction

Construction of the JCEP LNG terminal and South Dunes Power Plant would increase local noise levels. Noise levels 50 feet away from typical construction equipment that might be used during terminal construction, are provided in table 4.3.2-1.

The standard for noise reduction from point sources such as construction machinery is 6 dBA per doubling of distance under hard site conditions (over calm water, hard, smooth ground survace) and 7.5 dBA per doubling of distance under soft site conditions (because of roughened ground and/or vegetation cover) (WSDOT, 2011a). Based on the data in table 4.3.2-1, noise produced by construction activities would attenuate to daytime ambient noise levels in the vicinity of western snowy plover nests (estimated at 55 dBA because of breaking wave noise) within distances of 230 feet to 2,850 feet, depending on equipment/actions and hard site or soft site reduction ground surface conditions. Obscuring vegetation (tree cover), topography (interruption of line-of-sight), and atmospheric conditions (wind, air temperature, humidity) also affect noise reduction but can be highly variable between locations and over time and are generally not taken into account in estimates of noise attenuation over short distances (Resource Report 9, JCEP LNG Terminal Project). Consequently, predictions of noise levels some distance from the noise source are likely to be higher than actual noise levels.

Prior to the excavation work starting for the LNG carrier slip, an open cell sheet pile bulkhead and retaining wall will be installed. The sheetpile system will serve as a retaining wall for the shoreline on the east side and support the LNG ship loading dock and associated berthing and mooring facilities. The open cell sheet pile wall system consists of face sheetpiles for retaining the soils as well as tailwalls for anchorage of the retaining wall. All sheetpiles and tailwalls will be driven from the land while the slip construction activities are isolated from Coos Bay. Sheet piling is typically installed with a vibratory pile driver. Average maximum noise in air of a vibratory pile driver is 101 dBA at 50 feet (WSDOT, 2011a). Vibratory pile driver noise would likely attenuate to 55 dBA at 3,510 feet (soft site reduction) or 10,159 feet (hard site reduction) and would attenuate to 40 dBA at 14,039 feet (soft site reduction) or 57,469 feet (hard site reduction). Consequently, noise generated during installation of sheet piling could be above background noise at the northern end of the western snowy plover nesting habitat (depending on effects of surf noise on ambient noise levels), approximately 1.1 mile from the LNG slip construction site but not likely at the northern end of critical habitat on the North Spit, approximately 2.6 miles from the LNG terminal site.

**Table 4.3.2-1**
**Average Maximum Noise (Lmax) at 50 feet from Construction Equipment and Estimated Distance to Attenuate to Ambient Levels near the Surf Zone on the North Spit [1]**

| Construction Activity | Equipment | Noise dBA (Lmax measured at 50 feet) [2] | Distance (feet) to Attenuate to Assumed Ambient Noise Level of 55 dBA [1] | |
|---|---|---|---|---|
| | | | Soft Site Reduction at 7.5 dBA per double of distance | Hard Site Reduction at 6 dBA per double of distance |
| Clearing and Grading | Grader | 85 | 800 | 1,600 |
| | Scraper | 84 | 729 | 1,425 |
| | Warning Horn | 83 | 665 | 1,270 |
| | Dozer | 82 | 606 | 1,131 |
| | Excavator | 81 | 553 | 1,008 |
| | Backhoe | 78 | 419 | 713 |
| | Pickup Truck | 75 | 317 | 504 |
| | Flatbed Truck | 74 | 289 | 449 |
| Rock Excavation | Mounted Impact Hammer | 90 | 1,270 | 2,851 |
| | Auger Drill Rig | 84 | 729 | 1,425 |
| | Rock Drill | 81 | 553 | 1,008 |
| Stationary Equipment | Concrete Saw | 90 | 1,270 | 2,851 |
| | Pneumatic Tools | 85 | 800 | 1,600 |
| | Generator | 81 | 553 | 1,008 |
| | Air Compressor | 78 | 419 | 713 |
| | Welder Torch | 74 | 289 | 449 |

[1] WSDOT, 2011
[2] Federal Highway Administration, 2006

Construction of the LNG terminal and slip is expected to take 42 months (see Resource Report 1, JCEP LNG Terminal Project). Piling driving activities will take place over approximately an eight-month period and are expected to occur on a schedule of two shifts, six days per week (see Resource Report 9, JCEP LNG Terminal Project). Sheet pile driving will occur initially followed by the on-shore berthing structures as the marine foundation work begins. Sheet piling could be installed during the snowy plover breeding, nesting or rearing periods. Based on the distance of construction from western snowy plover critical habitat and potential nesting sites on the North Spit, acoustic disturbances from the proposed action are not expected to significantly affect western snowy plover breeding, nesting or rearing activities.

Construction of the PCGP across Haynes Inlet will occur between October 1 and February 15, the ODFW-recommended in-water construction window (ODFW, 2008a), which is outside of the nesting and fledgling season for the species on the Oregon coast (early April through August; FWS, 2001). It is not possible to anticipate any local occurrence of western snowy plover in the project area at the time of construction

Operation

Approximately 90 LNG ships will transit to the Project on an annual basis. Since it is not possible to identify which LNG ships will transit to the Project, exact noise levels cannot be determined at this time. For analysis purposes, noise levels have been determined for the 138,000 $m^3$ LNG ships which are typical of the LNG ships anticipated to transit the waterway to the Project. A noise level of 63 dB at 100 yards (82 dBA at 50 feet under soft-site conditions, 79 dBA at 50 feet under hard-site conditions) was determined for the 138,000 $m^3$ LNG ship (Resource Report 9, JCEP LNG Terminal Project). However, LNG ships transiting the waterway to the LNG terminal would be under tow by high bollard pull tractor tugs for which noise estimates have not been presented. Nevertheless, noise from tugs and/or LNG ships entering and exiting Coos Bay are expected to generate noise above ambient levels within the southern portion of critical habitat unit OR-10 which extends to the southern extent of the North Spit, approximately 100 feet from the edge of the North Jetty and Coos Bay channel.

In addition to LNG ships, the following major noise-producing equipment will normally be in operation at the Project (Resource Report 9, JCEP LNG Terminal Project):

- Four (4) refrigerant compressors / motors / piping;
- Four (4) refrigerant compressor interstage coolers;
- Four (4) refrigerant condensers;
- LNG expanders;
- Ship BOG return blowers;
- Six (6) BOG compressors / motors;
- Two (3) BOG compressor coolers; and
- Various other condensers, coolers, pumps and valves.

Additionally, the following noise-producing nonjurisdictional South Dunes Power Plant equipment packages will normally be in concurrent operation with the Project equipment:

- Six (6) combustion turbine generators (GE LM6000);
- Six (6) heat-recovery steam generators;
- Two (2) steam turbine generators;
- Two (2) air-cooled condensers;
- Twelve (12) boiler feed pumps;

- Two (2) fuel gas compressors;
- Fuel gas compressor cooler; and
- Steam piping, various motors, valves, air compressors, etc.

The above equipment packages have been specified to meet sound level requirements appropriate to support an overall far-field Project sound level that does not exceed the applicable FERC regulatory limits. As explained in Section 9.2.2.1 of Resource Report 9 (JCEP LNG Terminal Project), a constant Project sound level of less than 48 dBA would ensure compliance with all applicable regulations, including the FERC requirement limiting the average day/night noise level at the nearest residential noise sensitive areas to ≤55 dBA. With that restriction, it is assumed that noise generated by equipment at the functioning LNG site and South Dunes Power Plant will not exceed 55 dBA at western snowy plover breeding, nesting or rearing habitat on the North Spit.

During operations of the PCGP, aerial inspection of the pipeline will occur within the permanent right-of-way. Nesting snowy plovers are not expected to be impacted since the closest nesting population is more than three miles from proposed aerial inspections and air traffic is a constant disturbance with the existing North Bend Municipal Airport within less than three miles of the nesting habitat on North Spit. If the pipeline within the bay requires maintenance, activities and repair would occur in-water and within the permanent easement; therefore, impacts from maintenance activities should not impact snowy plovers any time of the year.

**Indirect Effects**

Project-related indirect effects to western snowy plovers which are caused by the action (induced by the action as human presence and use increase) and are later in time or farther removed in distance, but are still reasonably foreseeable are indirect effects. All indirect effects to western snowy plovers are expected to be secondary effects (Comer, 1982) due to an increased human population base, whether as a result of the requirements of the action itself (the workforce needed to construct or operate the Project) or as a consequence of the action (need for ancillary goods, services, opportunities resulting from the Project). Potential indirect or secondary effects by a project include increased recreation demand (including ORV use), increased habitat conversion, habitat degradation by human encroachment, and increased illegal harvest (Comer, 1982).

The following indirect effects by the proposed action to western snowy plovers are anticipated: 1) increased human presence, and 2) increased predation of western snowy plovers due to increased human presence. In addition, increased human presence may lead to destruction of nests and/or disturbance of plovers from the following activities: OHV usage, visitors or their dogs, predators such as crows and ravens (that are attracted to areas with humans and their garbage), beach walking or jogging, horseback riding, and beach raking.

Human Presence

The Coos Bay North Spit is currently utilized by a variety of recreational users for OHV driving, beach combing, boating, bay-shore clamming and crabbing, day hiking, picnicking, kayaking, surfing, and fishing (Natural Resource Trustees, 2006). In addition, the North Spit has become one of the most popular horseback riding areas in the region (BLM, 2005). Snowy plover habitat on the North Spit is currently owned by the BLM and COE and managed by the BLM, USFS, and Oregon Parks and Recreation Department (OPRD). This area is known as the Coos Bay

North Spit Recreation Management Area (CBNS RMA) and extends 3.37 miles north from the southern tip of the North Spit along the ocean-side shoreline, encompassing some, but not all, of the Plover Critical Habitat on the North Spit.

According to the OPRD 2007 Plover Habitat Conservation Plan, the peak number of visitors to the 15.62 miles of beach from Ten Mile Creek to Coos Bay (the beach segment including the CBNS RMA) was 3.84 people per mile (OPRD, 2005 and 2007), and the distribution of these visitors was described as "dispersed." The number of visitors per mile at the eight recreational management areas currently utilized by nesting plovers ranged from 3.45 to 13.22 (OPRD, 2007). The Habitat Conservation Plan for Western Snowy Plovers published by the OPRD in September 2007 states (with regard to the CBNS RMA), "This beach is open to street legal vehicle driving only, but is closed during the breeding season. There is illegal ATV [all-terrain vehicle] use on this beach. Recreation use here is low, but higher than other RMAs due to its close proximity to Coos Bay/North Bend/Charleston. The area is a popular surfing site."

The primary reasons that the public accessed the North Spit beach were to walk/run (16 percent) or to relax (21 percent). Of those surveyed, 4 percent reported bringing dogs to the beach, and none reported flying kites (OPRD, 2007). The percentage of people with dogs was significantly lower than the statewide average of 35 percent. All of the human-caused disturbances listed above can result in destruction of nests (by dogs or through inadvertent trampling and deliberate vandalism) and in diverse plover responses to human presence, including: flushing from and abandonment of nests, separation from broods, shifting to marginal habitat, cessation of foraging and adoption of vigilant or cryptic behaviors (FWS, 2007f).

The number of people employed on the North Spit in 2007 was approximately 110 (Southport Lumber Products – 70, Roseburg Forest Products – 20, DB Western Marine Division – 20). The Project would result in a large but temporary increase in people employed on the North Spit during construction (an average of 741 construction workers over the four year construction period) and a much smaller long-term increase of operations staff (150 employees at the LNG terminal). Construction would take 42 months, and the number of construction personnel would peak at 2,937 workers in project months 30 to 33 (Resource Report 5, JCEP LNG Terminal Project).

It is difficult to predict how the increase in short-term and long-term employment due to the future development of the North Spit would translate into increased recreational use of areas near snowy plover habitat. However, it is reasonable to assume that the Jordan Cove operations staff, their family and friends would be introduced to the area, and some minor increases in recreational use could occur. This increase in recreational use could result in increased plover disturbance. Recreation on the beach has been shown to cause a reduction in plover productivity. In total, it was estimated that between 2000 and 2006, recreational activities on the Oregon Coast resulted in the loss of 30 hatchlings and 11 fledglings per year, which equated to an annual loss of 5 adult equivalents (Jones and Stokes, 2007).

<u>Predators</u>

In the 2006 Coos Bay Annual Program Summary and Monitoring Report, BLM reports that corvids (crows, ravens and their allies), skunks and feral cats are the primary predators on the North Spit. However, the exact nature of predation pressures on snowy plover on the North Spit shifts annually, and during 2007 coyotes became a greater threat than they had been previously (Castelein, 2008). The BLM and OPRD have jointly managed a predator prevention program since 1990, which focuses on the removal of predators and the protection of nests via exclusion devices.

In 2006 on the Oregon Coast, plover nests that were covered by predator exclosures (n=68) had a 60 percent success rate, and unexclosed nests (n=79) had a 40 percent success rate. In 2012, the nesting success rate for exclosed nests (n = 22) was 82 percent but for unexclosed nests (n = 289) the success rate was 42 percent (Lauten et al., 2012). Fencing and public education have also been employed to help reduce inadvertent aid to potential predators. The relatively remote location of the CBNS RMA has helped to minimize the presence of scavengers and predators, most of which are encouraged or attracted by human disturbance such as campsites, garbage dumps, work sites or even footprints in the sand. Significant predators at this nesting site include corvids, coyotes, striped skunk, and feral cats. Although red fox were significant plover predators at other nesting sites, fox have not been significant predators at the CBNS RMA.

Increased foot traffic through snowy plover nesting has been shown to increase scavenger predation (Buick and Paton, 1989; Castelein, 2008). Therefore increased recreational use of the North Spit ocean beaches by off duty employees could create additional predation pressure. Food enticements associated with human presence could increase predator populations on the North Spit. Corvids, coyotes, cats and skunks are all curious, adaptable animals attracted to food waste and non-food human refuse. Increased human presence could also increase the potential for more dumping of unwanted pets in the area. An increase in the numbers of these predators could be detrimental to the recovery of snowy plover populations.

**Cumulative Effects**

Additional projects within the action area (estuarine analysis area and the Port-LNG terminal Analysis Area) are anticipated as human population growth continues in the region. Associated road and commercial development, as well as maintenance and upgrading of existing infrastructure within the Estuary, are likely to occur in the foreseeable future. For example, the Port of Coos Bay owns and operates the Charleston Marina, the Charleston Marina RV Park, and Charleston Shipyard. As a component of the Port’s economic development, the focus of the Charleston Marina Master Plan is to develop commercial fishing and seafood processing, recreational fishing and boating, tourism, and growth in the retail and commercial sectors. Other, similar economic developments in the region could occur and, if they did, could contribute to the region’s human population growth which could be detrimental to western snowy plovers within and around the Coos Bay estuary.

A standard of “reasonably certain to occur” is clarified as “those actions that are likely to occur, bearing in mind the economic, administrative, or legal hurdles which remain to be cleared”. Further, NMFS provides that “speculative actions that are factored into the cumulative effects analysis add needless complexity into the consultation process…” (51 FR 19933). No specific state or private actions have been identified within the action area that meet this standard. Further, activities described above are somewhat speculative in nature and cannot be quantified here. Therefore, a logical conclusion is that there would be no cumulative effects to western snowy plover associated with the proposed action.

Within the action area and estuarine analysis area, gradual habitat and water quality improvements may also occur over time as federal, state and private conservation and habitat enhancement efforts are implemented. There are a number of potential federally permitted projects (e.g. repair of the entrance jetties and widening and deepening of the lower portion of the Coos Bay navigation channel) that could result in cumulative effects. However, because these projects would require federal permits, their impacts would be evaluated through the federal permitting process when and if they occur.

**Critical Habitat**

The northern end of critical habitat on the North Spit, OR-10, is located approximately 2.6 miles from the LNG terminal. The proposed action would not directly or indirectly affect designated critical habitat or any of the essential physical and biological features within OR-10 that might be utilized by western snowy plovers. Cumulative effects due to increased human presence may occur within the action area but the certainty and extent of such secondary impact is speculative.

#### 4.3.2.4 Conservation Measures

Stockpiling material dredged from the slip area was going to occur as part of the import terminal project. Due to the snowy plover population on the North Spit, there was a concern that this Port stockpile area could attract snowy plover individuals from this population. To address this concern JCEP participated in the development of a number of conservation measures to reduce the potential effects on the North Spit snowy plover population due to the construction of the Project. Although the construction activity that was of the greatest concern for the snowy plover population is no longer part of the Project, JCEP will still commit to the proposed conservation measures as described in the following paragraphs.

Current management activities and use restrictions within the Coos Bay North Spit Recreation Management Area include:

- Predator management (i.e. nest exclosures, lethal and non-lethal predator removal and hazing);
- Symbolic fencing (ropes and signs installed around nesting areas);
- Habitat restoration (removal of European beachgrass, placement of shell hash, maintenance of gaps through the dunes);
- Public outreach and education provided by BLM staff;
- Monitoring of snowy plover populations; and
- Recreational use restrictions in place from March 15 – September 15 each year, including:
  - Seasonal re-routing of the foredune road;
  - Vehicles, camping, and dogs are prohibited.
  - Kite flying would be prohibited under the draft conservation plan.
- Non-prohibited recreational use (i.e. jogging, beach combing, horseback riding) is restricted to the wet sand outside of roped and signed breeding areas.

JCEP reviewed a list of conservation measures provided by the FWS, the BLM, and the ODFW through the Sediment Placement subgroup of the the Jordan Cove/Pacific Connector Interagency Task Force Working Group and agreed to provide funding as enumerated below. The funding would be provided to the entity as defined by the agencies and it would be the responsibility of the particular entity to administer the funding. It should be noted that these measures were developed partially in response to the concern that the Port stockpile site would provide potential habitat. The Port stockpile site is no longer part of the Project. JCEP is requesting that the funding of these conservation measures be used in part to contribute to other habitat mitigation requirements imposed by the ODFW.

Year 1 (when construction begins) – provide $60K for:

- Fencing (~$30K)
- Signage
- Application of shell hash
- Tree removal
- One year of maintenance – $10K

Years 2 and 3 – provide $30K (each year) for:

- Annual maintenance – $10K
- Beach grass elimination grant (minimum of $10K)
- Shell hash

Years 4 (to 2018) – provide $10K for:

- Annual maintenance

In addition to these conservation measures, Jordan Cove has agreed to mitigate Project impacts to western snowy plovers through implementation of 1) best management practices (BMPs), and 2) education and outreach programs.

Increased predator density related to increased human presence and habitat removal were identified as potential concerns related to Project construction. JCEP will address these concerns through these BMPs.

Best Management Practices

During construction and operation, the facility would be kept clear of construction debris and food wastes that could attract predators. Covered, animal proof receptacles would be provided in eating and break areas, parking lots, and at appropriate locations around the construction site. During construction the site would be policed on a daily basis to remove any food or other debris left by construction workers. During operations the facility and grounds would be regularly inspected to assure that no garbage is allowed to accumulate.

Structures associated with the LNG terminal and the Port's slip would be monitored to discourage use by avian predator species. Frequent inspections would ensure that nests are not being constructed and all nests found would be removed immediately. It is anticipated that there would be sufficient inspections and other activities mandated by safety and security requirements to keep the structures nest free. However, in the unlikely event that a nest becomes established and it is not discovered until young birds are present, the disposition of the nest would be handled in accordance with the provisions of the Migratory Bird Treaty Act.

The dredged material placement areas will be regularly policed to insure that no predator denning is occurring in the hillocks. This should not be as significant a concern as it was previously for the Port stockpile site as these placement areas will be part of the construction activities and the continuous activities will discourage use by individual birds. If necessary, nylon mesh or other exclusion fencing would be installed around the perimeter of the placement areas to prevent the establishment of coyote or skunk dens until the slopes are stabilized or constructed upon.

Education and Outreach

Surveys conducted in 2002 indicated that 76 percent of beach visitors were unaware of restrictions associated with snowy plovers (OPRD, 2007). This indicates that increased education could have a significant impact on public awareness of issues surrounding snowy plovers. Furthermore, the USFS at the Oregon Dunes National Recreation Area and the BLM staff have reported that the majority of contacted individuals are more willing to comply with beach-use restrictions after better understanding the reasons for them (FWS, 2007d).

JCEP would train all construction and operations staff on the need for snowy plover conservation; current snowy plover regulations and recreational use restrictions; and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on-leash, and remaining on established roads and trails. The training program would be developed based on guidance provided in Appendix K of the 2007 Plover Recovery Plan, or would be contracted for through state/local agencies or organizations (such as the Oregon Coast Aquarium, National Park Service, Western Snowy Plover Working Team, or Oregon Coast Community College) who may have pre-existing plover education and outreach programs. Prior to implementation, the training program would be submitted for comment to members of the Western Snowy Plover Working Team.

Environmental training would also be provided to operational personnel to ensure that all personnel are aware of and comply with the management tools in place to affect the recovery and maintenance of the snowy plover population on the North Spit. Printed educational materials would be posted at the proposed facilities for the life of the LNG terminal. Materials would also be distributed to existing North Spit employers for their use in training their personnel. The types of educational materials may vary, but could include posters, table tents, maps, brochures, or factsheets. Numerous sources for existing educational materials are provided in Appendix K of the Plover recovery plan (FWS, 2007d).

Monitoring

JCEP would fund one additional entry level Wildlife Services position dedicated to snowy plover predator monitoring and control during the 36-month construction period. This staff member would be employed by Oregon Wildlife Services, which is administered by the U.S. Department of Agriculture and Animal and Plant Health Inspection Services. The specific duties of this additional staff member would be determined by Wildlife Services based on Coos Bay North Spit management needs, but would concentrate on predator management. This additional position would allow Wildlife Services to better evaluate predator densities and more quickly and effectively respond in the unlikely event that predator pressure on the CBNS increases during Project construction.

### 4.3.2.5 Determination of Effects

**Species Effects**

The Project **may affect** western snowy plovers because:

- Active nesting by western snowy plovers occurs farther than 2.5 miles from the Port-LNG terminal analysis area. However, use of the Port-LNG terminal analysis area by western snowy plovers would be limited to infrequent occurrences.

- Snowy plovers nesting on the North Spit are currently affected by human use of the area whether due to destruction of nests by dogs, inadvertent trampling or deliberate vandalism and to diverse plover responses to human presence.
- Snowy plovers nesting on the North Spit are currently affected by scavengers and predators which may be attracted to nesting areas by human actions.
- The Project would result in a large but temporary increase in people employed on the North Spit during construction (up to 2,937 construction workers) and a much smaller long-term increase of operations staff (150 permanent employees at the LNG terminal).
- It is reasonable to assume that the LNG terminal construction and operations personnel would increase recreational uses of the North Spit. Increased recreational use could result in increased plover disturbance.
- Scavengers and predators (corvids, coyotes, striped skunk, feral cats), most of which are encouraged or attracted by human disturbance such as campsites, garbage dumps, work sites or even footprints in the sand may increase effects to nesting plovers as human use of the North Spit increases.

The project is **not likely to adversely affect** western snowy plover because:

- The nesting areas on the North Spit used by western snowy plover are approximately 1.1 miles from LNG terminal construction sites. Noise at nesting areas and critical habitat due to sheet pile driving is not expected be above ambient levels;
- Jordan Cove would minimize potential secondary effects to the critical habitat PCE that identifies disturbance by humans, pets, vehicles or human-attracted predators through implementation of 1) BMPs to minimize predator density related to increased human presence and habitat removal, and 2) education and outreach programs intended to train all construction and operations staff on the need for snowy plover conservation; current snowy plover regulations and recreational use restrictions; and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on-leash, and remaining on established roads and trails.

**Critical Habitat Effects**

The Project **may affect** designated critical habitat for the western snowy plover even though the northern end of critical habitat OR-10 on the North Spit is located approximately 2.6 miles from the LNG terminal.

- Essential physical and biological features of designated critical habitat includes the following PCE: sparsely vegetated areas above daily high tides that are relatively undisturbed by the presence of humans, pets, vehicles or human-attracted predators.
- Snowy plovers nesting on the North Spit are currently affected by human use of the area whether due to destruction of nests by dogs, inadvertent trampling or deliberate vandalism and to diverse plover responses to human presence.
- Snowy plovers nesting on the North Spit are currently affected by scavengers and predators which may be attracted to nesting areas by human actions.

However, the Project is **not likely to adversely affect** designated critical habitat for the western snowy plover because:

- Conservation measures provided by the FWS, the BLM, and the ODFW through the Sediment Placement subgroup of the Jordan Cove/Pacific Connector Interagency Task Force Working Group would be funded by Jordan Cove to enhance critical habitat by installing fencing, signage, applying shell hash, removing tree, eliminating beach grass and annual maintenance through 2020.
- Funding would be provided to the entity as defined by the agencies and it would be the responsibility of the particular entity to administer the funding.
- Jordan Cove would minimize potential secondary effects to the critical habitat PCE that identifies disturbance by humans, pets, vehicles or human-attracted predators through implementation of 1) BMPs to minimize predator density related to increased human presence and habitat removal, and 2) education and outreach programs intended to train all construction and operations staff on the need for snowy plover conservation; current snowy plover regulations and recreational use restrictions; and the importance of conservation measures, including: litter control, avoidance of nesting and foraging areas, keeping pets on-leash, and remaining on established roads and trails.

### 4.3.3 Marbled Murrelet

#### 4.3.3.1 Species Account and Critical Habitat

**Status**

Marbled murrelets (MAMUs) in Washington, Oregon, and California were listed as threatened under the ESA on October 1, 1992 (FWS, 1992a). The Final Rule cited loss and modification of nesting habitats, mostly by commercial timber harvest of late successional and old-growth forests, as the principal threat to the species, along with effects of coastal oil spills and gill-net fishing operations off the Washington coast (FWS, 1992a).

**Threats**

There are two components of marbled murrelet habitat that are biologically important: 1) terrestrial nesting habitat and associated stands, and 2) marine foraging habitat, including prey spawning and concentration areas. Threats to MAMU are apparent in both the terrestrial nesting environment and the marine foraging environment. Extensive harvest of late-successional and old-growth forest was the primary reason for listing the murrelet as threatened in 1992 (FWS, 1992a). In 1992, the amount of old-growth forest in western Oregon and Washington had been reduced by about 82.5 percent from pre-harvest levels. Because MAMUs utilize old-growth forests for nesting, this dramatic loss of older forested habitats is a serious threat to these birds. Harvesting within previously contiguous areas of old-growth forest causes habitat fragmentation on large and small scales. As forest fragmentation increases, the threat of habitat loss due to windthrow is likely to increase. Fire has also affected older coastal forests; however, unlike clearcut timber harvest, fire often allows diverse structural characteristics to develop in regenerating forests, such as scattered surviving old-growth trees that can be utilized by MAMUs for nesting (FWS, 1992a).

Predation is expected to be the principal factor limiting murrelet reproductive success and nest site selection (Ralph et al., 1995; Nelson and Hamer, 1995). Known predators of MAMU adults, chicks, and eggs in the terrestrial environment include great horned owls, peregrine falcon, sharp-shinned hawk, northern goshawk, bald eagle, Stellar’s jays, ravens and other corvids. Common ravens account for the majority of egg depredation (Nelson and Hamer, 1995).

Predation rates are influenced mainly by habitat stand size, habitat quality, nest placement (on the edge of a stand versus the interior of a stand), and proximity of the stand to human activity centers. Fragmentation of forested stands by timber harvest increases the potential for avian predation (FWS, 1992a). An increase in susceptibility of adults to predation can have greater impacts on MAMU populations than predation on eggs or young, as recent demographic modeling for MAMUs demonstrates (McShane et al., 2004).

Because MAMUs feed offshore, gill-net fisheries, especially for salmon, was an important mortality factor in 1992, primarily in Washington and British Columbia. New gill-netting regulations in northern California and Washington have reduced the threat to MAMUs (McShane et al., 2004). Off-shore oil spills, such as the *Exxon Valdez,* have also adversely affected MAMUs by causing direct mortality (FWS, 1992a). The 1999 oil spill associated with the grounding and wreck of the *New Carissa* on the Oregon coast near Coos Bay killed 252 MAMUs, the highest mortality for any spill during the 1993 to 2003 period (McShane et al., 2004). Oil spills and related mortality of MAMUs are believed to have remained constant since the species was listed. Although there has been a moratorium on offshore oil drilling off the California, Oregon, and Washington coastlines, there has been increased shipping traffic, including oil tankers, carrying the risk of future spills (McShane et al., 2004).

Other factors contributing to demographic threats and population viability include: 1) loss of genetic variation as a result of low population numbers and low immigration rates, 2) low potential for recolonization or recovery from local disturbances due to low immigration rates, and 3) bacterial, fungal, parasitic, and viral diseases, including potentially West Nile Virus (McShane et al., 2004).

**Species Recovery**

FWS published a recovery plan for the MAMU in 1997 for Washington, Oregon, and California (FWS, 1997). The objective of the recovery plan is to stabilize population size at or near current levels by increasing population productivity and removing and/or minimizing threats to survivorship. In the short-term, specific actions necessary to stabilize the population include maintaining occupied habitat, maintaining large blocks of suitable habitat, maintaining and enhancing buffer habitat, decreasing risks of nesting habitat loss due to fire and windthrow, reducing predation, and minimizing disturbance. Long-term conservation actions include increasing productivity and population size, increasing the amount, quality, and distribution of suitable nesting habitat, protecting and improving the quality of the marine environment, reducing or eliminating threats to survivorship, reducing predation in the terrestrial environment, and reducing anthropogenic sources of mortality at sea (FWS, 1997).

The recovery plan divided the range of the marbled murrelet into six Conservation Zones that extend inland a distance of up to 35 miles, coinciding with the “Inland Zone 1” boundary line described by the FEMAT for the NWFP: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6). FEMAT Inland Zone 1 contains large blocks of suitable habitat critical to the recovery of the marbled murrelet within California, Oregon, and Washington. The proposed action occurs within the highest density zones along Oregon’s coast (Conservation Zones 3 and 4), although the largest populations of murrelets are in Puget Sound and Strait of Juan de Fuca of Washington – Zone 1 (Huff et al., 2006). Management for

Conservation Zones 3 and 4 recommend the following: maintain designated occupied sites, minimize loss of unoccupied but suitable habitat, and decrease the time for development of new habitat. Specific recovery efforts should focus on maintenance of suitable and occupied marbled murrelet nesting habitat in BLM-administered forests (FWS, 1997).

FWS (2006e) concluded that the maintenance and/or increase of suitable nesting MAMU habitat in relatively large, contiguous blocks, whether occupied or unoccupied, would be needed to recover the MAMU, since unoccupied suitable habitat in proximity to occupied habitat could be used by dispersing MAMUs. Despite the above protection measures, an approximate 7 percent decline in the amount of available, higher suitable nesting habitat has been observed since the NWFP was implemented (1994 to 2006/2007). Stand-replacing fires on federal lands and habitat removal on nonfederal lands have been identified as the primary causes of more recent habitat loss (Raphael et al., 2011). Based on habitat modeling using 2006 habitat data, Raphael et al. (2011) estimated that there are approximately 1.4 million acres of moderately high to high suitable habitat available within the following states: Washington (802,700 acres), California (97,600 acres), and Oregon (486,200 acres).

**Life History, Habitat Requirements, and Distribution**

The MAMU is a long-lived, small seabird that spends most of its life in the marine environment, but utilizes a distinct nesting habitat type from other Alcidae (guillemots, puffins, auklets and murres), nesting primarily in coastal, old growth forests characterized by large trees, multi-storied stands, and moderate-to-high canopy coverage from Alaska to Monterey Bay, California (FWS, 2006e). They are also known to nest in mature forests with old-growth characteristics. Trees must have large branches or deformities such as high, moss-covered branches or branches with growths of dwarf mistletoe, which serve as nest platforms (Binford et al., 1975; Marshall, 1988a; Naslund, 1993; FWS, 1997). Old-growth conifers generally provide requisite conditions for MAMU nesting: 1) openings in forest canopies for nest access, 2) nest platforms on large branches or tree deformities, 3) substrate (mosses or epiphytes) for a nest cup, 4) horizontal and vertical cover at the nest site, and 5) enough height above ground to allow for “drop take-offs” and “stalled drop-in” landings (McShane et al., 2004). Generally, forests that provide suitable nesting habitat and nest trees require 200 to 250 years to develop (FWS, 2006e).

The distance inland that MAMUs breed is variable and influenced by a number of factors such as habitat availability, climate suitability, foraging range, and predation rates (McShane et al., 2004). In Oregon, MAMU nest sites and occupied stands are located as far as 30 to 40 miles from salt water (Mack et al., 2003), although most often sites are found within 12 miles of the ocean (FWS, 1996a). Social interactions may also play an important role in determining nesting location, since research has indicated that MAMUs in California and southern Oregon were less likely to occupy old-growth habitat if it was isolated from other nesting MAMUs by more than 3 miles (Meyer et al., 2002a). Murrelets do not form dense colonies, which is atypical for most seabirds; this is most likely to avoid detection by predators (Ralph et al., 1995). Also, in Oregon, MAMU occupied stands and nest sites are generally located away from high-contrast edge created by certain timber harvest practices and adjacent immature forests, most likely to reduce predation risk on eggs and juvenile MAMUs (Ripple et al., 2003). Meyer et al. (2002a) found at least a few years passed before birds abandoned fragmented forests. In northern California and southern Oregon, Meyer et al. (2002a) concluded that MAMU occupancy was most related to availability of low elevation, unfragmented old-growth forests within the fog zone that were close to highly productive marine areas. Federal lands account for the majority of suitable MAMU habitat in California, Oregon, and Washington (McShane et al., 2004).

These small seabirds spend most of their lives in the marine environment where they forage in shallow off-shore and inland saltwater areas on a variety of small fish and invertebrates, and large pelagic invertebrates (Marshall, 1988a, 1988b, and 1989; Becker, 2001). In Oregon and Washington, anchovy, sand lance, and smelt appear to be the major prey types provided to chicks (McShane et al., 2004). Murrelets generally forage within 3 miles of shore in western North America, although during the breeding season they stay closer to the coast, e.g., within 1.2 miles in Oregon (McShane et al., 2004). Courtship, loafing, molting, and preening also occur in near-shore marine waters (Nelson, 1997). The proposed action is within the zone of highest density of MAMUs along Oregon's coast, although the largest populations of MAMUs are in the Puget Sound and Strait of Juan de Fuca of Washington (Huff et al., 2006).

MAMUs are usually present year-round in California, Oregon, and Washington, whereas farther north in their breeding range, seasonal migration is common. Murrelets would migrate back to breeding grounds in the north in early to mid-April (McShane et al., 2004). Research suggests that MAMUs demonstrate site fidelity (Huff et al., 2006).

Breeding is asynchronous in the MAMU, varying regionally, although generally occurring between April and September (McShane et al., 2004; Huff et al., 2006). Both sexes share the incubation and foraging duties, usually with duty exchanges occurring at dawn. One to two days after hatching the chick will be left alone while both parents forage at sea. The chick will receive 1 to 8 meals per day, with the majority of the meals delivered in the morning, usually before sunrise. Additional meals are delivered at dusk and occasionally throughout the day. Murrelet chicks fledge from the nest 27 to 40 days after hatching, usually at dusk (McShane et al., 2004). Existing data do not provide information on how far or where fledglings disperse.

Sex ratios of juveniles and adults are equal and breeding begins when birds are 2 to 5 years old; only 1 egg is laid per breeding season (McShane et al., 2004). A substantial proportion of nests is known to fail (Nelson and Hamer, 1995); breeding success has been documented as high as 0.46 chicks per breeding pair in southern British Columbia but lower in northern California where telemetry studies documented between 0.135 and 0.324 chicks per pair (McShane et al., 2004). Such low breeding success is not expected to sustain populations in which adult survivorship ranges from 0.83 to 0.93. The mean lifespan of MAMUs is 10 years (McShane et al., 2004).

**Population Status**

The exact population size of MAMUs is not known; however, the North American population is currently thought to be about 950,000 birds, based on counts at sea (Huff et al., 2006). In the early 1990s, murrelet abundance in Washington, Oregon, and California had been estimated at 18,550 to 32,000 (Ralph et al., 1995). In the late 1990s, population survey protocols were established to provide a consistent methodology for estimating murrelet population and population trends. From 2000 to 2010, marbled murrelet population estimates within five conservation zones (Zones 1 through 5) in California, Oregon, and Washington ranged from 23,700 birds in 2002 to a low of 16,700 birds in 2010, representing a significant, average rate of decline of 3.7 percent annually (Miller et al., 2012). Within Conservation Zones 3 and 4 (which extend from northern California to Coos Bay and from Coos Bay the Columbia River), an average annual decline of 1.5 and 0.9 percent have been observed, respectively, although the trends are not significant (Miller et al., 2012). Using the data and trends provided in Miller et al. (2012) and other sources for time intervals [(2009-2010) Falxa et al, 2011, (2008) Falxa et al., 2009, (2000-2007) Marbled Murrelet Effectiveness Monitoring Program, 2008] a predicted estimate of marbled murrelets within Conservation Zones 3 and 4 by the proposed JCEP LNG terminal in-service year (2018) is 9,058 birds, but could range from 4,878 to 13,238 birds, based on 95 percent prediction intervals (estimated interval within which future observations are likely occur with a 95 percent probability, based on what was already observed and applied in the regression analysis). Figure 4.3-4 shows the declining population trend from 2000 to 2010 in Conservation Zones 3 and 4, combined, as well as projections of murrelet populations through construction of the Project (through 2017) using data from Miller et al. (2012) and other sources (see above).

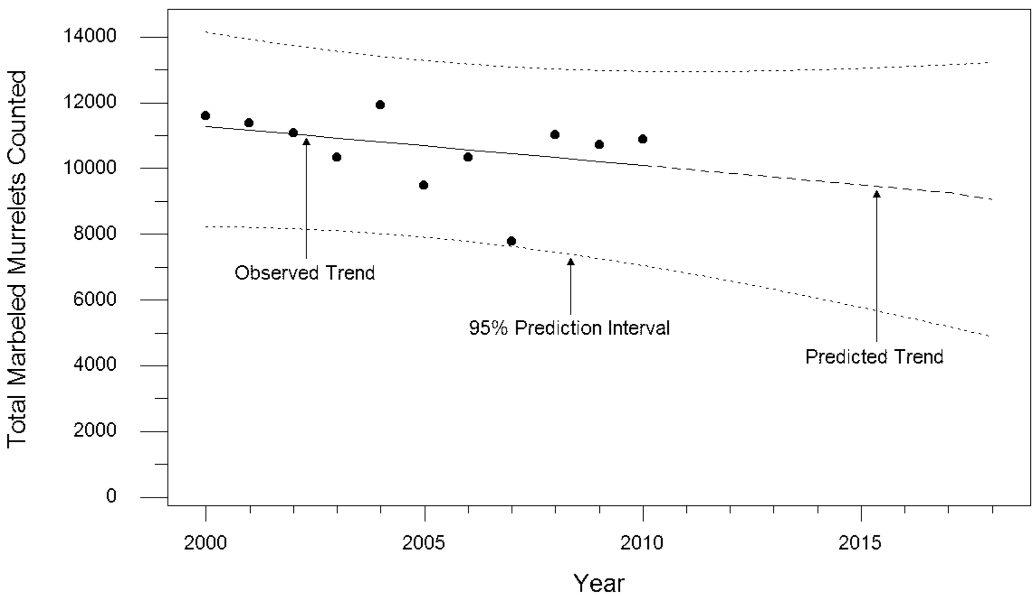



**Figure 4.3-4**
**Marbled Murrelet Population Trends from 2000 to 2010, and Predicted Estimates through Initial Operation of the JCEP LNG Project (through 2018) Based on Population Estimates Recorded for Conservation Zones 3 and 4, as well as 95% prediction intervals from 2000 through 2018 (see Miller et al., 2012)**

### Critical Habitat

Critical habitat for the MAMU was designated in Washington, Oregon, and California on May 24, 1996 and included 3,887,000 acres in 32 critical habitat units (CHUs; FWS, 1996a). On July 31, 2008, FWS proposed a revision to the 1996 critical habitat designation, proposing to remove approximately 254,070 acres in northern California and Oregon. This proposal was based on new information indicating that these areas do not meet the definition of critical habitat (FWS, 2008b). Critical habitat for the marbled murrelet was revised in 2011, removing approximately 189,671 acres in northern California and southern Oregon from the 1996 designation (FWS, 2011a). Habitat removed from the 1996 designation included areas in northern California within Inland Zone 2 that did not have historical or current survey records documenting marbled murrelet presence, and habitat in southern Oregon that is not associated with the hemlock/tanoak zone. The revised critical habitat includes approximately 3,698,100 acres in 22 CHUs within Washington, Oregon, and California.

There are two components of MAMU habitat that are biologically important: 1) marine foraging habitat, including prey spawning and concentration areas, and 2) terrestrial nesting habitat and associated stands. Because FWS is unable to define specific marine areas essential to the conservation of the species, only terrestrial habitat is considered for designation as critical habitat. Throughout the forested portion of their range, MAMU habitat use is positively associated with the presence and abundance of mature and old-growth forests, large core areas of old-growth, low amounts of edge and fragmentation, proximity to the marine environment, and increasing forest age and height, although the presence of platforms is the most important characteristic of nesting habitat (FWS, 2006e). As a result, the FWS designated the following as primary constituent elements (FWS, 2006e) that remain applicable to the revised critical habitat designated for the marbled murrelet (FWS, 2008b and 2011a): 1) forested stands containing large-sized trees, generally greater than 32 inches in diameter with potential nesting platforms at sufficient heights (≥ 33 feet); and 2) surrounding forested areas within 0.5 mile of these stands with a canopy height of at least one-half the site-potential tree height. In Oregon, trees with platforms have been greater than 19 inches diameter-at-breast-height and at least 98 feet tall (FWS, 2006e).

**NWFP Late-Successional Reserves**

Additional habitat protection for the marbled murrelet was established when the BLM and Forest Service in Washington, Oregon, and northern California adopted the NWFP in 1994. The NWFP defined the nesting portion of the marbled murrelet range into two inland zones: 1) Inland Zone 1, which is a 10- to 35-mile zone closer to the coast where the majority of murrelet nests and detections are located, and 2) Inland Zone 2 where detection data indicated only a small fraction of the murrelet population nests (Forest Ecosystem Management Assessment Team – FEMAT, 1993). Large amounts of Forest Service and BLM-administered lands were allocated for LSRs, of which the primary objective is to protect and enhance conditions of late-successional and old-growth forest ecosystems. These lands could then serve as habitat for old-growth-related species including the MAMU, while maintaining diversity associated with native species and thus providing a network of fully functioning LSRs in National Forests throughout the Pacific Northwest (USFS and BLM, 1994). The goals for LSR management are consistent with the function of CHUs to contribute to recovery of MAMUs. Management of LSRs should not only protect habitat currently suitable to MAMUs, but also promote the development of additional MAMU habitat on the landscape. A good portion of the federally designated critical habitats for MAMUs has an overlap with LSR designation.

The NWFP Standards and Guidelines also state that sites occupied by MAMUs and known northern spotted owl activity centers (100-acre areas identified by BLM and Forest Service), but occur within NWFP-designated matrix lands, are considered "unmapped LSRs" and managed as lands allocated as LSRs by the NWFP. Coos Bay and Roseburg BLM Districts also provide more specific management direction within their respective resource management plans to protect MAMUs and their habitat, including (Resource Management Plans; BLM, 1995a and 1995b): 1) protect and enhance contiguous, recruitment habitat within 0.5 mile of an occupied stand, and 2) restrict timber harvest within occupied marbled murrelet stands.

### 4.3.3.2 Environmental Baseline

**Analysis Area**

MAMU habitat can be categorized into various components, based on the life cycle needs of the species. Three main components that may be affected by Project-related activities are outlined below.

Terrestrial Nesting Analysis Area

Per direction provided in the FWS Conservation Framework (Trask & Associates, 2013 in appendix Z4), there are two components that are included in the Terrestrial Nesting Analysis Area: one for habitat removal or modification, and a second for disturbance/disruption of MAMU during the breeding season. The two components are combined together to create the Terrestrial Nesting Analysis Area. The Terrestrial Nesting Analysis Area extends inland along the Pacific Connector pipeline route to include MAMU Inland Zone 1 – MPs 1.47R to 53.73 - and MAMU Inland Zone 2 – MPs 53.73 to 75.64 and is shown in figure 4.3-5. The FWS Conservation Framework introduces MAMU suitable habitat units (SHUs) that define an area associated with each MAMU stand. The MAMU SHU consists of three elements (Trask & Associates, 2013): 1) MAMU stands considered for analysis within this BA, 2) a 300-foot buffer around each MAMU stand, and 3) federally-designated critical habitat that occurs within a 0.5-mile buffer of MAMU stands that are within 0.5 mile of critical habitat removal. Critical habitat located within the 0.5-mile buffer is an area considered important to the recovery of the species (see Trask & Associates, 2013 in appendix Z4). The 300-foot buffer incorporates an area that should maintain the integrity of the MAMU stand from windthrow or other environmental disturbances as well as provide protection from potential predation (FWS, 1997; ODF, 2004).

**Habitat Removal or modification:** This portion of the analysis area applies to all proposed action components that have the potential to remove or modify habitat, including construction of the LNG facilities and PCGP Project, as well as a 100-meter (328 feet) wide buffer along each edge of the area of habitat impact (e.g., edge of right-of-way, temporary extra work areas, new roads built for project access, etc.) in recruitment or capable habitat throughout the entire range of MAMU. It also includes MAMU SHUs that are included for analysis within this BA.

**Disturbance/Disruption (breeding season only):** The Terrestrial Nesting Analysis Area also includes all lands within 0.25 mile of the Project components (including identified access roads). Access roads considered do not include paved roads that are used regularly by the public (i.e., county roads, state highways). The size of this analysis area considers the maximum distance at which MAMUs could be harassed during the breeding season (April 1 through September 15) by noise generated from general construction, operation, and maintenance activities, smoke from burning slash piles, blasting, and/or Boeing Chinook (CH-47) or Boeing Vertol 107 (CH-46) helicopter use of the proposed action, or use of access roads (FWS, 2003b; Noise Report, appendix P).

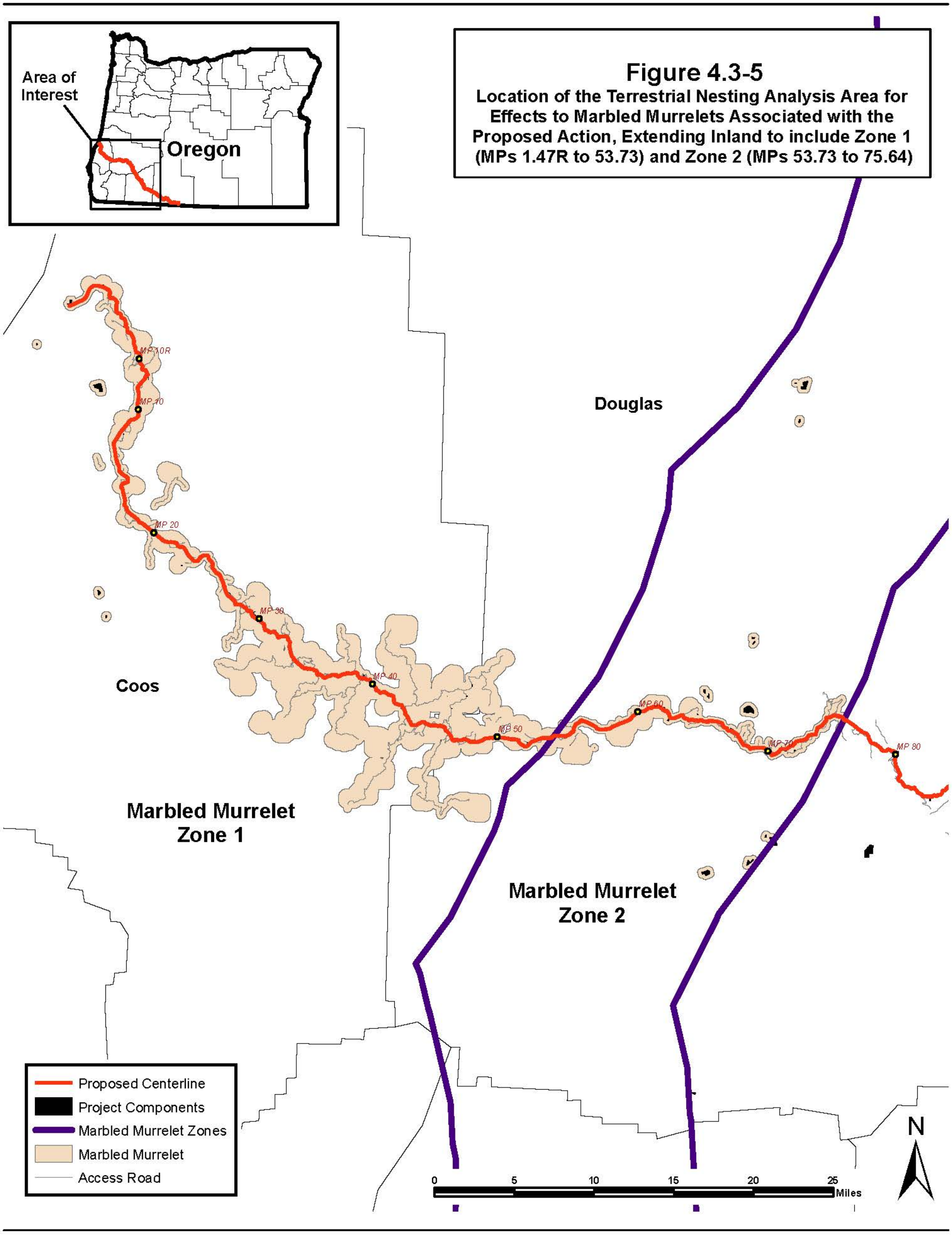


Figure 4.3-5
Location of the Terrestrial Nesting Analysis Area for Effects to Marbled Murrelets Associated with the Proposed Action, Extending Inland to include Zone 1 (MPs 1.47R to 53.73) and Zone 2 (MPs 53.73 to 75.64)
Area of Interest
Oregon
MP 10R
MP 10
MP 20
MP 30
MP 40
MP 50
MP 60
MP 70
MP 80
Douglas
Coos
Marbled Murrelet Zone 1
Marbled Murrelet Zone 2
Proposed Centerline
Project Components
Marbled Murrelet Zones
Marbled Murrelet
Access Road
0
5
10
15
20
25
Miles
N

Estuarine Analysis Area

The second component is the Coos Bay Estuarine analysis area (see figure 4.3-6) which encompasses all estuarine waters (and substrates) that are within the estuary between the North Jetty and South Jetty at the Coos Head entrance to the bay. The Estuarine analysis area includes 1) operational activities by LNG tankers entering and exiting Coos Bay, 2) approximately 3.1 miles downstream from the proposed LNG Terminal to a point 2.2 miles upstream from that site (distances were estimated for potential worst-case dispersion of turbidity, as provided by Moffatt and Nichol, 2006a), and 3) the 2.45-mile within-estuary route of the Pacific Connector pipeline after leaving the Weyerhauser property at MP 1.7R, crossing Haynes Inlet to where the pipeline emerges from the estuary at MP 4.1R.

EEZ Analysis Area

The third area which could be affected by the proposed action is the EEZ (see figure 4.2-1), which extends 200 nautical miles offshore. Within the analysis area, effects to the MAMU would be associated with LNG tankers which are assumed to transect the EEZ perpendicularly - east and west - as they approach and depart from Coos Bay (see the discussion above under Section 4.2.1, Blue Whale).

**Species Presence**

The proposed action occurs within Marbled Murrelet Inland Zone 1 and Marbled Murrelet Inland Zone 2; marbled murrelet nesting has been documented within the two inland zones in and near the Terrestrial Nesting Analysis Area. MAMU nesting behavior is cryptic, however, resulting in few nests being located by biologists. As a result, documented behaviors assumed to be associated with nesting, such as MAMUs flying into the canopy or circling very close above the canopy are used to infer nesting activity and thus occupancy of MAMU stands. Since these occupied behaviors are not detected during every visit to a stand, the Pacific Seabird Group inland MAMU survey protocol (Mack et al., 2003) recommends several visits to a stand that contains potential MAMU nest trees (up to 9 per year) for a duration of two years in order to determine with some certainty that a timbered stand is occupied or unoccupied. When occupied behavior is identified, the managing agency delineates the occupied stand and provides a master site number (MSNO). That stand is then considered "occupied" in perpetuity (Mack et al., 2003).

Pacific Connector obtained GIS data layers from Coos Bay and Roseburg BLM Districts (BLM, 2006; Espinosa, 2007 and 2008; Guetterman, 2007 and 2008a, b; NSR, 2012) to determine areas with known MAMU occupancy. Additionally, Pacific Connector requested murrelet survey data from private landowners within the project area; in 2008 Weyerhaeuser Timber Company provided Pacific Connector GIS files with areas of known MAMU occupancy and these areas have been incorporated into this BA. Within Marbled Murrelet Zones 1 and 2 along the Coast Range Province a total of 341 occupied MAMU stands were delineated, of which 261 were located within the Coos Bay and Roseburg BLM Districts. Overall, 46 occupied MAMU stands are considered for analysis within this BA. With the exception of two occupied stands identified/delineated on private timber lands, all occupied stands occur on BLM-administered lands within either Coos Bay or Roseburg BLM Districts, including 10 stands identified during surveys conducted by Pacific Connector in 2007 and 2008, and six stands identified during surveys conducted by Pacific Connector in 2013. See Pacific Connector survey details, below.

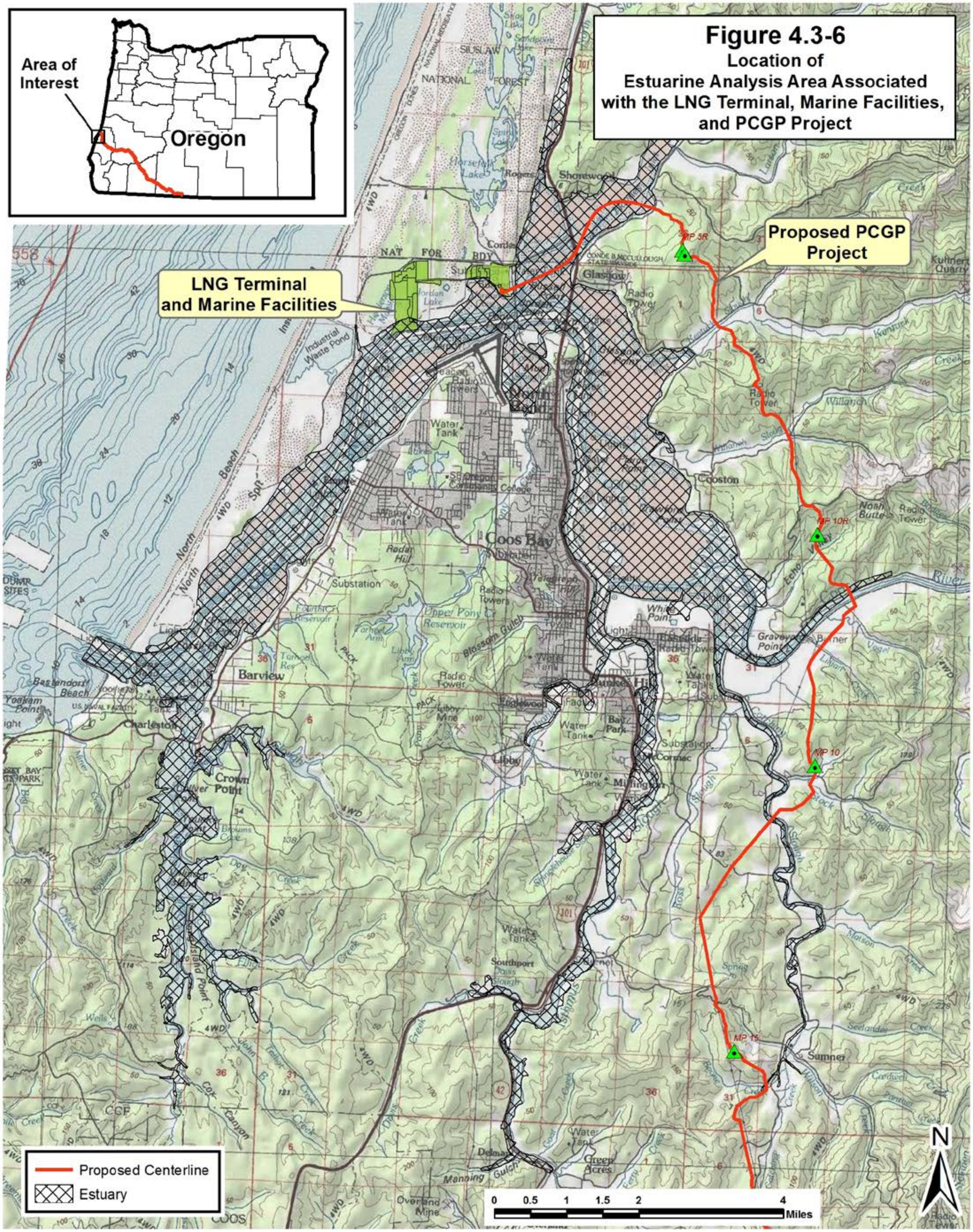


Figure 4.3-6
Location of
Estuarine Analysis Area Associated
with the LNG Terminal, Marine Facilities,
and PCGP Project
Area of Interest
Oregon
Proposed PCGP Project
LNG Terminal and Marine Facilities
MP 5R
MP 10R
MP 10
MP 15
Proposed Centerline
Estuary
0 0.5 1 1.5 2 4
Miles
N
Coos Bay
North Bend
Charleston
Barview
Glasgow
Cooston
Sumner
Libby
Millington
Southport
Green Acres

Pacific Connector Marbled Murrelet Surveys (2007/2008 and 2013/2014)

To determine known or presumed species presence within the proposed PCGP Project area, Pacific Connector contracted surveyors [Siskiyou BioSurveyors, Inc. (SBS) and Rogers & Associates (R&A)] to conduct two-year surveys within habitat containing suitable nesting structures as described by Mack et al. (2003).

Prior to surveys in 2007, habitat within 50 miles of the coast and within 0.25 mile of the proposed action was assessed by Richard Brock, Botanist and GIS Specialist for SBS, to determine all potential suitable MAMU nesting habitat within the analysis area. This analysis determined where MAMU surveys should be conducted for the PCGP Project. Delineation of suitable habitat was accomplished using a combination of aerial photographs (circa 2006), BLM FOI GIS data, local knowledge of on-the-ground habitat, and LIDAR that was flown in a corridor including 0.25 mile on either side of the proposed PCGP Project. As the proposed route changed, habitat was reassessed and included in survey efforts, if necessary.

A LIDAR data set was generated that displayed all trees with a canopy height greater than 107 feet. Polygons were derived from these data to indicate possible suitable MAMU nesting habitat and/or trees. Within 20 miles of the coastline a single tree qualified as potential nesting habitat (see SBS, 2008a). Further inland, clusters of 6 or more large trees within a floating 5 acre window were considered potential habitat. These polygons were reviewed using aerial photos and BLM FOI data to determine which stands were apparent habitat and which were uncertain habitat that required on-the-ground examination (referred to as "gray habitat"). To represent gray habitat, separate polygons were created. Areas with potential suitable habitat identified within 0.25 mile of the proposed Project were then plotted on maps.

**Initial Surveys – 2007/2008:** In areas where permission to survey had been granted, R&A conducted on-the-ground surveys to determine whether timber stands exhibited the characteristics of nesting habitat outlined in the Pacific Seabird Group protocol (Mack et al., 2003). Overall, 65 of 118 identified stands were examined, of which 46 of 65 (71 percent) timber stands and/or trees were determined not to exhibit the necessary nest tree characteristics and were removed from the list of stands/acreage to be surveyed for this Project. Two of these areas had been harvested in 2007 or 2008. In stands that exhibited potential nesting habitat and had landowner survey permission, R&A initiated the Pacific Seabird Group two-year survey protocol to detect occupied MAMU behavior during the MAMU nesting period from May 1 through August 5, 2007 (see Mack et al., 2003). Second year surveys were conducted in 2008 in stands that had survey permission in 2007 but did not have occupied behavior detected. Also in 2008, where ground-truthing identified suitable nesting structures in timbered stands within one mile of helicopter use and trench-blasting sites, first year surveys were conducted. Surveys were not conducted in 52 stands due to access denial by landowners of the proposed route as analyzed in the 2009 FERC FEIS. Additionally, ground-reconnaissance and/or protocol surveys were not conducted in 20 stands that were delineated in two reroutes analyzed in the final EIS (WC1A – upland Coos Bay route and Southern Route Alternative-R).

MAMU survey stations were set up on property where access was allowed and timber stands exhibited the characteristics of nesting habitat outlined in the Pacific Seabird Group protocol (Mack et al., 2003). Survey stations were positioned in such a manner that all of the potential habitat in a given stand could be seen, and that any MAMUs present would be able to be seen against the sky. Overall, R&A documented MAMU occupied behavior in 10 stands. Nine stands surveyed in 2007 and 2008 did not exhibit occupied behavior, and therefore were considered unoccupied.

Identified trees and/or timbered stands with potential suitable habitat located within the Terrestrial Nesting Analysis Area had either 1) one year of surveys conducted in 2008 and no occupied behavior detected (GS05), or 2) did not have survey access permission. Potentially suitable MAMU habitat that remains unsurveyed because of landowner access denial or incomplete surveys (e.g., only one year completed or no surveys) are considered "presumed occupied" for this biological assessment (see "Unsurveyed Suitable Habitat" in PC Trask & Associates, 2013 in appendix Z4).

**Additional Surveys – 2012/2013/2014:** In 2012, Pacific Connector reviewed 2012 aerial photography to determine if the 2007/2008 "presumed occupied" stands within the current Terrestrial Nesting Analysis Area were still forested; three had been harvested and removed for consideration as presumed occupied stands. Five other areas considered in 2007 that were determined not to provide suitable nesting habitat for the murrelets had also been harvested since 2006.

Also in 2012, where permission was received within the WC1A – upland Coos Bay route and Southern Route Alternative-R, R&A conducted on-the-ground surveys to determine whether timber stands exhibited the characteristics of nesting habitat outlined in the Pacific Seabird Group protocol (Mack et al., 2003). Twelve "stands" were ground-truthed in the WC1A Upland Coos Bay route and no suitable nesting habitat was observed (R&A, 2012); subsequently the 12 stands have been removed for consideration as "presumed occupied" for analysis in this BA. In the Southern Route Alternative-R one stand (MAMU Stand ALTR-A) on BLM-managed lands was determined to provide suitable nesting habitat for marbled murrelets and was surveyed in 2013 (see below), whereas three other stands did not provide suitable nesting structures for marbled murrelets and were removed from consideration as "presumed occupied" for this BA (R&A, 2012). Five stands within the 2009 FERC FEIS proposed reroutes that were not permitted survey access remain as "presumed occupied" stands for analysis in this BA.

Pacific Connector initiated additional surveys in suitable marbled murrelet nesting habitat where surveys were permitted to determine presence or absence of occupied behavior in accordance with the Pacific Seabird Group two-year survey protocol for marbled murrelets (see Mack et al., 2003). Surveys included five areas surveyed in 2007 and 2008 that did not detect occupied behavior (unoccupied stands: B02, B03, B07, B13, and B14), as well as three areas where suitable nesting habitat is present, but surveys in 2007 and/or 2008 did not occur [i.e., Southern Route Alternative-R (ALTR-A stand), Weaver Ridge reroute (EAR 46.51_A), and an area that received one year of surveys in 2008 (GS05)]. These areas are all located on BLM-administered lands. Six of the eight stands surveyed in 2013 were determined to be occupied by MAMU (R&A and SBS, 2014), including three stands that were considered "unoccupied" from surveys conducted in 2007 and 2008 (B02, B03, and B07). Coos Bay and Roseburg BLM Districts were provided the appropriate survey results; each Distirict has delineated the occupied stands and provided an MSNO for each MAMU stand that are included in analysis for this BA. Both the survey stand numbers and the MSNO provided by each BLM District for the stands documented in 2013 are included in this BA (B02 = C1080, B03 = C3163, B07 = C3165, GS05 = C3164, ALTR-A = R3036, and EAR 46.51_A = R3035). [Note: the private portion of "presumed occupied" stand ALTR-A was not surveyed and remains "presumed occupied]. Surveys will continue in the other two unoccupied stands (B13 and B14) in 2014. If additional "presumed occupied" stands receive permission to be surveyed and exhibit suitable nesting habitat, full protocol surveys will be initiated in 2014 and continue through 2015. When additional information on the status of these potential trees and/or timbered stands is acquired, Pacific

Connector would advise the FWS of the updated status, including whether it is determined to have suitable nesting structures, determined to be occupied or unoccupied, or determined to not be suitable habitat for nesting MAMUs.

One large "presumed occupied" (G50) received permission to survey in 2013; ground-truthing stand structures determined that no suitable nest trees were present (R&A and SBS, 2014). This presumed occupied stand has been subsequently removed from this BA analysis.

<u>Additional Stands Delineated – No Survey</u>

Additional direction was provided by the FWS and BLM Districts (Roseburg and Coos Bay) to identify and include additional unsurveyed suitable habitat that was not previously identified along PCGP proposed existing access roads, and additional stands that may be within 0.25 mile of construction activities, but not within 100 meters (328 feet) of timber removal (see survey guidance provided by FWS in SBS, 2008a). On BLM-administered lands, additional "presumed occupied" stands were delineated using MAMU-specific GIS layers provided by Coos Bay and Roseburg BLM Districts, in conjunction with BLM FOI data, a Pacific Connector delineated vegetation layer, and previous Pacific Connector ground-truthing survey efforts. Additional stands were delineated on private lands where the new MAMU habitat model (see below) had a dense grouping of modeled "value 4" pixels ("highest suitability") and forested habitat was present in an obvious stand that could be delineated, and which had not been harvested; 2012 aerial photography and a Pacific Connector GIS vegetation layer was used to help delineate these areas. The additional "presumed occupied" stands on BLM-administered and private lands were either provided a "PO" and sequential number from west to east along the proposed PCGP pipeline, or an existing access road name from the PCGP Project (i.e. EAR and MP range) plus a letter if within close proximity to a proposed existing access road. These areas will not be surveyed but Pacific Connector will assume they are occupied (i.e., presumed occupied stand) for analysis within this BA, particularly in relation to disturbance from the proposed action.

<u>Marbled Murrelet Stands Considered for Analysis within the Terrestrial Nesting Analysis Area</u>

Overall, 173 MAMU stands have been included for analysis within this BA. MAMU stands were included if located within 0.25 mile of the proposed action, including 0.25 mile from PCGP proposed existing access roads (excluding paved public roads used regularly by the public – i.e., county roads or state highways). Marbled murrelet stands were also included for analysis if located within 0.5 mile of federally-designated critical habitat that would be affected by the proposed action. Forty-six occupied stands (as defined by occupied behavior) are considered for analysis, including 16 stands detected during survey efforts by Pacific Connector within the proposed Project area in 2007, 2008, or 2013. Twenty-five occupied stands are only included because they are within 0.25 mile of proposed existing access roads, including two stands determined to be occupied during PCGP 2007/2008 MAMU survey efforts. Three stands analyzed in this draft BA are considered "unoccupied" – either surveyed in 2007/2008 (one stand) or surveyed again 2013 (two stands) with no occupied behavior detected. The other 124 stands included for analysis in this BA are "presumed occupied" - they either have had survey permission denied by the private landowner (36 stands) or have been recently incorporated into the analysis based on new information (BLM GIS data layers and MAMU habitat model) and direction from BLM and FWS (88 stands).

The number of "presumed occupied" stands present within the analysis area is most likely an overestimation. Pacific Connector does not expect presumed occupied stands between MPs 8.0R and 30.0 to have suitable habitat present based on 1) on-the-ground surveys adjacent to those stands with no suitable nesting habitat (see maps included in appendix Z1), 2) location of those identified stands within narrow riparian buffers surrounded by clear-cuts and/or residences, and/or 3) proximity of presumed occupied stands greater than 3.0 miles from known occupied stands. Presumed occupied stands with an asterisk next to their “Site ID” in tables Q-1 and Q-2 in appendix Q identify stands that exhibit at least one of the factors listed above. Additionally, FWS (2006e) indicated that generally, forests that provide suitable nesting habitat and nest trees require 200 to 250 years to develop. The majority of stands identified as “presumed occupied” do not occur in old-growth forest.

Table 4.3.3-1 below summarizes the number of MAMU stands (and status) considered for this analysis within each Marbled Murrelet Zone, by landowner in the Terrestrial Nesting Analysis Area. The table also tallies the number of stands that are included because of its proximity to proposed habitat removal and/or access roads for each Zone. Table Q-1 in appendix Q provides details for each stand, including location in relation to proposed action, distance from proposed action including access roads, landowner, land allocation, and overall acres in stand by Marbled Murrelet Inland Zone. Figure 1 in appendix Q shows an overview of occupied, unoccupied, and presumed occupied stands within the Analysis Area (occupied stands provided by Coos Bay and Roseburg BLM Districts, as well as North State Resources (NSR, 2012) are also depicted beyond the analysis area).

**Table 4.3.3-1**
**Summary of Marbled Murrelet Occupied, Unoccupied, or Presumed Occupied Stands within the Terrestrial Analysis Area that Will Be Analyzed in this Biological Assessment**

| Status of MAMU Stand [1] | Landowner | Marbled Murrelet Inland Zone 1 | | | Marbled Murrelet Inland Zone 2 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Stands in Zone 1 | Habitat Affected [2] | Access Roads [3] | Stands in Zone 2 | Habitat Affected [2] | Access Roads [3] | Total Stands | Habitat Affected [2] | Access Roads [3] |
| Occupied | Federal | 44 | 20 | 44 | 1 | 1 | 1 | 45 | 21 | 45 |
| | Non-Federal | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Occupied Total | | 45 | 20 | 45 | 1 | 1 | 1 | 46 | 21 | 46 |
| Unoccupied | Federal | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unoccupied Total | | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| Presumed Occupied | Federal | 61 | 14 | 58 | 8 | 5 | 7 | 69 | 19 | 65 |
| | Non-Federal | 55 | 44 | 51 | 0 | 0 | 0 | 55 | 44 | 51 |
| Presumed Occupied Total | | 116 | 58 | 109 | 8 | 5 | 7 | 124 | 63 | 116 |
| Overall Total | Federal | 116 | 35 | 103 | 11 | 8 | 10 | 117 | 43 | 113 |
| | Non-Federal | 49 | 44 | 52 | 0 | 0 | 0 | 56 | 44 | 52 |
| Overall Total | | 162 | 79 | 153 | 11 | 8 | 10 | 173 | 87 | 165 |

[1] “Occupied”: delineated stand that has identified occupied behavior during protocol surveys; “Unoccupied”: forested stand that provides suitable MAMU nesting structures but no occupied behavior has been detected during survey efforts; “Presumed Occupied”: forested stand has not been surveyed and habitat present is expected to provide suitable nesting structures.

[2] Habitat Affected considers MAMU stands located within 0.25 mile of all proposed disturbance, including uncleared storage areas (UCSAs), as well as stands within 0.5 mile of federally-designated critical habitat removal.

[3] Access roads considered does not include paved roads that are used regularly by the public (i.e., County Roads, State Highways). MAMU stands are included if the stand is within 0.25 mile of a proposed access road.

Table Q-1 in appendix Q provides details for each stand, including location in relation to proposed action, distance from proposed action including access roads, landowner, land allocation, and overall acres in stand by Marbled Murrelet Inland Zone.

Marbled Murrelet Presence within the Estuarine and EEZ Analysis Areas

Because occupied MAMU stands have been documented within the proposed Terrestrial Nesting Analysis Area (see table 4.3.3-1), and MAMUs have been recorded on the National Audubon Society's Christmas Bird Counts in the Coos Bay count circle that occurs within the delineated Estuarine and EEZ Analysis Areas (see available map at: http://audubon.maps.arcgis.com/apps/OnePane/basicviewer/index.html?appid=5c9c077ced02489587f4606488045a6b), MAMUs are expected to forage within the Project's Estuarine and EEZ analysis areas throughout the year. The most MAMUs reported in any survey were 16 counted during 95 observation hours (0.2 counted per hour) in 1992. On average, MAMUs have been recorded 3.1 times per count since 1977.

**Habitat**

The proposed action traverses two MAMU habitat inland zones designated by FEMAT. Inland Zone 1 encompasses a strip of land along the coast approximately 0 to 35 miles from the coast, and Inland Zone 2 includes areas along the western fringe of the species' range, about 35 to 50 miles from the coast. The most suitable habitat is expected to occur within MAMU habitat Inland Zone 1, and recent surveys provide evidence to support this (Raphael, 2006). The proposed action also occurs within Conservation Zones 3 and 4 as described by the MAMU Recovery Plan (FWS, 1997). Figure Q-1 in appendix Q provides the location of each MAMU Inland Zone and Conservation Zone within the Terrestrial Nesting Analysis Area.

Three categories of MAMU habitat have been identified within 1.5 miles of the proposed action within marbled murrelet Inland Zones 1 and 2: suitable nesting habitat, recruitment habitat, and habitat capable of becoming suitable nesting habitat (capable habitat). The following definitions were considered to classify MAMU habitat considering direction provided in several documents (Trask & Associates, 2013; FWS, 1996; BLM, 1995a and 1995b) to provide standardization of terms for habitat categories: 1) suitable habitat includes coniferous forest that provides structures, or may provide structures and/or a forested buffer necessary for nesting marbled murrelets, and generally consist of late seral forest; 2) recruitment habitat is coniferous forested stands greater than 60 years of age that do not provide suitable nesting structures for marbled murrelets and could become suitable habitat within 25 years; and 3) capable habitat is coniferous forested stands from 0 to 60 years of age that could become suitable habitat.

MAMU habitat within the Terrestrial Nesting Analysis area was developed in four steps, building upon each layer. Suitable nesting habitat was identified first, then recruitment; all other coniferous forest not included in the previous two categories was considered capable habitat. Non-forested habitat and deciduous forest was considered non-capable. The vegetation file developed for the PCGP Project was used as the base file. Vegetation cover types were digitized with GIS from 2012 aerial photography and delineated based on the predominate vegetation physiognomy (e.g., trees, shrubs, herbaceous vegetation) and the dominant species present. Forested vegetation was assigned an age class using available GIS data (BLM Forest Operations Inventory [FOI] database, Gradient Nearest Neighbor [GNN] raster data set [developed by Landscape Ecology, Modeling, Mapping & Analysis - LEMMA: http://www.fsl.orst.edu/lemma, and Moeur et al., 1996) LANDSAR late successional old-growth coverage. Age class was also reviewed by BLM and Forest Service biologists on their respective lands with specific focus on verifying/classifying late seral forest stands (Habitat Quality subtask group, 2007 through 2008), as well as verified/revised by Siskiyou BioSurvey, Inc. who conducted biological surveys for Pacific Connector. Age class for forested stands was categorized within five age ranges: clearcut (0-5 years), regenerating (5-40 years), mid-seral

(40-80 years), late successional (80-175 years), and old-growth (175+ years) (Lint, 2005). Areas of regenerating forest that appear to be "clearcut" on the aerial photography were identified as "early-regenerating" forest. The Pacific Connector vegetation file extends at least 100 meters (328 feet) from the proposed action and consists of smooth polygons following obvious vegetation breaks. Outside of the PCGP vegetation layer and outside BLM-managed lands, the MAMU habitat file becomes more pixelated (25 meter by 25 meter squares) and less refined because it relied on MAMU habitat modeled from Raphael et al. (2011) (see Habitat Modeling, Pacific Northwest Research Station below).

Table 4.3.3-2 provides a summary of MAMU habitat developed for the proposed action within the Terrestrial Nesting Analysis Area by MAMU Inland Zone, Recovery Plan Conservation Zone, and general landownership. Also, available habitat within the Terrestrial Nesting Analysis Area by habitat located within SHUs and outside of SHUs.

**Table 4.3.3-2**
**Marbled Murrelet Habitat Available within the Terrestrial Nesting Analysis Area**

| Conservation Zone | Landowner[1] | General Location | Total Acres within Analysis Area | Suitable Habitat[2] | | Recruitment Habitat[3] | | Capable Habitat[4] | | Total MAMU Habitat | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | |
| Zone 3 | Federal | Within SHUs | 20 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | | Outside of SHUs | 0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | | Total | 20 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | Non-Federal | Within SHUs | 710 | 260 | 36.6 | 88 | 12.3 | 305 | 43.0 | 653 | 92.0 |
| | | Outside of SHUs | 6,370 | 1 | 0.0 | 435 | 6.8 | 3,276 | 51.4 | 3,712 | 58.3 |
| | | Total | 7,081 | 261 | 3.7 | 523 | 7.4 | 3,582 | 50.6 | 4,366 | 61.7 |
| | Total Conservation Zone 3 | Within SHUs | 731 | 260 | 35.6 | 88 | 12.0 | 305 | 41.8 | 653 | 89.4 |
| | | Outside of SHUs | 6,370 | 1 | 0.0 | 435 | 6.8 | 3,276 | 51.4 | 3,712 | 58.3 |
| | | Total | 7,101 | 261 | 3.7 | 523 | 7.4 | 3,582 | 50.4 | 4,366 | 61.5 |
| Zone 4 | Federal | Within SHUs | 16,336 | 10,217 | 62.5 | 1,226 | 7.5 | 4,641 | 28.4 | 16,085 | 98.5 |
| | | Outside of SHUs | 7,090 | 2 | 0.0 | 2,856 | 40.3 | 3,780 | 53.3 | 6,638 | 93.6 |
| | | Total | 23,427 | 10,219 | 43.6 | 4,082 | 17.4 | 8,421 | 35.9 | 22,722 | 97.0 |
| | Non-Federal | Within SHUs | 4,775 | 965 | 20.2 | 724 | 15.2 | 2,939 | 61.5 | 4,627 | 96.9 |
| | | Outside of SHUs | 21,491 | 64 | 0.3 | 2,002 | 9.3 | 16,975 | 79.0 | 19,041 | 88.6 |
| | | Total | 26,266 | 1,029 | 3.9 | 2,726 | 10.4 | 19,914 | 75.8 | 23,668 | 90.1 |
| | Total Conservation Zone 4 | Within SHUs | 21,111 | 11,182 | 53.0 | 1,950 | 9.2 | 7,580 | 35.9 | 20,712 | 98.1 |
| | | Outside of SHUs | 28,582 | 66 | 0.2 | 4,858 | 17.0 | 20,754 | 72.6 | 25,679 | 89.8 |
| | | Total | 49,693 | 11,248 | 22.6 | 6,808 | 13.7 | 28,335 | 57.0 | 46,390 | 93.4 |
| Outside Conservation Zones | Federal | Within SHUs | 2,550 | 1,664 | 65.3 | 307 | 12.0 | 532 | 20.9 | 2,503 | 98.2 |
| | | Outside of SHUs | 1,173 | 35 | 3.0 | 587 | 50.0 | 540 | 46.0 | 1,162 | 99.0 |
| | | Total | 3,723 | 1,699 | 45.6 | 894 | 24.0 | 1,072 | 28.8 | 3,666 | 98.5 |
| | Non-Federal | Within SHUs | 705 | 103 | 14.6 | 149 | 21.2 | 362 | 51.3 | 614 | 87.1 |
| | | Outside of SHUs | 3,116 | 36 | 1.1 | 690 | 22.1 | 1,724 | 55.3 | 2,449 | 78.6 |
| | | Total | 3,821 | 139 | 3.6 | 839 | 22.0 | 2,085 | 54.6 | 3,063 | 80.2 |
| | Total Outside Conservation Zone | Within SHUs | 3,254 | 1,767 | 54.3 | 457 | 14.0 | 894 | 27.5 | 3,117 | 95.8 |
| | | Outside of SHUs | 4,290 | 71 | 1.7 | 1,276 | 29.8 | 2,264 | 52.8 | 3,611 | 84.2 |

| Conservation Zone | Landowner[1] | | Total Acres within Analysis Area | Suitable Habitat[2] | | Recruitment Habitat[3] | | Capable Habitat[4] | | Total MAMU Habitat | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **General Location** | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| | | Total | 7,544 | 1,838 | 24.4 | 1,733 | 23.0 | 3,158 | 41.9 | 6,729 | 89.2 |
| MAMU Inland Zone 1 Total | Federal | Within SHUs | 18,906 | 11,881 | 62.8 | 1,533 | 8.1 | 5,174 | 27.4 | 18,588 | 98.3 |
| | | Outside of SHUs | 8,264 | 37 | 0.5 | 3,443 | 41.7 | 4,320 | 52.3 | 7,800 | 94.4 |
| | | Total | 27,170 | 11,918 | 43.9 | 4,976 | 18.3 | 9,493 | 34.9 | 26,388 | 97.1 |
| | Non-Federal | Within SHUs | 6,190 | 1,328 | 21.4 | 961 | 15.5 | 3,606 | 58.2 | 5,894 | 95.2 |
| | | Outside of SHUs | 30,978 | 100 | 0.3 | 3,127 | 10.1 | 21,975 | 70.9 | 25,202 | 81.4 |
| | | Total | 37,168 | 1,428 | 3.8 | 4,088 | 11.0 | 25,580 | 68.8 | 31,097 | 83.7 |
| | Subtotal Marbled Murrelet Zone1 | Within SHUs | 25,096 | 13,209 | 52.6 | 2,494 | 9.9 | 8,779 | 35.0 | 24,482 | 97.6 |
| | | Outside of SHUs | 39,242 | 138 | 0.4 | 6,570 | 16.7 | 26,294 | 67.0 | 33,002 | 84.1 |
| | | Total | 64,338 | 13,346 | 20.7 | 9,064 | 14.1 | 35,074 | 54.5 | 57,485 | 89.3 |
| **Marbled Murrelet Inland Zone 2** | | | | | | | | | | | |
| Outside Conservation Zones | Federal | Within SHUs | 846 | 670 | 79.2 | 30 | 3.6 | 128 | 15.1 | 828 | 97.8 |
| | | Outside of SHUs | 898 | 6 | 0.7 | 508 | 56.6 | 291 | 32.4 | 805 | 89.7 |
| | | Total | 1,744 | 676 | 38.8 | 538 | 30.9 | 419 | 24.0 | 1,633 | 93.6 |
| | Non-Federal | Within SHUs | 395 | 1 | 0.3 | 184 | 46.5 | 187 | 47.4 | 372 | 94.2 |
| | | Outside of SHUs | 16,553 | 21 | 0.1 | 3,699 | 22.3 | 6,105 | 36.9 | 9,824 | 59.3 |
| | | Total | 16,948 | 22 | 0.1 | 3,883 | 22.9 | 6,292 | 37.1 | 10,196 | 60.2 |
| | Subtotal Marbled Murrelet Zone2 | Within SHUs | 1,241 | 671 | 54.1 | 214 | 17.2 | 315 | 25.4 | 1,200 | 96.7 |
| | | Outside of SHUs | 17,451 | 27 | 0.2 | 4,207 | 24.1 | 6,396 | 36.7 | 10,629 | 60.9 |
| | | Total | 18,692 | 698 | 3.7 | 4,421 | 23.7 | 6,711 | 35.9 | 11,829 | 63.3 |
| **Total Marbled Murrelet Range** | | | | | | | | | | | |
| Total Marbled Murrelet Range | *Federal* | Within SHUs | 19,752 | 12,551 | 63.5 | 1,564 | 7.9 | 5,301 | 26.8 | 19,416 | 98.3 |
| | | Outside of SHUs | 9,162 | 43 | 0.5 | 3,951 | 43.1 | 4,611 | 50.3 | 8,605 | 93.9 |
| | | Total | *28,914* | 12,594 | 43.6 | 5,514 | 19.1 | 9,912 | 34.3 | 28,021 | 96.9 |
| | *Non-Federal* | Within SHUs | *6,585* | 1,329 | 20.2 | 1,145 | 17.4 | 3,793 | 57.6 | 6,266 | 95.2 |
| | | Outside of SHUs | *47,531* | 121 | 0.3 | 6,826 | 14.4 | 28,079 | 59.1 | 35,026 | 73.7 |
| | | Total | *54,116* | 1,450 | 2.7 | 7,971 | 14.7 | 31,872 | 58.9 | 41,293 | 76.3 |
| | Total Marbled Murrelet Range | Within SHUs | *26,337* | 13,880 | 52.7 | 2,708 | 10.3 | 9,094 | 34.5 | 25,682 | 97.5 |
| | | Outside of SHUs | *56,692* | 165 | 0.3 | 10,777 | 19.0 | 32,690 | 57.7 | 43,631 | 77.0 |
| | | Total | *83,030* | 14,044 | 16.9 | 13,485 | 16.2 | 41,784 | 50.3 | 69,314 | 83.5 |

[1] Federal Landowners include Coos Bay BLM and Roseburg BLM Districts, Non-Federal Landowners include private and State lands.
[2] Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
[3] Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).
[4] Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).



Estimate of Suitable Habitat

Suitable habitat was incorporated into the MAMU habitat GIS file first. For this BA, suitable habitat includes all habitat that occurs within BLM delineated occupied stands (BLM, 2006; Espinosa, 2007 and 2008; Guetterman, 2007 and 2008a, b; NSR, 2012) and private occupied stands (e.g., Weyerhaeuser), regardless of habitat type and age class (in some instances, stands have been delineated to include younger forest). Potential suitable habitat identified by SBS for MAMU surveys within the PCGP Project area that have not been field-verified as suitable (see species presence section, above) were also included in the MAMU habitat file as suitable habitat. Based on the vegetation file developed for PCGP, these stands include coniferous forest ranging from mid-seral to old-growth. On BLM lands, additional suitable habitat was incorporated into the MAMU habitat file where GIS data provided by Coos Bay and Roseburg BLM Districts identified suitable habitat based on BLM FOI coverage (includes coniferous stands at least 80 years of age); these areas correspond to presumed occupied and unoccupied stands described above for species presence. On non-federal lands, additional suitable habitat was identified using a MAMU habitat model developed by the Pacific Northwest Research Center (see Raphael et al., 2011). Within 0.25 mile of the proposed action, areas modeled with "highest" suitable habitat potential (value 4 in the Raphael et al., 2011 model) and where obvious late seral stands were present (2012 aerial photography and Pacific Connector GIS vegetation layer) were included in the MAMU habitat file developed for the proposed action. Additional description of the MAMU habitat model developed at the Pacific Northwest Research Center is included, below. Suitable habitat included in the MAMU habitat GIS file consists of coniferous forest in the following age classes: old-growth (175+ years), late successional (80 to 175 years), and mid-seral (40 to 80 years).

Based on the proportion of suitable habitat known to be occupied by nesting MAMUs either as surveyed per protocol (see Mack et al., 2003), or expected to be occupied based on survey history in the area and the application of an occupancy index to unsurveyed areas, FWS estimated that approximately 408,621 acres of suitable MAMU habitat (51 percent of reported suitable habitat) are likely occupied in Oregon (McShane et al., 2004). Also, 97 percent of the stands identified by SBS that were potential MAMU nesting habitat were determined to be non-suitable nesting habitat after on-the-ground habitat surveys by R&A in 2007; most of those areas are uniform 40-60 year old stands. Therefore, the estimates of suitable nesting habitat included in the MAMU habitat file and summarized in table 4.3.3-2, are probably an over-estimation.

<u>Estimate of Recruitment Habitat</u>

Recruitment habitat was included into the MAMU habitat file next and only included areas not considered "suitable habitat", as described above. Delineation of recruitment habitat relied on several sources: Roseburg BLM District's MAMU-specific GIS layer, BLM FOI database, SBS habitat delineation for the PCGP Project and on-the-ground survey results, Pacific Connector's delineated vegetation GIS file, Pacific Northwest Research Center's MAMU habitat model developed by Raphael et al. (2011), and NRF and High NRF modeled for the NSO habitat model (discussed below in Section 4.3.4, for NSO).

First, areas that were identified as potential suitable habitat (gray habitat) based on LIDAR and aerial photography by SBS in 2007/2008/2013 but had subsequently been ground-truthed and determined to not provide suitable nesting structures were included as "recruitment" habitat. Next, habitat was identified as recruitment habitat on BLM-administered lands where forest had not been recently harvested (review of 2012 aerial photography) and 1) coniferous forest and mixed forest habitat was 60 years or greater (BLM FOI data, 2012), and/or 2) where Roseburg BLM District's MAMU-specific GIS layer identified the area as recruitment habitat.

On non-federal lands not included in the previous steps, the Pacific Connector vegetation GIS file was used to identify additional recruitment habitat. All coniferous late successional and old-growth forest not previously incorporated into the MAMU habitat GIS file as suitable habitat were included as recruitment habitat. Mid-seral habitat included in the vegetation GIS file located on non-federal lands and not previously identified as suitable habitat was included as "recruitment habitat." Outside of Pacific Connector vegetation GIS file, recruitment habitat was incorporated in the MAMU habitat file where Raphael et al. (2011) pixel values were classed as "moderately high" potential to be suitable MAMU habitat (pixel value 3). Recruitment habitat included in the MAMU habitat GIS file consists of coniferous forest in the following age classes: old-growth (175+ years), late successional (80 to 175 years), and mid-seral (40 to 80 years).

Estimate of Capable Habitat

Capable habitat incorporated into the MAMU habitat GIS file includes all other coniferous forested habitat not previously identified as suitable or recruitment habitat (see above). This includes coniferous forest areas that have been clearcut and are regenerating. On BLM-administered lands, mid-seral coniferous forest between 40 and 60 years of age not previously included as suitable or recruitment habitat was also included as capable in the MAMU habitat file. Capable habitat included in the MAMU habitat GIS file consists of coniferous forest in the following age classes: mid-seral (40 to 60 years), regenerating (5 to 40 years), and clearcut (0 to 5 years).

Non-Capable Habitat

This category includes all areas that are non-forested habitat (i.e., waterbodies, agriculture fields, existing rights-of-ways and corridors, grasslands/shrublands) and deciduous forest, as delineated within Pacific Connector's vegetation GIS layer.

Habitat Modeling, Pacific Northwest Research Station

Modeling of potential suitable MAMU nesting habitat has been generated by the Pacific Northwest Research Station (see Raphael et al., 2006; General Technical Report PNW-GTR-650) with the objective to estimate a baseline amount and distribution of potential nesting habitat at the inception of the NWFP in 1994 (USFS and BLM, 1994). Raphael et al. (2006) used vegetation data derived from satellite imagery to model MAMU habitat suitability to establish the habitat baseline. Raphael et al (2011) updated the baseline model focusing on results of a new approach for estimating baseline potential nesting habitat, and on changes to date from the original 2006 baseline. To model relative suitability of MAMU nesting habitat, Raphael et al. (2011) used recently developed habitat suitability modeling software called Maxtent (Phillips et al. 2006, Phillips and Dudík 2008) which estimates probabilities of occurrence at unobserved locations by using information at the observed locations and assuming as little as possible about background sites for which there is not information (Baldwin 2009). The resulting model included four habitat classes: highest (value 4), moderately high (value 3), marginal (value 2), and lowest (value 1).

**Critical Habitat**

The proposed action coincides with MAMU designated critical habitat unit OR-06-d (FWS, 2011a). CHUs OR-06-b, OR-06-c, and OR-06-d are within the Terrestrial Nesting Analysis Area located on lands of the Coos Bay and Roseburg BLM Districts (FWS, 2011a). Habitat modeled for the proposed action (see discussion, above) was intersected with each CHU to determine the amount of MAMU habitat available within the Terrestrial Nesting Analysis Area and CHU. Table 4.3.3-3 summarizes the MAMU habitat associated with the CHUs, and identifies known occupied stands within each CHU (both within the entire CHU and CHU within the Terrestrial Nesting Analysis Area). Primary constituent elements (PCE) are included in table 4.3.3-3 and below:

- PCE 1 includes individual trees with potential nest platforms, including supporting trees delineated as occupied or suitable (comparable to suitable habitat);

- PCE 2 includes forest lands of at least one half site-potential tree height, within 0.5 mile of individual trees/suitable habitat stand that are recruitment or capable habitat (comparable to recruitment habitat) not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).

Suitable MAMU nesting habitat within the proposed analysis area is considered equivalent to the MAMU critical habitat designation primary constituent element 1 for analysis within this BA – individual trees [and delineated stands] with potential nesting platforms. Recruitment habitat (or primary constituent element 2 is defined by FWS (2011a) as coniferous forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years. FWS (2011a) considers all forests within 0.5 mile of an occupied stand containing trees with at least one-half the site-potential tree height of the occupied stand to be recruitment habitat. Recruitment habitat is essential to provide and support suitable nesting habitat for successful reproduction of the marbled murrelet. Benefits of this habitat include reducing the differences in microclimates associated with forested and unforested areas, reducing the potential for windthrow during storms, and providing a landscape that has a higher probability of occupancy by marbled murrelets. FWS (Trask & Associates, 2013 – personal communication) has requested that for this BA that PCE2 consider recruitment and capable habitat as defined above in the habitat section.

Only 8,504 acres, or 11.3 percent of 75,334 acres available within MAMU CHUs OR-06-b, OR-06-c, and OR-06-d, occur within the proposed terrestrial nesting analysis area, of which approximately 4,490 acres (52.8 percent of the analysis area) are presumed to provide suitable nesting habitat for marbled murrelets (see table 4.3.3-3). The other portion of CHUs are comprised of recruitment habitat and forested stands capable of becoming suitable habitat (approximately 10.7 percent and 15.5 percent of available CHU in the terrestrial analysis area, respectively). The majority of CHU within the analysis area is located on federal lands designated as LSRs. The overlap of CHU with LSR affords a greater degree of protection to the designated critical habitat as the NWFP protections for LSRs are automatically imposed on those LSR acres that are found within a CHU. Thus, marbled murrelets located within these land allocations also benefit from increased protection. Eleven occupied marbled murrelet stands occur within CHU OR-06 (b, c, and d) within the proposed terrestrial analysis area, including four occupied stands detected during Pacific Connector survey efforts in 2007, 2008, and 2013. Twenty-eight other stands have also been delineated as presumed occupied stands within designated critical habitat in the terrestrial analysis area: OR-06-b (one stand), OR-06-c (three stands), and OR-06-d (24 stands; one unoccupied stand, too). Table Q-1 in appendix Q provides land allocations, including CHU that each MAMU stand (occupied, unoccupied, and presumed occupied) analyzed within this BA is associated, if applicable.

<u>NWFP Late Successional Reserves</u>

LSR RO261 is a large LSR complex (70,611 acres) within BLM-managed checkerboard lands on Coos Bay and Roseburg BLM Districts. Approximately 8,526 acres (12.1 percent) occur within the Terrestrial Nesting Analysis Area, of which 4,543 acres (53.3 percent) provides suitable nesting habitat, 908 acres (10.6 percent) provides recruitment habitat, and 2,988 acres (35.0 percent) is comprised of forested areas capable of becoming suitable habitat. Table 4.3.3-4, below provides a summary of MAMU habitat that occurs within LSR RO261 in the Terrestrial Nesting Analysis Area.

## Table 4.3.3-3
## Summary of Available Marbled Murrelet Habitat within MAMU Critical Habitat Units within the Terrestrial Nesting Analysis Area

| CHU Number | Total Acres in CHU | % Subunit within Analysis Area | Total Acres of CHU in Analysis Area[1] | Occupied Stands in CHU (Analysis Area) [2] | PCE 1 (Suitable Habitat)[3] | | PCE 2 (Recruitment Habitat)[4] | | PCE2 (Capable Habitat)[5] | | Total MAMU Habitat | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | |
| OR-06-b | 52,851 | 1.4 | 727 | 15 (3) | 489 | 67.3 | 99 | 13.6 | 107 | 14.7 | 695 | 95.6 |
| OR-06-c | 4,762 | 15.2 | 725 | 0 (0) | 418 | 57.7 | 39 | 5.4 | 264 | 36.4 | 721 | 99.4 |
| OR-06-d | 17,721 | 39.8 | 7,052 | 10 (8) | 3,582 | 50.8 | 771 | 10.9 | 2,647 | 37.5 | 7,001 | 99.3 |
| **Total CHU** | **75,334** | **11.3** | **8,504** | **25 (11)** | **4,490** | **52.8** | **909** | **10.7** | **3,018** | **35.5** | **8,417** | **99.0** |

[1] Total Acres within CHU Subunit in Terrestrial Nesting Analysis Area

[2] Occupied stands consider only known occupied stands and only those stands that occur within the Terrestrial Nesting Analysis Area; OR-06-d includes 2 MAMU Stands that occupied behavior was detected in 2013.

[3] PCE1/Suitable habitat: individual trees with potential nest platforms, including supporting trees delineated as occupied or suitable (comparable to suitable habitat)

[4] PCE2/Recruitment habitat: forest lands of at least one half site-potential tree height, within 0.5 mile of individual trees/suitable habitat stand that are recruitment or capable habitat (comparable to recruitment habitat) not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).

[5] PCE2/Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).

## Table 4.3.3-4
## Summary of Marbled Murrelet Habitat Available within LSRs and Unmapped LSRs within the Terrestrial Nesting Analysis Area

| Landowner | LSR Type | Total Acres Available in Analysis Area | Suitable Habitat [1] | | Recruitment Habitat [2] | | Capable Habitat [3] | | Total Acres | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres Available | Percent Available | Acres Available | Percent Available | Acres Available | Percent Available | Acres Available | Percent Available |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | |
| Coos Bay BLM District | LSR RO261 | 6,109 | 3,567 | 58.4 | 259 | 4.2 | 2,211 | 36.2 | 6,037 | 98.8 |
| | Unmapped LSR | 4,202 | 4,155 | 98.9 | 37 | 0.9 | 0 | 0.0 | 4,191 | 99.8 |
| Roseburg BLM District | LSR RO261 | 2,393 | 953 | 39.8 | 649 | 27.1 | 777 | 32.5 | 2,379 | 99.4 |
| | Unmapped LSR | 618 | 616 | 99.7 | 2 | 0.3 | 0 | 0.0 | 618 | 100.0 |
| Subtotal MAMU Zone 1 | LSR RO261 | 8,502 | 4,520 | 53.2 | 908 | 10.7 | 2,988 | 35.1 | 8,416 | 99.0 |
| | Unmapped LSR | 4,820 | 4,771 | 99.0 | 38 | 0.8 | 0 | 0.0 | 4,810 | 99.8 |
| **Total MAMU Zone 1** | | **13,322** | **9,291** | 69.7 | **946** | **7.1** | **2,988** | **22.4** | **13,225** | **99.3** |
| **Marbled Murrelet Inland Zone 2** | | | | | | | | | | |
| Roseburg BLM District | LSR RO261 | 24 | 24 | 100.0 | 0 | 0.0 | 0 | 0.0 | 24 | 100.0 |
| | Unmapped LSR | 132 | 128 | 96.7 | 2 | 1.5 | 1 | 0.6 | 131 | 98.8 |
| **Total MAMU Zone 2** | | **156** | **152** | **97.2** | **2** | **1.3** | **1** | **0.5** | **154** | **99.0** |
| **Marbled Murrelet Inland Zones 1 and 2** | | | | | | | | | | |
| BLM Districts | LSR RO261 | 8,526 | 4,543 | 53.3 | 908 | 10.6 | 2,988 | 35.0 | 8,439 | 99.0 |
| | Unmapped LSR | 4,952 | 4,899 | 98.9 | 40 | 0.8 | 1 | 0.0 | 4,940 | 99.8 |
| **Overall Total** | | **13,478** | **9,443** | **70.1** | **948** | **7.0** | **2,989** | **22.2** | **13,380** | **99.3** |

[1] Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.

[2] Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).

[3] Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).

Note: Unmapped LSRs include marbled murrelet occupied stands that occur on matrix lands (included in BLM and Forest Service LUA coverage, as well as stands determined to be occupied during PCGP survey efforts in 2007, 2008, and 2013 that occur on NWFP matrix lands but were not included in the LUA coverage) and BLM delineated known northern spotted owl activity centers on NWFP matrix lands.

Additionally, approximately 4,543 acres of unmapped LSRs occur within the terrestrial nesting analysis area, including 4,825 acres associated with occupied marbled murrelet stands and 127 acres of unmapped LSRs associated with known owl (NSO) activity centers (KOAC) located on Matrix lands. MAMU stands that have been determined to be occupied during PCGP survey efforts in 2007, 2008, and 2013 that occur on Matrix lands have also been included in the total of "unmapped LSR". As expected, the majority of unmapped LSRs provide suitable nesting habitat since the majority of unmapped LSRs within MAMU Inland Zones 1 and 2 are occupied murrelet stands that occur on NWFP matrix lands (see table 4.3.3-4).

Much of the LSRs (and unmapped LSRs) within the provincial analysis area overlap the FWS designated critical habitat units for MAMU. The overlap of LSRs with federally designated MAMU critical habitat affords a greater degree of protection to the MAMU and its critical habitat as the NWFP protections for LSRs are automatically imposed on those LSR acres that are found within a CHU. Thus, MAMUs located within these land allocations also benefit from increased protection. Table Q-1 in appendix Q provides land allocations, including LSRs and unmapped LSRs that each MAMU stand (occupied, unoccupied, and presumed occupied) analyzed within this BA is associated, if applicable.

### 4.3.3.3 Effects by the Proposed Action

### Direct Effects – EEZ and Estuarine Analysis Areas

MAMUs that forage offshore (EEZ Analysis Area) and/or within Coos Bay (Estuarine Analysis Area) could be directly affected by 1) underwater noise generated during construction of the LNG terminal and noise generated by LNG carriers transiting the EEZ and estuary, 2) disturbance during feeding by LNG vessel traffic, and 3) collisions with aboveground transmission lines at the LNG terminal during daily flights to and from foraging areas.

**Underwater Noise**

All vessels produce noise; propeller cavitations produce most of the broadband noise with dominant tones derived from the propeller blade rate. Propellers create more noise if damaged, if operating asynchronously, or operating without nozzles. Engines and auxiliary machinery can also radiate noise during operation which is related to ship size (larger ships are noisier than small ones), speed (noise increases with ship speed), and mode of operation (ships underway with full loads, towing or pushing loads, are noisier than unladen ships) (Greene and Moore, 1995).

Underwater noise due to pile driving is expected to cause hearing loss in marbled murrelets. Estimates of auditory injury from underwater pile driving noise are assumed to cause a temporary hearing impairment (demonstrated with pinnipeds by Kastak et al., 2005) termed TTS for temporary threshold shift rather than PTS, the abbreviation for permanent threshold shift. Repeated TTS may lead to PTS in which sensory hair cells in the inner ear are destroyed with damage to the cochlea (Nordmann et al., 2000).

The Federal Highway Administration, FWS, and Washington State Department of Transportation (2011b) developed and agreed to underwater noise level criteria for injury to marbled murrelets from noise. The criteria are for underwater sound resulting from impact pile driving of steel piles and/or repetitive impulsive underwater sounds (see table 4.3.3-5). However, FWS considers the sound levels in table 4.3.3-5 to be used as guidelines in effects analysis rather than threshold criteria for foraging murrelets. Other factors, including duration, are important to consider whether exposure in the zones will result in adverse effects. The thresholds do not apply to non-impact, non-impulsive underwater sounds such as ship noise. In this analysis however, they serve as references for potential effects of ship noise produced by LNG carriers on diving murrelets.

**Table 4.3.3-5**
**Current In-water Acoustic Thresholds for Marbled Murrelets**

| Criterion Zone | Threshold [1] |
|---|---|
| Auditory Injury Threshold | 202 dB SEL [2] |
| Non-auditory Injury Threshold | 208 dB SEL |
| Non-injurious Hearing Threshold Shift Zone | 183 dB SEL |
| Potential Behavioral Effects Zone | 150 $dB_{rms}$ [3] |

[1] All decibels (dB) referenced to 1 micro-Pascal (re: 1uPa).
[2] SEL – Sound level exposure – reported as the cumulative amount of exposure for a single pile driving event.
[3] Rms – the root mean squared for pile driving during a single pile driving impulse pressure event.

A review of LNG carriers in service during 2013 (Colton, 2013; MarineTraffic, 2013) revealed there are 267 vessels with capacities of 148,000 $m^3$ or less, the current size limit for LNG carriers utilizing the Jordan Cove terminal (although the LNG carrier berth was designed to accommodate LNG carriers up to 217,000 $m^3$). Hatch et al. (2008) determined underwater noise levels from various commercial ships while transiting the Stillwagen Bank National Marine Sanctuary off the Massachusetts coast. Estimates of sound levels from one ship, an LNG Taker (the Berge Everett also known as the BW Suez Everett) built in 2003 with 138,028 $m^3$ capacity (93,844 gross tonnage), are used here to estimate exposure of marine mammals to project-related shipping noise. Also, Hatch et al. (2008) reported noise for three tugs in the same area and used here as the standard for the following analysis of noise effects on marbled murrelets within the West Coast EEZ analysis area.

The ocean or waterway offshore from the entrance to Coos Bay is partially within the southern portion of offshore Conservation Zone 3 and partially within the northern portion of offshore Conservation Zone 4, as defined by Miller et al. (2012). In those portions of the Northern California- Oregon coast, the researchers estimated at-sea densities of MAMUs per $km^2$ of ocean surveyed from 2000 through 2010. Density estimates from 2000 through 2010 indicate a slight decline in zones 3 and 4, combined but the declining trend was not significant (see figure 4.3-4 and discussion in Section 4.3.3.1). However, the observations were used to forecast offshore densities from 2011 through 2018. In that first year of the Project's operation, 3.29 MAMUs per $km^2$ were estimated off the coasts of Northern California and Oregon, down from 3.95 MAMUs per $km^2$ in 2010. Because of the variability in data from 2000 through 2010, the forecast of 3.29 lies within a range between 1.77 and 4.80 MAMUs per $km^2$ in 2018 (see discussion in Section 4.3.3.1, above).

The LNG tanker in the Hatch et al. (2008) study produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter that attenuated to 160 dB at 35 ± 11 meters and to 120 dB at 16,185 ± 5,359 meters (Hatch et al., 2008). Based on the estimated densities of marbled murrelets off the combined Oregon/Washington coast in 2018 (3.29 murrelets per $km^2$ with estimates between 1.77 and 4.80 (95% prediction intervals) per $km^2$, see figure 4.3-4 above and Miller et al. 2012), marbled murrelets diving and feeding in the EEZ analysis area are not expected to be exposed to ship noise that would cause harm (see table 4.3.3-5) although murrelets would likely detect noise from LNG carriers transiting the EEZ. In 2018, an estimate of 4 marbled murrelets (estimated between 1 and 6 murrelets based on the density within distances of ± 2 standard deviations of LNG noise attenuating to 160 dB, from Hatch et al., 2008) would be exposed to noise levels of 160 dB which could cause potential behavioral effects due to LNG tanker noise. However, since marbled murrelets forage in shallow off-shore areas, they would not be expected to be exposed to LNG tanker noise but would be in areas of potential exposure to tug noise.

Two tractor tugs would guide each LNG tanker from a point approximately 5 nmi offshore the entrance to Coos Bay and to the JCEP LNG terminal. Noise produced by tugs would attenuate to 160 dB at 11 ± 4 meters (upper end) and to 120 dB at 4,992 ± 1,599 meters (upper end) (Hatch et al., 2008). Areas that are 5 nmi long by the widths of the different noise attenuation distances are used to estimate numbers of marbled murrelets that might be exposed to specific noise levels, given the density of 3.29 murrelets per $km^2$ during 2018. An estimate of 1 marbled murrelet would be exposed to noise levels of 160 dB which could cause potential behavioral effects due to tug noise. Similarly, an estimate of 14 marbled murrelets (estimated between 6 and 24 murrelets based on the density within distances of ± 2 standard deviations of tug noise attenuating to 120 dB, from Hatch et al., 2008) would be exposed to noise levels of 120 dB. Exposure to that noise level would not be expected to cause potential behavioral effects due to tug noise, as indicated in table 4.3.3-5. No underwater noise harassment from pile driving is expected to diving murrelets in the Estuarine Analysis Area because piling for marine structures at the LNG carrier berth would be "in-the-dry", concurrent with the dredging of the slip.

**Vessel Traffic**

Marbled murrelets are expected to forage in the Estuarine Analysis Area and probably within the EEZ Analysis Area at the same time LNG vessels would be in transit to and from the LNG terminal. No information has been found that describes marbled murrelet response to ships' presence and/or ship above-water noise. However, responses of Kittlitz's murrelet (Brachyramphus brevirostris, a congeneric of marbled murrelet) to ships' approach were studied in Glacier Bay, Alaska (Agness, 2006). The study reported that Kittlitz's murrelets were observed to immediately fly away from vessels; they flew 30 times more from vessels than in the absence of vessels and non-breeding birds (birds not holding fish) were more likely to take flight than breeding birds, those holding a fish (Agness, 2006). Modeled estimates of energy expense showed that non-breeding murrelets had a greater increase in energy expenditure when disturbed (up to 30 percent increase under the average scenario of ship traffic and greater than 50 percent increase under the peak scenario of ship traffic) than breeders (up to 10 percent and 30 percent increases under the average and peak vessel traffic scenarios, respectively). Likewise, non-breeding birds were more likely to experience chronic increases in energy expense (i.e. a greater percentage of days with an increase in energy expenditure) than breeding birds which would be expected to adversely affect energy partitioning for reproduction and survival behaviors (Agness et al., 2013).

Similar responses by foraging marbled murrelets to LNG vessel traffic would be expected once the JCEP terminal is operative in 2018. As discussed above in Section 4.2.1.3 for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with 0 and 17.6 vessels as reasonably foreseeable when the

LNG terminal is expected to begin operation in 2018 (see figure 4.2-4, above for blue whales). The foreseeable cumulative effect of 90 LNG carriers per year would exceed current vessel-related disturbance, if it occurs, to foraging marbled murrelets in the Coos Bay estuary and nearshore habitats in the vicinity of the Coos Bay channel in the EEZ Analysis Area.

**Power Line Collision**

Marbled murrelets fly at an average of 246 meters (807 feet) above ground level, although the lowest flight height reported was 63 meters (203 feet); less than 0.01 percent of all birds were observed flying at or below the height of typical transmission lines (Stumpf et al., 2011). Many different bird species have been documented colliding with transmission lines, including those the size of the 115 kilovolt (kV) overhead power transmission line proposed to connect the South Dunes Power Plant and the LNG Terminal (see Resource Report 1, JCEP LNG Terminal Project). Waterfowl, shorebirds, large birds with poor maneuverability (cranes, herons, swans, pelicans), and passerines have been killed by collisions with transmission lines (Manville, 2005). Seabirds are also killed by collisions with overhead lines (Avian Power Line Interaction Committee, 2012). Although documentation is lacking, marbled murrelets may be susceptible to power line collisions due to their rapid flight speeds which average 65 miles per hour when flying to the sea, but 55 miles per hour on return, landward flights (Stumpf et al., 2011). Murrelets fly faster than other species frequently killed by power line collisions. Also, marbled murrelet flights to and from nesting areas occur mainly near dawn and dusk with peak activity occurring well before sunrise (Manley et al., 1992; Burger, 2001) when light levels are low and coastal fog limits visibility.

The proposed transmission line is designed for two bottom 13.8 kV conductors (one on each side of a pole), the 115 kV double circuit with six phase conductors (three on a side), and two top shield or static wires, one on each side (see Figure 1.1-7, Resource Report 1, JCEP LNG Terminal Project), extending for 6,370 feet between the South Dunes Power Plant and the LNG Terminal (see Figure 1.1-2, Resource Report 1, JCEP LNG Terminal Project), using single poles between 76 and 111 feet tall, depending on terrain elevation. Flight height data for marbled murrelet (Stumpf et al., 2011) suggests that flight would be above the top shield wires of the power poles, but flight heights would be expected to decline as murrelets approach feeding sites within the Coos Bay estuary or Pacific Ocean. The proposed power line would be within 400 feet of open water in Coos Bay at its closest point and within the average distances of power lines from waterbodies where waterfowl, pelicans, sandhill cranes, and great blue herons have been documented colliding with powerlines (see Table 4.2 in Avian Power Line Interaction Committee, 2012).

Most studies have shown a reduction in collisions and/or an increase in behavioral avoidance at marked lines when compared to unmarked lines, but that is dependent on factors such as location, type of line marking device, and bird species (Avian Power Line Interaction Committee, 2012). JCEP has proposed to apply Bird Flight Diverters, manufactured by Preformed Line Products, or similar. Diverters would be installed on the shield wires to reduce risk of bird collisions with power lines. Typically they are installed at 30-foot intervals on both shield wires. The locations of the diverters on the two shield wires are staggered so that there is a diverter approximately every 15 feet along the length of the line segment, maximizing visibility of both wires. Studies of marker effectiveness have reported that birds responded (detected) marked lines at greater distances than unmarked lines and more flew higher than at line levels. Mortalities due to line collision were variable but several studies reported reduction in bird mortality by 55 percent or greater (see Table 6.8 in Avian Power Line Interaction Committee, 2012).

**Ship-Strike**

There are no records or any indication that MAMUs offshore are susceptible to ship-strikes. Seabirds collide with fishing trawlers in the North Pacific. Collisions of seabirds with stationary objects (including off-shore wind energy turbines) are possible, either by collisions of ships with birds on the ocean surface or collisions of birds in flight with ship structures although empirical data are limited (Wilson et al., 2007). Collisions between marbled murrelets and LNG carriers are possible but not likely within the EEZ analysis area.

**Release and Fire at Sea**

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a marbled murrelet surfaced to breathe at the LNG pool location, it could suffer from oxygen deficiency and potential physiological effects, which have been described for humans - ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations (Table 39 in Hightower et al., 2004) - but not for other species. Because the estimated densities of marbled murrelets are generally low within the California and Oregon-Washington strata of EEZ, the chance of an marbled murrelet becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Marbled murrelets generally forage within 3 miles of shore in western North America, although during the breeding season they stay closer to the coast, e.g., within 1.2 miles in Oregon (McShane et al., 2004). If an accidental release of LNG occurred within that nearshore distance, foraging marbled murrelets could be affected.

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Foraging underwater, then surfacing, marbled murrelets within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

If offshore densities were 3.95 murrelets per $km^2$ during 2010 and the overall population declines in 2018, the expected offshore density in 2018 will be 3.29 murrelets (between 1.77 and 4.80) per $km^2$. Based on the model of accidental LNG release and fire described above (from Hightower et al., 2004), a circular pool of released LNG with diameter of 685 feet would cover an area of 0.010 $nmi^2$. An ensuing fire would cause severe thermal injuries over an area of 0.057 $nmi^2$ and the area where fire could cause second degree burns would extend to an area of 0.563

nmi$^2$. Considerably fewer than one marbled murrelet would be expected to be present within those areas in the Oregon-Washington EEZ stratum during 2018 except 1 murrelet could be within range of low thermal flux during an LNG fire (causing second degree burns to humans). Injuries to marbled murrelets due to LNG release and fire are highly unlikely and would be insignificant and discountable.

**Indirect Effects – EEZ and Estuarine Analysis Areas**

Foraging Habitat

Murrelets forage in shallow off-shore and inland saltwater areas on a variety of small fish and invertebrates, including large pelagic invertebrates (Marshall, 1988a, 1988b, and 1989; Becker, 2001). In Oregon and Washington, anchovy, sand lance, and smelt appear to be the major prey types provided to chicks (McShane et al., 2004). Turbidity associated with dredging activities within Coos Bay may affect MAMU forage/prey species and their habitat. Dredging of the access channel is planned from October 1 through February 15 following ODFW's recommendation, and timing of these activities should minimize impact to MAMU forage/prey species.

During summers in 1992 and 1993, the majority of MAMUs off the Oregon coast were observed within 3,280 feet (1000 meters) from shore (Strong et al., 1995). Given the distribution of MAMUs close to shore, it is not surprising that they are susceptible to adverse effects from industrial pollution (Fry, 1995) and off-shore oil spills (Carter and Kuletz, 1995). Indeed, oil released during the grounding and break-up of the *New Carissa* near Coos Bay likely killed 262 MAMUs in February 1999 (Skrabis, 2005).

The potential for similar effects from LNG cargo is quite different from the potential for effect by crude or refined petroleum cargo. Based on the double hulled construction of LNG carriers and the outstanding operating and safety record of LNG carriers, the probability of any incidents that could result in the loss of LNG cargo is extremely low. Any potential spills that could occur and that could affect MAMUs offshore would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales and above for marbled murrelets. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface (Hightower et al., 2004). The cooling effects of the LNG plume on murrelet prey species are unknown but are expected to be localized. Similarly, effects of a fire on prey species would likely be very limited to the ocean – LNG pool interface.

Oil spills at sea or off shore might adversely affect food resources in the immediate area including schooling fish such as anchovies (NMFS, 2006a). However, effects of potential spills from LNG carriers are not comparable to spills from oil tankers for a number of reasons. LNG carriers only carry quantities of oil used for propulsion fuel and not the quantities transported by oil tankers.

**Direct Effects – Terrestrial Nesting Analysis Area**

MAMUs could be directly affected by 1) removal of nest trees or potential nest trees during the breeding season (April 1 through September 15) and 2) human presence and noise disturbance during the breeding period.

Habitat (Nest) Removal during Breeding Season

Removal of habitat during the breeding season within an occupied or presumed occupied stand could result in the potential death of nestlings if the nest tree is removed. Removing suitable nesting habitat outside of the entire breeding season (September 16 through March 31) would eliminate any direct impact to individual MAMUs or nestlings. Pacific Connector met with FWS on June 5, 2008 to review and discuss the proposed action and construction schedule and identify areas where the project and schedule could be adjusted to avoid or further decrease the disturbance impacts to MAMUs while allowing for a constructible pipeline Project that considered 1) MAMU seasonal and daily timing restrictions, 2) safety of the construction crew, and 3) meeting the targeted in-service date within a two-year construction period. FWS provided a preference of activities associated with timber removal and construction, including the following specific to habitat removal, listed below in descending order of importance:

- Felling nest trees outside the entire breeding season.
- No removal of habitat within an occupied stand during the entire breeding season.
- No fragmentation of an occupied stand (i.e., clipping the edge of the stand is not as bad as dissecting through the middle).

Pacific Connector moved and adjusted the proposed project to avoid and/or minimize effects to MAMU, where feasible. Appendix V (Marbled Murrelet and Northern Spotted Owl Avoidance and Minimization Plan) identifies the additional measures that have been incorporated into the project design in relation to occupied MAMU stands or potentially suitable MAMU habitat. Also, considering the factors above, Pacific Connector developed a timber removal and construction schedule that would minimize effects to MAMU, as well as ensure the safety of the timber removal and construction crew and meet the in-service date (see figures 3.2-1 and 3.2-3). Pacific Connector will remove forested habitat within 300 feet of an occupied stand, unoccupied stand, or presumed occupied stand outside of the entire breeding season to eliminate direct impact to individual MAMUs or nestlings. Timber will be removed beginning fourth quarter 2015, and if necessary, continue the following fall after the breeding season. This includes habitat that would be removed or potentially removed from 25 MAMU stands (14 occupied, two unoccupied, and nine presumed occupied stands). Habitat will also be removed within 0.25 mile of a northern spotted owl activity center outside of the breeding season (from October 1 through February 28); within the range of the MAMU, this includes forested habitat between MPs 37.33 and 37.87 and MPs 64.00 and 64.40. Elsewhere in the range of the MAMU, timber removal would precede construction and could occur during the breeding season; however, direct effects to MAMUs or nestlings would not be expected because suitable nesting habitat would have been removed outside of the breeding season.

Table 4.3.3-6 below tabulates the number of occupied, unoccupied, and presumed occupied stands by Murrlet Inland Zone that would have timber cleared within 300-feet of the MAMU stand outside of the breeding season, including 25 MAMU stands that would have suitable habitat removed from the stand. Although table 4.3.3-6 identifies 25 MAMU stands that would have habitat removed, it is expected that suitable habitat would not be removed in five of these stands (3 occupied, 1 unoccupied, and 1 presumed occupied) because the construction activity should be confined to the road through the stand or construction would occur adjacent to the MAMU stand in non-suitable habitat.

**Table 4.3.3-6**
**Number of Occupied, Unoccupied, and Presumed Occupied Stands that Will Have Habitat Removed Outside of the Breeding Season, Including the 300-foot Buffer**

| Status Of MAMU Stand | Number of MAMU Stands Stand | 300-foot Buffer | Total |
|---|---|---|---|
| **Marbled Murrelet Inland Zone 1** | | | |
| Occupied | 14 | 2 | 16 |
| Unoccupied | 0 | 0 | 0 |
| Presumed Occupied | 9 | 23 | 32 |
| **Total** | **23** | **25** | **48** |
| **Marbled Murrelet Inland Zone 2** | | | |
| Occupied | 0 | 0 | 0 |
| Unoccupied | 2 | 0 | 2 |
| Presumed Occupied | 0 | 0 | 0 |
| **Total** | **2** | **0** | **2** |
| **Overall Total** | | | |
| Occupied | 14 | 2 | 16 |
| Unoccupied | 2 | 0 | 2 |
| Presumed Occupied | 9 | 23 | 32 |
| **Total** | **25** | **25** | **50** |

No suitable MAMU nesting habitat would be removed during the construction of the LNG Terminal or South Dunes Power Plant; no direct effects to MAMUs would be expected from these proposed actions.

Noise and Visual Effects

Noise associated with timber clearing, construction, and operation of the proposed Project could disturb nesting MAMUs and negatively affect productivity. The term "disruption" was alluded to in the ESA, under the definition of "harassment" (50 CFR §§ 17.3) as:

> "an intentional or negligent act or omission which creates the likelihood of injury by annoying it (the organism) to such an extent as to significantly disrupt normal behavior patterns which include but are not limited to, breeding, feeding or sheltering".

The term "disturbance" was not included in the ESA but a reasonable working definition was provided by Leal (2006) and has been incorporated into this BA:

> "any potential auditory or visual stimuli or deviation from ambient/baseline conditions [that] an individual bird, at a given site, is likely to detect and potentially react to."

There is limited information on distances from sound (noise) and/or visual stimuli at which MAMUs react or flush from the nest, or the effect of such disturbance on productivity (FWS, 2003b). Most data gathered for disturbance on MAMUs have been obtained from observations incidental to other research (e.g., Long and Ralph, 1998). The sensitivity of an individual MAMU to noise and/or visual disturbance is likely related to levels of disturbance to which the bird is accustomed, including the level and proximity of the disturbance (Hamer and Nelson, 1998) as well as the timing of disturbance (time of day, time of year, and time within breeding season). The available research and anecdotal accounts show tha the effects of noise and vehicles on roads elicit disturbance-responses from marbled murrelets but not disruption-responses such as flushing, flight and/or missed feedings of chicks in nests to a level that would interfere with normal behavior patterns including but not limited to, breeding, feeding or sheltering. The following are brief summaries of available research and anecdotal accounts:

- No visible response to vehicles driving past MAMU nests 70 meters away from a paved, “well traveled park road” (Singer et al., 1995 in Long and Ralph, 1998)
- MAMU in nests in Big Basin Redwoods State Park showed no response to passing cars during several days of observation in 1989 (Nelson, personal communication, in Long and Ralph, 1998)
- MAMU nests 70 meters from lightly used logging road show little to no response when observers drove by in light trucks (Chinnici, personal communication, in Long and Ralph, 1998)
- MAMU in nests across river from road with moderate traffic (30 cars/day) showed no reactions when vehicles passed (Nelson, personal communication, in Long and Ralph, 1998)
- Adult MAMU reacted least to trucks on U.S. Highway 101 even though truck noise averaged 84 dB and usually reacted to automobiles only with noticeable response, auto noise averaged 72 dB (adults showed severe response ≈3% of all responses to autos); MAMU chick showed only low response to cars/trucks (Hamer and Nelson, 1998).
- Field study to measure behavioral responses of MAMU adults and chicks to disturbance produced by trail users, proximity to paved highways, and experimental disturbances produced by maintenance activities (chainsaws) (Hébert and Golightly, 2006):
  - Ambient sound at nest sites was <50 dB before and after exposure to chainsaw noise. Experimental noise was >65 dB generated by chainsaws.
  - MAMU chicks and adults in nests exposed to significantly louder experimental noise than before or after trial.
  - Adult MAMU spent less time at rest during disturbance than before and after.
  - Adult MAMU spent more time with head raised during disturbance than before and after.
  - MAMU chicks spent similar times at rest before, during, and after chainsaw noise trials.
  - Hatching success at control nests was 39%; hatching success at experimental nests (exposed to chainsaw noise) was 67%
  - Fledging success at control nests was 25-50%; fledging success at experimental nest was not significantly different.
  - Overall, MAMU avoided nesting close to high volume roads (U.S. Highway 101).
  - Concluded that vehicular traffic may have little or no effect on MAMU nesting success.

Available research suggests that marbled murrelets may be more sensitive to visual disturbances than to auditory disturbance conditioned by predators in the vicinity that may cause aborted or delayed feedings (Phifer, 2003; Bednarz and Hayden, 1994). Human presence attracts corvids, which increases the predation risk at MAMU nest sites that are located near project activities. Studies from other bird species suggest that disturbance can affect productivity by causing nest abandonment, egg and hatchling mortality due to exposure and predation, longer periods of incubation, premature fledging or nest evacuation, depressed feeding rates of adults and offspring, reduced body mass or slower growth of nestlings, and avoidance of otherwise suitable habitat (Henson and Grant, 1991; Rodgers and Smith, 1995, cited in BLM and USFS, 2008).

**Auditory and Visual Disturbance - FWS Guidance.** FWS (2003b and 2006f) established distances within which sound levels and visual disturbance for various activities may result in injury or harassment of MAMUs by significantly disrupting the normal behavior pattern of individuals or breeding pairs. FWS determined that visual disturbances within 100 yards of MAMU nest sites could lead to increased predation of nests by corvids when humans are present during project-related activities and would constitute a disruption of the nest site (Phifer, 2003).

FWS identified distances within which activities may "disrupt" nesting MAMUs (noise and/or visual disturbance). Disruption distances identify a distance from activities that FWS have determined would likely cause a MAMU to be distracted to such an extent as to significantly disrupt normal behavior and increase the likelihood of breeding season failure. The threshold disruption distances applied to marbled murrelets during the critical breeding period are either the same or extend farther (i.e., more conservative) than distances provided by FWS (2003b and 2006f; see Noise Evaluation in Appendix Z3). Other actions, including use of existing roads and large helicopters were added after 2006. Activities that occur beyond the disruption distances may "disturb" MAMU but should minimize effects and not result in harm or "disrupt" reproductive activities. Activities may disturb MAMU if the activities occur within 0.25 mile of MAMU; disturbance distances have often been applied as seasonal buffers to minimize impacts of projects to nesting MAMUs. FWS determined that activities occurring beyond these disturbance distances would not likely cause MAMUs to be distracted from their normal activity. Table 4.3.3-7 provides the threshold distances beyond which noise and visual disturbances are unlikely to result in disruption or disturbance to nesting murrelets during the breeding season (April 1 through September 15), which are generally based on distances to which noise levels and/or human presence are expected to disrupt or disturb nesting MAMU. In addition to the temporal and spatial restrictions presented in table 4.3.3-7, FWS also recommends limiting Project-related disturbance to two hours after sunrise until two hours before sunset near occupied and presumed occupied stands. Adhering to this daily timing restriction (DTR) minimizes the potential to disrupt adult MAMUs delivering meals to chicks at dawn and dusk. Application of DTRs during the breeding season should minimize effects from project activities, and would result in no disturbance or disruption for most activities if applied in the late breeding period, as identified in table 4.3.3-7.

Disruption and disturbance distances and temporal applications identified in table 4.3.3-7 are not the same as commonly used in FWS consultations with BLM (see Coos Bay FY2008-2013 Programmatic Consultation #13420-2008-F-0118). For example, BLM does not consider disruption or disturbance effects to occur to MAMU from use of existing access roads throughout the entire breeding season. Additionally, BLM generally does not consider disturbance effects to MAMU for certain activities (heavy equipment, chainsaw use, and small helicopter or use) in the late breeding season (see Coos Bay FY2008-2013 Programmatic Consultation #13420-2008-F-0118).

**Table 4.3.3-7**
**Threshold Distances Beyond Which Noise and Visual Disturbances are Unlikely to Result in Disruption or Disturbance to Nesting Marbled Murrelets during the Breeding Season [1]**

| Activity | **Disruption Threshold Distances From Occupied or Presumed Occupied Stands** | | | **Disturbance Threshold Distance From Occupied or Presumed Occupied Stands** | | |
|---|---|---|---|---|---|---|
| | **MAMU Critical Breeding Season [2]** | **MAMU Late Breeding Season – No DTRs [2, 3]** | **MAMU Late Breeding Season – With DTRs [2, 3]** | **MAMU Critical Breeding Season [2]** | **MAMU Late Breeding Season – No DTRs [2, 3]** | **MAMU Late Breeding Season – With DTRs [2, 3]** |
| Existing Road Use | 35 yards (105 feet) | No Disruption Anticipated | No Disruption Anticipated | 0.25 mile | 0.25 mile | No Disturbance Anticipated |
| Chainsaws | 100 yard (300 feet) | 100 yard (300 feet) | No Disruption Anticipated | 0.25 mile | 0.25 mile | No Disturbance Anticipated |
| Heavy equipment [4] | 100 yard (300 feet) | 100 yard (300 feet) | No Disruption Anticipated | 0.25 mile | 0.25 mile | No Disturbance Anticipated |
| Rock Ditching Equipment [5] | 120 yards (360 feet) | 120 yards (360 feet) | No Disruption Anticipated | 0.25 mile | 0.25 mile | No Disturbance Anticipated |
| Blasting – more than 2 lbs with mitigation measures | 120 yards (360 feet) | 120 yards (360 feet) | 120 yards (360 feet) | 0.25 mile | 0.25 mile | 0.25 mile |
| Small Helicopter/Airplanes | 120 yards (360 feet) | 120 yards (360 feet) | No Disruption Anticipated | 0.25 mile | 0.25 mile | No Disturbance Anticipated |
| Large/Transport Helicopters with mitigation measures [6] | 240 yards (720 feet) | 240 yards (720 feet) | 240 yards (720 feet) | 0.25 mile | 0.25 mile | 0.25 mile |

[1] Sources: FWS 2003b; Michael Minor & Associates, 2008 (appendix P); Trask & Associates, 2013 and 2014; Phifer, 2003.
[2] Marbled MAMU breeding period is from April 1-September 15; critical breeding period is considered from April 1-August 5; late breeding season is considered from August 6 – September 15.
[3] DTRs (Daily Timing Restrictions) – restricting activity between 2 hours after sunrise and 2 hours before sunset.
[4] Heavy equipment includes: back trackhoes, side-booms, bulldozers, semi-trucks, pneumatic hammers.
[5] Rock Ditching Equipment includes: auger drill rig, mounted impact hammer, rock drill, and blasting (mitigated or less than 2 lbs).
[6] Transport helicopters proposed for this Project include: Boeing Chinook (CH-47) and Boeing Vertol 107-II (CH-46)

FWS (2003b and 2006f) reviewed available scientific literature on behavioral and physiological responses of different bird species to various noise sources. They determined that birds would likely detect noises that were 4 decibels or more above ambient noise levels. FWS (2006f) also determined that anthropogenic noise attenuating to within 25 dB above ambient sound level would be the threshold above which harassment to individual murrelets is likely to occur. That determination, however, was based on one account of Mexican spotted owls responding to chainsaw noise (Delaney et al., 1999) and one account of a colonial nesting seabird (crested tern, Brown, 1990) responding to simulated aircraft noise. In both situations, the subject birds were exposed to human presence prior to exposure to noises and response to noises were not controlled for visual disturbances. Using those two studies however, FWS (2006) subtracted the noise level that elicited a harassment-indicating behavior (flight or flushing) from the minimum ambient noise at the respective sites and decided that action-generated noise levels that are 25 dB above ambient levels will constitute the sound level threshold above which harassment is likely to occur (FWS, 2006e). From that exercise, FWS (2006) decided that a noise level of 70 dB would be a disturbance threshold and noise ≥70 dB would be disruptive, based entirely on the responses of crested terns to simulated aircraft noise (Brown, 1990), as above. That conclusion appears to be arbitrary (WSDOT, 2011), has not been tested, and is not supported by field studies of marbled murrelets (see available research and anecdotal accounts, above). Consequently, Pacific Connector has not accepted or applied the FWS (2006) sound threshold of 25 dB above ambient noise or noise ≥70 dB as a decibel level above which harassment is likely to occur.

Injury to individuals of either species would occur if a threshold of 92 dBA occurs or is exceeded (FWS, 2003b). FWS (2006f) defined a "tolerance threshold" of 82 dB for marbled murrelets. The tolerance threshold assumes that respective nest sites become "intolerable" to the species and harassment occurs due to the total sound level the species must endure. However, no time duration component was associated with the tolerance threshold.

FWS (2003b) did not analyze injury threshold distances for noise associated with blasting or large helicopters. Rather, a conservative assumption was used for blasting with charges of 2 pounds or less; for larger blasts (greater than 2 pounds) a conventional 1-mile distance was considered due to the lack of dB information. During informal consultation with FWS (Smith et al., 2007; Wille et al., 2006), restricting the use of large helicopters to remove large timber and transport pipe to the construction right-of-way to a 1-mile disturbance threshold distance was considered as well. However, FWS also suggested that if additional studies could demonstrate that use of larger blasts (greater than 2 pounds) and large helicopters attenuated to less than 92 dB, and preferably 70 dB (disturbance threshold versus 92 dB disruption threshold) within a mile, the report and additional data demonstrating this would be considered to reduce the disturbance threshold distances for those activities (Smith et al., 2007; Wille et al., 2006).

**Blasting and Helicopter Noise Levels.** Pacific Connector has prepared a noise report (see appendix P) that analyzes the distances at which conventional blasting required for trenching within rock substrate for pipeline construction and transport helicopters attenuates to 92 dB, the threshold for injury to individual murrelets and is the sound level above which MAMU are likely to respond with behavior that indicate harassment (FWS, 2006f). Under the worst case conditions, with common and appropriate mitigation measures applied to trench blasting operations, it is expected that blasting noise would attenuate to 92 dB within 200 feet of the source and to 70 dB within 1,025 feet of the blast source in soft rock. Large transport helicopters would attenuate to 92 dB within 700 feet. The greater distance for helicopter use is due to the directional aspects of blade slap noise that is directed toward the ground.

Mitigation for helicopter noise includes operational restrictions such as maintaining a high altitude and keeping away from noise sensitive areas whenever possible. Analyses for MAMUs in this draft BA consider the distances for larger blasts and large helicopters to be more conservative than what the noise report suggests. Pacific Connector has used a disruption threshold distance for blasting greater than 92 dB but with mitigation measures discussed in appendix P applied to be the same disruption distance expected for smaller blasts (less than 92 dB) – 120 yards or 360 feet – more conservative than the noise report describes, and the disturbance threshold distance associated with large blasts to be expected within 0.25 mile of blasting activity (see table 4.3.3-7). It is expected that these distances be considered throughout the entire breeding season (April 1 – September 15), regardless of the application of DTRs, because of the sudden onset of noise associated with blasting activities. Pacific Connector has used a disruption threshold distance for large/transport helicopter use with proposed mitigation techniques discussed in appendix P to be slightly farther than the report suggests, considering a disruption distance of 240 yards or 720 feet and a disturbance threshold distance of 0.25 mile (see table 4.3.3-7). Even though FWS (2003b) provided some evidence suggesting that noise that builds in intensity, such as a helicopter approaching from a distance, may result in less risks and does not anticipate effects for smaller aircraft after the critical breeding period with DTRs applied, for analysis within this assessment, Pacific Connector anticipated that similar to large blasts (greater than 2 pounds) use of large/transport helicopters may disrupt or disturb MAMUs throughout the entire breeding season (April 1–September 15), regardless of the application of DTRs. In a memorandum provided to TetraTech, contractor to FERC (FWS, September 16, 2008), FWS indicated that if noise level above 92 dB is recorded at 0.25 mile of the blasting activities, that blasting operations should cease until more effective mitigation measures can be employed. Pacific Connector would ensure its contractor complies with all ESA-related noise restrictions along the proposed project.

**Noise Evaluation Procedure**. Pacific Connector is aware of the temporal and spatial restrictions recommended by FWS (see table 4.3.3-7); however, due to construction constraints within the range of the MAMU, safety of construction crew, and adherence to the in-service date, Pacific Connector cannot adhere to all recommended restrictions. Further, the distances were derived under forested situations and are not applicable to many of the field situations and habitats through which the PCGP project passes. Also, available research and anecdotal reports do not support use of fixed distances between a noise source and marbled murrelet behavioral response indicating disruption. Noise levels attenuate differently under various conditions which are not accounted for in the FWS guidance. Since the spatial restrictions included in table 4.3.3-7 have been established based on noise levels and attenutation at the MAMU stand (i.e., 92 dB), Pacific Connector evaluated expected noise levels at a particular MAMU stand from activities associated with construction of the Proposed Action and distance of the MAMU stand from activities (see site-specific Noise Evaluation, appendix Z3). The noise evaluation was used to assist in evaluating noise effects of proposed construction activities for each MAMU Stand within the Terrestrial Nesting Analysis Area, considering reviewed available scientific literature on behavioral and physiological responses of bird species to various noises, as well as the ambient noise level near each MAMU stand. The noise evaluation estimates noise attenuation at the closest edge of each MAMU stand to the proposed activities based on guidance provided by FWS (2006) due to hard site (hard, smooth surfaces intervening between source and receptors) and soft site (irregular, vegetated surfaces) conditions, intervening tree cover, topography, and/or differential elevations allowing lines-of-sight between sources and receptors. This noise evaluation has been used as an adjustment factor of direct effects (disturbance and disruption) for individual MAMU Stands in the impact assessments located in appendix Z1 and included in table Q-2 in appendix Q.

**Disruption and Disturbance – Timber Clearing, Pipeline Construction, Existing Road Use**. Pacific Connector will clear timber within MAMU Stands and a 300-foot buffer of MAMU stands outside of the entire breeding season (between September 16 and March 31) to avoid direct effects to murrelets, chicks, or eggs within MAMU stands and adjacent habitat. This includes approximately 52.5 miles of forested habitat within the range of the MAMU. Timber removal is expected to occur during Year 1 of the PCGP construction window; however, if timber removal is not completed prior to MAMU breeding season (April 1), timber removal would continue in Year 2 outside of the breeding season (between September 16 and March 31). Noise, visual disturbance, and in some instances large helicopter use associated with timber removal outside of the breeding season would be consistent with the temporal and spatial restrictions recommended by FWS to protect nesting murrelets (see table 4.3.3-7) and would not be expected to disturb or disrupt MAMUs.

Pacific Connetor, however, cannot adhere to the temporal and spatial restrictions recommended by FWS (see table 4.3.3-7) within 0.25 mile of all occupied and presumed occupied stands, and safely construct the pipeline within two years. Therefore, approximately 35.11 miles of construction activities along the proposed route, including an additional 15.52 miles of timber clearing (greater than 300 feet but within 0.25 mile of MAMU Stand), could occur during the MAMU breeding period within 0.25 mile of 20 occupied, three unoccupied, and 56 presumed occupied MAMU stands (see table 4.3.3-8). As a result, acoustic and visual disturbances from the proposed action could affect MAMU nesting and rearing activities. Pacific Connector has proposed to apply DTRs recommended by FWS for timber removal and construction activities that occur within 0.25 mile of a MAMU stand through the critical breeding period (April 1 through August 5), which would reduce direct effects from noise and visual disturbance. DTRs would be applied to large transport helicopters in the late breeding period (August 6 through September 15), if use of helicopters is necessary during that time period. Although timber removal and construction activities would likely occur within one breeding season in the proximity of each MAMU Stand, Pacific Connector conservatively assumes that each MAMU Stand could experience effects from activities for two years.

**Table 4.3.3-8**
**Total Miles Crossed by the Proposed Action within the MAMU Stand, and the 300-foot and 0.25 mile Buffer of MAMU Stands**

| Location of Project Activity | Marbled Murrelet Habitat (miles crossed) | | | | Total Miles Crossed |
|---|---|---|---|---|---|
| | Suitable | Recruitment | Capable | Not Habitat | |
| **Total MAMU Inland Zone 1** | | | | | |
| MAMU Stand [1] | 5.8 | 0 | 0 | 0 | 5.8 |
| 300-foot Buffer [1] | 0 | 4.4 | 6.0 | 3.5 | 13.9 |
| 0.25-mile Buffer | 0 | 3.6 | 16.8 | 7.2 | 27.7 |
| MAMU Inland Zone 1 Total | 5.8 | 8.0 | 22.8 | 10.7 | 47.4 |
| **MAMU Inland Zone 2** | | | | | |
| MAMU Stand [1] | 0.9 | 0 | 0 | 0 | 0.9 |
| 300-foot Buffer [1] | 0 | 0.5 | 1.2 | 0.3 | 1.9 |
| 0.25-mile Buffer | 0 | 0.8 | 0.5 | 1.0 | 2.4 |
| MAMU Inland Zone 2 Total | 0.9 | 1.3 | 1.7 | 1.4 | 5.2 |
| **Overall MAMU Range** | | | | | |
| MAMU Stand [1] | 6.7 | 0.00 | 0.00 | 0.01 | 6.7 |
| 300-foot Buffer [1] | 0.00 | 4.9 | 7.2 | 3.8 | 15.8 |
| 0.25-mile Buffer | 0.00 | 4.4 | 17.3 | 8.3 | 30.1 |
| **Overall Total MAMU Range** | **6.7** | **9.3** | **24.5** | **12.1** | **52.5** |

[1] Timber will be harvested outside of the entire breeding season (between September 16 and March 31); this includes habitat associated with 50 MAMU Stands (see table 4.3.3-6).

**Expected Disturbance Effects.** Noise expected during each phase of pipeline construction as it relates to equipment associated with each phase is provided in table 3.1.3.3-2, and applied to each MAMU stand individually in the Noise Evaluation (see appendix Z3). Impact assessments for each MAMU stand analyzed within this BA (appendix Z1) identify existing access roads within or within 0.25 mile of occupied, unoccupied, or presumed occupied stands, including distance from roads, expected improvements within the stand or 0.25 mile buffer, and surface of existing roads, including maps of the particular stand. The impact assessments also identify how far a MAMU stand is in relation to proposed construction activities, including large helicopter use and blasting. Many of the MAMU Stands occur in areas with higher existing disturbance (i.e., residential, commercial, and agricultural areas) and noise associated with construction of the project would be detectible, but often times not disruptive (see Noise Evaluation, appendix Z3). Informal consultations with FWS (June 5, 2008 meeting; see NSO and MAMU Avoidance Plan) identified disturbance from travel on existing roads to be less of an impact than other actions associated with the proposed Project, especially if farther than 35 yards (105 feet). Although use of existing roads may be detectible by MAMU within 0.25 mile, it is not expected that use of every existing road would disturb nesting murrelets and use of existing roads would not significantly disrupt normal behavior patterns and lead to harassment under the ESA, described above (see Pacific Connector's Noise Evaluation in appendix Z3). Therefore, Pacific Connector assumes that use of existing access roads (EARs) would be a potential disturbance to MAMU and could result in temporary reduced habitat suitabilility, but would not disrupt breeding behaviors.

Table Q-2 in appendix Q provides distances from actions and timing of those actions that are expected to occur within the occupied, unoccupied, or presumed occupied stands during proposed project activities (timber clearing, construction activities, road use) and through the life of the Project (i.e., maintenance and operation activities). Since nest locations within MAMU stands are not known, analyses in this BA have assumed that murrelets are nesting along the closest edge to disturbance or existing road from the marbled murrelet stand which is unlikely but, absent specific nest locations, is the most conservative approach. Additionally, table Q-2 in appendix Q provides the expected effect from noise and visual presence of proposed project activities (disruption, disturbance, no disturbance, or no effect) and rationale for each occupied, unoccupied, or presumed occupied stand based on timing and distance from the Project activities for each proposed activity (based on disturbance distances from table 4.3.3-7 and adjusted, if applicable, from site-specific analysis in the Noise Evaluation in appendix Z3).

Maps 1 through 10 in appendix Q show the locations of occupied, unoccupied, and presumed occupied stands in relation to different Project components and identify spatial buffers (360 feet and 0.25 mile buffers) associated with a MAMU stand. Rationale for location of the proposed Pacific Connector pipeline within each known occupied stand, presumed occupied stand, and unoccupied stand is located in the Marbled Murrelet and Northern Spotted Owl Avoidance and Minimization Plan (see appendix V).

Table 4.3.3-9 provides a summary of occupied, unoccupied, and presumed occupied stands within the Terrestrial Nesting Analysis Area that may be affected by the proposed Project and is based on the timing of activities (summarized from table Q-2 in appendix Q) and site-specific noise analysis. Stands that have not had surveys conducted to date because they have been denied access by the landowner or were identified for this BA have been presumed occupied for this analysis. If stands are surveyed and no suitable nesting structures are present, then no disturbance effect would be expected. Table 4.3.3-9 provides a conservative estimate of the stands likely to be disturbed by activities associated within the proposed action, because Pacific Connector does not expect the majority of presumed occupied stands on private lands to have suitable nesting habitat present based on 1) on-the-ground surveys adjacent to those stands with no suitable nesting habitat identified, 2) location of those identified stands within narrow riparian buffers surrounded by clear-cuts and/or residences, and/or 3) proximity of presumed occupied stands greater than 3.0 miles from known occupied stands. Additionally, activities will not occur simultaneously along the proposed route, and as a result some activities near MAMU stands may occur outside of the breeding period and/or within the latter part of the breeding season within the DTR timing window. Also, disturbance or disruption associated with construction activities will likely only occur in one year; however, Pacific Connector cannot guarantee that activities would only occur in one year (there may be unforeseeable circumstances that result in two years of activities), therefore, Pacific Connector has identified that disruption and disturbance activities could occur in both Years 1 and 2. Stands considered “unoccupied” for this BA will be surveyed again in 2014; it is not expected that these stands will document occupied behavior because three years of surveys (2007, 2008, and 2013) have not observed behavior to suggest MAMU occupancy or presence.

Marbled murrelet stands identified in the timber and removal/construction column could also experience effects during reclamation; however, reclamation activities within 0.25 mile of MAMU Stands would occur outside of the marbled murrelet breeding season (September 15 through March 31). Effects by reclamation to nesting murrelets would not be expected.

**Table 4.3.3-9**
**Number of Occupied or Presumed Occupied Stands within the Marbled Murrelet Zones with Expected Disturbances from Noise and/or Visuals Associated with Activities Proposed within 0.25 mile of Stands [1]**

| Status of Marbled Murrelet Stand | General Landowner | Total Number of Stands | Construction Activities and Road Use[2] | | Construction Activities Only[3] | | Road Use Only[4] | | None[5] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Disruption | Disturbance | Disruption | Disturbance | Disruption | Disturbance | |
| **Marbled Murrelet Zone 1** | | | | | | | | | |
| Occupied Stand | Federal | 44 | 14 | 5 | 0 | 0 | 0 | 24 | 1 |
| | Non-Federal | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | Total | 45 | 14 | 5 | 0 | 0 | 0 | 25 | 1 |
| Presumed Occupied | Federal | 61 | 0 | 12 | 0 | 0 | 0 | 45 | 4 |
| | Non-Federal | 55 | 14 | 21 | 0 | 5 | 0 | 14 | 1 |
| | Total | 116 | 14 | 33 | 0 | 5 | 0 | 59 | 5 |
| Unoccupied | Federal | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Total U Zone 1 | Federal | 106 | 14 | 18 | 0 | 0 | 0 | 69 | 5 |
| | Non-Federal | 56 | 14 | 21 | 0 | 5 | 0 | 15 | 1 |
| | Total | 162 | 28 | 39 | 0 | 5 | 0 | 84 | 6 |
| **Marbled Murrelet Zone 2** | | | | | | | | | |
| Occupied Stand | Federal | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Presumed Occupied | Federal | 8 | 0 | 3 | 0 | 1 | 0 | 4 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 8 | 0 | 3 | 0 | 1 | 0 | 4 | 0 |
| Unoccupied | Federal | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Murrelet Zone 2 | Federal | 11 | 2 | 4 | 0 | 1 | 0 | 4 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 11 | 2 | 4 | 0 | 1 | 0 | 4 | 0 |
| **Entire MAMU Range** | | | | | | | | | |
| Occupied Stand | Federal | 45 | 0 | 6 | 0 | 0 | 0 | 24 | 0 |
| | Non-Federal | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | Total | 46 | 14 | 6 | 0 | 0 | 0 | 25 | 0 |
| Presumed Occupied | Federal | 69 | 0 | 15 | 0 | 1 | 0 | 45 | 0 |
| | Non-Federal | 55 | 0 | 21 | 0 | 5 | 0 | 14 | 0 |
| | Total | 124 | 14 | 36 | 0 | 6 | 0 | 63 | 0 |
| Unoccupied | Federal | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Status of Marbled Murrelet Stand | General Landowner | Total Number of Stands | Construction Activities and Road Use[2] | | Construction Activities Only[3] | | Road Use Only[4] | | None[5] |
|---|---|---|---|---|---|---|---|---|---|
| | | | Disruption | Disturbance | Disruption | Disturbance | Disruption | Disturbance | |
| | Total | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| Total MAMU Range | Federal | 117 | 16 | 22 | 0 | 1 | 0 | 69 | 5 |
| | Non-Federal | 56 | 14 | 21 | 0 | 5 | 0 | 15 | 1 |
| | Total | 173 | 30 | 43 | 0 | 6 | 0 | 88 | 6 |

[1] Summarized from table Q-2 in appendix Q.
[2] Construction Activities and Road use: both proposed activities occur within 0.25 mile of MAMU Stands
[3] Construction Activities Only: includes general construction activities, blasting (> 2lbs explosives), and large transport helicopter use; no proposed road use within 0.25 mile of MAMU Stands
[4] Road use only: no construction activities proposed within 0.25 mile of MAMU Stands
[5] None: construction and proposed road use > 0.25 mile of MAMU Stands

**Maintenance and Operation.** No activities associated with general maintenance and operations of the proposed action are expected to affect occupied MAMU stands. FERC requires that vegetation maintenance activities occur only between August 1 and April 15 of any year (see appendix C); generally, outside of the critical breeding season. Pacific Connector would apply DTRs during activities during the late breeding season (August 5 through September 15) to ensure no effects to MAMU (see table 4.3.3-7); therefore, no disturbance is expected. Routine clearing of vegetation greater than 6 feet in height within the 30-foot permanent right-of-way would not occur more frequently than every 3 years. A 10-foot corridor centered over the pipeline may be maintained annually in an herbaceous state to facilitate periodic corrosion and leak surveys. Pacific Connector would also require pilots conducting annual aerial inspection (small plane/helicopter) of the pipeline to adhere to the spatial restrictions recommended in the vicinity of occupied stands (no overflight within 1,300 feet AGL during the critical breeding season (April 1 through August 5), resulting in no adverse effect from aerial pipeline inspection. However, some routine activities such as pipeline right-of-way inspection may require pipeline personnel to visit the right-of-way at any time; these visits along the right-of-way would be by a vehicle or via walking and adhere to DTRs.

Helicopter Rotor Wash

Strong winds can adversely affect MAMUs (FWS, 1990) by directly removing habitat from windthrow that could fragment forests and increase edge effects (risk of predation, microclimatological changes). Wind can also cause direct mortality by blowing chicks out of nests (FWS, 1992a). Helicopter drive rotors produce high velocity vortices (winds) that extend from the center of the helicopter outward in all directions. Vertical downwash of air (rotor wash) close enough to the ground produces surface winds that dissipate with distance away from the helicopter (sidewash). Induced winds caused by helicopter rotor wash may exceed hurricane force velocities that would be expected to adversely affect nesting MAMUs on a local level. Since induced rotor downwash and surface sidewash are functions of helicopter size, rotor surface area, helicopter weight, flight speed, and height above ground (Teske et al., 1997; Gordon et al., 2005), effects to nesting birds can be minimized or avoided by routing helicopter flight paths and staging locations far enough away from nests so that induced winds would not adversely affect nests or nestlings.

Maximum induced surface velocities produced by downwash and sidewash from various helicopters were measured in the field to determine the decay function of rotor-produced vortices near ground level (Teske et al., 1997). Field studies included measurements on three helicopter models that might be utilized during construction of the Pacific Connector pipeline: 1) the twin-rotor CH-47 (civilian variant is the Boeing HH-47 Chinook) with rotor diameter 59.1 feet, 2) the single rotor CH-54 with a rotor diameter of 72 feet (civilian variant is the Sikorsky S-64 Skycrane), and 3) the twin-rotor CH-46 (civilian variant Boeing Vertol 107) with a rotor diameter of 49.9 feet (Teske et al., 1997). Using parameters derived from the field trials, estimates of maximum induced surface velocities were made for each of the three helicopter models at varying heights above ground while flying at different ground speeds. In general, maximum induced surface velocities increase with rotor diameters, decrease with distance above ground, and decrease with faster ground speeds.

Results of modeling maximum induced surface velocities (model described in Teske et al., 1997) produced by a Chinook helicopter are shown in figure 4.3-7 for drop heights (heights above ground level at which the helicopter would discharge a payload of foam, water, or retardant during wild fire control) ranging from 10 to 320 feet while flying at ground speeds ranging from 5 to 25 miles per hour (mph). Included in figure 4.3-6 are four wind speed categories on the Beaufort Scale (NOAA: http://www.spc.noaa.gov/faq/tornado/beaufort.html) which was developed to describe damage associated with wind forces ranging from calm to hurricane forces. On the Beaufort Scale, induced surface winds of 9 to 11 mph produced by rotor wash would be equivalent to a "gentle breeze" during which leaves and small twigs would be constantly moving and light flags would be extended. Wind velocities of 19-24 mph are classified as a "fresh breeze" (small trees in leaf would sway). Winds 39 to 46 mph are "gale" force strength: difficult to walk against, twigs and small branches blown off trees. Winds greater than 74 mph are classified as a hurricane.

Figure 4.3-7 shows the heights above ground that Chinook helicopters would produce maximum induced surface winds with velocities equivalent to a "fresh breeze" while traveling at ground speeds of 5, 10, 15, 20 or 25 mph. For example, if traveling at a ground speed of 5 mph, the Chinook would have to be approximately 185 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a "fresh breeze". If traveling at ground speed of 25 mph, the Chinook could be 75 feet above ground and still induce a maximum surface velocity of 24 mph.

In the Project area, wind speeds reported by the Western Regional Climate Center (available online at http://www.wrcc.dri.edu/htmlfiles/westwind.final.html#OREGON) at the North Bend airport averaged 10.2 mph in June, 11.2 mph in July and 9.9 mph in August, the three months with highest average wind velocities during the period from 1996 to 2006. During the same period, winds in Roseburg averaged 5.0 mph in June, 5.2 mph in July, and 4.4 mph in August. These data indicate that winds as strong as a fresh breeze (19 to 24 mph) would be expected along the Oregon Coast and most likely inland during the period when MAMUs are nesting. We assume that induced winds the strength of a fresh breeze would not adversely affect young or nests.

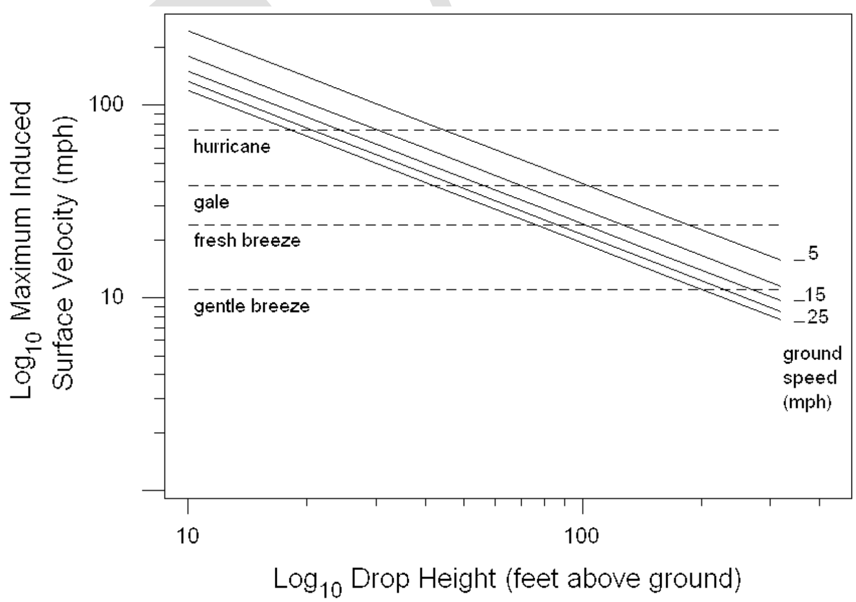



**Figure 4.3-7**
**Modeled Maximum Surface Velocities Induced by Chinook C-47 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground. (Modeled from data in Teske et al., 1997)**

Incoming or outgoing Chinook helicopters flying at 5 mph while 185 feet above a tree with a nest would most likely produce winds with velocities less than a fresh breeze at the tree top because there would be no resistance by the ground to induce maximum sidewash vortices.

Similar results were produced by the Boeing Vertol 107 (see figure 4.3-8) even though it is smaller than the Chinook (rotor diameter 49.9 feet compared to 59.1 feet). The Vertol 107, flying at a ground speed of 5 mph, would have to be approximately 200 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a fresh breeze. If traveling at ground speed of 25 mph, the Vertol 107 could be 82 feet above ground and still induce a maximum surface velocity of 24 mph. Overall, the Vertol 107 produces slightly greater maximum induced surface velocities than the Chinook CH-47 even though its maximum equipment weight is less than the Chinook.

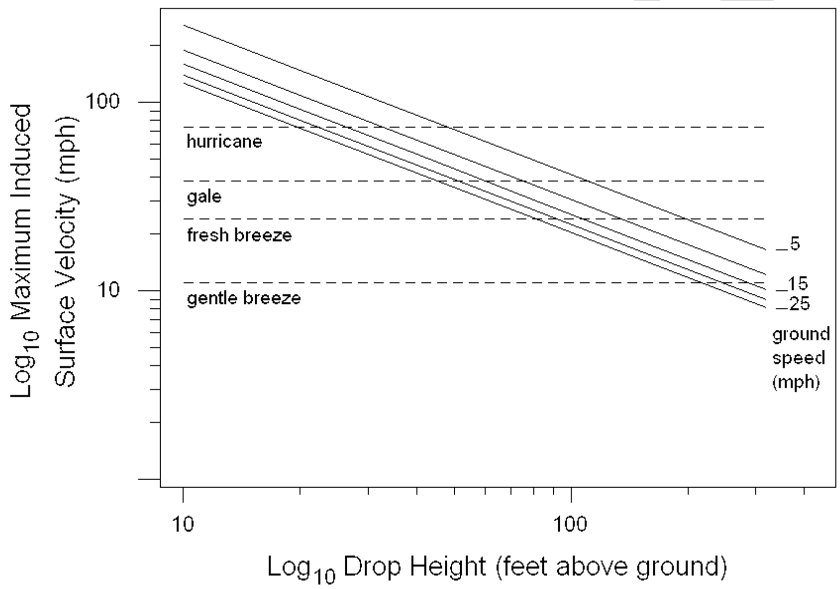



**Figure 4.3-8**
**Modeled Maximum Surface Velocities Induced by Boeing Vertol 107 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground (Modeled from data in Teske et al., 1997**

The single rotor S-64 Skycrane has the largest rotor diameter (72 feet diameter) of the three models. As modeled in figure 4.3-9, the Skycrane would produce greater maximum induced surface velocities while flying at the same ground speeds and same drop heights as the other two helicopter models.

Flying at a ground speed of 5 mph, the Skycrane would have to be approximately 233 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a fresh breeze. The Chinook and Vertol 107 helicopters would induce similar maximum surface velocities flying at heights of 185 feet and 200 feet above ground, respectively. If traveling at ground speed of 25 mph, the Skycrane could be 95 feet above ground to induce a maximum surface velocity of 24 mph.

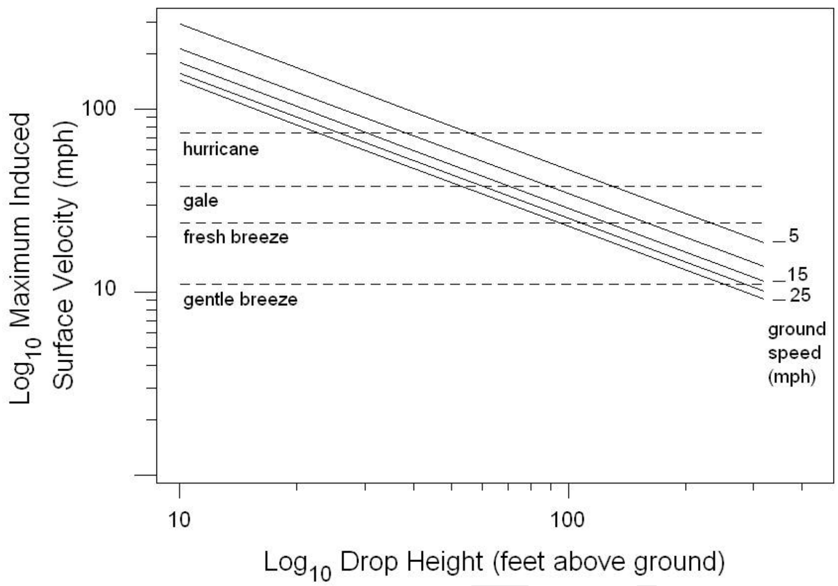



**Figure 4.3-9**
**Modeled Maximum Surface Velocities Induced by Skycrane S-64 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground. (Modeled from data in Teske et al., 1997**

Actual downwash and sidewash vortices produced by Chinook CH-47 and Skycrane (CH-54) helicopters were measured during field tests (Leese and Knight, 1974) while aircraft were hovering at 40-50 feet and 80-90 feet above ground level (agl) while under maximum loads of 36,000 pounds (CH-47) and 45,000 to 47,000 pounds (CH-54). The Vertol 107 (CH-46) was not included in the field tests.

With a 47,000-pound load, the single rotor CH-54 hovering at 40 feet agl produced a maximum sidewash velocity of 87 mph 50 feet away from the rotor hub; at 80 feet agl, the maximum sidewash was 74 mph, also measured at 50 feet from the hub though the gross weight was 45,000 pounds during that particular trial. Both maximum sidewash measurements were at heights of 0.3 feet above ground (Leese and Knight, 1974). Under the specified load conditions, the CH-54 produced a sidewash of 11 mph 170 feet away from the rotor hub while hovering at 40 feet agl and a sidewash of 9 mph 150 feet away from the hub while hovering at 80 feet agl. Maximum sidewash velocities of 74 to 87 mph that were associated with the CH-54 helicopter while it was hovering, are within the range of hurricane force winds on the Beaufort Scale while winds of 9 to 11 mph produced by rotor sidewash would be described as a “gentle breeze”. Sidewash velocities between 9 and 11 mph at distances 150 to 170 feet away from a CH-54 helicopter (Skycrane) would be unlikely to blow young MAMUs from their nests.

Downwash and sidewash velocities measured for the CH-47 helicopter (Chinook) were greater than 100 mph up to 70 feet horizontally from the rotor hub when it was hovering at 90 feet agl with maximum load of 36,000 pounds (Leese and Knight, 1974). The twin rotor CH-47 produced sidewash velocities as high as 56 mph 190 feet away from the rotor hub when it was hovering at 90 feet agl. The Beaufort Scale classifies winds between 55 and 63 mph as a “storm,” with trees uprooted and structural damage likely. The greater strength of winds produced by the CH-47 is likely due to the interaction of descending air produced by the two rotors (Fabey, 2008); sidewash winds are generally strongest at 120 and 240 degrees (4 o'clock and 8 o'clock, respectively) relative to the helicopter's heading (data in Leese and Knight, 1974).

Sidewash wind velocities produced by the CH-47 at various distances away from the rotor hub (Leese and Knight, 1974) were used to predict the distance at which the helicopter would be far enough to avoid adversely affecting MAMU nests and young. The prediction is based on the sidewash wind velocities produced by the CH-47, averaged for wind measurements made 0.3 feet above ground at angles of 120 and 240 degrees while the helicopter was hovering 90 feet agl under a load of 36,000 pounds. The prediction is shown below in figure 4.3-10 in which a sidewash velocity of 0 mph would occur 293 feet away from the rotor hub. Due to the observed variation in sidewash winds at different distances away from the rotor hub (solid circles in figure 4.3-10), the upper 95 percent prediction interval on that predictive estimate of 0 mph at 293 feet from the hub would be 23.8 mph. A wind velocity of 23.8 mph is classified as a fresh breeze on the Beaufort Scale. One can be 95 percent certain that a stronger wind, potentially adversely affect nesting MAMUs, would not occur.

These estimates clearly suggest that greater distances would be required to avoid adverse effects to MAMUs if Chinook helicopters, rather than Skycranes, are employed for heavy lifting along remote sections of the Pacific Connector pipeline construction right-of-way. Based on the similarities of maximum induced surface velocities between Chinook and Vertol 107 helicopters, sidewash velocities induced while hovering are likely to be similar as well. However, if known nest trees or stands can be avoided by at least 200 feet above tree tops by heavy-lifting helicopters in transit, and avoided horizontally by at least 300 feet while helicopters hover above staging sites, no adverse effects to the species from rotor downwash and induced sidewash would be expected.

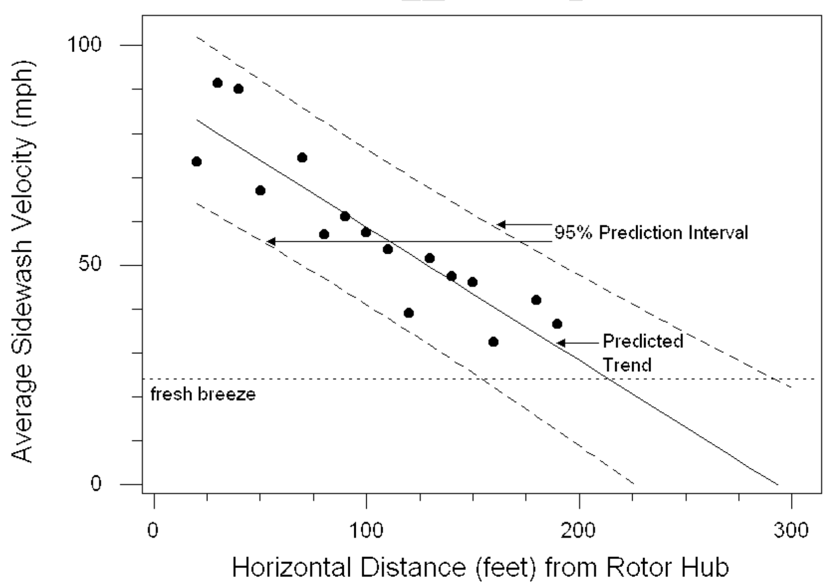



**Figure 4.3-10**
**Average Sidewash Wind Velocities Produced by the CH-47 at Varying Horizontal Distances from the Rotor Hub While Hovering 90 feet agl Under a Load of 36,000 pounds. The Observed Averages (solid circles) were used to Predict Sidewash Winds at Distances Out to 300 feet. (Source: Leese and Knight, 1974)**

Eleven MAMU stands occur within 0.25 mile of proposed helicopter use, of which seven stands are within 300 feet of proposed helicopter use (five occupied stands – C3073, C3090, C3094, C3095, and R3035 [EAR 46.51_A]; one unoccupied stand – B14; and one presumed occupied stand – G31). Helicopter use for timber extraction within 300 feet of a MAMU stand would occur outside of the entire breeding season (between September 16 and March 31); no adverse effects from rotor wash of large helicopters are expected during timber extraction. Adverse effects to MAMUs in the six stands identified above could occur from rotor wash of large helicopters during pipe delivery during construction of the proposed action, since activity could occur during the entire breeding season and may be within 200 feet above nest trees and horizontally within 300 feet of nest trees (the nest site is unknown within these stands but potential nest trees have been identified adjacent to the construction right-of-way and rotor wash could affect MAMU if present).

Burning and Smoke

Whether by prescribed burning as a habitat enhancement procedure or by burning slash, effects of smoke on MAMUs have not been studied. However, FWS et al. (2007) have declared (see Table 15, FWS et al. 2007) "that smoke can cause [northern spotted owl] adults to move off nest sites, therefore leaving eggs or young exposed to predation or resulting in lost feedings reducing the young's fitness." In the absence of reliable information, one would reasonably assume that the same effects apply to MAMUs.

According to BLM and Forest Service (2008, page 35), MAMUs "are potentially affected by fire control activities and drifting smoke during burning. The threshold distance for disturbance from smoke is 0.25 mile for MAMUs," which also would be subject to smoke-related disturbance during the critical breeding period (April 1 through August 5). Pacific Connector would not conduct slash burning during the critical breeding season within 0.25 mile of an occupied or presumed occupied MAMU stand. No direct effect to MAMUs due to slash burning is expected.

**Indirect Effects**

Project-related effects to MAMUs that are caused by the action (induced by the action and by human presence and use increase) and are later in time or farther removed in distance, but are still reasonably foreseeable are indirect effects. A primary indirect effect to MAMUs would be removal of suitable nesting habitat, and could also include removal of recruitment or capable habitat. Removal of MAMU habitat would be a long-term impact to MAMUs and would be expected to last at least 5 years or more. Short-term impact is expected with the use of UCSAs and is likely to last from the initiation of timber clearing until 1 to 5 years after restoration/revegetation. Other indirect or secondary effects by the Project could include increased human presence as a result of the requirements of the action itself (the workforce needed to construct or operate the Project), increased recreation (including ORV use, hunting), and habitat degradation (Comer, 1982).

Focus of Effects Analyses

Meyer et al., 2002a have indicated that social interactions may play an important role in determining nesting locations, in addition to available suitable habitat, since research has indicated that MAMU in California and southern Oregon were less likely to occupy old-growth habitat if it was isolated from other nesting MAMU by more than 3 miles. The FWS (FWS, 2008b and 2011a) and BLM (BLM, 1995a and 1995b) recognize that forested habitat within 0.5

mile of an occupied stand are important to recruit additional nesting habitat for the marbled murrelet in the future (e.g., potential nesting habitat within 25 years; BLM, 1995a and 1995b).

Indirect effects analyzed within this Draft BA are considered within three habitat areas defined by FWS as a Suitable Habitat Unit - SHU (PC Trask & Associates, 2013), which include habitat that could play an important role in maintaining and expanding MAMU populations: 1) the MAMU Stand with known or presumed suitable nesting structures; 2) a 300-foot buffer around the MAMU stand that includes forested habitat to protect/provide a buffer to nesting MAMUs as described by the MAMU Recovery plan (FWS, 1997); and 3) federally-designated critical habitat within a 0.5-mile buffer around a MAMU stand that is within 0.5 mile of critical habitat removal by the proposed action. This latter defined area includes forested habitat proximal to the MAMU stand that could provide suitable nesting structures in the future for the MAMU and has been federally protected through critical habitat designation. Within the Terrestrial Nesting Analysis Area where MAMU stands are in close proximity of each other (i.e., less than 300 feet or adjacent), SHUs overlap. Therefore, analyses provided in this Draft BA consider the SHUs within the Terrestrial Nesting Analysis Area collectively to eliminate duplication of acres of impact. Impacts to individual MAMU SHUs are included in appendix Z1. Figure 1 in appendix Z1 shows the MAMU SHUs in relation to the proposed action and Marbled Murrelet Inland Zones 1 and 2.

Nesting Habitat Removal/Modification

**Long-Term Effects to Habitat**. Removal of suitable nesting habitat by harvest of old-growth timber has been cited as the primary reason for the species' decline (FWS, 1992a). Implementation of the NWFP and late successional reserves, and the designation of critical habitat were designed to increase the amount of late successional forest habitat available for the long term, thus increasing potential nesting habitat for murrelets. The Coos Bay and Roseburg BLM Resource Management Plans (BLM, 1995a and 1995b) also identify the importance of forested habitat within 0.5-mile of occupied MAMU stands and state that removal of habitat within occupied stands should not occur and other forested habitat within a 0.5 mile radius of any occupied stand should be protected for recruitment of nesting habitat for marbled murrelets (i.e., stands that are capable of becoming marbled murrelet habitat within 25 years). Since 2003, effects to MAMU suitable habitat have been minimal (BLM and USFS, 2006a). Suitable murrelet nesting habitat takes a long time to develop (more than 250 years on average); therefore, any removal of suitable habitat or recruitment habitat may affect the recovery of the murrelet since recent trends indicate that murrelets may be declining (see Section 4.3.3.1).

Based on MAMU habitat delineated for the PCGP Project, construction of the proposed action will remove approximately 925.65 acres of MAMU habitat, including 57.98 acres of "suitable habitat" removed from 25 MAMU stands (14 occupied MAMU stands, two unoccupied MAMU stands, and nine presumed suitable stands; see table 4.3.3-9). Removal of 57.98 acres of suitable MAMU habitat amounts to approximately 0.4 percent of the 14,044 acres of suitable habitat available in the Terrestrial Nesting Analysis Area (see table 4.3.3-11). It is expected that recruitment habitat within SHUs, especially forested habitat greater than 60 years located on federally-managed lands, would provide potential nesting habitat for marbled murrelets in the future (BLM, 1995 a and b; PC Trask & Associates, 2013; FWS, 2008a and 2011b). The removal of suitable habitat would indirectly affect marbled murrelets over the long-term, for longer that the expected 40-year life of the project.

**Short-Term Effects to Habitat**. Additionally, 118.62 acres of MAMU habitat (12.68 acres of suitable habitat) have been identified for use by the PCGP Project as UCSAs that may be used to store forest slash, stumps, and dead and downed log materials that will be removed and scattered across the right-of-way after construction during restoration (see UCSA Column – table 4.3.3-10). Use of the UCSAs will be a short-term modification of understory species and will not affect the nesting habitat or characteristics.

**Summary of Effects to Habitat**. Table 4.3.3-10 below summarizes the amount of suitable habitat, recruitment habitat, and capable habitat that will be directly removed or used as UCSAs within and outside of SHUs.

Table 4.3.3-10 (summarized from table Q-3 in appendix Q) also identifies 201.70 acres of MAMU habitat that occur within the designated 30-foot maintenance corridor (16.00 acres of suitable habitat, 65.25 acres of recruitment habitat, and 120.45 acres of capable habitat) within Marbled Murrelet Inland Zones 1 and 2. After construction of the pipeline, approximately 723.95 acres of forested habitat within Marbled Murrelet Inland Zones 1 and 2 outside of the 30-foot maintenance corridor (see Suitable, Recruitment, and Capable in table 4.3.3-10, computed by subtracting areas in the 30-foot Corridor from areas in the Removed columns) will be replanted with tree species and effects of edge will decrease over time; Douglas-firs (12-inch seedlings in 1 gallon containers or bare root) will be planted on dry sites and western hemlock (12-inch seedlings in 1 gallon containers) will be planted on moist sites (see ECRP – appendix F). It is expected that 12-inch Douglas-firs and western hemlocks planted the year of or year after pipeline construction could be approximately 70 feet tall in 50 years (expected end of the PCGP Project life). During the first 30 years or so, coastal Douglas-fir are expected to grow at an average rate of 24 inches per year and may grow at a continuous rate of 6 to 9 inches per year to age 120 (McArdle et al., 1961; Hermann and Lavender, 2004). Young, unthinned stands of Douglas-fir (38 to 70 years old) were documented between 115 and 154 feet tall while young, thinned stands (40 to 73 years old) were 121 to 151 feet tall (Tappeiner et al., 1997). Western hemlock are highly productive; trees in Oregon were 140 feet tall at 100 years old (an approximate height growth rate of 16-17 inches per year). Marbled murrelet habitat within the 30-foot corridor will remain in an early seral state, maintained free of vegetation greater than 6 feet in height, through the life of the project.

Figure 1 in appendix Q provides an overview of MAMU habitat (suitable, recruitment, and capable) within the proposed Terrestrial Nesting Analysis Area and includes known occupied, presumed occupied, and unoccupied stands, designated critical habitat, NWFP LSRs, and unmapped LSRs within Marbled Murrelet Zones 1 and 2 and Conservation Zones 3 and 4. Table 4.3.3-11 summarizes the amount of MAMU habitat affected by the proposed Project within the Terrestrial Nesting Analysis Area pre- and post-action. The proposed action will remove the greatest percentage of available MAMU habitat within the Terrestrial Nesting Analysis Area on non-federal lands outside of SHUs; however, it is not expected that habitat on non-federal lands would provide suitable nesting structures, or that capable or recruitment habitat would mature to provide suitable MAMU nesting structures based on review of timber harvest practices in Oregon (Zhou, et al., 2005; Rasmussen, et al., 2012). These studies noted that forest harvest practices on non-federal lands typically occurs between 45 and 65 years of age.

**Table 4.3.3-10**
**Summary of Marbled Murrelet Suitable, Recruitment, and Capable Habitat Impacted During PCGP Construction and Operation (30-foot Corridor) within Marbled Murrelet Inland Zones 1 and 2, |Recovery Plan Conservation Zones, and within/outside Marbled Murrelet SHUs by Landowner**

| Conservation Zones | Land Owner | General Location[1] | Suitable Habitat[2] | | | Recruitment Habitat[3] | | | Capable Habitat[4] | | | Non-Capable Habitat[5] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | |
| *Conservation Zone 3* | State | Within SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 83.13 | 0.00 | 9.82 | 83.26 | 0.00 | 9.83 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 83.13 | 0.00 | 9.82 | 83.26 | 0.00 | 9.83 |
| | Private / Other | Within SHUs | 2.11 | 0.00 | 0.54 | 2.64 | 0.00 | 0.67 | 2.14 | 0.00 | 0.48 | 2.33 | 0.00 | 0.66 | 9.22 | 0.00 | 2.35 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 11.48 | 0.00 | 2.57 | 78.33 | 0.00 | 18.58 | 198.07 | 0.00 | 8.64 | 287.88 | 0.00 | 29.79 |
| | | Subtotal | 2.11 | 0.00 | 0.54 | 14.12 | 0.00 | 3.24 | 80.47 | 0.00 | 19.06 | 200.40 | 0.00 | 9.30 | 297.10 | 0.00 | 32.14 |
| *Total Conservation Zone 3* | | *Within SHUs* | *2.11* | *0.00* | *0.54* | *2.64* | *0.00* | *0.67* | *2.14* | *0.00* | *0.48* | *2.33* | *0.00* | *0.66* | *9.22* | *0.00* | *2.35* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *11.61* | *0.00* | *2.58* | *78.33* | *0.00* | *18.58* | *281.20* | *0.00* | *18.46* | *371.14* | *0.00* | *39.62* |
| | | *Total* | *2.11* | *0.00* | *0.54* | *14.25* | *0.00* | *3.25* | *80.47* | *0.00* | *19.06* | *283.53* | *0.00* | *19.12* | *380.36* | *0.00* | *41.97* |
| *Conservation Zone 4* | Coos Bay BLM | Within SHUs | 29.66 | 7.03 | 8.89 | 9.83 | 1.45 | 2.45 | 34.18 | 4.05 | 6.86 | 10.84 | 0.03 | 3.70 | 84.51 | 12.56 | 21.90 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 20.19 | 1.45 | 4.93 | 48.44 | 0.97 | 11.10 | 6.11 | 0.04 | 1.41 | 74.74 | 2.46 | 17.44 |
| | | Subtotal | 29.66 | 7.03 | 8.89 | 30.02 | 2.90 | 7.38 | 82.62 | 5.02 | 17.96 | 16.95 | 0.07 | 5.11 | 159.25 | 15.02 | 39.34 |
| | Roseburg BLM | Within SHUs | 2.48 | 0.00 | 0.71 | 1.52 | 0.00 | 0.22 | 1.44 | 0.00 | 0.01 | 0.92 | 0.00 | 0.03 | 6.36 | 0.00 | 0.97 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Subtotal | 2.48 | 0.00 | 0.71 | 1.52 | 0.00 | 0.22 | 1.44 | 0.00 | 0.01 | 0.92 | 0.00 | 0.03 | 6.36 | 0.00 | 0.97 |
| | State | Within SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.12 | 0.00 | 0.16 | 4.12 | 0.00 | 0.16 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.12 | 0.00 | 0.16 | 4.12 | 0.00 | 0.16 |
| | Private / Other | Within SHUs | 3.91 | 0.00 | 1.04 | 18.15 | 0.52 | 4.74 | 32.98 | 4.02 | 7.35 | 7.73 | 0.03 | 1.74 | 62.77 | 4.57 | 14.87 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 44.61 | 4.65 | 10.04 | 288.38 | 22.66 | 58.76 | 107.69 | 0.75 | 17.93 | 440.68 | 28.06 | 86.73 |
| | | Subtotal | 3.91 | 0.00 | 1.04 | 62.76 | 5.17 | 14.78 | 321.36 | 26.68 | 66.11 | 115.42 | 0.78 | 19.67 | 503.45 | 32.63 | 101.60 |
| *Total Conservation Zone 4* | | *Within SHUs* | *36.05* | *7.03* | *10.64* | *29.50* | *1.97* | *7.41* | *68.60* | *8.07* | *14.22* | *19.49* | *0.06* | *5.47* | *153.64* | *17.13* | *37.74* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *64.80* | *6.10* | *14.97* | *336.82* | *23.63* | *69.86* | *117.92* | *0.79* | *19.50* | *519.54* | *30.52* | *104.33* |
| | | *Total* | *36.05* | *7.03* | *10.64* | *94.30* | *8.07* | *22.38* | *405.42* | *31.70* | *84.08* | *137.41* | *0.85* | *24.97* | *673.18* | *47.65* | *142.07* |
| *Outside Conservation Zones* | Roseburg BLM | Within SHUs | 3.52 | 0.85 | 0.94 | 3.79 | 1.04 | 0.79 | 6.61 | 0.02 | 2.06 | 1.20 | 0.00 | 0.47 | 15.12 | 1.91 | 4.26 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 5.77 | 0.13 | 1.51 | 7.85 | 0.00 | 1.93 | 1.57 | 0.00 | 0.45 | 15.19 | 0.13 | 3.89 |
| | | Subtotal | 3.52 | 0.85 | 0.94 | 9.56 | 1.17 | 2.30 | 14.46 | 0.02 | 3.99 | 2.77 | 0.00 | 0.92 | 30.31 | 2.04 | 8.15 |
| | Private / Other | Within SHUs | 2.39 | 0.00 | 0.75 | 0.32 | 0.00 | 0.13 | 0.73 | 0.51 | 0.18 | 2.52 | 0.00 | 0.46 | 5.96 | 0.51 | 1.52 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 11.89 | 0.10 | 3.45 | 20.99 | 3.79 | 5.17 | 25.30 | 0.06 | 5.58 | 58.18 | 3.95 | 14.20 |
| | | Subtotal | 2.39 | 0.00 | 0.75 | 12.21 | 0.10 | 3.58 | 21.72 | 4.30 | 5.35 | 27.82 | 0.06 | 6.04 | 64.14 | 4.46 | 15.72 |
| *Total Outside Conservation Zones* | | *Within SHUs* | *5.91* | *0.85* | *1.69* | *4.11* | *1.04* | *0.92* | *7.34* | *0.53* | *2.24* | *3.72* | *0.00* | *0.93* | *21.08* | *2.42* | *5.78* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *17.66* | *0.23* | *4.96* | *28.84* | *3.79* | *7.10* | *26.87* | *0.06* | *6.03* | *73.37* | *4.08* | *18.09* |

| Conservation Zones | Land Owner | General Location[1] | Suitable Habitat[2] | | | Recruitment Habitat[3] | | | Capable Habitat[4] | | | Non-Capable Habitat[5] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) |
| | | *Subtotal* | *5.91* | *0.85* | *1.69* | *21.77* | *1.27* | *5.88* | *36.18* | *4.32* | *9.34* | *30.59* | *0.06* | *6.96* | *94.45* | *6.50* | *23.87* |
| *Marbled Murrelet Inland Zone 1* | Coos Bay BLM | Within SHUs | 29.66 | 7.03 | 8.89 | 9.83 | 1.45 | 2.45 | 34.18 | 4.05 | 6.86 | 10.84 | 0.03 | 3.70 | 84.51 | 12.56 | 21.90 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 20.19 | 1.45 | 4.93 | 48.44 | 0.97 | 11.10 | 6.11 | 0.04 | 1.41 | 74.74 | 2.46 | 17.44 |
| | | Subtotal | 29.66 | 7.03 | 8.89 | 30.02 | 2.90 | 7.38 | 82.62 | 5.02 | 17.96 | 16.95 | 0.07 | 5.11 | 159.25 | 15.02 | 39.34 |
| | Roseburg BLM | Within SHUs | 6.00 | 0.85 | 1.65 | 5.31 | 1.04 | 1.01 | 8.05 | 0.02 | 2.07 | 2.12 | 0.00 | 0.50 | 21.48 | 1.91 | 5.23 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 5.77 | 0.13 | 1.51 | 7.85 | 0.00 | 1.93 | 1.57 | 0.00 | 0.45 | 15.19 | 0.13 | 3.89 |
| | | Subtotal | 6.00 | 0.85 | 1.65 | 11.08 | 1.17 | 2.52 | 15.90 | 0.02 | 4.00 | 3.69 | 0.00 | 0.95 | 36.67 | 2.04 | 9.12 |
| | State | Within SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 87.25 | 0.00 | 9.98 | 87.38 | 0.00 | 9.99 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 87.25 | 0.00 | 9.98 | 87.38 | 0.00 | 9.99 |
| | Private / Other | Within SHUs | 8.41 | 0.00 | 2.33 | 21.11 | 0.52 | 5.54 | 35.85 | 4.53 | 8.01 | 12.58 | 0.03 | 2.86 | 77.95 | 5.08 | 18.74 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 67.98 | 4.75 | 16.06 | 387.70 | 26.45 | 82.51 | 331.06 | 0.81 | 32.15 | 786.74 | 32.01 | 130.72 |
| | | Subtotal | 8.41 | 0.00 | 2.33 | 89.09 | 5.27 | 21.60 | 423.55 | 30.98 | 90.52 | 343.64 | 0.84 | 35.01 | 864.69 | 37.09 | 149.46 |
| *Total MAMU Inland Zone 1* | | *Within SHUs* | *44.07* | *7.88* | *12.87* | *36.25* | *3.01* | *9.00* | *78.08* | *8.60* | *16.94* | *25.54* | *0.06* | *7.06* | *183.94* | *19.55* | *45.87* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *94.07* | *6.33* | *22.51* | *443.99* | *27.42* | *95.54* | *425.99* | *0.85* | *43.99* | *964.05* | *34.60* | *162.04* |
| | | *Total* | *44.07* | *7.88* | *12.87* | *130.32* | *9.34* | *31.51* | *522.07* | *36.02* | *112.48* | *451.53* | *0.91* | *51.05* | *1147.99* | *54.15* | *207.91* |
| **Marbled Murrelet Inland Zone 2** | | | | | | | | | | | | | | | | | |
| *Outside Conservation Zones* | Roseburg BLM | Within SHUs | 13.55 | 4.78 | 3.12 | 0.08 | 0.01 | 0.00 | 0.08 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 13.78 | 4.79 | 3.12 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 9.07 | 6.79 | 2.21 | 0.72 | 1.99 | 0.10 | 4.71 | 0.10 | 1.48 | 14.50 | 8.88 | 3.79 |
| | | Subtotal | 13.55 | 4.78 | 3.12 | 9.15 | 6.80 | 2.21 | 0.80 | 1.99 | 0.10 | 4.78 | 0.10 | 1.48 | 28.28 | 13.67 | 6.91 |
| | Private / Other | Within SHUs | 0.06 | 0.02 | 0.01 | 3.66 | 2.86 | 0.99 | 7.00 | 1.17 | 1.58 | 0.42 | 0.33 | 0.20 | 11.14 | 4.38 | 2.78 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 125.99 | 38.82 | 30.54 | 68.98 | 8.94 | 6.29 | 524.04 | 5.84 | 34.74 | 719.01 | 53.60 | 71.57 |
| | | Subtotal | 0.06 | 0.02 | 0.01 | 129.65 | 41.68 | 31.53 | 75.98 | 10.11 | 7.87 | 524.46 | 6.17 | 34.94 | 730.15 | 57.98 | 74.35 |
| *Total Marbled Murrelet Zone2* | | *Within SHUs* | *13.61* | *4.80* | *3.13* | *3.74* | *2.87* | *0.99* | *7.08* | *1.17* | *1.58* | *0.49* | *0.33* | *0.20* | *24.92* | *9.17* | *5.90* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *135.06* | *45.61* | *32.75* | *69.70* | *10.93* | *6.39* | *528.75* | *5.94* | *36.22* | *733.51* | *62.48* | *75.36* |
| | | *Total* | *13.61* | *4.80* | *3.13* | *138.80* | *48.48* | *33.74* | *76.78* | *12.10* | *7.97* | *529.24* | *6.27* | *36.42* | *758.43* | *71.65* | *81.26* |
| **Entire Marbled Murrelet Range** | | | | | | | | | | | | | | | | | |
| *Entire Marbled Murrelet Range* | Coos Bay BLM | Within SHUs | *29.66* | *7.03* | *8.89* | *9.83* | *1.45* | *2.45* | *34.18* | *4.05* | *6.86* | *10.84* | *0.03* | *3.70* | *84.51* | *12.56* | *21.90* |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 20.19 | 1.45 | 4.93 | 48.44 | 0.97 | 11.10 | 6.11 | 0.04 | 1.41 | 74.74 | 2.46 | 17.44 |
| | | Subtotal | 29.66 | 7.03 | 8.89 | 30.02 | 2.90 | 7.38 | 82.62 | 5.02 | 17.96 | 16.95 | 0.07 | 5.11 | 159.25 | 15.02 | 39.34 |
| | Roseburg BLM | Within SHUs | 19.55 | 5.63 | 4.77 | 5.39 | 1.05 | 1.01 | 8.13 | 0.02 | 2.07 | 2.19 | 0.00 | 0.50 | 35.26 | 6.70 | 8.35 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 14.84 | 6.92 | 3.72 | 8.57 | 1.99 | 2.03 | 6.28 | 0.10 | 1.93 | 29.69 | 9.01 | 7.68 |
| | | Subtotal | 19.55 | 5.63 | 4.77 | 20.23 | 7.97 | 4.73 | 16.70 | 2.01 | 4.10 | 8.47 | 0.10 | 2.43 | 64.95 | 15.71 | 16.03 |
| | State | Within SHUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 87.25 | 0.00 | 9.98 | 87.38 | 0.00 | 9.99 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 87.25 | 0.00 | 9.98 | 87.38 | 0.00 | 9.99 |

| Conservation Zones | Land Owner | General Location[1] | Suitable Habitat[2] | | | Recruitment Habitat[3] | | | Capable Habitat[4] | | | Non-Capable Habitat[5] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Removed[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) |
| | Private / Other | Within SHUs | 8.47 | 0.02 | 2.34 | 24.77 | 3.38 | 6.53 | 42.85 | 5.70 | 9.59 | 13.00 | 0.36 | 3.06 | 89.09 | 9.46 | 21.52 |
| | | Outside SHUs | 0.00 | 0.00 | 0.00 | 193.97 | 43.57 | 46.60 | 456.68 | 35.39 | 88.80 | 855.10 | 6.65 | 66.89 | 1505.75 | 85.61 | 202.29 |
| | | Subtotal | 8.47 | 0.02 | 2.34 | 218.74 | 46.95 | 53.13 | 499.53 | 41.09 | 98.39 | 868.10 | 7.01 | 69.95 | 1594.84 | 95.07 | 223.81 |
| *Total Marbled Murrelet Range* | | *Within SHUs* | *57.68* | *12.68* | *16.00* | *39.99* | *5.88* | *9.99* | *85.16* | *9.77* | *18.52* | *26.03* | *0.39* | *7.26* | *208.86* | *28.72* | *51.77* |
| | | *Outside SHUs* | *0.00* | *0.00* | *0.00* | *229.13* | *51.94* | *55.26* | *513.69* | *38.35* | *101.93* | *954.74* | *6.79* | *80.21* | *1697.56* | *97.08* | *237.40* |
| | | *Subtotal* | *57.68* | *12.68* | *16.00* | *269.12* | *57.82* | *65.25* | *598.85* | *48.12* | *120.45* | *980.77* | *7.18* | *87.47* | *1906.42* | *125.80* | *289.17* |

1 General Location identifies areas within Marbled Murrelet SHUs – marbled murrelet stands – occupied, unoccupied, unsurveyed, presumed and appropriate buffers and areas outside of Marbled Murrelet SHUs within the range of the marbled murrelet.
2 Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
3 Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (PC Trask & Associates, 2013).
4 Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).
5 Non-Capable habitat: not forested and not capable of becoming forest, or deciduous forest stands.
6 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
7 Acres identified as UCSAs have been incorporated into the 100-meter indirect effects. UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
8 Acres of habitat that would be maintained in an early seral / shrub state during the life of the project within the 30-foot maintenance corridor.

Summarized from table Q-3 in appendix Q, which also provides project effects by land allocation and within and outside of interior forest.

**Table 4.3.3-11**
**Summary of Effects to Marbled Murrelet Habitat within Marbled Murrelet Zones 1 and 2 and Recovery Plan Conservation Zones 3 and 4 within the Defined Terrestrial Nesting Action Area as a Result of the Proposed Project**

| Conservation Zone | Landowner[1] | General Location | Total Acres within Analysis Area | Suitable Habitat[2] | | | | Recruitment Habitat[3] | | | | Capable Habitat[4] | | | | Total MAMU Habitat | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action |
| | | | | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | |
| Conservation Zone 3 | Federal | Within SHUs | 20 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 |
| | | Outside of SHUs | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 |
| | | Total | 20 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 |
| | Non-Federal | Within SHUs | 710 | 260 | 2.11 | 0.8 | 258 | 88 | 2.64 | 3.0 | 85 | 305 | 2.14 | 0.7 | 303 | 653 | 6.89 | 1.1 | 646 |
| | | Outside of SHUs | 6,370 | 1 | 0.00 | 0.0 | 1 | 435 | 11.61 | 2.7 | 424 | 3,276 | 78.33 | 2.4 | 3,198 | 3,712 | 89.94 | 2.4 | 3,622 |
| | | Total | 7,081 | 261 | 2.11 | 0.8 | 259 | 523 | 14.25 | 2.7 | 509 | 3,582 | 80.47 | 2.2 | 3,501 | 4,366 | 96.83 | 2.2 | 4,269 |
| | Total Conservation Zone 3 | Within SHUs | 731 | 260 | 2.11 | 0.8 | 258 | 88 | 2.64 | 3.0 | 85 | 305 | 2.14 | 0.7 | 303 | 653 | 6.89 | 1.1 | 646 |
| | | Outside of SHUs | 6,370 | 1 | 0.00 | 0.0 | 1 | 435 | 11.61 | 2.7 | 424 | 3,276 | 78.33 | 2.4 | 3,198 | 3,712 | 89.94 | 2.4 | 3,622 |
| | | Total | 7,101 | 261 | 2.11 | 0.8 | 259 | 523 | 14.25 | 2.7 | 509 | 3,582 | 80.47 | 2.2 | 3,501 | 4,366 | 96.83 | 2.2 | 4,269 |
| Conservation Zone 4 | Federal | Within SHUs | 16,336 | 10,217 | 32.14 | 0.3 | 10,185 | 1,226 | 11.35 | 0.9 | 1,215 | 4,641 | 35.62 | 0.8 | 4,606 | 16,085 | 79.11 | 0.5 | 16,006 |
| | | Outside of SHUs | 7,090 | 2 | 0.00 | 0.0 | 2 | 2,856 | 20.19 | 0.7 | 2,836 | 3,780 | 48.44 | 1.3 | 3,731 | 6,638 | 68.63 | 1.0 | 6,569 |
| | | Total | 23,427 | 10,219 | 32.14 | 0.3 | 10,187 | 4,082 | 31.54 | 0.8 | 4,051 | 8,421 | 84.06 | 1.0 | 8,337 | 22,722 | 147.74 | 0.7 | 22,575 |
| | Non-Federal | Within SHUs | 4,775 | 965 | 3.91 | 0.4 | 961 | 724 | 18.15 | 2.5 | 706 | 2,939 | 32.98 | 1.1 | 2,906 | 4,627 | 55.04 | 1.2 | 4,572 |
| | | Outside of SHUs | 21,491 | 64 | 0.00 | 0.0 | 64 | 2,002 | 44.61 | 2.2 | 1,957 | 16,975 | 288.38 | 1.7 | 16,687 | 19,041 | 332.99 | 1.7 | 18,708 |
| | | Total | 26,266 | 1,029 | 3.91 | 0.4 | 1,025 | 2,726 | 62.76 | 2.3 | 2,663 | 19,914 | 321.36 | 1.6 | 19,592 | 23,668 | 388.03 | 1.6 | 23,280 |
| | Total Conservation Zone 4 | Within SHUs | 21,111 | 11,182 | 36.05 | 0.3 | 11,145 | 1,950 | 29.50 | 1.5 | 1,921 | 7,580 | 68.60 | 0.9 | 7,511 | 20,712 | 134.15 | 0.6 | 20,578 |
| | | Outside of SHUs | 28,582 | 66 | 0.00 | 0.0 | 66 | 4,858 | 64.80 | 1.3 | 4,793 | 20,754 | 336.82 | 1.6 | 20,418 | 25,679 | 401.62 | 1.6 | 25,277 |
| | | Total | 49,693 | 11,248 | 36.05 | 0.3 | 11,212 | 6,808 | 94.30 | 1.4 | 6,714 | 28,335 | 405.42 | 1.4 | 27,929 | 46,390 | 535.77 | 1.2 | 45,855 |
| Outside Conservation Zones | Federal | Within SHUs | 2,550 | 1,664 | 3.52 | 0.2 | 1,660 | 307 | 3.79 | 1.2 | 303 | 532 | 6.61 | 1.2 | 526 | 2,503 | 13.92 | 0.6 | 2,490 |
| | | Outside of SHUs | 1,173 | 35 | 0.00 | 0.0 | 35 | 587 | 5.77 | 1.0 | 581 | 540 | 7.85 | 1.5 | 532 | 1,162 | 13.62 | 1.2 | 1,149 |
| | | Total | 3,723 | 1,699 | 3.52 | 0.2 | 1,696 | 894 | 9.56 | 1.1 | 884 | 1,072 | 14.46 | 1.3 | 1,058 | 3,666 | 27.54 | 0.8 | 3,638 |
| | Non-Federal | Within SHUs | 705 | 103 | 2.39 | 2.3 | 101 | 149 | 0.32 | 0.2 | 149 | 362 | 0.73 | 0.2 | 361 | 614 | 3.44 | 0.6 | 610 |
| | | Outside of SHUs | 3,116 | 36 | 0.00 | 0.0 | 36 | 690 | 11.89 | 1.7 | 678 | 1,724 | 20.99 | 1.2 | 1,703 | 2,449 | 32.88 | 1.3 | 2,416 |
| | | Total | 3,821 | 139 | 2.39 | 1.7 | 136 | 839 | 12.21 | 1.5 | 827 | 2,085 | 21.72 | 1.0 | 2,063 | 3,063 | 36.32 | 1.2 | 3,027 |
| | Total Outside Conservation Zone | Within SHUs | 3,254 | 1,767 | 5.91 | 0.3 | 1,761 | 457 | 4.11 | 0.9 | 453 | 894 | 7.34 | 0.8 | 887 | 3,117 | 17.36 | 0.6 | 3,100 |
| | | Outside of SHUs | 4,290 | 71 | 0.00 | 0.0 | 71 | 1,276 | 17.66 | 1.4 | 1,259 | 2,264 | 28.84 | 1.3 | 2,235 | 3,611 | 46.50 | 1.3 | 3,565 |
| | | Total | 7,544 | 1,838 | 5.91 | 0.3 | 1,832 | 1,733 | 21.77 | 1.3 | 1,711 | 3,158 | 36.18 | 1.1 | 3,121 | 6,729 | 63.86 | 0.9 | 6,665 |
| MAMU Inland Zone 1 Total | Federal | Within SHUs | 18,906 | 11,881 | 35.66 | 0.3 | 11,845 | 1,533 | 15.14 | 1.0 | 1,518 | 5,174 | 42.23 | 0.8 | 5,132 | 18,588 | 93.03 | 0.5 | 18,495 |
| | | Outside of SHUs | 8,264 | 37 | 0.00 | 0.0 | 37 | 3,443 | 25.96 | 0.8 | 3,417 | 4,320 | 56.29 | 1.3 | 4,263 | 7,800 | 82.25 | 1.1 | 7,718 |
| | | Total | 27,170 | 11,918 | 35.66 | 0.3 | 11,883 | 4,976 | 41.10 | 0.8 | 4,935 | 9,493 | 98.52 | 1.0 | 9,395 | 26,388 | 175.28 | 0.7 | 26,213 |
| | Non-Federal | Within SHUs | 6,190 | 1,328 | 8.41 | 0.6 | 1,319 | 961 | 21.11 | 2.2 | 940 | 3,606 | 35.85 | 1.0 | 3,570 | 5,894 | 65.37 | 1.1 | 5,829 |
| | | Outside of SHUs | 30,978 | 100 | 0.00 | 0.0 | 100 | 3,127 | 68.11 | 2.2 | 3,059 | 21,975 | 387.70 | 1.8 | 21,587 | 25,202 | 455.81 | 1.8 | 24,747 |
| | | Total | 37,168 | 1,428 | 8.41 | 0.6 | 1,420 | 4,088 | 89.22 | 2.2 | 3,999 | 25,580 | 423.55 | 1.7 | 25,157 | 31,097 | 521.18 | 1.7 | 30,576 |

| Conservation Zone | Landowner[1] | General Location | Total Acres within Analysis Area | Suitable Habitat[2] | | | | Recruitment Habitat[3] | | | | Capable Habitat[4] | | | | Total MAMU Habitat | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action | Pre-Action | Removed | | Post-Action |
| | | | | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres | Acres | Acres | Percent | Acres |
| | Subtotal Marbled Murrelet Zone1 | Within SHUs | 25,096 | 13,209 | 44.07 | 0.3 | 13,165 | 2,494 | 36.25 | 1.5 | 2,458 | 8,779 | 78.08 | 0.9 | 8,701 | 24,482 | 158.40 | 0.6 | 24,324 |
| | | Outside of SHUs | 39,242 | 138 | 0.00 | 0.0 | 138 | 6,570 | 94.07 | 1.4 | 6,476 | 26,294 | 443.99 | 1.7 | 25,850 | 33,002 | 538.06 | 1.6 | 32,464 |
| | | Total | 64,338 | 13,346 | 44.07 | 0.3 | 13,302 | 9,064 | 130.32 | 1.4 | 8,934 | 35,074 | 522.07 | 1.5 | 34,552 | 57,485 | 696.46 | 1.2 | 56,788 |
| **Marbled Murrelet Inland Zone 2** | | | | | | | | | | | | | | | | | | | |
| Outside Conservation Zones | Federal | Within SHUs | 846 | 670 | 13.55 | 2.0 | 656 | 30 | 0.08 | 0.3 | 30 | 128 | 0.08 | 0.1 | 128 | 828 | 13.71 | 1.7 | 814 |
| | | Outside of SHUs | 898 | 6 | 0.00 | 0.0 | 6 | 508 | 9.07 | 1.8 | 499 | 291 | 0.72 | 0.2 | 290 | 805 | 9.79 | 1.2 | 795 |
| | | Total | 1,744 | 676 | 13.55 | 2.0 | 662 | 538 | 9.15 | 1.7 | 529 | 419 | 0.80 | 0.2 | 418 | 1,633 | 23.50 | 1.4 | 1,609 |
| | Non-Federal | Within SHUs | 395 | 1 | 0.06 | 4.7 | 1 | 184 | 3.66 | 2.0 | 180 | 187 | 7.00 | 3.7 | 180 | 372 | 10.72 | 2.9 | 362 |
| | | Outside of SHUs | 16,553 | 21 | 0.00 | 0.0 | 21 | 3,699 | 125.99 | 3.4 | 3,573 | 6,105 | 68.98 | 1.1 | 6,036 | 9,824 | 194.97 | 2.0 | 9,629 |
| | | Total | 16,948 | 22 | 0.06 | 0.3 | 22 | 3,883 | 129.65 | 3.3 | 3,753 | 6,292 | 75.98 | 1.2 | 6,216 | 10,196 | 205.69 | 2.0 | 9,991 |
| | Subtotal Marbled Murrelet Zone2 | Within SHUs | 1,241 | 671 | 13.61 | 2.0 | 658 | 214 | 3.74 | 1.7 | 210 | 315 | 7.08 | 2.2 | 308 | 1,200 | 24.43 | 2.0 | 1,175 |
| | | Outside of SHUs | 17,451 | 27 | 0.00 | 0.0 | 27 | 4,207 | 135.06 | 3.2 | 4,072 | 6,396 | 69.70 | 1.1 | 6,326 | 10,629 | 204.76 | 1.9 | 10,425 |
| | | Total | 18,692 | 698 | 13.61 | 2.0 | 684 | 4,421 | 138.80 | 3.1 | 4,282 | 6,711 | 76.78 | 1.1 | 6,634 | 11,829 | 229.19 | 1.9 | 11,600 |
| **Total Marbled Murrelet Range** | | | | | | | | | | | | | | | | | | | |
| Total Marbled Murrelet Range | *Federal* | Within SHUs | 19,752 | 12,551 | 49.21 | 0.4 | 12,502 | 1,564 | 15.22 | 1.0 | 1,548 | 5,301 | 42.31 | 0.8 | 5,259 | 19,416 | 106.74 | 0.5 | 19,309 |
| | | Outside of SHUs | 9,162 | 43 | 0.00 | 0.0 | 43 | 3,951 | 35.03 | 0.9 | 3,916 | 4,611 | 57.01 | 1.2 | 4,554 | 8,605 | 92.04 | 1.1 | 8,513 |
| | | Total | *28,914* | 12,594 | 49.21 | 0.4 | 12,545 | 5,514 | 50.25 | 0.9 | 5,464 | 9,912 | 99.32 | 1.0 | 9,813 | 28,021 | 198.78 | 0.7 | 27,822 |
| | *Non-Federal* | Within SHUs | *6,585* | 1,329 | 8.47 | 0.6 | 1,321 | 1,145 | 24.77 | 2.2 | 1,120 | 3,793 | 42.85 | 1.1 | 3,750 | 6,266 | 76.09 | 1.2 | 6,190 |
| | | Outside of SHUs | *47,531* | 121 | 0.00 | 0.0 | 121 | 6,826 | 194.10 | 2.8 | 6,632 | 28,079 | 456.68 | 1.6 | 27,623 | 35,026 | 650.78 | 1.9 | 34,376 |
| | | Total | *54,116* | 1,450 | 8.47 | 0.6 | 1,442 | 7,971 | 218.87 | 2.7 | 7,752 | 31,872 | 499.53 | 1.6 | 31,373 | 41,293 | 726.87 | 1.8 | 40,566 |
| | Total Marbled Murrelet Range | Within SHUs | *26,337* | 13,880 | 57.68 | 0.4 | 13,822 | 2,708 | 39.99 | 1.5 | 2,668 | 9,094 | 85.16 | 0.9 | 9,009 | 25,682 | 182.83 | 0.7 | 25,499 |
| | | Outside of SHUs | *56,692* | 165 | 0.00 | 0.0 | 165 | 10,777 | 229.13 | 2.1 | 10,548 | 32,690 | 513.69 | 1.6 | 32,177 | 43,631 | 742.82 | 1.7 | 42,889 |
| | | Total | *83,030* | 14,044 | 57.68 | 0.4 | 13,987 | 13,485 | 269.12 | 2.0 | 13,216 | 41,784 | 598.85 | 1.4 | 41,186 | 69,314 | 925.65 | 1.3 | 68,388 |

1 Federal Landowers include Coos Bay BLM and Roseburg BLM Districts; Non-Federal Landowners include Private and State.
2 Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
3 Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).
4 Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).

Temporary Loss of Habitat - Noise and Human Presence

There is a potential that indirect and temporary loss of approximately 6,841.34 acres of suitable nesting habitat (occupied, presumed occupied, and unoccupied MAMU stands) within the Terrestrial Nesting Analysis area could occur from noise and visual disturbance where proposed project activities, including existing road use occur within 0.25 mile of suitable habitat (MAMU stands) during the breeding season (April 1 through September 15; table 4.3.3-12). Project activities within the range of the MAMU could occur during the breeding season and would generally begin in Year One from April 1 and continue through Year Two (weather-permitting; see figures 3.2-1 and 3.2-3), with DTRs applied for timber removal and construction during the critical breeding season (April 1 through August 5) to minimize effects to MAMU. Pacific Connector would continue to apply DTRs in the late breeding season for use of large transport helicopter use, if necessary. Proposed activities would not occur simultaneously within MAMU Inland Zones 1 and 2, and therefore, actual temporary, indirect habitat loss would be less than estimated within table 4.3.3-12.

Based on the proportion of suitable habitat known to be occupied by nesting MAMUs either as surveyed per protocol (see Mack et al., 2003), or expected to be occupied based on survey history in the area and the application of an occupancy index to unsurveyed areas (51 percent of reported suitable habitat are likely occupied in Oregon; see McShane et al., 2004), approximately 3,489.08 acres (51 percent of suitable habitat; 6,841.34 acres in table 4.3.3-12) is likely occupied and could be indirectly impacted. It is not expected that use of existing access roads would disrupt or disturb MAMU to the extent of expected nest failure during the breeding season (see discussion above in Direct Effects Section).

**Table 4.3.3-12**
**Amount (acres) of Suitable Nesting Habitat [1] Indirectly Affected within 0.25 mile of Proposed Disturbance from Timber Removal and Construction During the Entire Breeding Season (April 1 through September 15)**

| Landowner | Length of Pipeline / EARs within 0.25 mile of MAMU Stands | | Suitable Nesting Habitat (MAMU Stands) within 0.25 mile of Proposed Project Activities | | | |
|---|---|---|---|---|---|---|
| | Pipeline (miles) | Access Roads (miles) | Construction/ Timber Removal and Access Roads | Construction/ Timber Removal Only | Access Roads Only | Overall Total |
| **Marbled Murrelet Inland Zone 1** | | | | | | |
| Federal | 16.0 | 83.2 | 1,305.62 | 288.12 | 4,088.69 | 5,682.43 |
| Non-Federal | 31.4 | 72.6 | 292.34 | 78.24 | 337.88 | 708.47 |
| Total Zone 1 | 47.3 | 155.8 | 1,597.96 | 366.36 | 4,426.57 | 6,390.90 |
| **Marbled Murrelet Inland Zone 2** | | | | | | |
| Federal | 1.9 | 4.3 | 220.85 | 183.07 | 46.52 | 450.44 |
| Non-Federal | 3.3 | 3.4 | 0 | | | 0.00 |
| Total Zone 2 | 5.2 | 7.7 | 220.85 | 183.07 | 46.52 | 450.44 |
| **Overall Marbled Murrelet Range** | | | | | | |
| Federal | 17.9 | 87.5 | 1,526.47 | 471.19 | 4,135.21 | 6,132.87 |
| Non-Federal | 34.6 | 76.0 | 292.34 | 78.24 | 337.88 | 708.47 |
| **Overall Total** | 52.5 | 163.5 | **1,818.81** | **549.43** | **4,473.10** | 6,841.34 |

[1] Acres of suitable habitat (MAMU Stands - occupied, presumed occupied, unoccupied) includes only the area of MAMU stands considered for analysis within this BA within 0.25 mile of proposed activitites.

Habitat Fragmentation

In addition to impact by surface disturbances, fragmentation of connected, contiguous habitats will occur. Fragmentation of MAMU habitat can reduce the amount and heterogeneous nature of the habitat, forest patch size, and amount of interior or core habitat, and can increase the amount of edge, isolate remaining habitat patches, and create "sink" habitats (FWS, 2006e). The ecological consequences of these habitat changes to MAMUs can include effects on population viability and size, local or regional extinctions, displacement, fewer nesting attempts, failure to breed, reduced fecundity, reduced nest abundance, lower nest success, increased predation and parasitism rates, and reduced adult survival (FWS, 2006e).

**Habitat Edge.** One manifestation of fragmentation is the amount of edge created through otherwise contiguous habitats. In the context of habitat fragmentation, edge is the portion of habitat (or ecosystem on a larger scale) "near its perimeter, where influences of the surroundings prevent development of interior environmental conditions" (page 38 in Forman, 1995). As compared to interior habitats, edge habitats generally support different species composition, structure, and species' abundance (Forman and Godron, 1986). For example, higher levels of flower and fruit production often occur along the edge (Forman, 1995) and vertebrate species richness (bird and amphibian) has positively associated with edges in fragmented Douglas-fir forests (Rosenberg and Raphael, 1986). Edges play a crucial role in controlling ecosystem interactions and landscape function, including the distribution of plants and animals, fire spread, vegetation structure, wildlife habitat conservation, and physical environments.

Research indicates that MAMUs within southern Oregon tend to nest in stands that are generally located away from high-contrast edge created from timber stand harvests and adjacent immature forests (Ripple et al., 2003; Meyer et al., 2002b). In Canada, Zharikov et al. (2006) found MAMUs commonly nesting in stands near edges, although when edge increased in the nest patch, more nests failed (Zharikov et al., 2007). Alternatively, a study conducted in British Columbia found no evidence suggesting that nesting near forest edges, especially natural edges, reduced reproductive success in marbled murrelets (Bradley, 2002). In addition, nests at edges of clearcuts, old growth, and second growth transitional forests were generally more successful than not successful. In that study, increased reproductive success at natural edges compared to interior forest stands was thought to be related to ease of nest tree accessibility have greater benefit to marbled murrelets than the risk of nest predation (Bradley, 2002).

Increase in edge within occupied or presumed occupied stands from construction of the Pacific Connector pipeline may result in reduced nest success. Also, since MAMUs may nest close to the edge of a stand (easier access to nest), removal of suitable habitat on the edge of an occupied or presumed occupied stand may result in removal of a nest or potential nest tree. Fragmentation of an occupied or presumed occupied stand may also result in eventual abandonment of the stand. Meyer et al. (in review) indicate that MAMUs appear to abandon newly fragmented areas smaller than 124 acres, but because of site fidelity, abandonment may occur sometime after fragmentation happens (i.e., 5 to 20 years later). The Terrestrial Nesting Analysis Area has already been subjected to extensive fragmentation by past land uses including transportation corridors, timber harvest and associated activities (i.e., road construction), and urban development. Table Q-4 in appendix Q identifies the location of MAMU Stands and associated SHU habitat areas in relation to existing rights-of-ways and corridors. Within MAMU Inland Zone 1 and Zone 2 (MP 1.47R to MP 75.64), the Pacific Connector pipeline would be located within or parallel to existing corridors for approximately 31.76 miles (40 percent of proposed action in MAMU range; see table Q-4 in appendix Q), thus minimizing fragmentation within known or potential suitable MAMU nesting habitat. However, additional fragmentation will occur within suitable nesting habitat (occupied, presumed occupied, and unoccupied stands), as well as recruitment and capable habitat due to the proposed project.

Twenty-five marbled murrelet stands (occupied, unoccupied, and presumed occupied) will be affected by construction of the PCGP Project. With the exception of seven marbled murrelet stands (six occupied and one unoccupied) most suitable habitat affected by construction of the PCGP Project either occurs on the edge of the marbled murrelet stand or between the interface of the older occupied stand and an adjacent young, regenerating stand and/or existing access roads. The proposed action would bisect six occupied stands and one unoccupied stand (see asterisk in table 4.3.3-13). Table 4.3.3-13 summarizes the length that each marbled murrelet stand is crossed by the proposed pipeline, how much each stand is reduced in size, and if habitat is removed from one or more edges, if any, as well as resulting habitat patches within seven MAMU stands that would be bisected by the project. Table Q-1 in appendix Q, as well as the MAMU Impact Categorization for each MAMU Stand in appendix Z1 identifies the suitable, recruitment, and/or capable MAMU habitat that would be removed within the 300-foot Buffer of each MAMU Stand outside of the MAMU breeding season (see also maps of each MAMU Stand located within appendix Z1).

The proposed Project occurs in MAMU recovery plan Conservation Zones 3 and 4, of which the recommended management to aid in recovery includes maintaining designated occupied sites and minimizing loss of unoccupied but suitable habitat (FWS, 1997). Pacific Connector has adjusted the proposed route to minimize impact to MAMU stands by 1) rerouting the pipeline to avoid occupied stands documented during 2007 and 2008 survey efforts, 2) incorporating minor alignment adjustments to reduce habitat removed occupied stands, 3) modifying or moving temporary extra work areas, and 4) restricting the pipeline construction right-of-way to roads within occupied, presumed occupied, and unoccupied stands. Approximately 57.68 acres of suitable habitat would be removed from occupied, presumed occupied, and unoccupied stands, removing a total of 0.4 percent from available suitable habitat within the analysis area (14,044 acres; see table 4.3.3-11, above) within the defined Terrestrial Nesting Analysis Area. Overall, 2.2 percent of habitat within delineated MAMU stands would be removed (see table 4.3.3-13). The integrity of known occupied stands within the terrestrial analysis area, especially those stands with large acreages, would likely be maintained.

Pacific Connector surveyed 17 occupied and unoccupied stands located on BLM-managed lands in fall 2013 to identify potential nest trees that may occur within the proposed action (see R&A and SBS, 2014). Trees with adequate nesting platform structures, as outlined in the Pacific Seabird Group protocol (Mack, et al., 2003) were considered "potential nest trees" and included: 1) mature (with or without an old-growth component) and old-growth coniferous trees, or 2) younger coniferous trees that have platforms. A nesting platform consists of a relatively flat surface (at least 4 inches in diameter) that occurs at least 33 feet from the ground in the live crown of a coniferous tree and can include a wide bare branch, moss or lichen covered a branch, mistletoe, witches brooms, or other deformities (i.e., squirrel nests). Additional description in table 4.3.3-13 describes the potential nest trees that were identified within the proposed construction area, if any. Additional maps have been prepared and included in appendix Z1 for the 25 MAMU stands that would potentially have suitable habitat removed by the proposed action. The maps include locations of potential nest trees located within the vicinity of the proposed action during survey efforts in fall 2013, and were available (23 of 25 MAMU stands), are produced with a Lidar background that depicts the structure and height of the MAMU stand. Based on these maps and the potential nest trees documented within the vicinity of the Project right-of-way, it can be assumed that each stand contains trees outside of the proposed project effects that could provide suitable nesting habitat (i.e., trees greater than 200 feet in height).

**Interior Forest Habitat**. Indirect effects from construction of the Pacific Connector pipeline are also expected within habitat adjacent to the PCGP construction right-of-way, including within interior forest that the marbled murrelet relies on for nesting habitat. The conversion of large tracts of old-growth forest to small, isolated forest patches with large edge areas can create changes in microclimate, vegetation species, and predator-prey dynamics. In general, microclimates along edges differ from those in forest interiors. Two main physical factors affecting and creating an edge microclimate are sun and wind (Forman, 1995; Chen et al. 1995; Harper et al., 2005). Compared to the forest interior, areas near edges receive more direct solar radiation during the day, lose more long-wave radiation at night, have lower humidity, and receive less short-wave radiation. Other physical factors affecting edge includes edge orientation (Chen et al., 1995). For example, the general orientation of the PCGP Project is from northwest to southeast. Therefore, edge effects will be most pronounced on the southwest-facing edges and weakest along the northeast-facing edges (see discussion in Chen et al., 1995). Harper et al. (2005) reported that the mean distance of edge influence could occur to approximately 100 meters (328 feet) and result in 1) tree mortality, damage, recruitment, growth rate, canopy foliage, understory foliage, and seedling mortality, 2) amounts of canopy trees, canopy cover, snags and logs, understory tree density, herbaceous cover, and shrub cover, and 3) stand composition metrics such as species, exotics, individual species and species diversity. In other younger coniferous forests or mixed forests with deciduous species, edge effects compared to interior forests have been much less pronounced (Heithecker and Halpern, 2007; Harper and Macdonald, 2002). The importance of interior forest habitat to marbled murrelets is unclear. Suitable nest trees may be present within interior forest but reproductive success may be lower than at forest edges if access to interior forest nest trees is problematic, decreasing site suitability (Bradley, 2002).

To determine indirect effects to marbled murrelet habitat (suitable, recruitment, capable) from construction of the PCGP Project, Pacific Connector assessed effects to marbled murrelet habitat within 100 meters (328 feet) of proposed habitat removal, including effects to interior forest. This distance has been recommended by FWS (Trask & Associates, 2013), which is similar to 300 feet considered in discussions within the Habitat Quality subtask force to analyze effects to interior forests (2007 and 2008), and the 295 feet used as an edge assessment by Raphael et al. (2011) within the NWFP 15 Year Monitoring Report for nesting marbled murrelet habitat. This assessment considers the indirect effects of the newly constructed right-of-way on marbled murrelet habitat within 100 meters of habitat removal, including interior forest. To determine which tracts of forested land (late regenerating, mid-seral, late successional, and old-growth) should be considered interior forest, existing edges, such as wide-surface roads, large rivers, early seral forest, and nonforested habitat were buffered by 100 meters, and forested habitat included in the buffered area was identified as forested habitat currently affected by existing edge (Trask & Associates, 2013; Trask & Associates, 2013 – personal communication, December 20, 2013). Smaller roads with existing canopy cover were buffered by 50 feet per direction of FWS (Trask and Associates, 2014). Forested habitat (late regenerating to old-growth forest) that was not included in buffered "curenntly affected" area was classified as "interior forest" and incorporated into the interior forest model.

**Table 4.3.3-13**
**Suitable Nesting Habitat removed from Occupied, Presumed Occupied, or Unoccupied Stands Affected by the Proposed Action**

| MSNO or Site ID[1] | Status[2] | Project Location (mp range in stand) | Land owner | Land Allocation[3] | Overall Acres in the Stand | Length Crossed | | Edge Created | Suitable Habitat Affected in MAMU Stand | | Additional Description (see Maps in appendix Z1) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | feet | miles | | Acres | Percent of Stand | |
| **MARBLED MURRELET ZONE 1** | | | | | | | | | | | |
| WC1A-F | Presumed | 8.60R-8.69R | Private | None | 70.56 | 484.85 | 0.09 | 0 | 1.51 | 2.1 | Habitat on both sides of 100' powerline corridor; ROW adjacent to powerline corridor; habitat removed on edge of "stand" - will not create additional edge; other "gray habitat" in area determined not suitable |
| WC1A-G | Presumed | 8.79R-8.85R | Private | None | 2.92 | 307.68 | 0.06 | 0 | 0.59 | 20.2 | Habitat on edge of 100' powerline corridor; ROW follows existing road ~ 50-100 feet from powerline corridor; will remove habitat either side of two-track road, generally reducing or removing all potential habitat in one lobe of WC1A-G between road and powerline corridor; other permitted 'gray' habitat around stand determined "not suitable'; no new edge created |
| G16 | Presumed | 12.27-12.29; 12.46-12.47 | Private | None | 5.13 | 143.24 | 0.03 | 0 | 0.38 | 7.4 | Habitat generally in "mid-seral" habitat as delineated; within mosaic of shrubs/trees; in close proximity to residences; will remove portion of "stands" - lobes that extend into shrub/grass areas; other "gray habitat" around the stand determined not suitable; no new edge created |
| G31 | Presumed | 18.91-18.92 | Private | None | 1.50 | 0 | 0 | 0 | 0.01 | 0.7 | Habitat 'mid-seral' as delineated; lidar indicated some taller trees; will most likely not remove any trees from delineated 'potential' stand; adjacent "gray habitat" determined not suitable; no new edge created |
| G33 | Presumed | 20.64-20.70; 20.74-20.78; 20.85-20.92; scattered north and south of ROW | Private | None | 65.43 | 863.65 | 0.16 | 2 | 2.59 | 3.9 | Habitat in serveral 'lobes' on either side of ~220' powerline corridor; ROW adjacent to or parallels (~200' from corridor) existing corridor; bisects one small lobe of stand and creates two additional edges; removes habitat from another lobe but does not further fragment; adjacent BLM habitat determined not suitable |
| G38* | Presumed | 23.08-23.14; EAR 23.09 | Private | None | 3.82 | 306.58 | 0.06 | 1 | 0.48 | 12.6 | Habitat 'mid-seral' as delineated; lidar indicated some taller trees; does not fragment stand but creates new edge - removes habitat from edge; however, contiguous with other older habitat around delineated stand; adjacent "grayhabitat" determined not suitable |
| C1080 (B02)* | Occupied - Jully 2013 | 27.13-27.48 | Coos Bay BLM | Matrix | 135.87 | 1810.2 | 0.34 | 2 | 4.10 | 3.0 | Project would bisect stand - no other existing fragmentation; resulting two lobes = 17.08 acres and 114.78 acres; approximately 93 potential nest trees were identified in the vicinity of the Project, of which 75 would likely be removed during construction (R&A and SBS, 2014) |
| G44 | Presumed | 29.17-29.19; 29.48-29.50; four scattered stands | Private | None | 1.38 | 194.12 | 0.04 | 4 (2 lobes) | 0.40 | 29.0 | Several lobes along existing timber road within riparian buffer; two small "lobes" bisected/removed; questionable if habitat - adjacent to road and/or residence |
| C3098* | Occupied - PCGP 07/08 | 32.04 - 32.47 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 128.42 | 2294.2 | 0.43 | 2 | 4.99 | 3.9 | Project would bisect stand increasing fragmentation of stand-existing road crosses stand; resulting two lobes = 106.68 acres and 16.47 acres; occupied behavior detected ~625 feet north of habitat removal; 5 potential nest trees were identified in the vicinity of the Project, of which 3 trees would likely be removed during construction (R&A and SBS, 2014) |

| MSNO or Site ID[1] | Status[2] | Project Location (mp range in stand) | Land owner | Land Allocation[3] | Overall Acres in the Stand | Length Crossed | | Edge Created | Suitable Habitat Affected in MAMU Stand | | Additional Description (see Maps in appendix Z1) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | feet | miles | | Acres | Percent of Stand | |
| C3042 | Occupied | 33.84-33.90 | Coos Bay BLM | Unmapped LSR | 249.13 | 325.86 | 0.06 | 0 | 0.87 | 0.3 | Habitat removed adjacent to regenerating forest from edge/small lobe of large stand; generally mid-seral even age forest - within groups of larger older trees outside of project area; 7 potential nest trees were identified within the vicinity of the Project, of which 1 potential nest tree could be removed during construction (R&A and SBS, 2014) |
| C3075 | Occupied | 33.80-33.84; 33.97-33.98 | Coos Bay BLM | Unmapped LSR | 43.36 | 195.72 | 0.04 | 0 | 1.19 | 2.7 | Remove one lobe of delineated stand adjacent to roads and other stand (C3042); no habitat (large trees) will be removed from other lobe of stand - adjacent to regenerating forest; approximately 4 potential nest trees were identified within the vicinity of the Project that could be removed during construction (R&A and SBS, 2014) |
| C3093 | Occupied - PCGP 07/08 | 35.34-35.43; 35.47-35.55; 35.65-35.76 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 326.95 | 1298.4 | 0.25 | 0 | 2.03 | 0.6 | Project travels along roads - in-road construction; approximately 5 potential nest trees were identified on edge of road in delineated stand (R&A and SBS, 2014), but no habitat would be removed from stand (overlap may occur from GIS); |
| C3165 (B07) | Occupied - Jully 2013 | 36.09-36.09 | Coos Bay BLM | Matrix | 67.11 | 0 | 0 | 0 | 0.59 | 0.9 | Project follows road; although GIS indicates habitat removed project will remain in road and within early regen across road from stand; 3 potential nest trees were identified on edge of road but would not be removed during construction (R&A and SBS, 2014) |
| C3073* | Occupied | 36.49-36.75; 36.83-37.02 | Coos Bay BLM | Unmapped LSR | 174.56 | 1344.7 | 0.25 | 2 | 3.12 | 1.8 | Project bissects narrow area of large delineated stand and follows existing road/regenerating forest along one lobe of stand and increases fragmentation in the stand; resulting two lobes = 119.75 acres and 51.42 acres; 22 potential nest trees were identified within the vicinity of the Project, of which 15 potential nest trees could be removed during construction (R&A and SBS<,2014) |
| C3090* | Occupied - PCGP 07/08 | 37.32-38.09 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 320.51 | 4072.8 | 0.77 | 2 | 9.42 | 2.9 | Project would bisect stand - no other existing fragmentation; resulting two lobes = 198.00 acres and 108.40 acres; 106 potential nest trees were identified within the vicinity of the Project, of which 72 potential nest trees could be removed during construction (R&A and SBS, 2014) |
| C3094 | Occupied - PCGP 07/08 | 38.09-38.18 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 76.56 | 479.97 | 0.09 | 1 | 0.92 | 1.2 | Habitat removed from southern edge of delineated occupied stand; in 2008 occupied behavior detected ~1,000 feet north of the proposed ROW; one hard edge created |
| C3095 | Occupied - PCGP 07/08 | 38.82-38.90 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 21.82 | 0 | 0 | 0 | 0.52 | 2.4 | Project travels along a road that currently divides the stand - in-road construction; no habitat removed in stand (overlap may occur from GIS) |
| G55 | Presumed | TEWA 40.34-N; north and south of ROW; three stands | Private | None | 4.21 | 0 | 0 | 1 | 0.06 | 1.4 | Habitat 'mid-seral' as delineated; lidar indicated some taller trees which was used to delineate "potential suitable habitat" in two areas; the project traverses between the two areas and does not remove habitat from delineated "stand" |
| C3070 | Occupied | 41.89-41.97 | Coos Bay BLM | LSR/CHU | 123.44 | 413.48 | 0.08 | 2 | 1.03 | 0.8 | One of the three areas delineated for this stand is clipped by the Project, generally within mid-seral to regenerating forest; 10 potential nest trees were identified within the vicinity of the Project, of which 8 potential nest trees could be removed during construction (R&A and SBS, 2014) |
| C3092 | Occupied - PCGP 07/08 | 45.40-45.47 | Coos Bay BLM | Unmapped LSR - Pacific Connector | 173.05 | 376.6 | 0.07 | 1 | 0.86 | 0.5 | Habitat along a ridge of a very large stand will be removed; stand will not be fragmented; trees in the northern portion of stand do not provide suitable nesting structures; one hard edge created |
| R3035* (EAR 46.51_A) | Occupied - Jully 2013 | 46.90-47.17 | Roseburg BLM | LSR/CHU | 201.26 | 1018.8 | 0.19 | 2 | 2.48 | 1.2 | Project would bisect stand - existing roads through stand; resulting two lobes = 188.31 acres and 10.47 acres; 31 potential nest trees were identified within the vicinity of the Project, of which 24 potential nest trees could be removed during construction (R&A and SBS, 2014) |

| MSNO or Site ID[1] | Status[2] | Project Location (mp range in stand) | Land owner | Land Allocation[3] | Overall Acres in the Stand | Length Crossed | | Edge Created | Suitable Habitat Affected in MAMU Stand | | Additional Description (see Maps in appendix Z1) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | feet | miles | | Acres | Percent of Stand | |
| ALTR-A* | Presumed | 50.81-51.04 | Private | None | 14.17 | 1081.2 | 0.20 | 2 | 2.39 | 16.9 | Project would bisect presumed occupied stand adjacent to R3036; resulting two lobes = 5.56 acres and 6.20 acres |
| R3036* (ALTR-A) | Occupied - June 2013 | 51.04-51.29 | Roseburg BLM | Unmapped LSR - Pacific Connector | 41.58 | 1329.2 | 0.25 | 2 | 2.92 | 7.0 | Project would bisect stand - existing road crosses stand; resulting two lobes = 30.78 acres and 7.83 acres; 3 potential nest trees were identified within the vicinity of the Project and could be removed during construction (R&A and SBS, 2014) |
| **Marbled Murrelet Zone 1 - Stands** | | | | | **2252.74** | ***18,341.3*** | ***3.46*** | ***N/A*** | **43.45** | 1.9 | |
| **MARBLED MURRELET ZONE 2** | | | | | | | | | | | |
| B13 | Unoccupied - Survey 07/08&13/14 | 53.69-53.70; 54.38-54.43 | Roseburg BLM/Private | Unmapped LSR/Other | 130.24 | 322.63 | 0.06 | 0 | 1.81 | 1.4 | Project is adjacent to stand and occurs within existing road and clearcut/regenerating forest north of stand; not expected to remove large trees (GIS overlap); no new edge created; 15 potential nest trees were identified within the vicinity of the Project, of which 14 could be removed during construction (R&A and SBS, 2014) |
| B14* | Unoccupied - Survey 07/08&13/14 | 60.85-61.66 | Roseburg BLM/Private | Matrix | 218.83 | 4274.4 | 0.81 | 2 | 12.40 | 5.7 | Project would bisect stand - no other existing fragmentation; resulting two lobes = 120.57 acres and 81.65 acres; 34 potential nest trees were identified within the vicinity of the Project, of which 20 could be removed during construction (R&A and SBS< 2014) |
| **Marbled Murrelet Zone 2 - Stands** | | | | | **349.07** | ***4597*** | ***0.87*** | ***N/A*** | **14.21** | **4.1** | |
| **Total Marbled Murrelet Stands** | | | | | **2,601.81** | **22,938.3** | **4.33** | **N/A** | **57.66** | **2.2** | |

[1] Asterisk (*) indicates proposed project would bisect stand and create at least two new edges.
[2] "Occupied" – areas/stands delineated that occupied marbled murrelet behavior has been documented. Stands have been provided by Coos Bay BLM, Roseburg BLM, and Northern States Resources (2012). "Unoccupied" – areas with suitable nesting habitat but surveys in 2007, 2008, and 2013 did not document occupied behavior. "Presumed" – these are areas that may provide suitable nesting habitat as determined through 1) lidar, 2) identified by Coos Bay and/or Roseburg BLM Districts, and/or 3) suitable habitat modeling (Raphael et al., 2006; habitat value 4).
[3] Land Allocation: LSR = Northwest Forest Plan (NWFP) late-successional reserves (LSR); Unmapped LSR = occupied marbled murrelet stand or northern spotted owl known activity center that occur in NWFP Matrix lands (identified by BLM and Forest Service, as well as other occupied marbled murrelet stands that have been included as unmapped LSRs by Pacific Connector).; CHU = Marbled Murrelet Critical Habitat Unit OR-06-d; Other = NWFP landuse allocations except for LSR; None = marbled murrelet stand on Private or Native American lands and do not have NWFP LUA or designated CHU.

Table 4.3.3-14 identifies the distance that MAMU habitat is crossed by the proposed project within and outside of interior habitat, summarizes the acreage of MAMU habitat directly removed and indirectly affected within 100 meters of the PCGP Project (habitat removal) by Marbled Murrelet Inland Zones 1 and 2, landowner, and within and outside of SHUs (summarized from table Q-3 in appendix Q). Approximately 5,412 acres of marbled murrelet habitat (490 acres of suitable habitat, 1,801 acres of recruitment habitat, and 3,121 acres of capable habitat) occur within 100 meters of habitat removal, of which 882 acres (16.3 percent) of interior murrelet habitat would be indirectly affected (219 acres of suitable habitat, 323 acres of recruitment habitat, and 340 acres of capable habitat; table 4.3.3-14). The majority of marbled murrelet habitat indirectly affected occurs outside of SHUs: 4,264 acres (78.8 percent) of all murrelet habitat within 100 meters of habitat removal, which includes 556 acres of interior marbled murrelet habitat and 3,708 acres of murrelet habitat currently affected by existing edge. Table Q-3 in appendix Q identifies the acres of marbled murrelet habitat affected 100 meters from habitat removal by Marbled Murrelet Inland Zone, Recovery Plan Conservation Zone, land allocations (critical habitat and LSR effects), and landowner within SHUs and interior forest. Effects to marbled murrelet habitat adjacent to the construction right-of-way will decrease as the forested area (approximately 724 acres; table 4.3.3-14) outside of the 30-foot maintenance corridor are replanted with trees and return to early regenerating stands. Based on the table below, it can be assumed that at least 8.1 miles of interior forest will experience fragmentation as a result of the proposed project, creating at least 16.2 miles (8.1 miles x 2) of additional edge in approximately 55.3 miles of MAMU habitat crossed by the project; this considers interior forest crossed by the proposed project within older regenerating forest to old-growth forest (see Trask & Associates, 2013). Additional fragmentation of approximately 15.5 miles within forest currently affected by existing disturbance ("other" forest in table 4.3.3-14) could be affected since approximately 40 percent (31.8 miles) of the project within the range of MAMU occurs within or is adjacent/parallels existing disturbance (see co-locate table Q-4 in appendix Q; 47.3 miles minus 31.8 miles), creating approximately 31.0 miles of additional edge in forest already affected by existing disturbance. In addition to MAMU habitat crossed and affected within the MAMU range, approximately 24.3 miles of non-capable habitat will be crossed and remove approximately 981 acres (see table Q-3 in appendix Q). Figure 4.3-11, below provides an example of how indirect effects to murrelet habitat, both within and outside of interior forest are considered within the range of the MAMU.

## Table 4.3.3-14
## Summary of Indirect Effects from Construction of the Proposed Action to Marbled Murrelet Habitat (Suitable, Recruitment, Capable), Including Interior Forest within and outside Marbled Murrelet SHUs by Landowner

| Landowner[1] | General Location[2] | Interior Forest[3] | Suitable Habitat[4] | | | | | Recruitment Habitat[5] | | | | | Capable Habitat[6] | | | | | Total MAMU Habitat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation |
| | | | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | | |
| **Conservaton Zone 3** | | | | | | | | | | | | | | | | | | | | | | |
| Non-Federal | Within SHU | Interior | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 2.73 | 0.00 | 0.00 | 0.00 | 0.00 | 1.18 | 0.00 | 0.00 | 0.00 | 0.00 | 4.65 | 0.00 | 0.00 |
| | | Other | 0.15 | 2.11 | 11.33 | 0.00 | 0.54 | 0.18 | 2.64 | 12.88 | 0.00 | 0.67 | 0.12 | 2.14 | 19.77 | 0.00 | 0.48 | 0.45 | 6.89 | 43.98 | 0.00 | 1.69 |
| | | Subtotal | 0.15 | 2.11 | 12.07 | 0.00 | 0.54 | 0.18 | 2.64 | 15.61 | 0.00 | 0.67 | 0.12 | 2.14 | 20.95 | 0.00 | 0.48 | 0.45 | 6.89 | 48.63 | 0.00 | 1.69 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 2.08 | 10.68 | 0.00 | 0.51 | 0.36 | 5.15 | 61.63 | 0.00 | 1.34 | 0.51 | 7.23 | 72.31 | 0.00 | 1.85 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 9.53 | 69.99 | 0.00 | 2.07 | 4.77 | 73.18 | 387.64 | 0.00 | 17.24 | 5.33 | 82.71 | 457.63 | 0.00 | 19.31 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 | 11.61 | 80.67 | 0.00 | 2.58 | 5.13 | 78.33 | 449.27 | 0.00 | 18.58 | 5.84 | 89.94 | 529.94 | 0.00 | 21.16 |
| | Total | Interior | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.14 | 2.08 | 13.41 | 0.00 | 0.51 | 0.36 | 5.15 | 62.81 | 0.00 | 1.34 | 0.51 | 7.23 | 76.96 | 0.00 | 1.85 |
| | | Other | 0.15 | 2.11 | 11.33 | 0.00 | 0.54 | 0.75 | 12.17 | 82.87 | 0.00 | 2.74 | 4.89 | 75.32 | 407.41 | 0.00 | 17.72 | 5.79 | 89.60 | 501.61 | 0.00 | 21.00 |
| | | Subtotal | 0.15 | 2.11 | 12.07 | 0.00 | 0.54 | 0.89 | 14.25 | 96.28 | 0.00 | 3.25 | 5.25 | 80.47 | 470.22 | 0.00 | 19.06 | 6.29 | 96.83 | 578.57 | 0.00 | 22.85 |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | | |
| **Conservaton Zone 4** | | | | | | | | | | | | | | | | | | | | | | |
| Federal | Within SHU | Interior | 1.31 | 15.55 | 124.64 | 5.65 | 4.76 | 0.08 | 1.27 | 5.49 | 0.28 | 0.30 | 0.41 | 5.78 | 33.30 | 1.26 | 1.50 | 1.81 | 22.60 | 163.43 | 7.19 | 6.56 |
| | | Other | 1.28 | 16.59 | 169.23 | 1.38 | 4.84 | 0.63 | 10.08 | 59.28 | 1.17 | 2.37 | 1.55 | 29.84 | 144.38 | 2.79 | 5.37 | 3.46 | 56.51 | 372.89 | 5.34 | 12.58 |
| | | Subtotal | 2.59 | 32.14 | 293.87 | 7.03 | 9.60 | 0.71 | 11.35 | 64.77 | 1.45 | 2.67 | 1.97 | 35.62 | 177.68 | 4.05 | 6.87 | 5.26 | 79.11 | 536.32 | 12.53 | 19.14 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 4.46 | 27.68 | 0.00 | 0.85 | 0.54 | 8.29 | 56.17 | 0.06 | 1.97 | 0.78 | 12.75 | 83.85 | 0.06 | 2.82 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.10 | 15.73 | 76.03 | 1.45 | 4.08 | 2.49 | 40.15 | 220.30 | 0.91 | 9.13 | 3.59 | 55.88 | 296.33 | 2.36 | 13.21 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 20.19 | 103.71 | 1.45 | 4.93 | 3.03 | 48.44 | 276.47 | 0.97 | 11.10 | 4.37 | 68.63 | 380.18 | 2.42 | 16.03 |
| | Subtotal | Interior | 1.31 | 15.55 | 124.64 | 5.65 | 4.76 | 0.32 | 5.73 | 33.17 | 0.28 | 1.15 | 0.96 | 14.07 | 89.47 | 1.32 | 3.47 | 2.58 | 35.35 | 247.28 | 7.25 | 9.38 |
| | | Other | 1.28 | 16.59 | 169.23 | 1.38 | 4.84 | 1.73 | 25.81 | 135.31 | 2.62 | 6.45 | 4.04 | 69.99 | 364.68 | 3.70 | 14.50 | 7.05 | 112.39 | 669.22 | 7.70 | 25.79 |
| | | Subtotal | 2.59 | 32.14 | 293.87 | 7.03 | 9.60 | 2.05 | 31.54 | 168.48 | 2.90 | 7.60 | 5.00 | 84.06 | 454.15 | 5.02 | 17.97 | 9.63 | 147.74 | 916.50 | 14.95 | 35.17 |
| Non-Federal | Within SHU | Interior | 0.00 | 0.03 | 8.76 | 0.00 | 0.00 | 0.11 | 1.61 | 19.04 | 0.35 | 0.39 | 0.10 | 0.97 | 19.94 | 0.00 | 0.35 | 0.20 | 2.61 | 47.74 | 0.35 | 0.74 |
| | | Other | 0.29 | 3.88 | 35.48 | 0.00 | 1.04 | 1.19 | 16.54 | 95.08 | 0.17 | 4.35 | 1.92 | 32.01 | 140.19 | 4.02 | 7.00 | 3.40 | 52.43 | 270.75 | 4.19 | 12.39 |
| | | Subtotal | 0.29 | 3.91 | 44.24 | 0.00 | 1.04 | 1.29 | 18.15 | 114.12 | 0.52 | 4.74 | 2.02 | 32.98 | 160.13 | 4.02 | 7.35 | 3.60 | 55.04 | 318.49 | 4.54 | 13.13 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 2.80 | 36.46 | 0.00 | 0.66 | 0.86 | 13.20 | 100.21 | 0.00 | 3.12 | 1.04 | 16.00 | 136.67 | 0.00 | 3.78 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.56 | 41.81 | 307.32 | 4.65 | 9.38 | 15.28 | 275.18 | 1356.07 | 22.66 | 55.64 | 17.84 | 316.99 | 1663.39 | 27.31 | 65.02 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.74 | 44.61 | 343.78 | 4.65 | 10.04 | 16.14 | 288.38 | 1456.28 | 22.66 | 58.76 | 18.88 | 332.99 | 1800.06 | 27.31 | 68.80 |
| | Total | Interior | 0.00 | 0.03 | 8.76 | 0.00 | 0.00 | 0.29 | 4.41 | 55.50 | 0.35 | 1.05 | 0.95 | 14.17 | 120.15 | 0.00 | 3.47 | 1.24 | 18.61 | 184.41 | 0.35 | 4.52 |
| | | Other | 0.29 | 3.88 | 35.48 | 0.00 | 1.04 | 3.75 | 58.35 | 402.40 | 4.82 | 13.73 | 17.20 | 307.19 | 1496.26 | 26.68 | 62.64 | 21.24 | 369.42 | 1934.14 | 31.50 | 77.41 |
| | | Subtotal | 0.29 | 3.91 | 44.24 | 0.00 | 1.04 | 4.04 | 62.76 | 457.90 | 5.17 | 14.78 | 18.16 | 321.36 | 1616.41 | 26.68 | 66.11 | 22.48 | 388.03 | 2118.55 | 31.85 | 81.93 |
| Total Conservation Zone 4 | Within SHU | Interior | 1.31 | 15.58 | 133.40 | 5.65 | 4.76 | 0.19 | 2.88 | 24.53 | 0.63 | 0.69 | 0.51 | 6.75 | 53.24 | 1.26 | 1.85 | 2.01 | 25.21 | 211.17 | 7.54 | 7.30 |
| | | Other | 1.56 | 20.47 | 204.71 | 1.38 | 5.88 | 1.82 | 26.62 | 154.36 | 1.34 | 6.72 | 3.48 | 61.85 | 284.57 | 6.81 | 12.37 | 6.85 | 108.94 | 643.64 | 9.53 | 24.97 |
| | | Subtotal | 2.87 | 36.05 | 338.11 | 7.03 | 10.64 | 2.01 | 29.50 | 178.89 | 1.97 | 7.41 | 3.98 | 68.60 | 337.81 | 8.07 | 14.22 | 8.86 | 134.15 | 854.81 | 17.07 | 32.27 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 7.26 | 64.14 | 0.00 | 1.51 | 1.40 | 21.49 | 156.38 | 0.06 | 5.09 | 1.82 | 28.75 | 220.52 | 0.06 | 6.60 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.66 | 57.54 | 383.35 | 6.10 | 13.46 | 17.77 | 315.33 | 1576.37 | 23.57 | 64.77 | 21.43 | 372.87 | 1959.72 | 29.67 | 78.23 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.08 | 64.80 | 447.49 | 6.10 | 14.97 | 19.17 | 336.82 | 1732.75 | 23.63 | 69.86 | 23.25 | 401.62 | 2180.24 | 29.73 | 84.83 |
| | Total | Interior | 1.31 | 15.58 | 133.40 | 5.65 | 4.76 | 0.60 | 10.14 | 88.67 | 0.63 | 2.20 | 1.91 | 28.24 | 209.62 | 1.32 | 6.94 | 3.83 | 53.96 | 431.69 | 7.60 | 13.90 |
| | | Other | 1.56 | 20.47 | 204.71 | 1.38 | 5.88 | 5.48 | 84.16 | 537.71 | 7.44 | 20.18 | 21.24 | 377.18 | 1860.94 | 30.38 | 77.14 | 28.29 | 481.81 | 2603.36 | 39.20 | 103.20 |
| | | Subtotal | 2.87 | 36.05 | 338.11 | 7.03 | 10.64 | 6.08 | 94.30 | 626.38 | 8.07 | 22.38 | 23.15 | 405.42 | 2070.56 | 31.70 | 84.08 | 32.11 | 535.77 | 3035.05 | 46.80 | 117.10 |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | | |
| **No Recovery Conservation Zone** | | | | | | | | | | | | | | | | | | | | | | |
| Federal | Within SHU | Interior | 0.20 | 2.30 | 15.06 | 0.00 | 0.73 | 0.11 | 1.22 | 6.80 | 0.00 | 0.38 | 0.01 | 0.18 | 2.45 | 0.00 | 0.04 | 0.32 | 3.70 | 24.31 | 0.00 | 1.15 |
| | | Other | 0.06 | 1.22 | 20.96 | 0.85 | 0.21 | 0.09 | 2.57 | 7.07 | 1.04 | 0.41 | 0.56 | 6.43 | 36.44 | 0.02 | 2.02 | 0.72 | 10.22 | 64.47 | 1.91 | 2.64 |
| | | Subtotal | 0.26 | 3.52 | 36.02 | 0.85 | 0.94 | 0.20 | 3.79 | 13.87 | 1.04 | 0.79 | 0.57 | 6.61 | 38.89 | 0.02 | 2.06 | 1.03 | 13.92 | 88.78 | 1.91 | 3.79 |
| | Outside | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 | 0.00 | 0.00 | 0.00 | 0.00 | 5.60 | 0.00 | 0.00 | 0.00 | 0.00 | 7.78 | 0.00 | 0.00 |

| Landowner[1] | General Location[2] | Interior Forest[3] | Suitable Habitat[4] | | | | | Recruitment Habitat[5] | | | | | Capable Habitat[6] | | | | | Total MAMU Habitat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation |
| | | | | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) |
| | SHU | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 5.77 | 18.66 | 0.13 | 1.51 | 0.51 | 7.85 | 43.22 | 0.00 | 1.93 | 0.90 | 13.62 | 61.88 | 0.13 | 3.44 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 5.77 | 20.84 | 0.13 | 1.51 | 0.51 | 7.85 | 48.82 | 0.00 | 1.93 | 0.90 | 13.62 | 69.66 | 0.13 | 3.44 |
| | Subtotal | Interior | 0.20 | 2.30 | 15.06 | 0.00 | 0.73 | 0.11 | 1.22 | 8.98 | 0.00 | 0.38 | 0.01 | 0.18 | 8.05 | 0.00 | 0.04 | 0.32 | 3.70 | 32.09 | 0.00 | 1.15 |
| | | Other | 0.06 | 1.22 | 20.96 | 0.85 | 0.21 | 0.48 | 8.34 | 25.73 | 1.17 | 1.92 | 1.07 | 14.28 | 79.66 | 0.02 | 3.95 | 1.62 | 23.84 | 126.35 | 2.04 | 6.08 |
| | | Subtotal | 0.26 | 3.52 | 36.02 | 0.85 | 0.94 | 0.59 | 9.56 | 34.71 | 1.17 | 2.30 | 1.08 | 14.46 | 87.71 | 0.02 | 3.99 | 1.93 | 27.54 | 158.44 | 2.04 | 7.23 |
| Non-Federal | Within SHU | Interior | 0.10 | 1.25 | 6.24 | 0.00 | 0.37 | 0.00 | 0.03 | 4.28 | 0.00 | 0.01 | 0.00 | 0.00 | 0.64 | 0.00 | 0.00 | 0.11 | 1.28 | 11.16 | 0.00 | 0.38 |
| | | Other | 0.10 | 1.14 | 5.41 | 0.00 | 0.38 | 0.03 | 0.29 | 4.51 | 0.00 | 0.12 | 0.05 | 0.73 | 7.72 | 0.51 | 0.18 | 0.19 | 2.16 | 17.64 | 0.51 | 0.68 |
| | | Subtotal | 0.21 | 2.39 | 11.65 | 0.00 | 0.75 | 0.04 | 0.32 | 8.79 | 0.00 | 0.13 | 0.05 | 0.73 | 8.36 | 0.51 | 0.18 | 0.29 | 3.44 | 28.80 | 0.51 | 1.06 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 3.06 | 25.12 | 0.00 | 0.89 | 0.12 | 1.96 | 8.09 | 0.00 | 0.46 | 0.37 | 5.02 | 33.21 | 0.00 | 1.35 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 8.83 | 94.06 | 0.10 | 2.56 | 1.29 | 19.03 | 132.56 | 3.79 | 4.71 | 1.98 | 27.86 | 226.62 | 3.89 | 7.27 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 11.89 | 119.18 | 0.10 | 3.45 | 1.41 | 20.99 | 140.65 | 3.79 | 5.17 | 2.35 | 32.88 | 259.83 | 3.89 | 8.62 |
| | Subtotal | Interior | 0.10 | 1.25 | 6.24 | 0.00 | 0.37 | 0.25 | 3.09 | 29.40 | 0.00 | 0.90 | 0.12 | 1.96 | 8.73 | 0.00 | 0.46 | 0.47 | 6.30 | 44.37 | 0.00 | 1.73 |
| | | Other | 0.10 | 1.14 | 5.41 | 0.00 | 0.38 | 0.72 | 9.12 | 98.57 | 0.10 | 2.68 | 1.34 | 19.76 | 140.28 | 4.30 | 4.89 | 2.17 | 30.02 | 244.26 | 4.40 | 7.95 |
| | | Subtotal | 0.21 | 2.39 | 11.65 | 0.00 | 0.75 | 0.97 | 12.21 | 127.97 | 0.10 | 3.58 | 1.46 | 21.72 | 149.01 | 4.30 | 5.35 | 2.64 | 36.32 | 288.63 | 4.40 | 9.68 |
| Total MAMU Zone 1 - No Conservation Recovery Zone | Within SHU | Interior | 0.30 | 3.55 | 21.30 | 0.00 | 1.10 | 0.11 | 1.25 | 11.08 | 0.00 | 0.39 | 0.01 | 0.18 | 3.09 | 0.00 | 0.04 | 0.42 | 4.98 | 35.47 | 0.00 | 1.53 |
| | | Other | 0.16 | 2.36 | 26.37 | 0.85 | 0.59 | 0.13 | 2.86 | 11.58 | 1.04 | 0.53 | 0.61 | 7.16 | 44.16 | 0.53 | 2.20 | 0.90 | 12.38 | 82.11 | 2.42 | 3.32 |
| | | Subtotal | 0.47 | 5.91 | 47.67 | 0.85 | 1.69 | 0.24 | 4.11 | 22.66 | 1.04 | 0.92 | 0.62 | 7.34 | 47.25 | 0.53 | 2.24 | 1.33 | 17.36 | 117.58 | 2.42 | 4.85 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 3.06 | 27.30 | 0.00 | 0.89 | 0.12 | 1.96 | 13.69 | 0.00 | 0.46 | 0.37 | 5.02 | 40.99 | 0.00 | 1.35 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 14.60 | 112.72 | 0.23 | 4.07 | 1.80 | 26.88 | 175.78 | 3.79 | 6.64 | 2.88 | 41.48 | 288.50 | 4.02 | 10.71 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 17.66 | 140.02 | 0.23 | 4.96 | 1.92 | 28.84 | 189.47 | 3.79 | 7.10 | 3.25 | 46.50 | 329.49 | 4.02 | 12.06 |
| | Total | Interior | 0.30 | 3.55 | 21.30 | 0.00 | 1.10 | 0.35 | 4.31 | 38.38 | 0.00 | 1.28 | 0.14 | 2.14 | 16.78 | 0.00 | 0.50 | 0.79 | 10.00 | 76.46 | 0.00 | 2.88 |
| | | Other | 0.16 | 2.36 | 26.37 | 0.85 | 0.59 | 1.21 | 17.46 | 124.30 | 1.27 | 4.60 | 2.41 | 34.04 | 219.94 | 4.32 | 8.84 | 3.78 | 53.86 | 370.61 | 6.44 | 14.03 |
| | | Subtotal | 0.47 | 5.91 | 47.67 | 0.85 | 1.69 | 1.56 | 21.77 | 162.68 | 1.27 | 5.88 | 2.55 | 36.18 | 236.72 | 4.32 | 9.34 | 4.58 | 63.86 | 447.07 | 6.44 | 16.91 |
| **TOTAL Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | | |
| Federal | Within SHU | Interior | 1.51 | 17.85 | 139.70 | 5.65 | 5.49 | 0.19 | 2.49 | 12.29 | 0.28 | 0.68 | 0.43 | 5.96 | 35.75 | 1.26 | 1.54 | 2.13 | 26.30 | 187.74 | 7.19 | 7.71 |
| | | Other | 1.33 | 17.81 | 190.19 | 2.23 | 5.05 | 0.72 | 12.65 | 66.35 | 2.21 | 2.78 | 2.11 | 36.27 | 180.82 | 2.81 | 7.39 | 4.17 | 66.73 | 437.36 | 7.25 | 15.22 |
| | | Subtotal | 2.85 | 35.66 | 329.89 | 7.88 | 10.54 | 0.91 | 15.14 | 78.64 | 2.49 | 3.46 | 2.54 | 42.23 | 216.57 | 4.07 | 8.93 | 6.30 | 93.03 | 625.10 | 14.44 | 22.93 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 4.46 | 29.86 | 0.00 | 0.85 | 0.54 | 8.29 | 61.77 | 0.06 | 1.97 | 0.78 | 12.75 | 91.63 | 0.06 | 2.82 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.49 | 21.50 | 94.69 | 1.58 | 5.59 | 3.00 | 48.00 | 263.52 | 0.91 | 11.06 | 4.49 | 69.50 | 358.21 | 2.49 | 16.65 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.72 | 25.96 | 124.55 | 1.58 | 6.44 | 3.54 | 56.29 | 325.29 | 0.97 | 13.03 | 5.27 | 82.25 | 449.84 | 2.55 | 19.47 |
| | Subtotal | Interior | 1.51 | 17.85 | 139.70 | 5.65 | 5.49 | 0.42 | 6.95 | 42.15 | 0.28 | 1.53 | 0.97 | 14.25 | 97.52 | 1.32 | 3.51 | 2.90 | 39.05 | 279.37 | 7.25 | 10.53 |
| | | Other | 1.33 | 17.81 | 190.19 | 2.23 | 5.05 | 2.22 | 34.15 | 161.04 | 3.79 | 8.37 | 5.11 | 84.27 | 444.34 | 3.72 | 18.45 | 8.66 | 136.23 | 795.57 | 9.74 | 31.87 |
| | | Subtotal | 2.85 | 35.66 | 329.89 | 7.88 | 10.54 | 2.64 | 41.10 | 203.19 | 4.07 | 9.90 | 6.08 | 98.52 | 541.86 | 5.04 | 21.96 | 11.57 | 175.28 | 1074.94 | 16.99 | 42.40 |
| Non-Federal | Within SHU | Interior | 0.10 | 1.28 | 15.74 | 0.00 | 0.37 | 0.11 | 1.64 | 26.05 | 0.35 | 0.40 | 0.10 | 0.97 | 21.76 | 0.00 | 0.35 | 0.31 | 3.89 | 63.55 | 0.35 | 1.12 |
| | | Other | 0.54 | 7.13 | 52.22 | 0.00 | 1.96 | 1.40 | 19.47 | 112.47 | 0.17 | 5.14 | 2.09 | 34.88 | 167.68 | 4.53 | 7.66 | 4.03 | 61.48 | 332.37 | 4.70 | 14.76 |
| | | Subtotal | 0.64 | 8.41 | 67.96 | 0.00 | 2.33 | 1.51 | 21.11 | 138.52 | 0.52 | 5.54 | 2.19 | 35.85 | 189.44 | 4.53 | 8.01 | 4.34 | 65.37 | 395.92 | 5.05 | 15.88 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 7.94 | 72.26 | 0.00 | 2.06 | 1.35 | 20.31 | 169.93 | 0.00 | 4.92 | 1.92 | 28.25 | 242.19 | 0.00 | 6.98 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.82 | 60.17 | 471.37 | 4.75 | 14.01 | 21.34 | 367.39 | 1876.27 | 26.45 | 77.59 | 25.16 | 427.56 | 2347.64 | 31.20 | 91.60 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.39 | 68.11 | 543.63 | 4.75 | 16.07 | 22.69 | 387.70 | 2046.20 | 26.45 | 82.51 | 27.07 | 455.81 | 2589.83 | 31.20 | 98.58 |
| | Subtotal | Interior | 0.10 | 1.28 | 15.74 | 0.00 | 0.37 | 0.68 | 9.58 | 98.31 | 0.35 | 2.46 | 1.44 | 21.28 | 191.69 | 0.00 | 5.27 | 2.22 | 32.14 | 305.74 | 0.35 | 8.10 |
| | | Other | 0.54 | 7.13 | 52.22 | 0.00 | 1.96 | 5.22 | 79.64 | 583.84 | 4.92 | 19.15 | 23.43 | 402.27 | 2043.95 | 30.98 | 85.25 | 29.19 | 489.04 | 2680.01 | 35.90 | 106.36 |
| | | Subtotal | 0.64 | 8.41 | 67.96 | 0.00 | 2.33 | 5.90 | 89.22 | 682.15 | 5.27 | 21.61 | 24.87 | 423.55 | 2235.64 | 30.98 | 90.52 | 31.41 | 521.18 | 2985.75 | 36.25 | 114.46 |
| Total MAMU Inland Zone 1 | Within SHU | Interior | 1.62 | 19.13 | 155.44 | 5.65 | 5.86 | 0.30 | 4.13 | 38.34 | 0.63 | 1.08 | 0.52 | 6.93 | 57.51 | 1.26 | 1.89 | 2.43 | 30.19 | 251.29 | 7.54 | 8.83 |
| | | Other | 1.87 | 24.94 | 242.41 | 2.23 | 7.01 | 2.13 | 32.12 | 178.82 | 2.38 | 7.92 | 4.21 | 71.15 | 348.50 | 7.34 | 15.05 | 8.21 | 128.21 | 769.73 | 11.95 | 29.98 |
| | | Subtotal | 3.49 | 44.07 | 397.85 | 7.88 | 12.87 | 2.42 | 36.25 | 217.16 | 3.01 | 9.00 | 4.73 | 78.08 | 406.01 | 8.60 | 16.94 | 10.64 | 158.40 | 1021.02 | 19.49 | 38.81 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 12.40 | 102.12 | 0.00 | 2.91 | 1.89 | 28.60 | 231.70 | 0.06 | 6.89 | 2.69 | 41.00 | 333.82 | 0.06 | 9.80 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.31 | 81.67 | 566.06 | 6.33 | 19.60 | 24.34 | 415.39 | 2139.79 | 27.36 | 88.65 | 29.65 | 497.06 | 2705.85 | 33.69 | 108.25 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.11 | 94.07 | 668.18 | 6.33 | 22.51 | 26.23 | 443.99 | 2371.49 | 27.42 | 95.54 | 32.34 | 538.06 | 3039.67 | 33.75 | 118.05 |
| | Total | Interior | 1.62 | 19.13 | 155.44 | 5.65 | 5.86 | 1.10 | 16.53 | 140.46 | 0.63 | 3.99 | 2.41 | 35.53 | 289.21 | 1.32 | 8.78 | 5.13 | 71.19 | 585.11 | 7.60 | 18.63 |
| | | Other | 1.87 | 24.94 | 242.41 | 2.23 | 7.01 | 7.44 | 113.79 | 744.88 | 8.71 | 27.52 | 28.54 | 486.54 | 2488.29 | 34.70 | 103.70 | 37.85 | 625.27 | 3475.58 | 45.64 | 138.23 |

| Landowner[1] | General Location[2] | Interior Forest[3] | Suitable Habitat[4] | | | | | Recruitment Habitat[5] | | | | | Capable Habitat[6] | | | | | Total MAMU Habitat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation |
| | | | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) |
| | | Subtotal | 3.49 | 44.07 | 397.85 | 7.88 | 12.87 | 8.53 | 130.32 | 885.34 | 9.34 | 31.51 | 30.95 | 522.07 | 2777.50 | 36.02 | 112.48 | 42.98 | 696.46 | 4060.69 | 53.24 | 156.86 |
| **Marbled Murrelet Inland Zone 2 (No Recovery Conservation Zone)** | | | | | | | | | | | | | | | | | | | | | | |
| Federal | Within SHU | Interior | 0.80 | 11.77 | 63.59 | 4.16 | 2.90 | 0.00 | 0.00 | 0.09 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 11.77 | 63.68 | 4.17 | 2.90 |
| | | Other | 0.06 | 1.78 | 27.76 | 0.62 | 0.22 | 0.00 | 0.08 | 0.77 | 0.00 | 0.00 | 0.00 | 0.08 | 4.50 | 0.00 | 0.00 | 0.06 | 1.94 | 33.03 | 0.62 | 0.22 |
| | | Subtotal | 0.86 | 13.55 | 91.35 | 4.78 | 3.12 | 0.00 | 0.08 | 0.86 | 0.01 | 0.00 | 0.00 | 0.08 | 4.50 | 0.00 | 0.00 | 0.86 | 13.71 | 96.71 | 4.79 | 3.12 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 1.99 | 13.68 | 0.92 | 0.58 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.16 | 1.99 | 14.50 | 0.92 | 0.58 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 | 7.08 | 47.32 | 5.87 | 1.63 | 0.02 | 0.72 | 10.78 | 1.99 | 0.10 | 0.44 | 7.80 | 58.10 | 7.86 | 1.73 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 9.07 | 61.00 | 6.79 | 2.21 | 0.02 | 0.72 | 11.60 | 1.99 | 0.10 | 0.61 | 9.79 | 72.60 | 8.78 | 2.31 |
| | Subtotal | Interior | 0.80 | 11.77 | 63.59 | 4.16 | 2.90 | 0.16 | 1.99 | 13.77 | 0.93 | 0.58 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.96 | 13.76 | 78.18 | 5.09 | 3.48 |
| | | Other | 0.06 | 1.78 | 27.76 | 0.62 | 0.22 | 0.43 | 7.16 | 48.09 | 5.87 | 1.63 | 0.02 | 0.80 | 15.28 | 1.99 | 0.10 | 0.51 | 9.74 | 91.13 | 8.48 | 1.95 |
| | | Total | 0.86 | 13.55 | 91.35 | 4.78 | 3.12 | 0.59 | 9.15 | 61.86 | 6.80 | 2.21 | 0.02 | 0.80 | 16.10 | 1.99 | 0.10 | 1.47 | 23.50 | 169.31 | 13.57 | 5.43 |
| Non-Federal | Within SHU | Interior | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.08 | 1.05 | 7.06 | 0.97 | 0.28 | 0.17 | 1.96 | 3.76 | 0.01 | 0.63 | 0.25 | 3.01 | 10.90 | 0.98 | 0.91 |
| | | Other | 0.00 | 0.06 | 0.42 | 0.02 | 0.01 | 0.19 | 2.61 | 10.61 | 1.89 | 0.71 | 0.26 | 5.04 | 8.28 | 1.16 | 0.95 | 0.45 | 7.71 | 19.31 | 3.07 | 1.67 |
| | | Subtotal | 0.00 | 0.06 | 0.50 | 0.02 | 0.01 | 0.27 | 3.66 | 17.67 | 2.86 | 0.99 | 0.44 | 7.00 | 12.04 | 1.17 | 1.58 | 0.70 | 10.72 | 30.21 | 4.05 | 2.58 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48 | 20.63 | 162.16 | 2.45 | 5.40 | 0.26 | 3.94 | 45.90 | 1.81 | 0.96 | 1.74 | 24.57 | 208.06 | 4.26 | 6.36 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.96 | 105.36 | 674.34 | 36.37 | 25.14 | 1.48 | 65.04 | 269.55 | 7.13 | 5.33 | 8.44 | 170.40 | 943.89 | 43.50 | 30.47 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.44 | 125.99 | 836.50 | 38.82 | 30.54 | 1.75 | 68.98 | 315.45 | 8.94 | 6.29 | 10.18 | 194.97 | 1151.95 | 47.76 | 36.83 |
| | Subtotal | Interior | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 1.56 | 21.68 | 169.22 | 3.42 | 5.68 | 0.44 | 5.90 | 49.66 | 1.82 | 1.59 | 2.00 | 27.58 | 218.96 | 5.24 | 7.27 |
| | | Other | 0.00 | 0.06 | 0.42 | 0.02 | 0.01 | 7.15 | 107.97 | 684.95 | 38.26 | 25.85 | 1.74 | 70.08 | 277.83 | 8.29 | 6.28 | 8.89 | 178.11 | 963.20 | 46.57 | 32.14 |
| | | Total | 0.00 | 0.06 | 0.50 | 0.02 | 0.01 | 8.70 | 129.65 | 854.17 | 41.68 | 31.53 | 2.18 | 75.98 | 327.49 | 10.11 | 7.87 | 10.89 | 205.69 | 1182.16 | 51.81 | 39.41 |
| Subtotal Marbled Murrelet Zone2 | Within SHU | Interior | 0.80 | 11.77 | 63.67 | 4.16 | 2.90 | 0.08 | 1.05 | 7.15 | 0.98 | 0.28 | 0.17 | 1.96 | 3.76 | 0.01 | 0.63 | 1.05 | 14.78 | 74.58 | 5.15 | 3.81 |
| | | Other | 0.06 | 1.84 | 28.18 | 0.64 | 0.23 | 0.19 | 2.69 | 11.38 | 1.89 | 0.71 | 0.26 | 5.12 | 12.78 | 1.16 | 0.95 | 0.51 | 9.65 | 52.34 | 3.69 | 1.89 |
| | | Subtotal | 0.86 | 13.61 | 91.85 | 4.80 | 3.13 | 0.27 | 3.74 | 18.53 | 2.87 | 0.99 | 0.44 | 7.08 | 16.54 | 1.17 | 1.58 | 1.57 | 24.43 | 126.92 | 8.84 | 5.70 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.64 | 22.62 | 175.84 | 3.37 | 5.98 | 0.26 | 3.94 | 46.72 | 1.81 | 0.96 | 1.90 | 26.56 | 222.56 | 5.18 | 6.94 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.39 | 112.44 | 721.66 | 42.24 | 26.77 | 1.50 | 65.76 | 280.33 | 9.12 | 5.43 | 8.89 | 178.20 | 1001.99 | 51.36 | 32.20 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.03 | 135.06 | 897.50 | 45.61 | 32.75 | 1.76 | 69.70 | 327.05 | 10.93 | 6.39 | 10.79 | 204.76 | 1224.55 | 56.54 | 39.14 |
| | Subtotal | Interior | 0.80 | 11.77 | 63.67 | 4.16 | 2.90 | 1.72 | 23.67 | 182.99 | 4.35 | 6.26 | 0.44 | 5.90 | 50.48 | 1.82 | 1.59 | 2.96 | 41.34 | 297.14 | 10.33 | 10.75 |
| | | Other | 0.06 | 1.84 | 28.18 | 0.64 | 0.23 | 7.57 | 115.13 | 733.04 | 44.13 | 27.48 | 1.76 | 70.88 | 293.11 | 10.28 | 6.38 | 9.40 | 187.85 | 1054.33 | 55.05 | 34.09 |
| | | Total | 0.86 | 13.61 | 91.85 | 4.80 | 3.13 | 9.29 | 138.80 | 916.03 | 48.48 | 33.74 | 2.20 | 76.78 | 343.59 | 12.10 | 7.97 | 12.36 | 229.19 | 1351.47 | 65.38 | 44.84 |
| **Total Marbled Murrelet Range** | | | | | | | | | | | | | | | | | | | | | | |
| Federal | Within SHU | Interior | 2.31 | 29.62 | 203.29 | 9.81 | 8.39 | 0.19 | 2.49 | 12.38 | 0.29 | 0.68 | 0.43 | 5.96 | 35.75 | 1.26 | 1.54 | 2.93 | 38.07 | 251.42 | 11.36 | 10.61 |
| | | Other | 1.40 | 19.59 | 217.95 | 2.85 | 5.27 | 0.72 | 12.73 | 67.12 | 2.21 | 2.78 | 2.11 | 36.35 | 185.32 | 2.81 | 7.39 | 4.23 | 68.67 | 470.39 | 7.87 | 15.44 |
| | | Subtotal | 3.71 | 49.21 | 421.24 | 12.66 | 13.66 | 0.91 | 15.22 | 79.50 | 2.50 | 3.46 | 2.54 | 42.31 | 221.07 | 4.07 | 8.93 | 7.16 | 106.74 | 721.81 | 19.23 | 26.05 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | 6.45 | 43.54 | 0.92 | 1.43 | 0.54 | 8.29 | 62.59 | 0.06 | 1.97 | 0.94 | 14.74 | 106.13 | 0.98 | 3.40 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.92 | 28.58 | 142.01 | 7.45 | 7.22 | 3.01 | 48.72 | 274.30 | 2.90 | 11.16 | 4.93 | 77.30 | 416.31 | 10.35 | 18.38 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.31 | 35.03 | 185.55 | 8.37 | 8.65 | 3.56 | 57.01 | 336.89 | 2.96 | 13.13 | 5.87 | 92.04 | 522.44 | 11.33 | 21.78 |
| | Subtotal | Interior | 2.31 | 29.62 | 203.29 | 9.81 | 8.39 | 0.58 | 8.94 | 55.92 | 1.21 | 2.11 | 0.97 | 14.25 | 98.34 | 1.32 | 3.51 | 3.86 | 52.81 | 357.55 | 12.34 | 14.01 |
| | | Other | 1.40 | 19.59 | 217.95 | 2.85 | 5.27 | 2.65 | 41.31 | 209.13 | 9.66 | 10.00 | 5.13 | 85.07 | 459.62 | 5.71 | 18.55 | 9.17 | 145.97 | 886.70 | 18.22 | 33.82 |
| | | Total | 3.71 | 49.21 | 421.24 | 12.66 | 13.66 | 3.23 | 50.25 | 265.05 | 10.87 | 12.11 | 6.10 | 99.32 | 557.96 | 7.03 | 22.06 | 13.03 | 198.78 | 1244.25 | 30.56 | 47.83 |
| Non-Federal | Within SHU | Interior | 0.10 | 1.28 | 15.82 | 0.00 | 0.37 | 0.19 | 2.69 | 33.11 | 1.32 | 0.68 | 0.27 | 2.93 | 25.52 | 0.01 | 0.98 | 0.56 | 6.90 | 74.45 | 1.33 | 2.03 |
| | | Other | 0.54 | 7.19 | 52.64 | 0.02 | 1.97 | 1.59 | 22.08 | 123.08 | 2.06 | 5.85 | 2.35 | 39.92 | 175.96 | 5.69 | 8.61 | 4.49 | 69.19 | 351.68 | 7.77 | 16.43 |
| | | Subtotal | 0.65 | 8.47 | 68.46 | 0.02 | 2.34 | 1.78 | 24.77 | 156.19 | 3.38 | 6.53 | 2.62 | 42.85 | 201.48 | 5.70 | 9.59 | 5.05 | 76.09 | 426.13 | 9.10 | 18.46 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.05 | 28.57 | 234.42 | 2.45 | 7.46 | 1.61 | 24.25 | 215.83 | 1.81 | 5.88 | 3.66 | 52.82 | 450.25 | 4.26 | 13.34 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.78 | 165.53 | 1145.71 | 41.12 | 39.15 | 22.82 | 432.43 | 2145.82 | 33.58 | 82.92 | 33.60 | 597.96 | 3291.53 | 74.70 | 122.07 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.82 | 194.10 | 1380.13 | 43.57 | 46.61 | 24.43 | 456.68 | 2361.65 | 35.39 | 88.80 | 37.26 | 650.78 | 3741.78 | 78.96 | 135.41 |
| | Subtotal | Interior | 0.10 | 1.28 | 15.82 | 0.00 | 0.37 | 2.24 | 31.26 | 267.53 | 3.77 | 8.14 | 1.88 | 27.18 | 241.35 | 1.82 | 6.86 | 4.22 | 59.72 | 524.70 | 5.59 | 15.37 |
| | | Other | 0.54 | 7.19 | 52.64 | 0.02 | 1.97 | 12.36 | 187.61 | 1268.79 | 43.18 | 45.00 | 25.17 | 472.35 | 2321.78 | 39.27 | 91.53 | 38.08 | 667.15 | 3643.21 | 82.47 | 138.50 |
| | | Total | 0.65 | 8.47 | 68.46 | 0.02 | 2.34 | 14.60 | 218.87 | 1536.32 | 46.95 | 53.14 | 27.05 | 499.53 | 2563.13 | 41.09 | 98.39 | 42.30 | 726.87 | 4167.91 | 88.06 | 153.87 |
| Total Marbled Murrelet Range | Within SHU | Interior | 2.42 | 30.90 | 219.11 | 9.81 | 8.76 | 0.38 | 5.18 | 45.49 | 1.61 | 1.36 | 0.69 | 8.89 | 61.27 | 1.27 | 2.52 | 3.49 | 44.97 | 325.87 | 12.69 | 12.64 |
| | | Other | 1.94 | 26.78 | 270.59 | 2.87 | 7.24 | 2.31 | 34.81 | 190.20 | 4.27 | 8.63 | 4.47 | 76.27 | 361.28 | 8.50 | 16.00 | 8.72 | 137.86 | 822.07 | 15.64 | 31.87 |

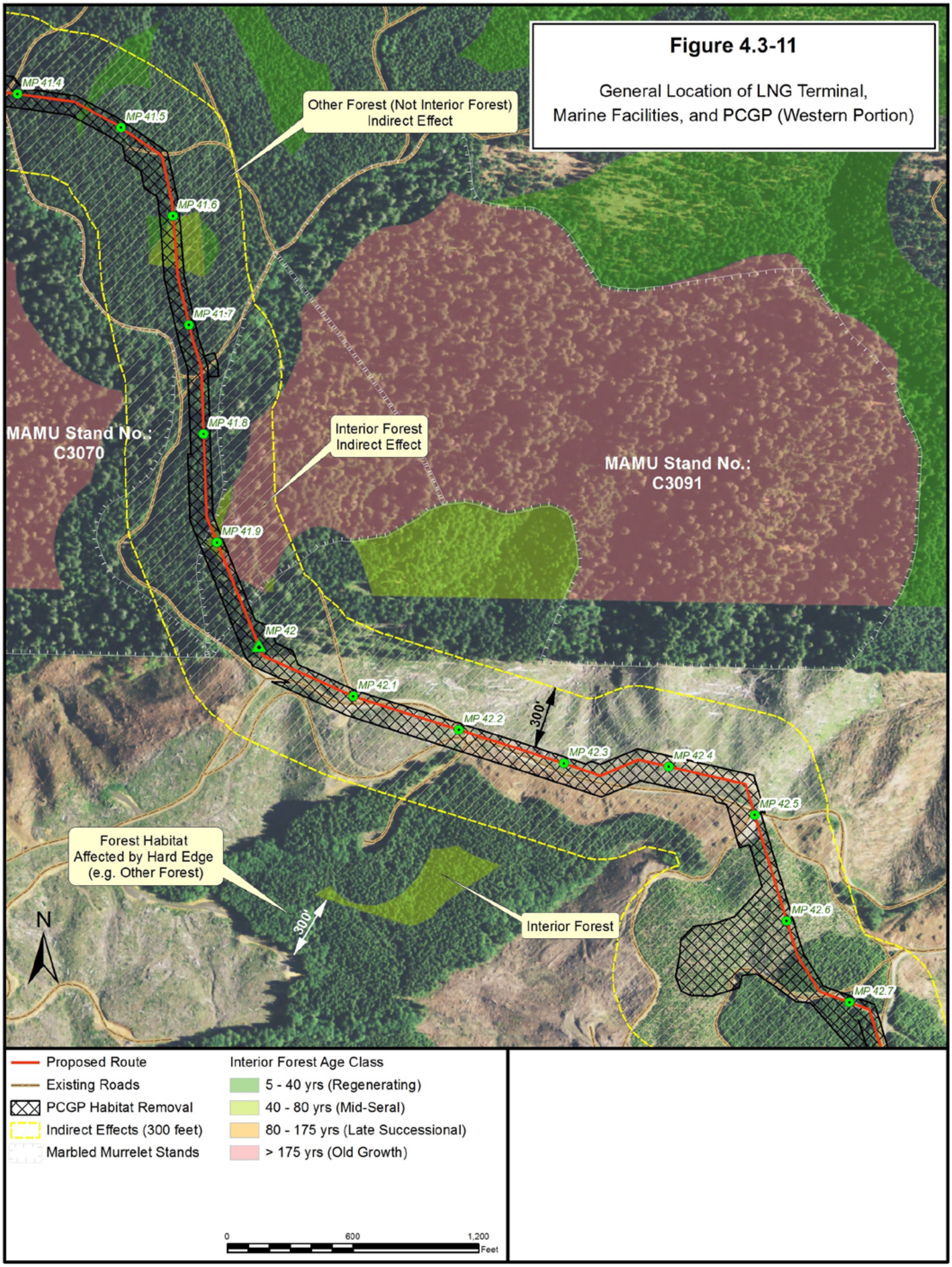
| Landowner[1] | General Location[2] | Interior Forest[3] | Suitable Habitat[4] | | | | | Recruitment Habitat[5] | | | | | Capable Habitat[6] | | | | | Total MAMU Habitat | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation |
| | | | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) | Miles Crossed | Removed[7] (acres) | Indirect[9] (acres) | UCSA[10] (acres) | 30-foot Corridor[11] (acres) |
| | | Subtotal | 4.35 | 57.68 | 489.70 | 12.68 | 16.00 | 2.69 | 39.99 | 235.69 | 5.88 | 9.99 | 5.16 | 85.16 | 422.55 | 9.77 | 18.52 | 12.21 | 182.83 | 1147.94 | 28.33 | 44.51 |
| | Outside SHU | Interior | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.44 | 35.02 | 277.96 | 3.37 | 8.89 | 2.16 | 32.54 | 278.42 | 1.87 | 7.85 | 4.60 | 67.56 | 556.38 | 5.24 | 16.74 |
| | | Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.70 | 194.11 | 1287.72 | 48.57 | 46.37 | 25.83 | 481.15 | 2420.12 | 36.48 | 94.08 | 38.53 | 675.26 | 3707.84 | 85.05 | 140.45 |
| | | Subtotal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.14 | 229.13 | 1565.68 | 51.94 | 55.26 | 27.99 | 513.69 | 2698.54 | 38.35 | 101.93 | 43.13 | 742.82 | 4264.22 | 90.29 | 157.19 |
| | Subtotal | Interior | 2.42 | 30.90 | 219.11 | 9.81 | 8.76 | 2.82 | 40.20 | 323.45 | 4.98 | 10.25 | 2.85 | 41.43 | 339.69 | 3.14 | 10.37 | 8.08 | 112.53 | 882.25 | 17.93 | 29.38 |
| | | Other | 1.94 | 26.78 | 270.59 | 2.87 | 7.24 | 15.01 | 228.92 | 1477.92 | 52.84 | 55.00 | 30.30 | 557.42 | 2781.40 | 44.98 | 110.08 | 47.25 | 813.12 | 4529.91 | 100.69 | 172.32 |
| | | Total | 4.35 | 57.68 | 489.70 | 12.68 | 16.00 | 17.83 | 269.12 | 1801.37 | 57.82 | 65.25 | 33.15 | 598.85 | 3121.09 | 48.12 | 120.45 | 55.33 | 925.65 | 5412.16 | 118.62 | 201.70 |

1 Landowner: Federal includes Coos Bay and Roseburg BLM Districts; Non-Federal includes State and Private lands.
2 General Location identifies areas within Marbled Murrelet SHUs– occupied, unoccupied presumed occupied and areas outside of Marbled Murrelet SHUs within the range of the marbled murrelet.
3 Interior Forest: not affected by existing disturbance (i.e., roads, existing corridors) or adjacent landuse/vegetation type (i.e., agriculture, non-forest, early regenerating forest); Other Forest Type includes forested habitat that is currently affected by existing disturbance or adjacent landuse/vegetation types within 100 meters of stand/MAMU habitat type.
4 Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
5 Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (PC Trask & Associates, 2013).
6 Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).
7 Total Habitat: only includes forested MAMU habitat
8 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
9 Acres identified as UCSAs have been incorporated into the 100-meter indirect effects. Indirect Effects considers habitat within 100-meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
10 UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
11 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.

Note: Table summarized from table Q-3 in appendix Q, which includes effects by general landowner, by Conservation Zones 3 and 4 and Marbled Murrelet Inland Zones 1 and 2. Habitat effects are also broken out marbled murrelet habitat type and within and outside of marbled murrelet SHUs (occupied, unoccupied, and presumed).

# Figure 4.3-11

General Location of LNG Terminal, Marine Facilities, and PCGP (Western Portion)



Predation and Edge

A long-held tenet of bird conservation is that habitat fragmentation with concomitant exposure of nests at habitat edges increases risks of nest predation and/or nest parasitism and ultimately affects species' population growth. However, various reviews of available literature have supported that relationship (Paton, 1994) while other reviews have found no relationships or ambiguous associations between fragmentation and nest predation (Murcia, 1995; Lahti, 2001). A common theme among reviews is poor representation of studies with tested hypotheses on the edge-predator hypothesis (Chalfoun et al., 2002). Some of the disparate results among studies come from forest characteristics, predator species, and predated species which makes generalizations about effects of fragmentation difficult; in western forests, fragmentation may reduce the abundance of some nest predating species while increasing the abundance of others (Tewksbury et al., 1998).

Early studies of fragmentation effects on predation of MAMU nests yielded mixed results (Meyer and Miller, 2002a). In British Columbia, murrelet nests greater than 150 meters (492 feet) from the edge of fragmented nest stands did not fail because of nest predation (Manley and Nelson, 1999 in Nelson, 2005). Nelson and Hamer (1995) found that murrelet nest success was higher for nests greater than 50 meters (164 feet) from forest edge. However, an experimental study using artificial nests in Washington did not detect differences in nest predation within fragmented or continuous forest stands (Marzuluff and Restani, 1999 cited in Meyer and Miller, 2002).

More recent investigations have given new support for the relationship between fragmentation, edges, and predation on marbled murrelet nests. Predation at experimental murrelet nests located at fragment edges and at forest interiors was recorded by cameras. Disturbances by avian predators (Steller's jay, *Cyanocitta stelleri*) were significantly more frequent at hard edges (between old growth and clearcut forest) relative to interiors, but less frequent at soft edges (between old growth and regenerating forest). There were no edge effects at natural-edged sites associated with riparian forest (Malt and Lank, 2007).

Nest disturbance probability at hard edges was 2.5 times that of interior sites, but soft edges had less than half the disturbance probability of interiors (Malt and Lank, 2009). The study also showed that the negative effects of fragmentation decrease over time as managed forests regenerate, changing edge characteristics from hard to soft contrasts with older forest stands. Further, the study found Steller's jay to be the dominant avian predator of simulated nests and abundance of Steller's jay increased across the landscape as old-growth forest cover declined (Malt and Lank, 2009). That study and another by Marzluff et al. (2004) demonstrated that Steller's jays prefer fragmented habitat and high contrast edges, often sites associated with residential sites and campgrounds, locations where jays are more likely to successfully forage and fledge young. Study results reported by Malt and Lank (2009) suggested that larger areas of habitat would lessen negative effects of hard edges, including surrounding or embedding small reserves of suitable murrelet nesting habitat within a protective matrix of surrounding regenerating forest that would reduce predation risks to nesting murrelets as well as to the conservation of other old-growth associated bird species (Malt and Lank, 2009). However in Oregon, Luginbuhl et al. (2001) found that predator densities and rates of nest predation are higher in areas with a variety of tree ages, so nest success is reduced in areas intermixed with young trees or brush habitat (Raphael, 2006).

In addition to Steller's jay, common ravens (*Corvus corax*) have been observed preying on marbled murrelet nestings and eggs (Nelson and Hamer, 1995; Peery and Henry, 2010). Significant increasing regional trends of corvids within the Pacific Connector pipeline vicinity, including Steller's jay and common raves have been observed during the National Audubon Society Christmas Bird Counts since the early 1990s (see figure 4.3-12) and have likely contributed to existing but undocumented nest predation of marbled murrelets and other bird species (see Liebezeit and George, 2002 for a comprehensive review of corvid predation). Population viability modeling of marbled murrelets in central California included various nest predation rates by corvids (Peery and Henry, 2010). With only a 40 percent reduction in predation, the extinction risk was dramatically reduced from 96 percent to 5 percent over 100 years and a 60 percent reduction resulted in a stable marbled murrelet population with assumed modest proportion of breeders, renesting rates, and corvid predation rates. The modeled population viability analysis revealed that nest predation would only need to be reduced by 40 percent to produce a stable population if corvid management was coupled with a modest increase in after-hatch-year survival rate (Peery and Henry, 2010). Corvid control resulted in greater gains in murrelet population size when the maximum number of breeders was allowed to increase over time, similar to what would be expected if the amount of old-growth nesting habitat increased over time (Perry and Henry, 2010). The authors and others (Liebezeit and George, 2002) advocate evaluating local corvid populations, local conditions that may subsidize artificially high population levels (eg., food, garbage), and marbled murrelet nest site vulnerability to develop a corvid management plan that may or may not include lethal removal if an immediate short-term solution to predation is required (eg., Liebezeit and George, 2002).

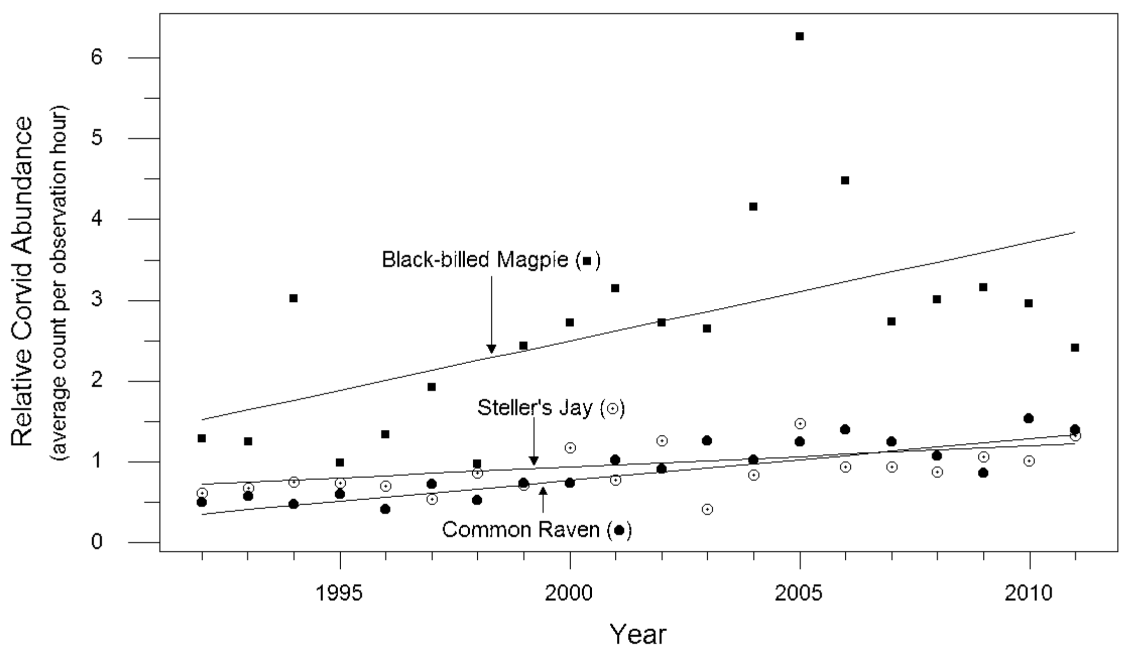



**Figure 4.3-12**
**Relative Abundance for Three Species of Corvids Surveyed During the National Audubon Society Christmas Bird Counts within the Pacific Connector Pipeline Vicinity, 1992 through 2011, with Significant Increasing Trends (Black-billed Magpie, P<0.01; Steller's Jay, P<0.01; Common Raven, <0.001).**

Creation of a 30-foot shrub/grass utility corridor could increase current corvid densities and result in reduced nest success, although revegetation (tree planting) outside of the 30-foot maintenance corridor and subsequent regrowth to reduce the effects of a hard edge may minimize predation on nesting MAMU. Food enticements associated with human presence during construction activities could also increase predator populations within the vicinity of the Pacific Connector pipeline. All trash, food waste, and other items attractive to ravens, jays, magpies, and other corvids would be picked up and removed from the Project area on a daily basis to minimize potential predation of MAMU nestlings.

**Critical Habitat/Late Successional Reserves**

The FWS (1996a, 2011a) determined the physical and biological habitat features associated with the terrestrial environment that support nesting, roosting, and other normal behaviors essential to the conservation of the MAMU. Within areas essential for successful MAMU nesting, FWS utilized the following physical and biological habitat features to identify critical habitat: PCE 1 – individual trees with potential nest platforms (comparable to suitable habitat within this draft BA); and PCE 2 – forest lands of at least one half site-potential tree height, within 0.5 mile of individual trees/suitable habitat stand that are recruitment or capable habitat (within a MAMU Group/SHU). Within this analysis, PCE 2 is comparable to recruitment habitat delineated (personal communication with FWS, 2013d).

A variety of ongoing or proposed activities that disturb or remove physical and biological habitat features may adversely affect, remove or modify MAMU critical habitat. Such activities include, but are not limited to: (1) forest management activities that greatly reduce stand canopy closure, appreciably alter the stand structure, or reduce the availability of nesting sites; (2) land disturbance activities such as mining, sand and gravel extraction, and road building; and (3) harvest of certain types of commercial forest products (e.g., moss).

Those activities have the following effects on the primary constituent elements of MAMU critical habitat:

1. Removal or degradation of individual trees with potential nesting platforms, or the nest platforms themselves, that results in a significant decrease in the value of the trees for future nesting use. Moss may be an important component of nesting platforms in some areas.
2. Removal or degradation of trees adjacent to trees with potential nesting platforms that provide habitat elements essential to the suitability of the potential nest tree or platform, such as trees providing cover from weather or predators.
3. Removal or degradation of forested areas with a canopy height of at least one-half the site-potential tree height and regardless of contiguity, within 0.5 mile of individual trees containing potential nest platforms. This includes removal or degradation of trees currently unsuitable for nesting that contribute to the integrity of the potential nest area (e.g., trees that contribute to the canopy of the forested area). These trees provide the canopy and stand conditions important for MAMU nesting (FWS, 1996a).

The proposed Pacific Connector pipeline crosses one federally designated critical habitat unit (OR-06-d) five times for a total of 2.14 miles see table 4.3.3-15, although not all habitat within designated ciritcial habitat is forested habitat (i.e., "non-capable" in tables Q-3 and Q-5 in appendix Q). Additionally four rock source and disposal sites occur within critical habitat: Signal Tree Road Quarry (Section 3 MP 45.86), Weaver Road Quarry Sites 1 and 2 (MP 47.00), and Signal Tree Road Quarry (Section 35, MP 47.00). These are existing quarries and provide no murrelet habitat; no additional MAMU habitat would be removed adjacent to these sites. Overall, construction of the proposed PCGP Project would remove 4.11 acres of suitable marbled murrelet nesting habitat (PCE-1) and 5.29 acres of recruitment (PCE-2) within CHU OR-06-d (see table 4.3.3-15), all within marbled murrelet SHUs. Additionally, approximately 0.85 acres of suitable habitat (PCE-1), and 1.04 acres of recruitment habitat within CHU OR-06-d have been identified for use by the PCGP Project as UCSAs that may be used to store forest slash, stumps, and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration (see UCSA Column, table 4.3.3-15). Use of the UCSAs would be a short-term disturbance of understory vegetation within suitable and potentially suitable habitat and would not affect potential nesting stand structures or characteristics. After construction of the pipeline, approximately 24.81 acres of MAMU habitat within CHU OR-06-d outside of the 30-foot maintenance corridor will be replanted with tree species and effects of edge will decrease over time. A detailed table of critical habitat unit OR-06-d affected by the project within and outside of MAMU SHUs and interior forest, as well as non-capable habitat that is affected and occurs in designated critical habitat is located in table Q-5 in appendix Q.

Designated critical habitat only occurs within MAMU Inland Zone 1. The majority (92 percent) of forested habitat within CHU OR-06-d affected by the proposed action overlaps with NWFP LSR unit RO 261 in Coos Bay and Roseburg BLM Districts, or unmapped LSRs (see table Q-3 in appendix Q). An additional 28.68 acres of forested land (suitable, recruitment, and capable habitat) within unmapped LSRs will be removed by construction of the proposed PCGP Project (see table 4.3.3-16). Likewise, an additional 6.84 acres of unmapped LSRs will be disturbed in UCSAs. Approximately 45 acres of forested habitat within NWFP LSRs and unmapped LSRs will be replanted with trees outside of the 30-foot maintenance corridor which will reduce the edge effects of edge over time (see table 4.3.3-16). Table 4.3.3-16 identifies the MAMU habitat that would be affected within LSR Unit RO 261 and within the unmapped LSR units from construction of the proposed Project. A detailed table of NWFP LSRs and unmapped LSRs affected by the project within and outside of MAMU SHUs and interior forest, as well as non-capable habitat that is affected and occurs in LSRs and unmapped LSRs is provided in table Q-6 in appendix Q. Table Q-3 in appendix Q provides the acres of marbled murrelet habitat affected within Marbled Murrelet Inland Zones 1 and 2 and Recovery Plan Conservation Zones 3 and 4, including landowner, and identifies the area that FWS-designated critical habitat unit OR-06-d overlaps with NWFP LSRs and unmapped LSRs within and outside of marbled murrelet SHUs.

Within Murrelet Inland Zones 1 and 2 where federal land is checker-boarded, Pacific Connector considered locations of NWFP LSRs and occupied MAMU stands when routing the proposed pipeline and tried to avoid those tracts of lands if another constructible route was feasible to minimize impacts to MAMU habitat (see MAMU and NSO Avoidance Plan). Minimizing effects to LSRs also minimizes effects to MAMU designated critical habitat since a lot of overlap of MAMU CHU OR-06-d and LSR RO 261 occurs. Table 4.3.3-17 summarizes the location of the project and MAMU habitat affected in relation to MAMU designated critical habitat unit OR-06-d.

## Table 4.3.3-15
## Summary of Marbled Murrelet Critical Habitat Unit OR-06d that will be Affected During Construction and Operation of the Proposed Action by Recovery Plan Conservation Zones and Landowner

| Land Owner | Land Owner | PCE1 / Suitable Habitat[1] | | | | | PCE2 / Recruitment Habitat[2] | | | | | PCE2 / Capable Habitat[3] | | | | | Total Acres | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation |
| | | | Removed[4] (acres) | Indirect[5] (acres) | UCSA[6] (acres) | 30-foot Corridor[7] (acres) | | Removed[4] (acres) | Indirect[5] (acres) | UCSA[6] (acres) | 30-foot Corridor[7] (acres) | | Removed[4] (acres) | Indirect[5] (acres) | UCSA[6] (acres) | 30-foot Corridor[7] (acres) | | Removed[4] (acres) | Indirect[5] (acres) | UCSA[6] (acres) | 30-foot Corridor[7] (acres) |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | |
| Conservation Zone 4 | BLM - Coos Bay | 0.08 | 1.03 | 31.45 | 0.00 | 0.28 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.83 | 14.38 | 77.56 | 1.04 | 2.94 | 0.91 | 15.41 | 109.84 | 1.04 | 3.22 |
| | BLM - Roseburg | 0.19 | 2.48 | 20.27 | 0.00 | 0.71 | 0.06 | 1.52 | 21.29 | 0.00 | 0.22 | 0.00 | 1.44 | 8.65 | 0.00 | 0.01 | 0.25 | 5.44 | 50.21 | 0.00 | 0.94 |
| Total Conservation Zone 4 | | 0.27 | 3.51 | 51.72 | 0.00 | 0.99 | 0.06 | 1.52 | 22.12 | 0.00 | 0.22 | 0.83 | 15.82 | 86.21 | 1.04 | 2.95 | 1.16 | 20.85 | 160.05 | 1.04 | 4.16 |
| Outside Conservation Zones | BLM - Roseburg | 0.01 | 0.60 | 17.59 | 0.85 | 0.02 | 0.20 | 3.77 | 13.66 | 1.04 | 0.78 | 0.57 | 6.61 | 36.90 | 0.02 | 2.06 | 0.78 | 10.98 | 68.15 | 1.91 | 2.86 |
| Total Critical Habitat | | 0.28 | 4.11 | 69.31 | 0.85 | 1.01 | 0.26 | 5.29 | 35.78 | 1.04 | 1.00 | 1.41 | 22.43 | 123.11 | 1.06 | 5.01 | 1.94 | 31.83 | 228.20 | 2.95 | 7.02 |

1 PCE1/Suitable Habitat: individual trees with potential nest platforms, including supporting trees delineated as occupied or suitable (comparable to suitable habitat)
2 PCE2/Recruitment Habitat: forest lands of at least one half site-potential tree height, within 0.5 mile of individual trees/suitable habitat stand that are recruitment or capable habitat (comparable to recruitment habitat) not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).
3 PCE2/Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).
4 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
5 Acres identified as UCSAs have been incorporated into the 100-meter indirect effects. Indirect Effects considers habitat within 100-meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
6 UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
7 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project.

Summarized from table Q-5 in appendix Q.

## Table 4.3.3-16
## Summary of MAMU Habitat within Late Successional Reserves and Unmapped Late Successional Reserves within Marbled Murrelet Inland Zones 1 and 2 and Recovery Plan Conservation Zones that Will Be Affected by Construction and Operation of the Proposed Action

| Recovery Plan Conservation Zone | Land Owner | Land Allocation[4] | Suitable Habitat[1] | | | | | Recruitment Habitat[2] | | | | | Capable Habitat[3] | | | | | Total Acres | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation | Miles Crossed | Construction | | | Operation |
| | | | | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) |
| **Marbled Murrelet Inland Zone 1** | | | | | | | | | | | | | | | | | | | | | | |
| Conservation Zone 4 | BLM - Coos Bay | NWFP LSR (R0261) | 0.08 | 1.03 | 31.50 | 0.00 | 0.28 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.83 | 14.38 | 77.50 | 1.04 | 2.94 | 0.91 | 15.41 | 109.83 | 1.04 | 3.22 |
| | | Unmapped LSR (MAMU Stand) | 2.31 | 28.62 | 241.40 | 7.03 | 8.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.31 | 28.62 | 241.40 | 7.03 | 8.61 |
| | *Coos Bay Subtotal* | | 2.39 | 29.65 | 272.90 | 7.03 | 8.89 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.83 | 14.38 | 77.50 | 1.04 | 2.94 | 3.22 | 44.03 | 351.23 | 8.07 | 11.83 |
| | BLM - Roseburg | NWFP LSR (R0261) | 0.19 | 2.44 | 19.93 | 0.00 | 0.70 | 0.06 | 1.52 | 21.29 | 0.00 | 0.22 | 0.00 | 1.44 | 8.65 | 0.00 | 0.01 | 0.25 | 5.40 | 49.87 | 0.00 | 0.93 |
| | | Unmapped LSR (MAMU Stand) | 0.00 | 0.04 | 0.34 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.34 | 0.00 | 0.01 |
| | *Roseburg Subtotal* | | 0.19 | 2.48 | 20.27 | 0.00 | 0.71 | 0.06 | 1.52 | 21.29 | 0.00 | 0.22 | 0.00 | 1.44 | 8.65 | 0.00 | 0.01 | 0.25 | 5.44 | 50.21 | 0.00 | 0.94 |
| Total Conservation Zone 4 | | NWFP LSR (R0261) | 0.27 | 3.47 | 51.43 | 0.00 | 0.98 | 0.06 | 1.52 | 22.12 | 0.00 | 0.22 | 0.83 | 15.82 | 86.15 | 1.04 | 2.95 | 1.16 | 20.81 | 159.70 | 1.04 | 4.15 |
| | | Unmapped LSR (MAMU Stand) | 2.31 | 28.66 | 241.74 | 7.03 | 8.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.31 | 28.66 | 241.74 | 7.03 | 8.62 |
| Conxervatin Zone 4 Total | | | 2.58 | 32.13 | 293.17 | 7.03 | 9.60 | 0.06 | 1.52 | 22.12 | 0.00 | 0.22 | 0.83 | 15.82 | 86.15 | 1.04 | 2.95 | 3.47 | 49.47 | 401.44 | 8.07 | 12.77 |
| Outside Recovery Zone | BLM - Roseburg | NWFP LSR (R0261) | 0.00 | 0.47 | 9.19 | 0.58 | 0.00 | 0.19 | 2.55 | 12.29 | 0.34 | 0.73 | 0.31 | 4.03 | 26.89 | 0.02 | 1.14 | 0.50 | 7.05 | 48.37 | 0.94 | 1.87 |
| | | Unmapped LSR (MAMU Stand) | 0.25 | 2.92 | 18.31 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 2.92 | 18.31 | 0.00 | 0.92 |
| | | Unmapped LSR (100 ac. KOAC) | 0.01 | 0.13 | 8.47 | 0.27 | 0.02 | 0.00 | 0.56 | 1.17 | 0.51 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.69 | 9.65 | 0.78 | 0.04 |
| Roseburg Total | | | 0.26 | 3.52 | 35.97 | 0.85 | 0.94 | 0.19 | 3.11 | 13.46 | 0.85 | 0.75 | 0.31 | 4.03 | 26.90 | 0.02 | 1.14 | 0.76 | 10.66 | 76.33 | 1.72 | 2.83 |
| Subtotal Marbled Murrelet Inland Zone 1 | | NWFP LSR (R0261) | 0.27 | 3.94 | 60.62 | 0.58 | 0.98 | 0.25 | 4.07 | 34.41 | 0.34 | 0.95 | 1.14 | 19.85 | 113.04 | 1.06 | 4.09 | 1.66 | 27.86 | 208.07 | 1.98 | 6.02 |
| | | Unmapped LSR (MAMU Stand) | 2.56 | 31.58 | 260.05 | 7.03 | 9.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.56 | 31.58 | 260.05 | 7.03 | 9.54 |
| | | Unmapped LSR (100 ac. KOAC) | 0.01 | 0.13 | 8.47 | 0.27 | 0.02 | 0.00 | 0.56 | 1.17 | 0.51 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.69 | 9.65 | 0.78 | 0.04 |
| Total MAMU Inland Zone 1 | | | 2.84 | 35.65 | 329.14 | 7.88 | 10.54 | 0.25 | 4.63 | 35.58 | 0.85 | 0.97 | 1.14 | 19.85 | 113.05 | 1.06 | 4.09 | 4.23 | 60.13 | 477.77 | 9.79 | 15.60 |
| **Marbled Murrelet Inland Zone 2** | | | | | | | | | | | | | | | | | | | | | | |
| Outside Recovery Zone | BLM - Roseburg | Unmapped LSR (100 ac. KOAC) | 0.00 | 0.32 | 15.84 | 0.00 | 0.00 | 0.00 | 0.04 | 0.38 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.00 | 0.00 | 0.00 | 0.38 | 16.27 | 0.00 | 0.00 |
| **Total Marbled Murrelet Range** | | | | | | | | | | | | | | | | | | | | | | |
| Total Marbled Murrelet Range | | NWFP LSR (R0261) | 0.27 | 3.94 | 60.62 | 0.58 | 0.98 | 0.25 | 4.07 | 34.41 | 0.34 | 0.95 | 1.14 | 19.85 | 113.04 | 1.06 | 4.09 | 1.66 | 27.86 | 208.07 | 1.98 | 6.02 |
| | | Unmapped LSR (MAMU Stand) | 2.56 | 31.58 | 260.05 | 7.03 | 9.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.56 | 31.58 | 260.05 | 7.03 | 9.54 |
| | | Unmapped LSR (100 ac. | 0.01 | 0.45 | 24.31 | 0.27 | 0.02 | 0.00 | 0.60 | 1.55 | 0.51 | 0.02 | 0.00 | 0.02 | 0.06 | 0.00 | 0.00 | 0.01 | 1.07 | 25.92 | 0.78 | 0.04 |

| Recovery Plan Conservation Zone | Land Owner | Land Allocation[4] | Suitable Habitat[1] | | | | | Recruitment Habitat[2] | | | | | Capable Habitat[3] | | | | | Total Acres | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation | | Construction | | | Operation |
| | | | Miles Crossed | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Miles Crossed | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Miles Crossed | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) | Miles Crossed | Removed[5] (acres) | Indirect[6] (acres) | UCSA[7] (acres) | 30-foot Corridor[8] (acres) |
| | | KOAC) | | | | | | | | | | | | | | | | | | | | |
| **Total Marbled Murrelet Range** | | | **2.84** | **35.97** | **344.98** | **7.88** | **10.54** | **0.25** | **4.67** | **35.96** | **0.85** | **0.97** | **1.14** | **19.87** | **113.10** | **1.06** | **4.09** | **4.23** | **60.51** | **494.04** | **9.79** | **15.60** |

[1] Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
[2] Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (Trask & Associates, 2013).
[3] Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).
[4] Unmapped LSRs include MAMU occupied stands that occur on matrix lands (included in BLM and Forest Service LUA coverage, as well as occupied murrelet stands within the project area that occur on matrix lands but were not included in the LUA coverage) and BLM delineated known northern spotted owl activity center.
[5] Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
[6] Acres identified as UCSAs have been incorporated into the 100-meter indirect effects. Indirect Effects considers habitat within 100-meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
[7] UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
[8] 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.

Summarized from table Q-7 in appendix Q. Non-Capable habitat (not forested and not capable of becoming suitable habitat, or deciduous forest) that occurs in NWFP LSRs and unmapped LSRs is included in table Q-7 in appendix Q.

**Table 4.3.3-17**
**Summary of Habitat Affected in Marbled Murrelet Designated Critical Habitat Unit OR-06-d from the Proposed Action**

| Critical Habitat Unit | Land Ownership | NWFP Land Use Allocation | Total acres of PCE1 that will be removed [1] | Total acres of PCE2/Recruitment removed [2] | Total acres of PCE2/Capable [3] | Length of pipeline through CHU OR-06-d (miles) | Additional Comments |
|---|---|---|---|---|---|---|---|
| OR-06-d | Coos Bay BLM | LSR | 1.03 | 0.0 | 14.38 | 0.96 | 1st crossing (MPs 41.33-42.01): pipeline routed through mostly regenerating (capable) and mid-seral (recruitment) forest, with a portion crossing through the edge of an old-growth/occupied (suitable) stand; crosses corner of critical habitat section. Follows or occurs within an existing road for a small portion.<br><br>2nd crossing (MPs 43.17-43.50): route mostly parallels a road through regenerating (capable) forest. |
| OR-06-d | Roseburg BLM | LSR / Unmapped LSR | 3.08 | 4.63 | 5.47 | 0.85 | 3rd crossing (MPs 46.91-47.17) – Weaver Ridge reroute: crosses mosaic of old-growth (suitable) and regenerating (capable) forest; parallels a road for approximately 0.06 mile.<br><br>4th crossing (MPs 52.61-52.94): crosses mid-seral (recruitment) and regenerating (capable) forest; crosses corner of critical habitat section.<br><br>5th crossing (MPs 53.10-53.36): mostly follows a road located between late successional (suitable) and regenerating (capable) stands. |
| OR-06-d | Roseburg BLM | Connectivity | 0.0 | 0.66 | 2.58 | 0.33 | 5th crossing (MPs 53.36-53.69): follows a road between regenerating (capable) and late successional (suitable) stands. |

[1] PCE 1 = suitable habitat
[2] PCE 2 = recruitment habitat
[3] PCE 2 = capable habitat, which includes early mid-seral forest, as well as clearcut and regenerating coniferous forest.

In addition to direct loss of critical habitat and effects to PCEs due to construction of the Project, the project's indirect effects to MAMU that were discussed above (fragmentation, edge, and effects to interior forest) indirectly affect designated critical habitats and PCEs. Edge effects and effects to interior forest may induce changes to forest characteristics later in time and would indirectly affect PCEs. Such effects may induce changes at individual nest trees and/or trees with potential nest platforms (PCE 1). Long-term effects on edges and interiors of recruitment habitat (PCE 2) are less well defined and over time, edge effects will diminish as edges evolve from "hard" to "soft" after revegetation occurs in the construction right-of-way, and in particular, trees are planted outside of the 30-foot maintenance corridor (see for example, Peery and Henry, 2010).

Long-term effects from removal of interior forest within critical habitat, NWFP LSRs, and unmapped LSRs by the Pacific Connector pipeline could occur from clearing MAMU habitat. Table 4.3.3-15 and table 4.3.3-16 identify the distance that MAMU habitat is crossed by the proposed project within and outside of interior habitat, summarizes the acreage of MAMU habitat directly removed and indirectly affected within 100 meters of the PCGP Project (habitat removal) by Marbled Murrelet Inland Zones 1 and 2, and landowner within critical habitat units and NWFP LSRs and unmapped LSRs, respectively. Tables Q-5 and Q-6 in appendix Q provide detailed effects to MAMU Habitat within critical habitat unit OR-06-d and NWFP LSRs and unmapped LSRs, respectively, including MAMU habitat affected within and outside of MAMU SHUs and interior forest. Most indirect effects to forested habitat within 100 meters of habitat removal occur in MAMU habitat that has been previously affected by existing edge, such as roads, waterbodies, early seral forest, and nonforested habitat.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA. The Pacific Connector pipeline would not be operational until at least 2017. Consequently, the foreseeable future required for cumulative effects analysis would actually occur before implementation of the proposed action, not after its implementation, which is more often the case.

Cumulative effects to marbled murrelets would be generated by timber harvesting and other sources of habitat losses on non-federal lands in the foreseeable future. Areas of marbled murrelet habitat-capable land have been monitored as a component of the Northwest Forest Plan (NWFP). Habitat-capable lands are capable of supporting forest structure with the potential to provide murrelet nesting habitat (Raphael et al. 2011). In Oregon, the evaluation of habitat-capable land was limited to Marbled Murrelet Zone 1 (of the NWFP) and did not include any analysis of habitat within Marbled Murrelet Zone 2.

In 2012, there were 1,428 acres of suitable habitat and 4,088 acres of recruitment habitat on non-federal lands within the Terrestrial Nesting Analysis Area (see table 4.3.3-2 in Section 4.3.3.2, above). Recruitment habitat and suitable habitat, used here, are considered equivalent to habitat Class 3 (moderately high likelihood of suitability) and habitat Class 4 (highest likelihood of suitability), respectively. Those two habitat classes were included in modeling changes in marbled murrelet habitat availability from 1996 (baseline conditions) to 2006 (Raphael et al. 2011).

Within Marbled Murrelet Zone 1, which coincides with the Coast Range physiographic province, there were 421.5 thousand acres of Class 3 and Class 4 habitats in 1996; by 2006 there were 377.9 thousand acres in those habitat classes on non-federal lands (see Table 9 in Raphael et al. 2011). There was a net loss of 43.6 thousand acres of Class 3 and Class 4 habitats (-10.3 percent), declining by 10.3 percent during the 10-year period (Table 9 in Raphael et al. 2011), and used here as an annual loss of suitable and recruitment habitats at 1.03 percent per year. That rate of decline on non-federal lands is assumed to be constant over time within the Terrestrial Nesting Analysis Area. Areas of suitable and recruitment habitats present in 2012 would be expected to decline at that annual rate. With an additional net loss in 2017, there would be 1,354 acres of suitable habitat and 3,877 acres of recruitment habitat within the analysis area on non-federal land by the time the PCGP project is expected to be implemented in 2017.

The Project would remove 8.41 acres of suitable habitat and 89.22 acres of recruitment habitat on non-federal (state and private) lands in Marbled Murrelet Zone 1 by 2017 (see table 4.3.3-10 in Section 4.3.3.3, above). The amount of suitable habitat removed would be 0.62 percent of the suitable habitat remaining on non-federal lands (1,354 acres) in the analysis area by 2017. Likewise, the amount of recruitment habitat removed would be 2.30 percent of the habitat remaining on non-federal lands (3,877 acres) in the analysis area by 2017. When compared to the estimated amount of suitable and recruitment habitat on non-federal land within the analysis area, the PCGP project would affect a total of 97.63 acres, which would be 1.87 percent of the total suitable and recruitment habitat available within the foreseeable future in 2017.

Although Raphael et al. (2011) limited their evaluation of habitat-capable land to Marbled Murrelet Zone 1 (of the NWFP), the same analysis was included, as described above, for Zone 2 using the annual loss of 1.03 percent which is included in table 4.3.3-18.

## Table 4.3.3-18
## Estimates for Losses of Marbled Murrelet Suitable and Recruitment Habitat on Non-Federal Land within the Terrestrial Nesting Analysis Area by 2017, with PCGP Project-Related Effects on Non-Federal Land Compared to Cumulative Effects

| Marbled Murrelet Inland Zone | Marbled Murrelet Habitat Areas on Non-Federal Land in Analysis Area in 2012 [1] | | | Loss of Marbled Murrelet Habitat Between 1996 and 2006 [2] | | Marbled Murrelet Habitat on Non-federal Land in Analysis Area Expected in 2017 | | | Marbled Murrelet Habitat Removed by PCGP on Non-federal Land in Analysis Area in 2017 [3] | | | Percent of Marbled Murrelet Habitat in Analysis Area Expected in 2017 to be Affected by PCGP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Suitable Habitat (acres) | Recruitment Habitat (acres) | Total Habitat (acres) | Percent Change from 1996 | Percent Change per Year | Suitable Habitat (acres) | Recruitment Habitat (acres) | Total Habitat (acres) | Suitable Habitat (acres) | Recruitment Habitat (acres) | Total Habitat (acres) | Suitable Habitat | Recruitment Habitat | Total Habitat |
| Zone 1 | 1,428 | 4,088 | 5,516 | -10.3% | -1.03% | 1,354 | 3,877 | 5,231 | 8.41 | 89.22 | 97.63 | 0.62% | 2.30% | 1.87% |
| Zone 2 | 22 | 3,883 | 3,905 | | | 21 | 3,682 | 3,703 | 0.06 | 129.65 | 129.71 | 0.29% | 3.52% | 3.50% |

[1] Data from table 4.3.3-2 in Section 4.3.3.2.
[2] Percent loss in Marbled Murrelet Zone 1 on Non-Federal Land from Table 9 in Raphael et al. 2011.
[3] Data from table 4.3.3-10 in Section 4.3.3.3.

#### 4.3.3.4 Conservation Measures

**Avoidance, Minimization, and Rehabilitation / Restoration:** Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to the Terrestrial Nesting Analysis Area. Those measures have been compiled in table 2C in appendix N. Specific conservation measures that would benefit MAMUs include those that:

- Minimize removal of forest by incorporating UCSAs into the Project design;
- Utilize two-year construction window to minimize the overall temporary extra work areas;
- Flag large diameter trees on edges of construction right-of-way or temporary work areas where feasible to save from clearing;
- Minimize soil erosion during and after construction;
- Ensure that all trash, food waste, and other items attractive to crows, jays, and other corvids will be contained and removed from the project area on a daily basis to minimize potential predation on murrelet nestlings;
- Use of logging methods to minimize damage to adjacent trees when clearing the right-of-way to reduce potential infestation from forest pathogens and insects; and
- Minimize potential for establishment of invasive vegetation and establish control of noxious weeds.

Pacific Connector has also proposed measures to rectify, repair, rehabilitate, and otherwise reduce impact to forested habitats once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N. Specific conservation measures that would benefit MAMUs include those that:

- Replant conifer species outside of the 30-foot wide maintenance corridor after construction, which will contribute to the reestablishment of native vegetation and soften the edge effect;
- Contribute to forest habitat structural diversity (e.g., snags and downed timber); and
- Minimize potential for increased human use of the reclaimed construction right-of-way and intrusion into undisturbed habitats.

Plans included in the appendices of Pacific Connector's POD will also minimize effects to marbled murrelet habitat and/or nesting murrelets. The Leave Tree Protection Plan describes the preconstruction surveys that will be completed to clearly mark the boundaries of the projects certificated working limits, and procedures to identify individual trees within and along the edges of the certificated work limits that can be conserved or left standing, as well as BMPs that would be employed to minimize damage to trees within UCSAs and protect trees not removed from the construction right-of-way (see Appendix P to the POD, available upon request). An Integrated Pest Management Plan (see Appendix N to the POD, available upon request) describes BMPs to address the control of noxious weeds, invasive plants, forest pathogens, and soil pests, as well as describes measures to minimize the potential spread of invasive species and potential adverse effects of control treatments. The Blasting Plan and Air Noise and Fugitive Dust Plans (see Appendices C and B to the POD, respectively – available upon request) provide mitigation measures and monitoring plans to minimize noise effects to nesting murrelets during construction of the PCGP Project.

Within known occupied stands, Pacific Connector has proposed the route within existing roads that traverse the stand or situated the right-of-way within existing edge (i.e., within clearcut or regenerating forest adjacent to a stand) to avoid or minimize habitat removal from the stand, where feasible. In other areas, Pacific Connector has rerouted the Original 2007 Route (FERC, 2009) to avoid removing habitat and further fragmenting suitable marbled murrelet stands – occupied, unoccupied, unsurveyed, and presumed occupied. Also, to minimize impacts to marbled murrelet stands and suitable nesting habitat, Pacific Connector has incorporated minor alignment adjustments or TEWA modifications into the proposed Project. Other major and minor route alternatives that further minimize effects to marbled murrelets and habitat have been considered and included into the Proposed Route which are discussed in the Marbled Murrelet and Northern Spotted Owl Avoidance and Minimization Plan, appendix V).

Pacific Connector initiated additional marbled murrelet surveys in spring 2013 within eight stands identified with suitable habitat, where surveys are permitted, to determine presence or absence of occupied marbled murrelet behavior. Where occupied marbled murrelet behavior was documented, measures similar to those applied to known occupied stands will be applied, if feasible, including: 1) reroute the pipeline to avoid occupied stands or suitable habitat, 2) incorporate minor route adjustment to reduce habitat removed, 3) modify or move temporary work areas, and 4) restrict the pipeline construction right-of-way to roads. Second year surveys will continue in two stands during the 2014 survey season, and if determined occupied, similar measures described above will be applied.

When Pacific Connector acquires survey access in stands identified to have potential nesting habitat (presumed occupied stands), where survey permission has been denied, Pacific Connector will evaluate the stands for trees with suitable nesting structures. If suitable nesting structures are identified and time permits for two years of surveys prior to beginning the proposed Project, Pacific Connector will survey those stands for occupied marbled murrelet behavior. When additional information on the status of these presumed occupied marbled murrelet stands is acquired, Pacific Connector will advise the FWS of their updated status, including whether they are determined to have suitable nesting structures, determined to be occupied or unlikely occupied, or determined to not be suitable habitat for nesting marbled murrelets.

Prior to timber clearing, Pacific Connector would apply a "Standards Rule Set" developed during a meeting in June 2008 with FWS and the cooperators to further minimize Project effects to MAMUs that would accomplish the following:

- identify potential nest trees that would be allowed to remain standing within TEWAs or edge of right-of-way;
- identify TEWAs to be reduced in size or eliminated to reduce removal of suitable habitat;
- identify any additional minor route adjustments that would not alter constructability but further reduce removal of suitable habitat;
- identify any previously unknown nest tree discovered and assure that it is properly protected by applying the appropriate seasonal limitations or daily timing restrictions associated with similar locations along the pipeline alignment; and
- EIs would be supported by qualified biologists to identify potential nest trees.

To avoid direct effects to MAMU, Pacific Connector will remove timber outside of the entire marbled murrelet breeding season (after September 15 but before March 31) within 300 feet of MAMU stands to ensure that murrelets and chicks are not felled. Additionally, to minimize disturbance within forested areas, Pacific Connector has designated nearly 129 acres (see table 4.3.3-10) of UCSAs within Marbled Murrelet Inland Zones 1 and 2 that will not be cleared of trees but be used to store forest slash, stumps, and dead and downed log materials during construction that will be scattered across the right-of-way after construction and during restoration. The UCSAs will be useful for the construction of the PCGP Project while not requiring removal of trees or understory vegetation, as well as allow the maintenance of suitable or potentially suitable and recruitment habitat function.

Construction of the proposed Project will occur within Marbled Murrelet Inland Zones 1 and 2, including within marbled murrelet occupied stands during the entire breeding season. Construction will occur after timber has been felled outside of the breeding season and will adhere to daily timing restrictions (DTRs, activity limited to 2 hours after sunrise and 2 hours before sunset) within 0.25 mile of marbled murrelet stands (occupied, presumed occupied, unoccupied) at least through the critical breeding season to minimize risk of disturbance to adult marbled murrelets entering and leaving the stand, as well as possible dispersal of juveniles. DTRs will continue to be applied to large transport helicopter use in the late breeding season within 0.25 mile of a MAMU stand if helicopter use is necessary.

During construction, Pacific Connector would ensure that the construction contracts include stipulations ensuring that all trash, food waste, debris, and other items attractive to crows, jays, and other corvids would be picked up and removed from the Project area on a daily basis during the breeding season to minimize potential predation of marbled murrelet nestlings. Pacific Connector's EI's would be responsible for overseeing that the construction contractor is adequately following these stipulations.

Following construction, affected forested lands (the construction right-of-way and TEWAs outside of the 30-foot maintenance right-of-way) would be replanted and allowed to return to the pre-construction condition, with tree species in the approximate proportion to those species removed. Tree establishment would be allowed to occur up to 15 feet on either side of the pipeline centerline. Over the long-term (200 to 250 years to become marbled murrelet suitable nesting habitat) revegetated areas outside of the 30-foot maintenance corridor may achieve tree structural characteristics comparable to trees that would be removed, had they not been affected. Over the short-term, replanting approximately 724 acres on the edge of the 30-foot maintenance corridor will provide a soft edge to adjacent forested habitat and minimize effects of edge, as well as reduce predator presence (see table 4.3.3-10).

**Compensatory Mitigation**: Since effects by the proposed action could not be fully mitigated on-site whether by avoidance, minimization, or restoration measures, Pacific Connector has developed a Compensatory Mitigation Plan (CMP) that provides a means to compensate for unavoidable impacts to listed species and their habitat, including marbled murrelets. The CMP combines agency-recommended projects to enhance existing forested and aquatic habitats, re-designation of allocated forest lands (NWFP), and acquisition of forested habitats to compensate for habitats affected by the project. The CMP includes opportunities for funding projects in southern Oregon that could be implemented by federal land managing agencies, state or local resources agencies, or conservation groups. Projects or actions that are being considered include permanent reclamation of existing disturbances within capable habitat, such as roads within LSRs that are no longer required for resource management. These mitigation funds would also be used to conduct noncommercial thinning treatments or other silvilcultural projects to create or accelerate development of old growth characteristics in trees elsewhere on federal land. Pacific

Connector also proposes to acquire easements or properties as conservation parcels within the range of the species that would preserve and protect potentially suitable and recruitment habitat as mitigation for Project impacts. These easements or parcels could be deeded to a federal agency or a conservation organization or trust.

The BLM and Forest Service have proposed a suite of off-site mitigation projects to address the effects of the PCGP Project on various resources within the project area and will ensure the Project can be consistent with the objectives of BLM Resource Management Plans and Forest Service Land and Resource Management Plans. The CMP provides the BLM and Forest Service mitigation summaries which describe the various offsite mitigation projects as a supplemental mitigation to address important issues or land management plan objectives that cannot be acceptably mitigated on-site (see Attachment 1 and Attachment 2 to the CMP, appendix O). A summary of BLM and Forest Service mitigation projects are provided in Table 1 of the CMP (see appendix O) Pacific Connector has assessed the BLM's mitigation projects in relation to the Project effects by watershed, along with the proposed mitigation projects proposed by the Forest Service, that have been approved in principle by Pacific Connector (see Attachment 4 to the CMP, appendix O). The BLM and Forest Service mitigation projects have also been reviewed with respect to the Project's responsibilities to mitigate for the potential effects to ESA listed species and their habitats. The BLM's and Forest Service's mitigation summaries list their proposed projects by watershed.

The following projects or actions, including those proposed by BLM and Forest Service, are also being considered as compensation in the CMP:

- decommissioning roads in LSRs that are identified by the BLM and Forest Service and are no longer required for management activities;
- acquiring title or easement to private lands in the range of the species that could be managed/preserved as late successional habitat;
- funding the conversion of matrix lands to LSR and enhancement of converted lands;
- funding non-commercial thinning treatments or other silvicultural projects to create or accelerate development of old growth characteristic elsewhere on federal land;
- funding to conduct silviculture (pre-commercial and commercial thinning) projects to reduce fuel load to minimize the risk of stand-replacing fires; and/or
- creating snags in adjacent habitat.

FWS has prepared Conservation Frameworks for the Pacific Connector Gas Pipeline Project that provides direction and methods to quantify and categorize the impact to marbled murrelets [and northern spotted owls] and their habitat (see appendix Z4) and means to offset the calculated impacts. In some instances, projects proposed by BLM and Forest Service would be considered applicable to offsetting the impact calculated and described, below.

The initial Framework (Trask & Associates, 2013) and subsequent revisions through personal communications provides guidance for categorizating effects to MAMU habitat into Severe Impact, High Impact, Moderate Impact, and Low Impact categories based on the amount and type of MAMU Habitat removed, as well as the area the habitat is removed within the MAMU SHU (see MAMU habitat impact categorization for each MAMU stand in appendix Z1). The Habitat Impact Category assigned to each MAMU SHU (appendix Z1) is then applied to acres of

MAMU habitat affected by the proposed Action (summarized in table 4.3.3-10 from table Q-3 in appendix Q). MAMU habitat affected outside of MAMU SHUs or within a MAMU SHU that were provided a "No Impact Category" in appendix Z1 are considered areas of "Low Impact", as well. Table 4.3.3-19, below provides a summary of MAMU habitat affected by Habitat Impact Category within and outside of interior forest. No MAMU stand was provided a "Severe Impact" category because Pacific Connector would remove suitable habitat outside of the breeding season, and it is also not expected that a MAMU nest tree would be removed. The FWS (Trask & Associates, 2013) recommends two primary actions to offset indirect impacts to MAMU habitats: land acquisition of like-to-like habitats affected by the Project (suitable, recruitment, and capable habitat) and/or silvicultural treatments for recruitment and capable habitat affected within MAMU SHUs. Following direction within the Habitat Conservation Framework (Trask & Associates, 2013), individual assessments included in appendix Z1 for each MAMU Stand (occupied, unoccupied, and presumed occupied) have been used to evaluate and determine the type and amount of mitigation recommended for impacts from the proposed action. The CMP identifies the amount of habitat acquisition proposed by Pacific Connector to offset effects of the proposed project on MAMU habitat (in consideration of NSO habitat overlap; see Section 1.6 in appendix O).

**Table 4.3.3-19**
**Summary of MAMU Habitat Removed from the Proposed Action by Habitat Impact Category**

| Habitat Impact Category[1] | Interior Forest[2] | Miles Crossed | MAMU Habitat Removed (acres) | | | |
|---|---|---|---|---|---|---|
| | | | Suitable[3] | Recruitment[4] | Capable[5] | Total Habitat Removed |
| High | Interior Forest | 3.3 | 30.91 | 3.82 | 8.51 | 43.24 |
| | Other | 7.2 | 26.18 | 30.87 | 55.07 | 112.12 |
| | High Impact Total | 10.5 | 57.09 | 34.69 | 63.58 | 155.36 |
| Moderate | Interior Forest | 0.2 | 0.00 | 1.36 | 0.37 | 1.73 |
| | Other | 1.5 | 0.59 | 3.94 | 21.21 | 25.74 |
| | Moderate Impact Total | 1.7 | 0.59 | 5.30 | 21.58 | 27.47 |
| Low | Interior Forest | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Other | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Low Impact Total | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Outside MAMU SHU / No Impact | Interior Forest | 4.6 | 0.00 | 35.02 | 32.54 | 67.56 |
| | Other | 38.5 | 0.00 | 194.11 | 481.15 | 675.26 |
| | Outside SHU / No Impact Total | 43.1 | 0.00 | 229.13 | 513.69 | 742.82 |
| Overall Total | Interior Forest | 8.1 | 30.91 | 40.20 | 41.42 | 112.53 |
| | Other | 47.3 | 26.77 | 228.92 | 557.43 | 813.12 |
| | Overall Total | 55.4 | 57.68 | 269.12 | 598.85 | 925.65 |

[1] see Trask & Associates (2013) for Impact Categorization factors and appendix Z1 for individual Habitat Impact Category assessments for each MAMU SHU.
[2] Interior Forest: not affected by existing disturbance (i.e., roads, existing corridors) or adjacent landuse/vegetation type (i.e., agriculture, non-forest, early regenerating forest); Other Forest Type includes forested habitat that is currently affected by existing disturbance or adjacent landuse/vegetation types within 100 meters of stand/MAMU habitat type
[3] Suitable Habitat: generally late-seral forested stands that provide or are presumed to provide nesting structures for marbled murrelet based on modeling and other available GIS data.
[4] Recruitment Habitat: forested land not currently suitable for marbled murrelet nesting that may be capable of becoming suitable marbled murrelet habitat within the next 25 years (FWS, 2006e; BLM, 1995a and b); generally forested stands 60 years or greater (PC Trask & Associates, 2013).
[5] Capable Habitat: forested land that has the capability of becoming suitable nesting marbled murrelet habitat, generally includes forest stand age 0 to 60 years (Trask & Associates, 2013).

FWS provided additional guidance to Pacific Connector on January 24, 2014 to assess and mitigate direct effects (disruption and disturbance) to MAMU by the Proposed Action (Trask & Associates, 2014). This new guidance essentially decoupled the direct effects from the previous guidance provided to Pacific Connector in June 2013 (see Trask & Associates, 2013) and outlined a new method to categorize direct effects to MAMU stands into the following Disruption-Disturbance (D/D) Impact Categories: High Impact, Moderate Impact, Low Impact, Low Impact – no mitigation, and No Impact. The assessment considers the timing, types, and location of Project-related activities in relation to MAMU stands that could result in disturbance or disruption of nesting MAMU to assist in determining a D/D Impact Category for each Project activity for each MAMU stand. In many instances a MAMU stand is provided more than one D/D Impact Category because of different project effects and different locations of effects on the MAMU stand (i.e., construction effects and proposed use of existing access roads; see D/D Impact Categorization in appendix Z1). The FWS provides a method to calculate the acres of MAMU stand by D/D Impact Category within a disruption and/or disturbance distance (0.25 mile) of project activities, including use of access roads. Calculated D/D Impact Category acres for each individual MAMU Stand within 0.25 mile of project activities is included in appendix Z1, with a list of factors considered when determining if an activity would be considered a disruption, a disturbance, or have no effect on each MAMU stand. The resulting D/D Impact Category(ies) is also included for each stand in table Q2 in appendix Q. Table 4.3.3-20 summarizes the acres of MAMU stands (occupied, presumed occupied, and unoccupied) within 0.25 mile of proposed activities that would be categorized as Moderate Impact, Low Impact, and No Impact. No MAMU stand was assigned a "High" category because Pacific Connector would adhere to DTRs during the critical breeding period for construction and timber removal activities that occur within 0.25 mile of MAMU stands. The FWS (Trask & Associates, 2014) recommends actions to offset direct impacts to nesting MAMU based on the acres of habitat within 0.25 mile of project activities and D/D Imapct Category and recommended acreage "multiplier". Following direction within the D/D Conservation Framework (Trask and Associates, 2014), individual assessments included in appendix Z1 for each MAMU Stand (occupied, unoccupied, and presumed occupied) have been used to determine the amount of acres by D/D Impact Type that should be mitigated to offset impacts (see appendix O).

This CMP has been developed in close consultation with the Forest Service and BLM. Pacific Connector has been and will continue to be in consultation with the FWS during development of the CMP.

**Table 4.3.3-20**
**Summary of Acres of MAMU Stand within 0.25 mile of Project Activities that Could Disturb or Disrupt MAMU Behavior by D/D Impact Category**

| Status of Marbled Murrelet Stand | General Landowner | Number of MAMU Stands within 0.25 mile of Project Activities | | | | Disturbance / Disruption Impact Category and acres affected | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Disruption | Disturbance | None4 | Total Number of Stands | Moderate Impact | Low Impact | No Impact / Low Impact (no mitigation) | Total Acres |
| Occupied Stand | Federal | 0 | 30 | 0 | 45 | 538.59 | 2,475.49 | 32.84 | 3,046.92 |
| | Non-Federal | 0 | 1 | 0 | 1 | 5.92 | 36.32 | 0.00 | 42.23 |
| | Total | 14 | 31 | 0 | 46 | 544.51 | 2,511.80 | 32.84 | 3,089.15 |
| Presumed Occupied | Federal | 0 | 61 | 0 | 69 | 10.67 | 2,654.12 | 6.78 | 2,671.57 |
| | Non-Federal | 0 | 40 | 0 | 55 | 77.67 | 572.13 | 16.43 | 666.24 |
| | Total | 14 | 105 | 0 | 124 | 88.35 | 3,226.25 | 23.21 | 3,337.81 |
| Unoccupied | Federal | 2 | 1 | 0 | 3 | 210.88 | 203.49 | 0.00 | 414.38 |
| | Non-Federal | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 2 | 1 | 0 | 3 | 210.89 | 203.49 | 0.00 | 414.38 |
| Total MAMU Range | Federal | 16 | 92 | 5 | 117 | 760.15 | 5,333.10 | 39.62 | 6,132.87 |
| | Non-Federal | 14 | 41 | 1 | 56 | 83.59 | 608.45 | 16.43 | 708.47 |
| | Total | 30 | 137 | 6 | 173 | 843.74 | 5,941.55 | 56.05 | 6,841.34 |

[1] Summarized from table Q-2 in appendix Q.
[2] Construction Activities include:
[3] Road use:
[4] None: 3 presumed occupied stands > 0.25 mile from project components, 1 occupied stand and 1 presumed occupied stand < 0.25 mile of roads but public road closer than other access road, and 1 presumed occupied stand just within 0.25 mile of project component but with existing ambient/background noise construction would not be detectible.

### 4.3.3.5 Determination of Effects

Listed Species

The Project **may affect** MAMUs because:

- Suitable habitat is available within the Terrestrial Nesting Analysis Area.
- Marbled Murrelets have been located within the Terrestrial Nesting Analysis Area during survey efforts for the proposed action.

The Project is **likely to adversely affect** MAMUs because:

- Disturbance associated with Project activities would occur within the critical breeding season and within 0.25 mile of known MAMU stands. Proposed actions which generate noise above local ambient levels might disturb MAMUs and interfere with essential nesting behaviors.
  - 79 MAMU stands (20 occupied, 56 presumed occupied, and 3 unoccupied) are within 0.25 mile of the proposed construction right-of-way that could be constructed during the breeding season.

- 161 MAMU stands (45 occupied, 113 presumed occupied, and 3 unoccupied) are within 0.25 mile of proposed access roads that could be used during the breeding season.

- Blasting activities may occur within 0.25 mile of MAMU stands between April 1 and September 30.
- Helicopter use within 0.25 mile of eleven MAMU Stands (7 occupied, 1 unoccupied, and 1 presumed occupied) during the breeding period (between April 1 and September 15) could occur and disturb MAMU adults and nestlings, as well as potentially blow nestlings out of the nest tree within seven MAMU Stands (5 occupied, 1 unoccupied, and 1 presumed occupied) from rotor wash.
- The proposed Project would remove and modify potential suitable nesting habitat and recruitment habitat within the range of the MAMU, which does not support the recovery of the species.

Critical Habitat

A **may affect** determination is warranted for MAMU critical habitat because:

- The Project occurs within designated MAMU critical habitat, and
- The Project would result in habitat impacts within designated critical habitat area.

A **likely to adversely affect** determination is warranted for MAMU critical habitat because:

- The proposed action could remove or degrade individual trees with potential nesting platforms or the nest platforms themselves, resulting in a significant decrease in the value of the trees for future nesting use (PCE1, or suitable or potentially suitable habitat).
- The proposed action could remove or degrade trees adjacent to trees with potential nesting platforms that provide habitat elements essential to the suitability of the potential nest tree or platform, such as providing cover from weather or predators (PCE 2, or recruitment/capable habitat).

### 4.3.4 Northern Spotted Owl

#### 4.3.4.1 Species Account and Critical Habitat

**Status**

The northern spotted owl (NSO) was listed by the FWS as threatened on June 26, 1990 (FWS, 1990), including populations in Oregon. The Final Rule cited declining populations due to loss and adverse modification of suitable habitat from timber harvest and natural catastrophes (wild fire, windthrow), as well as inadequate regulatory mechanisms to protect the owl or its habitat (FWS, 1990).

**Threats**

As of 1990, an estimated 60 percent of suitable NSO habitat present in the Pacific Northwest in 1800 had been eliminated with 90 percent of all remaining suitable habitat occurring on public lands (less than 5 percent of old growth habitats occurred on private, state or tribal lands in 1990). FWS (1990) indicated that given the current trends, remaining unprotected NSO habitat could be eliminated in 10 to 30 years. Since the inception of the NWFP in 1994 (1994 through 2007), NSO habitat on federal lands has decreased by 3.4 percent range wide (approximately

298,600 acres; most of the lost occurred within NWFP reserved allocations as a result of wildfires (approximately 203,900 acres) (Davis and Dugger, 2011). Further, the quality of 50 percent of total remaining NSO habitats was judged to be affected by reduction of individual stand size, fragmentation, and edge effects so that successful NSO reproduction was at risk (FWS, 1990). Continued logging practices were chiefly responsible for the loss and degradation of habitat, and public forest lands that are intensively managed for timber production generally are not able to achieve old-growth characteristics, which may require 200 years to develop (FWS, 1990). In the last two decades timber harvest on federal lands has been greatly reduced, but residual habitat loss and continued timber harvest on private lands across the range of the spotted owl continues to threaten this species (FWS, 2011c).

With decreased availability and scattered distribution of suitable habitats, NSO populations are becoming more isolated and at risk of ecological “bottlenecks” (FWS, 1990) that can lead to magnified deleterious effects from other, natural perturbations including fire (e.g., the 1933–1951 Tillamook burn), wind (e.g., the 1962 Columbus Day storm), and volcanic eruption (e.g., Mount St. Helens in 1980). Natural events and logging create a fragmented landscape that is utilized less by NSO than more intact landscapes (FWS, 1990). Further, fragmentation reduces potential metapopulation dynamic interactions between NSO-inhabited patches (extinction, colonization within patches), resulting in potential adverse genetic effects (FWS, 1990).

High levels of fragmentation, particularly fragmentation found on BLM lands interspersed with private lands forming a “checkerboard”, adversely affect adult survivorship and fecundity (FWS, 1990), which are the major drivers influencing population growth. Computed rates of annual population change from data available in 1990 indicated declining NSO populations, with a higher rate of decline in fragmented habitats (FWS, 1990).

In addition to the relationship of habitat quality and quantity to NSO population declines, predation by great horned owls was thought to adversely affect NSO, especially juveniles which would be more exposed and thus potentially more vulnerable in fragmented landscapes (FWS, 1990). In 1990, barred owls were recognized as a potential threat to NSO due to their aggressiveness and potential to displace NSO through competitive interactions (FWS, 1990).

Additional threats have emerged since the 1990 listing. By 2006, FWS (2007e) recognized that competition from barred owls was a significant “pressing” threat to NSO throughout its range. Threats from barred owls had developed within the context of habitat loss and diminished distribution of habitat by past logging activities and other catastrophic disturbances, as well as ongoing habitat losses from timber harvest, albeit reduced harvest levels since implementation of the NWFP (FWS, 2007e, FWS, 2008c). Hazards to NSO from barred owl include competition for resources and displacement from suitable habitat (Kelley et al., 2003; Kelley and Forsman, 2004) and to a lesser degree than thought in the 1990 listing, hybridization with NSOs (Courtney et al., 2004; Kelley and Forsman, 2004).

Since the Final Rule in 1990, demographic analyses (FWS, 2004) indicated that some NSO populations were declining at a higher rate than initially estimated (e.g., at Mount Rainier and the Olympic Peninsula in Washington), while analyses of other populations indicated they were stationary (including Tyee, Klamath, and South Cascades in Oregon).

Evidence also indicated that anticipated genetic consequences of small or isolated populations had not occurred. However, genetic evidence did reveal some hybridization with barred owls (FWS, 2004), which had not been discovered in 1990. Continued habitat loss from natural disturbances and timber management, particularly in southern Oregon, was also documented in the 5-year review (FWS, 2004). Conservation plans developed since 1990 and evolution of forest characteristics through natural succession and/or management actions were expected to provide some long-term benefits to NSO habitats, though habitat restoration takes decades to be effective (FWS, 2004).

Another threat to NSO populations is loss of habitat from wildfires, especially within forests that demonstrate succession toward climax communities in the absence of fires (FWS, 2011c; Courtney et al., 2004). In drier portions of NSO range, such as the Eastern Oregon Cascades and Klamath Mountains provinces, wildfire has become more of a threat (FWS, 2011c and 2004). New potential threats to the NSO and its habitat include West Nile virus and tree diseases (see Section 3.3.1.3), respectively (FWS, 2006f). A probable future threat to NSO is the West Nile Virus because it has the potential to reduce population numbers beyond what was anticipated from other causes. To date no mortality of NSO has been recorded, but the first cases of the virus in other avian species were recently recorded in the range of the NSO (Lint, 2005). At this time West Nile virus is not considered a significant effect to spotted owls (FWS, 2011c). Effects of climate change on vegetation and NSO habitats, in addition to expanding incidence of diseases such West Nile Virus (FWS, 2004), are potential though poorly defined future threats (FWS, 2007e).

**Species Recovery**

<u>1992 Draft Recovery Plan (FWS, 1992b)</u>

The 1992 Draft Recovery Plan for the Northern Spotted Owl considered threats to NSO populations within the proposed Project area to include: low and declining populations, loss and fragmentation of habitat, poor population connectivity within each province and with adjacent provinces, and high levels of predators. As a result of these threats, the 1992 Draft Recovery Plan established 196 designated conservation areas (DCAs), of which 56 were considered category 1 DCAs (having the potential to support at least 20 NSO pairs), and the other 140 were considered category 2 DCAs (potential to support 1 to 19 NSO pairs). DCAs were derived from concepts presented by Thomas et al. (1990) in "A Conservation Strategy for the Northern Spotted Owl" that focused on the establishment of large habitat blocks that could support self-sustaining populations of 15 to 20 pairs and protected lands for dispersal of juveniles. The Recovery Plan also provided guidelines for federal lands outside of designated DCAs to be managed for NSO breeding and dispersal habitat (since identified by the 1994 NWFP as LSRs), as well as encouraged contributions from non-federal lands within the vicinity of federal lands (i.e., conservation easements) contributing to the recovery of the NSO to increase habitat for pairs and/or provide dispersal between DCAs.

<u>2008 Final Recovery Plan (FWS, 2008e)</u>

In April 2007, the FWS released a NSO draft recovery plan for public review, identifying criteria and actions needed to stop NSO decline, reduce threats, and return the species to a stable, well-distributed population in Washington, Oregon, and California over the next 30 years (FWS, 2007e). In May 2008, FWS approved the Final Recovery Plan for the Northern Spotted Owl. The recovery plan recommended specific actions that address the threat of the barred owl, as well as actions to maintain habitat for the recovery and long-term survival of the NSO including dry-forest landscape management strategies. The recovery plan built off strategies set forth in the 1992 Draft Recovery Plan for NSO (FWS, 1992b) and the NWFP (BLM and USFS, 1994), using a network of Managed Owl Conservation Areas (MOCAs) on federal lands and Conservation Support Areas (CSAs) on federal and non-federal lands where recovery actions and criteria would be targeted. MOCAs are larger tracts of lands within non-fire-dominated provinces that are expected to support a stable number of breeding pairs of NSOs over time and allow for movement of NSOs across the network. Within the drier forests of the Eastern Cascades Province, the recovery plan did not identify MOCAs or CSAs since it is expected that the rate of loss of older forests to stand-replacing wildfires would continue or increase in the coming years as the climate changes (Westerling et al., 2006 in FWS, 2008c). Rather, the recovery plan recommended treatments to older forests to reduce risks of fires and insect outbreaks even though the strategy could have short-term impacts on NSO habitat, but would achieve the long-term goal of creating more sustainable NSO habitat.

<u>2011 Revised Final Recovery Plan (FWS, 2011c)</u>

The Northern Spotted Owl Recovery Plan was revised in 2011 after the Court remanded the 2008 Recovery Plan; it builds extensively on the 1992 Draft Recovery Plan, the 1994 NWFP, and the 2008 Recovery Plan. The revised recovery plan recognizes the importance of addressing the barred owl threat, as well as the importance of maintaining and restoring high value habitat for the recovery and long-term survival of the spotted owl. It integrates an adaptive management approach to achieve results and focus on the most important actions for recovery. Four recovery criteria have been identified to serve as objective, measureable guidelines to assist in determining if the spotted owl has recovered and may be delisted: 1) stable population trend, 2) adequate population distribution, 3) continued maintenance and recruitment of spotted owl habitat, and 4) post-delisting monitoring. Thirty-three recovery actions have been included to guide activities needed to accomplish the four recovery criteria. In some instances, recovery actions are specific to physiographic provinces, which have been identified as recovery units within the 2011 Revised Recovery Plan to assist managers in measuring the objectives of the recovery criteria.

**Life History, Habitat Requirements, and Distribution**

The NSO is a medium-sized owl that occurs in coniferous or mixed coniferous-hardwood forests from southwestern British Columbia through western Washington, Oregon, and northern California south to San Francisco Bay (FWS, 1990). Although NSO habitat is variable over its range, to support NSO reproduction, a home range requires appropriate amounts of nesting, roosting, and foraging (NRF) habitat arrayed so that nesting pairs can survive, obtain resources, and breed successfully. NSOs primarily occur in old-growth and mature forests because these habitat types provide the structure and characteristics required for NRF, but they may also inhabit younger forests with the appropriate structural, vegetation, and prey characteristics, including:

- moderate to high canopy cover (60 to 80 percent);
- multi-layered, multi-species canopy dominated by large overstory trees (greater than 30 inches diameter at breast height (dbh);
- a high incidence of large trees with various deformities,
- numerous large snags;
- large accumulations of fallen trees and other woody debris on the ground; and
- sufficient open space below the canopy to fly (FWS, 1990).

High canopy closure is important to help NSOs thermoregulate and reduce potential predation (FWS, 1990 and 2007e). Dispersing NSOs, whether adults moving between blocks of suitable

NRF habitat (generally 15 miles for females and 9 miles for males; Forsman et al., 2002), or juveniles dispersing from natal areas (a range of 0.3 to 69 miles; Forsman et al., 2002), utilize a wider array of forest types and structure including more open and fragmented habitat. Although forest attributes needed for successful dispersal have not been thoroughly evaluated, they generally consist of conifer and mixed mature conifer-hardwood habitats with canopy cover greater than or equal to 40 percent and conifer trees averaging at least 11 inches dbh (FWS, 1992b). Dispersal habitat may occur in nesting, roosting, or foraging habitat, but it lacks the optimal structural characteristics needed for nesting. Northern spotted owls have been reported to occur in the following forest types: Douglas-fir and western hemlock in the coastal forests of Washington and Oregon, Pacific silver fir on the west slope of the Cascades in Washington and Oregon, mixed conifer stands including Douglas-fir, grand fir, and ponderosa pine on the east slope of the Cascades, dry Douglas-fir and mixed conifer in southern interior Oregon, and Douglas-fir, mixed-conifer, and coastal redwood or mixed conifer-hardwood habitat types in California (FWS, 1992b; Forsman et al., 1984). The NSO has been reported from a variety of elevations, from 70 feet on the Olympic Peninsula in Washington to more than 6,000 feet in California (FWS, 1990).

NSOs remain on their home range throughout the year. As a result, NSO have large home ranges that provide all the habitat components and prey necessary for the survival and successful reproduction of a territorial pair. Home ranges vary in size by physiographic province, forest type, and heterogeneity but generally increase in size from south to north where habitat quality decreases and/or becomes more fragmented (Courtney et al., 2004; FWS, 1992b; Forsman et al., 1984). Courtney et al. (2004) determined that the home range size of NSOs appeared to be influenced by a variety of factors including proportion of mature and old-growth forest within the home range, forest fragmentation, and the availability of dominant prey species (larger home ranges where flying squirrels dominated the diet compared to home ranges where wood rats dominated the diet). Within the range of the NSO, home ranges typically encompass an area within a radius around the nest site as follows: 1.8 miles within the Washington Cascades, 2.2 miles within the Olympic Peninsula, 1.2 miles within the Oregon Cascades, 1.5 miles along the Oregon Coast Range, and 1.3 miles within the Klamath Province (FWS, 1992b).

Home ranges contain three distinct use areas: 1) the nest patch, which research has shown to be an important attribute for site selection by NSOs and includes approximately 70 acres of usually contiguous forest (300 meter radius around an activity center; FWS et al., 2008), 2) the core area, which is used most intensively by a nesting pair and varies considerably in size across the geographic range, but on average encompasses approximately 500 acres around the nest site (1/2 mile radius around the activity center), and is generally made up of mostly mature/old-growth forest (FWS, 2007e; Courtney et al., 2004), and 3) the remainder of the home range which is used for foraging and roosting and is essential to the year-round survival of the resident pair (FWS, 2007e).

Spotted owls are primarily nocturnal, foraging between dusk and dawn, with peak activity occurring two hours after sunset and two hours prior to sunrise (Delaney et al., 1999; Forsman et al., 1984). However, if prey is easily available near their day roosts, NSOs would take advantage of the opportunity, a behavior that is used to determine reproductive status in NSO survey protocol.

**Population Status**

Demographic data collected from nine study areas throughout the NWFP area in Washington, California, and Oregon have been used to monitor NSO populations in their geographical range from 1985 through 2008, of which five sites occur in Oregon (Anthony et al., 2006; Davis et al., 2011). The primary objectives of these studies were to estimate fecundity, apparent survival, and annual rate of change, and to determine if there were any temporal trends in these population parameters. Three of the study sites in Oregon, Tyee, Klamath, and southern Oregon Cascades, are located within and/or adjacent to the Project area. The proposed action is located within the Klamath and South Cascades study areas in Douglas County (approximately Pacific Connector MP 94.13 to MP 98.9) and in Jackson and Klamath counties (approximately Pacific Connector MP 153.87 to MP 172.25). Forests on these study sites were mostly characterized by mixtures of Douglas-fir and western hemlock or by mixed-conifer associations of Douglas-fir, grand fir, western white pine, and ponderosa pine (Anthony et al., 2006). Estimates of fecundity, apparent survival rates, and population change for five study sites within Oregon are included in table 4.3.4-1 (Forsman et al., 2011; Davis et al., 2011).

**Table 4.3.4-1**
**Estimates of Fecundity, Apparent Survival Rates and Population Change for the Five Northern Spotted Owl Demographic Study Sites on Federally-Managed Lands in Oregon [1]**

| | | Fecundity [2] | | Apparent Survival [2] | | Population Change | | |
|---|---|---|---|---|---|---|---|---|
| **Study Area** | **Land-ownership** | **%** | **Trend** | **%** | **Trend** | **Rate of Change (λ)** | **Trend** | **Overall Trend** |
| **Coast Range Physiographic Province** | | | | | | | | |
| Oregon Coast Range [3] | Mixed | 26.3 | Increasing | 85.9 | Declining since 1998 | 0.966 | Decrease | Declining |
| Tyee [3] | Mixed | 30.5 | Stable | 85.6 | Declining since 2000 | 0.996 | Stable [6] | Stable |
| **Klamath Mountains Physiographic Province** | | | | | | | | |
| Klamath [3] | Mixed | 37.7 | Declining | 84.8 | Stable | 0.990 | Stable [6] | Stable |
| **West and East Cascades Physiographic Provinces** | | | | | | | | |
| H.J. Andrews [4] | Federal | 32.3 | Increasing | 86.5 | Declining since 1997 | 0.977 | Decrease | Declining |
| South Cascades [5] | Federal | 34.7 | Declining | 85.1 | Declining since 2000 | 0.982 | Stable [6] | Stable |

1 Source: adapted from Davis et al., 2011.
2 Provides rates for adults greater than 3 years.
3 Trends based on data collected between 1990 – 2008
4 Trends based on data collected between 1988 – 2008
5 Trends based on data collected between 1991 – 2008
6 Although study sites appeared stationary throughout the study period, there was some suggestion that populations were declining in the last three years of the study.

Within Oregon, apparent adult survival rates are declining on all but the Klamath study area; most declines have occurred primarily in the last 10 years on the other four study sites. Effects of barred owls have been attributed to the spotted owl survival rate, but varied by study site: decreased survival was associated with barred owls in the Coast Ranges and H.J. Andrews study sites, whereas, in the Klamath study area, evidence was negligible. In Oregon, increased fecundity was associated with higher annual estimates of the amount of suitable habitat. Overall, demographic declines in some study sites were attributed to the increased numbers of barred owls and loss of habitat (Forsman et al., 2011; Davis et al., 2011).

A general discussion of NSO population trends was included in a biological assessment for the Roseburg BLM District (BLM, 2008b), which revealed a consistent declining trend among NSO pairs throughout Oregon. In the Tyee Density Study Area, the number of non-juvenile NSOs detected dropped from 146 in 2005 to 129 in 2006. By 2007, the number of non-juveniles in this study area had dropped to 119, the lowest since the population had been studied. The proportion of sites occupied by a pair of NSOs in the Klamath demography study area also declined, from 64 percent in 2002 to 52 percent in 2007.

BLM (2008b) hypothesized that potential NSO inbreeding and other genetic problems due to small population sizes could occur. However, BLM (2008b) cited studies that concluded there was no indication of reduced genetic variation or past bottlenecks in Washington, Oregon, or California.

**Critical Habitat**

Critical habitat for the NSO was originally designated on January 15, 1992 and included approximately 6.9 million acres in California, Oregon, and Washington, of which 3.3 million acres occurred in Oregon (FWS, 1992b). The 1992 designation was revised in 2008 (FWS, 2008d), and more recently in 2012 (FWS, 2012a). The 2012 final rule (FWS, 2012a) designates approximately 9.6 million acres within 11 critical habitat units (CHU) and 60 critical habitat subunits in California, Oregon, and Washington. Eight CHU and 58 subunits are identified in Oregon on a little more than 4.5 million acres. The FWS (2012a) relied on recovery criteria set forth in the Revised Recovery Plan for the NSO (FWS, 2011c) to ensure that designated CHUs met the following criteria: 1) ensures sufficient habitat to support stable, healthy populations across the range and within each critical habitat unit, 2) ensures distribution of northern spotted owl populations across the range of habitat conditions used by the species, and 3) incorporates uncertainty, including potential effects of barred owls, climate change, and wildfire disturbance risk.

The FWS (1992b) determined that the physical and biological habitat features (primary constituent elements – PCEs) that are essential for the recovery of the spotted owl are forested lands used or potentially used for nesting, roosting, foraging, and dispersal. Recently, FWS (2012a) revised its 1992 designation of critical habitat that provided more specificity to PCEs for the owl. Based on more current information on the life history, biology, and ecology of the species, the revised PCEs are (FWS, 2012a):

1. Forest types that may be in early-, mid-, or late-seral stages and that support northern spotted owls across its geographical range, primarily: sitka spruce, western hemlock, grand fir, Pacific silver fir, Douglas-fir, white fir, Shasta red fir, redwood/Douglas-fir (in coastal California and southwestern Oregon), and the moist end of the ponderosa pine coniferous forest zones. This PCE must occur in concert with at least one of the following PCEs.
2. Forested habitat (see PCE1) that provides for nesting and roosting, and could provide for foraging. Nesting and roosting habitat provides structural features for nesting, protection from adverse weather conditions, and cover to reduce predation risks for adults and young. Across the owl's range, habitat requirements are nearly identical and are associated with a high incidence of large trees with various deformities (large cavities, broken tops, mistletoe infections) or large snags suitable for nest placement. Patches of nesting habitat, in combination with roosting habitat, must be sufficiently large and

contiguous to maintain NSO core areas and home ranges, and must be proximate to foraging habitat.

3. Habitat that provides for foraging, which varies widely across the NSO range. It can consist of nesting and roosting habitat, and provide for dispersal, but its primary function is to provide a food supply for survival and reproduction. Foraging habitat is closely tied to the prey base and in some cases can include more open and fragmented forests, especially in the southern portion of the owl's range. NSO feed primarily on small mammals, especially northern flying squirrels and wood rats in southwestern Oregon (citations in Anthony et al., 2006).
4. Habitat that supports dispersal of spotted owls, which could provide nesting, roosting, and foraging habitat, but could also be composed of other forest types between larger blocks of nesting, roosting, and foraging habitat. Dispersal habitat must, at a minimum, provide stands with adequate tree size and canopy cover to provide protection from avian predators and at least minimal foraging opportunities. It is essential to maintaining genetic and demographic connections among populations across the range of the species.

Because not all life history functions require all the PCEs, not all proposed revised critical habitat would contain all four PCEs described above. Some CHUs contain all PCEs and support multiple life processes, while other units contain only one or two (FWS, 2012a). All CHUs have had or have presence of NSO.

Activities that disturb or remove the primary constituent elements within designated CHUs might adversely modify the owls' critical habitat. These activities could include actions that would reduce the canopy closure of a timber stand, reduce the average dbh of trees in the stand, appreciably modify the multi-layered stand structure, reduce the availability of nesting structures and sites, reduce the suitability of the landscape to provide for safe movement, or reduce the abundance or availability of prey species (FWS, 1992b).

<u>NWFP Late Successional Reserves</u>

Additional habitat protection for the NSO was established when the Forest Service and BLM adopted the Northwest Forest Plan (NWFP) in 1994. The NWFP (Forest Service and BLM 1994) was designed to protect habitat for NSO and other species associated with late-successional forests while allowing a reduced amount of commercial logging on federal lands. Large amounts of federal land within the range of NSO were allocated for riparian and late successional reserves; the primary objective for these lands was to maintain or restore habitat for NSO and other fish and wildlife species. Riparian Reserves and other NWFP land use allocations provide connectivity between LSRs and federally designated critical habitat. Additionally the NWFP states that sites occupied by marbled murrelets and known owl activity centers (100-acre areas identified by BLM and Forest Service) that are within Matrix lands are considered "unmapped LSRs" and managed as lands allocated as LSRs by the NWFP. A good portion of the federally designated critical habitat overlaps with LSR land allocations; however, some lands do not and therefore afford additional habitat protection for listed species.

#### 4.3.4.2 Environmental Baseline

<u>Provincial Analysis Area</u>

The proposed action is located within four Physiographic Provinces: Oregon Coast Range, Oregon Klamath Mountains, West Oregon Cascades, and East Oregon Cascades. NSO home ranges vary across provinces as a result of habitat heterogeneity and type, and prey availability (Courtney et al., 2004). NSO home ranges vary by province, using the following NSO home range radii: 1.5 miles within the Coast Range Physiographic Province, 1.3 miles within the Klamath Mountains Physiographic Province, and 1.2 miles within the West and East Cascades Physiographic Provinces. Described below are two components to the action area within which Project-related activities can affect NSOs; one for habitat removal or modification and a second for disturbance/disruption of NSO during the breeding season. The two components have been combined together to consider all components of the Provincial Analysis Area (see figure 4.3-13).

Habitat Removal or Modification

The Habitat Removal or Modification Analysis Area applies to all proposed action components that have the potential to remove or modify habitat, including construction of the Port's Multi-slip Terminal, LNG facilities, and Pacific Connector pipeline and aboveground facilities. Also, the Provincial Analysis Area includes a 100-meter (328 feet) wide buffer along the edge of the area of habitat impact (e.g., edge of right-of-way or edge of new roadway corridor). In addition to the 100-meter buffer, the Provincial Analysis Area includes any NSO Home Range with an activity center located between the outer edge of the 100-meter wide buffer of the proposed action components out to the distance equal to the applicable NSO physiographic home range radius: 1.5 miles, 1.3 miles, or 1.2 miles of the proposed Project.

Disturbance/Disruption

Harassment that could occur from proposed construction, including blasting (greater than 2 pounds) and/or large transport helicopter use by the proposed action is expected within 0.25-mile. A 0.25-mile analysis area would be considered for construction and timber removal activities, as well as existing roads that have been identified for access to the proposed action to account for disturbance from noise generated from traffic or road improvements.

**Species Presence**

NSO populations consist of resident owls (adult and subadult) that defend a territory vocally, and non-territorial owls (adult, subadult, and juvenile owls) that generally move through habitats in search of vacant territories or available mates and rarely vocalize. Surveys to determine if potential suitable NSO habitat is occupied are accomplished by imitating NSO calls to elicit a response, generally from the territorial owls. This is usually more effective at night, as NSOs will defend their territory more readily at night (Hobbs et al., 2004; Courtney et al., 2004; Forsman, 1983). Generally sites identified at night would be visited the following day to determine status (i.e., pair, nesting, resident single). Reproduction information for territorial owls is obtained by feeding an individual adult owl live mice to determine if it is a member of a nesting pair or not, based on the owl's behavior (Lint, 2001; FWS, 1992b). FWS (2012e) recommends conducting at least six visits a year for two years to determine site occupancy and potential reproductive success, although protocol suggests that this information can be gathered during 6 visits to a site in one year if noise disturbance is only expected from a project. Previous northern spotted owl survey protocol (FWS, 1992c) recommended 3 visits per year over a two year period.

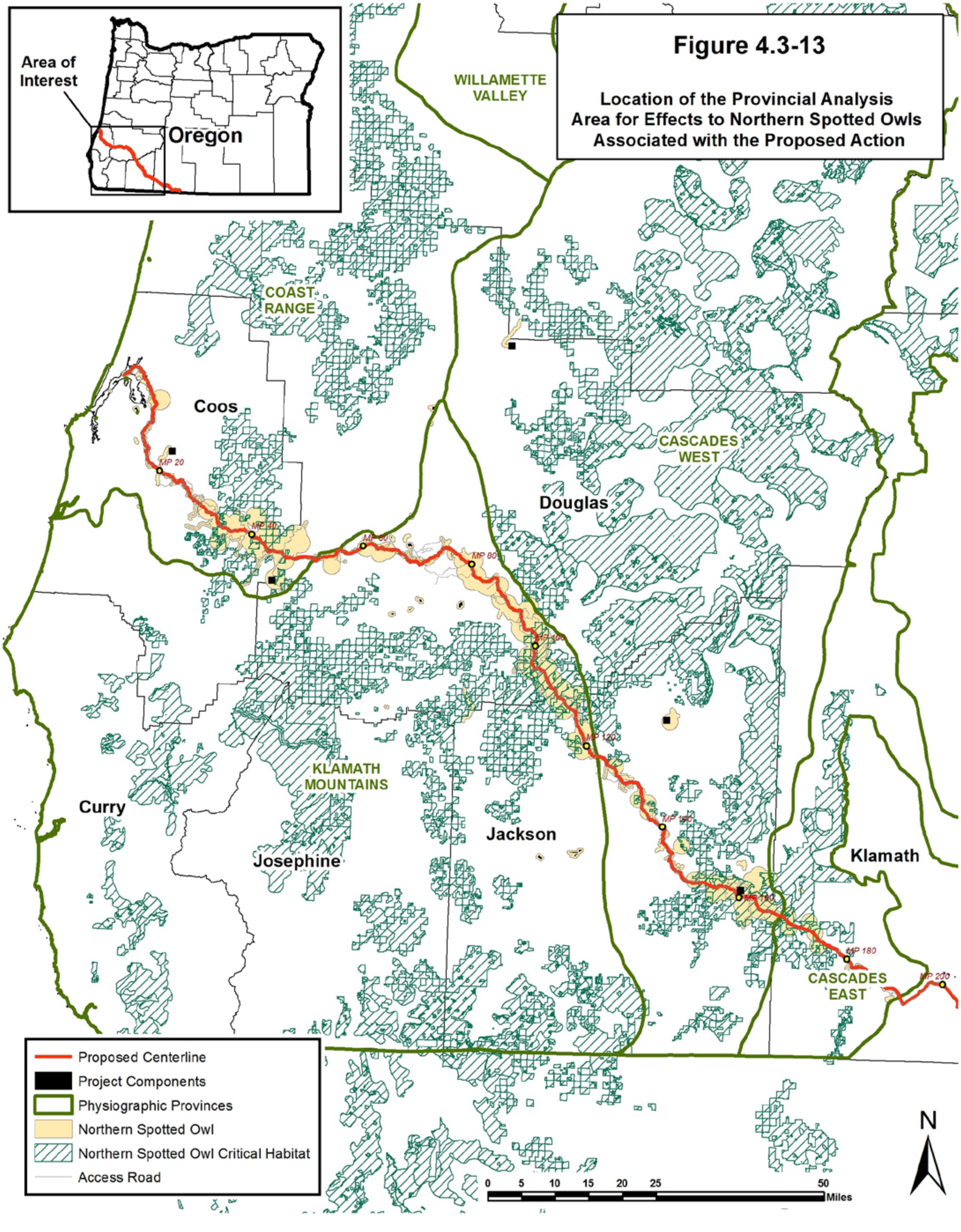


Figure 4.3-13
Location of the Provincial Analysis Area for Effects to Northern Spotted Owls Associated with the Proposed Action
Area of Interest
Oregon
WILLAMETTE VALLEY
COAST RANGE
CASCADES WEST
KLAMATH MOUNTAINS
CASCADES EAST
Coos
Douglas
Curry
Josephine
Jackson
Klamath
MP 20
MP 40
MP 60
MP 80
MP 100
MP 120
MP 140
MP 160
MP 180
MP 200
Proposed Centerline
Project Components
Physiographic Provinces
Northern Spotted Owl
Northern Spotted Owl Critical Habitat
Access Road
0 5 10 15 20 25 50 Miles
N

To determine species presence and/or absence within the Provincial Analysis Area, Pacific Connector obtained historical and current northern spotted owl locations from BLM Districts and National Forests crossed by the PCGP Project, as well as information collected from the demographic studies occurring within the PCGP Project area (various GIS data provided to Pacific Connector – BLM, 2006 and 2012; Forest Service, 2006 and 2012; FWS, 2008d). Additionally, Pacific Connector contracted Siskiyou BioSurvey, Inc (SBS – Eagle Point, Oregon) to conduct two years of surveys in 2007 and 2008 to determine species presence within 2009 FERC FEIS construction right-of-way. For analyses within the BA, Pacific Connector will assume all owl sites (known, best location, and PCGP assumed) are occupied.

Pacific Connector Spotted Owl Surveys (2007 and 2008)

To determine nesting NSO presence and/or absence, as well as nesting status (if possible) within the analysis area, NSO surveys were conducted by Pacific Connector between March 15 and August 31 in 2007 and 2008 as defined by the *Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls* (FWS, 1992c). Surveys were conducted by SBS and were carried out within suitable NSO habitat and outside of ongoing NSO demographic and monitoring survey efforts. In general, surveys were conducted within 0.5 mile of the proposed construction right-of-way where suitable NSO habitat would be removed by the Project. Otherwise, surveys were conducted within 0.25 mile of the proposed construction right-of-way if suitable habitat is present, but would not be removed (as advised by Smith et al., 2007). In areas that were identified as requiring blasting and/or timber removal and pipeline construction by helicopter, surveys within suitable NSO habitat were conducted 1 mile from the proposed pipeline alignment in 2008 (Smith et al. 2007; Wille et al., 2006).

The 0.25-mile disturbance and the 0.5-mile habitat alteration survey areas followed the 1992 FWS 2-year survey protocol (3 visits per year) in 2007 and 2008. Surveys conducted out to 1 mile from blasting (greater than 2 pounds) and/or large transport helicopter disturbance areas in 2008 followed the 1-year survey protocol (6 visits per year). Surveys conducted within the Project area took extra precautions to reduce negative effects of barred owls on NSO, following guidance provided by the FWS in March 2007, which dictate that if a barred owl responds to a NSO call, stop calling for the NSO. This guidance is similar to the direction provided in the 2012 revised and updated survey protocol (FWS, 2012e). To further reduce NSO harassment from multiple survey efforts, Pacific Connector did not conduct surveys where other survey efforts by agency biologists were ongoing, including demographic and monitoring studies in the Roseburg BLM District (approximately MP 46.8 through MP 100.7), South Cascades demographic study conducted in Jackson and Klamath counties (MP 155.2 through MP 170.7), and a NSO monitoring study area in Lakeview BLM District.

Within the defined survey area for 2007, approximately 28,774 acres were identified as suitable NSO habitat and were organized into 61 separate survey areas. Of that acreage, 8,562 acres identified were located on private lands but permission to survey was granted on only 3,713 acres was granted (access was denied for 4,849 acres). Overall, 83 percent or approximately 23,925 acres were surveyed in 2007 following the 2-year survey protocol. In 2008, an additional 32,221 acres were identified as potential suitable NSO habitat within 1 mile of areas that may require blasting (greater than 2 pounds) and large transport helicopter use. Of the 58,652 acres identified as suitable NSO habitat, permission to survey was granted for 47,679 acres (81 percent), and these were surveyed in 2008. New habitat identified followed the 1-year survey protocol whereas habitat surveyed in 2007 followed the 2-year protocol. Some areas where survey permission had been denied are covered in the call effective zone, but it cannot be assumed that these properties were surveyed since follow-up surveys could not be conducted. The call effective zone was created by SBS by initially applying a buffer of 1,980 feet to all calling station points to represent the effective auditory distance. Buffers were then assessed to determine variations from this distance based on topography. Where ridgelines appear significant enough to impede sound, the buffers were reduced accordingly. In four instances, the buffer was increased to one-half mile because the calling stations were located along major ridgelines with calling projected into smoothly dropping terrain. A 1,000-foot buffer was also applied to transects to represent the effective daytime continuous calling distance for daytime follow-up surveys.

NSO surveys conducted in 2007 detected NSO 115 times in 29 of the 61 survey areas established in the 2009 FERC FEIS project area. Twelve NSO pairs and one resident single (located at least three times on separate survey visits) were detected. No nest sites were located in 2007; however, at one site fledglings were observed with their parents, suggesting a nest location in the vicinity. During 2008 surveys, NSO were detected 190 times and were found in 26 of the 54 survey areas established, including survey areas established within 1-mile of proposed blasting (greater than 2 pounds) and large transport helicopter activities. NSO pairs were detected at 20 locations and two nests were located. Resident singles were identified at six sites. Approximate activity centers were drawn around the pairs and resident singles documented in 2007 and/or 2008 based on detection date and time, the age and sex of owls observed, the owls' behavior, and occasionally the habitat of a detection location. Seven NSO pairs documented within the 2009 FERC FEIS project area were assumed to be NSO activity sites previously documented and/or monitored by other agencies, and seven pairs were adopted as new activity sites within agency management areas considering activity documented during 2007 and/or 2008 survey results, including two areas that were previously identified as "predicted" owl sites by FWS (Thrailkill, 2008). NSO pairs or resident singles that were not associated with previous known NSO activity centers or were not adopted by agencies as new activity sites are considered PCGP "best location" activity centers for analysis within this BA.

Although survey design was not intended to locate or census barred owls, this species was documented 36 times in 14 survey areas in 2007, and 115 times in 14 survey areas in 2008, including 8 pairs.

For full description and information on NSO surveys and detections, see the 2007–2008 Northern Spotted Owl Survey Report included under separate cover with the June 2013 FERC Certificate application for the Pacific Connector.

Northern Spotted Owl Activity Sites Considered for Analysis

In 2008, Pacific Connector received a Northern Spotted Owl Occupancy Map (NSOOM) from FWS that included both historical and recent NSO sites provided by BLM Districts and National Forests within the proposed Project area that were combined with survey data collected for the PCGP Project by SBS in 2007/2008. Additionally, the NSOOM provided areas of potential northern spotted owl nests sites modeled or "predicted" to occur on the landscape based on current NSO occupancy and available NSO habitat (see Appendix 1 in Appendix A of Trapper Timber Sale Biological Opinion). Agency biologists reviewed the data and revised NSO activity centers considered for the PCGP Project based on local knowledge prior to providing the final data to Pacific Connector. The objective of the collaborative process was to generate a clean but complete NSO map that could be used for analyses purposes for the proposed Pacific Connector pipeline. Also, the objective was to take a conservative approach so that analysis considered the "worst case scenario." Therefore, recent survey efforts by Pacific Connector, local habitat knowledge, alternate nest sites, and barred owl activity were taken into consideration when finalizing the best location of owl activity to analyze. Some areas where owl activity was less certain, such as where resident single or pair activity was identified by SBS that may be associated with other known activity sites but not enough information was available (i.e., no band color collected), were included for analysis (i.e., PCGP best location sites). If an alternate nest site was closer to the PCGP Project, the alternate site was considered rather than the site with the most recent activity for a more conservative analysis. Consultations, discussions, and resolutions of specific sites within the proposed Project area provided for 2008 are included in table S-1 in appendix S.

To revise the 2008 NSOOM and account for new data and new survey efforts since 2008, Pacific Connector requested and obtained new NSO data from each of the BLM Districts and National Forests crossed, including demographic study data in March 2013. Using the same methodology that was applied to the 2008 NSOOM, a revised NSOOM was created for this current BA. The NSOOM methodology is intended to facilitate a reasonable basis for estimating potentially occupied NSO habitat within the proposed analysis area, especially where surveys have not been conducted or are incomplete as per FWS survey protocol, or barred owl presence may have negatively affected the response of NSOs during calling surveys. Table S-2 in appendix S provides summary of additional discussions and resolutions specific to the 2013 NSOOM use for analyses in this BA. This revised NSOOM was used in the September 2013 APDBA.

In June 2013, the use of the Owl Estimation Model (OEM) that produced "predicted" owls was challenged in federal district court. As a result of this challenge and other complaints, FWS, BLM, and Forest Service have requested that the use of "predicted owls" utilizing the OEM no longer be included in this BA analysis. The 2010 BA and the APDBA submitted in September 2013 included predicted owls utlilizing the OEM. Pacific Connector used the predicted owl sites to produce a more conservative analysis for habitat effects and disturbance disruption effects by the Project, as described above. As a result of the recent court activity and agency requests, Pacific Connector has removed 17 predicted owls created using the OEM from the analysis in this BA that were considered in the September 2013 APDBA. However, in order for Pacific Connector to continue with a conservative analysis approach for spotted owls (similar to Pacific Connector's approach for marbled murrelets – presumed occupied stands), Pacific Connector identified nine areas (PCGP assumed sites) within 1.2 to 1.5 miles of proposed Project disturbance (Cascades to Coast Range physiographic province home range radii distances) that could potentially support NSO pairs. PCGP assumed sites were established in areas that were either surveyed in 2007/2008 with NSO presence but no pair or resident single determined, or an area that could support a NSO pair based on suitable habitat available in an assumed nest patch/core area that is located farther than the average physiographic distance from a known or best location NSO site (> 2,084 meters in Coast Range, > 2,078 meters or 2,596 acres in Klamath Mountains, > 2,333 meters in West Cascades, and > 2,446 meters in East Cascades); see FWS et al, 2008. Pacific Connector took into consideration the general habitat characteristics of known NSO sites in the vicinity of potential "assumed" locations, since available NRF habitat within a PCGP assumed site often did not meet the FWS-recommended NRF threshold of more than 40 percent and more than 50 percent NRF in the home range and core area, respectively. Past predicted owl sites were also reviewed for consideration because PCGP survey efforts had targeted those areas; in five instances, PCGP assumed sites were established in the vicinity of previously "mapped" / "predicted" owl sites based on survey efforts or the amount of available high NRF/NRF that was also contiguous, interior forest. PCGP assumed sites have been placed in contiguous high NRF/NRF habitat at least 100 meters from the edge of the stand resulting in the site being placed in interior forest. These areas are PCGP assumed NSO sites and have been provided a site ID PCGP A-1 through PCGP A-9. No PCGP assumed sites were established between MPs 1.47R and 32.47 because this area consists of checkerboard BLM/private landownership where commercial timber harvest is prevalent and surveys conducted for the PCGP Project in areas of higher suitable habitat did not document NSO. Thus, PCGP eliminated OEM predicited owls from this BA but includes PCGP assumed sites based on best professional judgement of potentially available habitat.

Approximately 98 northern spotted owl home ranges – known current/historic (72), best location (17), and PCGP-assumed (9) occur within the vicinity of the proposed action, including existing access roads identified for use for construction and operation of the project, pipe yards, and rock storage areas. Ninety (90) home ranges are crossed by the proposed action and one (1) home range is within 100 meters of the proposed action, and an additional seven home ranges occur within 0.25 mile of existing access roads only and could be affected by use of roads (see table 4.3.4-2). Table 4.3.4-2 provides a summary of northern spotted owl home ranges, core areas, and nest patches (known, best location, or PCGP assumed) that intersect the proposed PCGP Project and/or proposed access roads within each physiographic province. Table Q-7 in appendix Q provides additional details for each NSO Home Range included in the Provincial Analysis Area, including available NSO habitat (high NRF, NRF, dispersal only, and capable) within each Home Range pre-action.

FWS et al. (2008) consider core areas with 50 percent or greater NRF habitat and home ranges with at least 40 percent NRF habitat to be necessary to maintain NSO life history function. Based on FWS et al. (2008) guidelines 35 spotted owl sites identified within the analysis area are above the threshold of available NRF habitat within both their core area (greater than 50 percent) and home range (greater than 40 percent): 29 of 72 (40 percent) known NSO sites and 6 of 17 (35 percent) best location sites. The remaining 63 spotted owl activity centers (43 known 11 best location, and nine PCGP assumed) are below NRF thresholds for the core area and/or home range. Table 4.3.4-3 provides a summary of the current habitat condition by Physiographic Province and owl status (known, best location, or PCGP assumed) of the 98 NSO sites within the provincial analysis area. Note that calculations of habitat conditions for each owl site in table 4.3.4-3 considered suitable habitat located on both federal and non-federal lands. The amount of NRF habitat currently available for each NSO within each habitat type (nest patch, core area, and home range) can be reviewed in table Q-7 in appendix Q. Amount of NRF habitat in table Q-7 in appendix Q is specific to each habitat type in its entirety; acres provided for the home range include acres that also occur within the core area and nest patch, and acres included in the core area also include acres within the nest patch. Table Q-7 in appendix Q provides the amount of suitable habitat for each individual owl in federal and non-federal lands and the habitat condition determined pre-action for each NSO home range. For a description of how NSO habitat was determined, see habitat section below.

## Table 4.3.4-2
## Summary of Known, Best Location, and PCGP Assumed Northern Spotted Owl Home Ranges, Core Areas, and Nest Patches Crossed by the PCGP Project, including Access Roads

| NSO Status | Number of NSO Activity Centers | Number of Home Ranges Crossed | | Number of Core Areas Crossed | | Number of Nest Patches Crossed | |
|---|---|---|---|---|---|---|---|
| | | Habitat Affected [1] | Access Roads [2] | Habitat Affected [1] | Access Roads [2] | Habitat Affected [1] | Access Roads [2] |
| **Coast Range Physiographic Province – 1.5 mile home range radius** | | | | | | | |
| Known Sites | 13 | 9 | 13 | 3 | 11 | 1 | 5 |
| Best Location Sites [3] | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| PCGP Assumed Sites | 4 | 4 | 4 | 2 | 3 | 0 | 1 |
| *Total* | *18* | *14* | *18* | *5* | *15* | *1* | *6* |
| **Klamath Mountains Physiographic Province – 1.3 mile home range radius** | | | | | | | |
| Known Sites | 33 | 33 | 33 | 13 | 21 | 1 | 6 |
| Best Location Sites [3] | 10 | 10 | 10 | 5 | 7 | 3 | 4 |
| PCGP Assumed Sites | 4 | 3 | 4 | 2 | 2 | 1 | 1 |
| *Total* | *47* | *46* | *47* | *20* | *30* | *5* | *11* |
| **West Cascades Physiographic Province – 1.2 mile home range radius** | | | | | | | |
| Known Sites | 21 | 19 | 21 | 5 | 12 | 1 | 7 |
| Best Location Sites [3] | 6 | 6 | 6 | 3 | 5 | 1 | 2 |
| PCGP Assumed Sites | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| *Total* | *28* | *26* | *28* | *9* | *18* | *2* | *9* |
| **East Cascades Physiographic Province – 1.2 mile home range radius** | | | | | | | |
| Known Sites | 5 | 5 | 4 | 1 | 2 | 1 | 0 |
| Best Location Sites [3] | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PCGP Assumed Sites | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Total* | *5* | *5* | *4* | *1* | *2* | *1* | *0* |
| **All Physiographic Provinces Crossed** | | | | | | | |
| Known Sites | 72 | 66 | 71 | 22 | 46 | 4 | 18 |
| Best Location Sites [3] | 17 | 17 | 17 | 8 | 13 | 4 | 6 |
| PCGP Assumed Sites | 9 | 8 | 9 | 5 | 6 | 1 | 2 |
| **Total** | **98** | **91** | **97** | **35** | **65** | **9** | **26** |

[1] Habitat Affected considers all proposed disturbance, including uncleared storage areas (UCSAs), pipeyards, and rock sources.
[2] Access roads considered does not include paved roads that are used regularly by the public (i.e., County Roads, State Highways). Home ranges are included if the activity center is within 0.25 mile of a proposed access road.
[3] Best Location Sites – areas identified with pair activity during PCGP survey efforts in 2007 and/or 2008 but the nest was not located; SBS and local agency biologists determined best potential nest site based on survey data and available habitat.
[4] PCGP Assumed Sites - area identifed by Pacific Connector that may provide habitat for NSO pair.

**Table 4.3.4-3**
**Status of the Northern Spotted Owl and its Habitat within the Provincial Analysis Area [1]**

| Suitable NRF Habitat Condition within Owl Home Ranges [2] | Owl Status [3] | Physiographic Province: Coast Range | Klamath Mountains | West Cascades | East Cascades | Total |
|---|---|---|---|---|---|---|
| Home Range > 40% AND Core Area > 50% | Known | 1 | 14 | 10 | 4 | 29 |
| | Best Location | 0 | 3 | 3 | 0 | 6 |
| | PCGP Assumed | 0 | 0 | 0 | 0 | 0 |
| | *Total* | *1* | *17* | *13* | *4* | *35* |
| Home Range > 40% AND Core Area < 50% | Known | 0 | 3 | 4 | 0 | 7 |
| | Best Location | 0 | 1 | 2 | 0 | 3 |
| | PCGP Assumed | 0 | 0 | 0 | 0 | 0 |
| | *Total* | *0* | *4* | *6* | *0* | *10* |
| Home Range < 40% AND Core Area > 50% | Known | 2 | 2 | 2 | 0 | 6 |
| | Best Location | 0 | 1 | 0 | 0 | 1 |
| | PCGP Assumed | 1 | 2 | 0 | 0 | 3 |
| | *Total* | *3* | *5* | *2* | *0* | *10* |
| Home Range < 40% AND Core Area < 50% | Known | 10 | 14 | 5 | 1 | 30 |
| | Best Location | 1 | 5 | 1 | 0 | 7 |
| | PCGP Assumed | 3 | 2 | 1 | 0 | 6 |
| | *Total* | *14* | *21* | *7* | *1* | *43* |
| Overall Total | Known | 13 | 33 | 21 | 5 | 72 |
| | Best Location | 1 | 10 | 6 | 0 | 17 |
| | PCGP Assumed | 4 | 4 | 1 | 0 | 9 |
| | *Total* | *18* | *47* | *28* | *5* | *98* |

[1] For detailed NRF/High NRF habitat available for each individual NSO and its habitat type (nest patch, core area, home range), refer to "pre-action" suitable habitat acres in table Q-7 in appendix Q.
[2] FWS et al. (2008) consider core areas with 50 percent or greater suitable NRF habitat and home ranges with at least 40 percent suitable NRF habitat to be necessary to maintain NSO life history function.
[3] Owl Status: 1) Known sites represent NSO activity sites provided by BLM and Forest Service biologists within the provincial analysis area; 2) Best Location sites represent pairs or resident singles documented by Pacific Connector during surveys in 2007 and 2008 with no nest site/activity center located, and; 3) PCGP Assumed sites include an area identifed by Pacific Connector that may provide habitat for NSO activity center.

Pacific Connector requested guidance from FWS in November 2012 to determine what additional surveys for NSO should be conducted for the proposed action, considering the revised survey protocol that was finalized in February 2010 (see FWS, 2010d) and previous surveys conducted in 2007 and 2008. FWS (McCorkle, 2012; appendix S – ROC) stated that additional full protocol NSO surveys across the entire project are not necessary, but recommended additional pre-construction "spot check" surveys with at least 3 site visits occur to confirm occupancy status, and to inform additional opportunities to fine-tune timing or distance buffers around active NSO activity centers. Pacific Connector will conduct additional "spot check" surveys within the analysis area (defined above) one year prior to scheduled timber removal in NRF habitat that is within 0.25 mile of the construction right-of-way in NSO home ranges to attempt to detect spotted owls that may have recently established territories in the project area (see "spot check" surveys in the revised NSO survey protocol; FWS, 2010). Surveys would not occur where annual monitoring survey efforts are on-going in the proposed action area to minimize NSO harassment. Reproductive follow-up surveys would occur at approximately 10 activity sites (five known, four best location, and one PCGP assumed site) that are within 0.25 mile of the construction right-of-way the following year prior to pipeline construction to determine if documented nest sites and/or pairs are active. The follow-up surveys would either consist of two visits before May 1 at least one week apart or one survey after May 1 as described by the revised NSO survey protocol (FWS, 2010d).

**Habitat**

FWS has identified four categories of northern spotted owl habitat that should be used to assess impacts to spotted owls and habitat for the proposed action (Trask & Associates, 2012): highly suitable NRF (high NRF), NRF, dispersal habitat, and capable habitat. High NRF is considered habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species (Trask & Associates, 2012). Other habitat definitions include (Trask & Associates, 2013; FWS; 2012a; North et al., 1999): 1) suitable NRF that consists of conifer-dominated stands older than 80 years, and are multi-storied in structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood but does not meet the definition of High NRF; 2) dispersal habitat that is comprised of conifer and mixed mature conifer-hardwood habitats with a canopy cover greater than or equal to 40 percent in moist forests and greater than 30 percent in dry forests, and conifer trees greater than or equal to 11 inches average diameter-breast-at-height; and 3) capable habitat that is forested habitat that could provide NSO suitable NRF in the future (including recently harvested stands – i.e., clearcut) but currently does not provide the structures described above for NSO High NRF, NRF, or dispersal habitat. Non-capable habitat has been defined as areas that will never provide habitat for NRF or dispersal habitat, such as agriculture fields, grasslands, rivers, rock outcroppings, roads, etc. (FWS, 2006f).

In the previous analysis conducted for the 2009 FERC FEIS, Pacific Connector used the BioMapper Habitat Model created by the Forest Service Northwest Research Station and used in the 10-year Monitoring Report (see Lint, 2005) as the foundation to determine suitable habitat within the PCGP Project area. Davis et al. (2011) determined that the BioMapper model overestimated owl habitat suitability in portions of the range, including pine-dominated forests of the eastern Cascades, and young stands in the Coast Range and western Cascades. Additionally in the previous filing, spotted owl dispersal habitat was determined through a query of a Gradient Nearest Neighbor raster data set (developed by Landscape Ecology, Modeling, Mapping, & Analysis, www.fsl.orst.edu/elemma) for areas where conifers had a dbh of 11 or greater and the canopy cover of the stand was 40 percent or greater. Capable habitat was considered all forested habitat not included in the modeled NRF or dispersal habitats. Since the previous 2009 FERC FEIS analysis (FERC, 2009), improved northern spotted owl habitat models have been developed to monitor status and trends of the northern spotted owl populations and habitat within the past 15 years in the NWFP area; the habitat suitability models represent northern spotted owl habitat as of 2006 in Oregon (see Davis et al., 2011). These models have been used to determine high NRF, NRF, dispersal, and capable habitat within the proposed action project area, in conjunction with the vegetation GIS coverage that was delineated for the PCGP Project that classified forested habitat by type and age classes (clear-cut – 0 to 5 years, regenerating forest – 5 to 40 years, mid-seral – 40 to 80 years, late successional – 80 to 175 years, and old-growth – greater than 175 years; see discussion in Vegetation, Section 3.3.1.1 in Pacific Connector's FERC Certificate application).

To determine the four recommended NSO habitat categories (see Trask & Associates, 2013) within the proposed action project area, including all home ranges that intersected the proposed project area and existing access roads, Pacific Connector used two habitat suitability models developed for the 15-year NSO monitoring reports available online (http://reo.gov/monitoring/data-maps/nso-data-maps.shtml): 1) Northern Spotted Owl Nesting/Roosting Habitat Suitability – 2006/2007 (nwwfp_nso_15yr) that models unsuitable, marginal, suitable, and highly suitable habitat; and 2) Northern Spotted Owl Habitat Map – 2006/2007 (nwfp_hab_15yr) that models nonforest, forested but not dispersal, dispersal habitat, and nesting/roosting habitat. The two files were combined and created 16 habitat combinations. Pacific Connector used a conservative approach and let the higher habitat category trump the lower (see table 4.3.4-4).

**Table 4.3.4-4**
**Matrix of Northern Spotted Owl Habitat Modeling Using Two Models Developed by the Pacific Northwest Research Center [1]**

| Habitat Suitability (nwfp_nso_15yr) | Habitat Map (nwfp_hab_15yr) | PCGP NSO Habitat Model [2] |
|---|---|---|
| Unsuitable | Nonforest | Not Habitat |
| Unsuitable | Forested, but not dispersal habitat | Capable |
| Unsuitable | Dispersal habitat | Dispersal |
| Unsuitable | Nesting/roosting habitat | NRF |
| Marginal | Nonforest | Capable |
| Marginal | Dispersal habitat | Dispersal Habitat |
| Marginal | Forested, but not dispersal habitat | Capable Habitat |
| Marginal | Nesting/roosting habitat | NRF |
| Suitable | Nonforest | NRF |
| Suitable | Forested, but not dispersal habitat | NRF |
| Suitable | Dispersal habitat | NRF |
| Suitable | Nesting/roosting habitat | NRF |
| Highly suitable | Nonforest | High NRF |
| Highly suitable | Forested, but not dispersal habitat | High NRF |
| Highly suitable | Dispersal habitat | High NRF |
| Highly suitable | Nesting/roosting habitat | High Suitable (NRF) |

[1] Habitat models [Northern Spotted Owl Nesting/Roosting Habitat Suitability – 2006/2007 (nwwfp_nso_15yr) and Northern Spotted Owl Habitat Map – 2006/2007 (nwfp_hab_15yr) ] available online: http://reo.gov/monitoring/data-maps/nso-data-maps.shtml.
[2] NSO habitat classifications are based on direction provided in the FWS NSO and MAMU conservation framework (Trask & Associates, 2013).

Next, two habitat modeling methods were used to determine habitat within the vicinity of the proposed action (approximately 300 meters from proposed habitat removal) and beyond 300 meters using the vegetation file that was delineated for the PCGP Project that incorporates forest age class and the resulting habitat model (see table 4.3.4-4). Two methods were considered because vegetation delineation within 300 meters of the proposed action, particularly in the affected area, was delineated at a finer scale using 2012 aerial photography and has been reviewed by local agency biologists, whereas beyond 300 meters, vegetation mapping generally relied on available data (i.e., BLM Forest Operation Inventory (FOI) coverage, late successional GNN coverage) and included areas that had not been refined using aerial photography or visited by Pacific Connector. Within 300 meters of the proposed action, NSO habitat was initially delineated considering the following age classes and forest type: clearcut and regenerating forest was considered "capable"; mid-seral coniferous and mixed forest lands, as well as deciduous forests were considered "dispersal only"; and late successional coniferous and old-growth forest were considered nesting, roosting, and foraging (NRF) habitat. The developed model (see table 4.3.4-4) was used to designate areas of "high NRF" where 40 percent or more of modeled high NRF pixels were included in delineated old-growth and late successional forest (NRF) stands (within the range of the marbled murrelet, this corresponded well to occupied murrelet stands that would be expected to have old-growth characteristics). Outside of the 300 meters, the resulting model (see table 4.3.4-4) was generally used to determine northern spotted owl habitat (high NRF, NRF, dispersal, and capable) and should represent the changing forest characteristics across the four physiographic provinces better than applying age class methodology, as within the 300 meters of the Project. Within both modeled areas, 2012 aerial photography was used to delineate obvious young stands (i.e., clearcuts or early regenerating forest) and identify the habitat as capable (in many instances, high NRF and NRF were modeled in clearcuts).

These methods, along with a hybrid method that has been discarded, were presented to FWS at a meeting in March 2013, generally to discuss and compare the difference in modeling results. Within 300 meters of the Project Area, the habitat modeling generally maps more areas as high NRF, NRF, and dispersal habitat than the merged models presented in (see table 4.3.4-4) and used beyond 300 meters; this is a result of "stands" rather than 25m X 25m modeled pixels being used to identify northern spotted owl habitat. The model outside of the 300 meters tends to identify more forested stands as capable, rather than dispersal. Pacific Connector conducted the analysis based on practical application of conceptual models proposed by FWS.

The resulting NSO Habitat file described above should provide a good approximation of the northern spotted owl habitat (high NRF, NRF, dispersal only, and capable) within the proposed action area that will be affected by construction of the PCGP Project. The model was used to determine the amount of high NRF, NRF, dispersal, and capable habitat within the Physiographic analysis area by Physiographic Province and jurisdiction (see table 4.3.4-5). Figures 2, 3, and 4 in appendix Q provide an overview of NSO habitat within the Project analysis area in relation to spotted owl home ranges, NSO critical habitat, and NWFP LSRs. Table Q-7 in appendix Q identify the amount of NSO Habitat (high NRF, NRF, dispersal only, and capable habitat) available within each NSO Home Range.

Both federal and non-federal land occurs within the defined Provincial Analysis Area, and based on acres of high NRF and NRF habitat available within each (see table 4.3.4-5), it is apparent that federally-managed lands provide substantially more suitable NRF habitat than non-federal lands. Therefore, it can be expected that non-federal land within the Provincial Analysis Area plays a minor role in supporting NSOs and aiding in their recovery. Overall, federal lands within the Provincial Analysis Area provide approximately 48 percent suitable NRF (including High NRF) habitat (see table 4.3.4-5), which meets the criterion that FWS et al. (2007) consider necessary to maintain NSO life history function within owl home ranges. Also note, the majority of available NRF occurs within NSO home ranges. If physiographic provinces are reviewed individually, less than 40 percent of suitable NRF is available within each physiographic province; however, on federal lands each individual physiographic province, as well as collectively provide more than 40 percent NRF habitat which above the recommended threshold (Coast Range provides 40.7 percent NRF, Klamath Mountains 54.4 percent NRF, West Cascades 46.1 percent NRF, and East Cascades 53.3 percent NRF).

**Table 4.3.4-5**
**Summary of NSO Suitable Nesting, Roosting, and Foraging, Dispersal, and Capable Habitat Available within the Provincial Analysis Area by Physiographic Province**

| Landowner [1] | General Location | Total Acres within Analysis Area [2] | High NRF Habitat[3] | | NRF Habitat[4] | | Dispersal Habitat Only [5] | | Capable Habitat[6] | | Total NSO Habitat [7] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| **Coast Range Physiographic Province** | | | | | | | | | | | | |
| Federal | Home Range | 27,188 | 10,756 | 39.6 | 1,376 | 5.1 | 7,126 | 26.2 | 7,708 | 28.3 | 26,966 | 99.2 |
| | Outside Home Range | 7,940 | 1,253 | 15.8 | 917 | 11.6 | 3,427 | 43.2 | 2,158 | 27.2 | 7,756 | 97.7 |
| | Subtotal | 35,128 | 12,009 | 34.2 | 2,293 | 6.5 | 10,554 | 30.0 | 9,865 | 28.1 | 34,721 | 98.8 |
| Non-Federal | Home Range | 34,023 | 1,220 | 3.6 | 1,267 | 3.7 | 4,911 | 14.4 | 24,255 | 71.3 | 31,653 | 93.0 |
| | Outside Home Range | 19,618 | 315 | 1.6 | 655 | 3.3 | 3,144 | 16.0 | 10,473 | 53.4 | 14,587 | 74.4 |
| | Subtotal | 53,641 | 1,535 | 2.9 | 1,922 | 3.6 | 8,055 | 15.0 | 34,728 | 64.7 | 46,241 | 86.2 |
| *Coast Range Total* | Home Range | 61,211 | 11,976 | 19.6 | 2,643 | 4.3 | 12,038 | 19.7 | 31,963 | 52.2 | 58,619 | 95.8 |
| | Outside Home Range | 27,558 | 1,569 | 5.7 | 1,572 | 5.7 | 6,572 | 23.8 | 12,630 | 45.8 | 22,343 | 81.1 |
| | Subtotal | 88,769 | 13,544 | 15.3 | 4,215 | 4.7 | 18,609 | 21.0 | 44,594 | 50.2 | 80,962 | 91.2 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | |
| Federal | Home Range | 48,686 | 14,585 | 30.0 | 12,870 | 26.4 | 6,531 | 13.4 | 14,039 | 28.8 | 48,025 | 98.6 |
| | Outside Home Range | 4,617 | 521 | 11.3 | 1,015 | 22.0 | 739 | 16.0 | 2,197 | 47.6 | 4,472 | 96.9 |
| | Subtotal | 53,303 | 15,107 | 28.3 | 13,884 | 26.0 | 7,270 | 13.6 | 16,237 | 30.5 | 52,498 | 98.5 |
| Non-Federal | Home Range | 49,357 | 3,986 | 8.1 | 6,429 | 13.0 | 8,918 | 18.1 | 24,026 | 48.7 | 43,359 | 87.8 |
| | Outside Home Range | 20,784 | 254 | 1.2 | 550 | 2.6 | 3,927 | 18.9 | 6,704 | 32.3 | 11,434 | 55.0 |
| | Subtotal | 70,141 | 4,240 | 6.0 | 6,979 | 9.9 | 12,845 | 18.3 | 30,731 | 43.8 | 54,794 | 78.1 |
| *Klamath Mountains Total* | Home Range | 98,043 | 18,571 | 18.9 | 19,299 | 19.7 | 15,449 | 15.8 | 38,066 | 38.8 | 91,385 | 93.2 |
| | Outside Home Range | 25,401 | 775 | 3.1 | 1,564 | 6.2 | 4,666 | 18.4 | 8,901 | 35.0 | 15,907 | 62.6 |
| | Subtotal | 123,444 | 19,346 | 15.7 | 20,863 | 16.9 | 20,115 | 16.3 | 46,967 | 38.0 | 107,291 | 86.9 |

| Landowner [1] | General Location | Total Acres within Analysis Area [2] | High NRF Habitat[3] | | NRF Habitat[4] | | Dispersal Habitat Only [5] | | Capable Habitat[6] | | Total NSO Habitat [7] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| **West Cascades Physiographic Province** | | | | | | | | | | | | |
| Federal | Home Range | 43,192 | 2,912 | 6.7 | 17,889 | 41.4 | 6,052 | 14.0 | 13,465 | 31.2 | 40,318 | 93.3 |
| | Outside Home Range | 5,599 | 255 | 4.6 | 1,430 | 25.5 | 2,342 | 41.8 | 970 | 17.3 | 4,997 | 89.3 |
| | Subtotal | 48,791 | 3,167 | 6.5 | 19,318 | 39.6 | 8,395 | 17.2 | 14,435 | 29.6 | 45,316 | 92.9 |
| Non-Federal | Home Range | 13,556 | 460 | 3.4 | 1,554 | 11.5 | 2,870 | 21.2 | 7,945 | 58.6 | 12,829 | 94.6 |
| | Outside Home Range | 11,140 | 39 | 0.3 | 263 | 2.4 | 1,309 | 11.8 | 7,555 | 67.8 | 9,166 | 82.3 |
| | Subtotal | 24,696 | 499 | 2.0 | 1,817 | 7.4 | 4,179 | 16.9 | 15,500 | 62.8 | 21,995 | 89.1 |
| *West Cascades Total* | Home Range | 56,748 | 3,372 | 5.9 | 19,443 | 34.3 | 8,922 | 15.7 | 21,410 | 37.7 | 53,148 | 93.7 |
| | Outside Home Range | 16,739 | 294 | 1.8 | 1,692 | 10.1 | 3,652 | 21.8 | 8,525 | 50.9 | 14,163 | 84.6 |
| | Subtotal | 73,487 | 3,666 | 5.0 | 21,136 | 28.8 | 12,574 | 17.1 | 29,936 | 40.7 | 67,311 | 91.6 |
| **East Cascades Physiographic Province** | | | | | | | | | | | | |
| Federal | Home Range | 11,416 | 1,619 | 14.2 | 4,614 | 40.4 | 1,127 | 9.9 | 3,833 | 33.6 | 11,194 | 98.1 |
| | Outside Home Range | 1,026 | 119 | 11.6 | 282 | 27.5 | 265 | 25.8 | 192 | 18.7 | 857 | 83.6 |
| | Subtotal | 12,442 | 1,738 | 14.0 | 4,896 | 39.4 | 1,392 | 11.2 | 4,025 | 32.4 | 12,051 | 96.9 |
| Non-Federal | Home Range | 3,546 | 24 | 0.7 | 121 | 3.4 | 497 | 14.0 | 2,644 | 74.6 | 3,285 | 92.7 |
| | Outside Home Range | 8,293 | 0 | 0.0 | 13 | 0.2 | 701 | 8.4 | 6,770 | 81.6 | 7,484 | 90.3 |
| | Subtotal | 11,838 | 24 | 0.2 | 134 | 1.1 | 1,197 | 10.1 | 9,414 | 79.5 | 10,770 | 91.0 |
| *East Cascades Total* | Home Range | 14,962 | 1,643 | 11.0 | 4,735 | 31.6 | 1,624 | 10.9 | 6,477 | 43.3 | 14,479 | 96.8 |
| | Outside Home Range | 9,318 | 119 | 1.3 | 295 | 3.2 | 965 | 10.4 | 6,962 | 74.7 | 8,341 | 89.5 |
| | Subtotal | 24,281 | 1,762 | 7.3 | 5,030 | 20.7 | 2,590 | 10.7 | 13,439 | 55.3 | 22,821 | 94.0 |
| **All Physiographic Provinces** | | | | | | | | | | | | |
| Federal | Home Range | 130,483 | 29,872 | 22.9 | 36,748 | 28.2 | 20,837 | 16.0 | 39,046 | 29.9 | 126,504 | 97.0 |
| | Outside Home Range | 19,182 | 2,148 | 11.2 | 3,644 | 19.0 | 6,773 | 35.3 | 5,517 | 28.8 | 18,082 | 94.3 |

| Landowner [1] | General Location | Total Acres within Analysis Area [2] | High NRF Habitat[3] | | NRF Habitat[4] | | Dispersal Habitat Only [5] | | Capable Habitat[6] | | Total NSO Habitat [7] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent | Acres Available | Percent |
| | Subtotal | 149,664 | 32,020 | 21.4 | 40,392 | 27.0 | 27,611 | 18.4 | 44,563 | 29.8 | 144,586 | 96.6 |
| Non-Federal | Home Range | 100,482 | 5,690 | 5.7 | 9,372 | 9.3 | 17,195 | 17.1 | 58,870 | 58.6 | 91,127 | 90.7 |
| | Outside Home Range | 59,835 | 608 | 1.0 | 1,480 | 2.5 | 9,081 | 15.2 | 31,502 | 52.6 | 42,671 | 71.3 |
| | Subtotal | 160,317 | 6,298 | 3.9 | 10,852 | 6.8 | 26,276 | 16.4 | 90,373 | 56.4 | 133,799 | 83.5 |
| *Overall Total* | Home Range | 230,964 | 35,562 | 15.4 | 46,120 | 20.0 | 38,033 | 16.5 | 97,916 | 42.4 | 217,631 | 94.2 |
| | Outside Home Range | 79,017 | 2,756 | 3.5 | 5,124 | 6.5 | 15,854 | 20.1 | 37,019 | 46.8 | 60,754 | 76.9 |
| | Subtotal | 309,981 | 38,318 | 12.4 | 51,244 | 16.5 | 53,887 | 17.4 | 134,935 | 43.5 | 278,384 | 89.8 |

[1] Landowner is summarized by Federal (BLM Districts and National Forests) and Non-Federal (Private, State, Corps of Engineers, and Bureau of Indian Affairs Land).
[2] Total acres available within the entire analysis area, including non-capable habitat not identified in this table.
[3] High NRF (Trask & Associates, 2013): forested habitat characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
[4] NRF (Trask & Associates, 2013; FWS, 2012a; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
[5] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
[6] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.

Discussion at the Task Force - ESA Consultation Subgroup meeting on April 2, 2008, indicated that NSO dispersal habitat could be considered adequate if at least 50 percent of the analysis area (in the Project's case, the defined Provincial Analysis Area) consists of dispersal habitat. Within the Provincial Analysis Area dispersal habitat is comprised of dispersal only habitat, as well as high NRF and NRF. Calculating the high NRF, NRF, and dispersal habitat within each physiographic province from table 4.3.4-5, the following acres of dispersal habitat are available within each province: 36,368 acres (41.0 percent) in the Coast Range, 60,324 acres (48.9 percent) in Klamath Mountains, 37,375 acres (50.9 percent) in West Cascades, and 9,382 acres (38.6 percent) in East Cascades. Only West Cascades physiographic province within the Provincial Analysis Area provides adequate levels of dispersal habitat (greater than 50 percent), although habitat in Klamath Mountains physiographic province is close.

**Critical Habitat**

Four federally-designated CHUs occur within the provincial analysis area (FWS, 2012a): Oregon Coast Ranges – OCR (Unit 2) totaling 859,864 acres and six subunits, East Cascades South – ECS (Unit 8) totaling 368,381 acres and three subunits, Klamath West – KLW (Unit 9) totaling 1,197,389 acres and 9 subunits, and Klamath East – KLE (Unit 10) totaling 1,052,731 acres and seven subunits. Eight subunits occur within the provincial analysis area (OCR-6, ECS-1, KLW-1, KLE-1, KLE-2, KLE-3, KLE-4, and KLE-5). All subunits are expected to function primarily for demographic support to the overall population, as well as connectivity between subunits and CHUs. Special management consideration or protection required for each subunit is to address threats from current and past timber harvest and competition from barred owls, as well as losses due to wildfire and the effects on vegetation from fire exclusion (with the exception of OCR-6).

- OCR (Unit 2): forest is dominated by western hemlock, Sitka spruce, and Douglas-fir. NSO nesting habitat tends to be limited to stands providing very large trees with cavities or deformities because Douglas-fir dwarf mistletoe is unusual in this region. Woodrats comprise an increasing proportion of the diet. One subunit occurs in the provincial analysis area: OCR-6.
    - OCR-6: consists of approximately 81,900 acres in Coos and Douglas Counties, Oregon and comprises lands managed by the BLM. 97 percent of the area was used by NSO at the time of listing.
- KLW (Unit 9): forest is a highly diverse mix of mesic forest communities such as Pacific Douglas-fir, Douglas-fir tanoak, and mixed evergreen forest interspersed with more xeric forest types; tanoak is a dominant factor. Douglas-fir dwarf mistletoe is uncommon and seldom used for nesting platforms by NSO. Prey is diverse, but dominated by woodrats and flying squirrels. One subunit occurs in the provincial analysis area: KLW-1.
    - KLW-1: consists of approximately 147,326 acres in Douglas, Josephine, Curry, and Coos Counties, Oregon and managed by the State of Oregon and BLM. 96 percent of the area was used by NSO at the time of listing.
- KLE (Unit 10): forest is a mixed-conifer/evergreen hardwood forest type and grades into the western hemlock forest. High summer temperatures and a mosaic of open forest conditions and Oregon white oak woodlands influence NSO distribution in this region. Dwarf mistletoe provides an important component of nesting habitat, enabling NSO to occasionally nest within stands of relatively younger, small trees. Five subunits occur in the provincial analysis area: KLE-1, KLE-2, KLE-3, KLE-4, and KLE-5.

- KLE-1: consists of 242, 338 acres in Jackson and Douglas Counties, Oregon and managed by Forest Service and BLM. 84 percent of the area was used by NSO at the time of listing.
- KLE-2: consists of 101,942 acres in Josephine and Douglas Counties, Oregon and is managed by BLM and the Forest Service. 92 percent of the area was used by NSO at the time of listing.
- KLE-3: consists of 111,410 acres in Jackson, Josephine, and Douglas Counties, Oregon and is managed by Forest Service and BLM. 97 percent of the area was used by NSO at the time of listing.
- KLE-4: consists of 254,442 acres in Jackson, Klamath, and Douglas Counties, Oregon and is managed by the Forest Service and BLM. 81 percent of the area was used by NSO at the time of listing.
- KLE-5: consists of 38,283 acres in Jackson County, Oregon and is managed by the BLM and Forest Service. 86 percent of the area was used by NSO at the time of listing.

- ECS (Unit 8): ponderosa pine is dominant at mid-to-lower elevations, with a narrow band of Douglas-fir and white fir at middle elevations providing the majority of NSO habitat. Dwarf mistletoe provides an important component of nesting habitat, enabling NSO to nest within stands of relatively younger smaller trees. One subunit occurs in the provincial analysis area: ECS-1.
    - ECS-1: consists of approximately 127,801 acres in Klamath, Jackson, and Douglas Counties, Oregon and comprises lands managed by the BLM and Forest Service. 78 percent of the area was used by NSO at the time of listing.

The current status of NSO habitat (high NRF, NRF, dispersal only, and capable) within designated CHUs and subunits located in the Project analysis area is shown in table 4.3.4-6. The baseline information shows that not all designated critical habitat is currently functioning as suitable NRF habitat. However, table 4.3.4-6 also provides the number of owls that are known to occur in the CHUs located in the analysis area (provided to Pacific Connector by FWS, BLM, and USFS. Given that suitable habitat acres within all affected CHUs currently support NRF habitat at levels that are adequate to support pairs of nesting NSOs, these CHUs are considered to be functional with respect to their recovery roles.

Of the 72 known, 17 best location, and 9 PCGP assumed NSO activity centers within the analysis area, 57 activity sites occur in Critical Habitat Units (43 known, 10 best location, 4 PCGP assumed). Table 4.3.4-7, below summarizes the number of activity sites analyzed within this BA that occur within each critical habitat subunit, and the condition of the home range (see table Q-7 in appendix Q). Just over half the activity centers (32 of 63) have suitable NSO habitat above the recommended level of 50 percent suitable NRF habitat in the core area and 40 percent suitable NRF habitat in the home range to support nesting and NSO survival.

## Table 4.3.4-6
## Summary of NSO High NRF, NRF, Dispersal Only, and Capable Habitat in Critical Habitat Subunits Available within the Provincial Analysis Area

| CHU and Subunit | Total Acres in CHU | Total Acres in Analysis Area | % Subunit within Analysis Area | Number of Known Owls [1] | High NRF in CHU [2] | | NRF in CHU [3] | | Dispersal Only in CHU [4] | | Capable in CHU [5] | | Total NSO Habitat in CHU [6] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Acres | Percent Total [7] | Acres | Percent Total [7] | Acres | Percent Total [7] | Acres | Percent Total [7] | Acres | Percent Total [7] |
| **Oregon Coast Range CHU (Unit 2 - 859,864 acres)** | | | | | | | | | | | | | | |
| OCR-6 | 81,900 | 13,041 | 15.9 | 52 | 5,750 | 7.0 | 1,159 | 1.4 | 2,297 | 2.8 | 3,759 | 4.6 | 12,965 | 15.8 |
| **Klamath West CHU (Unit 9 - 1,197,389 acres)** | | | | | | | | | | | | | | |
| KLW-1 | 147,326 | 621 | 0.4 | 120 | 30 | 0.0 | 29 | 0.0 | 528 | 0.4 | 10 | 0.0 | 597 | 0.4 |
| **Klamath East CHU (Unit 10 - 1,052,731 acres)** | | | | | | | | | | | | | | |
| KLE-1 | 242,338 | 25,190 | 10.4 | 112 | 9,025 | 3.7 | 5,574 | 2.3 | 3,208 | 1.3 | 7,179 | 3.0 | 24,986 | 10.3 |
| KLE-2 | 101,942 | 4,503 | 4.4 | 85 | 2,168 | 2.1 | 1,090 | 1.1 | 352 | 0.3 | 873 | 0.9 | 4,482 | 4.4 |
| KLE-3 | 111,410 | 4,597 | 4.1 | 75 | 157 | 0.1 | 2,541 | 2.3 | 1,320 | 1.2 | 543 | 0.5 | 4,561 | 4.1 |
| KLE-4 | 254,442 | 29,982 | 11.8 | 161 | 2,570 | 1.0 | 12,728 | 5.0 | 2,749 | 1.1 | 10,857 | 4.3 | 28,904 | 11.4 |
| KLE-5 | 38,283 | 3,324 | 8.7 | 32 | 10 | 0.0 | 1,613 | 4.2 | 840 | 2.2 | 702 | 1.8 | 3,164 | 8.3 |
| Total Unit 10 | 748,415 | 67,597 | 9.0 | 348 | 13,929 | 1.9 | 23,547 | 3.1 | 8,469 | 1.1 | 20,154 | 2.7 | 66,098 | 8.8 |
| **East Cascades South CHU (Unit 8 - 368,381 acres)** | | | | | | | | | | | | | | |
| ECS-1 | 127,801 | 9,758 | 7.6 | 16 | 1,306 | 1.0 | 3,861 | 3.0 | 1,172 | 0.9 | 3,206 | 2.5 | 9,545 | 7.5 |
| **Total CHU (3,478365 acres)** | | | | | | | | | | | | | | |
| Overall CHU Total | 1,105,442 | 91,016 | 8 | 535 | 21,014 | 1.9 | 28,596 | 2.6 | 12,466 | 1.1 | 27,129 | 2.5 | 89,205 | 8.1 |

[1] Number of Known Owls in entire CHU Subunit: known owl sites obtained from known owl locations provided by BLM (2006, 2013), Forest Service (2006, 2013), and FWS (Thrailkill, 2008) and 2007/2008 surveys conducted by Pacific Connector.

[2] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.

[3] NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.

[4] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.

[5] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.

[6] Total NSO Habitat within CHU Subunits that occur within the Provincial Analysis Area; does not include non-capable habitat.

[7] Percent total: percent of habitat available in entire critical habitat unit, not just the Provincial Analysis Area.

**Table 4.3.4-7**

**Summary of Northern Spotted Owl Activity Centers Analyzed that Occur within Northern Spotted Owl Critical Habitat Units, Including Condition of the NSO Activity Center**

| CHU and Subunit | Owl Status | Condition of high NRF/NRF in Activity Center | | | | Total Activity Centers |
|---|---|---|---|---|---|---|
| | | > 50% NRF in Core Area, > 40% NRF in Home Range | < 50% NRF in Core Area, > 40% NRF in Home Range | > 50% NRF in Core Area, < 40% NRF in Home Range | < 50% NRF in Core Area, < 40% NRF in Home Range | |
| **Oregon Coast Range CHU (Unit 2)** | | | | | | |
| OCR-6 | Known | 1 | 0 | 0 | 6 | 7 |
| | Best Location | 0 | 0 | 0 | 1 | 1 |
| | PCGP Assumed | 0 | 0 | 1 | 1 | 2 |
| | Total | 1 | 0 | 1 | 8 | 10 |
| **Klamath East CHU (Unit 10)** | | | | | | |
| KLE-1 | Known | 10 | 1 | 1 | 0 | 12 |
| | Best Location | 2 | 0 | 0 | 0 | 2 |
| | PCGP Assumed | 0 | 0 | 1 | 1 | 2 |
| | Total | 12 | 1 | 2 | 1 | 16 |
| KLE-2 | Known | 2 | 1 | 0 | 0 | 3 |
| | Best Location | 1 | 0 | 0 | 0 | 1 |
| | Total | 3 | 1 | 0 | 0 | 4 |
| KLE-3 | Known | 1 | 0 | 1 | 0 | 2 |
| KLE-4 | Known | 7 | 2 | 1 | 1 | 11 |
| | Best Location | 3 | 2 | 0 | 1 | 6 |
| | Total | 10 | 4 | 1 | 2 | 17 |
| KLE-5 | Known | 1 | 0 | 0 | 2 | 3 |
| **East Cascades South CHU (Unit 8)** | | | | | | |
| ECS-1 | Known | 4 | 0 | 0 | 1 | 5 |
| | Total | 4 | 0 | 0 | 2 | 6 |
| **Overall CHU Subunits** | | | | | | |
| Overall CHU Subunits | Known | 26 | 4 | 3 | 10 | 43 |
| | Best Location | 6 | 2 | 0 | 2 | 10 |
| | PCGP Assumed | 0 | 0 | 2 | 2 | 4 |
| | Total | 32 | 6 | 5 | 14 | 57 |

NWFP Late Successional Reserves

NWFP designated LSR Units occur within the Provincial Analysis Area: RO 261, RO 223, RO 227, and RO 224 (not affected by the proposed project). LSR RO 261, a large LSR complex (70,611 acres) and provides 5,178 acres of high NRF/NRF habitat within the Provincial Analysis Area. LSR RO 223 is also a large LSR complex (66,173 total acres) and provides 11,993 acres of high NRF/NRF habitat within the Provincial Analysis Area. Both LSR RO 261 and RO 223 are within BLM-managed checkerboard lands, with the exception of a portion of LSR RO 223 that occurs in a more contiguous configuration on Umpqua National Forest. LSR RO227 is the largest LSR complex crossed by the PCGP Project (101,600 acres). It provides 17,547 acres of high NRF/NRF within the Provincial Analysis Area. LSR RO 227 is located within Rogue River – Siskiyou National Forest and Fremont-Winema National Forest and is generally contiguous. Table 4.3.4-8, below provides a summary of NSO habitat that occurs within each LSR unit within the provincial analysis area.

Additionally, approximately 7,506 acres of unmapped LSRs occur within the provincial analysis area, including 4,490 acres of unmapped LSRs associated with occupied marbled murrelet stands and 3,016 acres of unmapped LSRs associated with known NSO activity centers (KOAC). Table 4.3.4-8 includes a summary of available habitat within unmapped LSRs.

Much of the LSRs (and unmapped LSRs) within the provincial analysis area overlap the FWS designated critical habitat units for NSO. The overlap of LSRs with federally designated NSO critical habitat affords a greater degree of protection to the NSO and its critical habitat as the NWFP protections for LSRs are automatically imposed on those LSR acres that are found within a CHU. Thus, NSOs located within these land allocations also benefit from increased protection.

Areas of Concern (AOCs)

Two AOCs have been identified in Oregon, of which one, the Rogue/Umpqua AOC, is located within the proposed analysis area in the Coast Range, Klamath Mountains, and West Cascades physiographic provinces. AOCs were identified as areas where NSO dispersal opportunities were limited because of the available forested habitat, land use allocations identified by the NWFP (BLM and USFS 1994), and the checkerboard land ownership pattern. The Rogue/Umpqua AOC is located in the northern portion of the Klamath Mountains physiographic province and provides a link between federally-designated CHUs Oregon Coast Ranges (Unit 2), Klamath West (Unit 9), and Klamath East (Unit 10). The northern portion of the Rogue/Umpqua AOC is located between Pacific Connector MP 28.13 and MP 62.48, and MP 82.71 and MP 111.11. Approximately 15.2 percent of the Rogue/Umpqua AOC occurs within the provincial analysis area, of which 47.4 percent (60,784 acres) provides dispersal habitat (NRF, high NRF, and Dispersal only). Table 4.3.4-9 below provides acres of dispersal habitat available in the Rogue/Umpqua AOC by federal and non-federal lands within the three physiographic provinces in which it is located. The AOC incorporates a large area of the Provincial Analysis Area. Approximately 53 of the 98 NSO activity centers that are analyized for this project occur in the AOC (table 4.3.4-9).

**Table 4.3.4-8**
**Summary of High NRF, NRF, Dispersal, and Capable Habitat Available within NWFP LSRs and Unmapped LSRs by Physiographic Province and Landowner within the Provincial Analysis Area**

| Landowner | Total Acres within Analysis Area | LSR Type[1] | High NRF Habitat[2] | | NRF Habitat[3] | | Dispersal Habitat Only [4] | | Capable Habitat[5] | | Total NSO Habitat [6] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Acres Available | Percent[7] | Acres Available | Percent[7] | Acres Available | Percent[7] | Acres Available | Percent[7] | Acres Available | Percent[7] |
| **Coast Range Physiographic Province** | | | | | | | | | | | | |
| Coos Bay BLM | 7,133 | LSR RO261 | 3,203 | 44.9 | 652 | 9.1 | 1,471 | 20.6 | 1,736 | 24.3 | 7,063 | 99.0 |
| | 4,422 | Unmapped LSR | 3,524 | 79.7 | 405 | 9.1 | 424 | 9.6 | 55 | 1.3 | 4,408 | 99.7 |
| Roseburg BLM | 3,461 | LSR RO261 | 1,076 | 31.1 | 128 | 3.7 | 1,049 | 30.3 | 1,194 | 34.5 | 3,448 | 99.6 |
| | 57 | Unmapped LSR | 4 | 7.4 | 44 | 76.9 | 3 | 5.3 | 1 | 2.0 | 52 | 91.6 |
| *Coast Range Total* | 10,593 | LSR Units | 4,280 | 40.4 | 780 | 7.4 | 2,521 | 23.8 | 2,930 | 27.7 | 10,511 | 99.2 |
| | 4,479 | Unmapped LSRs | 3,528 | 78.8 | 448 | 10.0 | 427 | 9.5 | 57 | 1.3 | 4,460 | 99.6 |
| | 15,072 | TOTAL | 7,808 | 51.8 | 1,228 | 8.2 | 2,948 | 19.6 | 2,986 | 19.8 | 14,971 | 99.3 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | |
| Roseburg BLM | 236 | LSR RO261 | 14 | 6.0 | 104 | 44.2 | 15 | 6.3 | 101 | 42.8 | 234 | 99.2 |
| | 5,558 | LSR RO223 | 2,430 | 43.7 | 1,464 | 26.3 | 485 | 8.7 | 1,148 | 20.7 | 5,527 | 99.4 |
| | 1,060 | Unmapped LSR | 629 | 59.3 | 391 | 36.8 | 24 | 2.2 | 7 | 0.7 | 1,050 | 99.1 |
| Medford BLM | 1 | LSR RO223 | 0 | 0.0 | 1 | 99.9 | 0 | 0.0 | 0 | 0.0 | 1 | 99.9 |
| | 419 | Unmapped LSR | 0 | 0.0 | 336 | 80.2 | 70 | 16.8 | 5 | 1.1 | 411 | 98.1 |
| Umpqua N.F. | 12,110 | LSR RO223 | 5,483 | 45.3 | 2,614 | 21.6 | 1,079 | 8.9 | 2,858 | 23.6 | 12,034 | 99.4 |
| | 677 | Unmapped LSR | 355 | 52.4 | 132 | 19.4 | 40 | 5.9 | 148 | 21.9 | 675 | 99.7 |
| *Klamath Mountains Total* | 17,906 | LSR Units | 7,927 | 44.3 | 4,184 | 23.4 | 1,579 | 8.8 | 4,106 | 22.9 | 17,797 | 99.4 |
| | 2,156 | Unmapped LSRs | 984 | 45.6 | 858 | 39.8 | 134 | 6.2 | 161 | 7.5 | 2,136 | 99.1 |
| | *20,062* | TOTAL | *8,911* | 44.4 | *5,042* | 25.1 | *1,713* | 8.5 | *4,267* | 21.3 | *19,933* | 99.4 |
| **West Cascades Physiographic Province** | | | | | | | | | | | | |
| Roseburg BLM | 11 | Unmapped LSR | 0 | 0.0 | 10 | 97.0 | 0 | 0.0 | 0 | 3.0 | 11 | 100.0 |
| Medford BLM | 89 | LSR RO224 | 37 | 41.4 | 22 | 24.9 | 13 | 14.5 | 17 | 19.2 | 89 | 100.0 |
| | 530 | Unmapped LSR | 56 | 10.6 | 291 | 54.9 | 164 | 30.9 | 18 | 3.3 | 529 | 99.7 |
| Rogue River N.F. | 31,508 | LSR RO227 | 2,361 | 7.5 | 13,133 | 41.7 | 2,895 | 9.2 | 11,042 | 35.0 | 29,431 | 93.4 |

| Landowner | Total Acres within Analysis Area | LSR Type[1] | High NRF Habitat[2] | | NRF Habitat[3] | | Dispersal Habitat Only [4] | | Capable Habitat[5] | | Total NSO Habitat [6] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Acres Available** | **Percent[7]** | **Acres Available** | **Percent[7]** | **Acres Available** | **Percent[7]** | **Acres Available** | **Percent[7]** | **Acres Available** | **Percent[7]** |
| (Fish Lake) | 5 | Unmapped LSR | 0 | 4.4 | 0 | 8.6 | 1 | 12.0 | 3 | 75.1 | 5 | 100.0 |
| *West Cascades Total* | 31,598 | LSR Units | 2,398 | 7.6 | 13,155 | 41.6 | 2,908 | 9.2 | 11,059 | 35.0 | 29,520 | 93.4 |
| | 546 | Unmapped LSRs | 57 | 10.4 | 302 | 55.3 | 164 | 30.1 | 21 | 3.9 | 544 | 99.8 |
| | *32,143* | TOTAL | 2,455 | 7.6 | 13,457 | 41.9 | 3,072 | 9.6 | 11,080 | 34.5 | 30,065 | 93.5 |
| **East Cascades Physiographic Province** | | | | | | | | | | | | |
| Lakeview BLM | 96 | Unmapped LSR | 0 | 0.0 | 93 | 96.9 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| Rogue River N.F. | 1,424 | LSR RO227 | 284 | 20.0 | 580 | 40.7 | 107 | 7.5 | 302 | 21.2 | 1,273 | 89.4 |
| Winema N.F. | 2,227 | LSR RO227 | 396 | 17.8 | 792 | 35.6 | 193 | 8.7 | 780 | 35.0 | 2,162 | 97.1 |
| (Lake of the Woods) | 229 | Unmapped LSR | 30 | 12.9 | 182 | 79.5 | 0 | 0.0 | 17 | 7.6 | 229 | 100.0 |
| *East Cascades Total* | 3,651 | LSR Units | 681 | 18.6 | 1,372 | 37.6 | 300 | 8.2 | 1,082 | 29.6 | 3,435 | 94.1 |
| | 325 | Unmapped LSRs | 30 | 9.1 | 278 | 85.6 | 0 | 0.0 | 17 | 5.3 | 325 | 100.0 |
| | *3,976* | TOTAL | *710* | 17.9 | *1,650* | 41.5 | *300* | 7.6 | *1,099* | 27.6 | *3,760* | 94.6 |
| **All Physiographic Provinces** | | | | | | | | | | | | |
| Overall Total | 63,748 | LSR Units | 15,286 | 24.0 | 19,491 | 30.6 | 7,308 | 11.5 | 19,177 | 30.1 | 61,263 | 96.1 |
| | 7,506 | Unmapped LSRs | 4,598 | 61.3 | 1,886 | 25.1 | 726 | 9.7 | 256 | 3.4 | 7,466 | 99.5 |
| | 71,254 | *TOTAL* | 19,884 | 27.9 | 21,377 | 30.0 | 8,034 | 11.3 | 19,433 | 27.3 | 68,728 | 96.5 |

[1] Unmapped LSRs consider MAMU occupied stands on NWFP matrix lands and KOAC.

[2] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.

[3] NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.

[4] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.

[5] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.

[6] Total NSO Habitat within NWFP LSRs and unmapped LSRs that occur within the Provincial Analysis Area; does not include non-capable habitat.

[7] Percent total: percent of habitat available in LSR units withint the Provincial Analysis Area.

**Table 4.3.4-9**
**Summary of Dispersal Habitat by Landowner in the Provincial Analysis Area Available within the Rogue/Umpqua Area of Concern**

| Land Owner | Total Acres in AOC | Total Acres of AOC within Analysis Area [1] | % AOC within Analysis Area | Number of NSO Sites within Analysis Area | High NRF | NRF | Dispersal Only Habitat | Total Dispersal Habitat [2] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Acres | Acres | Acres | Acres | Percent Total [3] |
| **Coast Range Physiographic Province** | | | | | | | | | |
| Federal Lands | 91,541 | 32,362 | 35.4 | 18 | 11,552 | 2,251 | 8,679 | 22,481 | 69.5 |
| Non-Federal Lands | 134,379 | 34,831 | 25.9 | 1 | 1,349 | 1,425 | 5,124 | 7,898 | 22.7 |
| *Coast Range Total* | *225,920* | 67,193 | 29.7 | 19 | 12,900 | 3,676 | 13,803 | 30,379 | 45.2 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | |
| Federal Lands | 246,644 | 25,809 | 10.5 | 28 | 9,024 | 5,737 | 2,869 | 17,630 | 68.3 |
| Non-Federal Lands | 353,178 | 32,548 | 9.2 | 6 | 2,321 | 3,799 | 6,023 | 12,142 | 37.3 |
| *Klamath Mountains Total* | *599,822* | 58,357 | 9.7 | 34 | 11,345 | 9,536 | 8,892 | 29,772 | 51.0 |
| **West Cascades Physiographic Province** | | | | | | | | | |
| Federal Lands | 11,914 | 272 | 2.3 | 0 | 6 | 61 | 41 | 109 | 40.0 |
| Non-Federal Lands | 8,568 | 2,525 | 29.5 | 0 | 78 | 305 | 140 | 523 | 20.7 |
| *West Cascades Total* | *20,482* | 2,796 | 13.7 | 0 | 85 | 366 | 182 | 632 | 22.6 |
| **Overall Total** | | | | | | | | | |
| Federal Lands | 350,098 | 58,442 | 16.7 | 46 | 20,582 | 8,048 | 11,590 | 40,220 | 68.8 |
| Non-Federal Lands | 496,125 | 69,904 | 14.1 | 7 | 3,748 | 5,529 | 11,287 | 20,564 | 29.4 |
| *Overall Total* | *846,223* | 128,347 | 15.2 | 53 | 24,330 | 13,578 | 22,877 | 60,784 | 47.4 |

[1] Total acres within the provincial analysis area, including capable and non-capable habitat.
[2] All dispersal habitat within the provincial analysis including high NRF, NRF, and dispersal only habitat.
[3] Percent of "dispersal" habitat within the Provincial Analysis Area.

### 4.3.4.3 Effects by the Proposed Action

#### Direct Effects

Project-related effects to NSOs would be caused by the action and occur at the same time and place, including the following within the provincial analysis area: 1) removal of a known nest tree during the entire breeding season (March 1 through September 30), and 2) human and noise disturbance due to right-of-way clearing and construction during the breeding period, including noise due to blasting and helicopter support during construction. These effects would extend over the short-term.

<u>Habitat Removal During Breeding Season</u>

Removal of habitat during the breeding season within a nest patch could result in the potential death of nestlings if the nest tree is felled. Removing habitat after the entire breeding season (after September 30) would eliminate any direct impact to individual NSOs or nestlings. Habitat removal within 0.25 mile of an activity center within the Project would occur after the entire breeding season (after September 30); therefore, no direct effect to NSOs through habitat removal is expected.

Noise and Visual

NSOs would be directly affected by noise and disturbance related to proximate human-related activities associated with timber removal, construction, and operation and maintenance of the Pacific Connector pipeline that would result in diminished reproductive success and survival (if behavior response to construction makes them more vulnerable to injury). Disturbance (both visual and noise) would include use of chainsaws and heavy equipment during vegetation clearing and pipeline construction, explosives to trench through rock, helicopters and/or small aircraft to inspect the pipeline once per year during the life of the Project, and brush control (i.e., mowing and cutting) within the permanent right-of-way every three to five years for the life of the Project. The term "disruption" was alluded to in the ESA, under the definition of "harassment" (50 CFR §§ 17.3) as:

> "an intentional or negligent act or omission which creates the likelihood of injury by annoying it (the organism) to such an extent as to significantly disrupt normal behavior patterns which include but are not limited to, breeding, feeding or sheltering".

The term "disturbance" was not included in the ESA but a reasonable working definition was provided by Leal (2006) and has been incorporated into this BA:

"any potential auditory or visual stimuli or deviation from ambient/baseline conditions [that] an individual bird, at a given site, is likely to detect and potentially react to."

Reactions of NSOs to close human presence in the canopy, and excessive noise levels in the immediate vicinity of owls are expected to include the following: 1) flushing from the nest site, which would leave eggs or young exposed to predation; 2) causing juveniles to prematurely fledge, which would increase juveniles' risk of predation; 3) interrupting foraging activities, which would result in the reduced fitness or even mortality of an individual; and/or 4) disrupting roosting activities which would cause a NSO to be displaced and possibly relocate. In the Northern Spotted Owl Status Review, none of these types of disturbance were considered a threat to the species (Courtney et al., 2004). However, at the individual level, based on anecdotal information and effects to other bird species (Wesemann and Rowe, 1987; Delaney et al., 1999; Delaney and Grubb, 2001; Swarthout and Steidl, 2001; FWS, 2003b; and FWS, 2005c), disturbance to NSOs could occur. Disturbance to owls is inversely related to stimulus distance and positively related to noise level, similar to results reported for bald eagles (Grubb and King, 1991), gyrfalcon (Platt, 1977), and other raptors (Awbrey and Bowles, 1990). For a significant disruption of NSO behavior to occur as a result of disturbance caused by an action, the disturbance and the NSO must be in close proximity to one another (FWS, 2003b; FWS, 2005c). Human presence on the ground is not expected to cause a significant disruption of behavior because NSOs do not seem to be startled by human presence (FWS, 2005c); however, increased human presence in an area that previously had minimal human presence may be an indirect effect of the proposed Project.

The available research and anecdotal accounts show that the effects of noise from a variety of sources elicit disturbance-responses from spotted owl subspecies (including Mexican spotted owls - MSO, northern spotted owls – NSO, and California spotted owls - CSO) but not disruption-responses such as flushing or flight that would be construed as interference with normal behavior patterns including but not limited to, breeding, feeding or sheltering. The following are brief summaries of available spotted owl research:

- All NSO foraged adjacent to roads and appeared undisturbed by the occasional passage of vehicles on narrow secondary gravel forest roads (Forsman et al., 1984).
- Male NSOs within 0.25 mile of a major logging road or timber harvest had higher fecal corticosterone levels than males farther away; no differences found for females related to distance from roads or timber harvest (Wasser et al., 1997).
- Proximity to roads (paved, improved surface, any type) was not correlated with fecal corticosterone in CSO (Tempel and Gutierrez, 2004).
- CSO exposure to chainsaw noise did not result in a detectable increase in fecal corticosterone level; CSO can tolerate low-intensity human sound in their environment without eliciting a physiological stress response (Tempel and Gutierrez, 2003).
- MSO nest occupancy <1 mile from firing sites was higher than nest occupancy > 1 mile away; MSO not affected by explosives but were affected by hikers (Hathcock et al., 2010).
- MSO response to military aircraft overflights (noise levels 78, 92 and 95 dB during sequential exposures) ranged from none to sudden head turning; behaviors during flights were no different than pre- and post-flight periods (Johnson and Reynolds, 2002).
- Relationships of NSO baseline physiology, nutritional stress, and reproductive success to exposures to high and low levels of routine OHV traffic (Hayward et al., 2011).
  - Male NSO show high fecal glucocorticoid (GC) response to OHV trials during incubation period.
  - Male NSO 50-800 m from loud roads show lower fecal GC response to motorcycle trials than males 50-800 m from quiet roads in July (fledging period).
  - Female NSO with good nutrition but no young show high fecal GC response to OHV trials.
  - Female NSO with good nutrition but no young show high fecal GC response to OHV trials.
  - Female NSO with 2 young and poor nutrition show low fecal GS response to OHV trials.
  - NSO close to roads had better nutrition but levels of fecal GC were not related to proximity to roads or noise.
  - NSO within 100 m of quiet roads fledged more young than NSO farther from roads; NSO within 100 m of noisy roads fledged fewer young.

NSOs disturbed at a roost site are presumably capable of moving away from disturbance without a significant disruption of behavior. Since NSOs are primarily nocturnal predators, projects that occur during the day are not likely to disrupt foraging behavior and the potential for effects is mainly associated with breeding behavior at an active nest site.

In the late breeding period, potential effects from Project activities decline because juvenile NSOs are increasingly more capable of moving as the nesting season progresses. Once capable of sustained flight, young owls are presumably able to distance themselves from disturbance and minimize their risk of predation. To ensure that more than 86 percent of juvenile NSOs in the Oregon Western Cascades Physiographic Province are able to move away from disturbances without increasing their risk of predation or harm, the critical nesting period is considered to be

March 1 through July 15. This is based on fledge data (Turner, 1999) and includes an additional two weeks to allow for development of flight skills. After July 15, most fledgling NSOs are assumed to be capable of sustained flight and can move away from harmful disturbances. The critical breeding period for the Oregon Western Cascades Physiographic Province is applied to the entire Provincial Analysis Area (March 1 through July 15), even though research has provided data that indicate NSOs fledge earlier in other Physiographic Provinces within the analysis area.

**Auditory and Visual Disturbance – FWS Guidance.** FWS (2003c and 2006e) indicated that the behaviors noted above may occur when 1) the project-generated sound level substantially exceeds existing ambient noise levels by 20 to 25 dB; 2) when the total sound level (project and ambient noise levels combined) exceeds 90 dB; or 3) when the visual proximity of human disturbance occurs within 130 feet of an active nest site. FWS concluded that noise and human presence can result in a significant disruption of breeding, feeding, and/or sheltering behavior of NSOs such that it creates the potential for injury to the individuals (i.e., incidental take in the form of harassment).

FWS (2006e) established distances within which sound levels and visual disturbance for various activities may result in injury or harassment of NSOs by significantly disrupting the normal behavior pattern of individuals or breeding pairs. Table 4.3.4-10 (Disruption Threshold Distance) provides the distances at which FWS (2003b and 2006e) indicate that NSOs could be disrupted or "harassed" by certain activities during the critical breeding period and late breeding period. In a previous Biological Opinion, FWS (FWS, 2006f) provides distances from a Project boundary within which NSOs could potentially be distracted, or "disturbed" from their normal activity. Those distances are often applied as seasonal buffers to minimize impacts of Projects on nesting NSOs (Disturbance Threshold Distance; table 4.3.4-10). The threshold disruption distances applied to NSO during the critical breeding period are either the same or extend farther (i.e., more conservative) than distances provided by FWS (2003b and 2006e; see Noise Evaluation in Appendix Z3). Other actions, including use of existing roads and large helicopters were added after 2006.

FWS (2003b and 2006e) reviewed available scientific literature on behavioral and physiological responses of different bird species to various noise sources. They determined that birds would likely detect noises that were ≥4 decibels or more above ambient noise levels. FWS (2006e) also opined that anthropogenic noise attenuating to within 25 dB above ambient sound level would be the threshold above which harassment to individual NSO is likely to occur. That determination, however, was based on one account of Mexican spotted owls responding to chainsaw noise (Delaney et al., 1999) and one account of a colonial nesting seabird (crested tern, Brown, 1990) responding to simulated aircraft noise. In both situations, the subject birds were exposed to human presence prior to exposure to noises and response to noises were not controlled for visual disturbances. Using those two studies however, FWS (2006e) subtracted the noise level that elicited a harassment-indicating behavior (flight or flushing) from the minimum ambient noise at the respective sites and decided that action-generated noise levels that are 25 dB above ambient levels will constitute the sound level threshold above which harassment is likely to occur (FWS, 2006e). From that exercise, FWS (2006e) decided that a noise level of 70 dB would be a disturbance threshold and noise ≥70 dB would be disruptive, based entirely on the responses of crested terns to simulated aircraft noise (Brown, 1990), as above. That conclusion appears to be arbitrary (WSDOT, 2011), has not been tested, and is not supported by field studies of NSO (see available research and anecdotal accounts, above). Consequently, Pacific Connector has not accepted or applied the FWS (2006e) sound threshold of 25 dB above ambient noise or noise ≥70 dB as a decibel level above which harassment is likely to occur.

Injury to individuals would occur if a threshold of 92 dBA occurs or is exceeded (FWS, 2003b). FWS (2006e) defined a "tolerance threshold" of 82 dB for marbled murrelets and northern spotted owls. The tolerance threshold assumes that respective nest sites become "intolerable" to the species and harassment occurs due to the total sound level the species must endure. However, no time duration component was associated with the tolerance threshold. FWS (2006e) did recognize that a tolerance threshold of 92 dB for aircraft (e.g., helicopters) would be applicable due to the usually slow onset of aircraft noise approaching spotted owls but they (FWS, 2006e) applied the threshold of 82 dB as a sound-related injury threshold level for spotted owls.

The FWS typically considers the disturbance threshold for general noise-generating activities within a 0.25-mile radius (125-acre area) of the activity during the critical breeding season (March 1 to July 15). For louder disturbance activities such as open air blasting using more than a 2 pound charge or large aircraft, FWS generally applies a 1.0 mile radius (2,176 acre area) around NSO sites during the entire breeding season (March 1 to September 30) to minimize disturbance to nesting NSO (FWS, 2003b; Smith et al., 2007; Wille et al., 2006). However, FWS suggested that if additional studies could demonstrate that use of larger blasts (greater than 2 pounds) and large helicopters with mitigation measures proposed for the Project attenuated to less than 92 dB, and preferably below 70 dB (disturbance threshold versus 92 dB disruption threshold) within a mile, to provide a report and additional data would be considered to reduce the threshold distances for those activities (Smith et al., 2007; Wille et al., 2006). Pacific Connector has adopted the FWS standard that northern spotted owls would detect project-related noise ≥4 dBA which would be a disturbance. Pacific Connector also adopted the FWS (2006e) threshold of 82 dB as a sound-related injury threshold level for northern spotted owls and a tolerance threshold of 92 dB for approaching aircraft. Based on evidence reviewed and summarized above, Pacific Connector has proposed and applied that project-related noise at levels between the two thresholds constitute a disturbance, not a disruption.

**Blasting and Helicopter Noise Levels.** Pacific Connector prepared a report (see appendix P) that analyzes the distances at which conventional blasting required for trenching within rock substrate for pipeline construction and transport helicopters attenuate to 92 dB. Appendix P shows empirical noise data evaluations for trench blasting and heavy transport helicopters and was used to determine the distances for which noise levels remain below 92 dB during construction operations with appropriate mitigation measures applied. Under the worst case conditions with common and appropriate mitigation measures applied to trench blasting operations, it is expected that blasting noise would attenuate to 92 dB within 200 feet of the source, and to 70 dB within 1,025 feet of the blast source in soft rock. Likewise, large transport helicopters would attenuate to 92 dB within 700 feet. The greater distance for helicopter use is due to the directional aspects of blade slap noise that is directed toward the ground.

Mitigation for helicopter noise includes operational restrictions, such as maintaining a high altitude and flight paths away from noise sensitive areas whenever possible. Analyses for NSOs in this biological assessment consider the distances for larger blasts and large helicopters to be more conservative than what the noise report suggests. Pacific Connector has suggested a disruption threshold distance for blasting greater than 92 dB but with mitigation measures applied to be the same disruption distance expected for smaller blasts (less than 92 dB) – 120 yards or 360 feet – more conservative than the noise report describes, and the disturbance threshold distance associated with large blasts to be expected within 0.25 mile of blasting activity (see table 4.3.4-10). It is expected that these distances be considered throughout the entire breeding season (March 1–September 30) because of the sudden onset of noise associated with blasting activities. Pacific Connector has suggested a disruption threshold distance for large/transport helicopter use with proposed mitigation to be slightly farther than the report suggests, considering disruption distance of 240 yards (720 feet) and a disturbance threshold distance of 0.25 mile (see table 4.3.4-10).

**Table 4.3.4-10**
**Threshold Distances Where Noise and Visual Disturbances are Unlikely to Occur to Nesting Northern Spotted Owls during the Breeding Season [1]**

| Activity | Disruption Threshold Distances From NSO Activity Centers | | Disturbance Threshold Distance From NSO Activity Centers | |
|---|---|---|---|---|
| | NSO Critical Breeding Season [2] | NSO Late Breeding Season [2] | NSO Critical Breeding Season [2] | NSO Late Breeding Season [2] |
| Existing Road Use [3] | 35 yards (105 feet) | No Disruption Anticipated | 0.25 mile | No Disturbance Anticipated |
| Chainsaws [4] | 45 yards (135 feet) | No Disruption Anticipated | 0.25 mile | No Disturbance Anticipated |
| Heavy equipment [3] | 35 yards (105 feet) | No Disruption Anticipated | 0.25 mile | No Disturbance Anticipated |
| Rock ditching equipment [4] | 120 yards (360 feet) | No Disruption Anticipated | 0.25 mile | No Disturbance Anticipated |
| Blasting – more than 2 pounds with mitigation measures | 120 yards (360 feet) | 120 yards (360 feet) | 0.25 mile | 0.25 mile |
| Small Helicopter/Airplanes | 120 yards (360 feet) | No Disruption Anticipated | 0.25 mile | No Disturbance Anticipated |
| Large/Transport Helicopters with mitigation measures [5] | 240 yards (720 feet) | 240 yards (720 feet) | 0.25 mile | 0.25 mile |

[1] Sources: FWS, 2003b, 2006f; PC Trask & Associates, 2013; Michael Minor & Associates, 2008 (see appendix P).
[2] Northern Spotted Owl breeding period is from March 1-September 30; critical breeding period is considered from March 1-July 15; late breeding season is considered from July 16-September 30.
[3] Heavy equipment includes: back trackhoes, side-booms, bulldozers, semi-trucks, pneumatic hammers.
[4] Rock ditching equipment includes: auger drill rig, mounted impact hammer (hoe ram), rock drill, and blasting (mitigated or less than 2 lbs; see figure 3.2-3.
[5] Transport helicopters proposed for this Project include: Boeing Chinook (CH-47) and Boeing Vertol 107-II (CH-46)

Even though FWS (2003b) provided some evidence suggesting that noise that builds gradually, such as a helicopter approaching from a distance, may result in less risks, and even though FWS does not anticipate effects from smaller aircraft use after the critical breeding period, for analysis within this assessment, Pacific Connector anticipated that use of large/transport helicopters may disrupt or disturb NSOs throughout the entire breeding season (March 1–September 30). In a memorandum provided to TetraTech, contractor to FERC (September 16, 2008), FWS indicated that if noise levels above 92 dB are recorded at 0.25 mile of the blasting activities, that blasting operations should cease until more effective mitigation measures can be employed.

**Noise Evaluation Procedure**. Pacific Connector has prepared a Noise Evaluation (see appendix Z3) to assist in evaluating noise effects of proposed activities for each NSO activity center analyzed within the Provincial Analysis Area, considering reviewed available scientific literature on behavioral and physiological responses of bird species to various noises, as well as the ambient noise level near each NSO activity center. The guidance provided in Table 4.3.4-10 was derived under forested situations and are not applicable to many of the field situations and habitats through which the PCGP Project passes. Also, available research and anecdotal reports do not support use of fixed distances between a noise source and northern spotted owl responses indicating disruption. Noise levels attenuate differently under various conditions which are not accounted for in the FWS guidance.

The noise evaluation estimates noise attenuation at each NSO nest site from the proposed project activities due to hard site (hard, smooth surfaces intervening between source and receptors) and soft site (irregular, vegetated surfaces) conditions, intervening tree cover, topography, and/or differential elevations allowing lines-of-sight between sources and receptors. This noise evaluation has been used as an adjustment factor of direct effects (disturbance and disruption) for individual NSO nest stands in the impact assessments located in appendix Z2 and included in table Q-8 in appendix Q.

**Disruption and Disturbance – Timber Clearing, Pipeline Construction, Existing Road Use.** Approximately 3.7 miles of timber clearing and construction will occur within 0.25 mile of 10 NSO activity centers (four known sites, four best location sites, and two PCGP assumed sites; see table 4.3.4-11). Pacific Connector has proposed to clear timber within 0.25 mile of NSO activity centers outside of the entire breeding season (between October 1 and February 28); therefore, noise, visual disturbance, and in some instances large helicopter use would not be expected to disturb or disrupt NSO breeding activities (see Habitat Removal during Breeding Season, above). However, due to construction constraints, safety of construction crew, and adherence to the in-service date, Pacific Connector would need to construct within 0.25 mile of activity centers during the breeding season. To minimize disturbance, though, Pacific Connector will construct within 0.25 mile of activity centers after the critical breeding season (after July 15). With the exception of helicopter activities that could occur within 0.25 mile of three NSO activity centers (2317B, PCGP 095.3, and assumed PCGP A-1) and potential blasting activities (greater than 2 pounds of explosives) that could occur within 0.25 mile of six NSO activity centers (two known sites, three best location sites, and one PCGP assumed site), acoustic and visual disturbances from the proposed action are not expected to disrupt NSO nesting and rearing activities because they would occur after the critical breeding season (see table 4.3.4-10). Table Q-8 in appendix Q provides distances from proposed project activities (timber clearing, construction activities, road use, operations/maintenance) and timing of those actions that are expected to occur within 0.25 mile of known, best location, and PCGP assumed NSO sites during timber removal, construction activities (including large transport helicopter use and blasting > 2 pounds of explosives), and access road use. Additionally, table Q-8 in appendix Q provides the expected direct effect (disruption, disturbance, no effect) and rationale for each known, best location, and PCGP assumed NSO site based on timing and distance from the Project activities for each proposed activity (based on disturbance distances from table 4.3.4-10), as well as site-specific analysis included in the Noise Evaluation (appendix Z3).

Informal consultations with FWS (June 5, 2008 meeting; see NSO and MAMU Avoidance Plan) identified disturbance from travel on existing roads to be less of an impact than other actions associated with the proposed Project, especially if farther than 35 yards (105 feet). Additionally, BLM does not consider disruption or disturbance effects to occur to MAMU from use of existing access roads throughout the entire breeding season (see Coos Bay FY2008-2013 Programmatic Consultation #13420-2008-F-0118). Based on available scientific literature, use of existing roads may be detectible by NSO within 0.25 mile but it is not expected that use of every existing road would disturb nesting northern spotted owls and use of existing roads would not significantly disrupt normal behavior patterns and lead to harassment under the ESA, described above (see also Pacific Connector's Noise Evaluation in appendix Z3). Therefore, Pacific Connector assumes that use of existing access roads (EARs), regardless of distance from road to activity center would be a potential disturbance to NSO and could result in temporary reduced habitat suitabilility, but would not disrupt breeding behaviors.

**Expected Disturbance Effects.** Impact assessments for each NSO activity center analyzed within this BA (see appendix Z2) identify how far a NSO activity center is in relation to proposed construction activities, including large transport helicopter use and blasting (greater than 2 pounds of explosives). The impact assessments also identify existing access roads within 0.25 mile of known, PCGP Assumed, or best location NSO sites, including distance from the access road(s) and expected road improvements within the nest patch or 0.25-mile buffer of the activity site. Each NSO activity center has a series of maps with the analysis that show the NSO home range in relation to the proposed actions and include a 0.25 mile spatial buffer around each activity center (see appendix Z2). Additionally, maps 1 - 50 in appendix Q show the locations of NSO activity centers in relation to different Project components and identify spatial buffers (360 feet and 0.25 mile buffers) associated with a NSO activity site. Table 4.3.4-11 summarizes the effects (disruption, disturbance, no effect) to known, best location, or PCGP assumed owl sites located within 0.25 mile of proposed project activities, including use of access roads within the Provincial Analysis Area affected (disturbed) by the proposed Project based on the timing of activities, distance from proposed activity to NSO activity center, and site-specific noise evaluations prepared for each NSO activity center (appendix Z3) (summarized from table Q-8 in appendix Q). Noise expected during each phase of pipeline construction as it relates to equipment associated with each phase is provided in table 3.1.3.3-2, and has been applied to each NSO activity center individually in the Noise Evaluation (appendix Z3). This analysis is conservative, assuming that each NSO activity site (known – historic and current location, best location sites – no known nest site, and PCGP assumed sites – no known nest site) is actively reproducing and if located within 0.25 mile of the project could be affected by project activities. Also, the closest alternate nest site was considered, although it may not have the most recent documented reproductive activity.

**Maintenance and Operation.** No activities associated with general maintenance and operations of the proposed action are expected to affect NSO sites. FERC requires that vegetation maintenance activities occur only between August 1 and April 15 of any year (see appendix C). To reduce impacts to nesting NSOs, Pacific Connector would maintain vegetation within the pipeline corridor after the entire breeding season within known, best location, and PCGP assumed nest patches and after the critical breeding season within a 0.25 mile of NSO activity centers. Routine clearing of vegetation greater than 6 feet in height within the 30-foot permanent right-of-way would not occur more frequently than every 3 years. A 10-foot corridor centered over the pipeline may be maintained annually in an herbaceous state to facilitate periodic corrosion and leak surveys. Pacific Connector would also require pilots conducting annual aerial inspection (small plane/helicopter) of the pipeline to adhere to the spatial restrictions recommended in the vicinity of known, best location, or PCGP assumed sites (no overflight within 1,300 feet agl during the critical breeding season [March 1 through July 15]); no effects from aerial pipeline inspection would be expected.

## Table 4.3.4-11
## Number of Northern Spotted Owl Sites within each Physiographic Province with Expected Disturbances from Noise and/or Visuals Associated with Activities Proposed within 0.25 mile of Activity Centers[1]

| Status of Northern Spotted Owl Site | Total Number of Owl Sites | Construction Activities and Road Use[2] | | Construction Activities Only[3] | | Road Use Only[4] | | None[5] |
|---|---|---|---|---|---|---|---|---|
| | | Disruption | Disturbance | Disruption | Disturbance | Disruption | Disturbance | |
| Known Site | 13 | 0 | 0 | 1 | 0 | 0 | 7 | 5 |
| Best Location | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| PCGP Assumed | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| Coast Range Total | 18 | 0 | 0 | 1 | 0 | 0 | 9 | 8 |
| **Klamath Mountains Physiographic Province** | | | | | | | | |
| Known Site | 33 | 0 | 1 | 0 | 0 | 0 | 7 | 25 |
| Best Location | 10 | 2 | 1 | 0 | 0 | 0 | 3 | 4 |
| PCGP Assumed | 4 | 0 | 1 | 0 | 0 | 0 | 1 | 2 |
| Klamath Mountains Total | 47 | 2 | 3 | 0 | 0 | 0 | 11 | 31 |
| **West Cascades Physiographic Province** | | | | | | | | |
| Known Site | 21 | 0 | 1 | 0 | 1 | 0 | 8 | 11 |
| Best Location | 6 | 0 | 1 | 0 | 0 | 0 | 2 | 3 |
| PCGP Assumed | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| West Cascades Total | 28 | 0 | 2 | 0 | 2 | 0 | 10 | 14 |
| **East Cascades Physiographic Province** | | | | | | | | |
| Known Site | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| Best Location | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PCGP Assumed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| East Cascades Total | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| **Total Physiographic Provinces** | | | | | | | | |
| Known Site | 72 | 0 | 3 | 1 | 1 | 0 | 22 | 45 |
| Best Location | 17 | 2 | 2 | 0 | 0 | 0 | 5 | 8 |
| PCGP Assumed | 9 | 0 | 1 | 0 | 1 | 0 | 3 | 4 |
| Overall Total | 98 | 2 | 5 | 1 | 2 | 0 | 30 | 58 |

[1] Summarized from table Q-8 in appendix Q.
[2] Construction Activities and Road use: both proposed activities occur within 0.25 mile of NSO activity center
[3] Construction Activities Only: includes general construction activities, blasting (> 2lbs explosives), and large transport helicopter use; no proposed road use within 0.25 mile of NSO activity centers
[4] Road use only: no construction activities proposed within 0.25 mile of NSO activity centers
[5] None: construction and proposed road use > 0.25 mile of NSO activity center

Helicopter Rotor Wash

Strong winds can adversely affect NSOs (FWS, 1990) by directly removing habitat from windthrow that could fragment forests and increase edge effects (risk of predation, microclimatological changes). Wind can also cause direct mortality by blowing chicks out of nests (FWS, 1992b). Helicopter drive rotors produce high velocity vortices (winds) that extend from the center of the helicopter outward in all directions. Vertical downwash of air (rotor wash) close enough to the ground produces surface winds that dissipate as they move away from the helicopter (sidewash). Induced winds caused by helicopter rotor wash may exceed hurricane force velocities and would be expected to adversely affect nesting NSOs in the area. Since induced rotor downwash and surface sidewash are functions of helicopter size, rotor surface area, helicopter weight, flight speed and height above ground (Teske et al., 1997; Gordon et al., 2005), effects to nesting birds can be minimized or avoided by routing helicopter flight paths and staging locations far enough away from nests so that locally induced winds would not adversely affect nests or nestlings.

Maximum induced surface velocities produced by downwash and sidewash from various helicopters were measured in the field to determine the decay function of rotor-produced vortices near ground level (Teske et al., 1997). Field studies included measurements on three helicopter models that might be utilized during construction of the Pacific Connector pipeline: 1) the twin-rotor CH-47 (civilian variant is the Boeing HH-47 Chinook) with rotor diameter 59.1 feet, 2) the single rotor CH-54 with a rotor diameter of 72 feet (civilian variant is the Sikorsky S-64 Skycrane), and 3) the twin-rotor CH-46 (civilian variant Boeing Vertol 107) with rotor diameter of 49.9 feet (Teske et al., 1997). Using parameters derived from the field trials, estimates of maximum induced surface velocities were made for each of the three helicopter models at varying heights above ground while flying at different ground speeds. In general, maximum induced surface velocities increase with rotor diameters, decrease with distance above ground, and decrease with faster ground speeds.

Results of modeling maximum induced surface velocities (model described in Teske et al., 1997) produced by a Chinook helicopter are shown in figure 4.3-14 for drop heights (heights above ground level at which the helicopter would discharge a payload of foam, water, or retardant during wild fire control) ranging from 10 to 320 feet while flying at ground speeds ranging from 5 to 25 miles per hour (mph). Included in figure 4.3-14 are four wind speed categories on the Beaufort Scale (NOAA: http://www.spc.noaa.gov/faq/tornado/beaufort.html) which was developed to describe damage associated with wind forces ranging from calm to hurricane forces. On the Beaufort Scale, induced surface winds of 9 to 11 mph produced by rotor wash would be equivalent to a “gentle breeze” during which leaves and small twigs would be constantly moving and light flags would be extended. Wind velocities of 19-24 mph are classified as a “fresh breeze” (small trees in leaf would sway). Wind velocities of 19 to 24 mph are classified as a “fresh breeze”; small trees in leaf would sway. Winds 39 to 46 mph are “gale” force strength – difficult to walk against while twigs and small branches would be blown off trees - and winds greater than 74 mph are classified as a “hurricane”.

Figure 4.3-14 shows the heights above ground that Chinook helicopters would produce maximum induced surface winds with velocities equivalent to a “fresh breeze” while traveling at ground speeds of 5, 10, 15, 20 or 25 mph. For example, if traveling at a ground speed of 5 mph, the Chinook would have to be approximately 185 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a "fresh breeze". If traveling at ground speed of 25 mph, the Chinook could be 75 feet above ground and still induce a maximum surface velocity of 24 mph.

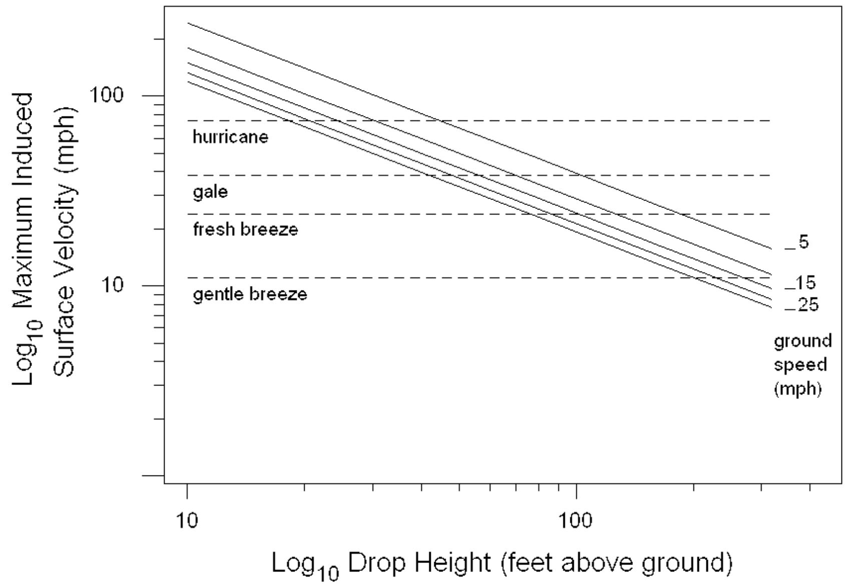



**Figure 4.3-14**
**Modeled Maximum Surface Velocities Induced by Chinook C-47 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground. (Modeled from data in Teske et al., 1997)**

In the Project area, wind speeds reported by the Western Regional Climate Center (available online at http://www.wrcc.dri.edu/htmlfiles/westwind.final.html#OREGON) at the North Bend airport averaged 10.2 mph in June, 11.2 mph in July and 9.9 mph in August, the three months with highest average wind velocities during the period from 1996 to 2006. During the same period, winds in Roseburg averaged 5.0 mph in June, 5.2 mph in July, and 4.4 mph in August. These data indicate that winds as strong as a fresh breeze (19-24 mph) would be expected along the Oregon Coast and most likely inland during the period when NSOs are nesting. We assume that induced winds the strength of a fresh breeze would not adversely affect young or nests. Incoming or outgoing Chinook helicopters flying at 5 mph while 185 feet above a tree with a nest would most likely produce winds with velocities less than a fresh breeze at the tree top because there would be no resistance by the ground to induce maximum sidewash vortices.

Similar results were produced by the Boeing Vertol 107 (see figure 4.3-15) even though it is smaller than the Chinook (rotor diameter 49.9 feet compared to 59.1 feet). The Vertol 107, flying at a ground speed of 5 mph, would have to be approximately 200 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a fresh breeze. If traveling at a ground speed of 25 mph, the Vertol 107 could be 82 feet above ground and still induce a maximum surface velocity of 24 mph. Overall, the Vertol 107 produces slightly greater maximum induced surface velocities than the Chinook CH-47 even though its maximum equipment weight is less than the Chinook.

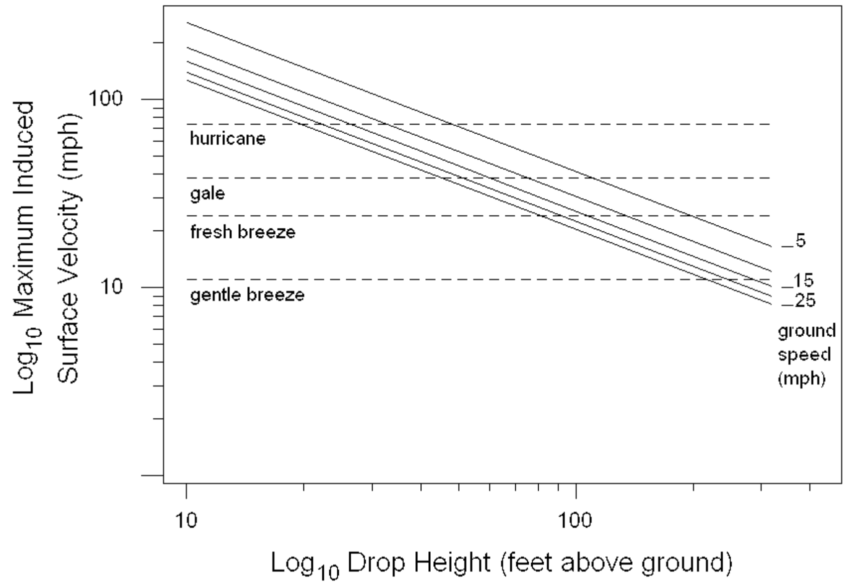



**Figure 4.3-15**
**Modeled Maximum Surface Velocities Induced by Boeing Vertol 107 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground (Modeled from data in Teske et al., 1997**

The single rotor S-64 Skycrane has the largest rotor diameter (72 feet diameter) of the three models. As modeled in figure 4.3-16, the Skycrane would produce greater maximum induced surface velocities while flying at the same ground speeds and same drop heights as the other two helicopter models.

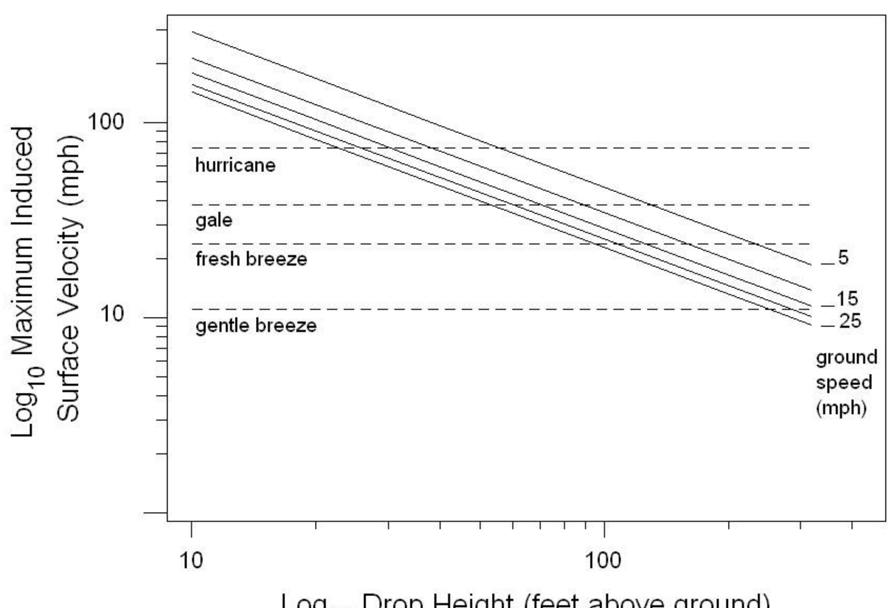



**Figure 4.3-16**
**Modeled Maximum Surface Velocities Induced by Skycrane S-64 Helicopters while Flying at Ground Speeds From 5 to 25 mph at Heights From 10 to 320 feet Above Ground. (Modeled from data in Teske et al., 1997**

Flying at a ground speed of 5 mph, the Skycrane would have to be approximately 233 feet above ground to produce a maximum induced surface velocity of 24 mph, equivalent to a fresh breeze. The Chinook and Vertol 107 helicopters would induce similar maximum surface velocities flying at heights of 185 feet and 200 feet above ground, respectively. If traveling at ground speed of 25 mph, the Skycrane could be 95 feet above ground to induce a maximum surface velocity of 24 mph.

Actual downwash and sidewash vortices produced by Chinook CH-47 and Skycrane (CH-54) helicopters were measured during field tests (Leese and Knight, 1974) while aircraft were hovering at 40–50 feet and 80–90 feet above ground level (agl) while under maximum loads of 36,000 pounds (CH-47) and 45,000 to 47,000 pounds (CH-54). The Vertol 107 (CH-46) was not included in the field tests.

With a 47,000-pound load, the single rotor CH-54 hovering at 40 feet agl produced a maximum sidewash velocity of 87 mph 50 feet away from the rotor hub. At 80 feet agl, the maximum sidewash was 74 mph, also measured at 50 feet from the hub though the gross weight was 45,000 pounds during that particular trial. Both maximum sidewash measurements were at heights of 0.3 feet above ground (Leese and Knight, 1974). Under the specified load conditions, the CH-54 produced a sidewash of 11 mph 170 feet away from the rotor hub while hovering at 40 feet agl and a sidewash of 9 mph 150 feet away from the hub while hovering at 80 feet agl. Maximum sidewash velocities of 74–87 mph that were associated with the CH-54 helicopter while it was hovering, are within the range of hurricane force winds on the Beaufort Scale while winds of 9–11 mph produced by rotor sidewash would be described as a “gentle breeze”. Sidewash velocities between 9 and 11 mph at distances 150 to 170 feet away from a CH-54 helicopter (Skycrane) would not create a risk of young NSOs being blown out of nests.

Downwash and sidewash velocities measured for the CH-47 helicopter (Chinook) were greater than 100 mph up to 70 feet horizontally from the rotor hub when it was hovering at 90 feet agl with maximum load of 36,000 pounds (Leese and Knight, 1974). The twin rotor CH-47 produced sidewash velocities as high as 56 mph 190 feet away from the rotor hub when it was hovering 90 feet agl. The Beaufort Scale classifies winds between 55 and 63 mph as a “storm”, with trees uprooted and structural damage likely. The strength of winds produced by the CH-47 is likely due to the interaction of descending air produced by the two rotors (Fabey, 2008); sidewash winds are generally strongest at 120 and 240 degrees (4 o’clock and 8 o’clock, respectively) relative to the helicopter’s heading (data in Leese and Knight, 1974).

Sidewash wind velocities produced by the CH-47 at various distances away from the rotor hub (Leese and Knight, 1974) were used to predict the distance at which the helicopter would be far enough away from adversely affecting NSO nests and young. The prediction is based on the sidewash wind velocities produced by the CH-47 averaged for wind measurements made 0.3 feet above ground at angles of 120 and 240 degrees while the helicopter was hovering 90 feet agl under a load of 36,000 pounds. The prediction is shown below in figure 4.3-17 in which a sidewash velocity of 0 mph would occur 293 feet away from the rotor hub. Due to the observed variation in sidewash winds at different distances away from the rotor hub (solid circles in figure 4.3-17), the upper 95 percent prediction interval on that predictive estimate of 0 mph at 293 feet from the hub would be 23.8 mph. A wind velocity of 23.8 mph is classified as a fresh breeze on the Beaufort Scale. One would be 95 percent certain that a stronger wind would not occur which could potentially adversely affect nesting NSOs.

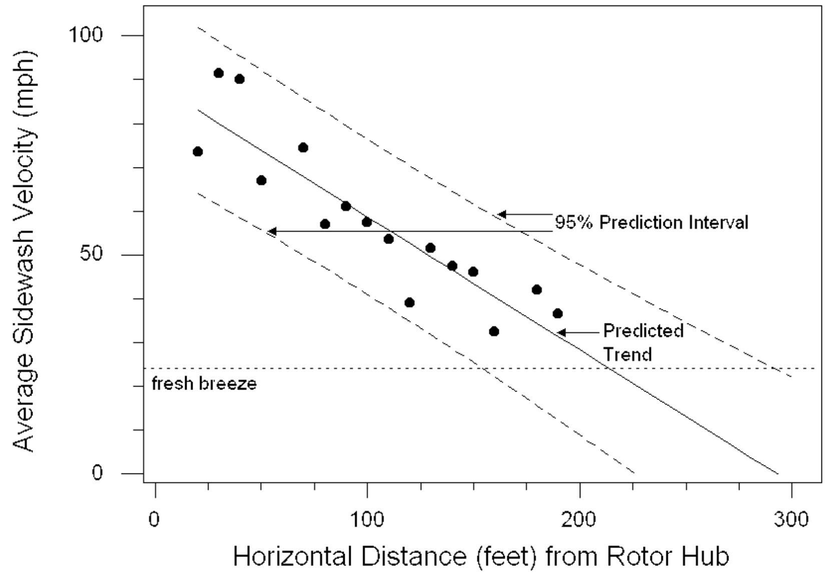



**Figure 4.3-17**
**Average Sidewash Wind Velocities Produced by the CH-47 at Varying Horizontal Distances from the Rotor Hub While Hovering 90 feet agl Under a Load of 36,000 pounds. The Observed Averages (solid circles) were used to Predict Sidewash Winds at Distances Out to 300 feet. (Source: Leese and Knight, 1974)**

These estimates clearly suggest that greater distances would be required to avoid adverse effects to NSOs if Chinook helicopters, rather than Skycranes, are employed for heavy lifting along remote sections of the Pacific Connector pipeline construction right-of-way. Based on the similarities of maximum induced surface velocities between Chinook and Vertol 107 helicopters, sidewash velocities induced while hovering are likely to be similar as well. However, if known NSO activity centers can be avoided by at least 200 feet above tree tops by heavy-lifting helicopters in transit and avoided horizontally by at least 300 feet while helicopters hover above staging sites, no adverse effects to the species would be expected due to rotor downwash and induced sidewash.

Three activity centers occur within 0.25 mile of proposed helicopter use (known 2317B, best location site PCGP 095.3, and assumed PCGP A-1), of which all sites could have helicopter activity within their nest patch (see table Q-8 in appendix Q, and individual NSO impact assessments, appendix Z2). Helicopter use for timber extraction within 0.25 mile of a NSO activity center would occur outside of the entire breeding season (between October 1 and February 28); no adverse effects from rotor wash of large helicopters are expected during timber extraction. Adverse effects to the three NSO activity centers could occur from rotor wash of large helicopters during pipe delivery for construction of the proposed action since it may be within 200 feet above nest trees and horizontally within 300 feet of nest trees; however, the nest site is unknown for each activity center, including known 2317B. Helicopter use would only occur after the critical breeding season (after July 15), minimizing risk to NSO.

Burning and Smoke

Effects on NSOs from smoke, whether by prescribed burning as a habitat enhancement procedure or by burning slash have not been studied. However, FWS et al. (2007) have declared (see Table 15, FWS et al., 2007) that "smoke can cause [spotted owl] adults to move off nest sites, therefore leaving eggs or young exposed to predation or resulting in lost feedings reducing the young's fitness."

According to BLM and Forest Service (2008, page 34), NSOs "are potentially affected by fire control activities and drifting smoke during burning. The threshold distance for disturbance from smoke is 0.25 mile for spotted owls," which would be subject to smoke-related disturbance during the critical breeding period (March 1 to July 15). Pacific Connector would not conduct slash burning during the critical breeding season within 0.25 mile of an occupied NSO activity center during the critical breeding season. No direct effect to NSOs due to slash burning is expected.

**Indirect Effects**

Project-related effects to NSOs which are caused by the action (induced by the action and by human presence and use increase) and are later in time or farther removed in distance, but are still reasonably foreseeable are indirect effects. Habitat loss and modification, whether to nesting, roosting or foraging habitats, due to forest clear-cutting has been the most significant factor causing declines of the NSO (FWS, 1992b). Habitat losses and habitat fragmentation have indirect impacts that can affect survival and reproduction of NSOs. Short-term impact is expected with UCSAs and is likely to last from the initiation of use until 1 to 5 years afterward. Long-term impact to NSOs and NSO habitat is expected to last at least 5 years or more.

Other indirect effects to NSOs that are often related to habitat loss or modification are increased predation, increased competition, and effects to prey utilized by NSOs. In addition, secondary effects (Comer, 1982) due to an increased human population base are expected, whether resulting from the requirements of the action itself (the workforce needed to construct or operate the Project) or as consequences of the action (need for ancillary goods, services, recreational opportunities resulting from the Project). Potential indirect or secondary effects by the proposed Project include increased recreation demand (including off-road vehicle use), increased habitat conversion, and habitat degradation by human intrusion and encroachment (Comer, 1982).

To determine effects to known, best location, and PCGP assumed owl home ranges within the Provincial Analysis Area, 14 NSO groups were created that included all known, best location, and PCGP assumed owls whose home ranges overlapped. Table 4.3.4-12 summarizes the number of owls by status (known, best location, and PCGP assumed) and physiographic province that occur within each owl group. The number of owls included in each group varied from one to 39 NSO activity centers (see table Q-7 in appendix Q for specific information on each northern spotted owl site included in each owl group). Owl groups have been used to identify the area of habitat being affected within and outside of NSO home ranges in the PCGP Project area.

**Table 4.3.4-12**
**Summary of the Number of Northern Spotted Owls Included in each Owl Group by Owl Status**
**(known, best location, PCGP assumed) and Physiographic Province [1]**

| NSO Group | Project Location | Number of Northern Spotted Owl Sites within each Group: Known [2] | Best Location [2] | PCGP Assumed [2] | Total |
|---|---|---|---|---|---|
| **Coast Range Physiographic Province** | | | | | |
| CR-A | MP 9.33R-12.04R | 1 | 0 | 0 | 1 |
| CR-B | MP 32.47-48.42 | 11 | 1 | 4 | 16 |
| CR-C | EAR 46.51; Kenyon Mountain CT | 1 | 0 | 0 | 1 |
| | *Total Coast Range* | *13* | *1* | *4* | *18* |
| **Klamath Mountains Physiographic Province** | | | | | |
| KM-D | MP 53.02 – 55.41 | 2 | 0 | 0 | 2 |
| KM-E | MP 58.95 – 65.66 | 1 | 2 | 0 | 3 |
| KM-F | MP 76.99 – 113.68 | 28 | 8 | 3 | 39 |
| KM-G | MP 116.21 – 121.38 | 2 | 0 | 2 | 4 |
| | *Total Klamath Mountains* | *33* | *10* | *5* | *48* |
| **West Cascades Physiographic Province** | | | | | |
| WC-H | MP 125.06 – 127.31 | 1 | 0 | 0 | 1 |
| WC-I | Flounce Rock CT | 1 | 0 | 0 | 1 |
| WC-J | MP 132.83 – 137.70 | 2 | 0 | 2 | 4 |
| WC-K | TEWA 144.00 | 1 | 0 | 0 | 1 |
| WC-L | MP 150.51 – 167.71 | 16 | 6 | 0 | 22 |
| | *Total West Cascades* | *21* | *6* | *2* | *29* |
| **East Cascades Physiographic Province** | | | | | |
| EC-L (part of group WC-L) | MP 167.71 – 170.70 | 2 | 0 | 0 | 2 |
| EC-M | MP 172.34 – 176.04 | 3 | 0 | 0 | 3 |
| | *Total East Cascades* | *5* | *0* | *0* | *5* |
| | **Overall Total within Provincial Analysis Area** | **72** | **17** | **9** | **98** |

[1] Summarized from table Q-7 in appendix Q.
[2] Owl status: known (provided by BLM Districts, Forest Service, or FWS within the project area), PCGP assumed (area identifed by Pacific Connector that may provide habitat for NSO activity center), best location (no nest located during PCGP survey efforts but survey results determined best potential site for nest).

Habitat Removal and Modification

The decline of NSOs has been linked to the removal and degradation of available suitable NRF habitat. Appropriate vegetation and structural components are necessary to maintain suitable habitat, and the removal of these components can potentially have adverse effects on NSO populations. These effects could include displacement from traditional nesting areas, increased concentration of NSOs into smaller, fragmented areas of suitable habitat, and diminished reproductive success (FWS, 2006f).

In the Provincial Analysis Area, NSO habitat needs and home ranges vary based on physiographic provinces and forest type. In the Coast Range Physiographic Province (MP 1.47R to MP 52.21), the home range is assumed to be circular with a radius of 1.5 miles. Within the Klamath Mountains Physiographic Province (MP 52.21 to MP 122.61) the home range radius is

1.3 miles, and in the West Cascades (MP 122.61 to MP 167.71) and East Cascade Physiographic Provinces (MP 167.71 to MP 191.19) the home range radius is 1.2 miles (FWS, 1992d). Although differences exist in natural stand characteristics that influence provincial home range size, habitat loss and forest fragmentation caused by timber harvest effectively reduce habitat quality in the home range. A reduction in the amount of suitable habitat reduces NSO abundance and nesting success (Bart and Forsman, 1992; Bart, 1995), and recent studies have indicated that NSOs' home ranges are substantially larger in more heavily fragmented stands (Courtney et al., 2004).

The Pacific Connector pipeline would affect NSOs over the long-term by habitat removal and modifications. Table 4.3.4-13 summarizes effects to NSO habitat from construction and operation (30-foot maintenance corridor) of the proposed Project by physiographic province, land owner, and Project component (see table Q-9 in appendix Q for detailed information on habitat impact including amount removed/modified from CHUs, NWFP LSRs, and interior forest, by landowner within and outside of NSO groups). Habitat cleared outside of the 30-foot maintenance corridor would be revegetated and allowed to return to its pre-action state.

In total, the Project would remove approximately 565 acres of suitable NRF (high NRF and NRF) habitat during construction (see table 4.3.4-13; table Q-9 in appendix Q), of which approximately 145 acres would be permanently lost to the pipeline corridor and maintained free of vegetation for the life of the Project within the 30-foot maintenance corridor (table 4.3.4-13; table Q-9 in appendix Q). The other 420 acres of suitable NRF habitat cleared outside the 30-foot maintenance corridor would be revegetated and considered capable of becoming NRF habitat in approximately 80 years, although some of it may become functional foraging or roosting habitat prior to 80 years. Removal of 565 acres of NRF habitat across the four physiographic provinces crossed represents approximately 0.6 percent of the 89,562 acres of suitable NRF/high NRF habitat in the Provincial Analysis Area (see table 4.3.4-5, above). Additionally, 245 acres of suitable NRF habitat have been identified for use by the proposed Project as UCSAs, which would not have vegetation removed but may be used to store forest slash, stumps, and dead and downed log materials between existing trees during construction and before they are scattered across the right-of-way after construction during restoration (see table 4.3.4-13; table Q-9 in appendix Q). Use of the UCSAs would be a short-term modification of suitable NRF habitat, and habitat function should be maintained.

Approximately 1,256 acres of dispersal habitat (high NRF, NRF, and dispersal only habitat) would be removed by the proposed action, of which the majority would be removed within Klamath Mountains Physiographic Province. Removal of 1,256 acres of dispersal habitat within the four physiographic provinces crossed by the proposed Project represents approximately 0.9 percent of all total available dispersal habitat (143,449 acres) within the Provincial Analysis Area (see high NRF, NRF, and dispersal only habitat in table 4.3.4-5).

Discussion at the Task Force - ESA Consultation Subgroup meeting on April 2, 2008 indicated that NSO dispersal habitat could be considered adequate if at least 50 percent of the analysis area (in the Project's case, the defined provincial analysis area) consisted of dispersal habitat. Table 4.3.4-5 shows the amount of dispersal habitat available and its percentage in each physiographic province within the defined provincial analysis area. Only one physiographic province is currently above the recommended threshold of 50 percent available dispersal habitat – West Cascades (50.9 percent). Removal of 313.13 acres of dispersal habitat from the West Cascades Physiographic Province crossed would not cause the amount of available dispersal habitat within the defined Provincial Analysis Area to drop below the recommended 50 percent dispersal habitat threshold (approximately 37,062 acres or 50.4 percent available). The reduction of available dispersal habitat within the provinces crossed is not considered significant. Additionally, removal of dispersal habitat would not be in one locale, but would be removed along 193.3 miles of proposed pipeline in the range of the NSO. After the Project is completed, neither the temporary 95-foot-wide construction right-of-way and associated temporary extra work areas or the permanent 30-foot maintenance corridor should impede the movement of juveniles and adults.

Construction and permanent effects to habitat capable of becoming suitable NRF habitat (Capable Habitats) are also included in table 4.3.4-13. Approximately 1,022 acres of NSO capable habitat would be removed by construction of the proposed Project, of which 223 acres would remain in a permanent herbaceous/shrub state within the 30-foot operational corridor for the life of the Project. Approximately 743 acres of capable habitat removed on private lands is not expected to mature to provide suitable NRF or high NRF habitat for NSO based on review of research on timber harvest practices in Oregon (Zhou et al., 2005; Rasmussen et al., 2012). These studies noted that forest harvest practices on non-federal lands typically occur between 45 and 65 years of age.

If just considering habitat within the known, best location, or PCGP assumed home ranges of NSOs within the analysis area (see NSO Groups in table 4.3.4-13), approximately 431 acres of suitable NRF habitat (high NRF and NRF) would be removed and impacted over the long term; 221 acres would be impacted over the short-term by potential use of proposed UCSAs. This is approximately 76 percent of suitable NRF habitat removed or modified by the proposed Project. Table Q-10 in appendix Q provides a summary of suitable, dispersal, and capable habitat affected by the proposed Project within NSO groups by nest patch, core area, and home range. Suitable but unoccupied habitat removed outside of known, best location, or PCGP assumed home ranges may reduce the physical, geographical, and/or demographic connectivity between habitat and population reserves.

Davis et al., (2011) observed increased extinction rates of spotted owls in response to decreased amounts of old forest within the core area and higher colonization rates when old-forest habitat was less fragmented in the Southern Cascades Study Area, which is situated within the PCGP Project area on federal lands (see Population Status Section, above). The proposed action would affect NSO high NRF and NRF habitat within approximately 30 core areas (18 known sites, seven best location sites, and five PCGP assumed sites) mostly within the Klamath Mountains Physiographic Province (see table 4.3.4-14), potentially increasing habitat abandonment and/or barred owl competition and encroachment (see Davis et al., 2011). Table Q-7 in appendix Q identifies the location and distance of each spotted owl site center from construction of the PCGP Project, as well as identifies the current condition of each spotted owl nest site and the amount of habitat removed from the nest patch, core area, and home range for each NSO activity center, where applicable. It would be expected that spotted owl sites with less habitat available within their core area (i.e., Habitat Condition 2 or 4 in table Q-7 in appendix Q) would be affected more by habitat removal within their core area: four PCGP assumed sites, four best location sites, and nine known spotted owl sites (table 4.3.4-16, below).

**Table 4.3.4-13**
**Effects (acres) to Northern Spotted Owl (NSO) Nesting, Roosting, and Foraging (NRF) Habitat by Land Ownership from Construction and Operation of the Proposed Action within the Range of the NSO**

| | | High NRF[2] | | | NRF[3] | | | Dispersal Only[4] | | | Capable [5] | | | Non-Capable[6] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| **Land Owner** | **General Location[1]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** | **Removed[7]** | **UCSA[8]** | **30-foot Corridor[9]** |
| **Coast Range Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| BLM - Coos Bay | NSO Groups | 20.94 | 5.27 | 6.62 | 2.20 | 0.00 | 0.66 | 32.40 | 6.50 | 7.60 | 34.39 | 3.18 | 6.50 | 14.42 | 0.06 | 4.57 | 104.34 | 15.03 | 25.96 |
| | Outside NSO Groups | 4.16 | 0.00 | 1.29 | 1.32 | 0.00 | 0.32 | 35.67 | 0.00 | 8.89 | 10.64 | 0.00 | 2.30 | 3.12 | 0.00 | 0.62 | 54.90 | 0.00 | 13.43 |
| | Total | 25.09 | 5.27 | 7.91 | 3.52 | 0.00 | 0.98 | 68.07 | 6.50 | 16.50 | 45.03 | 3.18 | 8.80 | 17.54 | 0.06 | 5.20 | 159.24 | 15.03 | 39.39 |
| BLM - Roseburg | NSO Groups | 2.51 | 0.00 | 0.74 | 0.50 | 0.00 | 0.21 | 4.37 | 0.13 | 0.86 | 1.87 | 0.00 | 0.08 | 1.73 | 0.00 | 0.10 | 10.98 | 0.13 | 1.99 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 2.93 | 0.00 | 0.93 | 2.42 | 0.00 | 0.66 | 7.25 | 0.00 | 1.81 | 0.76 | 0.00 | 0.38 | 13.38 | 0.00 | 3.79 |
| | Total | 2.51 | 0.00 | 0.74 | 3.43 | 0.00 | 1.14 | 6.79 | 0.13 | 1.53 | 9.12 | 0.00 | 1.89 | 2.50 | 0.00 | 0.48 | 24.35 | 0.13 | 5.78 |
| State | NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.02 | 0.07 | 0.00 | 0.02 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 83.62 | 0.00 | 9.94 | 83.74 | 0.00 | 9.95 |
| | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 83.68 | 0.00 | 9.97 | 83.81 | 0.00 | 9.97 |
| Private / Other | NSO Groups | 3.31 | 0.25 | 0.94 | 0.43 | 0.00 | 0.12 | 22.44 | 3.62 | 3.90 | 159.80 | 19.72 | 31.93 | 63.48 | 0.45 | 12.92 | 249.45 | 24.04 | 49.80 |
| | Outside NSO Groups | 0.71 | 0.00 | 0.22 | 10.38 | 0.00 | 2.94 | 51.39 | 1.04 | 13.16 | 240.54 | 7.85 | 52.76 | 345.06 | 0.37 | 21.63 | 648.07 | 9.26 | 90.72 |
| | Total | 4.01 | 0.25 | 1.15 | 10.80 | 0.00 | 3.06 | 75.34 | 5.02 | 17.39 | 414.75 | 27.56 | 88.27 | 408.54 | 0.82 | 34.56 | 913.45 | 33.65 | 144.44 |
| *Coast Range Subtotal* | *NSO Groups* | 26.76 | 5.52 | 8.30 | 3.12 | 0.00 | 0.99 | 59.20 | 10.25 | 12.36 | 196.06 | 22.90 | 38.51 | 79.70 | 0.52 | 17.62 | 364.83 | 39.19 | 77.78 |
| | *Outside NSO Groups* | 4.87 | 0.00 | 1.50 | 14.63 | 0.00 | 4.19 | 89.60 | 1.04 | 22.73 | 258.43 | 7.85 | 56.88 | 432.56 | 0.37 | 32.58 | 800.09 | 9.26 | 117.88 |
| | *Total* | 31.62 | 5.52 | 9.80 | 17.75 | 0.00 | 5.18 | 150.32 | 11.65 | 35.42 | 468.90 | 30.75 | 98.97 | 512.26 | 0.88 | 50.20 | 1180.85 | 48.80 | 199.58 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| BLM - Roseburg | NSO Groups | 58.03 | 43.01 | 14.71 | 30.37 | 32.23 | 6.27 | 13.64 | 4.67 | 2.57 | 50.11 | 28.27 | 8.51 | 18.72 | 3.11 | 5.32 | 170.87 | 111.29 | 37.37 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 4.97 | 6.12 | 0.98 | 1.32 | 0.01 | 0.41 | 3.75 | 1.82 | 0.86 | 5.13 | 1.12 | 1.64 | 15.16 | 9.07 | 3.89 |
| | Total | 58.03 | 43.01 | 14.71 | 35.34 | 38.35 | 7.25 | 14.96 | 4.69 | 2.97 | 53.85 | 30.09 | 9.37 | 23.85 | 4.23 | 6.96 | 186.03 | 120.36 | 41.27 |
| BLM - Medford | NSO Groups | 0.00 | 0.00 | 0.00 | 14.96 | 7.15 | 3.56 | 9.61 | 2.73 | 2.45 | 0.90 | 0.62 | 0.47 | 8.39 | 1.89 | 2.12 | 33.87 | 12.40 | 8.61 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 8.27 | 1.35 | 1.63 | 9.62 | 2.91 | 2.63 | 4.44 | 0.17 | 1.01 | 1.08 | 0.01 | 0.20 | 23.40 | 4.44 | 5.48 |
| | Total | 0.00 | 0.00 | 0.00 | 23.23 | 8.50 | 5.20 | 19.23 | 5.64 | 5.08 | 5.34 | 0.80 | 1.48 | 9.47 | 1.90 | 2.33 | 57.27 | 16.84 | 14.09 |
| Umpqua N.F. | NSO Groups | 57.31 | 26.70 | 14.54 | 29.91 | 8.74 | 7.85 | 30.46 | 7.13 | 6.51 | 28.52 | 1.35 | 7.65 | 24.32 | 0.60 | 3.03 | 170.52 | 44.52 | 39.57 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 57.31 | 26.70 | 14.54 | 29.91 | 8.74 | 7.85 | 30.46 | 7.13 | 6.51 | 28.52 | 1.35 | 7.65 | 24.32 | 0.60 | 3.03 | 170.52 | 44.52 | 39.57 |
| State | NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.59 | 0.00 | 0.00 | 3.59 | 0.00 | 0.00 |
| | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.59 | 0.00 | 0.00 | 3.59 | 0.00 | 0.00 |
| Private / Other | NSO Groups | 38.96 | 12.64 | 8.92 | 37.64 | 39.58 | 9.26 | 133.82 | 98.04 | 31.98 | 98.95 | 84.91 | 22.30 | 169.25 | 12.86 | 24.89 | 478.61 | 248.02 | 97.34 |
| | Outside NSO Groups | 7.80 | 1.81 | 1.71 | 3.91 | 1.33 | 0.75 | 113.38 | 29.91 | 27.48 | 72.08 | 27.21 | 8.72 | 1018.01 | 4.94 | 30.59 | 1215.19 | 65.20 | 69.25 |
| | Total | 46.75 | 14.45 | 10.62 | 41.55 | 40.91 | 10.01 | 247.20 | 127.95 | 59.46 | 171.03 | 112.12 | 31.02 | 1187.26 | 17.80 | 55.48 | 1693.80 | 313.23 | 166.59 |
| *Klamath Mountains Subtotal* | *NSO Groups* | 154.30 | 82.35 | 38.17 | 112.88 | 87.70 | 26.94 | 187.54 | 112.58 | 43.50 | 178.48 | 115.15 | 38.93 | 220.67 | 18.46 | 35.36 | 853.86 | 416.24 | 182.90 |
| | *Outside NSO Groups* | 7.80 | 1.81 | 1.71 | 17.15 | 8.80 | 3.37 | 124.32 | 32.83 | 30.53 | 80.26 | 29.20 | 10.59 | 1027.82 | 6.07 | 32.43 | 1257.34 | 78.71 | 78.62 |
| | *Total* | 162.10 | 84.16 | 39.88 | 130.02 | 96.50 | 30.31 | 311.86 | 145.41 | 74.03 | 258.74 | 144.35 | 49.52 | 1248.49 | 24.54 | 67.79 | 2111.21 | 494.95 | 261.52 |

| Land Owner | General Location[1] | High NRF[2] | | | NRF[3] | | | Dispersal Only[4] | | | Capable [5] | | | Non-Capable[6] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] |
| **West Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| BLM - Medford | NSO Groups | 0.00 | 0.00 | 0.00 | 17.11 | 1.71 | 3.70 | 6.99 | 1.18 | 1.88 | 24.85 | 0.43 | 5.78 | 24.96 | 0.16 | 4.74 | 73.91 | 3.48 | 16.10 |
| | Outside NSO Groups | 0.97 | 0.00 | 0.20 | 42.05 | 9.06 | 9.56 | 32.88 | 3.25 | 7.70 | 1.24 | 0.64 | 0.41 | 26.57 | 0.88 | 6.26 | 103.71 | 13.83 | 24.13 |
| | Total | 0.97 | 0.00 | 0.20 | 59.16 | 10.77 | 13.26 | 39.87 | 4.43 | 9.58 | 26.08 | 1.06 | 6.19 | 51.54 | 1.04 | 11.00 | 177.62 | 17.31 | 40.23 |
| Rogue River - Siskiyou N.F. | NSO Groups | 0.56 | 0.52 | 0.31 | 74.63 | 34.93 | 21.96 | 12.31 | 4.87 | 3.95 | 83.40 | 25.38 | 18.98 | 35.36 | 3.57 | 3.55 | 206.28 | 69.27 | 48.74 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 0.56 | 0.52 | 0.31 | 74.63 | 34.93 | 21.96 | 12.31 | 4.87 | 3.95 | 83.40 | 25.38 | 18.98 | 35.36 | 3.57 | 3.55 | 206.28 | 69.27 | 48.74 |
| State | NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.40 | 0.00 | 0.46 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.27 | 2.82 | 0.00 | 0.74 |
| | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.40 | 0.00 | 0.46 | 0.00 | 0.00 | 0.00 | 0.42 | 0.00 | 0.27 | 2.82 | 0.00 | 0.74 |
| Private / Other | NSO Groups | 0.00 | 0.00 | 0.00 | 10.78 | 4.12 | 2.57 | 28.34 | 4.51 | 6.70 | 41.44 | 7.79 | 9.96 | 19.44 | 1.04 | 4.35 | 99.99 | 17.47 | 23.57 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 19.07 | 2.51 | 4.93 | 65.04 | 3.60 | 15.90 | 6.66 | 0.83 | 1.51 | 121.59 | 0.53 | 27.78 | 212.35 | 7.47 | 50.12 |
| | Total | 0.00 | 0.00 | 0.00 | 29.85 | 6.63 | 7.50 | 93.37 | 8.11 | 22.60 | 48.09 | 8.62 | 11.46 | 141.03 | 1.57 | 32.13 | 312.34 | 24.93 | 73.70 |
| *West Cascades Subtotal* | *NSO Groups* | 0.56 | 0.52 | 0.31 | 102.53 | 40.76 | 28.23 | 47.64 | 10.56 | 12.53 | 149.68 | 33.60 | 34.71 | 79.77 | 4.77 | 12.64 | 380.18 | 90.22 | 88.41 |
| | *Outside NSO Groups* | 0.97 | 0.00 | 0.20 | 61.12 | 11.57 | 14.49 | 100.31 | 6.85 | 24.07 | 7.90 | 1.46 | 1.92 | 148.58 | 1.41 | 34.32 | 318.88 | 21.30 | 74.99 |
| | *Total* | 1.54 | 0.52 | 0.50 | 163.64 | 52.33 | 42.72 | 147.95 | 17.42 | 36.60 | 157.58 | 35.07 | 36.63 | 228.34 | 6.18 | 46.95 | 699.06 | 111.51 | 163.40 |
| **East Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| BLM - Lakeview | NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 12.62 | 0.00 | 3.36 | 1.04 | 0.00 | 0.28 | 0.00 | 0.00 | 0.00 | 1.19 | 0.00 | 0.13 | 14.86 | 0.00 | 3.78 |
| | Total | 0.00 | 0.00 | 0.00 | 12.62 | 0.00 | 3.36 | 1.04 | 0.00 | 0.28 | 0.00 | 0.00 | 0.00 | 1.19 | 0.00 | 0.13 | 14.86 | 0.00 | 3.78 |
| Rogue River - Siskiyou N.F. | NSO Groups | 2.18 | 0.89 | 0.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.98 | 0.28 | 0.30 | 0.00 | 0.00 | 0.00 | 3.16 | 1.17 | 1.05 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 2.18 | 0.89 | 0.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.98 | 0.28 | 0.30 | 0.00 | 0.00 | 0.00 | 3.16 | 1.17 | 1.05 |
| Fremont - Winema N.F. | NSO Groups | 11.74 | 1.33 | 3.34 | 16.84 | 2.29 | 4.79 | 2.78 | 0.92 | 0.84 | 26.88 | 4.21 | 7.33 | 2.94 | 0.06 | 0.45 | 61.17 | 8.81 | 16.74 |
| | Outside NSO Groups | 7.48 | 1.20 | 2.05 | 4.41 | 0.42 | 1.09 | 6.92 | 0.70 | 1.87 | 0.59 | 0.01 | 0.12 | 0.83 | 0.00 | 0.16 | 20.23 | 2.33 | 5.28 |
| | Total | 19.22 | 2.52 | 5.39 | 21.25 | 2.71 | 5.88 | 9.70 | 1.61 | 2.71 | 27.47 | 4.22 | 7.45 | 3.77 | 0.06 | 0.60 | 81.40 | 11.13 | 22.03 |
| Private / Other | NSO Groups | 0.02 | 0.01 | 0.01 | 0.29 | 0.00 | 0.07 | 3.06 | 0.00 | 0.70 | 20.22 | 2.31 | 5.32 | 2.83 | 0.01 | 0.83 | 26.42 | 2.33 | 6.93 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 2.54 | 0.01 | 0.77 | 67.59 | 0.00 | 19.61 | 88.45 | 0.37 | 25.30 | 34.49 | 0.05 | 4.17 | 193.07 | 0.43 | 49.85 |
| | Total | 0.02 | 0.01 | 0.01 | 2.83 | 0.01 | 0.84 | 70.65 | 0.00 | 20.31 | 108.67 | 2.68 | 30.62 | 37.32 | 0.06 | 5.00 | 219.49 | 2.76 | 56.78 |
| *East Cascades Subtotal* | *NSO Groups* | 13.95 | 2.23 | 4.10 | 17.13 | 2.29 | 4.86 | 5.83 | 0.92 | 1.54 | 48.08 | 6.80 | 12.95 | 5.77 | 0.07 | 1.28 | 90.75 | 12.31 | 24.73 |
| | *Outside NSO Groups* | 7.48 | 1.20 | 2.05 | 19.57 | 0.43 | 5.22 | 75.55 | 0.70 | 21.76 | 89.04 | 0.38 | 25.42 | 36.52 | 0.05 | 4.46 | 228.16 | 2.76 | 58.91 |
| | *Total* | 21.42 | 3.43 | 6.15 | 36.70 | 2.72 | 10.08 | 81.38 | 1.61 | 23.30 | 137.12 | 7.19 | 38.36 | 42.29 | 0.12 | 5.74 | 318.91 | 15.06 | 83.64 |

| Land Owner | General Location[1] | High NRF[2] | | | NRF[3] | | | Dispersal Only[4] | | | Capable [5] | | | Non-Capable[6] | | | Total Acres | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] | Removed[7] | UCSA[8] | 30-foot Corridor[9] |
| **Total Northern Spotted Owl Range** | | | | | | | | | | | | | | | | | | | |
| BLM | NSO Groups | 81.48 | 48.28 | 22.07 | 65.14 | 41.10 | 14.41 | 67.01 | 15.22 | 15.37 | 112.12 | 32.50 | 21.34 | 68.22 | 5.22 | 16.85 | 393.96 | 142.32 | 90.03 |
| | Outside NSO Groups | 5.13 | 0.00 | 1.48 | 72.16 | 16.53 | 16.79 | 82.95 | 6.17 | 20.58 | 27.31 | 2.63 | 6.40 | 37.86 | 2.01 | 9.25 | 225.41 | 27.34 | 54.49 |
| | Total | 86.61 | 48.28 | 23.56 | 137.30 | 57.62 | 31.19 | 149.95 | 21.39 | 35.94 | 139.43 | 35.13 | 27.73 | 106.08 | 7.24 | 26.10 | 619.37 | 169.66 | 144.53 |
| Forest Service | NSO Groups | 71.80 | 29.44 | 18.94 | 121.38 | 45.95 | 34.60 | 45.56 | 12.93 | 11.30 | 139.78 | 31.22 | 34.25 | 62.62 | 4.23 | 7.02 | 441.13 | 123.77 | 106.11 |
| | Outside NSO Groups | 7.48 | 1.20 | 2.05 | 4.41 | 0.42 | 1.09 | 6.92 | 0.70 | 1.87 | 0.59 | 0.01 | 0.12 | 0.83 | 0.00 | 0.16 | 20.23 | 2.33 | 5.28 |
| | Total | 79.28 | 30.63 | 20.99 | 125.79 | 46.38 | 35.69 | 52.48 | 13.62 | 13.17 | 140.37 | 31.23 | 34.37 | 63.45 | 4.23 | 7.18 | 461.36 | 126.10 | 111.40 |
| State | NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.02 | 0.07 | 0.00 | 0.02 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.52 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 87.62 | 0.00 | 10.22 | 90.14 | 0.00 | 10.69 |
| | Total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.52 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 87.69 | 0.00 | 10.24 | 90.21 | 0.00 | 10.71 |
| Private / Other | NSO Groups | 42.29 | 12.90 | 9.86 | 49.14 | 43.70 | 12.03 | 187.65 | 106.17 | 43.27 | 320.40 | 114.73 | 69.50 | 255.00 | 14.36 | 42.99 | 854.47 | 291.86 | 177.65 |
| | Outside NSO Groups | 8.50 | 1.81 | 1.92 | 35.90 | 3.86 | 9.39 | 297.40 | 34.55 | 76.17 | 407.73 | 36.25 | 88.29 | 1519.15 | 5.88 | 84.17 | 2268.69 | 82.36 | 259.94 |
| | Total | 50.79 | 14.71 | 11.78 | 85.04 | 47.55 | 21.41 | 486.56 | 141.08 | 119.77 | 742.55 | 150.99 | 161.38 | 1774.15 | 20.25 | 127.16 | 3139.09 | 374.57 | 441.51 |
| **Total Northern Spotted Owl Range** | **NSO Groups** | **195.56** | **90.62** | **50.87** | **235.65** | **130.75** | **61.03** | **300.21** | **134.31** | **69.93** | **572.30** | **178.46** | **125.09** | **385.90** | **23.82** | **66.89** | **1689.63** | **557.95** | **373.82** |
| | **Outside NSO Groups** | **21.11** | **3.01** | **5.46** | **112.47** | **20.80** | **27.26** | **389.79** | **41.42** | **99.08** | **435.63** | **38.89** | **94.80** | **1645.47** | **7.90** | **103.79** | **2604.47** | **112.03** | **330.40** |
| | **Total** | **216.68** | **93.63** | **56.33** | **348.12** | **151.55** | **88.30** | **691.51** | **176.09** | **169.35** | **1022.35** | **217.35** | **223.48** | **2031.37** | **31.72** | **170.68** | **4310.03** | **670.33** | **708.14** |

1 General Location identifies areas within Northern Spotted Owl Groups (areas within NSO home ranges; see table Q-10 in appendix Q) and areas outside of NSO groups (outside of NSO home ranges).
2 High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
3 NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
4 Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
5 Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.
6 Noncapable Habitat: not forested and not capable of becoming forested.
7 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
8 UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
9 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.

Note: More detailed information on BLM Districts and National Forests impacted, as well as critical habitat, NWFP late successional reserves, is located in table Q-9 in appendix Q.

## Table 4.3.4-14
## Effects (acres) to Northern Spotted Owl Habitat (NSO) in each NSO Habitat Type by Owl Groups Impacted by Construction of the Proposed PCGP Project within the Range of the NSO

| NSO Habitat Type | Number of Habitat Types Crossed by the Project within each Group[4] | High NRF Habitat[5] | | | NRF Habitat[6] | | | Dispersal Only Habitat[7] | | | Capable Habitat[8] | | | Non-Capable Habitat[9] | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation | Construction | | Operation |
| | | Removed[10] | UCSA[11] | 30-foot Corridor[12] | Removed[10] | UCSA[11] | 30-foot Corridor[12] | Removed[10] | UCSA[11] | 30-foot Corridor[12] | Removed[10] | UCSA[11] | 30-foot Corridor[12] | Removed[10] | UCSA[11] | 30-foot Corridor[12] | Removed[10] | UCSA[11] | 30-foot Corridor[12] |
| **Coast Range Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| Home Range | 14 | 11.54 | 1.65 | 3.89 | 0.46 | 0.00 | 0.13 | 53.48 | 8.87 | 11.18 | 191.84 | 22.21 | 38.57 | 73.58 | 0.25 | 15.37 | 330.91 | 32.98 | 69.14 |
| Core Area | 5 | 10.32 | 1.36 | 2.94 | 2.66 | 0.00 | 0.86 | 7.23 | 1.73 | 1.52 | 18.64 | 0.70 | 3.52 | 6.11 | 0.27 | 2.24 | 44.97 | 4.06 | 11.09 |
| Nest Patch | 1 | 4.89 | 2.51 | 1.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.89 | 2.51 | 1.45 |
| Overall Coast Range Total | N/A | 26.76 | 5.52 | 8.28 | 3.12 | 0.00 | 0.99 | 60.71 | 10.61 | 12.70 | 210.48 | 22.91 | 42.09 | 79.70 | 0.52 | 17.62 | 380.77 | 39.55 | 81.68 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| Home Range | 46 | 110.45 | 54.15 | 26.34 | 83.51 | 74.14 | 19.98 | 150.65 | 84.27 | 35.95 | 122.31 | 74.75 | 29.40 | 146.15 | 13.25 | 24.65 | 613.08 | 300.56 | 175.19 |
| Core Area | 20 | 42.12 | 26.45 | 11.26 | 26.56 | 11.64 | 6.24 | 35.15 | 27.94 | 7.00 | 49.62 | 36.69 | 7.94 | 72.96 | 5.02 | 10.55 | 226.41 | 107.73 | 23.34 |
| Nest Patch | 4 | 1.73 | 1.74 | 0.57 | 2.80 | 1.92 | 0.72 | 1.73 | 0.37 | 0.55 | 6.56 | 3.71 | 1.59 | 1.56 | 0.20 | 0.16 | 14.38 | 7.95 | 1.14 |
| Overall Klamath Mountains Total | N/A | 154.30 | 82.35 | 38.17 | 112.88 | 87.70 | 26.94 | 187.54 | 112.58 | 43.50 | 178.48 | 115.15 | 38.93 | 220.67 | 18.46 | 35.36 | 853.87 | 416.24 | 66.30 |
| **West Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| Home Range | 26 | 0.00 | 0.00 | 0.00 | 68.02 | 27.13 | 18.55 | 32.91 | 8.68 | 8.84 | 116.09 | 25.67 | 27.30 | 66.38 | 3.64 | 9.47 | 282.82 | 65.12 | 64.16 |
| Core Area | 9 | 0.56 | 0.52 | 0.31 | 32.60 | 13.22 | 9.26 | 14.73 | 1.88 | 3.69 | 30.12 | 7.40 | 6.37 | 13.22 | 1.13 | 3.12 | 91.23 | 24.16 | 22.75 |
| Nest Patch | 2 | 0.00 | 0.00 | 0.00 | 1.91 | 0.40 | 0.42 | 0.00 | 0.00 | 0.00 | 3.48 | 0.53 | 1.04 | 0.16 | 0.00 | 0.04 | 5.55 | 0.94 | 1.50 |
| Overall West Cascades Total | N/A | 0.56 | 0.52 | 0.31 | 102.53 | 40.76 | 28.23 | 47.64 | 10.56 | 12.53 | 149.68 | 33.60 | 34.71 | 79.77 | 4.77 | 12.64 | 379.60 | 90.22 | 88.41 |
| **East Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | |
| Home Range | 4 | 8.31 | 2.24 | 2.36 | 17.12 | 2.29 | 4.86 | 5.83 | 0.92 | 1.54 | 42.43 | 6.29 | 11.29 | 5.19 | 0.06 | 1.19 | 78.88 | 11.80 | 21.24 |
| Core Area | 1 | 5.47 | 0.00 | 1.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.65 | 0.51 | 1.66 | 0.58 | 0.00 | 0.09 | 11.71 | 0.51 | 3.40 |
| Nest Patch | 1 | 0.17 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.08 |
| Overall East Cascades Total | N/A | 13.95 | 2.24 | 4.10 | 17.12 | 2.29 | 4.86 | 5.83 | 0.92 | 1.54 | 48.08 | 6.80 | 12.95 | 5.77 | 0.07 | 1.28 | 90.75 | 12.31 | 24.73 |
| **Overall NSO Range** | | | | | | | | | | | | | | | | | | | |
| Home Range | 90 | 130.30 | 58.04 | 32.59 | 169.11 | 103.56 | 43.53 | 242.88 | 102.74 | 57.51 | 472.67 | 128.92 | 106.56 | 291.31 | 17.20 | 50.68 | 1,305.69 | 410.45 | 329.73 |
| Core Area | 35 | 58.48 | 28.33 | 16.17 | 61.83 | 24.86 | 16.37 | 57.11 | 31.56 | 12.21 | 104.02 | 45.30 | 19.49 | 92.88 | 6.42 | 16.00 | 374.31 | 136.47 | 60.58 |
| Nest Patch | 8 | 6.79 | 4.26 | 2.10 | 4.71 | 2.33 | 1.14 | 1.73 | 0.37 | 0.55 | 10.04 | 4.25 | 2.63 | 1.72 | 0.20 | 0.20 | 25.00 | 11.40 | 4.17 |
| Overall Physiographic Province Total | N/A | 195.57 | 90.62 | 50.86 | 235.65 | 130.75 | 61.03 | 301.72 | 134.67 | 70.27 | 586.72 | 178.47 | 128.68 | 385.90 | 23.82 | 66.89 | 1,704.99 | 558.33 | 261.12 |

[1] Nest patch: includes an area that is 300 meters from the site center (70 acres occur within a nest patch).
Core area: generally 502 acres occur within a core area.
Home range: generally 4,525 acres, 3,398 acres, and 2,895 acres occur within the Oregon Coast Range, Klamath Mountains, and Cascades NSO home ranges, respectively.
[2] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
[3] NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
[4] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
[5] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.
[6] Noncapable Habitat: not forested and not capable of becoming forested.
[7] Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
[8] UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.

NOTE: Summarized from table Q-10 in appendix Q.

There is a potential for temporary, indirect habitat loss occurring due to noise and human presence during the breeding season (i.e., within a 0.25 mile buffer around the proposed pipeline construction work space, access roads, etc.). Approximately 13,378 acres of suitable NRF habitat (high NRF and NRF) occur within 0.25 mile of the proposed action, of which 11,046 acres occur within NSO home ranges that could experience indirect and temporary loss of habitat due to associated noise disturbance within the NSO breeding season (March 1 through September 30; table 4.3.4-15). Within 0.25 mile of NSO activity centers, timber removal would occur outside of the entire breeding season beginning in October and construction activities would occur the following year after the critical breeding season (after July 15; see table Q-9 in appendix Q for specific timing within individual owl home ranges). Beyond 0.25 mile of NSO activity centers, timber removal and construction activities could occur during the entire NSO breeding season. Activity would not occur simultaneously within the 193.26 miles of the proposed Project that lies within the range of the NSO, and therefore, any temporary, indirect habitat loss would be less than estimated in table 4.3.4-15. Spot check surveys will be conducted within 0.25 mile of the proposed action one year prior to construction to determine if additional suitable habitat has become occupied and the above schedule will be adjusted, if necessary, further minimizing temporary, indirect habitat loss during the breeding season.

**Table 4.3.4-15**
**Amount (acres) of Nesting, Roosting, and Foraging Habitat (acres) Indirectly Impacted Due to Disturbance during the Breeding Season (March 1 through September 30)**

| Physiographic Province | Miles of Proposed Pipeline | Suitable NRF within 0.25 mile of Proposed Activities [1] | Suitable NRF within 0.25 mile of Proposed Activities within NSO Home Ranges [1] | Percent of NRF Habitat within NSO Home Ranges |
|---|---|---|---|---|
| Coast Range | 54.51 | 2,125 | 1,690 | 79.5 |
| Klamath Mountains | 71.02 | 6,650 | 5,814 | 87.4 |
| West Cascades | 44.88 | 3,806 | 3,035 | 79.7 |
| East Cascades | 22.85 | 796 | 507 | 63.7 |
| **Total** | **193.26** | **13,378** | **11,046** | **82.6** |
| [1] Suitable NRF Habitat includes both high NRF and NRF habitat within 0.25 mile of proposed habitat removal. | | | | |

Known, Best Location, or PCGP Assumed Owl Sites

There are 98 known, best location, or PCGP assumed owl home ranges that overlap the proposed Project. Of these, eight NSO home ranges would not have habitat removed or modified because they are only intersected by existing roads to be used to access the right-of-way or are within 100 meters of habitat removal. The effects of habitat changes to the other 90 known, best location, or PCGP assumed owls within the Provincial Analysis Area as a result of the proposed action were evaluated at three scales: the nest patch, the core area, and the home range. The pre-action and post-action habitat conditions are provided in table Q-7 in appendix Q for each NSO home range; the amount of NSO habitat is specific to each habitat type in its entirety; acres provided for the home range include acres that also occur within the core area and nest patch, and acres included in the core area also include acres within the nest patch. Also, amount of suitable NRF habitat removed within each owl habitat type does not consider overlap with neighboring owl sites.

Table 4.3.4-16 summarizes the number of NSO activity centers and acres of NSO habitat by physiographic province that would have NSO habitat removed from their nest patch, core area, and/or home range (summarized from table Q-7 in appendix Q). Spotted owls that are below the FWS recommended suitable habitat thresholds or are near those thresholds, either in the core area or home range, and would have suitable habitat removed could be impacted more by the Project than those above the recommended FWS suitable habitat thresholds (less than 50 percent and/or less than 40 percent available high NRF/NRF in their core area or home range, respectively). Table 4.3.4-16 tabulates the number of NSO home ranges/core areas that are below threshold, by physiographic province, that would have habitat removed and identifies the habitat use area (nest patch, core area, home range) that each owl would be affected. Generally, removal of habitat from home ranges already below threshold represents less than 0.2 percent of available suitable habitat within the owls' home range (see table Q-7 in appendix Q). Since removal of habitat represents such a small percentage of available suitable NRF habitat (high NRF and NRF) within the core area and/or home range, removal of habitat within owl site core areas and home ranges should not adversely impact those NSO pairs or resident singles. However, habitat removed in closer proximity to the nest site or nest patch may have a greater impact to the NSO pair or resident single.

NSOs with suitable habitat availability within their core area and/or home range below the FWS recommended threshold of suitable habitat (< 40 percent suitable habitat in home range, < 50 percent suitable habitat in core area) could be considered adversely affected, especially if habitat is removed during the breeding season within 0.25 mile of an activity center. Habitat would be removed from 90 home ranges (including 35 core areas) within the four physiographic provinces crossed, of which 56 home NSO activity centers are below the recommended habitat thresholds in the core area and/or home range. Habitat removal within 0.25 mile of 10 NSO activity centers (five known, four best location, and one PCGP assumed), of which six are below recommended NRF threshold, would occur outside of the entire breeding period (between October 1 and February 28); disturbance associated with these activities should not adversely affect spotted owls. If survey efforts prior to construction identify additional NSO activity within 0.25 mile, habitat removal will occur outside of the breeding seasion within 0.25 mile of those sites, as well.

Eight nest patches would be crossed by the proposed action; suitable NRF habitat (high NRF, NRF) would be removed from seven nest patches, of which five NSO home ranges have suitable habitat below the recommended NRF threshold in the core area and/or home range (see table 4.3.4-17). Timber would be removed outside the entire breeding season (after September 30 but before March 1) within each nest patch and 0.25 mile of that activity center; therefore, no direct impact to those NSOs is expected. Removal of habitat from the nest patches, however, could have an indirect, negative impact on those NSOs, especially in the five sites below recommended FWS NRF threshold for core area and/or home range. Four NSO sites represent pairs documented during 2008 survey efforts (best location sites); however, none of the sites had a nest tree identified. As a result, these nest patches represent a 300-meter radius around the "best location" as determined by the surveyors and local agency biologists based on detection date and time, individual owls (age and sex) present at particular detections, behavior of owls at a particular detection, and occasionally the habitat of a detection location. In discussions with various agency biologists (table S-1 in appendix S), it was thought that these sites were associated with other monitored pairs and that nesting at the "best location" sites was not occurring, but not enough information was available to be sure of this. Therefore, Pacific Connector continues to include these best location NSO pair sites for analyzing worst case scenarios. If additional surveys conducted prior to construction and timber clearing indicate that these are not active, Pacific Connector would revise the schedule accordingly. Table 4.3.4-17 provides details specific for each NSO nest patch crossed by the proposed Pacific Connector pipeline.

## Table 4.3.4-16
## Number of NSO Home Ranges, by Physiographic Province and Habitat Condition that Would Have NSO Habitat Removed by the Proposed Project[1]

| Suitable NRF Habitat Condition within Owl Home Ranges[2] | Owl Status[3] | Coast Range | | | Klamath Mountains | | | West Cascades | | | East Cascades | | | Overall Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Home Range | Core Area | Nest Patch | Home Range | Core Area | Nest Patch | Home Range | Core Area | Nest Patch | Home Range | Core Area | Nest Patch | Home Range | Core Area | Nest Patch |
| Home Range > 40% AND Core Area > 50% (*Above Threshhold*) | Known | 1 | 1 | 0 | 14 | 4 | 1 | 10 | 3 | 1 | 3 | 0 | 0 | 28 | 8 | 2 |
| | Best Location | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 0 | 6 | 3 | 1 |
| | PCGP Assumed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Total* | *1* | *1* | *0* | *17* | *4* | *1* | *13* | *6* | *2* | *3* | *0* | *0* | 34 | 11 | 3 |
| Home Range > 40% AND Core Area < 50% *(Below Threshold)* | Known | 0 | 0 | 0 | 3 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 7 | 1 | 0 |
| | Best Location | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| | PCGP Assumed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Total* | *0* | *0* | *0* | *4* | *0* | *0* | *6* | *1* | *0* | *0* | *0* | *0* | 10 | 1 | 0 |
| Home Range < 40% AND Core Area > 50% *(Below Threshold)* | Known | 2 | 0 | 1 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 3 | 1 |
| | Best Location | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 |
| | PCGP Assumed | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| | *Total* | *3* | *2* | *0* | *4* | *4* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | 8 | 7 | 2 |
| Home Range < 40% AND Core Area < 50% *(Below Threshold)* | Known | 6 | 0 | 0 | 14 | 7 | 0 | 4 | 0 | 0 | 1 | 1 | 1 | 25 | 8 | 1 |
| | Best Location | 1 | 0 | 0 | 5 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 4 | 2 |
| | PCGP Assumed | 3 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 4 | 0 |
| | *Total* | *10* | *2* | *0* | *21* | *12* | *2* | *6* | *1* | *0* | *1* | *1* | *1* | 38 | 16 | 3 |
| Overall Total | Known | 9 | 1 | 1 | 33 | 13 | 1 | 19 | 5 | 1 | 4 | 1 | 1 | 65 | 20 | 4 |
| | Best Location | 1 | 2 | 0 | 10 | 5 | 3 | 6 | 3 | 1 | 0 | 0 | 0 | 17 | 10 | 4 |
| | PCGP Assumed | 4 | 2 | 0 | 3 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 8 | 5 | 0 |
| | *Total* | 14 | 5 | 0 | 46 | 20 | 4 | 26 | 9 | 2 | 4 | 1 | 1 | 90 | 35 | 8 |

[1] For detailed NRF/High NRF habitat available for each NSO and its habitat type (nest patch, core area, home range), refer to “pre-action” suitable habitat acres in table Q-7 in appendix Q.

[2] FWS et al. (2008) consider core areas with 50 percent or greater suitable NRF habitat and home ranges with at least 40 percent suitable NRF habitat to be necessary to maintain NSO life history function. Habitat condition for each NSO affected is summarized from table Q-7 in appendix Q.

[3] Owl Status: 1) Known sites represent NSO activity sites provided by BLM and Forest Service biologists within the provincial analysis area; 2) Best Location sites represent pairs or resident singles documented by Pacific Connector during surveys in 2007 and 2008 with no nest site/activity center located, and; 3) PCGP assumed sites respresents and area identifed by Pacific Connector that may provide habitat for NSO pair.

## Table 4.3.4-17
## Summary of NSO Nest Patches Crossed by the Proposed Action

| MSNO or Site ID | Site Name | Nest Patch Location (MP) | Landowner | Land Allocation | Available High NRF/NRF[1] (acres) | Length Crossed[2] (feet) | High NRF/NRF Affected[3] | | Pre-Action Habitat Condition[4] | Additional Description |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Area (acres) | Percent of Available NRF | | |
| **Coast Range Physiographic Province** | | | | | | | | | | |
| 2317B | Brewster Valley | 37.40-37.80 | Coos Bay BLM | Unmapped LSR | 63.79 | 2,096 | 4.89 | 7.7 | <40% Home Range, >50% Core | Coos Bay BLM provided a newly documented alternate NSO activity center to Pacific Connector in January 2014; this area had been surveyed in previous years by Coos Bay BLM and Pacific Connector and spotted owl activity was identified in area, but no nest location or pair was documented (see Raymond et al., 2012; SBS, 2008a). Project will bisect late successional forest through the nest patch and western portion of the core area of this site; resulting two lobes of suitable NRF stand crossed = 198.00 acres and 108.40 acres (located within MAMU Stand C3090; see table 4.3.3-13). |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | |
| PCGP 064.2 | Kent Creek | 62.70-65.66 | Private | None | 7.81 | 1,091 | 0 | 0 | <40% Home Range, <50% Core Area | Project located in regenerating forest approximately 202 meters (663 feet) from best location site within strip of mid-seral forest adjacent to regenerating forest; one road travels through the nest patch; right-of-way would create additional fragmentation; will create edge within older regenerating interior forest for approximately 300 feet (600 feet of new edge in interior forest); approximately 360 feet of new edge in forest already affected by existing edge will also be created (720 feet). |
| PCGP 090.2 | Bland Mountain | 88.86-91.61 | Roseburg BLM | Matrix | 26.12 | 2,031 | 2.81 | 10.8 | <40% Home Range, <50% Core Area | Project located through middle of best location nest patch; best location site identifed adjacent to an existing access road that also bisects the nest patch; consultations within agencies (see table S-1 in appendix S) presume the nest site is not at this best location site; northern portion of the right-of-way traverses through old-growth for approximately 920 feet, including interior forest and bisects the stand. |
| PCGP 095.3 | Milo South | 93.82-97.04 | Roseburg BLM | LSR | 38.54 | 1,795 | 1.44 | 3.7 | <40% Home Range, > 50% Core | Project traverses through approximately 500 feet of old-growth forest, including approximately 240 feet of interior forest in best location nest patch; the remainder of project is adjacent to old-growth stand in early regenerating forest. |
| 4008B | Hatchet Creek South | 99.24-102.00 | Roseburg BLM | LSR CHU KLE1 | 29.22 | 302 | 0.29 | 1.0 | > 40% Home Range, >50% Core Area | Project follows existing road on edge of nest patch (approximately 275 meters or 911 feet from activity center); removes regenerating forest on edge of road. |

| MSNO or Site ID | Site Name | Nest Patch Location (MP) | Landowner | Land Allocation | Available High NRF/NRF[1] (acres) | Length Crossed[2] (feet) | High NRF/NRF Affected[3] | | Pre-Action Habitat Condition[4] | Additional Description |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Area (acres) | Percent of Available NRF | | |
| **West Cascades Physiographic Province** | | | | | | | | | | |
| PCGP 160.7 | Big Elk | 160.07-162.73 | Rogue River - Siskiyou N.F. | LSR CHU KLE4 | 59.17 | 1,058 | 1.24 | 2.1 | >40% Home Range, >50% Core Area | Project occurs approximately 262 meters (860 feet) from best location activity center generall along regenerating strip; one road traverses eastern portion of nest patch; will create new edge extending from regenerating strip to access road for approximately 360 feet in old-growth forest. |
| 0994 | Cox Creek | 161.81-164.49 | Rogue River - Siskiyou N.F. | LSR CHU KLE4 | 62.28 | 1,125 | 0.67 | 1.1 | >40% Home Range, >50% Core Area | Project located approximately 200 meters (650 feet) from activity center; project traverses through regenerating forest patch adjacent to late successional forest; will bisect regenerating interior forest for approximately 290 feet in the nest patch. |
| **East Cascades Physiographic Province** | | | | | | | | | | |
| 0023 | Buck Lake | 172.35-174.72 | Fremont-Winema N.F. | CHU ECS 1 | 30.64 | 123 | 0.17 | 0.6 | <40% Home Range, <50% Core Area | Project located approximately 285 meters (930 feet) from activity center; project parallels or is adjacent to Clover Creek Road in old-growth forest adjacent to regenerating forest. |

[1] Available high NRF and NRF in the nest patch; see table Q-7 in appendix Q.
[2] Length is provided for pipeline across the nest patch.
[3] Acres of NRF (high NRF and NRF) affected within the nest patch, if NRF affected; see table Q-7 in appendix Q.
[4] FWS et al. (2008) considers NSO home ranges and core areas to provide suitable NRF if the available NRF is greater than 50 percent (Core Area) or is greater than 40 percent (Home Range).

Habitat Fragmentation

In addition to impact by surface disturbances, fragmentation of connected, contiguous habitat will occur. Fragmentation of NSO habitat is considered a cause for poor demographic performance, although the threat posed by fragmentation is still not fully understood (Courtney et al., 2004). FWS (2004) indicated that habitat fragmentation was the "aggregate of effects of historical habitat loss, continuing habitat loss due to uncharacteristic wildfire, and continuing timber harvest, albeit at reduced levels," and that habitat fragmentation remained a threat in the northern part of the NSO's range but was reduced in the southern part. It is assumed that these broad statements are referring to the amount of timber harvest still occurring. Courtney et al. (2004) indicated that typically a larger area is required for NSO home ranges in more fragmented habitats. Based on this assumption, the Provincial Home Range Radii provided in the 2010 Northern Spotted Owl Survey Protocol would be indicative of more fragmented habitats in the northern part of the NSO's range than in the southern portion (1.8 mile radius in the Washington Cascades, 2.2 miles on the Olympic Peninsula, 1.2 miles in the Oregon Cascades, 1.5 miles in the Oregon Coast Ranges, and 1.3 miles in Klamath Province).

Fragmentation includes increasing levels of edge between older forests and younger forest types. NSO fecundity has been positively related to forest edge (Franklin et al., 2000, Olson et al., 2004; Hayward et al., 2011) and FWS (2011c) has suggested that spotted owls evolved with natural disturbance processes (e.g., fire) that caused mosaics of forest age classes, edges included. While the size of old-growth patches was strongly related to nest site selection by NSO, extent of clearcut forest and indices of forest fragmentation were not (Meyer et al., 1998). Prey abundance and higher nutritional status have been related to forest edges (Franklin et al., 2000, Franklin and Gutierrez, 2002; Hayward et al., 2011), particularly the abundance of woodrats (Ward et al., 1998), and possibly flying squirrels (Rosenberg and Anthony, 1992). Reproductive output was found to be greater at sites with more edge between older forest (mature and old growth) and other adjacent vegetation, while reproductive output declined in areas with greater amounts of interior forest (Franklin et al., 2000). Alternatively, NSO survival increased with more interior forest and increased edge (Franklin et al., 2000). As reviewed by Franklin and Gutiérrez (2002), locations in which NSO have high reproduction and high survivorship (collectively, high fitness) are a balance between the amounts of interior forest and edges with older forest.

Alternatively, increased fragmentation can lead to decreased survivorship of NSOs by facilitating predation by great horned owls, northern goshawks, and other avian predators (Franklin et al., 2000; FWS, 2011). Competition with barred owls may also be facilitated by forest fragmentation, although the levels of competition are not straight forward (Dugger et al., 2011). With increased fragmentation, NSO have been found to expand their home range size (Schilling et al., 2013) which could lead to increased predation (larger areas equating to more time spent away from nests) and possibly increased competition (Dugger et al., 2011).

The Provincial Analysis Area has already been subjected to extensive fragmentation by past land uses including transportation corridors, timber harvest and associated activities (i.e., road construction), and urban development. The project will occur within approximately 195.00 miles across four physiographic provinces (MP 1.47R to MP 190.58), of which 103.4 miles occur within NSO home ranges. Within the four physiographic provinces crossed by the proposed action, the Pacific Connector pipeline would be located within or parallel to existing corridors for approximately 70.3 miles (36.1 percent of proposed action in the NSO range; see table Q-4 in appendix Q), thus minimizing fragmentation within approximately 76 home ranges and NSO habitat. Table Q-4 in appendix Q identifies the location of NSO home ranges (including nest patches and core areas) in relation to existing rights-of-ways and corridors. However, additional fragmentation will occur within high NRF and NRF habitat, as well as dispersal and capable habitat due to the proposed project. Depending on local conditions, fragmentation may not be an adverse impact to NSO home ranges if prey abundance ultimately increases, but on the otherhand, fragmentation could contribute to increased predation of NSO nests which would be detrimental. Measures in the CMP include financial support of a barred owl management program that is expected to off-set negative aspects of fragmentation.

**Habitat Edge**. Indirect effects from construction of the Pacific Connector pipeline are also expected within habitat adjacent to the PCGP construction right-of-way, including within interior forest within NSO high NRF, NRF, dispersal, and capable habitat. The conversion of large tracts of old-growth forest to small, isolated forest patches with large edge areas can create changes in microclimate, vegetation species, and predator-prey dynamics. In general, microclimates along edges differ from those in forest interiors. Two main physical factors affecting and creating an edge microclimate are sun and wind (Forman, 1995; Chen et al. 1995; Harper et al., 2005). Compared to the forest interior, areas near edges receive more direct solar radiation during the day, lose more long-wave radiation at night, have lower humidity, and receive less short-wave radiation. Such a change in humidity could affect migration and dispersal of flying insects, including tree parasites such as the Douglas-fir beetle (Chen et al., 1995) and promote expansions of infestations which can affect interior forest stand structure and formations of gaps in formerly closed stands (Furniss, 1979). Humidity, coupled with soil moisture and temperature, also affects decomposition of litter and coarse woody debris; rates of litter decomposition were higher near edges with a shallower organic layer (Chen et al., 1995). Decreased humidity may also affect distribution of fungi that are dependent on old-growth forest environments. Since the diets of northern flying squirrels mostly consist of fungi (Verts and Carraway, 1998), changes in interior forest microclimates could affect local abundance of prey utilized by NSOs.

Other physical factors affecting edge includes edge orientation (Chen et al., 1995). For example, the general orientation of the PCGP Project is from northwest to southeast. Therefore, edge effects will be most pronounced on the southwest-facing edges and weakest along the northeast-facing edges (see discussion in Chen et al., 1995). Harper et al. (2005) reported that the mean distance of edge influence could occur to approximately 328 feet (100 meters) and result in 1) tree mortality, damage, recruitment, growth rate, canopy foliage, understory foliage, and seedling mortality, 2) amounts of canopy trees, canopy cover, snags and logs, understory tree density, herbaceous cover, and shrub cover, and 3) stand composition metrics such as species, exotics, individual species and species diversity. In other younger coniferous forests or mixed forests with deciduous species, edge effects compared to interior forests have been much less pronounced (Heithecker and Halpern, 2007; Harper and MacDonald, 2002).

Old-growth and late seral forests are important to northern spotted owls as NRF habitat, but edges associated with those NRF habitats have been shown to increase NSO fitness in terms of fecundity and survivorship (see Franklin et al., 2000, Olson et al., 2004; Hayward et al., 2011). Annual survival of NSO on territories was positively associated both with amounts of interior old-growth forest and with length of edge between those forests and other vegetation types. Conversely, reproduction was negatively associated with interior forest, but positively associated with edge between mature and old-growth conifer forest and other vegetation types (Franklin et al., 2000). Similarly, Olson et al. (2004) found that a mixture of mid- and late succesional with young forest and nonforested habitats appear best NSO reproduction and survival. Roads create edges that affect interior forest biotic and microclimatological conditions, even narrow forest roads 40 feet wide (Baker and Dillon, 2000). Edges created by roads with low levels of traffic disturbance have been shown to have a positive effect on northern spotted owl nutrition and fecundity (Hayward et al., 2011), perhaps due to abundance of prey (wood rats) along edges, including those associated with roads. Edges may affect interior old growth forests, but not necessarily adversely affect NSO fitness.

To determine indirect effects to NSO habitat (high NRF, NRF, dispersal, capable) from construction of the PCGP Project, Pacific Connector assessed effects to NSO habitat within 100 meters (328 feet) of proposed habitat removal, including effects to interior forest. This distance is similar to 300 feet that during discussions within the Habitat Quality subtask force to analyze effects to interior forests (2007 and 2008), and used as an edge assessment (295 feet) by Davis et al. (2011) within the NWFP 15 Year Monitoring Report for northern spotted owl habitat. Existing edge, such as roads, waterbodies, early seral forest, and nonforested habitat were incorporated into the interior forest modeling (buffered by 100 meters) to identify habitat currently affected by existing edge. This assessment considers the indirect effects of the newly constructed right-of-way on NSO habitat within 100 meters of habitat removal, including interior forest.

**Interior Forest Habitat**. Indirect effects from construction of the Pacific Connector pipeline are also expected within habitat adjacent to the PCGP construction right-of-way, including within interior forest that the marbled murrelet relies on for nesting habitat. To determine indirect effects to northern spotted owl habitat (high NRF, NRF, dispersal only, capable) from construction of the PCGP Project, Pacific Connector assessed effects to NSO habitat within 100 meters (328 feet) of proposed habitat removal, including effects to interior forest. Table 4.3.4-18 identifies the distance that NSO habitat is crossed by the proposed project within and outside of interior forest habitat, summarizes the acreage of NSO habitat directly removed and indirectly affected within 100 meters of the PCGP Project (habitat removal) by physiographic province, landowner, and NSO Groups (summarized from table Q-9 in appendix Q).

Approximately 14,234 acres of NSO habitat (3,243 acres of high NRF/NRF habitat, 4,336 acres of dispersal only habitat, and 6,656 acres of capable habitat) occur within 100 meters of habitat removal, of which 2,967 acres (20.8 percent of NSO habitat indirectly affected) of interior NSO habitat would be indirectly affected (962 acres of high NRF/NRF habitat, 1,134 acres of dispersal only habitat, and 872 acres of capable habitat; table 4.3.4-18). The majority of NSO habitat indirectly affected occurs within NSO groups crossed by the PCGP Project: 8,078 acres (56.7 percent) of all NSO habitat within 100 meters of habitat removal, which includes 1,997 acres of interior NSO habitat and 6,207 acres of NSO habitat currently affected by existing edge. Table Q-9 in appendix Q identifies the acres of NSO habitat affected 100 meters from habitat removal by physiographic province and general landowner, including effects within critical habitat and LSR. Effects to NSO habitat adjacent to the construction right-of-way will decrease as the forested area (approximately 1,741 acres; see table 4.3.4-13) outside of the 30-foot maintenance corridor are replanted with trees and return to early regenerating stands.

Based on analyses summarized in table 4.3.4-18, we assume that at least 26.4 miles of interior forest will experience fragmentation as a result of the proposed project, creating at least 52.8

miles (26.4 miles x 2) of additional edge in NSO habitat; this considers interior forest crossed by the proposed project within older regenerating forest to old-growth forest. Additional fragmentation of approximately 50.9 miles within forest currently affected by existing disturbance ("other" forest in table 4.3.4-18) could be affected since approximately 36.1 percent (70.3 miles) of the project within the range of NSO occurs within or is adjacent/parallels existing disturbance (see co-locate table Q-4 in appendix Q; 121.2 miles minus 70.3 miles = 50.9 miles), creating approximately 101.8 miles of additional edge in forest already affected by existing disturbance. In addition to NSO habitat crossed and affected within the NSO range, approximately 47.2 miles of non-capable habitat will be crossed and will remove approximately 2,031.37 acres (see table 4.3.4-13 and table Q-9 in appendix Q). Table 4.3.4-18 and figure 4.3-18 provide examples of how indirect effects to NSO habitat, both within and outside of interior forest are considered within the range of the NSO.

<u>Predation</u>

Few empirical studies exist to confirm that habitat fragmentation contributes to increased levels of predation on NSOs (Courtney et al., 2004). Great horned owls are known and potential predators of NSO (Johnson, 1992; Gutierrez et al., 1995), particularly in the context of effects of forest fragmentation on predation response, since great horned owls appear closely associated with forest openings and clearcuts (Johnson, 1992; Laidig and Dobkin, 1995). However, after a review of available evidence including predation by great horned owls, Courtney et al. (2004, pages 8–30) conclude: "there appears to be no reasonable basis for regarding an effect of fragmentation on predation levels as a primary or significant effect on NSO populations. Absent new information, the indirect effects of fragmentation through predation remains an untested hypothesis." Also, the FWS 5-Year Review (2004) stated that indirect evidence from demography studies suggests that predation, particularly by great horned owls, is not a major influence on NSO populations as was originally considered in the 1990 ESA listing.

Table 4.3.4-14 and table 4.3.4-16 indicate that 90 home ranges will be affected from habitat removal by the proposed action and may experience additional fragmentation with construction of the PCGP Project, including 35 core areas and eight nest patches (see also table Q-7 in appendix Q). It is possible that the 45 NSO sites that are below recommended threshold of available NRF habitat in the core area and/or home range, and/or would have interior forest habitat removed could experience a greater increase of predation, as great horned owls have been identified throughout the provincial analysis area during surveys in 2007 and 2008 (see biological reports submitted as a stand alone document to the FERC Certificate Application). Table 4.3.4-19 summarizes the number of home ranges that would have interior forest habitat (late regenerating forest to old-growth) removed by the proposed action and could experience additional fragmentation.

**Table 4.3.4-18**
**Indirect Effects from Construction of the Proposed Action to Northern Spotted Owl Habitat (High NRF, NRF, Dispersal Only, Capable), Including Interior Forest within and outside Northern Spotted Owl Groups by Landowner**

| Landowner[1] | General Location[2] | Interior Forest[3] | High NRF Habitat[4] | | | | NRF Habitat[5] | | | | Dispersal Only Habitat[6] | | | | Capable Habitat[7] | | | | Total Acres[8] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | | Construction | | | | Construction | | | | Construction | | | | Construction | | |
| | | | Miles Crossed | Removed[9] (acres) | Indirect[10] (acres) | UCSA[11] (acres) | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] |
| **Coast Range Physiographic Province** | | | | | | | | | | | | | | | | | | | | | | |
| *Federal* | NSO Groups | Interior | 1.08 | 13.18 | 106.63 | 4.49 | 0 | 0.01 | 1.41 | 0 | 0.38 | 4.11 | 24.68 | 1.96 | 0.46 | 6.75 | 38.4 | 0.8 | 1.92 | 24.05 | 171.12 | 7.25 |
| | | Other | 0.91 | 10.27 | 131.49 | 0.78 | 0.24 | 2.68 | 12.36 | 0 | 1.88 | 32.65 | 177.6 | 4.67 | 1.44 | 29.51 | 158.29 | 2.38 | 4.47 | 75.11 | 479.74 | 7.83 |
| | | Subtotal | 1.99 | 23.45 | 238.13 | 5.27 | 0.24 | 2.69 | 13.77 | 0 | 2.26 | 36.76 | 202.28 | 6.63 | 1.9 | 36.26 | 196.69 | 3.18 | 6.39 | 99.16 | 650.87 | 15.08 |
| | Outside NSO Groups | Interior | 0 | 0 | 9.67 | 0 | 0.2 | 2.31 | 14.82 | 0 | 0.59 | 9.68 | 64.59 | 0 | 0.08 | 1.61 | 12.11 | 0 | 0.87 | 13.6 | 101.19 | 0 |
| | | Other | 0.35 | 4.16 | 18.8 | 0 | 0.14 | 1.95 | 13.37 | 0 | 2.01 | 28.41 | 138.21 | 0 | 1.02 | 16.28 | 97.85 | 0 | 3.52 | 50.8 | 268.23 | 0 |
| | | Subtotal | 0.35 | 4.16 | 28.47 | 0 | 0.34 | 4.25 | 28.19 | 0 | 2.6 | 38.09 | 202.8 | 0 | 1.09 | 17.89 | 109.97 | 0 | 4.38 | 64.39 | 369.43 | 0 |
| | *Federal Sub total* | Interior | 1.08 | 13.18 | 116.3 | 4.49 | 0.2 | 2.32 | 16.23 | 0 | 0.97 | 13.79 | 89.27 | 1.96 | 0.54 | 8.36 | 50.52 | 0.8 | 2.79 | 37.65 | 272.32 | 7.25 |
| | | Other | 1.26 | 14.43 | 150.29 | 0.78 | 0.38 | 4.63 | 25.73 | 0 | 3.89 | 61.06 | 315.81 | 4.67 | 2.45 | 45.79 | 256.14 | 2.38 | 7.98 | 125.91 | 747.97 | 7.83 |
| | | Total | 2.34 | 27.61 | 266.6 | 5.27 | 0.58 | 6.95 | 41.96 | 0 | 4.86 | 74.86 | 405.08 | 6.63 | 2.99 | 54.15 | 306.66 | 3.18 | 10.77 | 163.57 | 1020.3 | 15.08 |
| *Non-Federal* | NSO Groups | Interior | 0 | 0 | 0.43 | 0 | 0 | 0 | 0.01 | 0 | 0.09 | 1.51 | 27.64 | 0.35 | 0.99 | 14.41 | 98.12 | 0 | 1.08 | 15.92 | 126.2 | 0.35 |
| | | Other | 0.26 | 3.31 | 14.99 | 0.25 | 0.03 | 0.43 | 1.33 | 0 | 1.05 | 22.44 | 211.9 | 3.62 | 8.79 | 159.8 | 786.33 | 19.72 | 10.13 | 185.98 | 1014.55 | 23.59 |
| | | Subtotal | 0.26 | 3.31 | 15.41 | 0.25 | 0.03 | 0.43 | 1.34 | 0 | 1.14 | 23.95 | 239.53 | 3.97 | 9.78 | 174.21 | 884.45 | 19.72 | 11.21 | 201.9 | 1140.73 | 23.94 |
| | Outside NSO Groups | Interior | 0 | 0 | 0.01 | 0 | 0.23 | 2.69 | 14.74 | 0 | 0.25 | 4.09 | 59.84 | 0 | 0.46 | 6.87 | 93.94 | 0 | 0.94 | 13.65 | 168.53 | 0 |
| | | Other | 0.06 | 0.71 | 2.43 | 0 | 0.58 | 7.69 | 46.58 | 0 | 3.36 | 47.42 | 321.27 | 1.04 | 14.02 | 233.67 | 1198.85 | 7.85 | 18.02 | 289.49 | 1569.13 | 8.89 |
| | | Subtotal | 0.06 | 0.71 | 2.44 | 0 | 0.81 | 10.38 | 61.32 | 0 | 3.6 | 51.51 | 381.11 | 1.04 | 14.47 | 240.54 | 1292.79 | 7.85 | 18.94 | 303.14 | 1737.66 | 8.89 |
| | *Non Federal Sub-total* | Interior | 0 | 0 | 0.44 | 0 | 0.23 | 2.69 | 14.74 | 0 | 0.34 | 5.61 | 87.48 | 0.35 | 1.44 | 21.28 | 192.06 | 0 | 2.01 | 29.58 | 294.72 | 0.35 |
| | | Other | 0.32 | 4.01 | 17.42 | 0.25 | 0.61 | 8.11 | 47.91 | 0 | 4.41 | 69.86 | 533.16 | 4.66 | 22.81 | 393.47 | 1985.18 | 27.56 | 28.15 | 475.45 | 2583.67 | 32.47 |
| | | Total | 0.32 | 4.01 | 17.85 | 0.25 | 0.84 | 10.8 | 62.65 | 0 | 4.74 | 75.46 | 620.64 | 5.02 | 24.25 | 414.75 | 2177.24 | 27.56 | 30.15 | 505.02 | 2878.38 | 32.83 |
| *Coast Range Total* | NSO Groups | Interior | 1.08 | 13.18 | 107.06 | 4.49 | 0 | 0.01 | 1.42 | 0 | 0.47 | 5.63 | 52.32 | 2.32 | 1.45 | 21.17 | 136.52 | 0.8 | 3 | 39.99 | 297.32 | 7.61 |
| | | Other | 1.16 | 13.58 | 146.48 | 1.03 | 0.27 | 3.11 | 13.69 | 0 | 2.93 | 55.09 | 389.49 | 8.29 | 10.23 | 189.3 | 944.61 | 22.1 | 14.59 | 261.08 | 1494.27 | 31.42 |
| | | Subtotal | 2.24 | 26.76 | 253.12 | 5.52 | 0.27 | 3.12 | 15.1 | 0 | 3.31 | 59.2 | 414.17 | 10.25 | 10.69 | 196.06 | 983.02 | 22.9 | 16.51 | 285.14 | 1665.41 | 38.67 |
| | Outside NSO Groups | Interior | 0 | 0 | 9.68 | 0 | 0.43 | 5 | 29.55 | 0 | 0.83 | 13.77 | 124.43 | 0 | 0.53 | 8.48 | 106.06 | 0 | 1.79 | 27.25 | 269.72 | 0 |
| | | Other | 0.41 | 4.87 | 21.23 | 0 | 0.72 | 9.63 | 59.95 | 0 | 5.37 | 75.83 | 459.48 | 1.04 | 15.03 | 249.95 | 1296.7 | 7.85 | 21.53 | 340.28 | 1837.36 | 8.89 |
| | | Subtotal | 0.41 | 4.87 | 30.91 | 0 | 1.15 | 14.63 | 89.5 | 0 | 6.2 | 89.6 | 583.91 | 1.04 | 15.56 | 258.43 | 1402.76 | 7.85 | 23.32 | 367.53 | 2107.08 | 8.89 |
| | *Coast Range Total* | Interior | 1.08 | 13.18 | 116.74 | 4.49 | 0.43 | 5.01 | 30.97 | 0 | 1.3 | 19.4 | 176.75 | 2.32 | 1.98 | 29.65 | 242.58 | 0.8 | 4.79 | 67.24 | 567.04 | 7.61 |
| | | Other | 1.58 | 18.45 | 167.71 | 1.03 | 0.99 | 12.74 | 73.64 | 0 | 8.3 | 130.92 | 848.97 | 9.33 | 25.26 | 439.26 | 2241.32 | 29.95 | 36.13 | 601.37 | 3331.64 | 40.31 |
| | | Total | 2.66 | 31.62 | 284.45 | 5.52 | 1.42 | 17.75 | 104.61 | 0 | 9.6 | 150.32 | 1025.72 | 11.65 | 27.24 | 468.9 | 2483.89 | 30.75 | 40.92 | 668.59 | 3898.67 | 47.92 |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | | | | | | | | | | | |
| *Federal* | NSO Groups | Interior | 2.43 | 33.49 | 254.02 | 27.45 | 1.68 | 23.85 | 128.65 | 17.09 | 0.75 | 10.79 | 144.7 | 8.69 | 0.66 | 9.88 | 79.85 | 3.69 | 5.52 | 78.01 | 607.22 | 56.92 |
| | | Other | 5.56 | 81.85 | 468.9 | 42.26 | 3.18 | 51.39 | 315.66 | 31.03 | 2.44 | 42.93 | 276.43 | 5.85 | 3.9 | 69.65 | 325.11 | 26.55 | 15.08 | 245.82 | 1386.1 | 105.69 |
| | | Subtotal | 7.99 | 115.34 | 722.92 | 69.71 | 4.86 | 75.24 | 444.31 | 48.12 | 3.19 | 53.72 | 421.12 | 14.54 | 4.56 | 79.53 | 404.95 | 30.24 | 20.6 | 323.83 | 1993.3 | 162.61 |

| Landowner[1] | General Location[2] | Interior Forest[3] | High NRF Habitat[4] | | | | NRF Habitat[5] | | | | Dispersal Only Habitat[6] | | | | Capable Habitat[7] | | | | Total Acres[8] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Construction | | | | Construction | | | | Construction | | | | Construction | | | | Construction | | |
| | | | Miles Crossed | Removed[9] (acres) | Indirect[10] (acres) | UCSA[11] (acres) | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] | Miles Crossed | Removed[8] | Indirect[9] (acres) | UCSA[10] |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 0.15 | 2.25 | 11.44 | 0.77 | 0.26 | 3.07 | 25.28 | 0.92 | 0.04 | 0.32 | 3.81 | 0 | 0.45 | 5.64 | 40.53 | 1.69 |
| | | Other | 0 | 0 | 3.62 | 0 | 0.54 | 10.98 | 57.91 | 6.69 | 0.57 | 7.86 | 46.82 | 2 | 0.46 | 7.86 | 43.1 | 1.99 | 1.57 | 26.7 | 151.45 | 10.68 |
| | | Subtotal | 0 | 0 | 3.62 | 0 | 0.69 | 13.23 | 69.35 | 7.47 | 0.84 | 10.94 | 72.1 | 2.92 | 0.5 | 8.18 | 46.91 | 1.99 | 2.03 | 32.35 | 191.98 | 12.38 |
| | *Federal Sub total* | Interior | 2.43 | 33.49 | 254.02 | 27.45 | 1.84 | 26.1 | 140.09 | 17.86 | 1.01 | 13.86 | 169.98 | 9.61 | 0.7 | 10.2 | 83.65 | 3.69 | 5.98 | 83.65 | 647.74 | 58.61 |
| | | Other | 5.56 | 81.85 | 472.52 | 42.26 | 3.72 | 62.37 | 373.57 | 37.73 | 3.01 | 50.79 | 323.24 | 7.85 | 4.36 | 77.51 | 368.21 | 28.54 | 16.65 | 272.52 | 1537.54 | 116.38 |
| | | Total | 7.99 | 115.34 | 726.54 | 69.71 | 5.56 | 88.47 | 513.66 | 55.59 | 4.02 | 64.65 | 493.22 | 17.46 | 5.06 | 87.71 | 451.86 | 32.23 | 22.63 | 356.17 | 2185.28 | 174.99 |
| *Non-Federal* | NSO Groups | Interior | 0.8 | 12.45 | 25.62 | 1.07 | 0.47 | 6.41 | 33.5 | 5.08 | 3.36 | 47.5 | 363.6 | 42.21 | 0.79 | 10.08 | 141.12 | 9.75 | 5.42 | 76.44 | 563.84 | 58.11 |
| | | Other | 1.66 | 26.51 | 66.36 | 11.57 | 2.06 | 31.23 | 151.73 | 34.49 | 5.46 | 86.32 | 590.82 | 55.82 | 5.31 | 88.88 | 649.46 | 75.16 | 14.49 | 232.94 | 1458.37 | 177.04 |
| | | Subtotal | 2.46 | 38.96 | 91.99 | 12.64 | 2.53 | 37.64 | 185.23 | 39.58 | 8.81 | 133.82 | 954.42 | 98.04 | 6.11 | 98.95 | 790.59 | 84.91 | 19.91 | 309.37 | 2022.23 | 235.17 |
| | Outside NSO Groups | Interior | 0.18 | 3.05 | 5.81 | 0.74 | 0.01 | 0.1 | 6.99 | 0.51 | 1.9 | 25.28 | 163.04 | 11.24 | 0 | 0.59 | 17 | 0 | 2.09 | 29.02 | 192.84 | 12.49 |
| | | Other | 0.29 | 4.75 | 6.77 | 1.07 | 0.2 | 3.82 | 23.17 | 0.82 | 5.69 | 88.11 | 598.79 | 18.68 | 2.41 | 71.49 | 379.24 | 27.2 | 8.59 | 168.17 | 1007.97 | 47.77 |
| | | Subtotal | 0.47 | 7.8 | 12.58 | 1.81 | 0.21 | 3.91 | 30.16 | 1.33 | 7.59 | 113.38 | 761.83 | 29.91 | 2.41 | 72.08 | 396.24 | 27.21 | 10.68 | 197.17 | 1200.81 | 60.26 |
| | *Non Federal Sub-total* | Interior | 0.97 | 15.5 | 31.43 | 1.82 | 0.48 | 6.51 | 40.49 | 5.59 | 5.26 | 72.77 | 526.65 | 53.45 | 0.79 | 10.66 | 158.12 | 9.76 | 7.5 | 105.44 | 756.69 | 70.62 |
| | | Other | 1.95 | 31.26 | 73.14 | 12.63 | 2.26 | 35.04 | 174.9 | 35.31 | 11.14 | 174.43 | 1189.61 | 74.5 | 7.72 | 160.37 | 1028.7 | 102.36 | 23.07 | 401.1 | 2466.35 | 224.8 |
| | | Total | 2.93 | 46.75 | 104.57 | 14.45 | 2.73 | 41.55 | 215.39 | 40.91 | 16.41 | 247.2 | 1716.25 | 127.95 | 8.52 | 171.03 | 1186.83 | 112.12 | 30.59 | 506.53 | 3223.04 | 295.43 |
| *Klamath Mountains Total* | NSO Groups | Interior | 3.23 | 45.93 | 279.64 | 28.53 | 2.15 | 30.26 | 162.15 | 22.17 | 4.1 | 58.28 | 508.3 | 50.9 | 1.46 | 19.96 | 220.97 | 13.44 | 10.94 | 154.43 | 1171.06 | 115.04 |
| | | Other | 7.22 | 108.36 | 535.26 | 53.82 | 5.24 | 82.62 | 467.4 | 65.53 | 7.9 | 129.25 | 867.25 | 61.68 | 9.21 | 158.52 | 974.57 | 101.71 | 29.57 | 478.75 | 2844.48 | 282.74 |
| | | Subtotal | 10.45 | 154.3 | 814.9 | 82.35 | 7.39 | 112.88 | 629.55 | 87.7 | 12 | 187.54 | 1375.54 | 112.58 | 10.67 | 178.48 | 1195.54 | 115.15 | 40.51 | 633.2 | 4015.53 | 397.78 |
| | Outside NSO Groups | Interior | 0.18 | 3.05 | 5.81 | 0.74 | 0.17 | 2.35 | 18.44 | 1.29 | 2.17 | 28.35 | 188.33 | 12.15 | 0.04 | 0.91 | 20.81 | 0 | 2.56 | 34.66 | 233.39 | 14.18 |
| | | Other | 0.29 | 4.75 | 10.4 | 1.07 | 0.73 | 14.8 | 81.07 | 7.51 | 6.26 | 95.97 | 645.6 | 20.68 | 2.87 | 79.36 | 422.34 | 29.2 | 10.15 | 194.88 | 1159.41 | 58.46 |
| | | Subtotal | 0.47 | 7.8 | 16.21 | 1.81 | 0.9 | 17.15 | 99.51 | 8.8 | 8.43 | 124.32 | 833.93 | 32.83 | 2.91 | 80.26 | 443.15 | 29.2 | 12.71 | 229.53 | 1392.8 | 72.64 |
| | *Klamath Mountains Total* | Interior | 3.4 | 48.98 | 285.45 | 29.27 | 2.31 | 32.61 | 180.58 | 23.46 | 6.27 | 86.64 | 696.62 | 63.06 | 1.5 | 20.87 | 241.78 | 13.45 | 13.48 | 189.1 | 1404.43 | 129.24 |
| | | Other | 7.52 | 113.11 | 545.66 | 54.89 | 5.98 | 97.42 | 548.47 | 73.04 | 14.16 | 225.22 | 1512.85 | 82.35 | 12.08 | 237.88 | 1396.91 | 130.9 | 39.74 | 673.63 | 4003.89 | 341.18 |
| | | Total | 10.92 | 162.1 | 831.11 | 84.16 | 8.29 | 130.02 | 729.06 | 96.5 | 20.43 | 311.86 | 2209.48 | 145.41 | 13.58 | 258.74 | 1638.69 | 144.35 | 53.22 | 862.72 | 5408.34 | 470.42 |
| **West Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | | | | |
| *Federal* | NSO Groups | Interior | 0 | 0 | 0.95 | 0 | 0.69 | 9.38 | 151.03 | 3.58 | 0.19 | 2.27 | 39.24 | 1.29 | 1.63 | 20.31 | 167.29 | 9.74 | 2.51 | 31.96 | 358.51 | 14.61 |
| | | Other | 0.07 | 0.56 | 2.93 | 0.52 | 6.44 | 82.36 | 467.88 | 33.06 | 1.42 | 17.03 | 120.63 | 4.76 | 5.18 | 87.94 | 433.69 | 16.07 | 13.11 | 187.89 | 1025.13 | 54.41 |
| | | Subtotal | 0.07 | 0.56 | 3.88 | 0.52 | 7.14 | 91.74 | 618.91 | 36.64 | 1.61 | 19.3 | 159.88 | 6.05 | 6.81 | 108.25 | 600.99 | 25.81 | 15.63 | 219.85 | 1383.66 | 69.02 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 1.12 | 17.61 | 129.8 | 3.73 | 0.49 | 7.26 | 35.89 | 1 | 0 | 0 | 0.46 | 0 | 1.61 | 24.87 | 166.15 | 4.73 |
| | | Other | 0.05 | 0.97 | 1.64 | 0 | 1.51 | 24.44 | 183.31 | 5.33 | 1.62 | 25.62 | 94.71 | 2.25 | 0.12 | 1.24 | 10.25 | 0.64 | 3.3 | 52.27 | 289.91 | 8.22 |
| | | Subtotal | 0.05 | 0.97 | 1.64 | 0 | 2.62 | 42.05 | 313.1 | 9.06 | 2.12 | 32.88 | 130.6 | 3.25 | 0.12 | 1.24 | 10.71 | 0.64 | 4.91 | 77.14 | 456.05 | 12.95 |
| | *Federal Sub total* | Interior | 0 | 0 | 0.95 | 0 | 1.81 | 26.99 | 280.83 | 7.31 | 0.68 | 9.53 | 75.13 | 2.29 | 1.63 | 20.31 | 167.76 | 9.74 | 4.12 | 56.83 | 524.67 | 19.34 |
| | | Other | 0.13 | 1.54 | 4.57 | 0.52 | 7.95 | 106.8 | 651.18 | 38.39 | 3.04 | 42.65 | 215.35 | 7.01 | 5.31 | 89.18 | 443.94 | 16.71 | 16.43 | 240.17 | 1315.04 | 62.63 |
| | | Total | 0.13 | 1.54 | 5.52 | 0.52 | 9.76 | 133.79 | 932.01 | 45.7 | 3.72 | 52.18 | 290.48 | 9.3 | 6.93 | 109.49 | 611.7 | 26.45 | 20.54 | 297 | 1839.71 | 81.97 |

| Landowner[1] | General Location[2] | Interior Forest[3] | High NRF Habitat[4] | | | | NRF Habitat[5] | | | | Dispersal Only Habitat[6] | | | | Capable Habitat[7] | | | | Total Acres[8] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles Crossed | Construction: Removed[9] (acres) | Construction: Indirect[10] (acres) | Construction: UCSA[11] (acres) | Miles Crossed | Construction: Removed[8] | Construction: Indirect[9] (acres) | Construction: UCSA[10] | Miles Crossed | Construction: Removed[8] | Construction: Indirect[9] (acres) | Construction: UCSA[10] | Miles Crossed | Construction: Removed[8] | Construction: Indirect[9] (acres) | Construction: UCSA[10] | Miles Crossed | Construction: Removed[8] | Construction: Indirect[9] (acres) | Construction: UCSA[10] |
| *Non-Federal* | NSO Groups | Interior | 0 | 0 | 0 | 0 | 0.14 | 1.62 | 12.06 | 0.94 | 0.29 | 5.04 | 28.67 | 1.03 | 0.15 | 2.08 | 16.86 | 0.04 | 0.58 | 8.74 | 57.59 | 2.01 |
| | | Other | 0 | 0 | 1.66 | 0 | 0.57 | 9.17 | 41.59 | 3.18 | 1.55 | 23.3 | 128.94 | 3.49 | 2.6 | 39.35 | 272.19 | 7.75 | 4.72 | 71.82 | 444.38 | 14.42 |
| | | Subtotal | 0 | 0 | 1.66 | 0 | 0.71 | 10.78 | 53.64 | 4.12 | 1.84 | 28.34 | 157.61 | 4.51 | 2.75 | 41.44 | 289.05 | 7.79 | 5.3 | 80.56 | 501.96 | 16.42 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 0.43 | 5.64 | 19.96 | 1.32 | 0.33 | 4.75 | 28.88 | 0.93 | 0.25 | 3.8 | 59.05 | 0.7 | 1.01 | 14.19 | 107.89 | 2.95 |
| | | Other | 0 | 0 | 0 | 0 | 0.92 | 13.43 | 39.83 | 1.2 | 4.16 | 62.69 | 254.5 | 2.67 | 0.17 | 2.86 | 446.38 | 0.12 | 5.25 | 78.98 | 740.71 | 3.99 |
| | | Subtotal | 0 | 0 | 0 | 0 | 1.35 | 19.07 | 59.8 | 2.51 | 4.49 | 67.44 | 283.39 | 3.6 | 0.41 | 6.66 | 505.43 | 0.83 | 6.25 | 93.17 | 848.62 | 6.94 |
| | *Non Federal Sub-total* | Interior | 0 | 0 | 0 | 0 | 0.57 | 7.25 | 32.02 | 2.26 | 0.62 | 9.78 | 57.56 | 1.96 | 0.39 | 5.88 | 75.92 | 0.75 | 1.58 | 22.91 | 165.5 | 4.97 |
| | | Other | 0 | 0 | 1.66 | 0 | 1.49 | 22.6 | 81.42 | 4.38 | 5.71 | 85.99 | 383.44 | 6.16 | 2.77 | 42.21 | 718.57 | 7.87 | 9.97 | 150.8 | 1185.09 | 18.41 |
| | | Total | 0 | 0 | 1.66 | 0 | 2.06 | 29.85 | 113.44 | 6.63 | 6.33 | 95.77 | 441 | 8.11 | 3.16 | 48.09 | 794.49 | 8.62 | 11.55 | 173.71 | 1350.59 | 23.36 |
| *West Cascades Total* | NSO Groups | Interior | 0 | 0 | 0.95 | 0 | 0.83 | 11 | 163.08 | 4.52 | 0.48 | 7.31 | 67.92 | 2.32 | 1.77 | 22.39 | 184.16 | 9.78 | 3.08 | 40.7 | 416.11 | 16.62 |
| | | Other | 0.07 | 0.56 | 4.59 | 0.52 | 7.02 | 91.53 | 509.47 | 36.24 | 2.97 | 40.33 | 249.57 | 8.24 | 7.79 | 127.3 | 705.88 | 23.82 | 17.85 | 259.72 | 1469.51 | 68.82 |
| | | Subtotal | 0.07 | 0.56 | 5.53 | 0.52 | 7.85 | 102.53 | 672.55 | 40.76 | 3.45 | 47.64 | 317.49 | 10.56 | 9.56 | 149.68 | 890.04 | 33.6 | 20.93 | 300.41 | 1885.61 | 85.44 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 1.55 | 23.25 | 149.76 | 5.05 | 0.83 | 12 | 64.77 | 1.93 | 0.25 | 3.8 | 59.52 | 0.7 | 2.63 | 39.05 | 274.05 | 7.68 |
| | | Other | 0.05 | 0.97 | 1.64 | 0 | 2.43 | 37.87 | 223.14 | 6.52 | 5.78 | 88.31 | 349.22 | 4.92 | 0.29 | 4.1 | 456.63 | 0.76 | 8.55 | 131.25 | 1030.63 | 12.2 |
| | | Subtotal | 0.05 | 0.97 | 1.64 | 0 | 3.98 | 61.12 | 372.9 | 11.57 | 6.61 | 100.31 | 413.99 | 6.85 | 0.54 | 7.9 | 516.15 | 1.46 | 11.18 | 170.3 | 1304.68 | 19.88 |
| | *West Cascades Total* | Interior | 0 | 0 | 0.95 | 0 | 2.38 | 34.25 | 312.85 | 9.56 | 1.3 | 19.31 | 132.69 | 4.25 | 2.02 | 26.19 | 243.68 | 10.48 | 5.7 | 79.75 | 690.17 | 24.29 |
| | | Other | 0.13 | 1.54 | 6.23 | 0.52 | 9.44 | 129.4 | 732.61 | 42.77 | 8.75 | 128.64 | 598.79 | 13.16 | 8.08 | 131.4 | 1162.51 | 24.59 | 26.4 | 390.98 | 2500.14 | 81.04 |
| | | Total | 0.13 | 1.54 | 7.18 | 0.52 | 11.82 | 163.64 | 1045.45 | 52.33 | 10.06 | 147.95 | 731.47 | 17.42 | 10.09 | 157.58 | 1406.19 | 35.07 | 32.1 | 470.71 | 3190.29 | 105.34 |
| **East Cascades Physiographic Province** | | | | | | | | | | | | | | | | | | | | | | |
| *Federal* | NSO Groups | Interior | 0 | 0 | 14.58 | 0 | 0.14 | 1.63 | 11.49 | 0.63 | 0 | 0.02 | 9.35 | 0 | 0.54 | 6.12 | 61.83 | 2.43 | 0.68 | 7.77 | 97.25 | 3.06 |
| | | Other | 1.13 | 13.92 | 68.47 | 2.22 | 1.18 | 15.21 | 67.58 | 1.66 | 0.23 | 2.76 | 29.75 | 0.92 | 1.56 | 21.74 | 114.85 | 2.06 | 4.1 | 53.63 | 280.65 | 6.86 |
| | | Subtotal | 1.13 | 13.92 | 83.05 | 2.22 | 1.31 | 16.84 | 79.07 | 2.29 | 0.23 | 2.78 | 39.1 | 0.92 | 2.1 | 27.86 | 176.68 | 4.49 | 4.77 | 61.4 | 377.9 | 9.92 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 0 | 0 | 8.21 | 0 | 0.03 | 0.24 | 10.81 | 0.27 | 0 | 0 | 4.94 | 0 | 0.03 | 0.24 | 23.96 | 0.27 |
| | | Other | 0.56 | 7.48 | 11.7 | 1.2 | 1.23 | 17.03 | 54.4 | 0.42 | 0.56 | 7.72 | 58.74 | 0.42 | 0.03 | 0.59 | 27.08 | 0.01 | 2.38 | 32.82 | 151.92 | 2.05 |
| | | Subtotal | 0.56 | 7.48 | 11.7 | 1.2 | 1.23 | 17.03 | 62.61 | 0.42 | 0.59 | 7.96 | 69.55 | 0.7 | 0.03 | 0.59 | 32.02 | 0.01 | 2.41 | 33.06 | 175.88 | 2.33 |
| | *Federal Sub total* | Interior | 0 | 0 | 14.58 | 0 | 0.14 | 1.63 | 19.7 | 0.63 | 0.03 | 0.26 | 20.16 | 0.27 | 0.54 | 6.12 | 66.78 | 2.43 | 0.71 | 8.01 | 121.22 | 3.33 |
| | | Other | 1.69 | 21.4 | 80.17 | 3.41 | 2.41 | 32.24 | 121.98 | 2.09 | 0.79 | 10.48 | 88.49 | 1.34 | 1.59 | 22.32 | 141.92 | 2.07 | 6.48 | 86.44 | 432.56 | 8.91 |
| | | Total | 1.69 | 21.4 | 94.74 | 3.41 | 2.54 | 33.87 | 141.68 | 2.71 | 0.82 | 10.74 | 108.65 | 1.61 | 2.13 | 28.45 | 208.7 | 4.5 | 7.18 | 94.46 | 553.77 | 12.23 |
| *Non-Federal* | NSO Groups | Interior | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 | 0 | 3.03 | 0 | 0.08 | 0.82 | 12.48 | 0.56 | 0.08 | 0.82 | 15.53 | 0.56 |
| | | Other | 0 | 0.02 | 0.27 | 0.01 | 0.02 | 0.29 | 1.59 | 0 | 0.19 | 3.06 | 14.39 | 0 | 1.36 | 19.4 | 101.84 | 1.74 | 1.57 | 22.77 | 118.09 | 1.75 |
| | | Subtotal | 0 | 0.02 | 0.27 | 0.01 | 0.02 | 0.29 | 1.61 | 0 | 0.19 | 3.06 | 17.43 | 0 | 1.44 | 20.22 | 114.32 | 2.31 | 1.65 | 23.59 | 133.63 | 2.32 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 1.17 | 15.28 | 104.59 | 0 | 0.47 | 6.05 | 64.33 | 0 | 1.64 | 21.33 | 168.94 | 0 |
| | | Other | 0 | 0 | 0.01 | 0 | 0.21 | 2.54 | 2.79 | 0.01 | 4.23 | 52.31 | 138.43 | 0 | 6.49 | 82.4 | 739.76 | 0.37 | 10.93 | 137.25 | 880.99 | 0.38 |
| | | Subtotal | 0 | 0 | 0.01 | 0 | 0.21 | 2.54 | 2.81 | 0.01 | 5.4 | 67.59 | 243.03 | 0 | 6.95 | 88.45 | 804.08 | 0.37 | 12.56 | 158.58 | 1049.93 | 0.38 |

| Landowner[1] | General Location[2] | Interior Forest[3] | High NRF Habitat[4] | | | | NRF Habitat[5] | | | | Dispersal Only Habitat[6] | | | | Capable Habitat[7] | | | | Total Acres[8] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | |
| | | | | Removed[9] (acres) | Indirect[10] (acres) | UCSA[11] (acres) | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] |
| | *Non Federal Sub-total* | Interior | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 1.17 | 15.28 | 107.63 | 0 | 0.55 | 6.87 | 76.81 | 0.56 | 1.72 | 22.15 | 184.47 | 0.56 |
| | | Other | 0 | 0.02 | 0.28 | 0.01 | 0.23 | 2.83 | 4.39 | 0.01 | 4.42 | 55.36 | 152.83 | 0 | 7.85 | 101.8 | 841.6 | 2.12 | 12.5 | 160.01 | 999.1 | 2.14 |
| | | Total | 0 | 0.02 | 0.28 | 0.01 | 0.23 | 2.83 | 4.42 | 0.01 | 5.59 | 70.65 | 260.46 | 0 | 8.4 | 108.67 | 918.41 | 2.68 | 14.22 | 182.17 | 1183.57 | 2.7 |
| *East Cascades Total* | NSO Groups | Interior | 0 | 0 | 14.58 | 0 | 0.14 | 1.63 | 11.51 | 0.63 | 0 | 0.02 | 12.38 | 0 | 0.63 | 6.94 | 74.31 | 3 | 0.77 | 8.59 | 112.78 | 3.63 |
| | | Other | 1.13 | 13.95 | 68.74 | 2.23 | 1.2 | 15.5 | 69.18 | 1.66 | 0.42 | 5.82 | 44.15 | 0.92 | 2.92 | 41.14 | 216.69 | 3.8 | 5.67 | 76.41 | 398.76 | 8.61 |
| | | Subtotal | 1.13 | 13.95 | 83.31 | 2.23 | 1.33 | 17.13 | 80.68 | 2.29 | 0.42 | 5.83 | 56.53 | 0.92 | 3.54 | 48.08 | 291 | 6.8 | 6.42 | 84.99 | 511.52 | 12.24 |
| | Outside NSO Groups | Interior | 0 | 0 | 0 | 0 | 0 | 0 | 8.23 | 0 | 1.2 | 15.53 | 115.41 | 0.27 | 0.47 | 6.05 | 69.27 | 0 | 1.67 | 21.58 | 192.91 | 0.27 |
| | | Other | 0.56 | 7.48 | 11.71 | 1.2 | 1.44 | 19.57 | 57.19 | 0.43 | 4.79 | 60.02 | 197.17 | 0.42 | 6.52 | 82.99 | 766.83 | 0.38 | 13.31 | 170.06 | 1032.9 | 2.43 |
| | | Subtotal | 0.56 | 7.48 | 11.71 | 1.2 | 1.44 | 19.57 | 65.42 | 0.43 | 5.99 | 75.55 | 312.58 | 0.7 | 6.99 | 89.04 | 836.11 | 0.38 | 14.98 | 191.64 | 1225.82 | 2.71 |
| | *East Cascades Total* | Interior | 0 | 0 | 14.58 | 0 | 0.14 | 1.63 | 19.73 | 0.63 | 1.2 | 15.54 | 127.79 | 0.27 | 1.09 | 12.99 | 143.58 | 3 | 2.43 | 30.16 | 305.68 | 3.9 |
| | | Other | 1.69 | 21.42 | 80.45 | 3.43 | 2.64 | 35.07 | 126.37 | 2.1 | 5.21 | 65.84 | 241.32 | 1.34 | 9.43 | 124.12 | 983.52 | 4.19 | 18.97 | 246.45 | 1431.66 | 11.06 |
| | | Total | 1.69 | 21.42 | 95.03 | 3.43 | 2.77 | 36.7 | 146.1 | 2.72 | 6.41 | 81.38 | 369.11 | 1.61 | 10.53 | 137.12 | 1127.11 | 7.19 | 21.4 | 276.62 | 1737.35 | 14.95 |
| **Entire Northern Spotted Owl Range** | | | | | | | | | | | | | | | | | | | | | | |
| *Federal* | NSO Groups | Interior | 3.51 | 46.66 | 376.17 | 31.94 | 2.51 | 34.87 | 292.58 | 21.29 | 1.31 | 17.19 | 217.97 | 11.95 | 3.29 | 43.07 | 347.38 | 16.66 | 10.62 | 141.79 | 1234.1 | 81.84 |
| | | Other | 7.67 | 106.62 | 671.79 | 45.78 | 11.04 | 151.64 | 863.48 | 65.76 | 5.97 | 95.38 | 604.41 | 16.2 | 12.08 | 208.83 | 1031.94 | 47.07 | 36.76 | 562.47 | 3171.62 | 174.81 |
| | | Subtotal | 11.18 | 153.28 | 1047.97 | 77.72 | 13.55 | 186.52 | 1156.06 | 87.05 | 7.29 | 112.56 | 822.38 | 28.14 | 15.37 | 251.9 | 1379.31 | 63.72 | 47.39 | 704.26 | 4405.72 | 256.63 |
| | Outside NSO Groups | Interior | 0 | 0 | 9.67 | 0 | 1.47 | 22.17 | 164.27 | 4.5 | 1.37 | 20.26 | 136.57 | 2.19 | 0.12 | 1.93 | 21.33 | 0 | 2.96 | 44.36 | 331.84 | 6.69 |
| | | Other | 0.97 | 12.61 | 35.76 | 1.2 | 3.41 | 54.4 | 308.98 | 12.44 | 4.77 | 69.61 | 338.47 | 4.67 | 1.63 | 25.97 | 178.28 | 2.64 | 10.78 | 162.59 | 861.49 | 20.95 |
| | | Subtotal | 0.97 | 12.61 | 45.43 | 1.2 | 4.88 | 76.57 | 473.25 | 16.95 | 6.14 | 89.86 | 475.05 | 6.87 | 1.75 | 27.9 | 199.61 | 2.64 | 13.74 | 206.94 | 1193.34 | 27.66 |
| | *Federal Sub total* | Interior | 3.51 | 46.66 | 385.84 | 31.94 | 3.98 | 57.04 | 456.84 | 25.8 | 2.69 | 37.45 | 354.54 | 14.14 | 3.41 | 45 | 368.71 | 16.66 | 13.59 | 186.15 | 1565.93 | 88.54 |
| | | Other | 8.64 | 119.22 | 707.56 | 46.97 | 14.46 | 206.05 | 1172.47 | 78.2 | 10.74 | 164.98 | 942.89 | 20.87 | 13.71 | 234.8 | 1210.21 | 49.71 | 47.55 | 725.05 | 4033.13 | 195.75 |
| | | Total | 12.15 | 165.89 | 1093.4 | 78.92 | 18.44 | 263.09 | 1629.31 | 104 | 13.43 | 202.43 | 1297.43 | 35.01 | 17.12 | 279.8 | 1578.92 | 66.37 | 61.14 | 911.21 | 5599.06 | 284.3 |
| *Non-Federal* | NSO Groups | Interior | 0.8 | 12.45 | 26.05 | 1.07 | 0.6 | 8.03 | 45.58 | 6.02 | 3.74 | 54.05 | 422.95 | 43.6 | 2.01 | 27.39 | 268.59 | 10.36 | 7.15 | 101.92 | 763.17 | 61.05 |
| | | Other | 1.92 | 29.84 | 83.28 | 11.83 | 2.69 | 41.11 | 196.24 | 37.67 | 8.25 | 135.11 | 946.05 | 62.93 | 18.07 | 307.43 | 1809.82 | 104.37 | 30.93 | 513.49 | 3035.39 | 216.8 |
| | | Subtotal | 2.72 | 42.29 | 109.33 | 12.9 | 3.29 | 49.14 | 241.82 | 43.7 | 11.99 | 189.16 | 1368.99 | 106.52 | 20.08 | 334.82 | 2078.41 | 114.73 | 38.08 | 615.41 | 3798.55 | 277.85 |
| | Outside NSO Groups | Interior | 0.18 | 3.05 | 5.82 | 0.74 | 0.68 | 8.42 | 41.71 | 1.83 | 3.65 | 49.4 | 356.37 | 12.16 | 1.17 | 17.3 | 234.32 | 0.71 | 5.68 | 78.17 | 638.22 | 15.44 |
| | | Other | 0.35 | 5.46 | 9.21 | 1.07 | 1.9 | 27.47 | 112.37 | 2.03 | 17.43 | 250.52 | 1312.99 | 22.39 | 23.08 | 390.42 | 2764.23 | 35.55 | 42.76 | 673.87 | 4198.8 | 61.04 |
| | | Subtotal | 0.53 | 8.5 | 15.04 | 1.81 | 2.58 | 35.9 | 154.08 | 3.86 | 21.08 | 299.92 | 1669.36 | 34.55 | 24.25 | 407.73 | 2998.55 | 36.25 | 48.44 | 752.05 | 4837.03 | 76.47 |
| | *Non Federal Sub-total* | Interior | 0.97 | 15.5 | 31.87 | 1.82 | 1.28 | 16.45 | 87.29 | 7.85 | 7.39 | 103.45 | 779.31 | 55.76 | 3.18 | 44.7 | 502.91 | 11.07 | 12.82 | 180.1 | 1401.38 | 76.5 |
| | | Other | 2.27 | 35.29 | 92.49 | 12.89 | 4.59 | 68.58 | 308.62 | 39.7 | 25.68 | 385.63 | 2259.04 | 85.32 | 41.14 | 697.85 | 4574.05 | 139.91 | 73.68 | 1187.35 | 7234.2 | 277.82 |
| | | Total | 3.25 | 50.79 | 124.36 | 14.71 | 5.87 | 85.04 | 395.91 | 47.55 | 33.07 | 489.08 | 3038.35 | 141.08 | 44.33 | 742.55 | 5076.96 | 150.99 | 86.52 | 1367.46 | 8635.58 | 354.33 |
| *Total NSO Range* | NSO Groups | Interior | 4.31 | 59.11 | 402.22 | 33.01 | 3.11 | 42.9 | 338.16 | 27.32 | 5.05 | 71.24 | 640.92 | 55.54 | 5.3 | 70.46 | 615.96 | 27.02 | 17.77 | 243.71 | 1997.26 | 142.89 |
| | | Other | 9.59 | 136.45 | 755.07 | 57.6 | 13.73 | 192.75 | 1059.73 | 103.43 | 14.22 | 230.49 | 1550.46 | 79.12 | 30.14 | 516.26 | 2841.76 | 151.44 | 67.68 | 1075.95 | 6207.02 | 391.59 |
| | | Subtotal | 13.9 | 195.56 | 1156.87 | 90.62 | 16.84 | 235.65 | 1397.88 | 130.75 | 19.19 | 300.21 | 2163.74 | 134.31 | 34.46 | 572.3 | 3359.6 | 178.46 | 84.39 | 1303.72 | 8078.09 | 534.14 |

| Landowner[1] | General Location[2] | Interior Forest[3] | High NRF Habitat[4] | | | | NRF Habitat[5] | | | | Dispersal Only Habitat[6] | | | | Capable Habitat[7] | | | | Total Acres[8] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | | Miles Crossed | Construction | | |
| | | | | Removed[9] (acres) | Indirect[10] (acres) | UCSA[11] (acres) | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] | | Removed[8] | Indirect[9] (acres) | UCSA[10] |
| | Outside NSO Groups | Interior | 0.18 | 3.05 | 15.49 | 0.74 | 2.15 | 30.59 | 205.98 | 6.33 | 5.03 | 69.66 | 492.94 | 14.36 | 1.29 | 19.24 | 255.65 | 0.71 | 8.65 | 122.54 | 970.06 | 22.14 |
| | | Other | 1.32 | 18.06 | 44.98 | 2.27 | 5.32 | 81.88 | 421.36 | 14.47 | 22.2 | 320.13 | 1651.47 | 27.06 | 24.71 | 416.39 | 2942.5 | 38.19 | 53.55 | 836.46 | 5060.31 | 81.99 |
| | | Subtotal | 1.5 | 21.11 | 60.47 | 3.01 | 7.46 | 112.47 | 627.33 | 20.8 | 27.22 | 389.79 | 2144.41 | 41.42 | 26 | 435.63 | 3198.16 | 38.89 | 62.18 | 959 | 6030.37 | 104.12 |
| | *NSO RangeTotal* | Interior | 4.48 | 62.16 | 417.71 | 33.76 | 5.26 | 73.49 | 544.13 | 33.65 | 10.08 | 140.89 | 1133.86 | 69.9 | 6.59 | 89.69 | 871.62 | 27.73 | 26.41 | 366.23 | 2967.32 | 165.04 |
| | | Other | 10.91 | 154.52 | 800.05 | 59.87 | 19.05 | 274.63 | 1481.08 | 117.9 | 36.42 | 550.62 | 3201.93 | 106.19 | 54.85 | 932.65 | 5784.26 | 189.62 | 121.23 | 1912.42 | 11267.32 | 473.58 |
| | | Total | 15.4 | 216.68 | 1217.76 | 93.63 | 24.31 | 348.12 | 2025.22 | 151.55 | 46.5 | 691.51 | 4335.78 | 176.09 | 61.44 | 1022.35 | 6655.88 | 217.35 | 147.65 | 2278.66 | 14234.64 | 638.62 |

1 Landowner is summarized by Federal (BLM Districts and National Forests) and Non-Federal (Private, State, Corps of Engineers, and Bureau of Indian Affairs Land).
2 General Location identifies areas within Northern Spotted Owl Groups (areas within NSO home ranges; see table Q-10 in appendix Q) and areas outside of NSO groups (outside of NSO home ranges).
3 Interior Forest: further than 100 meters from existing disturbance (i.e., high-traveled roads, existing corridors) or adjacent landuse/vegetation type (i.e., agriculture, non-forest, early regenerating forest); Other Forest Type includes forested habitat that is currently affected by existing disturbance or adjacent landuse/vegetation types within 100 meters of forested stand.
4 High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
5 NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
6 Dispersal ONLY (FWS, 2012): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
7 Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.
8 Total habitat only considers forested NSO habitat within the range of the NSO; non-capable habitat affected in range of NSO is included in table Q-9 in appendix Q.
9 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
10 Indirect Effects considers habitat within 100 meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
11 Acres identified as UCSAs have been incorporated into the 300-foot indirect effects. UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.

Summarized from table Q-9 in appendix Q.

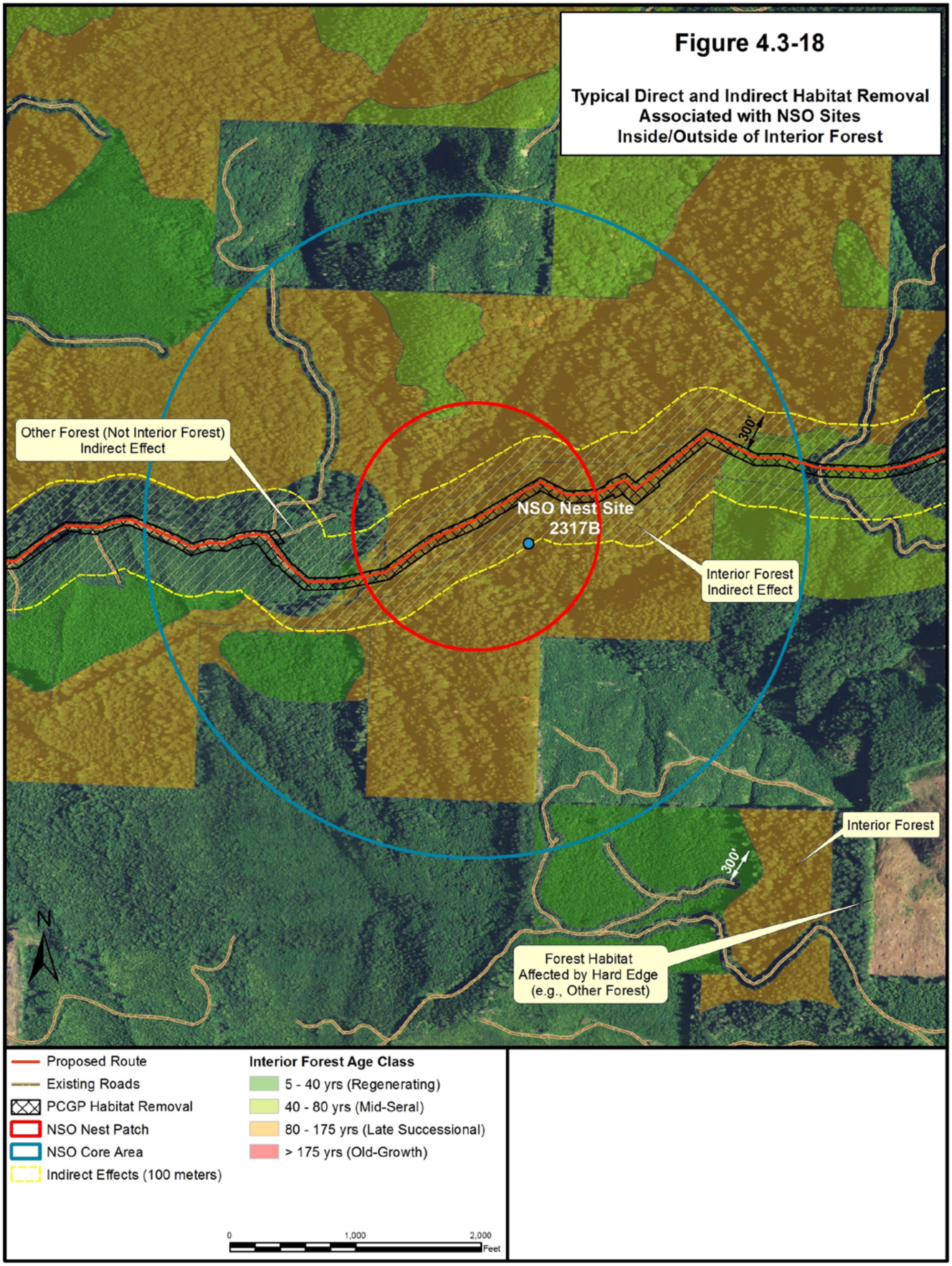


Figure 4.3-18
Typical Direct and Indirect Habitat Removal Associated with NSO Sites Inside/Outside of Interior Forest
Other Forest (Not Interior Forest) Indirect Effect
NSO Nest Site 2317B
Interior Forest Indirect Effect
300'
Interior Forest
300'
Forest Habitat Affected by Hard Edge (e.g., Other Forest)
N
Proposed Route
Existing Roads
PCGP Habitat Removal
NSO Nest Patch
NSO Core Area
Indirect Effects (100 meters)
Interior Forest Age Class
5 - 40 yrs (Regenerating)
40 - 80 yrs (Mid-Seral)
80 - 175 yrs (Late Successional)
> 175 yrs (Old-Growth)
0
1,000
2,000
Feet

**Table 4.3.4-19**
**Number of NSO Home Ranges by Physiographic Province that could Experience Additional Fragmentation (i.e., interior forest removed by Project)[1]**

| Suitable NRF Habitat Condition within Owl Home Ranges[2] | Owl Status[3] | Physiographic Province | | | | |
|---|---|---|---|---|---|---|
| | | Coast Range | Klamath Mountains | West Cascades | East Cascades | Total |
| Home Range >40% AND Core Area >50% (*Above Threshold)* | Known | 1 | 12 | 6 | 3 | 22 |
| | Best Location | – | 3 | 3 | – | 6 |
| | PCGP Assumed | – | – | – | – | 0 |
| | *Total* | *1* | *15* | *9* | *3* | 28 |
| Home Range >40% AND Core Area <50% (*Below Threshold)* | Known | – | 2 | 2 | – | 4 |
| | Best Location | – | 1 | 2 | – | 3 |
| | PCGP Assumed | – | – | – | – | 0 |
| | *Total* | *0* | *3* | *4* | *0* | 7 |
| Home Range <40% AND Core Area >50% (*Below Threshold)* | Known | 1 | 2 | 1 | – | 4 |
| | Best Location | – | 1 | – | – | 1 |
| | PCGP Assumed | 1 | 1 | – | – | 2 |
| | *Total* | *2* | *4* | *1* | *0* | 7 |
| Home Range <40% AND Core Area <50% (*Below Threshold)* | Known | 5 | 13 | 1 | 1 | 20 |
| | Best Location | 1 | 5 | 1 | – | 7 |
| | PCGP Assumed | 2 | 1 | 1 | – | 4 |
| | *Total* | *8* | *19* | *4* | *1* | 31 |
| Overall Total | Known | 7 | 33 | 19 | 4 | 50 |
| | Best Location | 1 | 10 | 6 | 0 | 17 |
| | PCGP Assumed | 3 | 2 | 1 | 0 | 6 |
| | *Total* | 11 | 41 | 17 | 4 | 73 |

[1] For detailed NRF/High NRF habitat available for each individual NSO and its habitat type (nest patch, core area, home range), refer to "pre-action" suitable habitat acres in table Q-7 in appendix Q. Interior forest includes habitat from late regenerating to old-growth.
[2] FWS et al. (2008) consider core areas with 50 percent or greater suitable NRF habitat and home ranges with at least 40 percent suitable NRF habitat to be necessary to maintain NSO life history function.
[3] Owl Status: 1) Known sites represent NSO activity sites provided by BLM and Forest Service biologists within the provincial analysis area; 2) Best Location sites represent pairs or resident singles documented by Pacific Connector during surveys in 2007 and 2008 with no nest site/activity center located, and; 3) PCGP assumed sites considered for analysis in this BA.

<u>Competition</u>

Since the listing of the NSO, recent reviews have more specifically identified competition with the barred owl in the Coast Range and wildfire in the relatively dry East Cascades and Klamath Mountain provinces, as greater threats than previously considered (FWS, 2011b; Anthony et al., 2006; FWS, 2004; Courtney et al., 2004; Kelley et al., 2003).

Barred owls are known to use a wide variety of forest types, including early successional habitats, and some authors have suggested that timber harvest activities may favor the species. For instance, fragmentation of forest habitat may have created favorable conditions for survival and reproduction of barred owls. By contrast, NSOs appear to be more generally associated with old growth forest or forests that are structurally complex (Courtney et al., 2004). Therefore, timber harvest may have increased overlap of the two species' preferred and potential habitats which has led to increased competition. Hicks et al. (2001) attempted to examine that hypothesis in the northern part of the range by determining the amounts of different habitat types surrounding NSO territories that either have or have not been invaded by barred owls. They detected no effect of surrounding habitat on the probability of replacement by competitive barred owls. Also, under the Plum Creek Habitat Conservation Plan, harvest was deferred for areas of nesting, roosting and foraging habitat around 30 productive NSO sites. After six years, only 10 sites had NSO presence – the rate of decline is very similar to that seen at other areas where timber harvest occurred.

Although survey design was not intended to locate or census barred owls or barred owl pairs, during surveys for NSOs conducted along the Pacific Connector pipeline route, barred owls were documented 79 times in 14 survey areas in 2007 (4 pairs), and 115 times in 14 survey areas in 2008 (8 pairs). Of the 194 barred owls documented, 33 were dispersed along the pipeline right-of-way within the Coast Range, 74 were documented within Klamath Mountains mostly along the eastern portion of the province, 21 were located in West Cascades, and 66 documented sites were located within the western portion of East Cascades province, of which seven were located while surveying the original Buck Lake route (see table 4.3.4-20). Ray Davis (2008b), a biologist with the Umpqua National Forest, provided an analysis using partial data (only 36 barred owl sites) provided in December 2007, that demonstrated barred owls located within the Pacific Connector pipeline occurred more often in marginal NSO suitable nesting, roosting, foraging habitat than the NSOs documented during 2007 surveys, which were generally located within the more contiguous and suitable NRF habitat within the Project Area. Reduction of suitable NSO habitat may have an effect on the NSO by providing a competitive advantage for barred owls, since some research and preliminary modeling by Davis (2007) has demonstrated that barred owls have a wider breadth of habitat use than the NSO and are more often located in marginal habitat than the NSO (Courtney et al., 2004).

Barred owls were documented in 44 of the 98 NSO home ranges during 2007/2008 PCGP survey efforts (see superscript "B" next to Site Name in table Q-7 in appendix Q), including five nest patches (two known NSO – UMP 0408 and UMP 0401, and three best location sites (PCGP 084.6, PCGP 097.6, and PCGP 165.8). A summary of barred owl locations for each physiographic province in respect to NSO home ranges and available suitable NRF habitat (high NRF and NRF) greater or less than 40 percent is provided in table 4.3.4-20. Habitat below the 40 percent available NRF habitat in the home range could be considered "marginal" habitat. Approximately 36 percent of the barred owls documented within NSO home ranges were documented in "marginal" habitat, and 51 percent of barred owls documented were located in NSO home ranges with more suitable NRF available (see >40 percent suitable NRF Habitat; table 4.3.4-20).

**Table 4.3.4-20**
**Summary of Barred Owl Locations Documented During 2007 and 2008 Northern Spotted Owl Surveys**

| Barred Owls Documented in 2007/2008 | Coast Range | | Klamath Mountains | | West Cascades | | East Cascades | | Total NSO Range | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # NSO Home Ranges | # of Barred Owls | # NSO Home Ranges | # of Barred Owls | # NSO Home Ranges | # of Barred Owls | # NSO Home Ranges | # of Barred Owls | # NSO Home Ranges | # of Barred Owls |
| Total Documented outside of NSO Home Ranges | N/A | 33 | N/A | 74 | N/A | 21 | N/A | 60 | N/A | 194 |
| Total Documented within < 40 percent suitable NRF Habitat | 8 | 26 | 8 | 12 | 1 | 2 | 1 | 7 | 18 | 69 |
| Total Documented within > 40 percent suitable NRF Habitat | 1 | 1 | 13 | 40 | 8 | 19 | 4 | 18 | 26 | 98 |
| Total Documented within NSO Home Ranges | 9 | 27 | 21 | 52 | 9 | 21 | 5 | 25 | 44 | 167 |

Table Q-7 in appendix Q provides a subscript “B” where barred owls were documented in the home range, core area, and/or nest patch.

It is conceivable that construction of the proposed pipeline may serve as a corridor for barred owl expansion, but this is speculative. Review of available literature did not indicate that linear transportation corridors increase barred owl presence/expansion. If inclusion of these additional barred owl locations indicates that barred owls do occur more often in marginal northern spotted owl habitat than northern spotted owls do, then focus should be on currently suitable northern spotted owl habitat (see Habitat Condition 1 in table Q-7 in appendix Q) being brought below FWS recommended thresholds by the proposed Project, and areas currently below thresholds that the proposed Project could further impact (see Habitat Conditions 2 through 4 in table Q-8 in appendix Q). With the exception of the Coast Range physiographic province, the majority of barred owls documented were located within northern spotted owl home ranges with adequate amounts of suitable habitat (greater than 40 percent suitable habitat available in home range and greater than 50 percent suitable habitat available in the core area).

Effects to Prey

Cleared areas would remove suitable habitat for arboreal prey species (flying squirrels, red tree voles), but could improve habitat for non-arboreal species (western red backed voles, deer mice) adjacent to cleared areas. NSOs seldom venture far into non-forested stands to hunt, although it is likely they would cross the corridor at night to forage on both sides of the right-of-way. Edges can be areas of high prey availability, but also increased vulnerability (Zabel et al., 1995). Prey animals could be more exposed in the disturbed area and may move away from edges in the short term. Some minor changes in prey availability could occur as cover is disturbed and animals redistribute within the understory. Disturbance might attract other predators such as other owls, hawks, and mammals. This could increase competition for NSOs in the treatment area, but the exposure of prey could also benefit NSOs.

Some disturbance of habitat could improve forage conditions in remaining stands on both sides of the corridor by bringing more light and resources into the stand, stimulating forbs, shrubs, and other prey food. Once the initial impact of disturbance recovers (6 months to two years), the understory habitat conditions for prey food would increase over the next few years, until shrubs and residual trees respond to again close in the stand.

**Critical Habitat**

The FWS (2012a) determined the physical and biological habitat features that support nesting, roosting, foraging, and dispersal activities for northern spotted owls and are essential to the conservation of this species include the following primary constituent elements (PCEs): PCE1 – forested habitat in a variety of seral stages that support the northern spotted owl across its geographical range; PCE2 – forested habitat that provides for nesting and roosting, and could provide for foraging; PCE3 – habitat the provides for foraging; and PCE4 – habitat that supports dispersal of spotted owls, which could provide nesting, roosting, and foraging habitat, but could also be composed of other forest types between larger blocks of nesting, roosting, and foraging habitat. Within this analysis, PCEs would be similar to northern spotted owl habitat mapped for the PCGP Project: PCE1 would be all forested habitat affected within the range of the northern spotted owl; PCE2 would include high NRF as well as NRF; PCE3 would include NRF and high NRF; and PCE4 would include dispersal only habitat, as well as high NRF and NRF that provide dispersal habitat for the spotted owl.

Activities that disturb or remove the PCEs within designated CHUs might adversely modify the owl's critical habitat. These activities may include actions that would reduce the canopy closure of a timber stand, reduce the average dbh of trees in the stand, appreciably modify the multi-layered stand structure, reduce the availability of nesting structures and sites, reduce the suitability of the landscape to provide for safe movement, or reduce the abundance or availability of prey species (FWS, 1992b).

In contrast, activities that would have no effect on critical habitat's primary constituent elements almost certainly would not adversely modify the critical habitat. However, even though an action may not adversely modify critical habitat, it may still affect northern spotted owls (e.g., through disturbance) and therefore be subject to consultation under the jeopardy standard of Section 7 of the ESA (FWS, 1992b).

Approximately 37.4 miles of the proposed pipeline route crosses seven designated critical habitat sub-units, of which 35.0 miles cross NSO habitat: ORC-6, KLE-1, KLE-2, KLE-3, KLE-4, KLE-5, and ECS-1 (see table 4.3.4-21). Table Q-11 in appendix Q provides the amount of high NRF, NRF, dispersal only, capable, and non-capable habitat within each critical habitat unit by landowner that would be removed and modified, which is summarized below in table 4.3.4-21. With the exception of CHU ECS-1, all CHU subunits occur completely within NSO home ranges, and partially within NWFP LSRs and unmapped LSRs (see table Q-9 in appendix Q for overlap of CHUs with NWFP LSRs and unmapped LSRs).

**Table 4.3.4-21**
**Summary of High NRF, NRF, Dispersal Only, and Capable Habitat by Physiographic Province Impacted within Northern Spotted Owl Critical Habitat Units during Construction and Operation of the Proposed Action**

| Critical Habitat Subunit | General Location[1] | Miles Crossed | High NRF[2] | | | | NRF[3] | | | | Dispersal Only[4] | | | | Capable [5] | | | | Total Acres[6] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation |
| | | | Removed[7] | Indirect Effects[8] | UCSA[9] | 30-foot Corridor[10] | Removed[7] | Indirect Effects[8] | UCSA[9] | 30-foot Corridor[10] | Removed[7] | Indirect Effects[8] | UCSA[9] | 30-foot Corridor[10] | Removed[7] | Indirect Effects[8] | UCSA[9] | 30-foot Corridor[10] | Removed[7] | Indirect Effects[8] | UCSA[9] | 30-foot Corridor[10] |
| ORC 6 | NSO Groups | 1.6 | 5.81 | 44.91 | 0.00 | 1.62 | 2.67 | 7.51 | 0.00 | 0.87 | 6.26 | 31.59 | 0.38 | 1.75 | 7.05 | 54.47 | 1.10 | 1.59 | 21.79 | 138.48 | 1.48 | 5.83 |
| | Outside NSO Groups | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 1.6 | 5.81 | 44.91 | 0.00 | 1.62 | 2.67 | 7.51 | 0.00 | 0.87 | 6.26 | 31.59 | 0.38 | 1.75 | 7.05 | 54.47 | 1.10 | 1.59 | 21.79 | 138.48 | 1.48 | 5.83 |
| KLE 1 | NSO Groups | 10.1 | 57.17 | 323.19 | 27.02 | 14.52 | 29.90 | 136.71 | 8.74 | 7.85 | 30.62 | 295.78 | 7.14 | 6.51 | 28.52 | 147.35 | 1.35 | 7.64 | 146.21 | 903.03 | 44.25 | 36.52 |
| | Outside NSO Groups | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| | Total | 10.1 | 57.17 | 323.19 | 27.02 | 14.52 | 29.90 | 136.71 | 8.74 | 7.85 | 30.62 | 295.78 | 7.14 | 6.55 | 28.52 | 147.35 | 1.35 | 7.64 | 146.21 | 903.03 | 44.25 | 36.56 |
| KLE 2 | NSO Groups | 2.0 | 21.58 | 148.11 | 12.00 | 5.42 | 0.92 | 4.77 | 1.22 | 0.05 | 6.26 | 19.84 | 1.31 | 1.05 | 1.58 | 16.47 | 1.92 | 0.87 | 30.34 | 189.19 | 16.45 | 7.39 |
| | Outside NSO Groups | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 2.0 | 21.58 | 148.11 | 12.00 | 5.42 | 0.92 | 4.77 | 1.22 | 0.05 | 6.26 | 19.84 | 1.31 | 1.05 | 1.58 | 16.47 | 1.92 | 0.87 | 30.34 | 189.19 | 16.45 | 7.39 |
| KLE 3 | NSO Groups | 0.1 | 0.00 | 0.00 | 0.00 | 0.00 | 3.04 | 19.03 | 0.00 | 0.55 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06 | 19.03 | 0.00 | 0.55 |
| | Outside NSO Groups | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 |
| | Total | 0.1 | 0.00 | 0.00 | 0.00 | 0.00 | 3.04 | 19.44 | 0.00 | 0.55 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06 | 19.44 | 0.00 | 0.55 |
| KLE 4 | NSO Groups | 12.9 | 3.39 | 24.63 | 1.89 | 1.24 | 74.66 | 503.62 | 34.92 | 21.97 | 12.27 | 116.36 | 4.87 | 3.96 | 85.58 | 483.24 | 26.04 | 19.60 | 175.90 | 1,127.85 | 67.72 | 46.77 |
| | Outside NSO Groups | 0.1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 13.0 | 3.39 | 24.63 | 1.89 | 1.24 | 74.66 | 503.62 | 34.92 | 21.97 | 12.27 | 116.36 | 4.87 | 3.96 | 85.58 | 483.24 | 26.04 | 19.60 | 175.90 | 1,127.85 | 67.72 | 46.77 |
| KLE 5 | NSO Groups | 1.6 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29 | 13.12 | 0.00 | 0.39 | 2.13 | 17.14 | 0.85 | 0.64 | 19.86 | 99.74 | 0.43 | 4.66 | 23.28 | 130.00 | 1.28 | 5.69 |
| | Outside NSO Groups | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total | 1.6 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29 | 13.12 | 0.00 | 0.39 | 2.13 | 17.14 | 0.85 | 0.64 | 19.86 | 99.74 | 0.43 | 4.66 | 23.28 | 130.00 | 1.28 | 5.69 |
| ECS 1 | NSO Groups | 4.4 | 11.08 | 61.38 | 0.84 | 3.15 | 16.82 | 79.02 | 2.29 | 4.79 | 2.78 | 39.05 | 0.92 | 0.84 | 25.52 | 162.86 | 3.84 | 6.99 | 56.20 | 342.31 | 7.89 | 15.77 |
| | Outside NSO Groups | 2.3 | 7.48 | 11.70 | 1.20 | 2.05 | 15.10 | 52.33 | 0.42 | 3.91 | 7.95 | 69.10 | 0.69 | 2.14 | 0.59 | 32.00 | 0.01 | 0.12 | 31.14 | 165.13 | 2.32 | 8.22 |
| | Total | 6.6 | 18.56 | 73.08 | 2.04 | 5.20 | 31.92 | 131.35 | 2.71 | 8.70 | 10.73 | 108.15 | 1.61 | 2.98 | 26.11 | 194.86 | 3.85 | 7.11 | 87.34 | 507.44 | 10.21 | 23.99 |
| Total CHU | NSO Groups | 32.7 | 99.03 | 602.22 | 41.75 | 25.95 | 129.30 | 763.78 | 47.17 | 36.47 | 60.34 | 519.76 | 15.47 | 14.75 | 168.11 | 964.13 | 34.68 | 41.35 | 456.78 | 2,849.89 | 139.07 | 118.52 |
| | Outside NSO Groups | 2.3 | 7.48 | 11.70 | 1.20 | 2.05 | 15.10 | 52.74 | 0.42 | 3.91 | 7.95 | 69.10 | 0.69 | 2.18 | 0.59 | 32.00 | 0.01 | 0.12 | 31.14 | 165.54 | 2.32 | 8.26 |
| | Total | 35.0 | 106.51 | 613.92 | 42.95 | 28.00 | 144.40 | 816.52 | 47.59 | 40.38 | 68.29 | 588.86 | 16.16 | 16.93 | 168.70 | 996.13 | 34.69 | 41.47 | 487.92 | 3,015.43 | 141.39 | 126.78 |

[1] General Location identifies areas within Northern Spotted Owl Groups (areas within NSO home ranges; see table Q-10 in appendix Q) and areas outside of NSO groups (outside of NSO home ranges).
[2] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
[3] NRF (Trask & Associates, 2013; FWS, 2012a; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
[4] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
[5] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.
[6] Total habitat only considers forested NSO habitat within NSO critical habitat units; non-capable habitat affected NSO critical habitats is included in table Q-11 in appendix Q.
[7] Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
[8] UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
[9] Indirect Effects considers habitat within 100 meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
[10] 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.
Note: More detailed information on BLM Districts and National Forests impacted in critical habitat units is located in table Q-11 in appendix Q. Overlap with LSRs can be reviewed in table Q-9 in appendix Q.

Overall, the proposed Project would remove 558.29 acres of northern spotted owl habitat from critical habitat units, of which 487.92 acres is NSO habitat or capable of becoming NSO habitat (106.51 acres of high NRF, 144.40 acres of NRF, 68.29 acres of dispersal only habitat, and 168.70 acres of capable habitat), of which 126.78 acres (28.00 acres in high NRF, 40.38 acres in NRF, 16.93 acres in dispersal only habitat, and 41.47 acres in capable) would be kept within an early seral state within the 30-foot maintenance corridor for the life of the Project (see table 4.3.4-21). Over the long-term, 361.14 acres of northern spotted owl habitat within critical habitat units would return to its original state (outside of the 30-foot operational corridor) and begin functioning as dispersal only habitat (see table 4.3.4-21). Table Q-11 in appendix Q provides further detail of critical habitat units affected, including landowner by physiographic province within or outside of interior forest.

In addition to direct loss of critical habitat and effects to PCEs due to loss that were summarized in table 4.3.4-21, the project's indirect effects to NSO that were discussed above (fragmentation, edge, and effects to interior forest) indirectly affect designated critical habitats and PCEs. Edge effects and effects to interior forest may induce changes to forest characteristics later in time and would indirectly affect PCEs. In particular, creation of isolated forest patches with large edge areas can create changes in microclimate, vegetation species, and predator-prey dynamics. Two main physical factors affecting and creating an edge microclimate are sun and wind (Forman, 1995; Chen et al., 1995, Harper et al., 2005) which could directly affect characteristics of nesting trees and could decrease canopy cover and stand conditions for future NSO habitat components described in the PCEs.

Interior forest has been defined as 100 meters (328 feet) from any existing edge of a contiguous forested stand (50 feet from canopy covered roads), including edges created by adjacent regenerating stands approximately 10 to 20 years old (see Harper et al., 2005). However effects of strong wind may extend beyond that distance (see Chen et al., 1995). Such effects are dependent on local conditions such as orientation of an edge; the magnitudes of change in humidity with distance from an edge are most extreme with south-facing edges, compared to east- and west-facing edges (see Figure 6 in Chen et al., 1995). Such effects may induce changes within PCEs. Long-term effects on edges and interiors of NSO habitat are less well defined and over time, edge effects will diminish as edges evolve from "hard" to "soft" (see for example, Peery and Henry, 2010).

There is considerable overlap of forest habitat, including interior forest that is within NSO CHUs and within LSRs. Long-term effects from removal of forest within critical habitat, NWFP LSRs, and unmapped LSRs by the proposed project would be expected. Most indirect effects to forested habitat within 100 meters of habitat removal occur in NSO habitat that has been previously affected by existing edge, such as roads, waterbodies, early seral forest, and nonforested habitat. Table Q-9 in appendix Q provides a more detailed tabulation of indirect effects to interior forest habitat within NSO critical habitat units and NWFP LSRs/unmapped LSRs by landowner and physiographic province.

<u>NWFP Late-Successional Reserves</u>

Additional habitat protection for the northern spotted owl was established when late successional reserves (LSRs) were adopted in the NWFP. Within the Provincial Analysis Area, northern spotted owl critical habitat units overlap with LSRs to varying degrees (see table Q-9 in appendix Q). The Pacific Connector pipeline crosses 21.8 miles of three allocated LSRs: RO

223 (BLM Roseburg District and Umpqua National Forest), RO 227 (Rogue River-Siskiyou National Forest), and RO 261 (BLM Coos Bay District and Roseburg District); see table 4.3.4-22.

There are three northern spotted owl activity centers that have been delineated on lands administered by Roseburg BLM that occur within the proposed PCGP Project area but occur on Matrix lands: P2199, P0361, and P2294. These areas are considered "unmapped LSRs" and are managed similarly as NWFP LSRs, as well as the occupied marbled murrelet stands that occur on Matrix lands, discussed above. Although these sites were identified as 100 acre core areas, recent activity has not been at these sites. For example, site P2199 is located between MPs 53.36 and 54.08 and recent activity for MSNO 2199B is over 1.25 miles southeast of P2199. Site P0361 is located between MPs 82.97 and 83.30 (MSNO 0361A) is over 0.75 mile northwest of this known spotted owl activity center. Site P2294 is located between MP 85.96 and 86.18; activity at this site and others has been monitored in the Klamath demographic for more than 20 years. Most recent activity at this site (P2294) was in 1994; however, the site remains in its current protected status by Roseburg BLM. Table Q-12 in appendix Q differentiates between the acres of unmapped LSRs that are occupied marbled murrelet stands or known spotted owl activity centers delineated on NWFP Matrix lands.

Table 4.3.4-22 summarizes the impact to northern spotted owl high NRF, NRF, dispersal, and capable habitat within each NWFP LSR and unmapped LSRs impacted (habitat removed or affected within UCSAs) by the proposed Project. Overall, the proposed Project would remove 395.96 acres from NWFP allocated late-successional reserves and unmapped LSRs (table Q-12 in appendix Q), of which 342.66 acres is NSO habitat or capable of becoming NSO habitat (106.28 acres of high NRF, 84.05 acres of NRF, 32.12 acres of dispersal only habitat, and 120.21 acres of capable habitat). After construction, approximately 90.01 acres (29.43 acres of high NRF, 24.05 acres of NRF, 8.77 acres of dispersal only habitat, and 27.76 acres of capable habitat) would be kept within an early seral state within the 30-foot maintenance corridor for the life of the Project (see table 4.3.4-22). Over the long-term, 252.65 acres of forested habitat within LSRs and unmapped LSRs would return to its original state (outside of the 30-foot operational corridor) and begin functioning as dispersal only habitat (see table 4.3.4-22). Table Q-12 in appendix Q provides NSO habitat affected within NWFP LSRs and unmapped LSRs, by landowner and physiographic province within and outside of interior forest.

LSRs and unmapped LSRs cover approximately 71,254 acres within the Provincial Analysis Area and provide approximately 41,261 acres of high NRF and NRF habitat (see table 4.3.4-8). The proportional amount of available NRF habitat that would be removed (190.33 acres) within NWFP LSRs and unmapped LSRs in the Provincial Analysis Area is 0.5 percent, while 0.2 percent of available NRF would be affected in the short-term within UCSAs (83.40 acres).

## Table 4.3.4-22
## Summary of High NRF, NRF, Dispersal, and Capable NSO Habitat Impacted within NWFP Late-Successional Reserves (LSRs) and Unmapped LSRs, Including Area within and outside of NSO Groups

| Landuse Allocation | General Location[1] | Miles NSO Habitat Crossed | High NRF Habitat[2] | | | | NRF Habitat[3] | | | | Dispersal Only Habitat[4] | | | | Capable Habitat[5] | | | | Total Acres[6] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation | Construction | | | Operation |
| | | | Removed[7] (acres) | Indirect[8] (acres) | UCSA[9] (acres) | 30-foot Corridor[10] | Removed[7] (acres) | Indirect[8] (acres) | UCSA[9] (acres) | 30-foot Corridor[10] | Removed[7] (acres) | Indirect[8] (acres) | UCSA[9] (acres) | 30-foot Corridor[10] | Removed[7] (acres) | Indirect[8] (acres) | UCSA[9] (acres) | 30-foot Corridor[10] | Removed[7] (acres) | Indirect[8] (acres) | UCSA[9] (acres) | 30-foot Corridor[10] |
| LSR RO 261 | NSO Groups | 1.34 | 3.18 | 45.53 | 0.00 | 0.90 | 2.30 | 14.76 | 0.92 | 0.21 | 6.59 | 49.36 | 0.00 | 2.00 | 11.37 | 69.32 | 1.06 | 2.19 | 23.44 | 178.97 | 1.98 | 5.30 |
| | Outside NSO Groups | 0.32 | 0.00 | 3.29 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 1.32 | 8.25 | 0.00 | 0.00 | 3.09 | 16.33 | 0.00 | 0.00 | 4.41 | 28.04 | 0.00 | 0.00 |
| | Subtotal | 1.66 | 3.18 | 48.82 | 0.00 | 0.90 | 2.30 | 14.93 | 0.92 | 0.21 | 7.91 | 57.61 | 0.00 | 2.00 | 14.46 | 85.65 | 1.06 | 2.19 | 27.85 | 207.01 | 1.98 | 5.30 |
| LSR RO 223 | NSO Groups | 7.36 | 74.75 | 475.60 | 31.96 | 19.39 | 1.27 | 15.25 | 1.22 | 0.46 | 8.28 | 100.52 | 1.31 | 1.74 | 19.43 | 121.08 | 3.22 | 5.91 | 103.73 | 712.45 | 37.71 | 27.50 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Subtotal | 7.36 | 74.75 | 475.60 | 31.96 | 19.39 | 1.27 | 15.25 | 1.22 | 0.46 | 8.28 | 100.52 | 1.31 | 1.74 | 19.43 | 121.08 | 3.22 | 5.91 | 103.73 | 712.45 | 37.71 | 27.50 |
| LSR RO 227 | NSO Groups | 12.80 | 2.74 | 17.86 | 1.41 | 1.06 | 74.62 | 507.41 | 34.91 | 21.95 | 12.27 | 116.38 | 4.87 | 3.96 | 84.09 | 374.00 | 25.65 | 19.24 | 173.72 | 1,015.65 | 66.84 | 46.21 |
| | Outside NSO Groups | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.90 | 0.00 | 0.00 | 0.00 | 8.90 | 0.00 | 0.00 |
| | Subtotal | 12.80 | 2.74 | 17.86 | 1.41 | 1.06 | 74.62 | 507.41 | 34.91 | 21.95 | 12.27 | 116.38 | 4.87 | 3.96 | 84.09 | 382.90 | 25.65 | 19.24 | 173.72 | 1,024.55 | 66.84 | 46.21 |
| Unmapped LSR | NSO Groups | 2.40 | 21.53 | 211.22 | 8.28 | 6.83 | 2.92 | 32.34 | 4.70 | 0.51 | 3.66 | 21.16 | 1.97 | 1.07 | 2.22 | 2.84 | 0.34 | 0.42 | 30.33 | 267.56 | 15.29 | 8.83 |
| | Outside NSO Groups | 0.59 | 4.08 | 27.72 | 0.00 | 1.25 | 2.94 | 18.19 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.00 | 0.00 | 7.03 | 45.96 | 0.00 | 2.17 |
| | Subtotal | 2.99 | 25.61 | 238.94 | 8.28 | 8.08 | 5.86 | 50.53 | 4.70 | 1.43 | 3.66 | 21.16 | 1.97 | 1.07 | 2.23 | 2.89 | 0.34 | 0.42 | 37.36 | 313.52 | 15.29 | 11.00 |
| ***Total LSRs and Unmapped LSRs*** | NSO Groups | 23.90 | 102.20 | 750.21 | 41.65 | 28.18 | 81.11 | 569.76 | 41.75 | 23.13 | 30.80 | 287.42 | 8.15 | 8.77 | 117.11 | 567.24 | 30.27 | 27.76 | 331.22 | 2,174.63 | 121.82 | 87.84 |
| | Outside NSO Groups | 0.91 | 4.08 | 31.01 | 0.00 | 1.25 | 2.94 | 18.36 | 0.00 | 0.92 | 1.32 | 8.25 | 0.00 | 0.00 | 3.10 | 25.28 | 0.00 | 0.00 | 11.44 | 82.90 | 0.00 | 2.17 |
| | *NSO RangeTotal* | 24.81 | 106.28 | 781.22 | 41.65 | 29.43 | 84.05 | 588.12 | 41.75 | 24.05 | 32.12 | 295.67 | 8.15 | 8.77 | 120.21 | 592.52 | 30.27 | 27.76 | 342.66 | 2,257.53 | 121.82 | 90.01 |

1 General Location identifies areas within Northern Spotted Owl Groups (areas within NSO home ranges; see Table Q10 in Appendix Q) and areas outside of NSO groups (outside of NSO home ranges).
2 High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
3 NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
4 Dispersal ONLY (FWS, 2012): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
5 Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.
6 Total habitat only considers forested NSO habitat within the range of the NSO; see table Q-12 in appendix Q for effects to non-capable habitat in NWFP LSRs and unmapped LSRs.
7 Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.
8 Indirect Effects considers habitat within 100 meters of habitat removal as measured from the edge of habitat removal/edge of right-of-way/TEWA.
9 Acres identified as UCSAs have been incorporated into the 100-meter indirect effects. UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.
10 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.

Note: More detailed information on BLM Districts and National Forests impacted in critical habitat units is located in table Q-12 in appendix Q. Overlap with CHUs can be reviewed in table Q-9 in appendix Q.

Areas of Concern (AOCs)

The proposed Project traverses the Rogue/Umpqua Area of Concern between MPs 28.13 and 62.48 and MPs 82.71 and 111.11. BLM (2008b) indicated that timber harvesting on private lands within these identified AOCs has reduced the overall dispersal habitat and would likely decline further as harvesting continues. Removal of forested habitat within this AOC may further limit the dispersal ability of NSOs; however, within this area, the pipeline has been routed generally along existing roads and so should minimize the amount of forested habitat removed and/or creation of additional corridors, as well as limit negative impacts to NSO dispersal (see appendix Q-4 in appendix Q).

Table 4.3.4-22 provides acres of dispersal habitat available within the Rogue/Umpqua AOC by federal and non-federal lands within the three physiographic provinces in which it is located, as well as dispersal habitat (high NRF, NRF, and dispersal only habitat) that would be removed or modified by the proposed Project. It is not anticipated that use of dispersal habitat (high NRF, NRF, and dispersal only habitat) within UCSAs would remove the function of the dispersal habitat. Within the Coast Range physiographic province, the removal of 104.3 acres of dispersal habitat within the Rogue/Umpqua AOC would result in a total loss of 0.2 percent of available dispersal habitat in the Coast Range Provincial Analysis Area (67,193 acres), and removal of approximately 295.0 acres of dispersal habitat within the Klamath Mountains physiographic province would result in a total loss of 0.5 percent of available dispersal habitat in the Klamath Mountains Provincial Analysis Area (58,357 acres; see table 4.3.4-9). No dispersal habitat would be impacted (removed or modified) within this AOC in the West Cascades physiographic province. Approximately 92.73 acres of total dispersal habitat would be left in a permanent herbaceous/shrub state along the 30-foot maintenance corridor but is not expected to limit dispersal of spotted owls. Over the life of the project, the 306.59 acres of dispersal habitat affected outside of the 30-foot maintenance corridor would be reforested/replanted and begin functioning as dispersal only habitat. Approximately 53 of the 98 NSO home ranges included within this BA would have dispersal habitat removed in the AOCs (table 4.3.4-9)

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA. The Pacific Connector pipeline would not be operational until at least 2017. Consequently, the foreseeable future required for cumulative effects analysis would actually occur before implementation of the proposed action, not after its implementation, which is more often the case.

# Table 4.3.4-23
## Summary of Northern Spotted Owl Dispersal Habitat Impacted by Landowner within the Rogue/Umpqua Area of Concern

| Landowner | High NRF [1] | | | NRF [2] | | | Dispersal Only [3] | | | Total Dispersal Habitat | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Removed [4] | UCSA [5] | 30-foot Corridor [6] | Removed [4] | UCSA [5] | 30-foot Corridor [6] | Removed [4] | UCSA [5] | 30-foot Corridor [6] | Removed [4] | UCSA [5] | 30-foot Corridor [6] |
| **Coast Range Physiographic Province** | | | | | | | | | | | | |
| Coos Bay BLM | 20.94 | 5.27 | 6.62 | 2.20 | 0 | 0.66 | 36.85 | 6.50 | 8.73 | 59.99 | 11.78 | 16.02 |
| Roseburg BLM | 2.51 | 0 | 0.72 | 3.43 | 0 | 1.14 | 6.79 | 0.13 | 1.53 | 12.73 | 0.13 | 3.38 |
| Non-Federal Lands | 3.31 | 0.25 | 0.94 | 2.98 | 0 | 1.06 | 25.34 | 3.97 | 4.71 | 31.62 | 4.22 | 6.71 |
| *Coast Range Total* | *26.76* | *5.52* | *8.27* | *8.61* | *0.00* | *2.90* | *68.98* | *10.61* | *15.03* | *104.34* | *16.13* | *26.20* |
| **Klamath Mountains Physiographic Province** | | | | | | | | | | | | |
| Roseburg BLM | 37.71 | 23.11 | 9.68 | 22.42 | 23.14 | 4.08 | 11.48 | 4.02 | 2.33 | 71.61 | 50.28 | 16.09 |
| Umpqua N.F. | 41.69 | 25.26 | 10.05 | 3.92 | 0 | 1.08 | 24.60 | 7.14 | 5.89 | 70.20 | 32.40 | 17.02 |
| Non-Federal Lands | 35.80 | 10.8 | 7.12 | 21.76 | 21.94 | 4.66 | 95.61 | 61.72 | 22.73 | 153.17 | 94.46 | 33.51 |
| *Klamath Mountains Total* | *115.19* | *59.18* | *26.77* | *48.10* | *45.07* | *9.88* | *131.68* | *72.87* | *30.41* | *294.98* | *177.13* | *67.06* |
| **Overall Total** | | | | | | | | | | | | |
| Federal Lands | 102.85 | 53.65 | 27.07 | 31.97 | 23.14 | 6.96 | 79.72 | 17.79 | 18.47 | 214.53 | 94.58 | 52.51 |
| Non-Federal Lands | 39.10 | 11.05 | 8.06 | 24.74 | 21.94 | 5.72 | 120.95 | 65.69 | 26.44 | 184.79 | 98.68 | 40.23 |
| *Overall Total* | *141.95* | *64.70* | *35.14* | *56.71* | *45.07* | *12.68* | *200.66* | *83.48* | *44.91* | *399.32* | *193.26* | *92.73* |

[1] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.

[2] NRF (Trask & Associates, 2013; FWS, 2012a; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.

[3] Dispersal ONLY (FWS, 2012a): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.

[4] Project components considered in calculation of habitat "Removed": Pacific Connector construction right-of-way, temporary extra work areas, aboveground facilities, permanent and temporary access roads (PAR, TAR), pipe storage yards, and hydrostatic locations.

[5] UCSAs would not be cleared of trees during construction and will not affect nesting structures or characteristics. These areas would be used to store forest slash, stumps and dead and downed log materials that would be removed and scattered across the right-of-way after construction during restoration and are considered as temporary insignificant understory habitat effects.

[6] 30-foot Maintenance Corridor will be kept in a shrub/sapling state for the life of the project; all other habitat outside of the 30-foot maintenance corridor will be revegetated.

Cumulative effects to NSO would be generated by timber harvesting and other sources of nesting, roosting, and or foraging (NRF) habitat losses on non-federal lands in the foreseeable future. High NRF is considered habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species (see Section 4.3.4.1, above). Suitable NRF consists of conifer-dominated stands older than 80 years, and are multi-storied in structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood but does not meet the definition of High NRF. As defined, High NRF and NRF NSO habitats correspond with Late Successional-Old Growth (LSOG) forests.

Areas of LSOG forest have been monitored as a component of the Northwest Forest Plan (NWFP). In Oregon, LSOG was evaluated in 1996 (Moeur et al., 2005) and in 2006 (Moeur et al., 2011). Differences in areas of LSOG forests were described in the four physiographic provinces that coincide with the PCGP project that showed an overall decline of LSOG on all lands. Most of the losses in LSOG on federal lands were attributed to large fire events including the 2002 Biscuit Fire in the Klamath Mountains, the 2003 B&B Fire in the Western Cascades, and the 2003 B&B Fire and Davis Fire in the Eastern Cascades (Moeur et al, 2011). However, losses associated with wildfire were negligible on non-federal lands where most of the decline in LSOG was due to timber harvest, primarily concentrated in the Oregon Coast Range province (see Table 7 in Moeur et al., 2003)

In 2012, there were 6,298 acres of High NRF habitat and 10,852 acres of NRF habitat on non-federal lands within the Provincial Analysis Area (see table 4.3.4-5 in Section 4.3.4.2, above) in all four Physiographic Provinces, combined. From 1996 to 2006 there was an overall net loss of LSOG on non-federal lands within the Coast Range province (-17.1 percent), Klamath Mountains province (-6.7 percent), Western Cascades province (-10.8 percent), and Eastern Cascades province (-12.6 percent) provinces (see Table 7 in Moeur et al., 2011). Percent loss of LSOG on non-federal lands during the 10-year period was used as the basis for the annual loss of High NRF and NRF habitats, included in table 4.3.4-24. Those rates of decline on non-federal lands were assumed to be constant over time within the Provincial Analysis Area. Areas of High NRF and NRF habitats present in 2012 would be expected to decline at the annual rates of loss specific to each Physiographic Province with a net loss in 2017. Using the annual rates of LSOG loss, there would be an estimated 5,997 acres of High NRF and 10,348 acres of NRF habitats within the analysis area on non-federal land by the time the PCGP project is expected to be implemented in 2017 (see table 4.3.4-24).

The Project would remove 50.79 acres of High NRF habitat and 85.04 acres of NRF habitat on non-federal (state and private) lands (see table 4.3.4-13 in Section 4.3.4.3) in all four Physiographic Provinces, combined by 2017. The amount of High NRF habitat removed would be 0.85 percent of the High NRF habitat remaining on non-federal lands (5,997 acres) within all four provinces of the analysis area by 2017. Likewise, the amount of NRF habitat removed by the PCGP project would be 0.82 percent of the NRF habitat remaining on non-federal lands (10,348 acres) within all four provinces of the analysis area by 2017. When compared to the estimated amount of NSO habitat on non-federal land within the analysis area, the PCGP project would affect a total of 135.83 acres, which would be 0.83 percent of the total High NRF and NRF habitat available within the foreseeable future in 2017.

## Table 4.3.4-24
## Estimates for Losses of Northern Spotted Owl Nesting, Roosting, and Foraging Habitat on Non-Federal Land within the Provincial Analysis Area by 2017, with PCGP Project-Related Effects on Non-Federal Land in Relation to the Expected Cumulative Effects

| Physiographic Province | LSOG Area on Non-federal Land in Analysis Area in 2012 [1] | | | Loss of LSOG in Province, Between 1996 and 2006 [2] | | LSOG Area on Non-federal Land in Analysis Area Expected in 2017 | | | LSOG Removed by PCGP on Nonfederal Land in Analysis Area in 2017 [3] | | | Percent of LSOG in Analysis Area Expected in 2017 Likely to be Affected by PCGP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High NRF (acres) | NRF (acres) | Total LSOG (acres) | Percent Change from 1996 | Percent Change per Year | High NRF (acres) | NRF (acres) | Total LSOG (acres) | High NRF (acres) | NRF (acres) | Total LSOG (acres) | High NRF | NRF | Total LSOG |
| Coast Range | 1,535 | 1,922 | 3,457 | -17.1% | -1.71% | 1,404 | 1,757 | 3,161 | 4.01 | 10.80 | 14.81 | 0.29% | 0.61% | 0.29% |
| Klamath Mountains | 4,240 | 6,979 | 11,219 | -6.7% | -0.67% | 4,099 | 6,746 | 10,845 | 46.75 | 41.55 | 88.30 | 1.14% | 0.62% | 1.14% |
| Cascades West | 499 | 1,817 | 2,316 | -10.8% | -1.08% | 472 | 1,719 | 2,190 | 0 | 29.85 | 29.85 | 0% | 1.74% | 0% |
| Cascades East | 24 | 134 | 158 | -12.6% | -1.26% | 22 | 125 | 148 | 0.02 | 2.83 | 2.85 | 0.09% | 2.25% | 0.09% |
| **Totals** | **6,298** | **10,852** | **17,150** | | | **5,997** | **10,348** | **16,345** | **50.79** | **85.04** | **135.83** | 0.85% | 0.82% | 0.85% |

[1] Data from table 4.3.4-5 in Section 4.3.5.2.
[2] Percent loss in Physiographic Provinces on Non-Federal Land from Table 7 in Moeur et al., 2011.
[3] Data from table 4.3.4-13 in Section 4.3.4.3.

#### 4.3.4.4 Conservation Measures

**Avoidance, Minimization, and Rehabilitation / Restoration:** Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to northern spotted owl habitat within the Provincial Analysis Area. Those measures have been compiled in table 2C in appendix N. Specific conservation measures that would benefit northern spotted owls include those that:

- Minimize removal of forest by incorporating UCSAs into the Project design;
- Utilize two-year construction schedule to minimize the overall temporary extra work areas;
- Flag large diameter trees on edges of construction right-of-way or temporary work areas where feasible to save from clearing;
- Minimize soil erosion during and after construction;
- Ensure that all trash, food waste, and other items attractive to crows, jays, and other corvids will be contained and removed from the project area on a daily basis to minimize potential predation of spotted owl nestlings;
- Use logging methods to minimize damage to adjacent trees when clearing the right of way to reduce potential infestation from forest pathogens and insects;
- Minimize potential for establishment of invasive vegetation and establish control of noxious weeds; and
- Route the pipeline through previously disturbed lands near LSRs so that impacts to these areas are minimized.

Pacific Connector has also proposed measures to rectify, repair, and rehabilitate and otherwise reduce impact to forested habitats once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N. Specific conservation measures that would benefit NSOs include those that:

- Replant conifer species outside of the 30-foot wide maintenance corridor after construction, which will contribute to the reestablishment of native vegetation and soften the edge effect created from construction of the PCGP Project;
- Contribute to forest habitat structural diversity (e.g., snags and downed timber); and
- Minimize potential for increased human use of the reclaimed construction right-of-way and intrusion into undisturbed habitats.

Plans included in the appendices of Pacific Connector's POD will also minimize effects to northern spotted owl habitat and/or nesting spotted owls. The Leave Tree Protection Plan describes the preconstruction surveys that will be completed to clearly mark the boundaries of the projects certificated working limits, and procedures to identify individual trees within and along the edges of the certificated work limits that can be conserved or left standing, as well as BMPs that would be employed to minimize damage to trees within UCSAs and protect trees not removed from the construction right-of-way (see Appendix P to the POD, available upon request). An Integrated Pest Management Plan (see Appendix N to the POD, available upon request) describes BMPs to address the control of noxious weeds, invasive plants, forest pathogens, and soil pests, as well as describes measures to minimize the potential spread of invasive species and potential adverse effects of control treatments. The Blasting Plan and Air Noise and Fugitive Dust Plans (see Appendices C and B to the POD, respectively – available upon request) provide mitigation measures and monitoring plans to minimize noise effects to nesting spotted owls during construction of the PCGP Project.

During the project route selection and construction footprint design processes (i.e., placement and size of temporary extra work areas), Pacific Connector determined a pipeline alignment that would ensure the long-term safety and integrity of the proposed pipeline through geotechnical evaluations while attempting to minimize adverse impacts to northern spotted owl nest patches, core areas, critical habitat, LSRs, and otherwise potential suitable habitat. However, not all designated critical habitat, LSRs, suitable habitat, and known northern spotted owl nest patches and core areas could be avoided. Major and minor route alternatives have been considered and incorporated into the Proposed Route that minimize effects to northern spotted owl and habitat (see Resource Report 10/Sections 10.5 and 10.6 in the FERC Certificate application). Pacific Connector prepared an Avoidance and Minimization Plan for marbled murrelet and northern spotted owl (see appendix V) which identifies the additional measures that have been incorporated into the project design to reduce impacts to both marbled murrelets and northern spotted owls. This avoidance plan was developed through consultations with the FWS and the cooperating agencies (Interagency Habitat Quality Subgroup-Micro Siting Working Group, June 4, 2008). Application of measures outlined in the plan would minimize the impacts to suitable NSO habitat by 1) converting TEWAs to UCSAs to reduce the amount of suitable habitat removed by the Project, 2) moving TEWAs to avoid impacts to suitable habitat within core areas, and 3) moving the pipeline alignment to avoid NSO nest patches. A "Standard Rules Set" was developed during the meeting to further minimize effects to NSO nest patches, and this would be implemented prior to or concurrent with tree felling. The Standard Rules Set measures include:

- identify potential nest trees to be allowed to remain standing within TEWAs or edge of right-of-way;
- identify TEWAs to be reduced in size or eliminated to reduce removal of suitable habitat;
- identify any additional minor route adjustments that would not alter constructability but would further reduce removal of suitable habitat;
- identify any previously unknown nest trees discovered and assurance that they are properly protected by applying seasonal restrictions associated with similar locations along the Project alignment; and
- support of EIs by qualified biologists to identify habitat or potential nest trees.

Prior to timber clearing, Pacific Connector will have experienced biologists cruise northern spotted owl core areas and nest patches where high NRF and NRF habitat will be modified by PCGP construction and mark trees that currently have northern spotted owl nesting structures. Pacific Connector will avoid removal of those marked trees, if feasible. To further minimize impact to northern spotted owls, Pacific Connector will remove timber outside of the entire northern spotted owl breeding season (after September 30 and before February 28) within at least 0.25 mile of activity centers (known best location, and PCGP assumed sites) to ensure that nesting spotted owls and owlets are not felled. Additionally, to minimize disturbance within forested areas, Pacific Connector has designated nearly 638.6 acres (see table 4.3.4-13) of UCSAs within the range of northern spotted owls that will not be cleared of trees but be used to store forest slash, stumps, and dead and downed log materials during construction that will be scattered across the right-of-way after construction and during restoration. The UCSAs will be useful for the construction of the PCGP Project while not requiring removal of trees or understory vegetation, as well as allow the maintenance of high NRF, NRF, dispersal, and capable habitat function. Where feasible, Pacific Connector would leave large trees on the edges of the construction right-of-way and TEWAs throughout the Project area to benefit the northern spotted owl and other late-successional-dependent wildlife species.

Construction of the proposed Project will occur within range of the northern spotted owl during the breeding season; however, where activity centers (known, best location, PCGP assumed) occur within 0.25 mile of the proposed Project, construction will occur after the critical breeding period (after July 15). Construction within 0.25 mile of activity centers will occur after timber has been felled outside of the breeding season. During construction, Pacific Connector would ensure that the construction contracts include stipulations ensuring that all trash, food waste, debris, and other items attractive to crows, jays, and other corvids would be picked up and removed from the Project area on a daily basis during the breeding season to minimize potential predation of northern spotted owlets. Pacific Connector's EI's would be responsible for overseeing that the construction contractor is adequately following these stipulations.

Following construction, approximately 1,741 acres of affected forested lands (the construction right-of-way and temporary extra work areas outside of the 30-foot maintenance right-of-way; table 4.3.4-13) would be replanted and allowed to return to pre-construction condition with tree species in the approximate proportion to those species removed. Tree establishment would be allowed to occur up to within 15 feet on either side of the pipeline centerline. Over the long-term (80 years or more), revegetated areas outside of the 30-foot maintenance corridor may achieve tree structural characteristics comparable to trees that would be removed, had they not been affected, and could serve as northern spotted owl suitable habitat. Although nesting function may not be reestablished over the long-term, the habitat may provide structures suitable for foraging, roosting, and dispersal as it regrows.

One year prior to construction activities, Pacific Connector will conduct spot check surveys within 0.25 mile of Project activities in known, best location, and PCGP assumed NSO home ranges, where permitted, to supplement the full survey efforts conducted in 2007 and 2008, as recommended by FWS (see McCorkle, 2012; appendix S – ROC). These surveys would determine if the site is still occupied or has moved, attempt to locate the nest trees per protocol, determine if best location or PCGP assumed owl sites are occupied, adjust the construction schedule to apply seasonal constraints, if necessary, and apply minor route adjustments to further minimize impact, if feasible. The spot check surveys will include at least three night visits spaced a minimum of 7 days apart to confirm occupancy status (FWS, 2012a). If occupancy is documented within 0.25 mile of Project activities during spot check surveys, all construction activity within 0.25 mile of that proposed site would not occur until after the critical breeding period (after July 15), and timber clearing would occur in the fourth quarter of Year One outside of the breeding period. If spotted owls are not detected during spot-check surveys, construction of the PCGP Project could occur during the breeding season; however, spot checks should be repeated each year if construction activities during the critical breeding season are anticipated (FWS, 2012a).

**Compensatory Mitigation**: Since effects by the proposed action could not be fully mitigated on-site whether by avoidance, minimization, or restoration measures, Pacific Connector has developed a Compensatory Mitigation Plan (CMP) that provides a means to compensate for unavoidable impacts to listed species and their habitat, including northern spotted owls. The CMP combines agency-recommended projects to enhance existing forested and aquatic habitats, re-designation of allocated forest lands (NWFP), and acquisition of forested habitats to compensate for habitats affected by the project. The CMP includes opportunities for funding projects in southern Oregon that could be implemented by federal land managing agencies, state or local resources agencies, or conservation groups. Projects or actions that are being considered include permanent reclamation of existing disturbances within capable habitat, such as roads within LSRs that are no longer required for resource management. These mitigation funds would also be used to conduct noncommercial thinning treatments or other silvilcultural projects to create or accelerate development of old growth characteristics in trees elsewhere on federal land. Pacific Connector also proposes to acquire easements or properties as conservation parcels within the range of the species that would preserve and protect potentially suitable and recruitment habitat as mitigation for Project impacts. These easements or parcels could be deeded to a federal agency or a conservation organization or trust.

The BLM and Forest Service have proposed a suite of off-site mitigation projects to address the effects of the PCGP Project on various resources within the project area and will ensure the Project can be consistent with the objectives of BLM Resource Management Plans and Forest Service Land and Resource Management Plans. The CMP provides the BLM and Forest Service mitigation summaries which describe the various offsite mitigation projects as a supplemental mitigation to address important issues or land management plan objectives that cannot be acceptably mitigated on-site (Attachment 1 and Attachment 2 to the CMP, appendix O). A summary of BLM and Forest Service mitigation projects are provided in Table 1 of the CMP (see appendix O). Pacific Connector has assessed the BLM's mitigation projects in relation to the Project effects by watershed, along with the proposed mitigation projects proposed by the Forest Service, that have been approved in principle by Pacific Connector (see Attachment 4 to the CMP, appendix O). The BLM and Forest Service mitigation projects have also been reviewed with respect to the Project's responsibilities to mitigate for the potential effects to ESA listed species and their habitats. The BLM's and Forest Service's mitigation summaries list their proposed projects by watershed.

The following projects or actions, including those proposed by BLM and Forest Service are also being considered as compensation in the CMP:

- decommissioning roads in LSRs that are identified by the BLM and Forest Service and are no longer required for management activities;
- acquiring title or easement to private lands in the range of NSO that could be managed/preserved as late successional habitat;
- funding the conversion of matrix lands to LSR and enhancement of converted lands;
- funding non-commercial thinning treatments or other silvicultural projects to create or accelerate development of old growth characteristic elsewhere on federal land;
- funding to conduct silviculture (pre-commercial and commercial thinning) projects to reduce fuel load to minimize the risk of stand-replacing fires; and/or
- creating snags in adjacent habitat.

FWS has prepared Conservation Frameworks for the Pacific Connector Gas Pipeline Project that provides direction and methods to quantify and categorize the impact to northern spotted owls [and marbled murrelets] and their habitat (see appendix Z4) and means to offset the calculated impacts. In some instances, projects proposed by BLM and Forest Service would be considered applicable to offsetting the impact calculated and described, below.

The initial Framework (Trask & Associates, 2013) and subsequent revisions through personal communications provides guidance for categorizating effects to NSO habitat within home ranges into High Impact, Moderate Impact, and Low Impact categories based on the amount and type of NSO Habitat removed, as well as the area the habitat is removed within the habitat use type – home range, core area, and/or nest patch (see NSO habitat impact categorization for each NSO home range in appendix Z2). The Habitat Impact Category assigned to each NSO home range (appendix Z2) is then applied to acres of NSO habitat affected by the proposed Action (summarized in table 4.3.4-13 from table Q-9 in appendix Q). NSO habitat affected outside of NSO home ranges or within NSO home ranges that were provided a "No Impact Category" in appendix Z2 are considered areas of "Low Impact", as well. Table 4.3.4-25, below provides a summary of NSO habitat affected by Habitat Impact Category within and outside of interior forest. No NSO home range was provided a "Severe Impact" category because Pacific Connector would not remove a known nest site or activity center or cause a NSO home range to become nonfunctional (loss of the territory).

**Table 4.3.4-25**
**Summary of NSO Habitat Removed[1] from the Proposed Action by Habitat Impact Category**

| Habitat Impact Category[1] | Interior Forest[2] | Milse Crossed | NSO Habitat Removed (acres) | | | | |
|---|---|---|---|---|---|---|---|
| | | | High NRF[3] | NRF[4] | Dispersal Only[5] | Capable[6] | Total Habitat Removed |
| High | Interior Forest | 16.1 | 59.11 | 42.87 | 63.02 | 56.41 | 221.41 |
| | Other | 57.4 | 136.46 | 185.32 | 186.40 | 404.20 | 912.38 |
| High Impact Total | | 73.5 | 195.57 | 228.19 | 249.42 | 460.61 | 1,133.78 |
| Moderate | Interior Forest | 0.4 | 0.00 | 0.03 | 5.62 | 0.46 | 6.10 |
| | Other | 5.3 | 0.00 | 4.68 | 19.28 | 53.78 | 77.74 |
| Moderate Impact Total | | 5.7 | 0.00 | 4.71 | 24.89 | 54.24 | 83.84 |
| Low | Interior Forest | 1.3 | 0.00 | 0.00 | 2.60 | 13.59 | 16.19 |
| | Other | 5.0 | 0.00 | 2.76 | 24.81 | 58.29 | 85.85 |
| Low Impact Total | | 6.3 | 0.00 | 2.76 | 27.41 | 71.88 | 102.04 |
| Outside Home Range | Interior Forest | 8.6 | 3.05 | 30.59 | 69.66 | 19.24 | 122.53 |
| | Other | 53.4 | 18.06 | 81.87 | 320.13 | 416.40 | 836.46 |
| Outside Home Range Total | | 62.1 | 21.11 | 112.46 | 389.79 | 435.63 | 959.00 |
| Overall Total | Interior Forest | 26.4 | 62.16 | 73.49 | 140.89 | 89.69 | 366.23 |
| | Other | 121.1 | 154.52 | 274.62 | 550.62 | 932.67 | 1,912.43 |
| Overall Total | | 147.5 | 216.68 | 348.11 | 691.51 | 1,022.36 | 2,278.66 |

[1] see Trask & Associates (2013) for Impact Categorization factors and appendix Z2 for individual Habitat Impact Category assessments for each NSO Home Range.
[2] Interior Forest: not affected by existing disturbance (i.e., roads, existing corridors) or adjacent landuse/vegetation type (i.e., agriculture, non-forest, early regenerating forest); Other Forest Type includes forested habitat that is currently affected by existing disturbance or adjacent landuse/vegetation types within 100 meters of stand/MAMU habitat type
[3] High NRF (Trask & Associates, 2013): forested habitat that is characterized by large trees (> 32 dbh), high canopy cover (>60 percent), and multistoried with sufficient down wood and snags to support prey species.
[4] NRF (Trask & Associates, 2013; FWS, 2012; North et al., 1999): conifer-dominated forested habitat greater than 80 years that does not meet the definition of High NRF but has multi-storied structure with large overstory trees (20-30 inch dbh), moderate to high canopy closure greater than 60 percent, and sufficient snags and down wood.
[5] Dispersal ONLY (FWS, 2012): an average tree diameter of 11 inches dbh or greater; conifer overstory trees; canopy closure greater than 40 percent in moist forests and greater than 30 percent in dry forests; open space beneath the canopy to all for NSO to fly; High NRF and NRF provide dispersal habitat, as well.
[6] Capable Habitat (Trask & Associates, 2013): habitat that is forested or could become forested (i.e., recently harvested timberlands) that do not provide dispersal or NRF characteristics.

The FWS (Trask & Associates, 2013) recommends two primary actions to offset indirect impacts to NSO habitats: land acquisition of like-to-like habitats affected by the Project (high NRF, NRF, dispersal, and capable) and/or silvicultural treatments to offset effects to dispersal and capable habitat on federal lands. Following direction within the Habitat Conservation Framework (Trask & Associates, 2013), individual assessments included in appendix Z2 for each NSO home range (known, best location, and PCGP assumed) have been used to evaluate and determine the type and amount of mitigation recommended for impacts from the proposed action. The CMP identifies the amount of habitat acquisition proposed by Pacific Connector to offset effects of the proposed project on NSO habitat (in consideration of MAMU habitat overlap; see Section 1.6 in appendix O).

FWS provided additional guidance to Pacific Connector on January 24, 2014 to assess and mitigate direct effects (disruption and disturbance) to NSO by the Proposed Action (Trask & Associates, 2014). This new guidance essentially decoupled the direct effects from the previous guidance provided to Pacific Connector in June 2013 (see Trask & Associates, 2013) and outlined a new method to categorize direct effects to NSO pairs into the following Disruption-Disturbance (D/D) Impact Categories: High Impact, Moderate Impact, Low Impact, Low Impact – no mitigation, and No Impact. The assessment considers the timing, types, and location of Project-related activities in relation to NSO activity centers that could result in disturbance or disruption of NSO to assist in determining a D/D Impact Category for each Project activity for each NSO activity center. In many instances an NSO activity center could experience disturbance from more than one proposed activity (i.e., construction effects and proposed use of existing access roads; see D/D Impact Categorization in appendix Z2). Pacific Connector determined the D/D Impact Category for each NSO activity center within 0.25 mile of proposed project activities in appendix Z2, and included a list of factors considered when determining if an activity would be considered a disruption, a disturbance, or have no effect on each NSO activity center, including consideration of the site-specific noise evaluation for each NSO activity center. The resulting D/D Impact Category is also included for each NSO activity center in table Q-8 in appendix Q. The FWS (Trask & Associates, 2014 – appendix Z4) identified a couple of opportunities to offset the direct effects to NSO, including financial support of established programs that would assist in the recovery of the species (e.g., the barred owl control experimental program). Table 4.3.4-26 summarizes the number of NSO activity centers by D/D Impact Category and status of NSO activity center: Moderate Impact, Low Impact, and No Impact. No NSO activity center was assigned a “High” category because within 0.25 mile of an NSO activity center, Pacific Connector would remove timber outside of the entire breeding period and construct outside the critical breeding period (March 1 to July 15). Following direction within the D/D Conservation Framework (Trask and Associates, 2014), individual assessments included in appendix Z2 for each NSO home range (known, best location, and PCGP assumed) have been used to determine the funding necessary for barred owl mitigation to offset impacts (see appendix O).

**Table 4.3.4-26**
**Summary of NSO Activity Centers within the PCGP Project Area Assigned a D/D Impact Category**

| NSO Status | Disruption/Disturbance Impact Category | | | | Overall Total |
|---|---|---|---|---|---|
| | High | Moderate | Low | No/None | |
| Known | 0 | 1 | 25 | 46 | 72 |
| Best Location | 0 | 2 | 7 | 8 | 17 |
| PCGP Assumed | 0 | 0 | 5 | 4 | 9 |
| Total | 0 | 3 | 37 | 58 | 98 |

This CMP has been developed in close consultation with the Forest Service and BLM. Pacific Connector has been and will continue to be in consultation with the U.S. Fish and Wildlife Service (FWS) during development of the CMP.

#### 4.3.4.5 Determination of Effects

**Listed Species**

The Project **may affect** NSOs because:

- Suitable habitat is available within the Provincial Analysis Area.
- NSO pairs and resident singles have been located within the Provincial Analysis Area during survey efforts.

The Project is **likely to adversely affect** NSOs because:

- Noise from blasting and helicopter use within 0.25 mile of NSO sites during the late breeding season would occur and could increase the risk of predation to fledglings that are generally not as able to escape as adults during the latter part of the breeding season.
- The proposed action would remove high NRF and NRF habitat within the range of the NSO including effects to nest patches, core areas, and home ranges of known, best location, and PCGP assumed owls, some of which are currently below thresholds needed to sustain NSOs. Once suitable NRF habitat is reduced or modified in NSOs' home ranges, there is an increased likelihood that NSOs remaining in the Project area would be subject to:
  - displacement from nesting areas;
  - concentration into smaller, fragmented areas of suitable nesting habitat that may already be occupied;
  - increased interspecific (with barred owls) and intraspecific competition for suitable nest sites;
  - decreased survival due to increased predation and/or limited resource (forage) availability; and
  - diminished reproductive success for nesting pairs.
- The proposed Project would remove and modify high NRF, NRF, dispersal, and capable habitat for NSOs throughout the Project area, including removal of habitat within the home range of 90 NSOs, 56 of which are currently below sustainable threshold levels of suitable habitat for continued persistence in their home range and/or core area.

- The proposed Project would bring two NSO core areas below the 50 percent NRF threshold (one known NSO activity center and one best location activity center).

**Critical Habitat**

A **may affect** determination is warranted for NSO critical habitat because:

- The Project would occur within designated NSO critical habitat; and
- The Project would result in habitat impacts within designated critical habitat areas.

A **likely to adversely affect** determination is warranted for NSO critical habitat because:

- The proposed action would remove or potentially downgrade PCEs in critical habitat sub-units ORC-6, KLE-1, KLE-2, KLE-3, KLE-4, KLE-5, and ECS-1 as defined in the Final Rule designating critical habitat for the NSO (FWS, 2012).

### 4.3.5 Streaked Horned Lark

#### 4.3.5.1 Species Account and Critical Habitat

**Status**

The streaked horned lark (*Eremophila alpestris strigata*) was listed as threatened under the ESA in a final rule published Octorber 3, 2013 (FWS, 2013i). The species had been proposed for listing in October 2012 (FWS, 2012j).

**Threats**

Loss of nesting habitat in native prairies has lead to streaked horned larks nest on artificially maintained short grass areas adjacent to several airports in Washington and Oregon (FWS, 2013i). Maintenance mowing during the nesting period affects the species. Industrial developments in open areas has altered breeding and wintering habitat. Native grasslands have become isolated and intermingled with residential, municipal, and farm lands. In coastal areas, exotic beachgrasses have invaded dune habitats that were used for nesting by horned larks and have reduced nesting habitats in some area. In addition, predation of streaked horned lark nests has be a primary source of nest failure (FWS, 2010h). Predation can have a significant effect on small, declining, isolated populations. Those same population characteristics have contributed to overall loss of genetic diversity in the subspecies which may contribute lower fecundity. Other known or potential threats include climate change, unpredictable extreme weather events, aircraft and vehicle-related mortality (strikes), application of toxic herbicides and/or pesticides, and nest losses due to recreationists, especially along the coast (FWS, 2013i).

**Species Recovery**

No recovery information is available for the streaked horned lark.

**Life History, Habitat Requirements, and Distribution**

There are three subspecies of horned lark in Oregon (Marshall et al., 2006): the streaked horned lark, *E. a. strigata* (Willamette Valley, along the northern coast, from Multnomah County south to Lane County, and historically in the Rogue Valley of Jackson County), the subspecies *E. a. alpina* (breeds at higher elevations in the Washington Cascades), subspecies *E. a. merrilli* (breeds in intermountain valleys in Sherman, Wasco, Morrow, Klamath, and Lake counties), and subspecies *E. a. lamprochroma* (breeds in lowland shrub-steppe and agriculture in Lake, Harney, Umatilla, Wallowa, and Baker Counties). The subspecies also occurs on remnant prairies in the Puget Trough lowlands and along the outer coast of Washington (Stinson, 2005).

In Washington, horned larks on the outer coasts and on Columbia River islands occur year round while birds in the Puget lowlands are mostly migratory. Nests were initiated by early May and breeding completed by the end of July although clutch initiation along the coast may be earlier and later than inland (Pearson and Hopey, 2005). Clutch sizes ranged from 2 to 5 in coastal habitats, 2 to 4 in the Puget lowlands (Pearson and Hopey, 2005) with no significant difference between the two habitats. Nesting habitats include open grasslands, beaches and dredge spoils islands with sparse vegetation, and agricultural fields, preferring bare ground to vegetation several inches tall (Stinson, 2005). The same preferences are assumed for birds in Oregon: horned larks breed in the Willamette Valley and wintering flocks there may be a mixture of several subspecies (FWS, 2010). Wintering habitats used by migrating birds are also open; use of ocean beaches, dunes and airports have been described (Stinson, 2005).

**Population Status**

Estimates from 2010 were 330 streaked horned larks that bred at 12 sites in Washington and at least 500 birds in Oregon but there had been no comprehensive surveys conducted in the Willamette Valley. They appeared to be extirpated from British Columbia (FWS, 2010h). At the time of listing in 2013, streaked horned larks were declared extirpated from the northern Puget Trough, the Washington coast north of Grays Harbor, the Oregon coast, and the Rogue and Umpqua valleys in southwest Oregon (FWS, 2013i). The current rangewide population is estimated at 1,170 to 1610 birds with approximately 150-170 breeding in the Puget lowlands, 120 – 140 horned larks breeding on the Washington coast and Columbia River islands, and 900 – 1,300 streaked horned larks breeding in the Willamette Valley (FWS, 2013i).

**Critical Habitat**

Critical habitat was designated in a final rule (FWS, 2013j) at the same time streaked horned larks were listed as threatened. There are three critical habitat units in Washington and Oregon including the Washington Coast, islands in the Columbia River, and the Willamette Valley in which there are three subunits. Primary Constituent Elements for streaked horned lark critical habitat include (FWS, 2013j) areas having a minimum of 16 percent bare ground with sparse, low growing vegetation composed primarily of grasses and forbs ≤13 inches (33 cm) tall within the following site situations:

1. Large (300-acre (120-ha)), flat (with 0 to 5 percent slope) areas within a landscape context that provides visual access to open areas such as open water or fields, or
2. Areas smaller than described in (1), but provide visual access to open areas such as open water or fields.

All of the units designated as critical habitat are currently occupied by the streaked horned lark and contain the primary constituent elements to support the life-history needs of the subspecies (FWS, 2013j).

### 4.3.5.2 Environmental Baseline

**Analysis Area**

The same LNG terminal analysis area as described above for western snowy plovers (Section 4.3.2.2) would apply to streaked horned larks. The analysis area extends 1.7 miles beyond the perimeter of the LNG terminal project area to include sand dune and beach habitat on the North Spit and includes Horsfall Lake, old dredge spoils (eg., Menasha Spoils at Pony Slough), and portions of the Oregon Dunes National Recreational Area (see figure 4.3-2 in Section 4.3.2.2, western snowy plover).

**Species Presence**

The streaked horn lark was proposed for listing as threatened in Washington and Oregon (Benton, Clackamas, Clatsop, Columbia, Lane, Linn, Marion, Multnomah, Polk, Washington, and Yamhill Counties) in October 2012 with proposed critical habitat in Washington and Oregon (Clatsop, Columbia, Lane, Linn, Marion, Multnomah, Polk, and Yamhill Counties) (FWS, 2012). None of the counties crossed by the PCGP project were included in the sub-species range. FWS (2013a, citing Gabrielson and Jewett, 1940) noted there were historical records of nonbreeding horned larks in coastal counties of Clatsop, Tillamook, Coos and Curry counties from before 1940. However, Marshall et al. (2006) did not include southwestern Oregon within the range of *Eremophila alpestris* in the state.

Further investigations have revealed additional records of horned larks in the PCGP Project vicinity. In addition to the pre-1940 records noted by FWS (2013a), Contreras (1998) listed seven instances of horned larks within Coos County (Table 4.3.5-1), three of which were in near proximity to the JCEP site, including two on the Coos Bay North Spit and one at Horsfall Lake, approximately 0.9 mile north of the proposed LNG terminal. Based on the records in Table 4.3.5-1, Contreras (1998) described the horned lark in Coos County as a rare but regular fall and winter visitor found mainly on the outer coast.

**Table 4.3.5-1**
**Available Records of Horned Larks, *Eremohphilia alpestris*, in the Vicinity of Coos Bay (Contreras, 1998).**

| Observation Date | Location | Number |
|---|---|---|
| February 16-17 Before 1940 | unknown | unknown |
| Late November 1978 | North Spit Coos Bay | small flock |
| November 20 1979 | North Spit Coos Bay | one |
| December16 1979 | unknown | unknown |
| September 19 1981 | Bullard’s Beach Park | unknown |
| November 3 1985 | Bandon | one (with Lapland longspurs) |
| October 7 1987 | Horsfall Lake | six |
| November 20 1989 | unknown | unknown |

Horned larks were reported during Audubon Christmas Bird Counts (CBC) within the following CBC Count Circles (Audubon, 2013) nearest to the PCGP route:

1. Coos Bay: 6 in 2005, 18 in 2006.
2. Medford: 3 in 2000, 1 in 2002, and 4 in 2005.

3. Klamath Falls: 5 in 1996, 15 in 2000, 8 in 2002, 31 in 2007, and 1 in 2009.

None of the records identified by Contreras (1998) or reported in Audubon CBC Count Circles included any subspecies separation of *Eremophila alpestris*. Consequently, there is no way to determine if observations were of *E. a. strigata*, of *E. a. articola* (northeastern and eastern Oregon in winter), *E. a. merrilli* (east of the Oregon Cascades into northeastern California) or *E. a. lamprochroma* (eastern Oregon). Since *E. a. strigata* can be found in coastal dune habitats (FWS, 2010h), and birds in Coos County generally occurred as fall or winter migrants on Oregon's outer coast (Contreras, 1998), it is likely that observations in Coos County, including the records in the CBC Coos Bay count circle, were of *E. a. strigata*. Birds observed within the Medford CBC could have been *E. a. strigata* and/or *E. a. merrilli*. Birds observed within the Klamath Falls CBC could have been *E. a. merrilli* and/or *E. a. lamprochroma*. However, there no way of knowing which subspecies was observed at any of the locations.

In the winter, most streaked horned larks that breed in the south Puget Sound migrate south to the Willamette Valley or west to the Washington coast; streaked horned larks that breed on the Washington coast either remain on the coast or migrate south to the Willamette Valley (FWS, 2013i). Winter migrants from these populations may inhabit the Oregon coast, although there is no information to support that possibility. Streaked horned larks spend the winter in large groups of mixed subspecies of horned larks in the Willamette Valley at least as far south as Corvallis, and in smaller groups along the Washington coast and Columbia River (FWS, 2013i). Perhaps some of the horned larks seen in the project vicinity during fall and winter may have been streaked horned larks but there is no way to be certain.

**Habitat**

A focused field evaluation of the JCEP project site on the North Spit was conducted by SHN Consulting (SHN) staff on April 23, 2013, to assess the potential for streaked horned lark habitat to occur (see Resource Report 3, JCEP LNG Terminal Project). One small area, approximately 75 feet by 150 feet was noted at the proposed South Dunes Power Plant site; however, it is surrounded by the previous mill site industrial footprint and is not adjacent to open water. Along the utility corridor and access road between the South Dunes Power Plant and LNG Terminal sites, sparsely vegetated portions of the rolling (and at times steep) dunes in the area was noted; again, the sites were not adjacent to open water. Small pockets of potential habitat were also noted in the upper half of the slip site, but they are surrounded by and being encroached by European beachgrass, gorse, and Scotch broom. An additional area at the northwest tip of the Project site, immediately south of the Trans-Pacific Parkway, also provides sparsely vegetated sand habitat but is not adjacent to open water. These sites would be unsuitable habitat according to specific conditions described above as Primary Constituent Elements in critical habitat.

The "weedy fields between the shoreline and dunes on the Roseburg Forest Products facility" noted in previous surveys as potential habitat (LBJ, 2006) were scraped off approximately five years ago and planted with grass that has become dense. When the previous surveys were conducted in 2005 and 2006, the site was likely at the stage between unvegetated landscape and dense covering of grasses. That habitat no longer exists and the site would no longer be considered potential habitat for the streaked horned lark.

**Critical Habitat**

The PCGP Project does not coincide with any designated critical habitat units, the closest of which is the Willamette Valley Subunit 4-C at the William L. Finley National Wildlife Refuge, 80 miles north of the Project.

### 4.3.5.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Winter migrants from northern populations may inhabit the Oregon coast, although there is no information to support that possibility. Since streaked horned larks spend the winter in large groups of mixed subspecies of horned larks in the Willamette Valley at least as far south as Corvallis (FWS, 2013i), some of the horned larks observed in the vicinity of Coos Bay, reported by Contreras (1998) and within the Coos Bay CBC Count Circle (Audubon, 2013) may have been streaked horned larks. Alternatively, none of those horned larks may have been *Eremophila alpestris strigata*.

Occurrence of the subspecies near the JCEP project might be limited to a few individuals during fall and winter, probably present during migrations some years, not others. No suitable habitats for migrating or wintering streaked horned larks would be affected by the Proposed Action. Construction of buildings associated with the LNG Terminal and South Dunes Power Plant would alter the open quality of the local landscape but there is no indication that horned larks occur at either location. Initial construction at the JCEP site could displace one or several streaked horned larks if any are present in the area coincidental with the activities. Continuing construction and operation of the LNG terminal would likely be avoided by any horned lark in the area.

If they occur, direct effects of the proposed action on streaked horned larks would be similar to those described above for western snowy plover. Direct effects could include increased noise associated with construction of the LNG terminal and operation activities associated with shipping although effects of noise on breeding or wintering streaked horned larks has not been described. The following were anticipated indirect effects to western snowy plovers by the proposed project: 1) increased human presence, and 2) increased predation of western snowy plovers due to increased human presence. In both types, effects were expected to lead to destruction of nests and/or disturbance of nesting plovers. Neither type would affect wintering streaked horned larks.

**Cumulative Effects**

Additional projects within the action area (estuarine analysis area and the LNG terminal Analysis Area) are anticipated as human population growth continues in the region. Associated road and commercial development, as well as maintenance and upgrading of existing infrastructure within the Estuary, are likely to occur in the foreseeable future. These were describe above, for western snowy plovers and are not repeated here. No specific state or private actions have been identified within the analysis area.

**Critical Habitat**

No critical habitat designated for the streaked horned lark would be affected by the Proposed Action.

#### 4.3.5.4 Conservation Measures

JCEP has committed to multiple conservation measures to offset any impact to western snowy plovers (see Section 4.3.2.4, above). Many of the measures target conservation of western snowy plover breeding and nesting habitat on the Coos Bay North Spit and would have limited or no conservation value to a migrating or wintering streaked horned lark, if one occurred. Removal or European beachgrass would probably have the greatest potential benefit. Other Best Management Practices described in Section 4.3.2.4 might benefit streaked horned larks, if one occurred.

#### 4.3.5.5 Determination of Effects

**Species Effects**

The Project **may affect** streaked horned larks because:

- Horned larks have been observed during fall and winter in the vicinity of the JCEP LNG terminal analysis area. It is possible that one or more of the horned larks reported was *Eremophila alpestris strigata*.
- However, use of the JCEP LNG terminal analysis area by streaked horned larks would be limited to infrequent occurrences. No suitable habitat is present at the project site.

The project is **not likely to adversely affect** streaked horned larks because:

- Birds in the vicinity of the project area could detect noise produced during construction and operation of the JCEP LNG terminal site but noise is not expected to cause any harm to streaked horned larks.
- Future presence of streaked horned lakes in the JCEP LNG terminal analysis area at the time of construction is extremely unlikely, considered to be discountable.

**Critical Habitat Effects**

No designated critical habitat for the streaked horned lark will be affected.

## 4.4 HERPETOFAUNA

### 4.4.1 Green Turtle

#### 4.4.1.1 Species Account and Critical Habitat

**Status**

Green turtles were listed as threatened, except for an endangered population nesting on the Pacific Coast of Mexico, under the ESA on July 28, 1978 (FWS, 1978).

**Threats**

The green turtle has long been susceptible to harvest of both eggs and adults. Harvesting is the most serious direct problem faced by the green turtle; however, it is assumed that direct take in the United States doesn't exist (NMFS and FWS, 1998a). As modernization and technology was adopted by native people of various island and coastal communities throughout the Pacific that harvested green turtles, traditional practices of restraint in the harvest of green turtles were abandoned (NMFS and FWS 1998a). The evidence for the human impact on green turtles is further strengthened by the fact that the only breeding sites of any significance that are left are found in those areas that are not inhabited by humans or are visited rarely for exploitation (NMFS and FWS, 1998a).

Although 26 different types of threats have been identified for green turtles, the threats vary depending upon the geographic area where the turtles are found. On the U.S. West Coast, three primary threats are identified including debris, boat collisions, and incidental capture of turtles from fishing operations (NMFS and FWS, 1998a). Other threats include environmental contaminants and dredging (NMFS and FWS, 1998a).

**Species Recovery**

Recovery plans for the East Pacific and Pacific green turtles were issued on May 22, 1998 (NMFS and FWS, 1998a). The recovery goal is to delist the species, and the plan listed the following necessary actions:

- Minimize boat collision mortalities, particularly within San Diego County, California.
- Minimize incidental mortalities of turtles by commercial fishing operations.
- Support the efforts of Mexico and the countries of Central America to census and protect nesting East Pacific green turtles, their eggs, and nesting beaches.
- Determine population size and status in U.S. waters through regular surveys.
- Identify stock home range(s) using DNA analysis.
- Identify and protect primary foraging areas in U.S. jurisdiction.

The stepdown outline in the recovery plan included the following recommendations:

- Protect and manage turtles on nesting beaches (no nesting in U.S. jurisdiction).
- Protect and manage nesting habitat.
- Protect and manage East Pacific green turtle populations in the marine habitat.
- Protect and manage marine habitat, including foraging habitats.
- Develop standards for the care and maintenance of sea turtles, including diet, water quality, tank size, and treatment of injury and disease.

- Establish a catalog of all captive sea turtles to enhance use for research and education.
- Designate rehabilitation facilities.
- Support existing international agreements and conventions to ensure that turtles in all life-stages are protected in foreign waters.
- Encourage ratification of CITES for all non-member Pacific countries, compliance with CITES requirements, and removal of sea turtle trade reservations held by member nations.
- Develop new international agreements to ensure that turtles in all life-stages are protected in foreign waters.
- Develop or continue to support informational displays in U.S. airports and ports of entry that have direct flights to Mexico and Latin America.

**Life History, Habitat Requirements, and Distribution**

The green turtle is found in warm tropical waters and, to a lesser extent, subtropical waters with temperatures above 20ºC (68ºF) (NMFS and FWS, 1998a). Many facets of the green turtle's life history and ecology remain unknown, including details of its residence in and use of the U.S. Pacific Coast. The Pacific green turtle nests on tropical beaches in Hawaii and other islands of the Pacific, while the East Pacific green turtle is a separate population of the same species, nesting primarily on the coast of Michoacan, Mexico and in the Galapagos Islands. The green turtle has a worldwide distribution in tropical and subtropical waters. Except during breeding migrations, green turtles tend to be found in shallow waters such as those inside reefs, bays, and inlets. The turtles are attracted to lagoons and shoals with an abundance of marine grass and algae. Seagrasses are the principal dietary component of juvenile and adult green turtles throughout the Caribbean region and degradation of seagrass beds has slowed recovery of green turtles due to reduced carrying capacity of seagrass meadows (NMFS, 1998b). Green turtles apparently have strong nesting site fidelity and migrate long distances between feeding grounds and nesting beaches.

The green sea turtle grows to a maximum size of about 4 feet and a weight of 440 pounds. Hatchling green turtles eat a variety of plants and animals, but adults are vegetarian, feeding on sea grass and algae. The nesting season varies with the locality and clutch size varies from 75 to 200 eggs (FWS, 2007g). Incubation of the eggs varies between 45 and 75 days. Age at sexual maturity is between 20 to 50 years (FWS, 2007g).

**Population Status**

The mean annual number of nesting green turtle females has declined by 48 to 67 percent over the last three generations, which was estimated from index nesting sites (Marine Turtle Specialist Group 2004). East Pacific green turtles are widely distributed in coast waters south of the United States, in Mexico and Central America where the main aggregations are along the west coast of Baja California, in the Sea of Cortez, along the coast of Oaxaca, and breeding ground s of Michoacan, Mexico (NMFS and FWS, 1998b). A small population (about 30 turtles in 1990) occurred in San Diego Bay, California, the northernmost resident population reported, although there is no known nesting by green turtles on the U.S. west coast (NMFS and FWS, 1998b).

**Critical Habitat**

Critical habitat was established for this species on Culebra Island, Puerto Rico on September 2, 1998 (NMFS, 1998b). No critical habitat for this species occurs on the U.S. West Coast or within the within the EEZ analysis area.

### 4.4.1.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to green turtles is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head and from San Diego to Cape Flattery, the same as described above for blue whales (see figure 4.2-1). Within the EEZ analysis area, effects to green turtles would be associated with LNG carriers inbound and outbound from the LNG terminal. ).

For reasons discussed for blue whales (see Section 4.2.1.4), LNG carriers are assumed to traverse the EEZ mostly perpendicularly - east and west - as they approach and depart from Coos Bay. Ships could also traverse the EEZ parallel to the U.S. West Coast if originating on or passing along the west coasts of Central or South America. The assumption of perpendicular transits is based on existing shipping traffic between Asia and the U.S. West Coast most of which travels a “Great Circle route” (Pacific States/British Columbia Oil Spill Task Force, 2002), and LNG imports for the LNG terminal are assumed to come from Australia and Southeast Asia.

**Species Presence**

Green sea turtles have been sighted from Baja California to southern Alaska, but most commonly occur from San Diego south (NMFS, 2007b). Green sea turtles primarily use three types of habitat: oceanic beaches (for nesting), convergence zones in the open ocean, and benthic feeding grounds in coastal areas (NMFS, 2007b). Reports of strandings suggest that the green turtle is a frequent visitor off the California coast. The northernmost stranding was reported in 1993 in Homer, Alaska, although it was speculated that this turtle may have died farther to the south and drifted north (NMFS, 1998b). Based on this data, green turtles are likely infrequent visitors to the Oregon coast, but may occasionally be found in the EEZ analysis area and within the LNG ship transit zone.

**Habitat**

Sightings offshore of the Pacific Coast have occurred but there are no known sea turtle nesting sites on the West Coast of the United States (NMFS and FWS, 1998a). The East Pacific green turtle was the most commonly observed hard-shelled sea turtle on the U.S. Pacific Coast (NMFS and FWS, 1998a) but most of the sightings (62 percent) were reported from northern Baja California and Southern California. The northernmost known resident population of East Pacific green turtles occurs in San Diego Bay, in the warm effluent of a power plant (NMFS and FWS, 1998a).

**Critical Habitat**

Critical habitat has been designated in the Caribbean, off Puerto Rico (NMFS, 1998b) but no critical habitat for this species occurs within the EEZ analysis area.

#### 4.4.1.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, underwater ship noise, and potential adverse effects from a ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect green turtles by impacting forage species. These effects are addressed below.

<u>Ship Strikes by LNG Carriers</u>

The proposed action would result in increased shipping traffic and may increase potential vessel strikes to green turtles within the EEZ analysis area. Boat collisions are listed as a major problem for green turtle recovery off the U.S. West Coast (NMFS, 1998b). Sea turtles can be injured or killed when struck by a boat, especially by an engaged propeller. Eighty percent of sea turtle deaths reported recently in San Diego Bay and Mission Bay, California were associated with evidence of boat collision. Experiments conducted with a small 20-foot aluminum boat used to approach green sea turtles at various speeds found that turtles could avoid the boat and collision more effectively at slow speeds than at fast speeds (Hazel et al., 2007). However, methods for reducing boat collisions are not included in recovery objectives, and based on their warm water requirements, green sea turtles are likely to only be occasional visitors to waters as far north as Oregon.

The proposed action is expected to increase traffic by 180 additional ship transits through the EEZ analysis area each year of operation. Given the low population and occurrence of the green turtles in Oregon coastal waters and current estimate of vessel traffic, the addition of 180 LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to green turtles. However, lack of ship-strike incidences to sea turtles in general or frequencies of collision preclude any estimate of effects to green turtles of additional vessel traffic due to LNG carriers. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because reports of strandings in California are more frequent. LNG carriers are expected to transit at least 50 nmi off the coast and so would be expected to avoid nearshore feeding areas used by green turtles.

<u>Underwater Noise</u>

Loggerhead sea turtles can detect sound and their hearing is most sensitive to lower frequencies below 1000 Hz (Bartol et al., 1999; Martin et al., 2012), within the same range of low frequencies generated by ships and sounds generated by large baleen whales (Würsig and Richardson, 2009). The same is assumed to be true of green sea turtles. However, studies have focused on sea turtle response to seismic operations (McCauley et al., 2000; Holst et al., 2006); turtles were observed to move away from the operations. Responses to ship noise have not been reported. Loggerhead and green turtles hear and respond to low frequency sound from seismic operations (increased swimming speed, increased activity, change in swimming direction, and avoidance) but their hearing threshold appears to be high. Based on available information, it is considered unlikely that sea turtles are more sensitive to seismic operations than cetaceans or some fish (Department of Fisheries and Oceans Canada, 2004).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on green sea turtles are possible in the West Coast EEZ analysis area but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a sea turtle surfaced to breathe at the LNG pool location, oxygen deficiency would occur with potential physiological effects, described for humans (ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations, see Table 39 in Hightower et al., 2004) but not for sea turtles. Because the estimated densities of sea turtles are believed to be low within the West Coast EEZ analysis area, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing sea turtles within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of green sea turtles in the West Coast EEZ analysis area during 2018 are expected to be so low that the chance of a sea turtle surfacing in an area of pooled LNG or close enough to a fire to be injured is insignificant and discountable.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6

vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whale). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2. Consequently, cumulative effects to green turtles would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4 under blue whales) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the prediticions. Cumulative effects of 90 LNG carriers per year to green sea turtles may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

No critical habitat would be affected by the proposed action.

#### 4.4.1.4 Conservation Measures

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of cetaceans are observed near an underway ship would provide some protection to green turtles. However, it is highly unlikely that green turtles or other sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (Blue Whale) apply to green turtles.

#### 4.4.1.5 Determination of Effects

**Species Effects**

The Project **may affect** green turtles because:

- Green turtles may occur within the EEZ analysis area during operation of the proposed action.

- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** green turtles because:

- Whether or not green turtles have been struck by ships is unknown but is expected to be highly unlikely.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase for potential ship strikes to green turtles.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals, which should also benefit sea turtles.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on green sea turtles could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected green sea turtle presence (based on assumed densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to green sea turtles if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for the green turtle.

### 4.4.2 Leatherback Turtle

#### 4.4.2.1 Species Account and Critical Habitat

**Status**

Leatherback turtles were listed as endangered under the Endangered Species Conservation Act on December 2, 1970 (FWS, 1970) and have been listed under the ESA since its implementation in 1973.

**Threats**

Egg collection was one of the primary reasons the leatherback turtles became endangered, along with harvest of female egg-laying turtles. NMFS and FWS (1998b) lists incidental take as the primary threat to leatherback turtles. This includes entanglement in nets and ingestion of marine debris.

Direct threats to leatherback turtles include harvesting. The primary threat to leatherback turtles on the U.S. West Coast continues to be incidental take in commercial fisheries operations (NMFS and FWS, 1998b). Other threats include injestion of debris, primarily plastics and plastic bags that are thought to be mistaken for jellyfish and eaten, leading to esophagus and stomach blockage and eventually death (Mrosovsky et al., 2009; Plotkin, 1995). These deaths, and the evidence for this type of death by this specific type of ingestion, appear to be on the rise (Plotkin, 1995). Threats at nesting grounds outside the United States still remain from collection of eggs and development along the coast. In addition, artificial light (during egg hatch viewing) causes confusion of newly hatched turtles that head in the direction of the light rather than out to sea (Plotkin, 1995; FWS, 2012f; NMFS and FWS, 1998b).

**Species Recovery**

A recovery plan was issued for the U.S. Pacific Coast population on May 22, 1998. The recovery goal (NMFS and FWS, 1998b) is to delist the species, and the plan listed the following necessary actions:

- Eliminate incidental take of leatherbacks in United States and international commercial fisheries.
- Support the efforts of Mexico and the countries of Central America to census and protect nesting leatherbacks, their eggs, and nesting beaches.
- Determine movement patterns, habitat needs, and primary foraging areas for the species throughout its range.
- Determine population size and status in U.S. waters through regular aerial or on-water surveys.
- Identify stock home ranges using DNA analysis.

The stepdown outline in the recovery plan included the following recommendations:

- Protect and manage turtles on nesting beaches.
- Protect and manage nesting habitat.
- Protect and manage leatherback turtle populations in the marine habitat.
- Protect and manage marine habitat, including foraging habitats.
- Support existing international agreements and conventions to ensure that turtles in all life-stages are protected in foreign waters.
- Encourage ratification of CITES for all non-member Pacific countries, compliance with CITES requirements, and removal of sea turtle trade reservations held by member nations.
- Develop new international agreements to ensure that turtles in all life-stages are protected in foreign waters.
- Develop or continue to support informational displays in airports that provide connecting legs for travelers to the areas where leatherbacks occur.

**Life History, Habitat Requirements, and Distribution**

The leatherback is the largest,most migratory, and widest range of all extant sea turtles (FWS, 2012f). Leatherback sea turtle nesting grounds are located around the world, with the largest remaining nesting assemblages found on the coasts of northern South America and West Africa. Adult leatherback sea turtles are capable of tolerating a wide range of water temperatures, and have been sighted as far north as the Gulf of Alaska (NMFS and FWS, 2007a). Their diet consists of soft-bodied prey, such as jellyfish and tunicates. Nesting occurs on sandy tropical beaches, with each female laying several clutches at intervals of 8 to 12 days. Mating occurs in the waters adjacent to nesting beaches within migration corridors. After nesting, female leatherbacks migrate from tropical waters to more temperate latitudes, which support high densities of jellyfish prey in the summer (NMFS and FWS, 1998b). Incubation of the eggs takes between 55 and 75 days, and hatching occurs at night. Sexual maturity is reached between 6 and 10 years (FWS, 2012f). No known nesting locations occur on the U.S. Pacific Coast.

NMFS (2012e) defined nine geographic areas along the west coast from Washington to Northern California that are occupied by leatherback turtles. Areas 2 and 3 include nearshore waters Point Arena in northern California to Cape Flattery Washington, extending offshore to the 2000 meter isobath. Area 2 (Cape Blanco to Cape Flattery) includes most of the Oregon coast and is a principal foraging area for leatherbacks. They feed on a variety of moon jellies brown sea nettles that are present in high densities associated with the Columbia River Plume and Heceta Bank, Oregon (NMFS, 2012c). Areas 4 and 5 extend offshore west of Areas 2 and 3 to EEZ. Jellyfish densities in those areas are unknown and likely serve as secondary foraging areas and area of passage to the primary foraging region in Area 2.

**Population Status**

Leatherbacks foraging off the coast of California nest on beaches in Indonesia, Papua New Guinea, and the Solomon Islands. Turtles foraging along the California coast are part of a distinct Western Pacific breeding stock (Harris et al., 2011). The same is assumed for leatherbacks foragiing along the Oregon and Washington coasts. Between 1984 and 2011, there was an overall significant decline of 78 percent in the number of leatherback turtle nests monitored in Papua Barat, Indonesia (Tapilatu et al., 2013). Approximately 75 percent of the total leatherbacks nesting in the the western Pacific nest at Papua Barat. In the Pacific, it is estimated that leatherback turtle populations have declined by 80 percent (NMFS 2007b).

**Critical Habitat**

Critical habitat was established for this species in the U.S. Virgin Islands on March 23, 1979 (NMFS, 1979). On January 5, 2010, NMFS proposed the designation of approximately 70,600 square miles within the EEZ as critical habitat for leatherback turtles (NMFS, 2010c). NMFS' final rule designated 16,910 square miles as critical habitat for leatherback turtles along the California coast from Point Arena to Point Arguello and 25,004 square miles along the Washington and Oregon coasts from Cape Blanco, Oregon to Cape Flattery, Washington (NMFS, 2011f).

Two PCEs were proposed (NMFS, 2010c): 1) occurrence of prey species, primarily jellyfish, of sufficient condition, distribution, diversity, and abundance to support individual as well as population growth, reproduction and development, and 2) migratory pathway conditions to allow for safe and timely passage and access to/from/within high use foraging areas (NMFS, 2010c). NMFS (2011c) eliminated the proposed migratory pathway PCE. In the final designation, there is only one PCE, occurrence of prey species, primarily scyphomedusae of the order Semaeostomeae (especially brown sea nettles, *Chrysaora fuscescens*) of sufficient condition, distribution, diversity, abundance and density necessary to support individual as well as population growth, reproduction, and development of leatherbacks.

Within those areas, the condition, distribution, diversity, and abundance of prey utilized by turtles may be affected by the same activities that may affect passage as well as effects from point pollution, pesticides, power plants, desalination plants, and LNG (NMFS, 2010c).

### 4.4.2.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to leatherback turtles is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head, the same as described above for green turtles and blue whales (see figure 4.2-1).

**Species Presence**

The leatherback sea turtle is the most common sea turtle in U.S. waters north of Mexico (NMFS and FWS, 1998b). Leatherbacks occur as far north as Alaska, and numerous sightings have been documented off the Oregon coast. Green et al. (1992) observed 16 Pacific leatherback turtles off the Oregon and Washington coasts, all of them north of a point due west of Pacific City, Tillamook County, Oregon. Sixty-two percent of the sightings occurred over the continental slope, with the remainder occurring over the continental shelf. Incidental catch of leatherback turtles has also occurred in gill-nets off the coasts of Washington, Oregon, and California. These data suggest that leatherback sea turtles migrate through and would be present in the EEZ analysis area.

**Habitat**

Adult leatherback turtles are highly migratory and available information indicates that eastern Pacific migratory corridors exist along the West Coast of the United States (NMFS and FWS, 1998b). The West Coast of the United States may represent some of the most important foraging habitat in the world for the leatherback turtle (NMFS and FWS, 1998b). The importance of the EEZ analysis area to leatherback turtles is unknown though they are expected to occur. Coastal upwelling of the California Current occurs along the Oregon Coast north of Cape Blanco. Peak numbers of leatherback turtles (July to September) occur in neritic zones when intermittent decrease of upwelling, allowing surface water temperatures to increase. Leatherback aggregate in the warm highly productive coastal areas to forage on preferred prey, scyphomedusae, the cnidarian jellies (NMFS, 2012c).

**Critical Habitat**

NMFS' final rule designated critical habitat within 25,004 square miles along the Washington and Oregon coasts from Cape Blanco, Oregon to Cape Flattery, Washington (NMFS, 2011c). NMFS (2011c) defined an area (Area 2) from Cape Blanco to Cape Flattery, including most of the Oregon coast, as a principal foraging area for leatherbacks. They feed on a variety of moon jellies and brown sea nettles that are present in high densities associated with the Columbia River Plume and Heceta Bank, Oregon (NMFS, 2012c). Based upon the best available scientific information, the features of Area 2 produce sufficient prey to provide for foraging by leatherback turtles that is essential to the conservation of the species, thus this area contains the prey PCE (NMFS, 2012b). Critical habitat extends to a water depth of 80 meters from the ocean surface and is delineated along the shoreline at the line of extreme low water offshore to the 2,000-meter depth contour. Critical habitat coincides with nearshore waters through which LNG carriers would transit to Coos Bay and the Jordan Cove terminal.

### 4.4.2.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, underwater ship noise, and potential adverse effects from a ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect leatherback turtles by impacting forage species. These effects are addressed below.

Ship Strikes by LNG Carriers

The proposed action would result in increased shipping traffic and may increase potential vessel strikes to leatherback sea turtles within the analysis area. However, the largest threat to leatherback turtles outside of their nesting grounds is entanglement in gill-nets and other incidental take. Boat collisions are not listed as a current threat to the recovery of leatherback populations (NMFS and FWS, 1998b). However, Harris et al. (2011) reported two of 19 leatherback turtles examined had multiple parallel lacerations in the carapaces that had healed but consistant with wounds from boat propellers. Risk of collision increases within increased vessel speed (Hazel et al., 2007), as discussed for green sea turtles, above. The risk was described for small craft but is unknown for large tankers.

The proposed action is expected to increase traffic by 180 additional ship transits through the EEZ analysis area each year of operation. Given the low population and occurrence of the leatherback turtles in Oregon coastal waters and current estimate of vessel traffic, the addition of 180 LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to leatherback turtles. However, lack of ship-strike incidences to sea turtles in general or frequencies of collision precludes any estimate of effects to leatherback turtles of additional vessel traffic due to LNG carriers. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because leatherback turtles are more common in California waters. LNG carriers are expected to transit ≥ 50 nmi off the coast and so would be expected to avoid most frequented areas on the continental slope.

Underwater Noise

Loggerhead sea turtles can detect sound and their hearing is most sensitive to lower frequencies below 1000 Hz (Bartol et al., 1999; Martin et al., 2012), within the same range of low frequencies generated by ships and sounds generated by large baleen whales (Würsig and Richardson, 2009). The same is assumed to be the case for leatherback turtles. However, studies have focused on sea turtle response to seismic operations (McCauley et al., 2000; Holst et al., 2006); turtles were observed to move away from the operations. Responses to ship noise have not been reported. Loggerhead and green turtles hear and respond to low frequency sound from seismic operations (increased swimming speed, increased activity, change in swimming direction, and avoidance) but their hearing threshold appears to be high. Based on available information, it is considered unlikely that sea turtles are more sensitive to seismic operations than cetaceans or some fish (Department of Fisheries and Oceans Canada, 2004).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on leatherback sea turtles are possible in the West Coast EEZ analysis area but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a sea turtle surfaced to breathe at the LNG pool location, oxygen deficiency would occur with potential physiological effects, described for humans (ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations, see Table 39 in Hightower et al., 2004) but not for sea turtles. Because the estimated densities of sea turtles are believed to be low within the West Coast EEZ analysis area, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing sea turtles within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of leatherback sea turtles in the West Coast EEZ analysis area during 2018 are expected to be so low that the chance of a sea turtle surfacing in an area of pooled LNG or close enough to a fire to be injured is insignificant and discountable.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this Biological Assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whale). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2. Consequently, cumulative effects to leatherback turtles would likely be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4 under blue whale) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the prediticions. Cumulative effects of 90 LNG carriers per year to leatherback turtles may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

Critical habitat has been designated within 25,004 square miles along the Washington and Oregon coasts from Cape Blanco, Oregon to Cape Flattery, Washington (NMFS, 2012c). NMFS (2012b) defined an area (Area 2) from Cape Blanco to Cape Flattery, including most of the Oregon coast, as a principal foraging area for leatherbacks. Critical habitat coincides with nearshore waters through which LNG carriers would transit to Coos Bay and the Jordan Cove terminal.

As discussed under Blue Whales, above, LNG carriers arriving from LNG source ports near the equator are assumed to traverse the EEZ perpendicular to the Oregon coastline. Those carriers would pass through critical habitat north of Cape Blanco, Oregon, described by NMFS (2012b). LNG carriers arriving from or passing Central and South America are expected to parallel the coast from California to Coos Bay and are assumed to follow a course 50 nmi offshore. Those carriers would pass through proposed critical habitat off the California coast from Point Arena, north of San Francisco Bay, south to Point Arguello which extends seaward approximately 100 nmi or more.

The proposed action could affect proposed critical habitat areas within the EEZ analysis area if a spill or release occurred from a LNG carrier. Spills could impact both leatherback turtles and their jellyfish prey. As discussed above, it appears that the background rate of spills off the Oregon Coast by fishing vessels, recreation vessels, and other vessel types is generally low. Any potential spills that could occur and that could affect the turtles or their prey would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

If an unignited LNG spill were to occur along the LNG carrier transit route where turtles and jellyfish were present, the LNG would float on the water until it vaporizes and would not have an adverse effect on the turtles or jellyfish, unless they came in direct contact with the LNG. Ignition of LNG would accelerate evaporation and methane would rise above sea level. Sea turtles surfacing to breathe could suffer hypoxia or anoxia.

There have been approximately 11 reportable LNG transport incidents between 1979 and 2006, worldwide. Because LNG has not been transported to the Pacific Northwest, no data are available. However, due to the double hull-construction of LNG carriers, none of the incidents that have occurred with LNG carriers have resulted in the loss of LNG cargo or other significant petroleum based spills.

#### 4.4.2.4 Conservation Measures

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of cetaceans are observed near an underway ship would provide some protection to leatherback turtles. However, it is highly unlikely that leatherbacks or other sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (blue whale) apply to leatherback turtles.

#### 4.4.2.5 Determination of Effects

**Species Effects**

The Project **may affect** leatherback turtles because:

- Leatherback turtles may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** leatherback turtles because:

- Whether or not leatherback turtles have been struck by ships is unknown but is expected to be highly unlikely.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase for potential ship strikes to leatherback turtles.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals, which should also benefit sea turtles.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on leatherback turtles could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected leatherback turtle presence (based on assumed low densities). Ignited LNG

would not extend far enough from the LNG pool to cause severe or mild thermal effects to leatherback turtles if they emerged during a fire..

**Critical Habitat Effects**

The Project **may affect** proposed critical habitat for the leatherback turtle because:

- The EEZ analysis area to be used by LNG carriers includes coastal marine waters in California between Point Arena and Point Argello, California and between Cape Blanco, Oregon and Cape Flattery, Washington, both of which are included as designated critical habitat.

The Project is **not likely to adversely affect** proposed critical habitat for the leatherback turtle because:

- Spills or releases of LNG at sea would not cause the water column to cool to the point of affecting sea turtles in the water. Ignited LNG would affect species on the water but not sea turtles or jellyfish submerged in the water. The possibility that spills or releases at sea would affect passage of leatherback turtles and/or their prey is insignificant and discountable.

### 4.4.3 Olive Ridley Turtle

#### 4.4.3.1 Species Account and Critical Habitat

**Status**

Olive ridley turtles were listed as threatened, except for the breeding colony populations on the Pacific coast of Mexico, which were listed as endangered, under the ESA on July 28, 1978 (FWS 1978).

**Threats**

Direct threats to the species include the harvesting of sea turtles and their eggs and boat collisions (NMFS and FWS, 1998c). Olive ridley turtle eggs were collected at first by indigenous people and then for economic gain to sell in markets once the eggs were found to have commercial value (NMFS and FWS, 1998c). Another market was created that used olive ridley turtle leather that aided in the demise and ultimately the listing of the olive ridley turtle as threatened/endangered (NMFS and FWS, 1998c).

Natural disasters, debris entanglement and ingestion, and incidental take from domestic fisheries are listed as minor threats to olive ridley turtles (NMFS and FWS, 1998c). Primary threats to olive ridley turtles off the West Coast of the United States include incidental take from commercial fishing and boat collisions usually involving smaller boats (NMFS and FWS, 1998c). The more frequent occurrence of El Niño and general warming trends in the Pacific may be the reason that the zooplankton in the California Current are declining, resulting in the reduction of higher level vertebrates and other foods for the turtles to forage on (Plotkin, 1995).

**Species Recovery**

A recovery plan was issued in 1998. The recovery goal (NMFS and FWS, 1998c) is to delist the species, and the plan listed the following necessary actions:

- Minimize incidental mortalities of turtles by commercial fishing operations.

- Support the efforts of Mexico and the countries of Central America to census and protect nesting olive ridleys, their eggs, and nesting beaches.
- Identify stock home ranges using DNA analysis.

The stepdown outline in the recovery plan included the following recommendations:

- Protect and manage turtles on nesting beaches.
- Protect and manage nesting habitat.
- Protect and manage olive ridley populations in the marine habitat.
- Protect and manage marine habitat, including foraging habitats.
- Develop standards for the care and maintenance of sea turtles, including diet, water quality, tank size, and treatment of injury and disease.
- Establish a catalog of all captive sea turtles to enhance use for research and education.
- Designate rehabilitation facilities.
- Support existing international agreements and conventions to ensure that turtles in all life-stages are protected in foreign waters.
- Encourage ratification of CITES for all non-member Pacific countries, compliance with CITES requirements, and removal of sea turtle trade reservations held by member nations.
- Develop new international agreements to ensure that turtles in all life-stages are protected in foreign waters.
- Develop or continue to support informational displays in airports that provide connecting legs for travelers to the areas, which support olive ridleys.

**Life History, Habitat Requirements, and Distribution**

The olive ridley is primarily a pelagic sea turtle, but does occasionally inhabit coastal areas such as bays and estuaries. Olive ridleys undertake an annual migration from open-ocean foraging grounds to coastal breeding and nesting grounds. Olive ridley turtles are well known for their arribada behavior where hundreds to tens of thousands of ridley tutles emerge synchronously from the ocean over a few days to nest in close proximity (NMFS and FWS, 2007b).

Olive ridleys have been observed as far as 2,400 miles from shore. Adult turtles are small compared to other sea turtles, with an average weight of approximately 100 pounds. The olive ridley feeds on a variety of food items, including algae, lobster, crabs, tunicates, mollusks, shrimp, and fish. Females nest each year after reaching sexual maturity at about age 15. They nest one to three times per season, producing clutches of approximately 100 eggs each time. Incubation of the eggs generally takes between 50 and 60 days.

**Population Status**

The olive ridley is considered the most abundant sea turtle in the world, with an estimated 800,000 females nesting annually. However, there has been an estimated 50 percent reduction in population since the 1960s (Marine Turtle Specialist Group 2004 in NMFS 2007c). The eastern Pacific population that nests in El Salvador, Guatemala, Costa Rica, and Panama has declined since the 1970s. However, since Mexico banned harvest of nesting females and eggs, the nesting population at La Escobilla, Oaxaca, Mexico increased from 50,000 nests in 1988 to >1 million nests in 2000 (FWS, 2013h). At-sea estimates of density and abundance of olive ridley turtles were conducted along the Mexico and Central American coasts from 1992 to 2006. the yearly weighted average was 1.39 million in the eastern Pacific and consistent with increased nesting during prior to 2007 (NMFS and FWS, 2007b).

**Critical Habitat**

Critical habitat has not been designated for this species.

### 4.4.3.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to olive ridley turtles is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head, the same as described above for green sea turtles and blue whales (see figure 4.2-1).

**Species Presence**

At-sea occurrences in waters under U.S. jurisdiction are limited to the West Coast of the continental United States and Hawaii, where the species is rare, but possibly increasing. This species does not nest in the United States, but during feeding migrations, olive ridley turtles nesting in the East Pacific may disperse into waters off the Pacific west coast as far north as Oregon (FWS, 2013h). Olive ridleys have occasionally been killed by gill-nets and boat impacts as well as cold-stunning (or cold-stranding due to hypothermia by rapid decline of water temperatures) in Oregon and Washington (NMFS and FWS, 1998c). Based on sightings off the Oregon coast, olive ridley turtles may occasionally occur in the EEZ analysis area.

**Habitat**

Little is known about the abundance and distribution of olive ridley turtles in the northeastern Pacific. The olive ridley sea turtle strayed into Washington State waters on just a single documented occasion; the species is unlikely to occur along the Washington coast since ocean surface temperatures are apparently too low (Richardson, 1997). Important foraging grounds have not been identified although forage areas most likely exist along the coast of Baja California and Southern California (NMFS and FWS, 1998c). Less is known about the potential importance of Oregon waters and the EEZ analysis area to olive ridley turtles.

**Critical Habitat**

Critical habitat has not been designated for this species.

### 4.4.3.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Direct effects of the proposed action include injury and/or mortality due to ship strikes, underwater ship noise, and potential adverse effects from an accidental ship release of LNG and at sea. Spills and/or released LNG could indirectly affect olive ridley turtles by impacting forage species. These effects are addressed below.

Ship Strikes by LNG Carriers

The proposed action would result in increased shipping traffic and may increase potential vessel strikes to olive ridley turtles within the analysis area. Boat collisions are listed as a moderate problem for olive ridley turtle recovery off the U.S. West Coast (NMFS and FWS, 1998c). Sea turtles can be injured or killed when struck by a boat, especially by an engaged propeller. Risk of collision with sea turtles increases within increased vessel speed (Hazel et al., 2007), as discussed for green sea turtles, above. However, methods for reducing boat collisions are not included in recovery objectives, and based on their warm water requirements, olive ridley sea turtles are likely only occasional visitors to waters as far north as Oregon.

The proposed action is expected to increase traffic by 180 additional ship transits through the EEZ analysis area each year of operation. Given the low population and occurrence of the olive ridley turtles in Oregon coastal waters and current estimate of vessel traffic, the addition of 180 LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to leatherback turtles. However, lack of ship-strike incidences to sea turtles in general or frequencies of collision precludes any estimate of effects to leatherback turtles of additional vessel traffic due to LNG carriers. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because olive ridley turtles are more common in California waters. LNG carrier are expected to transit ≥ 50 nmi off the coast and so would be expected to avoid most frequented areas on the continental slope.

Underwater Noise

Loggerhead sea turtles can detect sound and their hearing is most sensitive to lower frequencies below 1000 Hz (Bartol et al., 1999; Martin et al., 2012), within the same range of low frequencies generated by ships and sounds generated by large baleen whales (Würsig and Richardson, 2009). The same is assumed to be the case for olive ridley turtles. However, studies have focused on sea turtle response to seismic operations (McCauley et al., 2000; Holst et al., 2006); turtles were observed to move away from the operations. Responses to ship noise have not been reported. Loggerhead and green turtles hear and respond to low frequency sound from seismic operations (increased swimming speed, increased activity, change in swimming direction, and avoidance) but their hearing threshold appears to be high. Based on available information, it is considered unlikely that sea turtles are more sensitive to seismic operations than cetaceans or some fish (Department of Fisheries and Oceans Canada, 2004).

The proposed action is expected to increase traffic by 180 additional ship transits through the EEZ analysis area each year of operation. Given the low population and occurrence of the green turtles in Oregon coastal waters and current estimate of vessel traffic, the addition of 180 LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to olive ridley turtles. However, lack of ship-strike incidences to sea turtles in general or frequencies of collision preclude any estimate of effects to green turtles of additional vessel traffic due to LNG carriers. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because reports of strandings in California are more frequent. LNG carriers are expected to transit at least 50 nmi off the coast and so would be expected to avoid nearshore feeding areas used by olive ridley turtles.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a sea turtle surfaced to breathe at the LNG pool location, oxygen deficiency would occur with potential physiological effects, described for humans (ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations, see Table 39 in Hightower et al., 2004) but not for sea turtles. Because the estimated densities of olive ridley turtles are believed to be low within the West Coast EEZ analysis area, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing olive ridley turtles within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of olive ridley turtles in the West Coast EEZ analysis area during 2018 are expected to be so low that the chance of an olive ridley turtle surfacing in an area of pooled LNG or close enough to a fire to be injured is insignificant and discountable.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whale). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2 (under blue whale). Consequently, cumulative effects to olive ridley turtles would likely be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-3) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the prediticions. Cumulative effects of 90 LNG carriers per year to olive ridley turtles may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

No critical habitat would be affected by the proposed action; none has been designated.

#### 4.4.3.4 Conservation Measures

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of cetaceans are observed near an underway ship would provide some protection to olive ridley turtles. However, it is highly unlikely that olive ridleys or other sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (blue whale) apply to olive ridley turtles.

#### 4.4.3.5 Determination of Effects

**Species Effects**

The Project **may affect** olive ridley turtles because:

- Olive ridley turtles may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** olive ridley turtles because:

- Whether or not olive ridley turtles have been struck by ships is unknown but is expected to be highly unlikely.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase for potential ship strikes to olive ridley turtles.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals, which should also benefit sea turtles.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on olive ridley turtles could exceed NMFS

interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.

- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected olive ridley turtle presence (based on assumed low densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to olive ridley turtles if they emerged during a fire. .

### 4.4.4 Loggerhead Turtle

#### 4.4.4.1 Species Account and Critical Habitat

**Status**

Loggerhead turtles were listed as threatened under the ESA in 1978 (FWS, 1978). In 2007, NMFS and FWS completed a 5-year review in which the agencies determined that populations might be separated by ocean basins but more information was needed before applying distinct population segments (DPS) to the species under ESA while retaining its threatened status. Also in 2007, NMFS and FWS were petitiond to classify loggerhead turtles in the North Pacific as a DPS with endangered status with designated critical habitat. In Novermber 2007, NMFS and FWS released a notice of petition finding to list the loggerhead turtle population in the Pacific to be a DPS with endangered status. The finding stated that the petitioned action “may be warranted” (Conant et al., 2009). In 2011, NMFs (2011d) published a final rule in which the agencies determine loggerhead sea turtles are componsed of nine DPSs distributed worldwide; four DPSs are listed as threatened and five are listed as endangered. The North Pacific Ocean DPS is listed as endangered (NMFS, 2011d).

**Threats**

Direct threats to the loggerhead turtle include harvesting. There is no information about direct take of the loggerhead turtle, although is it assumed to be nonexistent in the Pacific Coast because of its rarity. Reasons for listing the loggerhead turtle include direct harvest in the Bahamas, Cuba, and Mexico as well as incidental capture of turtles in commercial fishing gear (NMFS, 2013b).

Two primary threats to loggerhead turtles include natural disasters and incidental take from commercial fishing operations (NMFS and FWS, 1998d). Minor threats to loggerhead turtles on the U.S. West Coast include natural disasters, environmental contaminants, debris entanglement and ingestion, and power plant entrapment (NMFS and FWS, 1998d). Threats (the degree of which are unknown) include predation, boat collision, and oil exploration and development (NMFS and FWS, 1998d). Dredging is listed as another important potential threat to loggerhead turtles, as they spend much of their time in continental shelf waters closer to shoreline looking for food (Plotkin, 1995).

**Species Recovery**

A recovery plan was issued on May 22, 1998 (NMFS and FWS, 1998d). The recovery goal is to delist the species, and the plan listed the following necessary actions:

- Reduce incidental capture of loggerheads by coastal and high seas commercial fishing operations.

- Establish bilateral agreements with Japan and Mexico to support their efforts to census and monitor loggerhead populations and to minimize impacts of coastal development and fisheries on loggerhead stocks.
- Identify stock home ranges using DNA analysis.
- Determine population size and status (in U.S. jurisdiction) through regular aerial or on-water surveys.
- Identify and protect primary foraging areas for the species.

The stepdown outline in the recovery plan included the following recommendations:

- Protect and manage turtles on nesting beaches.
- Protect and manage nesting habitat.
- Protect and manage loggerhead populations in the marine habitat.
- Protect and manage marine habitat, including foraging habitats.
- Develop standards for the care and maintenance of sea turtles, including diet, water quality, tank size, and treatment of injury and disease.
- Establish a catalog of all captive sea turtles to enhance use for research and education.
- Designate rehabilitation facilities.
- Support existing international agreements and conventions to ensure that turtles in all life-stages are protected in foreign waters.
- Encourage ratification of CITES for all non-member Pacific countries, compliance with CITES requirements, and removal of sea turtle trade reservations held by member nations.
- Develop new international agreements to ensure that turtles in all life-stages are protected in foreign waters.
- Develop or continue to support informational displays in airports and other ports of call that provide connecting legs for travelers to the area.

**Life History, Habitat Requirements, and Distribution**

Loggerhead turtles occur throughout temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans. They are the most abundant sea turtle found in U.S. coastal waters, although they are much more prevalent on the Atlantic than Pacific Coasts, with major nesting areas being present in Florida. In the North Pacific, loggerhead nesting has only been documented in Japan but may also occur on beaches of the South China Sea (NMFS, 2011d). Turtles hatching on Japanese beaches enter the Kuroshio and North Pacific Currents and develop during migration; some reach the eastern Pacific and Baja California. Foraging areas have been documented off the coast of Baja California, Mexico (NMFS, 2011d). Evidence indicates that loggerhead turtles hatching in Japan remain in the North Pacific Basin for their entire life cycle, never crossing the equator into the South Pacific Basin (NMFS, 2011d).

Loggerheads reach sexual maturity at around 35 years of age. In the southeastern United States, mating occurs in late March to early June and females lay eggs between late April and early September. Females generally lay three to five nests per season. The eggs incubate approximately 2 months before hatching between late June and mid-November. Hatchlings move from their nest to the surf, swim and are swept through the surf zone, and continue swimming away from land for about one to several days. Post-hatchlings within this habitat are float-and-wait foragers feeding on a wide variety of floating food items. From these relatively nearshore habitats, juvenile turtles are swept into the open ocean by currents. Between the ages of seven and 12 years, oceanic juveniles migrate to nearshore coastal areas where they remain until reaching adulthood.

**Population Status**

In the United States, loggerhead turtles lay an estimated 68,000 to 90,000 eggs per year. There is no known nesting of loggerhead turtles on the U.S. Pacific Coast. Occasional cold-strandings occur in Washington and Oregon and incidental take by fisheries probably occurs (NMFS and FWS 1998d). In the eastern Pacific, loggerheads have been reported as far north as Alaska. In the U.S., occasional sightings are reported from the coasts of Washington and Oregon, but most records are of juveniles off the coast of California. The west coast of Mexico, including the Baja Peninsula, provides critically important developmental habitats for juvenile loggerheads. Records of females in the North Pacific Oceans DPS nesting on Japanese beaches indicate numbers increased from the late 1990s through 2005 but declined in 2006 and 2007 (Conant et al., 2009).

**Critical Habitat**

Critical habitat has not been designated for this species.

#### 4.4.4.2 Environmental Baseline

**Analysis Area**

The analysis area applicable to loggerhead turtles is the EEZ, extending 200 nautical miles offshore from the Coos Bay Head, the same as described above for green turtles and blue whales (see figure 4.2-1).

**Species Presence**

Loggerhead turtles sighted in U.S. Pacific Coast waters likely originate on Japanese nesting grounds (NMFS and FWS, 1998d). In the United States, occasional sightings are reported from the coasts of Washington and Oregon, but most records are of juveniles off the coast of California. Therefore, based on sightings and documented strandings, loggerhead turtles are likely at visitors to the EEZ analysis area, at least occasionally. The California/Oregon (CA/OR) drift gillnet fishery (for swordfish and thresher shark) was observed to incidentally capture 17 loggerheads (12 released alive, one injured, and four killed) from 1990 to 2000. Based on a worst-case scenario, NMFS estimated that a maximum of 33 loggerheads in a given year could be incidentally taken by the CA/OR drift gillnet fleet (Conant et al., 2009).

**Habitat**

The fact that juveniles are captured incidentally in longlines and driftnets in the pelagic Pacific indicates that the species’ range includes coastal and pelagic waters (NMFS and FWS, 1998d). The potential importance of Oregon waters and the EEZ analysis area to loggerhead turtles is unknown. Loggerheads are likely to move into the U.S. Pacific coast from Baja California as they follow preferred prey species, the pelagic red crab (Conant et al., 2009).

**Critical Habitat**

Critical habitat has not been established for this species.

### 4.4.4.3 Effects by the Proposed Action

### Direct and Indirect Effects

Direct effects of the proposed action include injury and/or mortality due to ship strikes, underwater ship noise, and potential adverse effects from an accidental ship release of LNG and fire at sea. Spills and/or released LNG could indirectly affect loggerhead turtles by impacting forage species. These effects are addressed, below.

Ship Strikes by LNG Carriers

The proposed action would result in increased shipping traffic and may increase potential vessel strikes to loggerhead sea turtles within the analysis area. However, the largest threat to loggerhead turtles outside of their nesting grounds is entanglement in gill-nets and other incidental take. Boat collisions are not listed as a current threat to the recovery of loggerhead populations (NMFS and FWS, 1998d). However, risk of collision with sea turtles increases within increased vessel speed (Hazel et al., 2007), as discussed for green sea turtles, above.

The proposed action is expected to increase traffic by 180 additional ship transits through the EEZ analysis area each year of operation. Given the low population and occurrence of the loggerhead turtles in Oregon coastal waters and current estimate of vessel traffic, the addition of 180 LNG carrier transits through the EEZ analysis area is not expected to result in measurable additional ship strike-related mortality or injury to leatherback turtles. However, lack of ship-strike incidences to sea turtles in general or frequencies of collision precludes any estimate of effects to leatherback turtles of additional vessel traffic due to LNG carriers. The possibility of ship strikes by LNG carriers paralleling the California coast may be higher because loggerhead turtles are more common in California waters. LNG carrier are expected to transit ≥ 50 nmi off the coast and so would be expected to avoid most frequented areas on the continental slope.

Underwater Noise

Loggerhead sea turtles can detect sound and their hearing is most sensitive to lower frequencies below 1000 Hz (Bartol et al., 1999; Martin et al., 2012), within the same range of low frequencies generated by ships and sounds generated by large baleen whales (Würsig and Richardson, 2009). However, studies have focused on sea turtle response to seismic operations (McCauley et al., 2000; Holst et al., 2006); turtles were observed to move away from the operations. Responses to ship noise have not been reported. Loggerhead and green turtles hear and respond to low frequency sound from seismic operations (increased swimming speed, increased activity, change in swimming direction, and avoidance) but their hearing threshold appears to be high. Based on available information, it is considered unlikely that sea turtles are more sensitive to seismic operations than cetaceans or some fish (Department of Fisheries and Oceans Canada, 2004).

Existing commercial vessels within the West Coast EEZ analysis area produce underwater noise levels that are comparable or exceed noise from the LNG tanker described by Hatch et al. (2008). Noise generated by various types of commercial ships (container ships, crude oil tankers, product tankers, bulk carriers, and others) were recently evaluated by McKenna et al. (2012). Underwater noise levels varied by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age (older vessels tended to be louder than newer vessels). With the existing levels of background shipping noise and the expected increase in shipping traffic by 2018, effects by project LNG tanker-related noise on loggerhead sea turtles are possible in the West Coast EEZ analysis area but the noise would be commensurate with existing noise levels and would not be expected to cause injury.

Releases and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface; methane is an asphyxiant but with low toxicity, at least to humans (Hightower et al., 2004). If a sea turtle surfaced to breathe at the LNG pool location, oxygen deficiency would occur with potential physiological effects, described for humans (ranging from impaired thinking to loss of consciousness with decreasing oxygen concentrations, see Table 39 in Hightower et al., 2004) but not for sea turtles. Because the estimated densities of loggerhead sea turtles are believed to be low within the West Coast EEZ analysis area, the chance of an animal becoming asphyxiated by contact with a pool of LNG would extremely remote (see discussion about potential thermal injury, below).

Sandia National Laboratories modeled LNG spills from a standard LNG vessel (with capacity of 125,000 to 140,000 $m^3$) over water and potential injury to humans due to ignition of the fuel (Hightower et al., 2004). Thermal effects from a fire would vary, depending on the size of the LNG pool released. If one LNG tank is accidentally breached, due to collision with another ship, grounding, or ramming, the potential spill of LNG could form a pool with diameter of 685 feet. Ignition could cause a fire to burn for 20 minutes with severe thermal injuries extending to 820 feet away from the center of the pool (based on an exposure of 10 minutes and thermal flux of 37.5 $kW/m^2$) and second-degree skin burns on exposed skin (human) to a distance of 2,572 feet (based on an exposure of 10 minutes and thermal flux of 5 $kW/m^2$) from the center of the burning pool of LNG (see Table 41 in Hightower et al., 2004). Surfacing loggerhead turtles within those distances would be assumed to experience severe burns or mild burns, based on similar thermal fluxes effects on humans although exposures for 10 minutes or more would be unlikely.

Expected densities of loggerhead turtles in the West Coast EEZ analysis area during 2018 are expected to be so low that the chance of a turtle surfacing in an area of pooled LNG or close enough to a fire to be injured is insignificant and discountable.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4 under blue whale). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue into the foreseeable future.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated dry bulk vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay which would have exceeded 90 vessels per year in 1992 given the current trend in figure 4.2-2 (under blue whale). Consequently, cumulative effects to loggerhead turtles would likely be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to loggerhead turtles may be more or may be less than the estimate of direct effects discussed above.

**Critical Habitat**

No critical habitat would be affected by the proposed action; none has been designated.

#### 4.4.4.4 Conservation Measures

Measures to reduce ship speeds once inside the Coos Bay navigation channel to between 4 to 6 knots and within the EEZ when pods or large assemblages of cetaceans are observed near an underway ship would provide some protection to loggerhead turtles. However, it is highly unlikely that loggerheads or other sea turtles would be seen from a LNG carrier. Nevertheless, the same Ship-Strike Reduction Plan, including marine mammal avoidance guidelines and LNG Management Plan to minimize risk of spills and releases at sea that were described in Section 4.2.1.4 (blue whale) apply to loggerhead turtles.

#### 4.4.4.5 Determination of Effects

**Species Effects**

The Project **may affect** loggerhead turtles because:

- Loggerhead turtles may occur within the EEZ analysis area during operation of the proposed action.
- The proposed action would increase shipping traffic (LNG carriers) within the EEZ analysis area.

However, the Project is **not likely to adversely affect** loggerhead turtles because:

- Whether or not loggerhead turtles have been struck by ships is unknown but is expected to be highly unlikely.
- The increase in annual ship traffic due to the proposed action is expected to cause an immeasurable increase for potential ship strikes to loggerhead turtles.
- Jordan Cove would provide a ship strike avoidance measures package to shippers delivering LNG cargo to the LNG terminal. The package consists of multiple measures to avoid striking marine mammals, which should also benefit sea turtles.
- LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port.
- Noise produced by LNG carriers would contribute to overall noise within the EEZ en route to the Port of Coos Bay and effects of ship noise on loggerhead turtles could exceed NMFS interim noise exposure criteria for Level B single non-pulse noise but would not exceed existing background ship noise levels and would not cause injury.
- Accidental releases of LNG at sea would not cover an area large enough to coincide with expected loggerhead turtle presence (based on assumed low densities). Ignited LNG would not extend far enough from the LNG pool to cause severe or mild thermal effects to loggerhead turtles if they emerged during a fire.

**Critical Habitat Effects**

No critical habitat has been designated or proposed for the loggerhead turtle.

### 4.4.5 Oregon Spotted Frog

#### 4.4.5.1 Species Account and Critical Habitat

**Status**

The Oregon spotted frog (*Rana pretiosa*) was proposed for listing as threatened under the ESA in August 2013 (FWS, 2013e). The species had been petitioned for listing in May 2004 with a positive (warranted but precluded) 90-day finding issued in 2005 and had been a candidate species since then with Listing Priority of 2 (imminent with high magnitude of threat, see FWS, 2011d).

**Threats**

Oregon spotted frogs may be extirpated from as much as 90 percent of their historically documented range including all historical locations in California (FWS, 2013e). The species' wetland habitats have been lost from 30 to 85 percent across its range. Sources of loss include draining wetlands, water diversions, conversion of wetlands to agriculture and livestock grazing, developments adjacent to occupied habitats that alter seasonal hydrology (through creation of impervious surfaces), and occurrence of droughts which have become more frequent in parts of the species' range. Also, riverine functions that promote early successional wetland habitats have been altered including connectivity with floodplains. Beaver activities had contributed to historical mosaic of aquatic habitats and fires burning in summer influenced shallow water breeding habitats the following spring (FWS, 2013a). Introductions of exotic species, including reed canarygrass that degrades native wetland vegetation and nonnative predators including bullfrogs and warm water fish species have been and continue to threaten the species. Chytrid fungus infections have been documented Oregon spotted frog population in all of the sites sampled, including five sites located in the Klamath Basin (Pearl et al., 2009). Declines in various amphibian populations have been associated with fungal infections and may have contributed to the demise of Oregon spotted frog populations although some populations appear to be resistant (Padgett-Flohr and Hayes, 2011). There may be additional pathogens that affect Oregon spotted frogs (FWS, 2013a).

**Species Recovery**

The species has been proposed for listing and no recovery plan has been published. A Conservation Agreement to conserve Oregon spotted frogs in the Klamath Basin has been developed by the FWS, Forest Service, BLM (FWS et al., 2010) with the objectives to:

> "1) manage occupied habitat in a manner that sustains and/or restores its ability to support Oregon spotted frog populations; 2) stabilize or increase populations within the Klamath Basin; 3) reduce threats; and 4) increase distribution among available suitable habitats by restoring or creating habitat."

Implementing the conservation agreement has focused on bullfrog eradication program on Crane Creek since bullfrogs appeared in 2010 and controlling and reducing bullfrogs and analyzing the gut contents of bullfrogs at all life stages on BLM lands at Wood River. While the number of bullfrogs removed and seen at that site has decreased, bullfrog removal has also focused on areas outside the Oregon spotted frog. Despite these efforts, bullfrogs continue to persist in these Oregon spotted frog habitats in the Klamath Basin (FWS, 2013e).

**Life History, Habitat Requirements, and Distribution**

The current range of Oregon spotted frogs extends from the Fraser River sub-basin in southern British Columbia (Haycock, 2000) and adjacent areas in Whatcom County, Washington, south through the Puget Trough lowlands, through the Willamette Valley, southeast Oregon including Jackson and Klamath counties, and adjacent areas in the Pit River sub-basin of northern California (FWS, 2011d).

Spotted frogs inhabit perennial water bodies such as springs, ponds, lakes or slow moving streams and are usually associated with nonwoody, herbaceous wetland vegetation communities composed of sedges, rushes and grasses (Leonard et al., 1993). Several aspects of the Oregon spotted frog's life history have been proposed as contributing to the species' vulnerability to habitat alterations (FWS, 2011d): 1) communal egg laying at sites used year after year restricts the number of reproductive sites; 2) the species' warm water requirement results in habitat overlap with introduced warm water fish; 3) the active season warm water requirement may limit suitable habitat in the cool climates of the Pacific Northwest; 4) the species may be vulnerable to the potential loss or alteration of springs used for overwintering; and 5) changes that increase deep, permanent water components are likely to favor establishment of non-native bullfrogs and fish, both of which may be detrimental to Oregon spotted frogs.

In lower elevations of eastern and western Washington and Oregon, breeding occurs during February and March; at higher elevation breeding occurs in late May or early June (Leonard et al., 1993). Oregon spotted frogs typically oviposit communally; males may gather in large groups at a location and females lay eggs adjacent to or attached to other egg masses which are only partially submerged. These aggregations can contain eggs from 100 or more females in larger populations (FWS, 2011d). Spotted frog use traditional oviposition sites, year after year. Such sites may have limited availability because of unique characteristics and adults may have limited flexibility to switch sites if they become unsuitable. That possibility makes the Oregon spotted frog particularly vulnerable to habitat changes at oviposition sites (FWS, 2011d).

**Population Status**

Population estimates in most sub-basins inhabited by Oregon spotted frogs are insufficient to derive any trends (FWS, 2013e). The best available information indicates an undetermined population trend in Oregon but trends from the lower Fraser River in British Columbia and Middle Klickitat sub-basin in Washington indicate declining populations (FWS, 2013e).

There are 39 populations of Oregon spotted frog locations (sites) known, excluding those in British Columbia, with eight in Washington and 31 in Oregon (FWS, 2011d). Oregon spotted frogs have not been documented in recent surveys in California. In Oregon the species' extant distribution includes 23 sites in the Central Oregon Cascades (with the largest population of 500 to 2,500 breeding females at two sites) and nine sites in the Klamath Basin (FWS, 2011d). In 2005, personnel with the Forest Service surveyed 28 different sites in Lake, Klamath, and Jackson counties but no new Oregon spotted frogs were found. Data from the Klamath Basin data suggests that one population has declined since 2000, two populations appear stable, and five sites do not have enough data to determine trend, including the Buck Lake site. The Buck Lake site is isolated from all other Oregon spotted frog populations with little or no chance for genetic interchange or re-colonization; there is no hydrologic connectivity to other occupied habitats in the Klamath Basin (FWS, 2011d).

**Critical Habitat**

Critical habitat for the Oregon spotted frog was proposed in August 2013 (FWS, 2013f) at the same time that the species was proposed for listing as threatened under the ESA. The proposal includes critical habitat in Washington (Units 1 through 6) and in Oregon (Units 7 through 14). The Buck Lake site is within proposed critical habitat Unit 14: Upper Klamath, Oregon.

FWS (2013f) determine that the primary constituent elements specific to the Oregon spotted frog are:

1. Primary constituent element 1 (applicable to the following seasonal life stage periods - Nonbreeding (N), Breeding (B), Rearing (R), and Overwintering Habitat (O)) is <u>ephemeral or permanent bodies of freshwater</u>, including, but not limited to natural or manmade ponds, springs, lakes, slow-moving streams, or pools within or oxbows adjacent to streams, canals, and ditches, that have one or more of the following characteristics:
    - Inundated for a minimum of 4 months per year (B, R) (timing varies by elevation but may begin as early as February and last as long as September);
    - Inundated from October through March (O);
    - If ephemeral, areas are hydrologically connected by surface water flow to a permanent water body (e.g., pools, springs, ponds, lakes, streams, canals, or ditches) (B, R);
    - Shallow water areas (less than or equal to 30 centimeters (12 inches), or water of this depth over vegetation in deeper water (B, R);
    - Total surface area with less than 50 percent vegetative cover (N);
    - Gradual topographic gradient (less than 3 percent slope) from shallow water toward deeper, permanent water (B, R);

- Herbaceous wetland vegetation (i.e.,emergent, submergent, and floating leaved aquatic plants), or vegetation that can structurally mimic emergent wetland vegetation through manipulation (B, R);
- Shallow water areas with high solar exposure or low (short) canopy cover (B, R);
- An absence or low density of nonnative predators (B, R, N).

2. Primary constituent element 2 is aquatic movement corridors. Ephemeral or permanent bodies of fresh water that have one or more of the following characteristics:
    - Less than or equal to 5 kilometers (3.1 miles) linear distance from breeding areas;
    - Impediment free (including, but not limited to, hard barriers such as dams, biological barriers such as abundant predators, or lack of refugia from predators).
3. Primary constituent element 3 is refugia habitat. Nonbreeding, breeding, rearing, or overwintering habitat or aquatic movement corridors with habitat characteristics (e.g., dense vegetation and/or an abundance of woody debris) that provide refugia from predators (e.g., nonnative fish or bullfrogs).

#### 4.4.5.2 Environmental Baseline

**Analysis Area**

Similar to listed fish species, the analysis area for Oregon spotted frogs is the Spencer Creek riverine analysis area associated with Spencer Creek and Buck Lake which includes the water column and substrate of Spencer Creek to the extent downstream where water quality is adversely affected by turbidity generated during construction and sediment generated by runoff from the construction right-of-way. The associated riparian zone of Spencer Creek is included in the analysis area over the short-term during construction and in the long-term by operation.

Construction across Spencer Creek is expected to mobilize silt, assumed to be the predominant substrate particle at the crossing location. As discussed below, the downstream distance that silt particles would be expected to settle out of the water column during dam-and-pump construction is estimated to be 1,450 feet (based on assumptions and estimation procedures below). Consequently, the Spencer Creek riverine analysis area would extend 1,450 feet downstream from the point of pipeline construction, shown in figure 4.4-1.

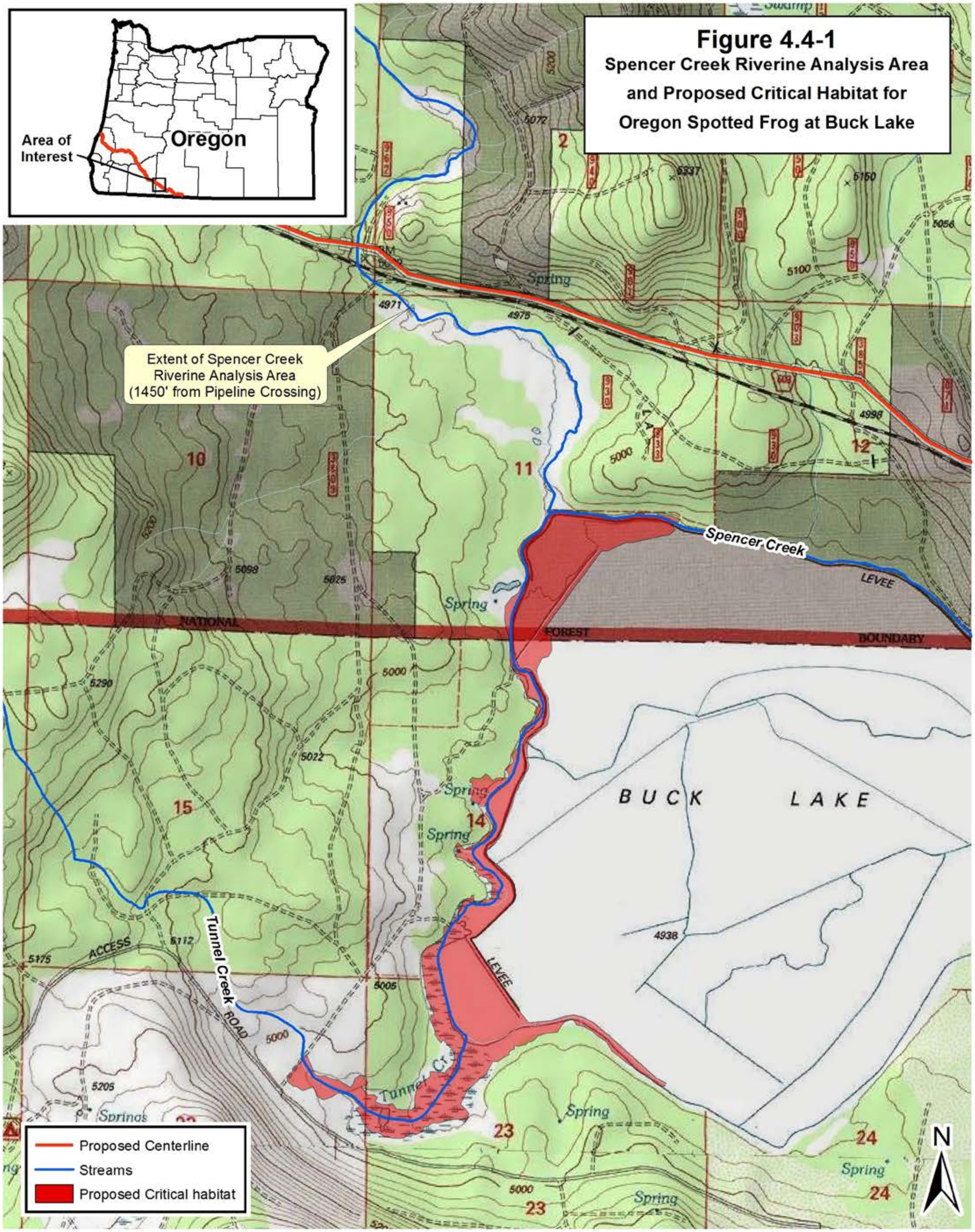


Figure 4.4-1
Spencer Creek Riverine Analysis Area
and Proposed Critical Habitat for
Oregon Spotted Frog at Buck Lake
Area of Interest
Oregon
Extent of Spencer Creek
Riverine Analysis Area
(1450' from Pipeline Crossing)
Spencer Creek
LEVEE
NATIONAL
FOREST
BOUNDARY
BUCK LAKE
Spring
Tunnel Creek
ACCESS
ROAD
Tunnel Cr
Proposed Centerline
Streams
Proposed Critical habitat
N

**Species Presence**

Oregon spotted frogs inhabit Buck Lake. Spotted frogs were first documented in 1994 at Buck Lake in the Winema National Forest and adjacent private lands in a canal on the northwest edge of Buck Lake and on BLM lands within Tunnel Creek (USFS and BLM, 1995), inhabiting the channelized portion of the perennial stream that enters the Buck Lake basin from the southwest. These are the only sites in the Spencer Creek watershed likely to be inhabited by Oregon spotted frogs (USFS and BLM, 1995).

A mark-recapture study to assess the Oregon spotted frog population in Buck Lake was conducted between 1995 and 1997 by Marc Hayes. The study results provided a population estimate of about 519 adults (with a range of 0 to 1,499, derived from 95 percent confidence intervals) (Lerum, 2012). Demographic information from this study showed limited evidence of recruitment likely attributable to the presence of resident brook trout (FWS, 2011d). Observations of adult Oregon spotted frogs made between 1994 and 2001 ranged from 25 to 176, no adult frog were observed in 2005 or 2009 (FWS, 2011d; see figure 4.4-2). Since Hayes' study, various USFS, BLM, USFWS, and USGS personnel have sporadically resurveyed this population documenting continued presence through 2011 (Lerum, 2012). Since 2006, egg mass surveys have been conducted in addition to searches for adult frogs. Results are included in figure 4.4-2 and range from 6 egg masses in 2011 to 38 egg masses counted in 2010. However, the locations and search efforts varied from year to year, making inferences about trends based on egg masses counted inappropriate (Lerum, 2012).

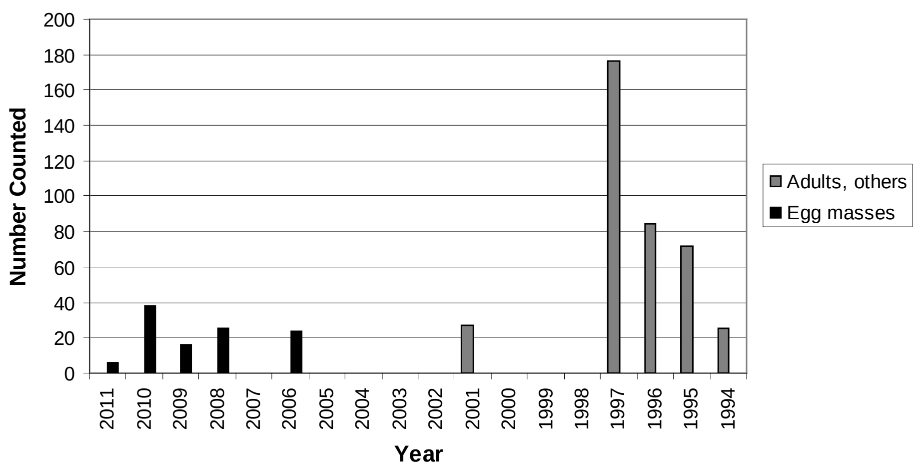



**Figure 4.4-2**
**Observations of Oregon Spotted Frog Adults (including juveniles and metamorphs) and Egg Masses at Buck Lake (Sources: FWS, 2011; Lerum, 2012)**

**Habitat**

Historically, Buck Lake was likely a large shallow marsh fed by springs and streams. Two perennial streams, Spencer Creek and Tunnel Creek, flow into Buck Lake but the basin is currently a meadow with drainage ditches, and at least two impounded areas fed by springs (Lerum, 2012). ORBIC (2012) has mapped Oregon spotted frog habitat at Buck Lake to include Spencer Creek from its inflow at the lake to approximately 6,100 feet upstream to where Spencer Creek passes through a culvert beneath Clover Creek Road. That segment of Spencer Creek is almost equally subdivided into Buck Marsh, closest to the highway, and Buck Meadow, closest to Buck Lake (Lerum, 2012). Spencer Creek flows through Buck Marsh and Buck Meadow on US Forest Service lands; Buck Marsh is fed by several springs with evidence of beaver activities and Buck Meadow is a pasture that often floods in the spring but does not stay flooded long enough to provide spotted frog breeding habitat. Further, soils are dense, possibly compacted by past heavy livestock use, provide little water infiltration and riparian vegetation is sparse and likely would not support beaver occupancy (Lerum, 2012). Neither Buck Marsh nor Buck Meadow currently provides habitat for Oregon spotted frogs (Lerum, 2012).

Some winters Spencer Creek freezes and flows cease. It is unknown if the site could provide overwintering habitat. It is not known exactly where Oregon spotted frogs in the Buck Lake complex overwinter. Underwater video cameras installed in 2010 and 2011 did not detect Oregon spotted frogs at suspected overwintering sites until March when frogs began to move to breeding sites (Lerum, 2012).

Lerum (2012) reported a Level II stream survey of Spencer Creek flowing through Buck Marsh and Buck Meadow conducted by the Forest Service on June 28, 2010 (USFS, 2011 cited in Lerum, 2012). Spencer Creek characteristics in this area (Reach 5) were summarized as: “Reach 5 was determined to be a Rosgen E6 stream channel type due to its gradient and silt dominated substrate. A large portion (3500’) of reach 5 was determined to be a marsh. The average wetted width (Rosgen E channel only) is 6.4 feet. The reach averages 19 pools per mile with residual pool depth of 1.2 feet. Stream banks are 98% stable and 2% unstable with sections of unstable bank along both sides of the stream. The reach had 6 pieces of LWD per mile (0 large/medium and 6 small pieces per size class). The stream side vegetation was dominated by grass forbs with an overstory of grass forbs. There are some isolated pockets of lodgepole pine. The stream runs through a very large valley dominated by marshland. A channel begins to take shape at the end of the valley up to the road crossing. There are active beaver dams in the marsh. Unidentified fish were observed throughout the reach.”

Typical Rosgen E6 channels (Wildland Hydrology, 1994):

- are slightly entrenched (entrenchment ratio >2.2);
- have very low width to depth ratios (ratio <12);
- have high sinuosity (>1.5);
- have water surface slope gradients <2 percent;
- channel substrate particles are predominantly silt and clay.

In 2002, lower Spencer Creek was listed by the Oregon Department of Environmental Quality (303(d) List, ODEQ, 2002) as impaired due to sediment based on the formation of appreciable bottom or sludge deposits. However, there are no estimates of ambient turbidity in Spencer Creek (USFS and BLM, 1995) although intense cattle grazing on Buck Lake has contributed to elevated sediment in the creek, probably downstream from Buck Lake. Within the watershed, the principal causes of stream sedimentation are bank erosion and delivery of sediment from roads and stream crossings (BLM, 2008).

There are no long-term discharge data for Spencer Creek. Flows were measured downstream from Buck Lake from 1992 to 1998 during which annual peak flows were from 150 to 200 cfs and summer base flows were 20 cfs, with a minimum of 5 cfs following a dry winter (BLM, 2008c). Peak flows in the middle portion of the Spencer Creek watershed were caused by snowmelt and rain-on-snow events.

### Critical Habitat

Proposed critical habitat Unit 14 includes seasonally wetted areas adjacent to the western edge of Buck Lake encompassing Spencer Creek, three unnamed springs, and Tunnel Creek, shown in figure 4.4-1. Buck Marsh and Buck Meadow are not included in the proposed critical habitat. The proposed critical habitat is approximately 6,400 feet downstream from where the proposed pipeline would cross Spencer Creek. There are 185.7 acres within proposed Unit 14 at Buck Lake, 38.23 acres are managed by the BLM, 0.17 acre is on the Fremont-Winema National Forest, and 147.30 acres are privately owned. Another area, Keene Creek in Jackson County, is also included in Unit 14 but is separated by approximately 14.5 miles from the proposed critical habitat at Buck Lake. According to FWS (2013f, page 53551), "all of the essential physical or biological features are found within the unit, but are impacted by woody vegetation succession, nonnative predators, lack of beaver, and hydrological changes. The essential features within this unit may require special management considerations or protection to ensure maintenance or improvement of the existing nonbreeding, breeding, rearing, and overwintering habitat; aquatic movement corridors, or refugia habitat, and to address any changes that could affect these features."

### 4.4.5.3 Effects by the Proposed Action

### Direct and Indirect Effects

Construction of the PCGP Project could directly and/or indirectly affect Oregon spotted frog and proposed critical habitat through one or more of the following pathways:

- Interference with key life history functions.
- Acoustic shock from blasting pipe trench through bedrock streambeds or use of a track hoe or impact hammer if frogs are proximate to the construction site.
- Turbidity generated during pipeline construction across waterbodies can adversely affect Oregon spotted frogs and aquatic habitats.
- Introduction and/or re-distribution of nonnative aquatic species and pathogens.
- Accidental release of fuels and entry of other petroleum products into surface waters can adversely affect spotted frogs and other aquatic organisms.
- Application of herbicides to control noxious weeds near waterbodies may adversely affect Oregon spotted frogs.

<u>Timing</u>

State guidelines (ODFW, 2008) would allow instream construction across Spencer Creek (a tributary to the Klamath River below Keno) from July 1 through September 30. Construction during that period would avoid any downstream effects to egg masses or spotted frogs during metamorphosis in Buck Lake.

<u>Acoustic Shock</u>

The base material where the pipeline is proposed to cross Spencer Creek is described as igneous rock and locally tuffaceous rock with local valley fill. There is a high potential for blasting to construct the pipeline trench across Spencer Creek if volcanic rocks cannot be excavated to the appropriate depth (GeoEngineers, 2013a). Effects of underwater blasting on frogs is generally unknown although effects on frogs' lungs are expected to be similar to effects on fish with swim bladders, and would cause mortality (Keevin and Hempen, 1997). Effects of underwater blasts on coho salmon are discussed below in Section 4.5.3.3. The analysis in that section identified straight line distances through rock and other materials for a single shot explosive charge, of given weight, to dissipate to an overpressure standard of 2.7 psi, the threshold for non-lethal pressure for anadromous fish, and assumed to be applicable to frogs. Pacific Connector may opt to blast across stream locations where consolidated rock makes traditional trenching methods unfeasible.

Typical trench blasting scenarios use multiple 1- to 2-pound charges separated by an 8-milisecond delay to excavate the trench. With use of 1- to 2-pound charges in rock, the set back distance (at which 2.7 psi would occur) from the blast trench to the aquatic habitat is between 34 and 49 feet (see Table 3, in Alaska Department of Fish and Game, 1991). Blasting would be conducted within dry streambanks isolated from the water column, most likely using dam-and-pump construction to bypass water around the dry workspace. Since no Oregon spotted frogs are expected in the vicinity of the Spencer Creek construction right-of-way, blasting is not expected to affect any animals. Native fish (eg, redband trout) are likely to be present, however. The same mitigation measures and fish salvage measures that have been described for coho salmon would be employed at Spencer Creek.

Suspended Sediment

Suspended sediments (turbidity) directly affect survival and growth of salmonids and other fish species, interferes with gill function, and adversely affects substrate for fish egg development (reviewed and compiled by Newcombe and Jensen, 1996 and Bash et al., 2001). Effects of turbidity on frogs have not been extensively reported. However, sedimentation and turbidity in wetlands accessible to cattle were reported to be 3.5 times greater than in wetlands that were not accessible; cattle increased turbidity by trampling vegetation, disturbing sediment, and defecation. In part due to increased turbidity, the relative abundances for larvae of two frog species were less in the cattle-accessed wetlands (Schmutzer et al., 2008). In another situation, road construction was found to cause sedimentation in previously unaffected streams. When compared to adjacent, unaffected streams, densities of three amphibian species were significantly lower in the streams impacted by sediment (Welsh and Ollivier, 1998). As summarized by Henley et al. (2000), sedimentation can reduce food availability, water and environmental quality, and habitats used by aquatic organisms resulting in decreased plant, zooplankton, and insect abundance and biomass that would affect aquatic food chains and consequently would affect frogs during different life stages.

Although background levels of suspended sediment in Spencer Creek are unknown (USFS and BLM, 1995), construction of the PCGP Project would probably mobilize particles into the water column, primarily silt which is the predominant substrate material in Spencer Creek (see above and Lerum, 2012). The distance downstream that silt particles would be transported can be estimated with the following equation (Trow Equation, see Harper and Trettel, 2002):

$$\mathbf{L = (D\ V_A) / V_S}$$

where **L** is the transported distance downstream (in feet); **D** is the average depth of stream flow (in feet), $\mathbf{V_S}$ is the particle size-specific settling velocity (in inches or feet per second), and $\mathbf{V_A}$ is the average streamflow velocity (in feet per second). The settling velocity ($\mathbf{V_S}$) for medium silt is 0.009 inch per second or 0.00075 feet per second (see the Wentworth Grain Size Chart, USGS, 2003). The average depth of streamflow within Spencer Creek at the time of construction is unknown but, using the average wetted width of 6.4 feet (see above and Lerum, 2012) and a low width to depth ratio of 10 (for Rosgen E6 channels the width to depth ratios are <12), the average depth is estimated to be 0.64 feet (8 inches).

Assuming a rectangular channel cross section, the cross-sectional area is **A** = 4.1 square feet (ft$^2$). The estimated cross-sectional area (**A**) can be used in Manning's Formula (Limerinos, 1970; Arcement and Schneider, 1989) to estimate **Q**, the stream discharge rate (cubic feet per second, or cfs) and ultimately to estimate $\mathbf{V_A}$ , the average streamflow velocity. Manning's Formula is:

$$\mathbf{Q = A\ (\mathit{k}/n)\ (R^{2/3})\ (S^{1/2})}$$

with estimated **A** = 4.1 ft$^2$, **R** is the hydraulic radius (in feet, where **R** = **A/P**, and **P** is the wetted perimeter in feet), **S** is the slope of channel (vertical feet per horizontal feet), the constant ***k*** equals 1.486 if English units are used but ***k*** equals 1 with metric units, and **n** is Manning's roughness coefficient (Manning's **n**).

For Spencer Creek, the wetted perimeter **P** = (2 x 0.64 feet) + 6.4 feet = 7.68 feet so that the hydraulic radius **R** = 0.53 feet, the slope of channel **S** = 0.015 (or 1.5 percent, for Rosgen E6 channels the water surface slope gradient is <2 percent). Manning's **n** was estimated at **n** = 0.070, based on a natural stream channel with sluggish reaches, weedy, and with deep pools (Chow, 1959).

With these parameters estimated, the solution for Manning's Equation is **Q** = 6.98 cfs. With the estimate for **Q**, and **A** = 4.1 ft$^2$, the estimated stream velocity is $\mathbf{V_A}$ = **Q** / **A** = 1.7 feet per second.

Solving the Trow Equation (above) using the following values: **D** = 0.64 feet, $\mathbf{V_S}$ = 0.00075 feet per second, and $\mathbf{V_A}$ = 1.7 feet per second, the estimated distance downstream (**L**) that silt particles would settle out of the water column would be **L** = 1,453 feet from the location where the PCGP project crosses Spencer Creek. That distance will fall within Buck Marsh. Currently, there are no Oregon spotted frogs inhabiting Buck Marsh although the presence of beaver activity and spring flooding could provide suitable breeding habitat (Lerum, 2012). Based on current information however, sediment mobilized during construction is not expected to reach habitats occupied by frogs in Buck Lake.

<u>Introduction of Non-Native Species and Disease</u>

Non-indigenous aquatic species (NAS) are aquatic species that degrade aquatic ecosystem function and benefits, in some cases completely altering aquatic systems by displacing native species, degrading water quality, altering trophic dynamics, and restricting beneficial uses (Hanson and Sytsma, 2001). FWS (2013g) identified warm water non-native fish (bullhead, fathead minnows), and cold water non-native brook trout that had been introduced to Buck Lake, although bullfrogs were absent. Non-native fish may limit numbers of juvenile frogs by predating larvae and/or juveniles. Bullfrogs also may act as direct predators on larval and juvenile frogs but bullfrogs are not known to occur on federal land in the Buck Lake complex (Lerum, 2012). Although unlikely, introduction of bull frogs and/or other warm water predaceous fish species due to the Proposed Action could occur through hydrostatic test water discharge.

Oregon spotted frogs in Buck Lake are infected with the fungal pathogen *Batrachochytrium dendrobatidis* (Bd) which causes chytridiomycosis (Pearl et al., 2009; FWS, 2013c). However, Oregon spotted frogs experimentally infected with the chytrid pathogen were able to clear the infections with no mortality suggesting some resistance to Bd (Padgett-Flohr and Hayes, 2011). The fungus may infect other nonamphibian hosts (eg, crayfish), persisting in freshwater ecosystems that are uninhabited by frogs but infected hosts may transmit the disease to uninfected frogs (McMahon et al., 2013)

The water mold *Saprolegnia* has been suggested as one possible cause of amphibian declines in the Pacific Northwest which destructs developing Oregon spotted frog egg masses (FWS, 2013a). Water-molds of the genus *Saprolegnia* have been identified in Oregon spotted frog populations in the Klamath Basin (Lerum, 2012). Mortality may be caused by parasitic infections by the trematode *Ribeiroia ondatrae* which are transmitted through aquatic snails (genus *Planorbella*), an intermediate host. The infections cause limb malformations in amphibians. Human manipulation of upland areas adjacent to amphibian breeding areas and direct manipulation of the breeding areas can affect the prevalence of *Planorbella* snails and the infection rate of *Ribeiroia ondatrae* (FWS, 2013e). Increased prevalence of trematodes and risks of parasitism to frogs may occur if water runoff from areas of heavy livestock use causes eutrophication, algal blooms, and increased snail abundance of in frog habitats (Johnson et al., 2007). The trematode has not been documented in the Buck Lake frog population (FWS, 2013g).

The risk of introducing *Saprolegnia*, *Ribeiroia ondatrae*, and/or other pathogens into Buck Lake during pipeline construction appears to be low. Pathogens might be brought to the Spencer Creek construction site if attached to machinery or if introduced by hydrostatic water discharged at a test header. The closest hydrostatic discharge location to Spencer Creek (MP 171.06) is 2 miles away at MP 173.10; at that site, 1,041,111 gallons (3.20 acre feet) of test water are proposed to be discharged on the construction right-of-way. Although the discharge site is 2,060 feet away and uphill from Buck Lake, the Clover Creek Road intervenes and would block any flow toward the lake.

Pacific Connector has developed BMPs to avoid the potential spread of the aquatic invasive species and pathogens of concern (see Hydrostatic Testing Plan – appendix U). If determined to be feasible for hydrostatic testing requirements, all water used in hydrostatic testing would be returned to its withdrawal source location after use; however, cascading water from one test section to another to minimize water withdrawal requirements may make it impractical to release water within the same watershed where the water was withdrawn. If it is not possible to return the water to the same water basin from where it was withdrawn, various water treatment methods would be used to disinfect water that would be transferred across water basin boundaries including screening/filtering, chlorine treatment, and discharge to upland sites. After hydrostatic test water withdrawal, all equipment used in the withdrawal process would be cleaned and sanitized to prevent the potential spread of aquatic invasives and pathogens from the use of this equipment in other waterbody sources (see appendix U).

Fuel and Chemical Spills

Oregon spotted frog habitat in the Buck Lake complex could be adversely affected if petroleum products were accidentally discharged into aquatic environments. Such materials are toxic to algae, invertebrates, fish and amphibians. Of the products likely to be present during pipeline construction, data compiled from a wide range of sources indicate that diesel fuels and lubricating oils are considerably more toxic to aquatic organisms than other, more volatile products (gasoline) or heavier crude oil (Markarian et al., 1994). Release of diesel fuel in freshwater habitats significantly reduced aquatic invertebrate densities and species richness at least 3 miles downstream but invertebrate densities recovered within a year (Lytle and

Peckarsky, 2001). Impacts to aquatic habitats that primarily affect aquatic substrates – hence spawning, incubating and rearing habitats – can remain for much longer periods (Markarian et al., 1994).

Construction equipment used to construct the pipeline across waterbodies can potentially release hydraulic fluid that include a variety of compounds those common of which are mineral oil-based, organophosphate esters, and polyalphaolefins (U.S. Department of Health and Human Services, 1997). Release from machinery can occur through faulty seals, hoses, sumps and reservoirs, or general system failure. Components of mineral oil and polyalpaolefins do appear to bioaccumulate in animals whereas larger molecular constituents in organophosphate esters can concentrate in fish, primarily partitioning in fat tissue (U.S. Department of Health and Human Services, 1997). In general, toxicity of organophosphate esters is greater than either mineral oil or polyalphaolefin-based hydraulic fluids for inhalation, oral, and dermal for humans but toxicities have not been clearly described for aquatic invertebrates, fish, or amphibians and would be dependent on specific chemical components (U.S. Department of Health and Human Services, 1997).

Inadvertent spills of fluids used during construction, such as fuels and lubricants, could contaminate wetland soils and vegetation. To minimize the potential for spills and any impacts from such spills, Pacific Connector's Spill Prevention, Containment, and Countermeasures Plan (SPCC Plan – see appendix L) will be implemented. In general, hazardous materials, chemicals, fuels, lubricating oils, and concrete-coating activities will be not be stored, nor will refueling operations be conducted within 150 feet of a wetland or waterbody in accordance with FERC's Wetland and Waterbody Procedures (see appendix C) and the SPCC Plan (see appendix L).

<u>Herbicide Application</u>

Following construction, Pacific Connector will implement a Noxious Weed Control Plan in part through the application of herbicides. Herbicides have the potential to cause toxic effects to different salmonid life stages and to other aquatic species, causing direct impacts, if used improperly. When herbicides are properly used according to label restrictions and BMPs to control noxious weeds, there is little to no chance of causing injury or mortality to fish or other aquatic organisms; the impact may be avoided or indirect.

Pacific Connector has developed an Integrated Pest Management Plan (IPM) in consultation with the Oregon Department of Agriculture, BLM and Forest Service (see Appendix I to the POD, available upon request) to address the control of noxious weeds and invasive plants across the project. The BMPs will minimize the potential spread of invasive species and minimize the potential adverse effects of control treatments.

According to the Pacific Northwest Weed Management Handbook (see Peachey et al., 2007), herbicides used in forests to control brush and weed-trees could include one of the following: 2,4-D, glyphosate, imazapyr, picloram, and ticlopyr which are applied during spring or fall dormancy although triclopyr or 2,4-D was not approved use by the Fremont-Winema National Forest (NF). Clopyralid may be used during summer to control thistles, other composites, and legumes while not damaging conifers. Only herbicides which are approved for use within treated lands (private, state, or federal) would be used. Chronic, long-term, elevated but sublethal toxic effects can lead to skin or eye irritation, headache, nausea, and possibly birth defects, genetic disorders, paralysis, cancer, and death (Tu et al., 2001). In general, most impact to waterbodies occurs from direct overspray or drift of herbicides (aerial applications) as well as leaching through soils into groundwater or as they are carried by surface/subsurface runoff (Tu et al., 2001). The ester form of herbicides is more toxic to fish and other aquatic species than salt or acid forms because esters are readily adsorbed through skin and gills. Esters are also water insoluble so that they are not diluted in waterbodies (Tu et al., 2001).

Herbicides potentially used during the project will breakdown over various periods of time, marked by the average half-life (the time it takes for the herbicide concentration to decline by 50% due to microbial metabolism –dependent on the microbial population, environmental pH, soil moisture and temperature - mineralization, and/or photolysis:

- 2,4-D – averages 10 day half-life in soils, less than 10 days in water. Salt formulations with low toxicity are registered for use against aquatic weeds, Acute exposure of 2,4-D to leopard frog tadpoles reduces their activity and feeding does not appear to be a particularly strong threat to larvae (Ryan et al., 2005).
- Glyphosate - ranges from several weeks to years, but averages two months. In water, glyphosate is rapidly dissipated through adsorption to suspended and bottom sediments, and has a half-life of 12 days to ten weeks. Toxicity of glyphosate-based pesticides to amphibians varies with developmental stage because there is some evidence that some formulations may interfere with metamorphosis (Howe et al., 2004).
- Imazapyr – ranges from 1 to 5 months in soil. In aqueous solutions with photodegradation the half-life may be 2 days. It has low toxicity to fish and algae and other submerged vegetation are not affected. Adverse effects to terrestrial and aquatic animals appear to be unlikely (Durkin and Follansbee, 2004).
- Toxicity of picloram and triclopyr on amphibians is not well understood (Durkin and Follansbee, 2003) although triclopyr applied to amphibian habitats could adversely affect them (Antunes-Kenyon and Kennedy, 2004).

The potential for adverse effects to Oregon spotted frogs and other aquatic species by these herbicides appear to be extremely remote, especially since application would be at least 100 feet from wetlands and waterbodies unless allowed by the appropriate agency. Pacific Connector will not use aerial herbicide applications and will not use herbicides for general brush/tree control within the 30-foot maintained easement. Given low toxicities and short half-lives in soil and water, expected effects of the other herbicides to amphibians would be discountable and insignificant.

Where weed control is necessary along the construction right-of-way, Pacific Connector's first priority will be to employ hand and mechanical methods (pulling, mowing, biological, disking, etc.) applicable to the species to prevent the spread of potential weed infestations, where feasible. To determine if an herbicide is to be used over other control methods, Pacific Connector will base the decision on weed characteristics and integrated weed management principles (Forest Service, 2005). If herbicides are used to control noxious weed infestations, they would be used when they are the most appropriate treatment method. Spot treatments and the use of selective herbicides would be utilized to minimize impact to native or non-target species. Pacific Connector will employ a state or federally-licensed herbicide applicator to ensure that the appropriate herbicides are utilized for the targeted weed species during its proper phenological period and at the specified rate. The applicator will ensure that the herbicides and any adjuvants[1] are used according to the labeling restrictions, and warnings, following all applicable laws and conforming to the appropriate land managing agency decision documents. The applicator will also ensure that the herbicides that are used are registered for their intended use. Permits or approvals for the use of herbicides and adjuvants on federal lands would be obtained prior to use/treatment, as detailed in the IPM (see Appendix I to the POD, available upon request).

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA. One hundred percent of the Spencer Creek riverine analysis area is within the Fremont-Winema National Forest. Consequently, there would be no private actions that would affect the PCGP riverine analysis area in the foreseeable future.

**Critical Habitat**

Proposed critical habitat for the Oregon spotted frog does not coincide with the Spencer Creek riverine analysis area. None of the three primary constituent elements identified for the proposed critical habitat Unit 14 in Buck Lake would be affected downstream from the riverine analysis area.

#### 4.4.5.4 Conservation Measures

Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to waterbodies and riparian zones. Those measures have been compiled in table 2C in appendix N and would apply to Oregon spotted frogs.

#### 4.4.5.5 Determination of Effects

**Listed Species**

The Project **may affect** Oregon spotted frogs because:

- The project will cross Spencer Creek which is hydrologically connected to Buck Lake which is occupied by the frog.

Because Oregon spotted frog are proposed for listing the Project **will not jeopardize the continued existence** of Oregon spotted frogs because:

- Buck Lake is approximately 6,400 feet downstream from where the pipeline would cross Spencer Creek. Suspended sediment generated by the Proposed Action is expected to remain in the water column for 1,450 feet downstream from the construction site. Suspended sediment in Spencer Creek would pass through Buck Marsh but Oregon spotted frogs do not currently inhabit Buck Marsh.
- If the Oregon spotted frogs does occur in Buck Marsh at the time of pipeline construction, conservation measures will limit potential effects due to acoustic shock, introduction of non-native species and/or disease, fuel and chemical spills, and

[1] Adjuvant(s) are substances added to the pesticide formulation to enhance the toxicity of the active ingredient or to make the active ingredient easier to handle.

herbicides. Future presence of Oregon spotted frogs in the Spencer Creek riverine analysis area at the time of construction is extremely unlikely, considered to be discountable.

**Critical Habitat**

Because critical habitat has been proposed for the Oregon spotted frog, the Project will **not adversely modify** the proposed critical habitat for Oregon spotted frogs in Unit 14.

## 4.5 FISH

### 4.5.1 North American Green Sturgeon (Southern Distinct Population Segment)

#### 4.5.1.1 Species Account and Critical Habitat

**Status**

On January 29, 2003 (NMFS, 2003), NMFS determined that the North American Green Sturgeon is comprised of two DPS's that qualify as species under the ESA: 1) a northern DPS consisting of populations in coastal watersheds northward of and including the Eel River in California; and 2) a southern DPS consisting of coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River. At that time however, neither DPS was listed because of the uncertainty about the population structure and status.

In April 2006, NMFS listed the Southern DPS as threatened under ESA within California, including spawning population of green sturgeon south of the Eel River, principally the Sacramento River green sturgeon spawning population (NMFS, 2006f). The Pacific Northern DPS, which includes coastal spawning populations from the Eel River north to the Klamath and Rogue Rivers, remains unlisted but is a Species of Concern (NMFS, 2007d).

**Threats**

The southern DPS was proposed for listing as threatened in 2005 (NMFS, 2005b) because 1) the majority of spawning adults were concentrated in one spawning river (Sacramento River), 2) threats since the first status review (see NMFS, 2002) have not been adequately addressed, 3) new evidence of loss of spawning habitat in the upper Sacramento and Feather Rivers, and 4) data showing a negative trend in juvenile green sturgeon abundance. One factor that was not considered a primary factor causing the decline of the Southern DPS, but likely poses a threat to the Southern DPS, was past and present commercial and recreational fishing, primarily ocean and estuarine bycatch of green sturgeon in the Oregon and Washington white sturgeon and salmonid fisheries; however, recent fishing regulations have reduced the risk for Southern DPS in Oregon and Washington (NMFS, 2006f). Actions that may negatively affect the Southern green sturgeon DPS include water diversion for human use, point and non-point source discharge of persistent contaminants, contaminated waste disposal, water quality standards, and fishery management practices (NMFS, 2006f).

The principal threat to the southern DPS green sturgeon remains as limited spawning habitat in the Sacramento River, California. Multiple dams on the river prevent adult migration to former spawning sites. Also, flow rates in the river and Delta have been affected by water diversions for agricultural, municipal and industrial uses and insufficient flow rates in the Sacramento River system are likely a significant threat to green sturgeon (NMFS, 2006f). In particular, entrainment of juveniles in water diversion structures has been identified though may not be as much as a problem as thought earlier (NMFS, 2005b). Other adverse effects within the Sacramento River system include elevated water temperatures and contamination from toxic materials (e.g., bioaccumulation of PCBs and selenium). Past and present commercial and recreational fishing may also affect green sturgeons including incidental catches (bycatch) by salmon fisheries in Oregon and Washington (NMFS, 2006e).

**Species Recovery**

No recovery plan has been drafted.

**Life History, Habitat Requirements, and Distribution**

Green sturgeons spawn in deep pools in large, turbulent river mainstems, generally from March through July with peak spawning from mid-April to mid-June Moyle, 2002). Adults migrate to/from spawning grounds during the spring and fall, consecutively, and juvenile migration occurs from April through November (Rien et al., 2001). Northern DPS green sturgeons enter the Rogue River during March through June to spawn. Spawning appears to be related to water temperature ($8.8^{o}$ to $16.4^{o}$C or $48^{o}$ to $62^{o}$F) but low flows probably dictate how far upstream sturgeon are able to migrate to potential spawning habitat (Erickson and Webb, 2007).

Little is known about sturgeon feeding, but some studies have found that adults and juveniles feed on benthic invertebrates including shrimp, mollusks, amphipods, and even small fish (Moyle, 2002). They are thought to spend most of their lives in nearshore oceanic waters, bays, and estuaries (NMFS, 2007d).

Green sturgeon move into estuaries of non-natal rivers to feed (Beamis and Kynard, 1997). They occupy large estuaries during the summer and early fall in the Pacific Northwest. Green sturgeons enter Washington estuaries during summer when water temperatures are more than $4^{o}$F warmer than adjacent coastal waters (Moser and Lindley, 2007). Green sturgeon abundance peaks during October in the Columbia River estuary, based on commercial catches. In Washington, (Willapa Bay and Grays Harbor) green sturgeons appear to be present from June until October (Moser and Lindley, 2007). Sturgeons in the Southern DPS that originate in the Sacramento River have been found in to be relatively extensive Washington estuaries and Columbia River. In the lower Columbia River (river mile 0 to 35), between 77 and 88 percent of the green sturgeons collected originated from the Southern DPS (Israel and May, 2007).

Data from tagged green sturgeons occurring offshore from the Klamath River in California suggests they are from the northern and southern DPS. Tagged green sturgeons that utilize the lower Klamath River have been observed in Grays Harbor, Washington (McCovey, 2007), approximately 400 nmi north of the Klamath River. There are no records of tagged green sturgeon occurring within Coos Bay which is approximately 125 nmi from the Klamath River estuary.

**Population Status**

It has been reported that there are no good data on current population of the green sturgeon (NMFS, 2007d). ODFW evaluated the presence of green sturgeon in coastal tributaries through 2005 and provided summaries of harvests of green sturgeon in California, Oregon, and Washington commercial and sport fisheries (Farr and Kern, 2005). Although many factors contribute to annual catch of sturgeons in the three states whether in coastal, estuarine, or riverine habitats, the overall declining trend since 1985 (see figure 4.5-1) is probably indicative of the species' declining population.

There are confirmed records of green sturgeon in the Umpqua River, captured above the zone of tidal influences. In 2000, two juvenile green sturgeons were regurgitated from a smallmouth bass caught in the Umpqua River (river kilometer 134) and in 1979, a green sturgeon nearly 2 meters long was caught at river kilometer 164 (NMFS, 2005b). In addition, a possible juvenile green sturgeon was captured at Big Butte Creek, near Lost Creek Dam on the Rogue River (NMFS, 2005b). From 2000 to 2004, 249 green sturgeons were captured in the Rogue River and 33 fish were capture while 2 sturgeons that had been tagged were recaptured in the Umpqua River (Farr and Kern, 2005). However, there is no indication to which DPS any of those reported green sturgeons belonged.

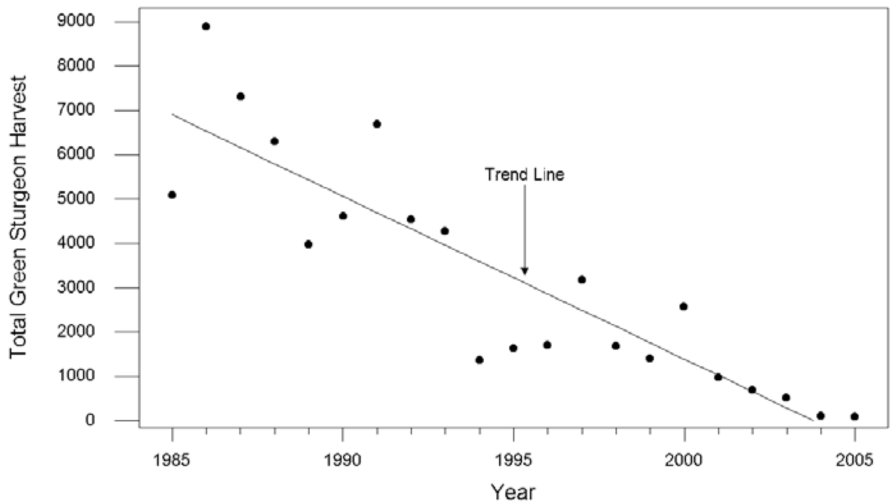



**Figure 4.5-1**

**Total Harvest of Green Sturgeon in California, Oregon, and Washington Commercial and Sport Fisheries from 1985 yo 2005. The linear relationship is significant ($r^2$ = 0.786, P<0.001). Source: Farr and Kern, 2005.**

## Critical Habitat

During reviews prior to designating critical habitat, NMFS (2008b) determined that subadult and adult Southern DPS green sturgeon inhabited certain estuaries along the coast of northern California, Oregon, and Washington during summer and inhabited coastal marine waters from central California to British Columbia. NMFS (2008b) noted large numbers of adult and subadult green sturgeons used Coos Bay as summer habitat, used by Southern DPS green sturgeons tagged in San Pablo Bay, a northern extension of San Francisco Bay. Based on that information, NMFS (2009b) designated critical habitat for the Southern DPS of North American green sturgeon to include all tidally influenced area of Coos Bay up to the elevation of mean higher high water, including the head of tide endpoint in the Coos River, Catching Slough, Stock Slough, Monkey Gulch, and Haynes Inlet, all of which are crossed by the PCGP Project. Critical habitat has also been designated in the Coos River, Boone Creek, Catching Slough, Monkey Gulch, Stock Slough, and Haynes Inlet, also crossed by the pipeline but critical habitat is limited to reaches downstream of tide gates near the mouths of those waterbodies.

PCEs have been identified for critical habitats including: 1) freshwater riverine systems, 2) estuarine habitats, and 3) nearshore coastal marine area. The fresh water riverine component includes the Upper and Lower Sacramento River, Lower Feather River, Lower Yuba River, and several bypasses in the Sacramento-San Joaquin Delta, all of which are in California.

The PCGP Project has potential to affect estuarine PCEs within Haynes Inlet in Coos Bay and coastal tributaries when occupied by subadult and adult green sturgeon (NMFS, 2009b). NMFS (2008b) determined that the Coos Bay estuary provided food resources, water flow, water quality, and migratory corridors to support migration and possibly feeding by subadult and adult green sturgeon. Estuarine PCEs include:

1. Food resources. Abundant prey items within estuarine habitats and substrates for juvenile, subadult, and adult life stages.
2. Water flow. Within bays and estuaries adjacent to the Sacramento River (i.e., the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds.
3. Water quality. Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.
4. Migratory corridor. A migratory pathway necessary for the safe and timely passage of Southern DPS fish within estuarine habitats and between estuarine and riverine or marine habitats.
5. Depth. A diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages.
6. Sediment quality. Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.

NMFS (2009b) identified coastal marine water depths within 110 meters (360 feet, or 60 fathoms) as occupied areas necessary to critical habitat, including coastal waters segments from San Francisco Bay to Humboldt Bay, California and from Humboldt Bay to Coos Bay. Migratory corridors, water quality and food resources are PCEs associated with coastal marine habitat components of critical habitat (NMFS, 2009b).

The specific PCEs in coastal marine areas include:

1. A migratory pathway necessary for the safe and timely passage of Southern DPS fish within marine and between estuarine and marine habitats without human-induced impediments, either physical, chemical, or biological, that would affect the migratory behavior of the fish such that its survival or the overall viability of the species is compromised.
2. Coastal marine waters with adequate dissolved oxygen levels and acceptably low levels of contaminants (*e.g.,* pesticides, PAH heavy metals that may disrupt the normal behavior, growth, and viability of subadult and adult green sturgeon).
3. Abundant prey items for subadults and adults, which may include benthic invertebrates and fish.

### 4.5.1.2 Environmental Baseline

#### Analysis Area

Two analysis areas are applicable to green sturgeons in the Southern DPS. First is the estuarine analysis area which includes: 1) the waters of Coos Bay in which construction-related effects to approximately 3.1 miles downstream from the proposed LNG terminal to a point 2.2 miles upstream from that site which includes the former Weyerhaeuser linerboard mill (distances were estimated for potential worst-case dispersion of turbidity, as provided by Moffatt and Nichol, 2006), 2) the 2.80-mile within-estuary route of the Pacific Connector pipeline after leaving the Weyerhauser Cove Pipe Yard at MP 1.7, crossing Haynes Inlet to where the pipeline emerges from the estuary at MP 4.1, and 3) accessible freshwater tributaries to Coos Bay that would be crossed by the PCGP project below the head-of-tide influence with potential use by green sturgeon (see figure 4.3-6 under section 4.3.3.2 marbled murrelet).

In addition, the proposed action could affect the green sturgeons within the EEZ analysis area which extends 200 nmi offshore. Within the analysis area, effects to green sturgeons within coastal marine waters up to 110 meters deep would be associated with LNG tankers, are assumed to transect the EEZ perpendicularly - east and west - as they approach and depart from Coos Bay or paralleling the West Coast – south and north (see figure 4.2-1 and the discussion above under Section 4.2.1.3 blue whale).

**Species Presence**

It is likely that the North American green sturgeon (both the unlisted Northern DPS and threatened Southern DPS) occur within Coos Bay and its adjacent waterbodies, such as the Coos River, since green sturgeon have been taken in almost all of the Oregon coastal estuaries from the Chetco River to Nehalem Bay (Environmental Protection Information Center et al., 2001) and genetic studies indicate that both Northern DPS and Southern DPS occur in the Columbia River (Israel et al., 2004).

There are historical records of green sturgeons caught in the Coos Bay commercial fishery (ranging from 67 to nearly 2,000 pounds of fish annually) between 1923 and 1949. Further, ODFW has records of green sturgeon caught off Cooson Point, Hays Slough, at the confluence of the Millicoma and Coos Rivers, in Davis Slough, and South Coos River (Farr and Kern, 2005). If their presence in Coos Bay is similar to occurrences on other large estuaries in Oregon and Washington, including the Columbia River, Willapa Bay and Grays Harbor, then a relatively high proportion of green sturgeons may be from the Southern DPS, perhaps as high as 77 to 88 percent similar to occurrence in the lower Columbia River (Israel and May, 2007).

Green sturgeon movements within the 100 meter isobath during migration along the West Coast were monitored using pinger-tags and hydrophone arrays. Although data are limited, tagged sturgeons moved from Seal Rock, Lincoln County, on the Oregon coast north of Coos Bay, south to Monterey Bay, California at the rate of 2 km per day and from Seal Rock north to Brooks Peninsula, B.C. at the rate of 4.2 km per day (Lindley et al., 2008). Migrating green sturgeons were documented along the Oregon coast (Seal Rock) mostly between October and June (Lindley et al., 2008).

**Habitat**

Coos Bay is known to support a small population of green sturgeon; however, natural reproduction in the estuary is considered low (Wagoner et al., 1990). The Coos River system is not considered to provide suitable spawning habitat for green sturgeon (Whisler et al., 1999). However, historical records of the American shad gill-net fishery in the Isthmus Slough indicate that green sturgeon were incidentally captured nearly every year from 1980 to 1992 (Farr and Rien, 2002). ODFW reported that many of these fish were probably younger than three years old based on their size, and suggested that the Coos Bay system may provide spawning or at least rearing habitat for juveniles (Cummings and Schwartz 1971; ODFW, 2006b). Green sturgeons may utilize both shallow and deep water habitats within the estuarine analysis area though there is no information relating individuals' occurrence to DPS membership.

Coastal bays and estuaries provide habitats that support juvenile rearing and growth through the time when they enter coastal marine habitats (NMFS, 2009b). Since no spawning occurs in freshwater tributaries to Coos Bay, the estuary most likely provides feeding and migratory habitat for adult and possibly subadult green sturgeons. Based on food habit studies in several Washington estuaries, adult and subadult green sturgeon fed on a variety of invertebrates (crangonid shrimp, burrowing thalassinidean shrimp - primarily burrowing ghost shrimp (*Neotrypaea californiensis*) and possibly other related species, amphipods, clams, and juvenile Dungeness crab (*Cancer magister*) as well as vertebrates including anchovies, sand lance (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*), and other fish (NMFS, 2009b).

Presence of potential forage species within the vicinity of the Coos Bay Navigation Channel (Miller et al., 1990) was discussed above for Oregon Coast coho salmon. Total benthic invertebrate densities in Coos Bay were found to be lower than densities observed in the Umpqua River Estuary and the Columbia River Estuary (Bottom et al., 1985; Miller et al., 1989; Durkin and Emmett, 1980). Benthic studies conducted by NMFS within and in the vicinity of Coos Bay found that the amphipod, *Corophium salmonis*, occurred in much lower densities than other Oregon estuaries (Miller et al., 1990; Bottom et al., 1985; Miller et al., 1989; Durkin and Emmett, 1980). Previous studies in Coos Bay have found that *Corophium* spp. were abundant in intertidal areas and constituted an important diet element for juvenile Chinook salmon and striped bass (USDI, 1971).

Green sturgeons utilize West Coast estuaries during summer months when estuarine water temperatures exceed ocean coastal temperatures, perhaps optimizing their growth potentials by foraging in relatively warm, saline estuarine water (Moser and Lindley, 2007). The Oregon Department of Environmental Quality (ODEQ) periodically monitored water temperatures in Coos Bay at Marker #23 (near Henderson Marsh) from 1957 to 2005 (ODEQ, 2006), located just downstream from the Project site. Although the data are not continuous, they provide a general range of water temperatures in close proximity to the Project site. Temperatures collected during the period of record ranged from 5°C to 13°C (41°F to 55°F) in the winter to 9°C to 20°C (48°F to 68°F) in the summer (ODEQ, 2006).

Dissolved oxygen (DO) in lower Coos Bay is generally higher in the winter and lower in the summer. During winter, DO ranged from 8.9 to 10.4 mg/L and averaged 9.4 mg/L. During summer, DO ranged from 6.0 to 9.6 mg/L and averaged 7.4 mg/L (ODEQ, 2006). Arneson (1976) also sampled DO in the bay and reported that DO concentrations were slightly higher in December and March than in June and September. Lower DO levels in the summer are associated with lower freshwater inputs but would be a "properly functioning" habitat indicator, overall. Lower DO levels Coos Bay during the summer are associated with lower freshwater inputs.

**Critical Habitat**

NMFS (2009b) designated critical habitat for the Southern DPS of North American green sturgeon to include all tidally influenced areas of Coos Bay up to the elevation of mean higher high water, including the head of tide endpoints in the Coos River, Boone Creek, Catching Slough, Monkey Gulch, Stock Slough, and Haynes Inlet, all of which are crossed by the PCGP Project.

The Coos Bay estuary provides several primary constituent elements including food resources, migratory corridors (passage) between estuarine and marine habitats, sediment quality and water quality (NMFS, 2009b), all necessary to support various green sturgeon life stages. Similarly, coastal marine waters between Coos Bay and San Francisco Bay provide food, passage, and water quality as PCEs.

NMFS (2008b) determined that the Coos Bay estuary provided food resources, water flow, water quality, and migratory corridors to support migration and possibly feeding by subadult and adult green sturgeon. Shallow water habitats near the Project site have been mapped as habitat for *Corophium* spp. by Coos County Planning Department (1979). Ghost shrimp more commonly inhabit tide flats closer to the ocean and in Coos Bay, ghost shrimp may be further inland because of predation by the Pacific staghorn sculpin (Hornig et al., 1989; Posey 1986). Those species as well as bivalve mollusks (softshell, butter, littleneck, cockle, gaper piddocks and mussels) may provide food for migratory green sturgeon within the estuarine and near-shore EEZ analysis areas.

NMFS (2009b) has noted that subadults and adults feeding in bays and estuaries may be exposed to contaminants that may affect growth and reproduction. Such effects due to bioaccumulation of pesticides and other contaminants have been documented in white sturgeons that also inhabit West Coast estuaries (NMFS, 2009b). Sediments within the proposed dredge prism for the access channel were sampled to determine whether they meet Dredged Material Evaluation Framework (DMEF) guidelines, as identified for the Lower Columbia River Management Area, for in-water disposal (SHN Consulting Engineers and Geologists, Inc. 2006). An analysis of grain size distribution and total volatile solids composition was initially performed to determine if the sediments require further testing for chemical analysis. All of the samples were primarily composed of medium to fine grained sand and had a very low percentage of total volatile solids (SHN, 2006). Since none of the samples exceeded 20 percent fines or 5 percent total volatile solids, no further chemical testing was required and the sediments were deemed suitable for in-water disposal, according to DMEF guidelines. These findings indicate that resuspension of sediments associated with the dredging for the access channel should not result in significant increases the bioavailability of contaminants to fish and fish food organisms within the Project action area.

This conclusion is further supported by previous sediment evaluations conducted for Coos Bay channel maintenance and improvement dredging. Most recently in 2004, the COE performed sediment sampling and characterization at various stations along the Coos Bay Navigation Channel (COE, 2005). Throughout the entire sampling area, only low levels of sediment contaminants were identified, with all levels well below their respective DMEF screening levels. One of the sampling stations (0915CB-BC-10) was located approximately 0.4 mile downstream of the Project site. The 2004 sediment sampling effort found only low levels of chemical contaminants, with all levels below their respective DMEF screening levels. None of the samples contained DDT or its derivative by-products (DDE, DDD) at levels that could cause adverse effects to fish resources. No evidence for bioaccumulation of contaminants in potential prey species has been found.

Lower Coos Bay provides unobstructed migratory access for juvenile and adult salmonids, discussed above, and similarly assumed to be unobstructed for green sturgeons. Within the estuarine analysis area and lower riverine analysis area entering Coos Bay, access for migrating fish species is uninhibited, and is considered “properly functioning.”

#### 4.5.1.3 Effects by the Proposed Action

Coastal marine waters within depths of 110 meters (360 feet or 60 fathoms or fm) were identified as occupied areas necessary to critical habitat, including coastal waters segments from San Francisco Bay to Humboldt Bay, California and from Humboldt Bay to Coos Bay (NMFS, 2009b). As discussed for blue whales in section 4.2.1.3 above, LNG carriers traveling within the EEZ parallel to the coasts of California and Oregon are expected to transit 50 nmi off shore.

**Direct Effects – Estuarine Analysis Area**

Project-related effects to the Southern DPS of green sturgeon would be caused by the action and occur at the same time and place, including the following direct impacts within the estuarine analysis area: 1) turbidity effects from dredging the slip and access channel, 2) turbidity effects from LNG vessel propeller wash and ship wake, 3) turbidity effects from constructing the Pacific Connector pipeline within the estuary, 4) stranding sturgeons by LNG vessel propeller wash and ship wake, 5) introduction of exotic, invasive species from ballast water, 6) entrainment and impingement of sturgeons in LNG carriers' intake port, 7) estuary water cooling during LNG carrier cargo loading, 8) potential effects by effects by operational lighting, and 9) acoustic effects to sturgeon during LNG terminal construction.

<u>Timing</u>

In-water construction of the JCE and PCGP Project within the Coos Bay estuary is planned from October 1 through February 15 following ODFW's recommendation. Because no spawning occurs in freshwater tributaries to Coos Bay, the estuary most likely provides feeding and migratory habitat for adult and possibly subadult green sturgeons. Adults migrate to/from spawning grounds during the spring and fall, consecutively, and juvenile migration occurs from April through November (Rien et al., 2001). Green sturgeon move into estuaries of non-natal rivers to feed (Beamis and Kynard, 1997) and occupy large estuaries during the summer and early fall in the Pacific Northwest. Green sturgeon abundance peaks during October in the Columbia River estuary, but the same may not be true of green sturgeon abundance in Coos Bay. Nevertheless, Southern DPS of green sturgeon could be present within the estuary coincidental with in-water construction for the JCE and PCGP Project and within designated critical habitat offshore within the EEZ. Principal direct impact during in-water construction would most likely be related to turbidity generated by construction of the slip, dredging the access channel, and construction of Pacific Connector's pipeline across Haynes Inlet.

<u>Turbidity Effects –Slip and Access Channel</u>

Construction of the LNG terminal slip will require the excavation and dredging of approximately 4.3 million cubic yards (cy) of material (2.3 million cy excavated and 2.0 million cy dredged) and the construction of the access channel will require the dredging of 1.3 million cy for a total of approximately 5.6 million cy. The slip will be dredged to a depth of minus 45 feet (NAVD88). Volume estimates include two feet of over depth dredging. The 5.6 million cy will be used beneficially for the Project in raising both the LNG Terminal site and the nonjurisdictional South Dunes Power Plant site to elevations above the tsunami inundation zone. A total of 1.9 million cy will be placed on the LNG Terminal site, while the remaining 3.7 million cy will be placed on the power plant site.

The majority of the dredging for the slip will be conducted in isolation from the waters of Coos Bay. While the future slip area is being excavated and dredged, a berm (with a 3H:1V slope to the slip and a natural grade to the channel) will be maintained to provide complete separation of the excavation and dredging activities from the bay, resulting in no turbidity being released to the waters of Coos Bay.

Dredging of the berm separating the portion of slip from the bay and the access channel will result in temporary siltation and sedimentation impacts similar to those that currently occur during maintenance dredging activities. The dredging activity will occur only during the in-water work window established by ODFW.

On average, the USACE removes approximately 550,000 cy from the bar, 200,000 cy from Channel Mile (CM) 2-12 and 150,000 cy from CM 12-15 each year. In comparison, approximately 500,000 cy will be removed in the water during the removal of the berm and dredging of the access channel. Since the duration of the dredging in the bay will be 4-6 months and only during the in-water work window from October 1 to February 15 (ODFW, 2008), the minimal amount of turbidity created will be relatively short term and localized. Turbidity modeling demonstrated that turbidity levels dropped to near background levels beyond 200 meters (660 feet) of the dredging activity.

Turbidity was modeled for the new construction and maintenance dredging operations based on the anticipated geotechnical and environmental conditions for this project using the United States Army Corps of Engineers (USACE) DREDGE model and two dimensional numerical model Mike21 (developed by Danish Hydraulic Institute). Re-suspension of sediments during dredging operations can be a significant source of turbidity; however, through proper operational controls and potentially the use of physical barriers, this source can be controlled. Turbidity generation is a factor of the dredge type, dredging practices, sediment characteristics, and environmental conditions at the site (e.g., currents). From the results of the DREDGE model for the open "clamshell" dredge, during construction stage the maximum modeled suspended sediment concentrations (primarily sand) were less than 6,000 mg/l at the dredge location rapidly decreasing with distance to less than 50 mg/l at 200 m (approximately 660 feet). For the hydraulic cutterhead dredge the TSS levels were significantly lower with maximum of 500 mg/l in the vicinity of the dredge. The TSS concentrations reduce rapidly to maximum of 14 mg/l by a distance of 60 meters (200 ft).

During the maintenance dredging period, the dredged material is expected to be primarily fines (mud, clay, silt). Concentration predicted with the DREDGE model for the open "clamshell" dredge were lower than during the construction stage with the maximum of 830 mg/l in vicinity of the dredge and decreasing to 125 mg/l at 200 m (approximately 660 feet). The results from the Mike21 simulations show that distribution of the generated plume depends on location of the dredge in the channel and basin area. For dredging with an open "clamshell" dredge in the channel the generated sediment plume (concentration higher than 150 mg/l) can move up to 1.2–1.9 miles from the dredging location at highest ebb or flood currents; however, the duration of such entrainment is limited by not more than a two hour period and the time average concentrations do not exceed natural ambient concentrations (10–30 mg/l) outside the dredging area. During maintenance dredging with an open "clamshell" dredge, the maximum concentrations in the generated plume do not exceed 50 mg/l. Based on these results it is not anticipated that turbidity generation at the dredging site will be a significant issue.

Turbidity Effects –Propeller Wash and Ship Wake

Propeller wash from LNG vessels and tug boat propellers associated with the Project, as well as ship wakes breaking on shore, could cause increased erosion along the shoreline and re-suspend the eroded material within the water column. This may affect the diversity and health of the benthic community regarding food availability and feeding conditions for foraging and migrating fish species. At high concentrations, suspended sediments can affect oxygen exchange over the gills, resulting in weakened individuals or mortality. However, ship wakes associated with the operation of the slip are not expected to result in significant bank erosion or effects due to the low speed at which carriers would traverse the lower bay when approaching or departing the slip and the limited number of trips (approximately 90 round trips per year).

The possible impacts on the shoreline along the navigation route to and from the LNG Terminal from the pressure fields generated by passing deep-draft vessels and vessel wakes generated by assisting tug boats were analyzed (see Resource Report 2 and Volume 2 of the C&H Technical Report in Appendix H.2 for JCEP LNG Terminal Project).

The results of the analysis show that hydrodynamic effects from pressure field velocities measured along the sensitive shoreline from existing deep-draft vessels exceed the pressure field velocities that may be generated by future LNG carriers. The reason for this is that the USCG has mandated that all LNG carriers be escorted by a minimum of two tractor tugs each with 80 tonne bollard pull capacity. The use of these tugs allows the LNG carrier to transit at a lower speed than the existing vessels which transit without tug assist. Vessel velocity, rather than its size has a much greater impact on the amplitude of the pressure wave. The conclusion of this finding is that the potential impact from the proposed LNG carrier on coastal processes at the sensitive shoreline would be smaller than that from the existing deep-draft vessels.

Vessel wake effects have been studied using the 2-D spectral wave model SWAN (SWAN) for waves/wakes generation and propagation and empirical formulation for evaluation of swash sediment transport. The potential vessel wake impact at the sensitive areas was determined by comparing swash sediment transport for Post-Project Conditions relative to Existing Conditions. The possible impact on sensitive shoreline from increased vessel wake energy along the navigation route to the Project was evaluated using calculations of swash sediment transport. Swash sediment transport indicates the potential for shoreline response to waves/wakes energy delivered to the shoreline itself.

Swash sediment transport at the sensitive areas for Existing Conditions was assumed to be formed from two different contributing factors:

- Swash sediment transport generated by wind waves.
- Swash sediment transport generated by present traffic of tug-boat wakes.

Swash sediment transport at the sensitive areas for Post-Project Conditions was assumed to be formed from three different contributing factors:

- Swash sediment transport generated by wind waves.
- Swash sediment transport generated by present traffic of tug-boat wakes.
- Swash sediment transport generated by future traffic of tug-boat wakes.

SWAN was applied to generate wind-waves and propagate them to the sensitive shorelines from different directions at various tide elevations. A total of 1,080 modeling scenarios, combinations of wind speed, directions, and tide elevations were simulated with SWAN.

The results of the swash transport calculations show a small increase in wake-generated swash sediment transport at the areas of interest due to LNG carriers. The results show that the increase in swash sediment transport from combined inbound and outbound carrier traffic would not exceed six percent at Pigeon Point, eight percent at Clam Island, and five percent at the Airport sensitive shorelines. The total sediment transport for future inbound and outbound LNG carrier traffic will be less than eight percent of the existing and future wind-wave swash sediment transport. The estimated increase in swash sediment transport due to the LNG carrier traffic is a small fraction of the swash sediment transport due to the natural wind-wave conditions. This increase most likely would not be detected in a general balance of swash sediment transport due to yearly variability of wind-wave conditions and swash sediment transport.

Turbidity Effects – Pipeline Construction

Pacific Connector will construct the proposed pipeline across Haynes Inlet between October 1 and February 15, the in-water construction period recommended by ODFW (2008a). It is unlikely that green sturgeon would be present in the Coos Bay estuary during pipeline construction across Haynes Inlet. Construction would increase turbidity in the immediate vicinity of the construction right-of-way across Haynes Inlet but eulachon, if present, would be expected to avoid local turbid conditions. Natural turbidity in the Coos Bay estuary was judged to be higher at upper bay locations, away from water influx from the ocean (Moffatt and Nichol, 2006). Turbidity measured at the Charleston Bridge, near the entrance to Coos Bay varied from 3.7 to 18.1 NTU (5.7 to 45.7 mg/L) but sometimes exceeded 200 NTU. Modeled turbidity due to dredging in Coos Bay suggests a very narrow range of elevated suspended sediment (>100 mg/L) during low tidal velocity extending a few hundred feet from the dredge, while during typical tidal cycle values were as high as 50 mg/L from 0.2 to 0.3 mile away from the dredge. Moderately low values of 25 to 50 mg/L may extend out to about 3.5 miles depending on flow, sediment, and equipment used (Moffatt and Nichol, 2006). Expected turbidity levels during pipeline construction would be elevated but within ambient levels and would not be likely to affect eulachon, if present.

Trench excavation to install the pipeline in the bay would bury, displace, or injure benthic organisms (e.g. worms, clams starfish and vegetation). Mobile organisms like crabs, shrimp, and fish would move away from the trenching activities. Short-term impacts would occur to other benthic taxa in Coos Bay that include ribbon worms (Nemertinea), various burrowing segmented worms (Polychaeta), small crustaceans including amphipods, Dungeness crab, echinoderms, clams (i.e., *Macoma* sp.), and coral/anemone polyps (Anthoszoa) (Miller et al., 1990). However, benthic communities on mud substrates in Coos Bay that were disturbed by previous dredging activities recovered to pre-dredging levels in four weeks (Newell et al., 1998). Some impacts may be long-term if important habitat elements are affected, such as the effects of turbidity on eelgrass growth (Martin and Tyrrel, 2002

Construction of the pipeline across the Coos Bay estuary will utilize a wet-open cut method. The current pipeline route in the bay will cross 2.5 miles and disturb approximately 75.6 acres of subtidal (33.2 acres), mud/sandflat (36.2 acres and 1.2 acres of estuarine wetlands) habitats. Ellis Ecological Services, Inc. (2013) conducted a survey of eelgrass beds within Coos Bay along the pipeline route. Based on the survey of the route in 2013, there were about 5.0 acres of eelgrass beds that will be directly affected by the construction right-of-way (including temporary extra work areas - TEWAs). Eelgrass beds were placed into three categories based on density: low, medium, and high. From that survey, most of the area affected would be low density, and none were categorized as high-density eelgrass. Approximately 0.1 percent of the total eelgrass beds present in Coos Bay would be directly disturbed from pipeline construction across Haynes Inlet (Ellis Ecological Services, 2013).

On the chance that a sturgeon might be present, construction related effects would be due to local increases in turbidity. In that instance, the water quality PCE could be affected over the short term within critical habitat and disruption to intertidal and sub-tidal substrates could affect the food resources PCE for sturgeon critical habitat. However, sediment concentrations from pipeline trenching in Haynes Inlet would be similar to winter background levels for much of the construction period and few fish would be near the highest plume concentration due to active avoidance.

The pipeline will cross the Coos River using a HDD and will cross Catching Slough using a conventional bore. Other waterbodies within critical habitat will be crossed by dry-open cut construction between July 1 and September 15, the recommended in-water construction dates for Boone Creek, Catching Slough, Monkey Gulch, and Stock Slough (ODFW, 2008). Sediment released during dry open-cut construction is generally restricted to short-term peaks associated with installation and removal of isolation (temporary dams) and bypass structures (flume pipe, pump intake and exit conduit). Reid et al. (2004) evaluated sediment generated during dry open-cut construction and found that total suspended sediment (TSS) concentrations at flumed dry open-cut pipeline crossing was only 3.7 percent of TSS concentrations generated during wet open-cut construction. Likewise, TSS produced during dam-and-pump dry open-cut construction was 0.85 percent of the TSS produced during wet open-cut.

Turbidity and increased suspended sediment would be generated during pipeline construction across the Coos Bay estuary. While the exact duration of pipeline construction in the bay is unknown it would be completed during one season (i.e., less than the 4.5-month in-water work window). "Wet" crossing construction or open cutting (trench excavation, pipe installation, and backfilling the trench through flowing water) produces the highest downstream (or relative tidal flow direction) sediment loads of any construction technique (Mutrie and Scott, 1984; Reid and Anderson, 1999; Reid et al., 2004). Estuarine environments often have moderately elevated suspended sediment concentrations (i.e. >15 mg/L) and they are very productive (Gregory and Northcote, 1993). The amount of sediment produced by open cutting depends on multiple characteristics at the construction site including depth and width of the waterbody (effects mixing of the sediment plume in the water column), current velocity and local turbulence at the site and downstream, concentrations of suspended sediment initially at the site and at some distance downstream, particle diameter, specific weight, and settling velocity of the excavated and backfilled materials (Ritter, 1984; Reid et al., 2004). Based on sediment transport modeling, dispersal of the exposed and disturbed sediments will be very minor in intertidal areas of Haynes Inlet due to the low water velocities and sediment composition in that area and turbidity is not expected to adversely affect green sturgeon.

Stormwater Discharge at LNG Terminal

Stormwater discharge has the potential to contain chemicals toxic to green sturgeon. However the NPDES permit that the applicant would obtain requires discharges to not modify state water quality standards of the receiving water. The stormwater permit application states "The permit registrant must not cause a violation of instream water quality standards." Since the water quality standards are designed to protect aquatic resources, including green sturgeon, the applicant is to insure the standards are not exceeded, and therefore not cause adverse harm to the aquatic resources. So issuance of the permit by the state should insure that aquatic resources are protected. However, it is known that stormwater runoff often does result in chemical concentration values at the point of discharge in excess of EPA water quality criteria (WDOE, 2009). The general characteristics of the stormwater system and levels of some discharge items are presented below.

The proposed stormwater management system is designed to direct any flow that does not come into contact with any equipment containing potential contaminants (grease or lubrication oil) to the multi-user slip. Stormwater collected from non-LNG containing paved and curbed areas of the facility would be collected into an Oily Water Collection Sump. Primarily, these localized drains are located around equipment to contain grease and/or lubrication oil. The oily water from the collection sump overflows to the Oily Water Separator Package which is equipped with plate type separation devices to remove any oil and grease washed down from the facility equipment. Recovered oil and grease is held in the sump and periodically pumped directly to storage drums for disposal. The water would be kept in a holding area in the fire water pond where it would be tested for compliance with Oregon water quality standards to ensure that the water discharged meets the water quality criteria for the receiving water body, which have been established to be protective of fish. Water from the holding area would be released to the fire water pond and would be discharged via the NPDES permitted discharge point to the ocean.

The proposed oil and grease treatment system is designed to limit discharges of oil and grease to no more than 15 mg/l daily maximum. This system design would ultimately need approval from the State to obtain the NPDES permit. The treatment system function is an additional level of protection for inadvertent spills that come into contact with stormwater. The facility is not designed to intentionally mix oil and grease with stormwater and there are no continuous discharges of oil and grease from the LNG terminal. Discharges from the LNG terminal that could contain oil and grease would only occur during stormwater events. Only in the event of a significant spill or leak from a piece of equipment that occurred during a stormwater event would the concentration of oil and grease in the stormwater discharged from the LNG terminal approach the 15 mg/l daily maximum. Based on information available in the literature, it would appear that the 15 mg/l is below the limit where adverse effects occur on fish species. In 96-hour tests of acute toxicity, the LC50 (lethal concentration for 50 percent of the subjects) for juvenile coho salmon exposed to diesel fuel ranged between 2,186 and 3,017 mg/l (1 mg/L = 1 ppm) (World Health Organization, 1996). Water accommodated fractions (standardized preparation of water systems with dissolved oil components for toxicity studies) prepared from oils higher in aromatics (e.g. the middle distillates including Fuel Oil No. 2, kerosene, and diesel) are generally more toxic than those prepared from crude oils and gasoline (e.g. Anderson et al., 1974; Rice et al., 1976; Markarian et al., 1994). Consequently, LC50's for crude oil would most likely be higher than those, above, for diesel fuel. Discharges of most water containing oil products would be limited to the ocean discharge, where rapid dilution would occur, and further reducing potential effects.

The exact levels of other runoff chemicals can not be predicted at this time. However Washington State, in a review of all of their permitted monitored stormwater discharge facilities, found that copper and zinc, two chemicals commonly of concern to aquatic organisms, were relatively high often exceeding benchmark standards (WDOE, 2009). They noted that the sources of metals pollution include oils and lubricants from motor vehicles, tire dust, brake pad dust, raw material and products, and exposed galvanized metal surfaces on buildings, fences, and equipment (WDOE, 2009). It is likely many of these components would be present at the project site. In the Washington study across all stormwater discharges zinc levels exceeded benchmark values more than 50% of the time, while copper exceed the benchmark values in the range of 20 to 50 percent of the time. White sturgeon, and presumably green sturgeon, are sensitive to both copper and zinc in fairly low concentrations during embryonic, larval and development through fry life stages (Vardy et al., 2011). However, only adult and sub-adult green sturgeon would potentially be exposed to metal components in stormwater discharge and exposure effects to adults are unlikely.

Stranding from Ship Wake and Propeller Wash

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not. Size of juvenile green sturgeons that have been reported caught in the Coos Bay esturary in the 1950s through the 1990s have varied from 40 cm to over 100 cm (15.7 to >39.4 inches) fork length or total length (Farr and Kern, 2005). The sizes of green sturgeon expected in the estuary are considerably larger than sizes of juvenile chinook salmon (<9 cm) stranded by ship wakes in the Columbia River (Pearson et al., 2006) and may not be susceptible to stranding by ship wake.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds have been observed to cause occasional stranding of juvenile salmon (Pearson et al., 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al., 2006) to cause stranding. In models and research conducted by the JCEP, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute o stranding of green sturgeons within Coos Bay.

Exotic, Invasive Species

NMFS (2005b) identified effects by exotic species as a risk to green sturgeons in the Southern DPS. For example, exotic species are concerns because of replacement of food items; the exotic clam *Potamocorbula amurensis*, was introduced to the Sacramento-San Joaquin River and Delta systems (California) in ship ballast water from Asia in 1988 and become the most common food of white sturgeon. The clam was also found in the only green sturgeon so far examined and is known to bioaccumulate selenium (Linville et al., 2002), a toxic metal potentially causing teratogenesis or abnormal embryonic developmental (Lemly, 1996). Further, rapid expansion of the exotic clam caused changes in the primary productivity and benthic community dynamics of portions of San Francisco Bay (Werner and Hollibaygh, 1993; Nichols et al., 1990).

Loaded with water from the surrounding ports and coastal waters throughout the world, ships can carry a diverse assemblage of marine organisms in ballast water that may be foreign and exotic to the ship's port of destination. The transfer of water from port-to-port can result in aquatic biological invasions. Invasive species threaten to outcompete and exclude native species and the overall health of an ecosystem, causing algal blooms and hypoxic conditions and affecting all trophic levels resulting in a decline in biodiversity.

Ballast water from ships' precedent ports would be emptied and exchanged with ocean seawater approximately 200 nmi offshore, at the outer edge of the EEZ. The ballast water exchange (BWE) process is mandatory under the National Ballast Water Management Program – originally established by Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and further amended by National Invasive Species Act of 1996 and National Aquatic Invasive Species Act of 2003 – amended in 2005 and again in 2007. On March 23, 2012, the USCG issued its Rule regarding Standards for Living Organisms in Ships' Ballast Water Management Discharged in U.S. Waters, which amends the existing regulations and creates a standard for the allowable concentration of living organisms in ballast water discharged in U.S. waters consistent with the International Maritime Organization's International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM Conventions). This Rule will require all vessels equipped with ballast tanks bound for (or departing) U.S. ports to utilize at least one Ballast Water Management method described in the Rule (77 FR 17254). The most likely convention given the advanced technologies used by LNG carriers will involve a complete BWE in an area 200 nautical miles from any shore prior to discharging ballast water.

LNG ships will discharge ballast concurrently with the LNG cargo loading at the LNG terminal. The amount of ballast water discharged must, at a minimum, be adequate to maintain the LNG ship in a positive stability condition and with an adequate operating draft while the LNG cargo is loaded. The ballast water discharged at the terminal will be that from 200 miles out in the open sea as occurred as part of the mandated BWE process to eliminate or minimize risks of introducing exotic, invasive species.

Entrainment and Impingement

LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is likely that some organisms small enough to pass through the screens covering the carrier's intake port will be drawn in with the cooling water and will be lost from the population in the slip area; however, it is anticipated that the effect associated with the intake of cooling water will be minimal. Juvenile fish would need to be present in the slip area near the carrier's intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen. Generally the total water intake would occur over a 24-hour period during each loading period, about 90 times per year.

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The power requirements for loading LNG in the export mode are less than those for unloading LNG in the import mode because the LNG carrier does not have to use on board LNG pumps to handle LNG cargo; hence both the LNG carrier engine requirement and the required amount of cooling water flow are reduced. The amount of cooling water to be re-circulated is a function of the propulsion system of the LNG ship and, once the LNG ship fleet has been identified, the issue of cooling water circulation requirements can be further addressed. For purposes of this analysis, typical cooling water flow rates were used. Cooling water flows while at the berth are approximately 1,300 $m^3$/hr (343,421 gallons per hour or 5,723 gpm). For a 148,000 $m^3$ ship this would total approximately 4.3 million gallons while loading LNG cargo. In the event that a 217,000 $m^3$ ship is used, the amount of water required would be on the order of six million gallons. The intake port for this cooling water is approximately the same size and at the same location as the ballast water intake port, 3.5 to 4.2 square meters covered by a screen with 4.5 mm bars, spaced every 25 mm and approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG ship. The velocity across this port is approximately 0.28 ft/sec with a temperature differential of three degrees centigrade. It is likely that some organisms that are small enough to pass through the screens covering the ship's intake port will be drawn in with the cooling water and will be lost from the population in the slip area. It is anticipated that the effect associated with the intake of cooling water will be minimal. The intake velocities for the cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be impinged on the intake screen.

Water Cooling

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The engines will be running to provide power for standard hotelling activities as well as running the ballast water pumps. The activities that will require LNG carrier power and the assumptions used to develop the cooling water flow requirements are as follows:

- Hotelling operations require the generation of 1.9 MW of power during the entire time that the LNG carrier remains in the slip. The vessel is anticipated to be within the slip for a total of 17.5 hours.
- A typical auxiliary power unit for an LNG carrier is the Wartsila 34DF. This is a dual fuel (liquid and natural gas) unit that is a complete primary driver/generator package capable of being sized upwards to 6.9 MW output. Fuel to power conversion is 7,700 kilojoules (kJ) per kilowatt-hour (kWh) (kJ/kWh) (7,305 British thermal units (Btu) per kWh (Btu/kWh)). This system has an overall fuel to power efficiency of 46.7 percent, thereby resulting in the rejection of 3,893 Btu of heat into the cooling water for each kWh of power generated.

- All calculations that follow are based upon the transfer of 148,000 $m^3$ of LNG from the LNG storage tanks to the LNG carrier. The 148,000 $m^3$ carrier is set as the basis because it represents the largest vessel authorized to call on the LNG Terminal.

The total gross waste heat discharged into the slip from the cooling water stream will be due primarily from the hotelling operations (including the power required to run the ballast water discharge pumps) as the shore side LNG pumps will be used to transfer the LNG from the LNG storage tanks to the LNG carrier. The hotelling operations were assumed to be as follows:

- Hotelling Operations -17.5 total hours x 1,900 kW x 3,983 Btu/kWh = 132.5 million Btu (MMBtu). The total amount of heat discharged into the slip during each vessel call is approximately 132.5 MMBtu.

Because of the extreme differential of the temperature of the cargo in the LNG carrier (-260$^{o}$F) and that of the surrounding air and water (nominally 45$^{o}$F) there is a constant uptake of heat by the LNG carrier from its surroundings. This heat uptake is manifested by the amount of LNG cargo that changes state from liquid to vapor on a daily basis. The typical LNG carrier sees 0.25 percent of its liquid cargo converted to the gaseous state each 24 hours. In this process 219 Btu of heat is absorbed for each pound of LNG converted to vapor. This results in a total of 53 MMBtu absorbed by a typical 148,0000 $m^3$ LNG carrier during the 17.5 hours it is within the slip. Given the distribution of vessel surfaces between those surfaces in contact with water as opposed to those surfaces in contact with air it is reasonable to assume that 50 percent or more of the heat take up by the vessel is extracted from the water. This assumption is further reinforced by the fact that the heat transfer coefficient between water and steel is significantly higher than the heat transfer coefficient between air and steel. Applying this allocation of heat absorption sources results in having 26.5 MMBtu being removed from the slip by the LNG vessel during its stay. Thus a portion of the 132.5 MMBtu of thermal energy discharged into the slip from the cooling water is offset by the uptake of 26 MMBtu by the LNG vessel itself, resulting in a net heat input to the slip of 106.5 MMBtu per 148,000 $m^3$ LNG carrier call.

Analysis and numerical modeling were performed to identify potential impacts of LNG carrier cooling water discharge on water quality in the slip and adjacent area of Coos Bay. The modeling was initially performed with two different numerical models: the 3-D UM3 model and the DKHW model. The models simulate hydrodynamic mixing processes of submerged discharges and predict temperature fields and dispersion of non-conserved substances in ambient water bodies. Cooling water numerical modeling requires input of steady-state flow velocity in the modeling domain. The results of tidal flowing modeling using the SELFE model showed that ambient current velocities inside the LNG Terminal area vary, depending on tidal stage. Peak current speeds in the berth only exceed approximately 0.32 ft/sec less than two percent of the time. Therefore, for cooling water modeling, two steady state ambient flow velocities were assumed and used further in the analysis: high velocity = 0.32 ft/sec and typical velocity = 0.16 ft/sec.

The following conservative assumptions were used in the analysis. The assumptions are conservative in that a steam powered ship was used. The steam powered ships tend to be older than the newer more modern dual fuel diesel electric ships that require lower quantities of cooling water.

- LNG carriers are steam-powered with a cargo capacity of 148,000 $m^3$.

- Maximum pump capacity for main condenser cooling is 10,000 $m^3$/hr (44,030 gpm) and maximum pump capacity for LNG carrier's equipment cooling is 3,000 $m^3$/hr (13,209 gpm). Total capacity being used at a given time is typically in the range of 6,300 $m^3$/hr (27,739 gpm). For the analysis, 6,300 $m^3$/hr (27,739 gpm) was used.
- Diameter of the horizontal discharge port is 1.1 meters (3.6 feet).
- Depth of discharge port below still water is 10.0 meters (32.8 feet).
- Maximum heating of cooling water at time of discharge is 3 ºC (5.4 ºF) above ambient temperature.

Results of the modeling showed that for typical ambient flow conditions at a distance of 50 feet from the discharge point (LNG carrier sea chest), temperatures will not exceed 0.3 ºC (0.54 ºF) above the ambient temperature. This difference will decrease with further distance.

<u>Effects of Operational Lighting</u>

Localized changes in light regime have been shown to affect fish species behavior in a variety of ways (Valdimarsson et al., 1997; Tabor et al., 2004, Nightingale and Simenstad, 2001). Disorientation may cause delays in migration, while avoidance responses may cause diversion of migratory routes into deeper, less protected waters. In some cases, increased light may attract both predators and potential prey species (Simenstad et al. 1999; Valdimarsson et al. 1997; Tabor et al. 2004).

Lighting at the LNG Terminal and onshore facilities would likely include a mixture of low-power fluorescent lighting and higher intensity security lighting that would primarily be located on shore, in and adjacent to the slip. When an LNG carrier is not in the berth, the lighting would be reduced to that required for security. It would be focused upon the structures and not be in proximity to the water so as to serve as an attractant or deterrent to fish species. When an LNG carrier is at the berth, it would physically block the lighting on the berth from the slip waters and, due to its proximity to the slip wall, would block the fish from getting too close to the lighting on the berth. Lighting used would be similar to that already in place at other Coos Bay facilities.

Lighting on the tug dock would be low intensity lighting for safety, providing sufficient light for personnel movements on the trestle out to the tug berth and for movement on the berth itself. There is no intention to provide lighting near the water line or high intensity lighting that would be associated with activities other than the simple berthing of the tugs at this location. The reduced lighting levels near the water would reduce or eliminate any behavioral effects to fish in the Project vicinity. Increased lighting from facility operations are not expected to significantly affect green sturgeon, Southern DPS.

<u>Acoustic Effects</u>

Underwater noise may affect green sturgeon. Prior to the excavation work starting for the LNG carrier slip, an open cell sheet pile bulkhead and retaining wall will be installed. The sheetpile system will serve as a retaining wall for the shoreline on the east side and support the LNG ship loading dock and associated berthing and mooring facilities. The open cell sheet pile wall system consists of face sheetpiles for retaining the soils as well as tailwalls for anchorage of the retaining wall. All sheetpiles and tailwalls will be driven from the land while the slip construction activities are isolated from Coos Bay.

Underwater noise may be generated by driving sheet piles on land (dry piles) since some noise propagates through ground and sediments (especially through harder substrates such as rock and clay), and may transfer to the water column somewhere else (known as sound flanking). Sound in the water column would be at a lower level than at the source (Washington State Department of Transportation, 2011a) since most sound energy does not travel through water but through the sediment. There would be minimal chance that driving pilings on land could physically injure fish from the impact of percussive sound pressure in the same was as driving piles in water (see Popper, et al. 2006).

**Direct Effects – EEZ Analysis Area**

Project-related effects to the Southern DPS of green sturgeon would be caused by the action and occur at the same time and place, including the following direct impacts within the within the EEZ analysis area could include: 1) sediment discharge at Site F, 2) acoustic effects to sturgeon from LNG ships transiting the EEZ, and 3) spills and releases of LNG at sea.

Turbidity at Site F

Discharge of the maintenance dredging at Site F, about 1.6 miles off the mouth of Coos Bay, would generate a turbidity plume that could affect green sturgeon within the EEZ analysis area. Site F is about 2,700 acres and ranges from 25 to 150 feet deep. Approximately 37,700 cy is the total maintenance dredging volume expected at year 1 and 34,600 cy is the total maintenance dredging volume expected at year 10. In the first 10 years, an approximate total of 360,000 cy would be removed and in the next 10 years approximately 330,000 cy would be removed for an approximate total of 690,000 cy in comparison to the earlier prediction of 1.75 million cy. This is a substantial reduction in volume which in turn will reduce the demand for disposal space at Site F. The original estimate for the frequency of dredging was every two years. Now, with the additional information from the modeling, the recommended future maintenance dredging requirements are approximately 115,000 cy would need to be dredged every three years for the first 9-12 years (10 years approximately) and after 10 years it would be safe to reduce the volume of dredging to some values in the range of 115,000 to 160,000 cy with a frequency of five years between dredging events.

Turbidity generated from discharge at Site F would be rapidly dissipated and may cause some short-term avoidance of the area by green sturgeon during discharge. But there is the possibility that young sturgeon (about 2 feet in length) if they were present directly under the sediment discharge from the barge or ship would be unable to dart out of the plume of sediment and become trapped in the sediment during active discharge. Potential adverse effects would occur to smaller subadults if they were present within the area.

Acoustic Effects

Underwater noise may affect green sturgeon. LNG carriers transiting the EEZ would produce underwater noise. Underwater noise levels are expected to vary by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age - older vessels tended to be louder than newer vessels (see discussion in Section 4.2.1.3 for blue whales). Based on the general trend for higher underwater noise generated by larger vessels (McKenna et al., 2012), it is possible for many of the LNG carriers that would utilize the Jordan Cove terminal to generate more noise than the LNG tanker built in 2003 with 138,028 $m^3$ capacity reported by Hatch et al. (2008) that produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 µPa @ 1 meter.

State agencies in Washington, Oregon, and California, along with federal agencies have developed interim noise exposure threshold criteria for pile driving effects on fish (Washington

State Department of Transportation, 2011a; Popper et al., 2006). Interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a) include 1) a cumulative sound exposure level ($SEL_{cum}$) of 187 dB re 1 $\mu Pa^2$ s for fishes more than 2 grams, 2) a $SEL_{cum}$ of 183 dB re 1 $\mu Pa^2$ s for fishes less than 2 grams, and 3) a single-strike peak level ($SPL_{peak}$) of 206 dB re 1 μPa for all sizes of fishes (Washington State Department of Transportation, 2011a). $SEL_{cum}$ is the cumulative sound pressure squared, integrated over time, and normalized to one second. $SEL_{cum}$ is calculated as SEL (single strike at 10 meters from the pile) + 10 Log(number of strikes). Although ship noises reported by Hatch et al. (2008) and McKenna et al. (2013) are not directly equivalent to pile driving noise, or the interim noise exposure criteria, any LNG carrier noise generated in the EEZ would be below thresholds for adverse effects to fish, including sturgeons. Noise from LNG carriers would likely increase the background noise within the EEZ, and which is occurring globally (Slabbekoorn et al., 2010). Sturgeons in the EEZ might detect noise from LNG carriers but are not expected to be adversely affected by the projected since vessel traffic due to LNG carries is expected to add to the projected vessel traffic in 2017-2018 by 1.2 percent increase in shipping in coastal Oregon and Washington over the 2017-2018 estimates (see discussion in Section 4.2.1.3 for blue whales). Neither underwater noise generated during construction nor ship noises from LNG carriers transiting the EEZ are expected to adversely affect green sturgeon, Southern DPS.

Release and Fire at Sea

Oil or LNG spills at sea or offshore are unlikely to harm green sturgeon. The low amount of petroleum product on LNG vessels and low chance of LNG spill or fish contacting a spill greatly reduce chance of impacts in the marine environment from spills. Based on the double hulled construction of LNG carriers and the outstanding operating and safety record of LNG carriers, the probability of any incidents that could result in the loss of LNG cargo are extremely low. Any potential spills that could occur and that could affect the green sturgeon would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales and Section 4.3.3.3 for marbled murrelets. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface (Hightower et al., 2004). The cooling effects of the LNG plume on submerged green sturgeons are unknown but are expected to be localized at the surface. Similarly, effects of a fire on prey species would likely be very limited to the ocean – LNG pool interface. Neither the LNG pool nor an ensuing fire would be expected to adversely affect green sturgeon.

LNG carriers have been operating commercially since 1959. Since then there have been more than 38,000 LNG carrier voyages, covering more than 60 million miles and transported a total of 1.5 billion cubic meters of LNG. Currently, approximately 352 LNG carriers safely transport more than 51,975,000 million cubic meters of LNG annually to ports around the world (Lloyd's, 2013). There have been approximately 11 reportable incidents between 1979 and 2006, worldwide. Because LNG has not been transported to the Pacific Northwest, no data are available. However, due to the double hulls of LNG carriers, none of the incidents that have occurred with LNG carriers have resulted in the loss of LNG cargo or other significant petroleum-based spills.

### Indirect Effects – Estuarine Analysis Area

Project-related effects to the Southern DPS of green sturgeon would be caused by the action (induced by the action as human presence and use increase), and are later in time or farther removed in distance, but are still reasonably foreseeable include the following indirect effects: 1) localized reduction of benthic and epibenthic invertebrates, 2) removal of eelgrass, and 3) shading the water surface by overhead structures.

Habitat Effects –Slip and Access Channel

Benthic and epibenthic invertebrates that presently inhabit shallow intertidal and subtidal regions within the boundaries of the proposed access channel dredging area would be removed with the dredged material. Ghost shrimp and sand shrimp (adults, juveniles and larvae), amphipods, clams, Dungeness crab, and various fish species are important prey for green sturgeon. Therefore, the loss of invertebrates and vertebrates at the access channel would result in a reduction in fish food available to green sturgeon in those areas affected by the Project.

As noted above, benthic communities in Coos Bay inhabiting mud substrates recovered to pre-dredging conditions in four weeks (Newell et al., 1998). Although the substrate proposed for maintenance dredging in the access channel and berth would largely be sand and silt, it is anticipated that recovery would occur within a similar time frame, resulting in only short-term effects to the benthic community and potential food resources for green sturgeon.

Habitat Effects – Pacific Connector pipeline

Construction of the pipeline across the Haynes Inlet of Coos Bay estuary would span 2.45 miles and disturb approximately 0.068 mile of eelgrass or 2.8 percent of that amount, most of which classified as low-density eelgrass beds. Eelgrass can be adversely affected by turbidity because the depth and distribution of eelgrass is strongly associated with water clarity and depth of light penetration (Dennison and Orth, 1993; Thom et al., 1998) as well as nutrient availability (Short et al., 1995), salinity, and water temperatures (Thom et al., 2003). Construction of the pipeline across the estuary is planned from October 1 through February 15 following ODFW's recommendation. During most of that period, eelgrass in Coos Bay would be dormant, coinciding with low temperatures and short photoperiods (Fonseca et al., 1998).

Shading Effects

Shading from over-water structures reduces the amount of light available to phytoplankton and aquatic macrophytes. However, the area where shading LNG terminal facilities would occur is intended for industrial uses and not the creation of new habitat. The general habitat in the slip's region would not be conducive for many marine resources because of depth and steep rip/raped armored banks, so relatively few resources would likely utilize this newly created area. The water areas within the slip are being created from upland areas and therefore shading of currently un-shaded habitat would occur, and no net loss in productivity due to shading would occur. Project components that potentially could shade the new open water created by the construction of the slip include:

- At the proposed slip, the access gangway to the LNG facility is narrow and well above the water surface and would have open mesh grating. Shade produced by the gangway is expected to be biologically insignificant.

- The unloading platform for the LNG facility is 60 feet wide and would be located at an elevation of +30 feet NAVD88. Because the platform is located offshore in deep water, no shading of shallow water habitat would occur.
- The tug dock is the only structure to be built over open water portion of the newly developed slip and it is 400 feet long by 12 feet wide. Shading would be minimized by open mesh grating, which is now commonly used on piers to reduce effects to marine resources from shading.
- The tug dock would be connected from shore by a narrow gangway. The dock would be 12 feet in width and located at +12 feet NAVD88. This too would have open mesh grating to reduce shading. Consequently, shading impacts would be small and probably insignificant.

Temporary underwater shading would also occur beneath the 1.3-mile long hydraulic slurry line to the Port's sand stockpile area. The slurry line would be floating offshore and would provide some shadow. It would be 20-inch diameter pipe and would total 0.3 acres of shade. It would be installed only during the in-water work window and would be used for a 4- to 6-month period, total. The pipe would be fused together on shore and would need minimal number of lines back to the onshore anchors. The anchor lines would not be the small size that one would find in a net, rather large enough to avoid potential entanglements.

Most fish, including coho salmon, have developed countershading as an adaptation to avoid predation (Moyle and Cech 2000) from above (dark dorsal surface blends with bottom substrate) and from below (light ventral surface blends with light from the surface). Fish within a shaded area would be more easily detected by a predator, especially from below because light colored ventral surfaces would stand out against a shaded water surface. Predation potential, based on some observed fish behavior, is a concern (Nightingale and Simenstad, 2001). However actual increased occurrence in predator numbers from even substantial overwater structures has rarely been documented. Additionally review of many marina and pier studies have not documented actual increased predation at these facilities (Nightingale and Simenstad, 2001). For example, marine marina studies have found no documentation of increased concentrations of juvenile salmonid predators and some predators such as birds may be of lower abundance than under natural shoreline conditions (Cardwell et al., 1980, and Heiser and Finn, 1970, as cited in NMFS, 2005c). The extent to which any of these predators affect juvenile green sturgeon in shaded areas created by the proposed action is unknown. But the actions taken (open mesh grating of all structures) should reduce the probability of this occurring.

**Cumulative Effects**

Additional projects within the action area (estuarine analysis area and the Port-terminal analysis area) are anticipated as human population growth continues in the region. Associated road and commercial development, as well as maintenance and upgrading of existing infrastructure within the Estuary, are likely to occur in the foreseeable future. For example, the Port of Coos Bay owns and operates the Charleston Marina, the Charleston Marina RV Park, and Charleston Shipyard. As a component of the Port's economic development, the focus of the Charleston Marina Master Plan is to develop commercial fishing and seafood processing, recreational fishing and boating, tourism, and growth in the retail and commercial sectors. Other, similar economic developments in the region could occur and, if they did, could contribute to the region's human population growth which could be detrimental to Southern DPS green sturgeon within and around the Coos Bay estuary.

A standard of “reasonably certain to occur” is clarified as “those actions that are likely to occur, bearing in mind the economic, administrative, or legal hurdles which remain to be cleared.” Further, NMFS provides that “speculative actions that are factored into the cumulative effects analysis add needless complexity into the consultation process…” (51 FR 19933). No specific state or private actions have been identified within the action area that meets this standard. Further, activities described above are somewhat speculative in nature and cannot be quantified here. Therefore, a logical conclusion is that there would be no cumulative effects to green sturgeon associated with the proposed action.

Within the action area and estuarine analysis area, gradual habitat and water quality improvements may also occur over time as federal, state and private conservation and habitat enhancement efforts are implemented. There are a number of potential federally permitted projects (e.g. repair of the entrance jetties and widening and deepening of the lower portion of the Coos Bay navigation channel) that could result in cumulative effects. However, since these projects would require federal permits, their impacts would be evaluated through the federal permitting process when and if they occur. As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of total vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2018 (see figure 4.2-4). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated total vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay. Consequently, cumulative effects to green sturgeon would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2017) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to green sturgeon may be more or may be less than the estimate of direct effects discussed above.

Releases of diesel fuel and/or gasoline by commercial and recreational vessels are possible. According to annual reports published by the Pacific States/British Columbia Oil Spill Task

Force (2002), ODEQ reported 34 spills from fishing vessels or other harbor craft in 2002, 38 spills in 2003, and 7 spills from fishing vessels plus spills from 27 other vessel types in 2004. Those relatively consistent incidences apparently increased in 2005 with 18 spills from fishing vessels, 20 from recreational vessels, and 27 spills by other vessel types. By contrast in 2006, there were 3 spills from fishing vessels, 6 spills from recreational vessels, and only 6 spills from other vessel types. Though not known, it appears that the background rate of spills off the Oregon coast (incidence of spills in proportion to total vessel operation) by fishing vessels, recreation vessels, and other vessel types is generally low. Based on existing information, future rates of off-shore releases are also expected to be low and potential for green sturgeon to be affected by contamination by oil and other pollutants is not expected to increase above existing levels.

**Critical Habitat**

Coos Bay has been included in estuarine critical habitat for the species. The Coos Bay estuary provides several primary constituent elements including food resources, migratory corridors (passage) between estuarine and marine habitats, sediment quality and water quality (NMFS, 2009b), all necessary to support various green sturgeon life stages. Similarly, coastal marine waters 110 m (60 fm) deep or less, between Coos Bay and San Francisco Bay provide food, passage, and water quality as PCEs. Within Coos Bay, NMFS (2009b) noted that inwater construction or alterations, point and non-point source pollution, and LNG projects could affect PCEs within the Coos Bay estuary portion of designated critical habitat. Project-related effects to Southern DPS green sturgeon within the Coos Bay estuary are likely to be similar to those discussed above including the following: 1) turbidity effects to forage/prey species and habitat by dredging the access channel, 2) turbidity effects to forage/prey species and habitat by construction of the Pacific Connector pipeline and disposal at Site F, 3) shading effects on marine plants, 4) introduction of exotic species, and 5) ship wake.

LNG carriers traveling within the EEZ parallel to the coasts of California and Oregon are expected to transit 50 nmi off shore. Ships entering and exiting Coos Bay and San Francisco Bay would coincide with depths of <110 m (<60 fm) for approximately 9 nmi (Coos Bay) to 23 nmi (San Francisco Bay), but depths off either approach are highly variable. During transits however, barges maintaining a course 12 nmi off the coastline would be in waters deeper than 110 m (60 fm) except for an approximate 18 nmi-long segment south of Point St. George near Crescent City, California. Effects to water quality within coastal marine waters could occur by loss of LNG cargo but the chances of spills are very small and, for most of the EEZ analysis area, would not coincide with proposed coastal marine critical habitat.

Site F is within coastal marine critical habitat for Southern DPS green sturgeon. It is assumed that the existing approved permit would remain valid for discharge at Site F or that the COE and EPA would be coordinating with NMFS to have their operating permits modified to allow for the continued disposal of dredge material at these sites.

### 4.5.1.4 Conservation Measures

Unavoidable effects to North American green sturgeon, Southern DPS include removal of eelgrass by the LNG slip and access channel and the construction dock and temporary eelgrass effects from the PCGP within Haynes Inlet of the Coos Bay Estuary. The Estuary is included as designated critical habitat for the North American green sturgeon, Southern DPS.

The estuarine effects associated with Jordan Cove include 2.5 acres of eelgrass, 3.37 of shallow subtidal, 9.65 acres of intertidal, 0.20 acre of salt marsh, and 15.4 acres if deep subtidal. The estuarine effects will result from construction of the barge berth, slip and access channel, Trans Pacific Parkway/Highway 101 intersection improvements, power plant, and North Point Workforce Housing. Effects will be offset by wetland restoration mitigation at a former golf course. This area is now known as the Kentuck wetland mitigation site. The loss of the 2.5 acres of eelgrass by construction and operation of the LNG terminal will be mitigated at an offsite proposed eelgrass mitigation location south of the west end of the Southwest Oregon Regional Airport; at this site approximately 7.50 acres of new eelgrass habitat will be created. Alternative eelgrass mitigation sites are currently being evaluated, with one of those areas being in Jordan Cove.

The interim loss of the 13.02 acres of unvegetated mud flat (intertidal and shallow subtidal habitats) would be restored at a 3:1 ratio. Restoration would occur at the Kentuck Slough golf course, east of North Bend, where a portion of the golf course would be converted to intertidal and mudflat habitat to offset the estuarine impacts. Conversion would require removing existing levees and removing tide gates, actions that will reestablish tidal connections between former intertidal habitat within the golf course and Kentuck Slough. The Proponents also propose wetland mitigation to offset the effects on freshwater wetlands associated with the development of the LNG terminal site, power plant site, and utility corridor and access road between the LNG terminal and power plant (see attachment 9 to appendix O).

The 5.0 acres of eelgrass temporarily affected by the pipeline would be restored onsite at a 1:1 ratio (see attachment 7 to appendix O).

#### 4.5.1.5 Determination of Effects

**Species Effects**

The Project **may affect** green sturgeon (Southern DPS) because:

- Adult and/or subadult green sturgeons may occur within the estuarine analysis area during construction and operation of the proposed action;
- Adult and/or subadult green sturgeons may occur within the EEZ analysis area during operation of the proposed action;
- The proposed action may affect potential food resources and water quality during the short-term construction period and biennial maintenance dredging within the estuarine and nearshore marine analysis area;
- The discharge at Site F may directly entrap small subadults during biennial dredge and discharge at this marine location;
- The proposed action may affect water quality during the long-term operation period within the EEZ analysis area.

Some project components are **likely to adversely affect** southern green sturgeon, including:

- Bottom disturbance from project construction and biennial maintenance dredging may reduce benthic food supply within Coos Bay and at Site F;
- Discharge of dredge spoils biennially at Site F may trap small subadults that are present during biennial sediment discharge to this site.

**Critical Habitat Effects**

The Project **may affect** critical habitat for the green sturgeon (Southern DPS) because:

- The estuarine analysis area includes the Coos Bay estuary which is included as estuarine critical habitat;
- The EEZ analysis area includes coastal marine waters 110 meters (60 fm) deep or less, between Monterey Bay and Coos Bay and between Coos Bay and Strait of Juan de Fuca, which have been included as Nearshore Marine critical habitat.

While several project actions are not likely to cause adverse effects to critical habitat, some effects from project components **are likely to adversely affect** critical habitat for southern green sturgeon because:

- Bottom disturbance from project construction and biennial maintenance dredging may disrupt local food supply and habitat usability within Coos Bay;
- Discharge of dredge spoils at Site F may also reduce local food sources and have repeated short term reduction of usability during discharge from elevated turbidity.

## 4.5.2 Pacific Eulachon (Southern Distinct Population Segment)

### 4.5.2.1 Species Account and Critical Habitat

**Status**

NMFS was petitioned on July 16, 1999 to list and designate critical habitat under the ESA for Columbia River populations of Pacific eulachon (Columbia River smelt) in 1999. NMFS (1999a) found that although eulachon catches within the Columbia River basin had recently declined, substantial scientific information was lacking to support the petition (NMFS 1999a). In 2007, the Cowlitz Indian Tribe petitioned NMFS to list the eulachon population south of the U.S./Washington-Canada Border as threatened or endangered under the ESA (Cowlitz Indian Tribe, 2007). The NMFS found that the 2007 petition did provide sufficient information to warrant delineation of a Distinct Population Segment (DPS) for the eulachon south of the U.S./Washington-Canada Border and that this population had substantially declined in abundance (NMFS, 2009c).

NMFS listed the eulachon (Columbia River smelt), Southern DPS, as threatened in 2010 (NMFS, 2010d). The Southern DPS includes eulachon spawning in rivers from California into British Columbia (NMFS, 2008c).

**Threats**

Five primary threats to the eulachon included 1) climate change impacts on ocean conditions, 2) climate change impacts on freshwater habitat, 3) eulachon by-catch in offshore shrimp fisheries, 4) dams and water diversions in the Klamath and Columbia Rivers, and 5) predation in the Fraser and British Columbia coastal rivers (NMFS, 2008c).

The most serious threat recognized throughout the four subareas is climate change impacts on ocean conditions. This is closely followed by climate change impacts on freshwater habitat and eulachon by-catch in offshore shrimp fisheries. Additional threats cited include dams and water diversions in the Klamath and Columbia Rivers and predation in the Fraser and British Columbia coastal rivers (NMFS, 2008c).

**Species Recovery**

No recovery plan has been published but NMFS recently produced a Recovery Outline, Eulachon Southern DPS (NMFS, 2013b). The preliminary recovery strategy includes research and monitoring actions that include but are not limited to the following: 1) estimating long-term spawner abundance, 2) survival of larval eulachon, 3) evaluating importance of the tidal freshwater, estuary, plume, and nearshore ocean environments to the viability and recovery of eulachon in the Klamath, Columbia, and Fraser Rivers, 4) determining the significance of plume and ocean conditions that affect eulachon survival, 5) developing a marine abundance survey for eulachon and correlation with riverine abundance estimates, 6) determining the significance of climate-related impacts on ocean conditions that affect eulachon survival, and 7) determining the significance of water quality degradation by potential contaminants on eulachon recovery potential). Preliminary management recovery actions include: 1) maintaining a conservative fisheries program, 2) regulating catch size for the pink shrimp fisheries, 3) enhancing flows and water quality in the Columbia River to improve eulachon survival in plume and nearshore ocean environments, 4) maintain dredging and disposal BMPs on the Columbia River Navigation Channel Operations and Maintenance Dredging Program, 6) continue removal of Klamath River dams, monitor eulachon by-catch rates in trawl fisheries, and 7) establish better inter- and intra-agency coordination regarding scientific research conducted on eulachon.

**Life History, Habitat Requirements, and Distribution**

Pacific eulachon are an anadromous smelt and are endemic to the northeastern Pacific Ocean. They range from northern California to southwest and south-central Alaska and into the southeastern Bering Sea (NMFS, 2013b). Adult eulachon usually spend three to five years in saltwater before returning to fresh water to spawn from late winter though early summer (NMFS, 2009c). Eulachon generally spawn at night in rivers that are glacier-fed and/or have peak spring freshets, and it has been suggested that imprinting is confined to an estuary not a specific individual spawning river (Hay and McCarter, 2000). The typical spawning temperature is from $4^{o}$ to $10^{o}$ C in the Columbia River and tributaries and from $0^{o}$ to $2^{o}$ C in the Nass River (NMFS, 2009c).

Spawning time is mostly likely dependent on geographic location, with those individuals in the southern part of the range spawning earlier than their northern counterparts. Eulachon spawn earlier in southern portions of their range than in rivers to the north. River-entry and spawning begins as early as December and January in the Columbia River system (NMFS, 2008c). Reports have indicated spawning beginning in January in rivers of the Copper River Delta of Alaska and in May in North California. Within coastal British Columbia, the typical pattern is reversed, with spawning occurring as early as February in the Nass River and the latest spawning occurring in April and May in the Fraser River. Data also supports the evidence of waves or runs of eulachon spawning in some basins (Hay and McCarter, 2000). Most eulachon adults die after spawning.

Eulachon spawn earlier in southern portions of their range than in rivers to the north. River-entry and spawning begins as early as December and January in the Columbia River system (NMFS, 2008c). Most eulachon adults die after spawning. Euchalon sexes must synchronize their activities closely because eulachon sperm remain viable for only a short time, estimated to be minutes (Hay and McCarter, 2000). Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. After leaving estuarine rearing areas, juvenile eulachon move from shallow near shore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, with fish found mostly at depths up to 15 m (50 feet) but sometimes as deep as 182 m (600 feet) (Hay and McCarter, 2000).

Unlike other group spawners, the sexes must synchronize their activities closely because eulachon sperm remain viable for only a short time, estimated to be minutes (Hay and McCarter 2000). Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Eulachon eggs hatch in 20 to 40 days, with incubation time dependent on water temperature. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine and ocean currents (NMFS, 2009c).

After leaving estuarine rearing areas, juvenile eulachon move from shallow near shore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, with fish found mostly at depths up to 15 m but sometimes as deep as 182 m (Hay and McCarter, 2000). There is currently little information available about eulachon movements in near shore marine areas and the open ocean.

Eulachon larvae and post-larvae eat phytoplankton, copepods and their eggs, mysids, barnacle larvae, worm larvae, and other eulachon larvae (NMFS, 2009c). Adults and juveniles commonly forage at moderate depths (15 to 182 m) in inshore waters, feeding on zooplankton, primarily eating crustaceans (Hay and McCarter, 2000). With their high lipid content and massing during spawning runs, eulachon are an important part of the Pacific coastal food web. Eulachon are prey to numerous fish, avian species, marine mammals, and terrestrial mammals (NMFS, 2009c).

Historically, the eulachon distributions correspond closely with the EPA's Coastal Range Ecoregion which extends from the Olympic Peninsula through the Coast Range and down to the Klamath Mountains and the San Francisco Bay Area. Streams within this region exhibit two distinct annual flow patterns: 1) streams draining coastal watersheds, where winter rain storms are common, have high flow periods coinciding with these storms; 2) streams draining more interior areas, such as the Columbia and Cowlitz Rivers, have a distinct spring freshet period coinciding with snow melt. Eulachon production is highest in these latter systems (NMFS. 2009c).

**Population Status**

The Columbia River has historically shown the largest returns of spawning population throughout the eulachon's range. A review of records has shown that eulachon spawning runs from California to southeastern Alaska have declined in the past 20 years, with a significant trend observed since the mid 1990s (Hay and McCarter 2000). From 1938 to 1992, the median commercial catch of eulachon in the Columbia River was approximately 1.9 million pounds. From 1993 to 2006, the median catch had declined to approximately 43,000 pounds, representing a 97.7 percent reduction in catch from the prior period. Despite a short increasing trend noted for the Columbia River from 2001-2003, recent catches remain lower than the historical median (Cowlitz Indian Tribe, 2007).

Similar trends were noted by the Cowlitz Indian Tribe for tributaries of the Columbia River in Oregon and Washington, as well as Fraser River; a rapid decline in the mid-1990s, increasing returns during 2001-2003, and a recent decline to low levels (NMFS, 2008c). The 2007 petition noted that the eulachon is most likely extirpated or nearly so in the Klamath River, Mad River, Redwood Creek, and Sacramento River (Cowlitz Indian Tribe 2007; NMFS, 2008c).

### Critical Habitat

Critical habitat for Pacific eulachon was designated in 2011 (NMFS, 2011e). Critical habitat for eulachon includes freshwater creeks and rivers and their associated estuaries comprising approximately 335 miles of habitat within in 16 specific estuarine and freshwater areas in California, Oregon, and Washington. Essential to the conservation of the species are physical and biological features of freshwater spawning and incubation sites include water flow, water quality, water temperatures, suitable substrate for spawning and incubation, and migratory access for adults and juveniles. The physical and biological features of freshwater migration corridors include water flow, water quality and water temperatures to support larval and adult mobility; abundant prey items to support larval feeding (NMFS, 2011e).

Activities that may affect the physical and biological features essential to the southern DPS of eulachon include: 1) dams and water diversions; 2) dredging and disposal of dredged material; 3) inwater construction or alterations; 4) pollution and runoff from point and non-point sources; 5) tidal, wind, or wave energy projects; 6) port and shipping terminals; and 7) habitat restoration projects (NMFS, 2011h). These activities may have an effect on one or more of the essential physical and biological features by altering alteration of one or more of the following: 1) stream hydrology, 2) water level and flow, 3) water temperature, 4) dissolved oxygen, 5) erosion and sediment input/transport, 6) physical habitat structure, 7) vegetation, 8) soils, 9) nutrients and chemicals, 10) fish passage, and 11) estuarine/marine prey resources (NMFS, 2011e).

## 4.5.2.2 Environmental Baseline

### Analysis Area

Two analysis areas are applicable to effects determinations for eulachon in the Southern DPS. The Estuarine analysis area includes 1) operational activities by LNG ships entering and existing Coos Bay, 2) construction-related effects to approximately 3.1 miles downstream from the proposed slip and LNG terminal to a point 2.2 miles upstream from that site (distances were estimated for potential worst-case dispersion of turbidity, as provided by Moffatt and Nichol, 2006), and 3) the crossing of the Haynes Inlet portion of Coos Bay by the Pacific Connector Pipeline (see figure 4.3-6 under section 4.3.3.2 marbled murrelet). Euchalon occur within marine waters off-shore and within the EEZ analysis area where they could be affected by 1) spills and accidental releases, and 2) discharge of sediment at Site F (see figure 4.2-1 and the discussion above under section 4.2.1.3 blue whale).

### Species Presence

Although Coos Bay is within the historic range of the eulachon, south of the Columbia River mouth, eulachon have been identified in very few coastal streams (Cowlitz Indian Tribe, 2007). Adults are found rarely in Coos Bay (NMFS, 1999a) and spawning runs have not been documented for the Coos River. The BRT review of status of eulachon also concluded that their presence in Coos Bay was "rare" (NMFS, 2008c). Observations of adult eulachon have been reported from the Umpqua and Rogue rivers, Oregon (Emmett et al., 1991).

### Habitat

Coos Bay is known to occasionally support adult populations of eulachon (NMFS, 1999a). When present, eulachon may utilize both shallow and deep water habitats within the estuary. Eulachon were captured in beach seine hauls in the Coos River estuary, June through September (NMFS, 2008c).

### Critical Habitat

Small numbers of eulachon have been observed in a few coastal rivers and creeks in Oregon, including historical accounts of their occurrence in the Siuslaw River, Coos Bay, and Rogue River estuaries (NMFS, 2008c). Critical habitat has been designated within the Lower Umpqua River. Eulachon apparently spawn and migrate within the lower Umpqua River from the mouth upstream to below the confluence with Mill Creek (NMFS, 2011e). No critical habitat has been designated within the Coos Bay Estuary or within the EEZ analysis area.

## 4.5.2.3 Effects by the Proposed Action

Some of the Project effects to Pacific eulachon, Southern DPS would be similar to those described above for North American green sturgeon.

### Direct Effects – Estuarine Analysis Area

Project-related effects to the Southern DPS of Pacific eulachon would be caused by the action and occur at the same time and place, including the following direct impacts within the estuarine analysis area: 1) turbidity effects from dredging the slip and access channel, 2) turbidity effects from LNG vessel propeller wash and ship wake, 3) turbidity effects from constructing the Pacific Connector pipeline within the estuary, 4) stranding eulachon by LNG vessel propeller wash and ship wake, 5) introduction of exotic, invasive species from ballast water, 6) entrainment and impingement of eulachon in LNG carriers' intake port, 7) estuary water cooling during LNG carrier cargo loading, 8) potential effects by effects by operational lighting, and 9) acoustic effects to eulachon during LNG terminal construction.

Timing

In-water construction of the JCE and PCGP Project within the Coos Bay estuary is planned from October 1 through February 15 following ODFW's recommendation. Because no spawning occurs in freshwater tributaries to Coos Bay, the estuary most likely provides incidentally occupied habitats for eulachon. Seasonal presence of eulachon in the estuary has not been definitively documented but fish have been reported captured in the estuary from June through September (NMFS, 2008c). If those reports are indicative of their seasonal occurrence, in-water construction would not coincide with eulachon presence.

Turbidity

Turbidity could be generated during dredging, by LNG propeller wash and ship wake, and during construction of the PGCP Project across Haynes Inlet (see discussion of direct impacts to green sturgeon within the estuarine analysis area, above). If present during in-water construction work and coincidental with LNG carriers, eulachon would be expected to avoid the LNG ships in the channel by using the shallow areas of the channel that the LNG ships are not able to use. Given the deep and shallow water habitats available, there is a low likelihood that there would be a significant impact on eulachon in Coos Bay, should they occur. The effects of ship traffic on spawning runs is not one of the threats listed by the NMFS for the eulachon, which further supports the low likelihood of adverse impacts that would be due to the Project.

Other Effects within the Estuarine Analysis Area.

Stranding of eulachon is by ship wake is possible but unlikely. The size of eulachon expected in the estuary would be 20 to 30 cm (Moyle, 2002), considerably larger than sizes of juvenile chinook salmon (<9 cm) stranded by ship wakes in the Columbia River (Pearson et al., 2006) and may not be susceptible to stranding by ship wake. Other direct impact to eulachon within the estuarine analysis area, are not expected to be adverse effects, similar to the discussions for green sturgeons in relation to introductions of exotic, invasive species from ballast water, entrainment and impingement of eulachon in LNG carriers' intake port, effects of estuary water cooling during LNG carrier cargo loading, potential effects by effects by operational lighting, or acoustic effects to eulachon during LNG terminal construction.

**Direct Effects – EEZ Analysis Area**

Project-related effects to the Southern DPS of green sturgeon would be caused by the action and occur at the same time and place, including the following direct impacts within the within the EEZ analysis area could include: 1) sediment discharge at Site F, and 2) spills and releases of LNG at sea.

Turbidity at Site F

Discharge of the maintenance dredging at Site F, about 1.6 miles off the mouth of Coos Bay, would generate a turbidity plume that could affect green sturgeon within the EEZ analysis area. Turbidity generated from discharge at Site F would be rapidly dissipated and may cause some short-term avoidance of the area by eulachon during discharge. There is the possibility that eulachon if they were present directly under the sediment discharge from the barge or ship would be unable to dart out of the plume of sediment and become trapped in the sediment during active discharge.

Release and Fire at Sea

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales and Section 4.3.3.3 for marbled murrelets. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface (Hightower et al., 2004). The cooling effects of the LNG plume on submerged eulachon are unknown but are expected to be localized at the surface. Similarly, effects of a fire on prey species would likely be very limited to the ocean – LNG pool interface. Neither the LNG pool nor an ensuing fire would be expected to adversely affect eulachon.

**Cumulative Effects**

Cumulative effects include the effects of future state, tribal, local or private actions that are reasonably certain to occur in the action area considered in this BA. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

As discussed above for blue whales, available information indicates that ship calls to the Port of Coos Bay have been declining since 2002. The observed declining linear trend in total annual vessel traffic over time is significant and, when used to forecast numbers of total vessel calls to Coos Bay in the future, no vessels are predicted to enter Coos Bay in 2018 with between 0 and 17.6 vessels as reasonably foreseeable when the LNG terminal is expected to begin operation in 2017 (see figure 4.2-4). And as discussed above for blue whales, it appears that the background rate of spills off the Oregon coast by fishing vessels, recreation vessels, and other vessel types is generally low, a frequency that would be expected to continue.

The foreseeable cumulative effect of 90 LNG carriers per year with anticipated total vessel traffic in 2018 would be less than effects based on past or present levels of vessel traffic calls to the Port of Coos Bay. Consequently, cumulative effects to fin whales would likely be less than the estimate of direct effects discussed in the previous section. Those effects were judged to be insignificant and discountable.

The volume of annual vessel transits within the EEZ of California, Oregon, and Washington is related to numbers of vessel calls to ports in those states. Total annual calls for all vessels at ports in California, Oregon, and Washington (MARAD, 2013) were plotted above in figure 4.2-2 for 2002 through 2011. Unlike the trend analyzed for calls to Coos Bay (see figure 4.2-4) the observed linear trend in annual vessel traffic (port calls) along the U.S. West Coast was significantly increasing at a rate of 2.1 percent per year between 2002 and 2007. The increasing trend was interrupted by the global economic crisis in 2008 but data through 2011 indicate a return to the established increasing trend prior to 2008. The pre-2008 trend predicts 21,530 vessel calls to West Coast ports in 2018 (with 95% prediction intervals ranging from 17,360 to 25,710 vessel calls), the year the JCEP and PCGP projects are expect to be in service. Even with the uncertainty generated by available data, there is a reasonably foreseeable increasing trend, albeit imprecise, for vessel traffic volume in the future (by 2018) although unforeseen global events such as future economic crises could influence the predictions. Cumulative effects of 90 LNG carriers per year to eulachon may be more or may be less than the estimate of direct effects discussed above.

Releases of diesel fuel and/or gasoline from non-project related vessels are possible in the foreseeable future. According to annual reports published by the Pacific States/British Columbia Oil Spill Task Force, Oregon DEQ reported 34 spills from fishing vessels or other harbor craft in 2002, 38 spills in 2003, and 7 spills from fishing vessels plus spills from 27 other vessel types in 2004. Those relatively consistent incidences apparently increased in 2005 with 18 spills from fishing vessels, 20 from recreational vessels, and 27 spills by other vessel types. By contrast in 2006, there were 3 spills from fishing vessels, 6 spills from recreational vessels, and only 6 spills from other vessel types. Though not known, it appears that the background rate of spills off the Oregon coast (incidence of spills in proportion to total vessel operation) by fishing vessels, recreation vessels, and other vessel types is generally low and expected to continue at low frequencies in the foreseeable future.

**Critical Habitat**

Critical habitat has been designated for this species but no critical habitat would be affected by the Proposed Action.

### 4.5.2.4 Conservation Measures

Measures developed for application within the Estuarine analysis area to conserve green sturgeon would also benefit the eulachon southern DPS if they are present within the estuarine analysis area during construction and operation of the Project.

### 4.5.2.5 Determination of Effects

**Species Effects**

The Project **may affect** Pacific eulachon (Southern DPS) because:

- Eulachon may be present within the estuarine analysis area during construction and operation of the Project;

- Eulachon may occur within the EEZ analysis area during operation of the proposed action;
- The proposed action may affect potential food resources and water quality during the short-term construction period and maintenance dredging within the estuarine and nearshore marine habitats in the EEZ analysis area;
- The discharge at Site F may directly entrap adults during dredge and discharge at this marine location;
- The proposed action may affect water quality during the long-term operation period within the EEZ analysis area.

Project components are **not likely to adversely affect** Pacific eulachon (Southern DPS), because:

- Bottom disturbance from project construction and biennial maintenance dredging may reduce benthic food supply within Coos Bay and at Site F although there is no documentation to suggest that eulachon would be present at either location;
- The possibility that discharge of dredge spoils at Site F every three years would entrap adults is very remote and discountable.

**Critical Habitat Effects**

The Project will have **no effect** on critical habitat for the Pacific eulachon (Southern DPS) because m designated critical habitat is present within the estuarine analysis area.

### 4.5.3 Coho Salmon (Southern Oregon Northern California Coast ESU)

#### 4.5.3.1 Species Account and Critical Habitat

**Status**

The Southern Oregon Northern California Coast (SONCC) ESU coho salmon was listed as a threatened species in 1997 (NMFS, 1997c). The SONCC coho ESU includes all coastal tributaries to the Pacific Ocean between Punta Gorda, California and Cape Blanco, Oregon. It includes all naturally spawning populations as well as three artificial propagation programs, of which one, the Cole Rivers Hatchery (ODFW stock #52) located on the Rogue River, is within the PCGP Project area. At the time of listing, less than 10,000 naturally reproducing SONCC coho were estimated (NMFS, 1997c).

**Threats**

At the time the SONCC coho salmon ESU was proposed for listing, various factors were included as threats to West Coast salmon populations in general but were not specific to the SONCC ESU. Logging, agricultural practices, urbanization, stream channelization, dams, wetland loss, water withdrawals with unscreened diversions for irrigation, and mining were at the start of the list of threats (NMFS, 1995a). Pathways initiated by those actions and leading to impact included soil erosion and stream sedimentation (logging and road networks), degradation of riparian zones and increased water temperatures, decreased recruitment of large woody debris (LWD) in streams and decreased habitat complexity, damage to riparian vegetation by livestock grazing, and pollution by agriculture and urbanization. Overharvest by commercial and recreational fisheries as well as disease, drought, warming ocean temperatures, and artificial propagation with associated impact of hatchery populations on wild stock have been contributory threats to all West Coast salmon (NMFS, 1995a).

NMFS published a status review in 1995 that included the SONCC coho salmon ESU (Weitkamp et al., 1995). In that document, all coho salmon populations in the ESU were depressed. In the Rogue River, wild coho salmon were heavily affected by hatchery production with little natural production in the mainstem. The declining trend of coho salmon was indicative that natural populations in the Rogue River and others within the ESU were not self-sustaining (Weitkamp et al., 1995).

NMFS published a more recent status review in 2005 (Good et al., 2005). Though coho salmon populations continue to be depressed within the ESU as a whole, the Rogue River stock has demonstrated a recent average increase in numbers of spawners. While the Rogue River run includes hatchery fish, and hatchery releases from the Cole Rivers hatchery have been relatively consistent between 1987 and 2002 (see Table 76 in Spence et al., 2005), those fish are Rogue River coho salmon (with no out-of basin fish) for which propagation began in 1973 to mitigate for impact due to construction of Lost Creek Dam (Spence et al., 2005). Consequently there is reduced genetic risk to wild stock in the Rogue River. Ocean harvest of the Rogue-Klamath stock by commercial and recreational fishers has been controlled since 1999 (not to exceed 13 percent) and river harvest within the ESU has not been allowed since 1994 (with tribal harvests excepted).

Most recently, NMFS (2012d) released a draft recovery plan for SONCC coho salmon that identified ten stress, or limiting, factors and 13 threats to various life-stages for coho in the Upper Rogue River population. Limiting factors or stresses that were determined to be very high to all life stages included 1) altered hydrologic function primarily due to reservoirs constructed to support irrigated cropland and ground water depletions for a variety of uses, 2) degraded riparian forest conditions caused by removal of large conifers, channelization, wetland drainage, and other alterations, 3) impaired water quality, principally due to increased water temperature (from lower water flows, removal of riparian trees) with lower dissolved oxygen, 4) lack of floodplain and channel structure (channelization and reduction of slow, cool edgewater habitats where coho fry and juveniles thrive), and 5) altered sediment supply from roads, timber harvest, and bank erosion following removal of riparian vegetation causing elevated fine sediment input (NMFS, 2012d). In addition, barriers to upstream migrations by small temporary agricultural dams, large diversion dams, and seasonal loss of stream flow in tributaries such as Trail Creek are a key limiting factor for the population.

Threats to all life stages having very high or high severity rankings contribute to the limiting factors discussed, above. Severe threats to the Upper Rogue River population include 1) roads and high road densities that cause chronic fine sediment and increase probabilities of landslides, 2) urban-residential-industrial developments have lead to channelization, increased non-point source storm water pollution, and resulted in loss of aquatic system function, 3) channelization-diking have impaired floodplain functions, constricted channels, and reduced surface-groundwater connections that adversely affect water temperatures and salmon carrying capacities, 4) timber harvest causing early seral stage forests and high road densities in riparian zones, 5) agricultural dams and diversions that impede upstream adult salmon passage or strand downstream-migrating juveniles, if fish screens are not in place, 6) gravel extraction has altered river channels, formed new ones, and degrading formerly productive coho salmon rearing habitats, and 7) climate change which will likely cause increased regional average temperatures over the next 50 years and is leading to ocean acidification which will affect numerous marine habitat conditions, including prey availability (NMFS, 2012d).

Historically, the SONCC coho salmon ESU inhabited the Upper Klamath Basin. However, construction of the Copco 1 Dam on the mainstem Klamath River in 1918, followed by construction of the Copco 2 Dam in 1925 and the Iron Gate Dam in 1962 were impassible to anadromous fish. Prior to construction of the dams, anadromous fish including SONCC coho salmon potentially could utilize over 600 miles of spawing, incubation, and rearing riverine habitats upstream from Iron Gate Dam (Hamilton et al., 2005). The historical extent of coho salmon upstream from Iron Gate Dam is believed to be Spencer Creek (Hamilton et al., 2005), which would have coincided with the Pacific Connector pipeline if not for the downstream barriers. Currently, the Upper Klamath River coho salmon population of coho salmon is not viable and at high risk of extinction according to the population viability criteria. Summer and winter rearing habitat is in poor condition in many areas and is limited in its extent and connectivity. Mainstem conditions during the summer are prohibitive for migration and rearing and hatchery influences on the population are very high. Overall, the removal of the four mainstem Klamath River dams up to Keno Dam is the most significant action that can be taken 15 to restore the viability of the Upper Klamath population unit. (NMFS, 2012d).

In 2008 the Oregon Fish and Wildlife Commission approved a plan to initiate effort to re-establish anadromous fish into the Oregon portion of the Klamath River Basin. Although there is no definite timetable, this could result in the ESA-listed SONCC coho salmon being present in the Klamath River system at some point in the future. Actual introduction would be unlikely to occur prior to pipeline construction.

**Species Recovery**

A draft recovery plan was released in 2012 for public review and input (NMFS, 2012d). The draft plan addressed limiting factors and threats to each coho population within the SONCC ESU including those within the Upper Rogue River population (see discussion under Threats, above). The draft plan calls for immediate habitat restoration and threat reduction in areas currently occupied by coho salmon in Evans, Trail, Elk, Big Butte, and Little Butte creeks. The greatest factor limiting recovery of coho salmon in the Upper Rogue River is the lack of suitable rearing habitat for juveniles (NMFS, 2012d). Consequently, recovery actions create and maintain juvenile rearing habitat must be restored by restoring flow, increasing habitat complexity within the channel, restoring off-channel rearing areas, and reducing threats to instream habitat.

The following actions have been proposed: 1) reconnecting channels with floodplains, 2) increasing channel complexity, 3) improving flow timing and volumes, 4) improving fish access, 5) improving large wood recruitment, bank stability, shading, and food subsidies, 6) reducing predation and competition from non-native fish species, 7) improving estuarine habitat, 8) manage fisheries consistend with recovery of SONCC coho salmon, 9) manage scientific collection consistent with recovery of SONCC coho salmon, 10) track population abundance, spatial structure, productivity, or diversity, 11) track habitat condition, 12) reduce delivery of sediment to streams, and 13) reduce pollutants.

**Life History, Habitat Requirements, and Distribution**

Five life phases are generally recognized for the coho salmon: juvenile rearing, juvenile migration, growth and development, adult migration, and spawning. Juvenile summer and winter rearing areas and spawning areas are often located in small headwater streams. Juvenile migration corridors, adult migration corridors, and spawning areas are found in tributaries as well as mainstream reaches and estuarine zones. Growth and development to adulthood happens primarily in near- and offshore marine waters. Final maturation takes place in freshwater tributaries when the adults return to spawn (NMFS, 1999b). Typically coho salmon begin their spawning migration as 3 year olds in late summer and fall and spawn by mid-winter. Eggs incubate for 1.5 to 4 months and then hatch. Juveniles rear for about 15 months in freshwater before migrating in spring to the ocean. They generally spend two growing seasons within the ocean before migrating back to their natal stream to spawn (NMFS, 1997d).

Adult coho salmon rarely migrate farther up freshwater streams greater than 150 miles and generally return to spawn at sites where they hatched. Returning to parental spawning grounds ensures repeated use of suitable redd sites (Sandercock, 1991). Straying (movements in non-natal stream systems), has been documented. In streams with deteriorated habitat such as low water flow, straying rates up to 50 percent have been documented (Sandercock, 1991).

Preferred water temperatures during adult coho salmon upstream migration range between 7.2$^{o}$C and 15.6$^{o}$C (45$^{o}$F to 60$^{o}$F) with an upper lethal limit for adult coho salmon of 25.8$^{o}$C or 78 $^{o}$F (Table 3 in Laufle et al., 1986). Preferred coho salmon spawning temperatures range from 4.4$^{o}$C to 9.4$^{o}$C (40$^{o}$F to 49$^{o}$F) while temperatures between 4.4$^{o}$C to 13.3$^{o}$C (40$^{o}$F to 56$^{o}$F) during egg incubation are preferred; the warmer the temperature, the less time before eggs hatch. The preferred range for juvenile survival systems is between 11.8$^{o}$C to 14.6$^{o}$C (53$^{o}$F to 58$^{o}$F) (Laufle et al. 1986). Elevated temperatures in streams may lead to early smoltification and ultimately premature migration towards sea during unfavorable conditions for young coho salmon (McMahon, 1983).

Productive coho salmon streams are those that have a riffle to pool ratio of close to 1:1. Smaller streams are preferred over larger rivers due to the higher proportion of slack water to midstream area (Sandercock, 1991). Substrate composition and riffles are other factors, along with terrestrial vegetation, that are important for producing aquatic and terrestrial insects which are food for coho salmon. Benthic invertebrate production is best in rubble, followed by bedrock, gravel, and sand. Coho salmon parr abundance is greatest in larger deeper pools where they can find cover near the streambank from logs, roots, debris, undercut banks, and overhanging vegetation (McMahon, 1983).

Adult coho salmon require minimum water depths of 0.18 meters or 7 inches (Laufle et al., 1986) during upstream migration. Redd sites are found in waters at least 15 cm (5.9 inch) deep, though once hatched, coho salmon fry and parr prefer water at least 0.30 meters (1 foot) deep (McMahon, 1983). During adult migrations upstream to spawn, water velocities less than 2.44 meters per second (m/sec; 8 feet/sec) are most desirable. At spawning grounds, coho salmon select redd sites where flows range between 5.0 and 6.8 cubic meters per minute ($m^3$/minute; 177 to 240 cubic feet per minute [$ft^3$/minute] or from 3 to 4 cubic feet per second [cfs]), and where stream width does not exceed 1 meter or 3.2 feet (Sandercock, 1991). For adult migration upstream, dissolved oxygen (DO) concentrations exceeding 6.3 mg/l are preferred (McMahon 1983). Incubation of eggs is best near DO saturation concentrations and weight gains by fry are maximized in water with DO concentrations between 4 and 9 mg/l (Laufle et al., 1986).

Spawning substrate is gravel size between 1.3 and 10.2 cm (0.5 to 4 inches) (Laufle et al., 1986). Gravels less than 16 cm (6.3 inches) account for 85 percent of redd sites (Sandercock, 1991). Average coho salmon redd size is 2.8 $m^2$ (30 $ft^2$); the recommended area per spawning pair is

11.7 $m^2$ or 126 $ft^2$ (Laufle et al., 1986). Egg survival to fry emergence has a positive correlation with gravel sizes between 3.35 mm and 26.9 mm (0.13 to 1.06 inches). For successful fry emergence, not more than 15 percent of the substrate should be fine sediment (McMahon 1983) because higher concentrations of fines may lead to earlier fry emergence, smaller fry, and fry with more yolk (Sandercock, 1991). Silt loads less than 25 mg/l are preferable for survival of eggs and juvenile coho salmon (Laufle et al., 1986).

Coho salmon diets in freshwater differ between locations and seasons, though young coho salmon feed mainly on aquatic and terrestrial insects, becoming more piscivorous as they grow (McMahon 1983). After emergence, fry feed mostly on various life stages of aquatic insects including dipterans (true flies), ephemeropterans (mayflies), plecopterans (stoneflies), and others as well as crustaceans and fish (Laufle et al., 1986). In the West Fork Smith River in Douglas County (Oregon), diets of juvenile coho salmon (from December through May) were mostly benthic invertebrates (larval dipterans, ephemeropterans, limnephilid caddisflies, and plecopterans), but also included salmon eggs, aquatic snails, salamanders, and terrestrial invertebrates (Olegario, 2006).

Major rivers, estuaries, and bays known to support coho salmon within the range of the SONCC ESU include the Rogue River, Smith River, Klamath River, Mad River, Humboldt Bay, Eel River, and Mattole River (NMFS, 1999b), of which the Rogue and Klamath Rivers are within the Pacific Connector pipeline area. Historically, SONCC coho inhabited the Upper Klamath Basin. However, construction of the Copco 1 Dam on the mainstem Klamath River in 1918, followed by construction of the Copco 2 Dam in 1925 and the Iron Gate Dam in 1962 were impassible to anadromous fish. Prior to construction of the dams, anadromous fish including SONCC coho salmon potentially could utilize over 600 miles of spawning, incubation, and rearing riverine habitats upstream from Iron Gate Dam (Hamilton et al., 2005). The historical extent of coho salmon upstream from Iron Gate Dam is believed to be Spencer Creek (Hamilton et al., 2005), which would have coincided with the Pacific Connector pipeline if not for the downstream barriers.

Specific timings of life history phases for SONCC coho salmon within the pipeline area are shown in figure 4.5-2. Included are the Rogue River mainstem and Upper Rogue River tributaries from Marial Creek to Lost Creek. Evident in figure 4.5-2 is the general synchrony in life phases within the mainstem and tributaries. Peak occurrence of juvenile out-migration lasts longer in tributaries than in the mainstem. In general, adult coho migrate upstream beginning in September and October and spawn during November through January. Fry emergence occurs about one month after spawning and juvenile rearing continues throughout the year with juvenile out-migration extending from February through early June.

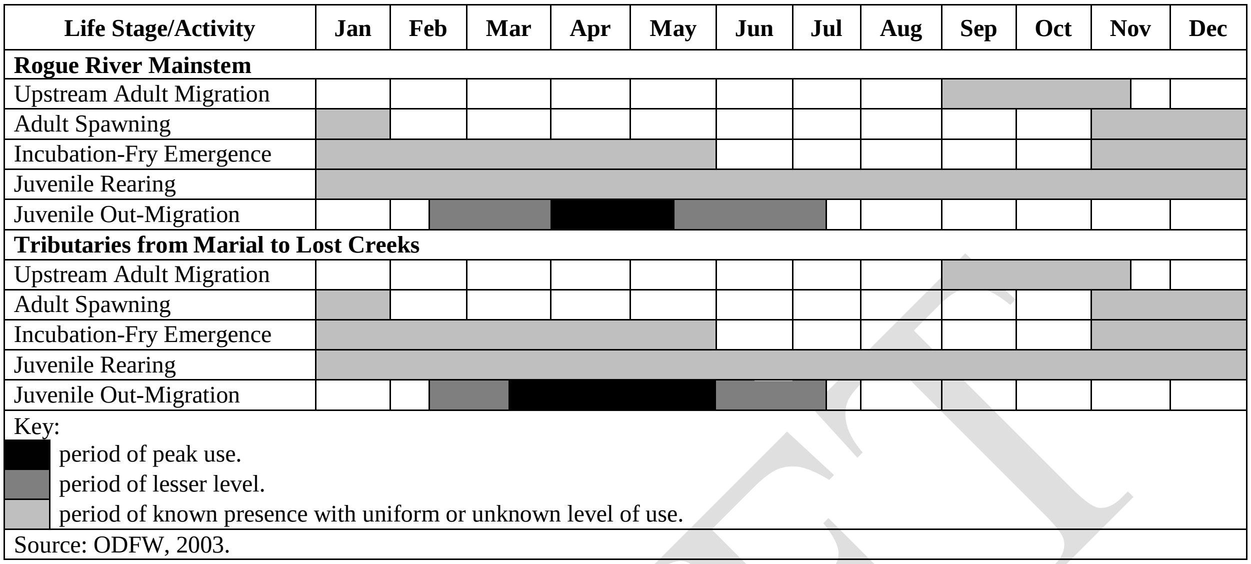



**Figure 4.5-2**
**Approximate Timing of SONCC ESU Coho Salmon Use of the Rogue River Mainstem and Tributaries from Marial to Lost Creek**

Coho in the SONCC ESU inhabit waterbodies in the following four fifth field watersheds in the Upper Rogue Sub-basin that will be crossed by the PCGP: Trail Creek (HUC 1710030706), Shady Cove-Rogue River (HUC 1710030707), Big Butte Creek (HUC 710030704), and Little Butte Creek (HUC 1710030708). Table 4.5.3-1 summarizes the number of waterbodies crossed within the PCGP Project area that are known or assumed to support SONCC coho.

**Table 4.5.3-1**
**Number of Waterbodies Crossed by the PCGP Project within the Upper Rogue Sub-basin and 5th Field Watersheds with SONCC Coho Designated Critical Habitat and Coho Presence (Known or Assumed)**

| Sub-basin and 5th Field Watersheds | Hydrologic Unit Code | Number of Waterbodies | | |
|---|---|---|---|---|
| | | Critical Habitat [1] | Coho Known [2] | Coho Assumed [3] |
| **Upper Rogue Subbasin** | **17100307** | | | |
| Trail Creek | 1710030706 | 3 | 3 | 0 |
| Shady Cove-Rogue River | 1710030707 | 1 | 1 | 1 |
| Big Butte Creek | 1710030704 | 2 | 2 | 3 |
| Little Butte Creek | 1710030708 | 2 | 2 | 5 |
| | **Total** | 8 | 8 | 9 |

[1] NMFS, 1999b.
[2] ODFW, 2012a.
[3] Assumed presence based on connectivity to occupied stream reaches.

**Population Status**

At the time NMFS proposed this ESU for listing, population estimates for naturally reproducing coho salmon in the SONCC ESU included escapement records from Gold Ray Dam on the upper Rogue River as well as some catch estimates from all Oregon rivers and estimates of run size in the Rogue River. During the 1940s, 2,000 adult coho salmon were counted at the Gold Ray Dam per year, but that number declined to fewer than 200 adults in the early 1970s (NMFS, 1995). The Gold Ray Dam on the Rogue River was removed in August 2010. ODFW (2012b) counted adult coho and other anadromous salmonids passing the former Gold Ray Dam as they utilized a fish ladder between late September and January. Abundance of coho returning to the Upper Rogue River above Gold Ray Dam increased from 1996 to 2002 but significantly declined from 2002 through 2009, the last year counted before the dam was removed (see figure 4.5-3).

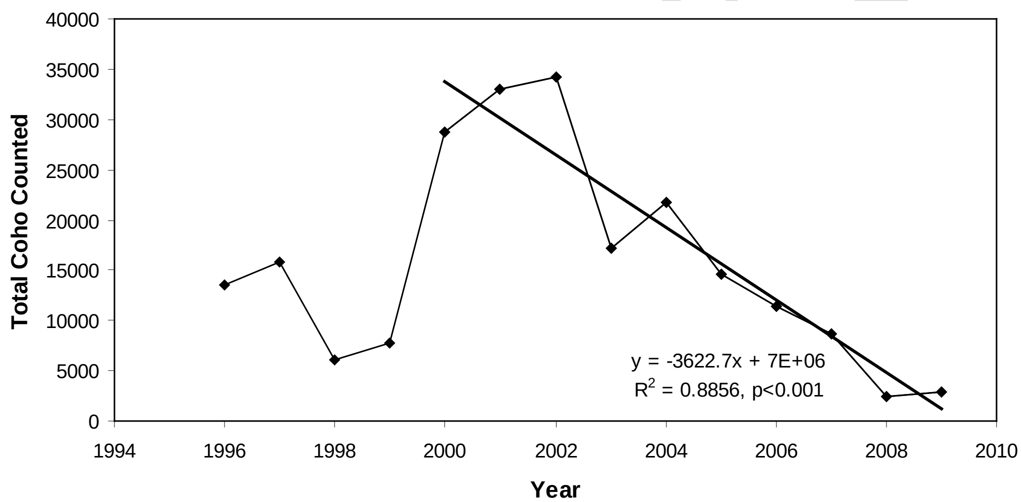



**Figure 4.5-3**

**Total Number of SONCC Adult Coho Counted at the Gold Ray Dam Fish Ladder on the Middle Rogue River, from 1996 to 2009. The decreasing trend from 2001 through 2009 is significant (data from ODFW, 2012d)**

Similar declines were demonstrated with counts made at Huntley Park, at RM 8 on the lower Rogue River, using daily totals of seine counts from 1997 to 2011 (ODFW, 2012c). Oregon has been monitoring spawner abundance on a regular basis on the Rogue River by seine estimates conducted in the vicinity of Huntley Park. Numbers of coho counted at Huntley Park represent salmon in the Illinois, Middle, and Upper Rogue populations aggregated together. From 1980 to 2004, the trend for adult spawner abundance on the Rogue River consistently increased (Spence et al., 2005), mostly due to decreased harvest. However, the trend since 2000 has been decreasing at a significant rate through 2011 such that the coho population is predicted to be zero before 2012 although the upper 95% prediction interval of 15,654 fish in 2012 indicates a high level of uncertainty in the prediction (see figure 4.5-4).

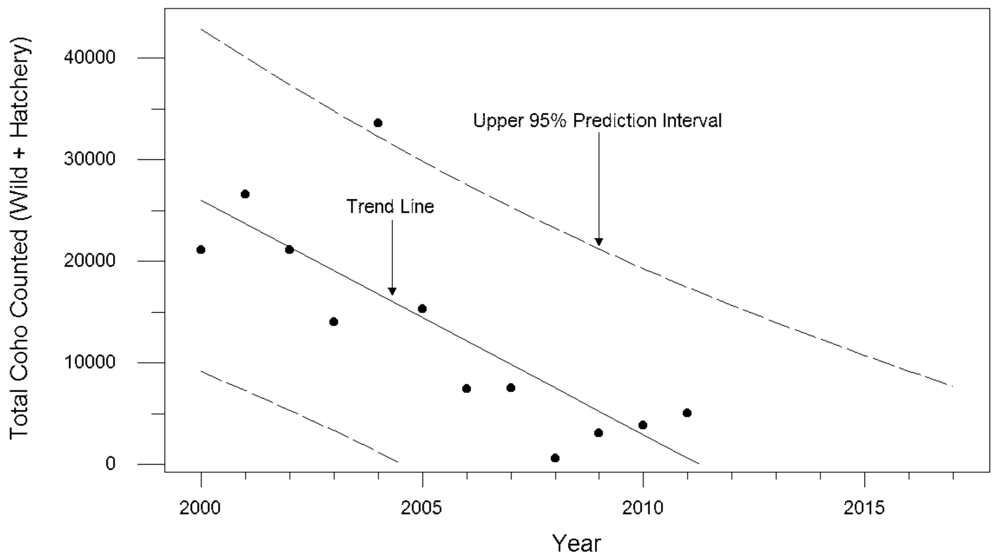



**Figure 4.5-4**
**Total Number of SONCC Coho (Wild plus Hatchery-raised) Counted at Huntley Park (RM 8) on the Rogue River, from 2000 to 2011. The decreasing trend from 2000 through 2011 (solid line) is significant ($r2 = 0.633$, $P<0.005$) with 95% Prediction Intervals (dashed lines) Through 2017 (ODFW, 2012c)**

### Critical Habitat

Critical habitat for coho salmon in the SONCC ESU has been designated (NMFS, 1999c) based on species' requirements such as space for growth and behavior, nutritional and physiological requirements, cover and/or shelter, reproduction sites, and habitats that are protected from disturbance or are representative of historically known population sites (NMFS, 1999b). Other known essential physical and biological features, referred to as primary constituent elements (PCEs), are crucial to species conservation and critical habitat. These features include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation (NFMS, 1999c).

Generally, riparian areas form the basis of healthy watersheds and impacts on them in turn affect these PCEs (NFMS, 1999c). However, the PCEs that create healthy salmonid habitat vary throughout the coho salmon's range and the extant of the adjacent riparian zone may change accordingly. A site-potential tree height is a suitable benchmark in some cases, but in order to better assess the features of a specific locale, site-specific analyses provide the best means to characterize the riparian zone (NFMS, 1999b).

Critical habitat for coho salmon in the SONCC ESU includes the accessible reaches of all rivers (including water, substrate, and adjacent riparian zone of estuarine and riverine reaches) between the Mattole River in California and the Elk River in Oregon. Within the counties traversed by the proposed pipeline, critical habitat has been designated in USGS hydrologic unit (HU) Middle Rogue (17100308 – Jackson County) up to the Emigrant Lake Dam/Emigrant Lake, HU Upper Rogue (17100307 – Jackson, Klamath, and Douglas Counties) up to the Agate Lake Dam/Agate Lake, Fish Lake Dam/Fish Lake, Willow Lake Dam/Willow Lake, and Lost Creek Dam/Lost Creek Reservoir, HU Applegate (17100309 – Jackson County) up to Applegate Dam, and HU Upper Klamath (18010206 – Jackson County) up to Irongate Dam (NMFS, 1999b). The Pacific

Connector pipeline would cross designated critical habitat within waterbodies of the Upper Rogue HU (17100307) below the Lost Creek, Willow Creek, and Fish Lake Dams (NMFS, 1999c). Eight waterbodies within the four 5$^{th}$ field watersheds crossed by the PCGP Project are known to support designated critical habitat for SONCC coho, nine others are assumed to support coho and may provide critical habitat (see table 4.5.3-1).

#### 4.5.3.2 Environmental Baseline

**Analysis Area**

Two analysis areas are applicable to coho salmon in the SONCC ESU. First is the freshwater, in-stream or riverine analysis area, which includes two components: 1) the water column and substrate of all waterbodies crossed by the Pacific Connector pipeline from the point of crossing to the extent downstream where water quality is not adversely affected by suspended sediments generated during construction and sediment generated by runoff from the construction right-of-way, and 2) waterbodies' associated riparian zones affected in the short-term during construction and in the long term by operation. Riparian zones widths are defined as the distance from each bank extending to one site-potential tree height. Only the riverine analysis area associated with fresh waterbodies within the Upper Rogue Sub-basin (HU 17100307) is applicable to coho salmon in the SONCC ESU.

In addition, the proposed action could affect the SONCC ESU within the EEZ analysis area, which extends 200 nmi offshore. Within the analysis area, effects to coho salmon within coastal marine waters would be associated with LNG carriers that are assumed to transect the EEZ perpendicularly - east and west - as they approach and depart from Coos Bay (see the discussion above under Section 4.2.1 Blue Whale).

Total suspended solid (TSS) concentrations generated during wet open-cut pipeline construction have been estimated from models developed by Reid et al. (2004). Amounts of TSS produced during dry open-cut construction (fluming, dam-and-pump) adjustments are fractions of the concentrations produced during wet-open cuts (Reid et al., 2004). Estimates of TSS produced during dry open-cut construction across waterbodies in fifth field watersheds are presented below in Section 4.5.3.3. Average sediment percentages (grain sizes including gravel, sand, silt, and organics) for streams within each fifth field watershed (below, see table 4.5.3-4 and table 4.5.3-6) were assumed as fractions of the TSS generated during construction and concentrations of each grain class at various distances downstream were estimated using Ritter's (1984) model for minor perennial waterbodies. Distances at which concentrations near zero (settle out of suspension) differ considerably for the different grain sizes and are dependent on water depths and stream discharge rates at the time of construction (see below, table 4.5.3-7). Downstream settling distances will be much greater for deeper waterbodies with high flow velocities than for shallow, slow flowing streams.

For streams within range of SONCC coho that would be crossed by the PCGP project, the average downstream distance expected to near a concentration of 0 mg/L of silt (0.0016 cm diameter, 0.023 cm/sec settling velocity) during fluming is about 208 m (682 feet); the average downstream distance expected to near a concentration of 0 mg/L of clay (0.0004 cm diameter, 0.0014 cm/sec settling velocity) is about 3,095 m (10,154 feet). These estimates are for average peak flows likely to occur during pipeline construction within the ODFW (2008) instream timing recommendations. Downstream distances to reach concentrations of 0 mg/L for silt and clay mobilized by flumed construction during average low flows would be less.

The riverine analysis area used in this biological assessment has been limited to downstream distances up to 10,154 feet (1.9 miles) within the affected fifth field watersheds in the range of SONCC coho (see figure 4.5-5).

### Species Presence

Coho salmon in the SONCC ESU are known to occur or are expected within the Upper Rogue River Hydrologic Unit (HU 17100307) and all perennial tributaries. The Pacific Connector pipeline would cross four fifth-field watersheds including Trail Creek (HUC 1710030706), Rogue River-Shady Cove (HUC 1710030707), Big Butte Creek (HUC 1710030704), and Little Butte Creek (HUC 1710030708). All affected waterbodies within the Upper Rogue Sub-basin and within the range of SONCC coho salmon ESU proximate to the Pacific Connector pipeline are included in table 4.5.3-2. There are 76 waterbodies included in the table, of which 13 are perennial, 60 are intermittent, and 3 are ponds. Coho salmon are known to occur in 8 of the waterbodies and are assumed to be present in 9 others based on connectivity to perennial streams known to support coho salmon, the presence of resident salmonids, and/or information provided by fisheries biologists.

**Table 4.5.3-2**
**Waterbodies Crossed or Adjacent to the Pacific Connector Pipeline within the Upper Rogue Basin River (HU 17100307) and in the Range of the Southern Oregon Northern California Coast Coho Salmon ESU**

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| **Upper Rogue (HUC 17100307) Sub-basin, Trail Creek (HUC 1710030706) Fifth field Watershed, Jackson County** | | | | | | | |
| Trib. to W. Fork Trail Creek (ESI068) | Forest Service – Umpqua NF | 110.76 | Intermittent | Adjacent to centerline within TEWA | None | None | Jun 15 to Sep 15 |
| West Fork Trail Creek (ASP202) | 1228425426750 Private | 118.89 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |
| Trib. to Trail Creek (RS019) | 1228364426705 BLM-Medford District | 119.83 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Trail Creek (Denied Access16) | 1228364426705 Private | 119.90 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Canyon Creek (NSP011) | 1228328426655 BLM-Medford District | 120.45 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |
| Trib. to Trail Creek (ASI205) | 1228233426599 Private | 120.92 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Trail Creek (ASI206) | 1228173426535 Private | 121.58 | Intermittent | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |
| **Upper Rogue (HUC 17100307) Sub-basin, Shady Cove-Rogue River (HUC 1710030707) Fifth field Watershed, Jackson County** | | | | | | | |
| Trib. to Cricket Creek (ESI071) | 1228054426435 Private | 121.87 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Cricket Creek (ESI070) | 1228054426435 Private | 121.89 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Cricket Creek (ESI072) | 1228054426435 Private | 121.93 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Cricket Creek (ESI073) | 1228054426435 Private | 121.94 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Cricket Creek (ESI074) | 1228054426435 Private | 122.09 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Rogue River (ASP235) | 1244292424210 Private | 122.65 | Perennial | HDD | Coho | Coho Rearing Migration | Jun 15 to Aug 31 |
| Trib. to Indian Creek (ASI223) | 1227634426166 Private | 125.91 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (ASI222) | 1227628426207 Private | 125.98 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (RS004) | 1227548426186 BLM-Medford District | 126.50 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (ASI220) | 1227541426191 BLM-Medford District | 126.52 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (ASI221) | 1227834426001 BLM-Medford District | 126.59 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (RS003) | 1227537426184 BLM-Medford District | 126.59 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (ASI311) | 1227537426184 Private | 126.65 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Deer Creek (ASP307) | 1227449425936 Private | 128.49 | Perennial | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Indian Creek (AW278) | 1227370425935 Private | 128.63 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jun 15 to Sep 15 |
| Trib. To Indian Creek (ASP310) | 1227366425936 Private | 128.70 | Perennial | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. To Indian Creek (AW309) | BLM-Medford District | 128.89 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. To Indian Creek (ASI400) | BLM-Medford District | 129.13 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. To Indian Creek (ASI306) | BLM-Medford District | 129.21 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Indian Creek (ASI277) | 1227196425923 Private | 129.48 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| **Upper Rogue (HUC 17100307) Sub-basin, Big Butte Creek (HUC 1710030704) Fifth field Watershed, Jackson County** | | | | | | | |
| Trib. to Neil Creek (AW245) | Private | 130.84 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Neil Creek (AW244) | Private | 130.85 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Neil Creek (ASI246) | 1226986425909 Private | 130.89 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Neil Creek (ASI250) | 1226855425888 BLM-Medford District | 131.55 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Neil Creek (ASI251) | 1226826425841 BLM-Medford District | 131.72 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Neil Creek (ASP252) | 1226711425881 Private | 132.00 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |
| Quartz Creek (ASI265) | 1226814425828 Private | 132.75 | Intermittent | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Trib. to Quartz Creek (AW264) | Private | 132.77 | Intermittent | Dry Open-Cut (Streambed-bedrock) | Coho possible | Unknown | Jun 15 to Sep 15 |
| Trib. to Quartz Creek (ASP241) | 1226739425651 BLM-Medford District | 133.35 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jun 15 to Sep 15 |
| Medford Aqueduct Ditch (ASP240) | 1228043424382 BLM-Medford District | 133.38 | Perennial | Conventional Bore | Coho Assumed | Unknown | Jun 15 to Sep 15 |
| **Upper Rogue (HUC 17100307) Sub-basin, Little Butte Creek (HUC 1710030708) Fifth field Watershed, Jackson County** | | | | | | | |
| Whiskey Creek (ASI207) | 1226599424838 Private | 137.48 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI208) | 1226422425032 Private | 138.26 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI210) | 1226367425084 Private | 138.45 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI211) | 1226343425011 Private | 138.71 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI214) | 1226268425015 Private | 139.15 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Stock Pond (AL215) | Private | 139.17 | Stock pond | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI216) | 1226260425019 Private | 139.19 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI216) | 1226260425019 Private | 139.21 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI217) | 1226395424936 Private | 139.39 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI226) | 1226220424994 Private | 139.59 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI227) | 1226220424994 Private | 139.63 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI228) | 1226220424994 Private | 139.68 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI229) | 1226220424994 Private | 139.72 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI232) | 1226295424937 Private | 139.83 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Lick Creek (ASI233) | 1226975424638 BLM-Medford District | 140.26 | Intermittent | Dry Open-Cut Level 1 | Coho Assumed | Unkown | Jun 15 to Sep 15 |
| Trib. to Lick Creek (ASI189) | 1226125424921 Private | 140.58 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Salt Creek (ASI187) | 1226075424805 BLM-Medford District | 141.17 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Salt Creek (ASI188) | 1226059424757 BLM-Medford District | 141.44 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jun 15 to Sep 15 |
| Trib. to Salt Creek (RS017) | 1226059424757 BLM-Medford District | 141.49 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Salt Creek (ESI030) | 1226069424718 BLM-Medford District | 141.95 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Salt Creek (ESI031) | 1226114424647 Private | 142.36 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Salt Creek (ESP034) | 1226522424385 Private | 142.57 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Trib. to Salt Creek (ESI037) | 1226145424620 Private | 143.10 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Long Branch Creek (ESI038) | 1225948424477 Private | 143.47 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Long Branch Creek (ESI039) | 1225959424522 Private | 143.71 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Stock Pond (EL041) | Private | 143.73 | Stock Pond | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Long Branch Creek (ESI038) | 1225948424477 Private | 143.73 | Intermittent | Adjacent to centerline within ROW | None | None | Jun 15 to Sep 15 |
| Trib. to Long Branch Creek (ESI040) | 1225957424527 Private | 143.74 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to Long Branch Creek (ESI038) | 1225948424477 Private | 144.11 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jun 15 to Sep 15 |
| Trib. to S. Fork Long Branch (GSP005/ESP048) | 1225946424357 Private | 144.70 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jun 15 to Sep 15 |
| South Fork Long Branch Cr (GPS006/ESP059) | 1226063424364 Private | 145.27 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Trib. to S. Fork Long Branch (ESI061) | 11225996424261 Private | 145.54 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| North Fork Little Butte Creek (ESP066) | 1226154424196 Private | 145.69 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jun 15 to Sep 15 |
| Trib. to N. Fork Little Butte Creek (ESI056) | 1225859424250 Private | 146.05 | Intermittent | Dry Open-Cut | Coho possible | Unknown | Jun 15 to Sep 15 |
| Trib. to N. Fork Little Butte Creek (ESI055) | 1225855424210 Private | 146.38 | Intermittent | Dry Open-Cut | Coho possible | Unknown | Jun 15 to Sep 15 |
| Trib. to N. Fork Little Butte Creek (ESI052) | 1225847424179 Private | 146.75 | Intermittent | Adjacent to ROW | None | None | Jun 15 to Sep 15 |
| Stock Pond (AL169) | BLM-Medford District | 152.33 | Stock Pond | Adjacent to TEWA 152.29-N | None | None | Jun 15 to Sep 15 |
| South Fork Little Butte Creek (ASP165) | 1226154424195 Forest Service-Rogue River Siskiyou NF | 162.45 | Perennial | Dry Open-Cut | None | None | Jun 15 to Sep 15 |
| Daley Creek (ESI076) | 1223666423096 Forest Service-Rogue River Siskiyou NF | 166.21 | Intermittent | Dry Open-Cut | None | None | Jun 15 to Sep 15 |

[1] Dry open cut crossing methods include flume or dam-and-pump procedures. Dam-and-pump methods would be utilized where streambed blasting is anticipated to eliminate blasting around the flume. The dam-and-pump crossing method is the preferred crossing procedure in steep incised drainage valleys where worker safety may be compromised when placing ("threading") the pipe string under the flume pipe and where there is a risk of upsetting the flume during this operation. The dam-and-pump crossing method is also the preferred crossing method on small streams under low flow conditions during the recommended ODFW-recommended in-water work period. Pacific Connector proposes temporary/short-term fish passage restriction when completing dam-and-pump crossings within the ODFW-recommended in-water work period. Appendix M provides details of stream crossings.

[2] Oregon Department of Fish and Wildlife. 2012a. Fish Distribution Data, 1:24,000 Scale. Oregon Department of Fish and Wildlife Natural Resources Information Management Program. Online: https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata).

[3] Assumes fisheries construction windows only apply to those waterbodies flowing at the time of construction and windows do not apply to HDD crossings.

[4] Steambed bedrock based on Pacific Connector's Wetland and Waterbody delineation surveys. Streambed bedrock may require special construction techniques to ensure pipeline design depth. Special construction techniques may include rock hammering, drilling and hammering, or blasting. The need for blasting would be determined by the construction contractor and would only be initiated after ODFW blasting permits are obtained.

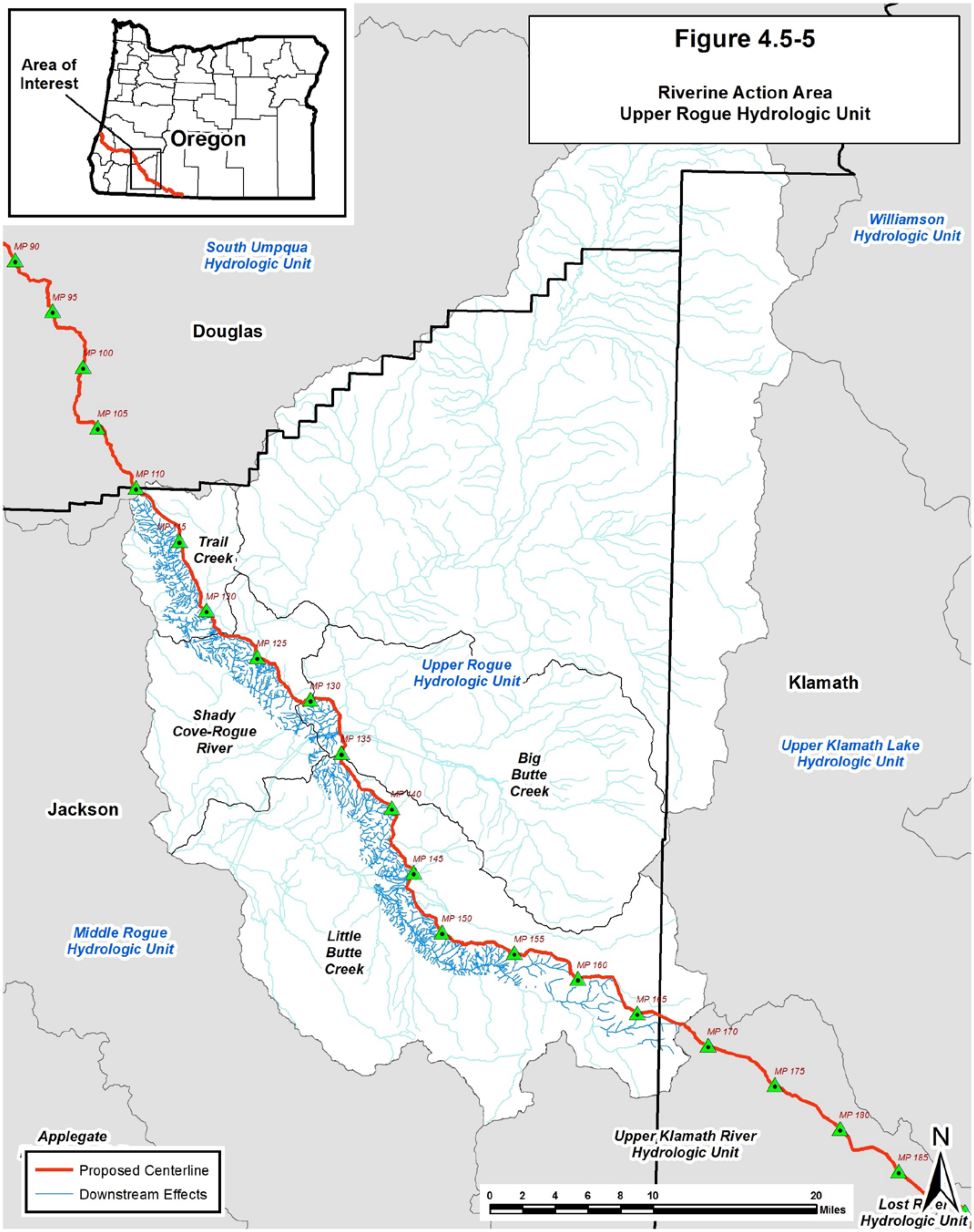


Figure 4.5-5
Riverine Action Area
Upper Rogue Hydrologic Unit
Area of Interest
Oregon
South Umpqua Hydrologic Unit
Williamson Hydrologic Unit
Douglas
Trail Creek
Upper Rogue Hydrologic Unit
Klamath
Shady Cove-Rogue River
Big Butte Creek
Upper Klamath Lake Hydrologic Unit
Jackson
Middle Rogue Hydrologic Unit
Little Butte Creek
Upper Klamath River Hydrologic Unit
Applegate
Lost River Hydrologic Unit
MP 90
MP 95
MP 100
MP 105
MP 110
MP 115
MP 120
MP 125
MP 130
MP 135
MP 140
MP 145
MP 150
MP 155
MP 160
MP 165
MP 170
MP 175
MP 180
MP 185
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20 Miles
N

**Habitat**

Existing conditions of aquatic habitats within the $5^{th}$ field watersheds in the Upper Rogue Sub-basin that would be crossed by the PCGP Project were evaluated with data collected by ODFW in their Aquatic Inventories Project (ODFW, 1997) in cooperation with other agencies, has conducted stream surveys throughout the state including streams within watersheds crossed by the PCGP Project. Four types of habitat information provide quantitative evaluations of the fish habitat condition within various fifth field watersheds to be crossed by the PCGP Project: 1) pool habitat condition, 2) riffle habitat condition, 3) woody debris habitat condition, and 4) riparian habitat condition. ODFW (Foster et al., 2001) has developed benchmark criteria for each of these habitat conditions that would represent undesirable and desirable habitat conditions. The benchmarks are provided in table 4.5.3-3 along with the various aquatic habitat conditions to which they apply. The conditions of specific streams crossed by the PCGP Project are assumed to be comparable to the average conditions for the sampled reaches in each of the four $5^{th}$ field watersheds. Compilations of ODFW stream-reach data (see appendix X) are summarized in table 4.5.3-4 for the four watersheds in the project area occupied by SONCC coho. The percent of sampled stream reaches that are at or above desirable benchmark conditions and percent that are at or below undesirable conditions indicate the aquatic habitat conditions.

Benchmark conditions are not absolute but they provide a method for comparing values of key aquatic habitat components (Foster et al., 2001). Pools provide refuges for fish during high and low stream flows. Pools provide slow water habitats for adults and juveniles, provide over-wintering habitat for some fish species, provide habitat during periods of low summer flows, and pools associated with large wood provide habitat complexity. Riffles provide spawning habitats for various salmonid species that construct nests or redds in gravels of various sizes, specific to salmonid species. Sand, silt, and organic debris can reduce suitability of spawning habitats by filling pores between gravel particles that are necessary for intergravel stream flows, availability of oxygen, and for development of embryos; high percentages of sand, silt, and organic material in riffles indicate poor conditions as spawning habitat.

Riparian trees provide shade over stream channels which reduce deleterious effects of high summer water temperatures. Roots of riparian vegetation stabilize stream banks, contribute to development of bank undercutting (thermal and hiding cover), limit erosion and sedimentation from stream banks, and provide large woody debris (LWD) as an important component of the aquatic habitat. LWD, especially contributed by riparian conifers, provides cover for fish, physical habitat complexity that influences stream flows and channel diversity, and biological complexity as substrate for macroinvertebrate communities that provide food for salmonids during different life stages (Foster et al., 2001).

**Table 4.5.3-3**
**Oregon Department of Fish and Wildlife Aquatic Inventory and Analysis Project Criteria for Aquatic Habitat Conditions and Benchmarks**

| | **Benchmark Level for Condition** | |
|---|---|---|
| **Aquatic Habitat Condition** | **Undesirable** | **Desirable** |
| **Pools** | | |
| • Pool Area (% total stream area) | <10 | >35 |
| • Pool Frequency (channel widths between pools) | >20 | 5-8 |
| • Residual Pool Depth (m) | | |
| Small Streams (<7m wide) | <0.2 | >0.5 |
| Medium Streams (≥7m and <15m width) | | |
| Low Gradient (slope <3%) | <0.3 | >0.6 |
| High Gradient (slope >3%) | <0.5 | >1.0 |
| Large Streams (≥15m width) | <0.8 | >1.5 |
| • Complex Pools (pools with ≥3 LWD pieces / km of reach length) | <1 | >2.5 |
| **Riffles** | | |
| • Width/Depth Ratio (active channel based) | | |
| East Side | >30 | <10 |
| West Side | >30 | <15 |
| • Gravel (% area) | <15 | ≥35 |
| • Silt-Sand-Organics (% area) | >20 | <10 |
| Volcanic Parent Material | >15 | <8 |
| Sedimentary Parent Material | >20 | <10 |
| Channel Gradient <1.5% | >25 | <12 |
| **Shade** (Reach Average, Percent) | | |
| Stream Width <12 meters | | |
| West Side | <60 | >70 |
| Northeast | <50 | >60 |
| Central-Southeast | <40 | >50 |
| Stream Width >12 meters | | |
| West Side | <50 | >60 |
| Northeast | <40 | >50 |
| Central-Southeast | <30 | >40 |
| **Large Woody Debris** | | |
| • Pieces/100m Stream Length | <10 | >20 |
| • Volume ($m^3$)/100m Stream Length | <20 | >30 |
| • "Key" Pieces (>60cm and 10m long)/100m | <1 | >3 |
| **Riparian Conifers** (30m From Both Sides of Channel) | | |
| • Number >20in DBH/1000ft Stream Length | <150 | >300 |
| • Number >35in DBH/1000ft Stream Length | <75 | >200 |
| Source: Foster et al., 2001 | | |



BLM and Oregon Forest Industry Council (OFIC) surveyed 127 stream reaches in the four 5th field watersheds within the Upper Rogue Sub-basin that will be crossed by the PCGP Project: 21 in the Trail Creek HUC 1710030706, five in the Shady Cove-Rogue River HUC 1710030707, 42 in the Big Butte Creek HUC 1710030704, and 59 in the Little Butte Creek HUC 1710030708. Surveys were conducted during summers in different watersheds between 1994 and 1999. Conditions for benchmark aquatic habitat criteria in the four watersheds are included in table 4.5.3-4.

For most of the stream reaches sampled in the four watersheds, habitat conditions related to pools (area, frequency, residual depths) were between moderate levels and desirable benchmarks.

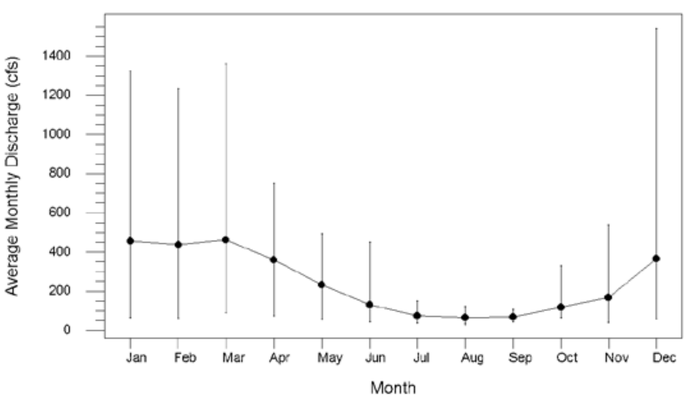
The majority of reaches were deficient in complex pools associated with LWD. Numbers of LWD pieces, LWD volume, and numbers of key pieces were below benchmark conditions in most stream reaches, which helps explain the poor state of pool complexity associated LWD. Related to low levels of LWD are the low numbers of large conifers (>20 inches diameter-at-breast-height - DBH) within sampled riparian zones. However, shade conditions are generally at moderate or desirable benchmark levels, primarily due to the narrow widths of most streams and presence of broadleaf riparian red alders and cottonwoods that provide shade during summer months (Upper Rogue Watershed Association, 2006).

In general, riffle habitat conditions are better than pool habitat conditions, but they are not at desirable conditions overall. Ratios of stream widths to depths in most stream reaches in the four watersheds were generally low, more narrow and deep than wide and shallow. However, areas of gravel substrates were not at or above desirable benchmarks in most sample reaches and areas of fine sediments in riffles generally exceeded the desirable benchmarks. However, some of this analysis is based on data from before the flood event of the winter of 1996-1997, and conditions could have changed significantly from what the data shows (Little Butte Creek Watershed Council, 2003).

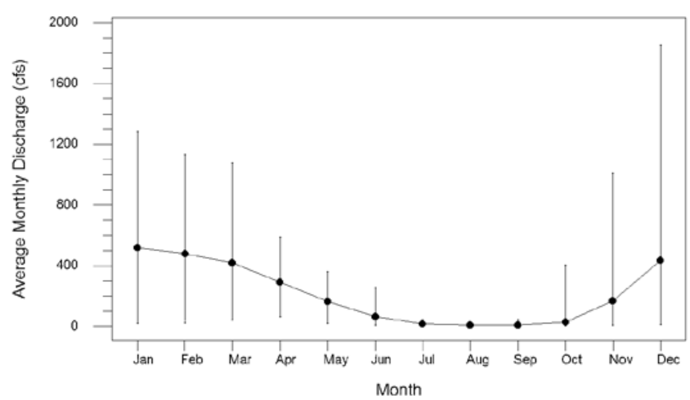
Monthly average stream discharges over the annual cycle are provided in figure 4.5-6 for two waterbodies within the Upper Rogue Sub-basin, Big Butte Creek – a tributary to Rogue River with a 245 square mile watershed, and Elk Creek with a watershed area of 379 square miles.

Although highly variable, monthly flows in the Upper Rogue River below Lost Creek Lake are heavily influenced by irrigation water withdrawals. Water is also diverted for use in hydroelectric power generation (Upper Rogue Watershed Association, 2006). Monthly flows in Big Butte Creek and Elk Creek at the confluence with the Rogue River near Trail were selected as representative because neither segment is influenced by dam releases for irrigation or hydropower. Precipitation falling as snow during winter months does not affect discharges until later in the year (April through May). Minimum flows tend to occur during June, July, August, and September. The ODFW (2008a) instream construction window for Upper Rogue River and tributaries is June 15 to September 15, coinciding with low flows.






A




B

**Figure 4.5-6**
**Average Monthly Discharge (cfs) in (A) Big Butte Creek (USGS Gage 14337500) from 1945 to 2012, and (B) Elk Creek (USGS Gage 1433800) from 1946 to 2012. Vertical lines show maximum and minimum discharges during the periods of record.**

**Table 4.5.3-4**
**Aquatic Habitat Conditions from Samples Taken by ODFW in Stream Reaches within 5th Field Watersheds of the Upper Rogue Sub-basin Crossed by the PCGP Project**

| Aquatic Habitat Condition | Mean Values (with Standard Errors) in Relation to Benchmark Conditions in Surveyed Reaches (by %) of Watersheds[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Trail Creek HUC 1710030706 | | Shady Cove-Rogue River HUC 1710030707 | | Big Butte Creek HUC 1710030704 | | Little Butte Creek HUC 1710030708 | |
| | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions |
| **Pools** | | | | | | | | |
| Pool Area (% total stream area) | 15.2 (2.8) | 42.9% 4.8% | 15.2 (1.8) | 0% 0% | 19.4 (2.4) | 35.7% 19.0% | 17.2 (2.2) | 39.0% 10.2% |
| Pool Frequency (channel widths between pools) | 37.5 (12.4) | 23.8% 9.5% | 61.0 (6.0) | 0% 0% | 19.0 (2.2) | 35.7% 42.9% | 28.5 (9.9) | 23.7% 20.3% |
| Residual Pool Depth (m) by stream size and gradient | 0.6 (0.0) | 4.8% 61.9% | 0.4 (0.0) | 0% 0% | 0.5 (0.0) | 4.8% 42.9% | 0.5 (0.1) | 11.9% 25.4% |
| Complex Pools (pools with ≥3 LWD pieces ≥3 per km of reach length | 0.8 (0.7) | 90.5% 4.8% | 0.4 (0.4) | 80.0% 0% | 0.2 (0.1) | 90.5% 2.4% | 0.1 (0.0) | 96.6% 0% |
| **Riffles** | | | | | | | | |
| Width/Depth Ratio (active channel based) | 12.9 (1.1) | 0% 61.9% | 10.2 (1.0) | 0% 100% | 13.2 (0.9) | 0% 71.4% | 24.3 (3.6) | 22.0% 47.5% |
| Gravel (% of area) | 19.7 (0.9) | 4.8% 0% | 26.2 (2.7) | 0% 0% | 19.5 (1.4) | 26.2% 4.8% | 27.6 (1.6) | 13.6% 30.5% |
| Silt-Sand-Organics (% of area) by parent material and gradient[2] | 20.3 (1.8) | 19.0% 9.5% | 10.4 (2.4) | 0% 60.0% | 24.4 (2.3) | 45.2% 23.8% | 29.9 (2.0) | 59.3% 6.8% |
| **Shade** | | | | | | | | |
| Reach Average, % by stream width | 88.0 (2.1) | 0% 90.5% | 61.0 (6.0) | 40.0% 20.0% | 65.9 (3.1) | 26.2% 42.9% | 75.3 (2.9) | 23.7% 62.7% |
| **Large Woody Debris** | | | | | | | | |
| LWD Pieces/100m of Stream Length | 6.4 (0.9) | 76.2% 0% | 4.4 (1.9) | 80.0% 0% | 6.0 (0.6) | 83.3% 0% | 7.5 (0.9) | 64.4% 6.8% |
| LWD Volume ($m^3$)/100m of Stream Length | 17.5 (3.3) | 66.7% 19.0% | 5.8 (3.6) | 80.0% 0% | 13.0 (1.8) | 76.2% 9.5% | 10.3 (1.7) | 81.4% 5.1% |
| Key Pieces (≥60cm D by ≥12m L)/100m of Stream Length | 1.2 (0.4) | 61.9% 9.5% | 0.3 (0.2) | 80.0% 0% | 0.7 (0.1) | 73.8% 2.4% | 0.6 (0.1) | 69.5% 1.7% |
| **Riparian Conifers** | | | | | | | | |
| Number >20in DBH/1000ft of Stream Length | 288.3 (78.7) | 47.6% 33.3% | 88.0 (54.3) | 60.0% 0% | 386.7 (81.2) | 40.5% 35.7% | 539.1 (125.4) | 50.8% 42.4% |
| Number >35in DBH/1000ft of Stream Length | 65.9 (32.7) | 76.2% 14.3% | 0.0 (0.0) | 100% 0% | 80.4 (28.8) | 78.6% 14.3% | 65.4 (23.8) | 86.4% 10.2% |

[1] Values unweighted by surveyed reach length.
[2] Assumes sedimentary parent material in all surveyed reaches.
[3] D= diameter, L = length

**Critical Habitat**

Critical habitat for coho salmon in the SONCC ESU (NMFS, 1999c) includes "all waterways, substrate, and adjacent riparian zones below longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years)." The Pacific Connector pipeline crosses designated critical habitat associated with waterbodies in the Upper Rogue Sub-basin (HU 17100307), below the Lost Creek, Willow Creek, and Fish Lake Dams. Essential features of coho salmon critical habitat in those waterbodies include adequate 1) substrate, 2) water quality, 3) water quantity, 4) water temperature, 5) water velocity, 6) cover and shelter, 7) food, 8) riparian vegetation, 9) space, and 10) safe passage conditions (NMFS, 1999c).

Critical habitat for SONCC coho salmon is designated based on species requirements such as space for growth and behavior, nutritional and physiological requirements, cover and/or shelter, reproduction sites, and habitats that are protected from disturbance or are representative of historically known population sites (NMFS, 1999c). Additionally, NMFS uses other known essential physical and biological features that are crucial to species conservation and critical habitat. These PCEs include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation (NMFS, 1999c). Activities that may affect critical habitat and PCEs include, but are not limited to, timber sales, road building, mining, dredge and fill, and bank stabilization activities (NMFS, 1999c).

Generally, riparian areas form the basis of healthy watersheds and impacts on them in turn affect these PCEs (NMFS, 1999b). However, the PCEs that create healthy salmonid habitat vary throughout the coho salmon's range and the extant of the adjacent riparian zone may change accordingly. A site-potential tree height is a suitable benchmark in some cases, but in order to better assess the features of a specific locale, site-specific analyses provide the best means to characterize the riparian zone (NMFS, 1999c).

Riparian areas provide the following functions: shade, sediment, nutrient or chemical regulation, streambank stability, and input of LWD or organic matter. In addition, critical habitat includes inaccessible headwater or intermittent streams which provide key habitat elements (e.g., LWD, gravel, water quality) crucial for coho salmon in downstream reaches (NMFS, 1999c). Widths of adjacent riparian zones may vary by site-specific and/or landscape characteristics but a distance of one site-potential tree height serves to define riparian zone widths in some cases (NMFS, 1999c). With these considerations, all perennial and intermittent streams in table 4.5.3-2 are included in critical habitat within the riverine analysis area.

### 4.5.3.3 Effects by the Proposed Action

The PCGP Project would cross 17 waterbodies which are known or presumed to be inhabited by coho salmon in the SONCC ESU (see table 4.5.3-1). Effects by the project could occur to freshwater in-water construction activities, terrestrial/riparian habitat modification, accidental spills or leaks of hazardous materials, and periodic maintenance of the pipeline. Construction of the PCGP Project could directly and/or indirectly affect SONCC coho salmon and critical habitat through one or more of the following pathways:

- Interference with key life history functions for native species.
- Acoustic shock from blasting pipe trench through bedrock streambeds or use of a track hoe or impact hammer if fish are proximate to the construction site.
- Turbidity generated during pipeline construction across waterbodies can adversely affect coho and aquatic habitats.

- Introduction and/or re-distribution of aquatic nuisance species
- Removal of riparian vegetation that can reduce shade (which could increase water temperatures), limit streambank stability, and affect recruitment of LWD.
- Accidental release of fuels and entry of other petroleum products into surface waters can adversely affect coho and other aquatic organisms.
- Application of herbicides to control noxious weeds near waterbodies may adversely affect coho.

**Direct Effects**

Timing

Waterbodies within the Upper Rogue Sub-basin would be crossed between June 15 and September 15 (ODFW, 2008) which partially coincides with adult upstream migrations of coho (see figure 4.5-3). Pacific Connector will cross fish-bearing waterbodies within the SONCC coho ESU to prevent construction during periods of sensitive fish use. In general, construction of the pipeline would be timed to miss periods of major juvenile or adult migrations. The instream construction window coincides with coho juvenile rearing. Construction across waterbodies within the Upper Rogue Sub-basin could occur during adult upstream migration, beginning in September, but would be completed before spawning in early November (see figure 4.5-3).

Acoustic Shock

There are 17 waterbodies within the SONCC coho ESU where shallow bedrock may occur where potential blasting and/or mounted impact hammers may be required to construct a trench through bedrock substrates (see table 4.5.3-2). Explosives detonated near water produce shock waves that can be lethal to fish, eggs, and larvae by rupturing swim bladders and addling egg sacs (British Columbia Ministry of Transportation, 2000). Explosives detonated underground produce two modes of seismic wave (Alaska Department of Fish and Game, ADFG, 1991), 1) body waves that are propagated as compressional primary (P) waves and shear secondary (S) waves, and 2) surface waves produced when a body wave travels to the earth surface and is reflected back. Shock waves propagated from ground to water are less lethal to fish than those from in-water explosions because some energy is reflected or lost at ground-water interface (ADFG, 1991). Peak overpressures as low as 7.2 pounds per square inch (psi) produced by blasting on a gravel/boulder beach caused 40 percent mortality in coho salmon smolts and other studies revealed 50 percent mortality in smolts with peak overpressures ranging from 19.3 to 21.0 psi (ADFG, 1991).

The best approach to protect fish species is to limit the instantaneous hydrostatic pressure change (resulting from nearby blasting) to levels below those known to be harmful to fish. ADFG (1991) reported that a pressure change of 2.7 psi is the level for which no fish mortality occurs and is from 1.7 to 4.5 psi below any level where mortality would be expected, as reported in other studies cited in the document. Based on those studies, and until additional research reveals otherwise, ADFG (1991) concluded that fish would be sufficiently protected from blasting on land by limiting overpressures to 2.7 psi. That limit has apparently been continuously applied by Alaska Department of Natural Resources (see below, in reference to ADFG ,1991).

ADFG (1991) analyzed the straight line distances through rock and other materials for a single shot explosive charge, of given weight, would dissipate to an overpressure standard of 2.7 psi (non-lethal pressure for anadromous fish). Pacific Connector may opt to blast across stream locations where consolidated rock makes traditional trenching methods unfeasible. Typical trench blasting scenarios use multiple 1- to 2-pound charges separated by an 8-milisecond delay to excavate the trench. With use of 1- to 2-pound charges in rock, the set back distance (at which 2.7 psi would occur) from the blast trench to the fish habitat is between 34 and 49 feet (see Table 3, in ADFG, 1991). Blasting would be conducted within dry streambanks isolated from the water column, most likely using dam-and-pump construction to bypass water around the dry workspace.

Several approaches have been suggested to reduce risk of injury or mortality to fish in closest proximity to blasting locations (Wright and Hopky, 1998):

- deployment of bubble curtains/air curtains to disrupt the shock wave;
- deployment of noise generating devices, such as an air compressor discharge line, to scare fish away from the site; or
- removal or exclusion of fish from the work area before the blast occurs.

A Fish Salvage Plan is provided in appendix T. The plan includes measures to exclude fish and prevent them from re-entering isolated portions within waterbodies crossed for distances sufficient to avoid or minimize adverse effects by blasting bedrock in streambeds.

Underwater Noise

Impulsive type sounds, sound generated by pile driving for example, create stress waves in the piling material that radiate sound through the surrounding media of substrate, air, and water and may propagate outward from the source through bottom sediment (Popper and Hastings, 2009). Various studies have reported fish mortality, physical injury, auditory tissue damage, decreased viability of eggs, and decreased larval growth due to noise, mostly explosive blasts, seismic survey blasts, and air gun blasts (Hastings and Popper, 2005). State agencies in Washington, Oregon, and California, along with federal agencies have developed interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a; Popper et al., 2006).[2] The threshold noise levels are assumed to be applicable to noise from a mounted impact hammer operating on bedrock substrates for 17 waterbodies potentially affected by the PCGP Project in the Upper Rogue River sub-basin (see table 4.5.3-2, above).

Average maximum noise produced by mounted impact hammers due to impact on substrates (eg, rock) has been reported at 90 dBA from 50 feet away in the air (see Table 7-4 in Washington State Department of Transportation, 2011a).[3] Using a simplified conversion of dB between air



[2] Interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a) include 1) a cumulative sound exposure level ($SEL_{cum}$) of 187 dB re 1 µ$Pa^2$ ● s for fishes more than 2 grams, 2) a $SEL_{cum}$ of 183 dB re 1 µ$Pa^2$ ● s for fishes less than 2 grams, and 3) a single-strike peak level ($SPL_{peak}$) of 206 dB re 1 µPa for all sizes of fishes (Washington State Department of Transportation, 2011a).

$SEL_{cum}$ is the cumulative sound pressure squared, integrated over time, and normalized to one second. $SEL_{cum}$ is calculated as SEL(single strike at 10 meters from the pile) + 10 Log(number of strikes).

[3] For consistency, the maximum noise level ($L_{max}$ of the impact hammer at 1 meter (3.28 feet) is computed as:

$$L_{max} = \text{Construction } L_{max} \text{ at 50 feet} - 25 \text{ Log}(D/D_o) = 119.58 \text{ dBA at 1 meter (3.28 feet).}$$

Where Construction $L_{max}$ = 90 dBA, D = distance from the noise source (3.28 feet) and $D_o$ = the reference measurement distance (here, 50 feet). Noise measured on the A-weighted decibel scale is based on the reference pressure of 20 micro-Pascal (µPa), where one Pascal is the pressure (force of 1 newton) exerted over an area of 1 square meter and applies to sound in the air. Sound in water is referenced (abbreviated as “re:” in reference expressions) to 1 µPa instead of 20 µPa referenced in air.

and water (see footnote, below and Pacific Marine Environmental Laboratory-NOAA, 2012), the noise produced by the impact hammer in air would be equivalent to about 182 dB re: 1 µPa @ 1 meter in water. However, there is no information available to determine whether that noise level would be equivalent to peak sound levels or root mean square (RMS) levels, which are the basis for evaluating potential harm to fish, particularly related to cumulative sound exposure levels caused by multiple impact hammer strikes.

Further, the estimate of noise produced by in-water use of an impact hammer in any waterbody would be influenced by water currents, water depth, and bottom material and topography, as well as configuration and materials of the river banks. The effects of these factors are unknown (Washington State Department of Transportation, 2011a). However, noise propagation in any waterbody, upstream and downstream from the construction site will be limited by the stream channels' sinuosity since the propagation is limited to straight-line distance from the source (Washington State Department of Transportation, 2011a). Noise produced by impact hammers will be much reduced if construction does not occur within the water column, similar to reduction set back distances from the blast trench to the fish habitat to reduce blast overpressures to below 2.7 psi, discussed above.

Sounds produced by a mounted impact hammer operating in dry conditions might be conducted through bedrock substrate to approach the hearing threshold of fish, as for example the Atlantic salmon, which is around 90 dB re: 1 µPa (see Figure 3 in Hastings and Popper, 2005). It is assumed that salmonids in the PCGP Project area at the time of construction will have hearing thresholds similar to Atlantic salmon. With that assumption, listed and non-listed salmonids present at the time of construction might detect the noise produced by animpact-hammer striking bedrock, but the noise is not expected to be of sufficient intensity to cause them injury as would SELs produced by pile driving.

Dry open-cut construction, more than likely dam-and-pump methodology, would be used at sites where blasting and/or mounted impact hammers would be required to construct a trench through bedrock substrates. When using the dam-and-pump stream crossing methodology, the typical right-of-way distribution of an isolated streambed (dry open-cut) would be no less than 25-feet on one side of the pipe trench and 50+ feet on the opposite side of the pipe trench depending on whether it's a 75 or 95 foot width crossing. Therefore an area within the waterbody crossing equivalent to length of the blasting trench and approximately 25-feet wide (in the worst-case scenario) would be exposed to instantaneous hydrostatic pressure changes above 2.7 psi. In reality the distance in water affected outside of the 25 feet on land would be less than an additional 25 feet because water does not transmit energy pressure waves as well as rock (only about 70 percent of the distance away from the charge relative to rock, the most conductive substrate of pressure waves; see calculations in ADFG, 1991), which the maximum distance is based upon.

---

The characteristic impedance of sound in water (related to the density of water and speed of sound) is approximately 3600 times the impedance in air so conversion for the intensity of sounds of equal pressures in air compared to water is 10 Log(3600) = 36 dB (Pacific Marine Environmental Laboratory-NOAA, 2012). Taking into account the different reference pressures for sound in air and in water (20 µPa and 1 µPa) the intensity measurements for sound of equal pressures differ by 26 dB + 36 dB = 62 dB (Pacific Marine Environmental Laboratory-NOAA, 2012). Using this simplified conversion of dB between air and water, the noise produced by the impact hammer in air (120 dB re: 20 µPa @ 1 m) would be equivalent to about 120 dB + 62 dB = 182 dB re: 1 µPa @ 1 m in water.

Suspended Sediment

Salmonids exposed to moderate to high levels of suspended sediment for extended periods could be adversely affected. At high levels, turbidity directly affects survival and growth of salmonids and other species, interferes with gill function, and adversely affects substrate for egg development (reviewed and compiled by Bash et al., 2001). Turbidity can also reduce macrophyte cover (over the long-term) by limiting photosynthesis (Goldsborough and Kemp, 1988), as well as adversely affecting fish vision, which is a requisite for social interactions (Berg and Northcote, 1985), feeding (Vogel and Beauchamp, 1999; Gregory and Northcote, 1993), and predator avoidance (Meager et al., 2006; Miner and Stein, 1996).

Salmonids may avoid areas of increased turbidity levels at 20 mg/L suspended sediment, and possibly lower concentrations depending on length of exposure (Newcombe and Jensen, 1996). The elevated suspended sediment conditions would be short-term during pipeline installation and would not be continuous at any one location. This would reduce the chances of continuous elevated exposure for fish that may move little. Concentrations as low as 17 mg/L have been noted to potentially have some adverse effects (e.g. gill irritation, respiration) for juvenile coho salmon (Wheeler, 2008, based on Berg and Northcote, 1985). Some other studies have found varied effects including lesser effects at these concentrations, with overall effects related to both duration as well as concentration (Newcomb and Jensen, 1996).

Newcombe and Jensen (1996) compiled research from many sources that demonstrate effects to anadromous and resident salmonids by various levels of turbidity and exposure over time. The compiled information was used to develop several models of risks to salmonids and non-salmonids. Input for each of two models (Model 1, juvenile and adult salmonids; Model 3, juvenile salmonids) includes TSS concentration (mg/L) and duration (hours) of exposure to the concentration. Output from each model is a severity-of-ill-effects (SEV) score ranging from 0 to 14 where SEV of 0 indicates no effects, SEV between 1 and 3 indicates behavioral effects, SEV from 4 to 8 indicates sublethal effects, and SEV from 9 through 14 indicate lethal and paralethal effects (see Table 1 in Newcombe and Jensen, 1996).

Before the procedures can be used to evaluate effects of suspended sediment concentrations and variable durations of exposure on fish, there must be some estimate of TSS concentrations generated during construction by the PCGP Project. The following sections develop the information that will lead to estimates of TSS entrained during pipeline construction. The following sections apply to waterbodies crossed by the project, not to the 14 waterbodies (see table 4.5.3-2) that are adjacent to the pipeline, within construction rights-of-way, and would not be crossed.

Background Turbidity and Suspended Sediment. Turbidity, generally reported in Nephelometric Turbidity Units (NTUs), is a measure of the lack of transparency (cloudiness) of water caused by suspended or dissolved substances which cause light to be scattered and adsorbed. Turbidity is often measured on-site using a turbidity meter that measures the scattering of light in a water sample relative to a known range turbidity standards. Turbidity is directly related to the concentration of sediments suspended in water but the relationship between turbidity and suspended sediment is complicated by sediment particle size, particle composition, and water color (ODEQ, 2010).

GeoEngineers (2011a and 2013b) evaluated the potential risk of turbidity increasing during construction of the PCGP across waterbodies. The qualitative evaluation was based on each affected waterbody's hydroperiod, presence of erodible clay and loam soils in streambanks, presence of clay in streambed (suspended clay contributes to turbidity), long-term stability of stream channels, and level/duration of construction effort and stabilization measures likely added at the time of construction. The turbidity risk was scored from 1 (low) to 5 (high). Of 402 canals, ditches, and waterbodies evaluated, 130 were scored with a low risk (score of 1 or 2) of turbidity increase over a 24 hour period, and 272 were scored with a moderate risk (score of 3 or 4), generally due to soil erosion potential, presence of clay or mud, and/or the presence of steep slope or an incised channel that would require construction of a deep trench (GeoEngineers, 2013a). The evaluation concluded that turbidity generated during construction may exceed Oregon water quality standards for short distances and short durations downstream from each stream crossing, either coinciding with construction across perennial waterbodies or in intermittent streams coincidental with autumn precipitation.

Ambient turbidity was not addressed by GeoEngineers (2011a and 2013b). Turbidity (NTU) has been evaluated by ODEQ (2013) and retrieved from Laboratory Analytical Storage and Retrieval (LASAR) Web Application for some of the waterbodies crossed by the PCGP Project. Turbidity within individual streams may be highly variable with highest measurements reported during winter months, usually January through March (see table 4.5.3-5a). During the period coinciding with ODFW (2008a) instream construction windows, reported turbidity has been minimal in streams for which data exists (see table 4.5.3-5b).

The majority of ODEQ LASAR data are turbidity (NTU) measurements taken in the field. TSS have occasionally been reported but mostly without measuring corresponding turbidity. Relationships between turbidity and suspended solid concentrations are determined on a stream-by-stream basis (Downing, 2008). Relationships have been reported for streams in Alaska (Lloyd, 1987; Lloyd et al., 1987) and streams in the Puget Lowlands (Packman et al., 1999); the models are non-linear. They produce differing estimates of TSS conversions from turbidity and conversions between models are most deviant at higher turbidity levels (see table 4.5.3-5a). At low turbidity levels (see table 4.5.3-5b), conversions of NTUs to TSS are relatively consistent. Based on these conversions, an overall background level of 2 mg/L is assumed for TSS concentrations for all streams crossed by the PCGP Project during the ODFW instream construction window. In support of that assumption, ODEQ (2010) reported that during dry seasons, background turbidity levels are relatively low and consistent in small streams throughout Oregon. A six-year ODEQ ambient monitoring study completed during dry seasons inventoried small wadeable stream sites in Oregon's eight ecoregions and found that overall median turbidity levels were approximately 1 NTU, regardless of lithology (resistant or erodible), or the degree of human disturbance. From the data provided in table 4.5.3-5b, background levels of 1 NTU would average about 2 mg/L or slightly less. A background TSS concentration of 2 mg/L during summer is also consistent with measurements reported by USGS in Myrtle Creek, Big Butte Creek, and the Rogue River mainstem during summers 1977, 1978, and 1979 (historical data provided by USDA-Forest Service).

**Table 4.5.3-5a**
**Turbidity (NTU) Records Measured by ODEQ during All Times of Year in Waterbodies Crossed by the PCGP Project in the Upper Rogue Sub-Basinand Conversion to TSS by Available Models**

| Sub-Basin | Waterbody | Number of Records | Period of Record | Mean Turbidity (NTU) (Maximum) (Minimum) | Model Conversion to TSS (mg/L) [1] | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Model 1 Mean TSS (Maximum) (Minimum) | Model 2 Mean TSS (Maximum) (Minimum) | Model 3 Mean TSS (Maximum) (Minimum) | Model 4 Mean TSS (Maximum) (Minimum) |
| Upper Rogue | Trail Creek | 26 | 1998-2008 | 15.3<br>(54)<br>(1) | 67.9<br>(272.1)<br>(2.6) | 18.9<br>(68.6)<br>(1.1) | 22.0<br>(98.0)<br>(0.5) | 50.4<br>(224.9)<br>(1.2) |
| | W.Fk. Trail Creek | 48 | 1998-2008 | 8.5<br>(53)<br>(0.9) | 34.4<br>(266.2)<br>(2.3) | 10.3<br>(67.3)<br>(1.0) | 10.3<br>(95.7)<br>(0.4) | 23.7<br>(219.4)<br>(1.0) |
| | S.Fk Little Butte Creek | 18 | 1998-2001 | 3.4<br>(16)<br>(1) | 11.6<br>(65.9)<br>(2.6) | 4.0<br>(19.5)<br>(1.1) | 3.0<br>(19.7)<br>(0.5) | 6.9<br>(45.1)<br>(1.2) |
| | S.Fk Little Butte Creek | 16 | 2001-2002 | 2.3<br>(6)<br>(0.7) | 7.2<br>(21.0)<br>(1.7) | 2.6<br>(7.1)<br>(0.7) | 1.7<br>(5.4)<br>(0.3) | 3.9<br>(12.4)<br>(0.7) |

[1] Models used to convert Turbidity (T) to Suspended Solids Concentration (SSC) or Total Suspended Solids (TSS) in waterbodies crossed or proximate to the PGCP Project . Turbidity information source: Oregon Department of Environmental Quality, Laboratory Analytical Storage and Retrieval (LASAR) Web Application (Online at: http://deq12.deq.state.or.us/lasar2/default.aspx).

Model 1 (Lloyd, 1987; Lloyd et al., 1987) applicable to waters throughout Alaska: $T = 0.44\ (SSC)^{0.858}$
Model 2 (Lloyd, 1987; Lloyd et al., 1987) applicable to interior Alaskan streams: $T = 1.103\ (SSC)^{0.968}$
Model 3 (Packman et al., 1999) Rutherford Creek, King County, Washington: $\ln(TSS) = 1.32 \ln(NTU) – 0.68$
Model 4 (Packman et al., 1999) nine streams sampled in the Puget Lowlands, Washington: $\ln(TSS) = 1.32 \ln(NTU) + 0.15$

**Table 4.5.3-5b**
**Turbidity (NTU) Records Measured by ODEQ during Periods of ODFW Instream Construction Windows in Waterbodies Crossed by the PCGP Project in the Upper Rogue Sub-Basin and Conversion to TSS by Available Models.**

| Sub-Basin | Waterbody | Number of Records | Period of Record | Mean Turbidity (NTU) (Maximum) (Minimum) | Model Conversion to TSS (mg/L) [1] | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Model 1 Mean TSS (Maximum) (Minimum) | Model 2 Mean TSS (Maximum) (Minimum) | Model 3 Mean TSS (Maximum) (Minimum) | Model 4 Mean TSS (Maximum) (Minimum) |
| Upper Rogue | Trail Creek | 6 | 1998-2000 | 1.8<br>(2)<br>(1) | 5.3<br>(5.8)<br>(2.6) | 2.1<br>(2.3)<br>(1.1) | 1.1<br>(1.3)<br>(0.5) | 2.6<br>(2.9)<br>(1.2) |
| | West Fork Trail Creek | 7 | 1998-2002 | 3.0<br>(5)<br>(0.9) | 9.6<br>(17.0)<br>(2.3) | 3.5<br>(5.9)<br>(1.0) | 2.3<br>(4.2)<br>(0.4) | 5.2<br>(9.7)<br>(1.0) |
| | South Fork Little Butte Creek | 11 | 1998-2000 | 2.0<br>(4)<br>(1) | 5.9<br>(13.1)<br>(2.6) | 2.3<br>(4.7)<br>(1.1) | 1.3<br>(3.2)<br>(0.5) | 3.0<br>(7.2)<br>(1.2) |
| | South Fork Little Butte Creek | 6 | 2001 | 0.9<br>(1)<br>(0.7) | 2.3<br>(2.6)<br>(1.7) | 1.0<br>(1.1)<br>(0.7) | 0.5<br>(0.5)<br>(0.3) | 1.0<br>(1.2)<br>(0.7) |

[1] See footnote to table 4.5.3-5a

Sediment in Streambed Substrate. ODFW (1997) conducted stream surveys throughout the state including streams within fifth-field watersheds crossed by the PCGP Project (see Habitat in Section 4.5.3.2). Sampled stream reaches were evaluated for 1) average percent sand, silt, and organics in the surface substrate, 2) average percent gravel in the surface substrate, 3) average percent of bedrock in the surface substrate (only reported in reaches sampled after 1999), and 4) the number of boulders ≥0.5 meter in diameter within the sampled reach. We standardized that measurement by converting numbers of boulders to boulders per meter of primary and secondary stream channel lengths. Reported values for fractions of surface area substrates were averaged for all sampled stream reaches within fifth-field watersheds crossed by the PCGP Project; averages are included in table 4.5.3-4, above and in appendix X. We assumed that there are equal parts of sand, silt and organics (clay) within the reported average percent sand, silt, and organics fraction; the assumed percent of silt and clay (fine sediments) is included in table 4.5.3-6.

As noted, the average percent of bedrock in the surface substrate has only been reported in reaches sampled after 1999 and so summaries of the average bedrock substrate component in watersheds are incomplete or not reported. The average substrate fractions in table 4.5.3-6 were incorporated into analyses of sediment effects on salmonids without modification, even though percentages do not total 100.

We assumed that the average surface substrate fractions reported in ODFW (1997) streams surveys and averaged for all sampled streams within a fifth-field watershed are applicable to other streams in the watershed that would be crossed by the PCGP Project. Sediment generated during dry open-cut construction would most likely be surface sediments disturbed during installation and removal of isolation structures (temporary dams placed upstream and downstream from the workspace) and bypass structures (flume pipe, pump intake and exit conduits). It is not necessary to assume that surface substrate fractions are similar to excavated from the pipeline trench by a track-hoe. The use of dry open-cut construction restricts excavated sediment from entering the water column unless there is some failure of the isolation structures or seals between the stream bed and structures.

Known streambed bedrock has been determined for 17 streams proposed for crossing within the Upper Rogue Sub-basin (see table 4.5.3-2) and based on Pacific Connector’s Wetland and Waterbody delineation survey. If bedrock is present at the construction site, special construction techniques to ensure pipeline design depth may be required (rock hammering, drilling and hammering, and/or blasting) but only after the workspace has been isolated with temporary dams placed upstream and downstream. Dam-and-pump construction, rather than fluming, would be used at the crossing. Since presence of bedrock mostly or entirely precludes the presence of other surface substrates, other surfaces sediment fractions for streams in fifth-field watersheds in table 4.5.3-6 would not apply to streams with bedrock present.

**Table 4.5.3-6**
**Average Fractions of Surface Substrates by Area Reported for Sampled Stream Reaches in Fifth-Field Watersheds of the Upper Rogue Sub-Basin Crossed by the PCGP Project [1]**

| Sub-Basin | Fifth Field Watershed | Average % Sand, Silt, Organics in Surface Substrate | Assumed % Silt and Organics in Surface Substrate [2] | Average % Gravel in Surface Substrate | Average % Bedrock in Surface Substrate [3] | Number of Boulders ≥0.5m Diameter per meter of Channel [4] |
|---|---|---|---|---|---|---|
| Upper Rogue | Trail Creek | 20.3 | 13.5 | 19.7 | 7.0 (inc) | 0.3 |
| | Shady Cove-Rogue River | 10.4 | 6.9 | 26.2 | 12.0 (inc) | 0.2 |
| | Big Butte Creek | 24.4 | 16.3 | 19.5 | 11.6 (inc) | 0.2 |
| | Little Butte Creek | 29.9 | 19.9 | 27.3 | not reported | 0.6 |

[1] Data from ODFW, 1997
[2] Assuming equal fractions of sand, silt, and organics
[3] Average percent of bedrock in the surface substrate has only been reported in reaches sampled after 1999
[4] Numbers of boulders counted within the reach divided by the total length (m) of primary and secondary channels within the sampled reach.

Suspended Sediment Transport. In part, sediment transport in streams depends on stream channel characteristics. GeoEngineers (2011b and 2013c) developed a database on stream channel characteristics for 96 streams to be crossed by the PCGP Project (values for modeled streams in appendix Y). The streams were representative of each ecoregion and represent the range of widths/gradients and aspects of the stream crossings in each ecoregion traversed by the PCGP project. The database included (but was not limited to) the channel gradient (percent), bankfull width (feet), and streambed material (bedrock, boulder, cobble, gravel, sand, silt, mud, and clay). GeoEngineers (2012 and 2013d) developed additional stream-specific data to evaluate thermal impact on stream water temperatures due to removal of shading vegetation and increased solar loading within riparian zones during and after pipeline construction. The additional database included (but was not limited to) the wetted width (feet), bankfull width (feet), and predominant depth (feet).

GeoEngineers data were used to estimate the stream channel cross-section shape and cross-section area. If the predominant depth was greater than ½ the bankfull width, the cross-section channel shape was assumed to be a V. If the predominant depth was less than ½ the bankfull width, the cross-section channel shape was assumed to be a trapezoid with each bank as a 1:1 slope, dependent on predominant depth. Manning's Formula (Limerinos, 1970; Arcement and Schneider, 1989) was used to estimate **Q**, the stream discharge rate (cubic feet per second):

$$\mathbf{Q = A\ (\mathit{k}/n)\ (R^{2/3})\ (S^{1/2})}$$

with estimates of **A**, the cross-sectional area of a stream (square feet or square meters), **R**, the hydraulic radius (feet or meters, where **R = A/P**, and **P** is the wetted perimeter in feet or meters), **S**, the slope of channel (vertical feet per horizontal feet), the constant ***k*** equals 1.486 if English units are used but ***k*** equals 1 with metric units, and n is Manning's roughness coefficient. Values reported by GeoEngineers, 2011b and 2012 were used to estimate **A** and **R** and **S** (where a 100 percent gradient = 1). Manning's **n** was estimated from various sources (Chow, 1959; Limerinos, 1970; Arcement and Schneider, 1989), primarily based on streambed materials and streambank conditions reported by GeoEngineers (2011b) and included in appendix Y for each stream modeled. Stream flow rate or discharge rate, **Q**, is related to cross-sectional area (**A**) and average streamflow velocity ($\mathbf{V_A}$):

$$\mathbf{Q = A\ V_A}$$

Estimates of **Q** derived with Manning's Formula are assumed to be measures of the carrying capacity (bankfull flow) of a particular channel section (Arcement and Schneider, 1989). Carrying capacities of a channel section are assumed to occur during periods of high flow, generally during winter months in the project area. Where possible, estimates of **Q** were compared to estimates of maximum instantaneous flows that could occur once every 2 years through once every 500 years, using the USGS web-based GIS hydrologic regression tool, StreamStats (see http://water.usgs.gov/osw/ streamstats/index.html). Though not every waterbody crossed by the PCGP Project has been modeled in StreamStats, those that have provided peak flow estimates (cubic feet per second, or cfs) within the same orders of magnitude (generally within the range of maximum peak flows every 2 years through peak flows every 500 years) as estimates of **Q** derived from application of Manning's Formula to the stream data compiled by GeoEngineers (2011b and 2012).

Sediment particles will be transported distances downstream (**L**, in feet or meters) based on 1) the particle size and settling velocity ($\mathbf{V_S}$, - inches per second, micrometers per second – in water at 20$^o$C, see for example the Wentworth Grain Size Chart, USGS, 2003), 2) the average streamflow velocity, and 3) the average depth of flow (**D**, feet or meters) downstream, using the following equation (Trow Equation, see Harper and Trettel, 2002);'

$$\mathbf{L = (D\ V_A) / V_S}$$

Estimates of transport distances (**L** in feet) for various sediment particles ranging in sizes from clay to coarse gravel are provided, as examples, in table 4.5.3-7 for three of the waterbodies that would be crossed by the PCGP Project outside of the Upper Rogue River sub-basin. Particle sizes deleterious to salmonids (250 µm or less in the models of Newcombe and Jensen, 1996, above) could settle out of suspension less than 1 meter (0.2 feet) downstream (e.g., medium sand in low flows for Tributary to Catching Creek in examples, below). Alternatively, particles could remain suspended for 200 km (100 miles) or more (very fine silt during high flows in Willis Creek).

**Table 4.5.3-7**
**Estimated Downstream Transport Distances for Particles (ranging from Very Fine Silt to Coarse Gravel) in Three Streams (as examples) with Simulated High and Low Flows that Will Be Crossed by the PCGP Project**

| | | | Estimated Particle Transport Distance (L) Downstream [1] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tributary to Catching Creek | | Steele Creek | | Willis Creek | |
| Particle Description | Particle Diameter | Settling Velocity ($V_S$) | High Flow [2] | Low Flow [2] | High Flow | Low Flow | High Flow | Low Flow |
| Coarse Gravel | 1.60 cm (0.63 in) | 90 cm/s (35.43 in/s) | 0 m (1 ft) | 0 m (0 ft) | 1 m (3.6 ft) | 0 m (0 ft) | 3 m (10 ft) | 0 m (0.2 ft) |
| Very Coarse Sand | 0.1 cm (0.039 in) | 15 cm/s (5.91 in/s) | 2 m (6 ft) | 0 m (0 ft) | 7 m (21 ft) | 0 m (0.3 ft) | 19 m (62 ft) | 0 m (1.4 ft) |
| Coarse Sand | 0.05 cm (0.02 in) | 8 cm/s (3.15 in/s) | 3 m (11 ft) | 0 m (0.1 ft) | 12 m (40 ft) | 0 m (0.6 ft) | 35 m (116 ft) | 1 m (2.7 ft) |
| Medium Sand | 0.025 cm (0.01 in) | 3 cm/s (1.18 in/s) | 9 m (29 ft) | 0 m (0.2 ft) | 33 m (107 ft) | 0 m (1.5 ft) | 94 m (308 ft) | 2 m (7.3 ft) |
| Fine Sand | 0.0125 cm (0.005 in) | 1.25 cm/s (0.49 in/s) | 21 m (69 ft) | 0 m (0.6 ft) | 78 m (257 ft) | 1 m (3.6 ft) | 225 m (742 ft) | 5 m (18 ft) |

| Particle Description | Particle Diameter | Settling Velocity ($V_S$) | Estimated Particle Transport Distance (L) Downstream [1] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tributary to Catching Creek | | Steele Creek | | Willis Creek | |
| | | | High Flow [2] | Low Flow [2] | High Flow | Low Flow | High Flow | Low Flow |
| Very Fine Sand | 0.0062 cm (0.002 in) | 0.329 cm/s (0.13 in/s) | 80 m (260 ft) | 1 m (2.1 ft) | 297 m (970 ft) | 4 m (14 ft) | 856 m (2,798 ft) | 20 m (66 ft) |
| Coarse Silt | 0.0031 cm (0.001 in) | 0.085 cm/s (0.03 in/s) | 308 m (1,025 ft) | 3 m (8.3 ft) | 1,148 m (3,820 ft) | 16 m (53 ft) | 3,313 m (11,024 ft) | 78 m (259 ft) |
| Medium Silt | 0.0016 cm (0.0006 in) | 0.023 cm/s (0.009 in/s) | 1,139 m (3,760 ft) | 9 m (31 ft) | 4,243 m (14,008 ft) | 59 m (196 ft) | 12,244 m (40,421 ft) | 289 m (951 ft) |
| Very Fine Silt-Clay | 0.0004 cm (0.0002 in) | 0.0014 cm/s (0.0006 in/s) | 18,712 m (56,400 ft) | 153 m (459 ft) | 69,710 m (210,120 ft) | 977 m (2,932 ft) | 201,155 m (606,320 ft) | 4,742 m (14,269 ft) |

[1] Parameter values used to estimate L:

**Trib. Catching Creek:** High Flow: $V_A$ = 1.72 m/s (5.64 ft/s), D = 0.15 m (0.5 ft); Low Flow: $V_A$ =0.27 m/s (0.88 f/s), D = 0.01 m (0.03 ft).
**Steele Creek**: High Flow: $V_A$ = 1.88 m/s (6.18 f/s) D = 0.5 m (1.7 ft); Low Flow: $V_A$ = 0.53 m/s (1.73 ft/s); D = 0.03 m (0.09 ft).
**Willis Creek**: High Flow: $V_A$ = 2.10 m/s (6.89 ft/s), D = 1.2 m (4.4 ft); Low Flow: $V_A$ = 0.66 m/s (2.16 ft/s), D = 0.1 m (0.3 ft).

[2] High flows are based on highest average flows during winter months (assumed to be within bankfull stream widths) during the period of record; low flows are estimated flows during ODFW construction windows.

Seasonal Discharge. Pipeline construction across waterbodies will occur during ODFW (2008a) instream construction windows (see discussion, above). Hydrographs of monthly discharges within the Upper Rogue Sub-basin crossed by the PCGP Project (see figure 4.5-6) show peak seasonal flows during winter months, December through February. Lowest flows occur during summer months, coinciding with the ODFW construction windows. Assuming that high winter stream flows correspond to the carrying capacities of channel sections (Arcement and Schneider, 1989), instream flows during ODFW construction windows would be some fraction of the winter flows. The fractions, included in table 4.5.3-8a and table 4.5.3-8b as a percent of winter high flow during the construction window, have been estimated for waterbodies in each of the four sub-basins based on the most recent 10-year record within USGS hyodrograph data sets. Stream flows during construction windows were estimated for waterbodies in each sub-basin by reducing stream depths and affected parameters in Manning's Formula to achieve an average stream discharge rate, Q, that is the same as the percent (by mid-point) of high flows in table 4.5.3-8a and table 4.5.3-8b for the sub-basin.

**Table 4.5.3-8a**
**Recorded High Flows During Winter and Average Flows During the ODFW Instream Construction Window in Hydrographic Data in the Upper Rogue Sub-Basin by the PCGP Project.**

| Sub-basin | Hydrograph | High Flow (cfs) (Month) | Instream Construction Window | Average Flows (cfs) During Window | Percent of High Flow During Window | Percent Mid-Point |
|---|---|---|---|---|---|---|
| Upper Rogue | Big Butte Creek | 372 (Jan) | Jun 15- Sep 15 | 62.1 | 16.7 | 9.1 |
| | Elk Creek | 537 (Jan) | Jun 15- Sep 15 | 13.7 | 2.6 | |

**Table 4.5.3-8b**
**Recorded High Flows During Winter and Average Peak Flows During the ODFW Instream Construction Window in Hydrographic Data in Four Sub-basins Crossed by the PCGP Project.**

| Sub-basin | Hydrograph | High Flow (cfs) (Month) | Instream Construction Window | Average Peak Flows (cfs) During Window | Percent of High Flow During Window | Percent Mid-Point |
|---|---|---|---|---|---|---|
| Upper Rogue | Big Butte Creek | 372 (Jan) | Jun 15- Sep 15 | 111.8 | 30.1 | 19.8 |
| | Elk Creek | 537 (Jan) | Jun 15- Sep 15 | 50.8 | 9.5 | |

For example, 10-year average stream flows in the Upper Rogue Sub-basin during the ODFW instream construction window are 9.1 percent of high winter flows, based on discharge data for Big Butte Creek and Elk Creek during December (see figure 4.5-6). Stream depths for all waterbodies within the Upper Rogue Sub-basin were reduced by the same proportion. Reduced stream depths generated reduced values of **A**, **P**, and **R** in Manning's Formula. Estimates of **Q** (and $\mathbf{V_A}$) were likewise reduced for all streams in the sub-basin and were compared to **Q** generated during high winter flows. Reduction of stream depths by iteration was continued until the percent of high winter flows by average flows during the construction window was 9.1 percent for waterbodies crossed by the PCGP Project.

The same procedure was used to evaluate stream discharge rates during average peak flows that were documented in the sub-basins during instream construction windows. Peak flows were obtained from maximum daily flow data during the instream construction window and averaged for the most recent 10-year period (see table 4.5.3-8b).

Sediment Generated During Pipeline Construction. Modeled concentrations of TSS produced in waterbodies during wet open-cut pipeline construction were developed from empirical data collected during construction across 15 to 19 streams in North America (Reid et al., 2004). Models were developed to predict mean and peak TSS concentrations immediately downstream of pipeline construction sites. Models included TSS generated by all construction activities and by trenching, pipe lowering, and backfilling. The models predicting mean TSS generated by all activities (including trenching, pipe lowering, and backfilling) and mean TSS generated by trenching had the highest correlation coefficients (Reid et al., 2004). The model predicting mean TSS ($\boldsymbol{C}_{\mathbf{av}}$) by all construction activities is:

$$\boldsymbol{C_{av}} = \mathbf{1.5 \times 10^6}\ \boldsymbol{U}^{\mathbf{1.09}}\ \boldsymbol{d}_{\mathbf{50}}^{\mathbf{0.95}}\ \boldsymbol{P}_{\mathbf{f}}^{\mathbf{0.35}}\ \boldsymbol{q}^{\mathbf{-1}}$$

where $\boldsymbol{U}$ = mean flow velocity (m per second) at the crossing location during the construction period and is assumed to be equivalent to $\mathbf{V_A}$ derived using Manning's Formula; $\boldsymbol{d}_{\mathbf{50}}$ = the median sediment size (m) of the excavated material by weight; $\boldsymbol{P}_{\mathbf{f}}$ = percentage of fines (silt and clay) in the excavated material (%) and is assumed to equal the percent of silt and organics in surface substrates for all streams within a given fifth-field watershed in the Upper Rogue sub-basin tabulated in table 4.5.3-6; $\boldsymbol{q}$ = the width adjusted stream flow rate where $\boldsymbol{q = Q/B}$, ($m^2$ per second) with $\boldsymbol{B}$ = the watercourse width (m) adjusted for a particular flow rate and $\boldsymbol{Q}$ = stream flow rate ($m^3$ per second) derived using Manning's Formula. In these simulations, **Q** is related to **B** through Manning's Formula and as **B** increases numerically, **Q** also increases but at a faster numerical rate. If all other model parameters are held constant in the Reid et al. (2004) model, increased width adjusted stream flow rate, $\boldsymbol{q}$ (due high flow, **Q**, and proportionally smaller watercourse widths, $\boldsymbol{B}$) will decrease the TSS concentration ($\boldsymbol{C}_{\mathbf{av}}$) because $\boldsymbol{q}$ is factored as $\boldsymbol{q}^{\mathbf{-1}}$ or $\mathbf{1/}\boldsymbol{q}$ in the equation. Conversely, lower $\boldsymbol{q}$ values will generate higher $\boldsymbol{C}_{\mathbf{av}}$ with all other parameters in the equation held constant.

Available data do not appear suitable to estimate values for $\boldsymbol{d}_{\mathbf{50}}$. In these analyses it is assumed that $\boldsymbol{d}_{\mathbf{50}}$ = 0.00025 m (250 µm) since particles that size or less adversely affect salmonids and other fish in the evaluation procedures by Newcombe and Jensen (1996), introduced above and applied below.

In addition to developing predictive models of TSS concentrations generated by wet-open cut pipeline construction, Reid et al. (2004) measured TSS downstream from 12 flumed pipeline crossings and 23 dam-and-pump crossings (dry-open cut or isolated pipeline construction crossings) with comparisons to 11 wet open-cut construction crossings. By accounting for flow, background TSS concentrations, sampling distance downstream, and duration of construction, Reid et al. determined that mean TSS concentrations generated during dry open-cut construction for fluming were 3.7 percent of the wet open-cut concentrations and 0.85 percent of the wet open-cut concentrations for dam-and-pump construction.

Reid et al. (2004) also predicted peak TSS generated by all construction activities. The model predicting peak TSS ($\boldsymbol{C}_\mathbf{p}$) by all activities is:

$$C_p = 5.7 \times 10^5 \; U^{1.86} \, d_{50}^{0.57} \, P_f^{1.2} \, q^{-1}$$

The model has the same component descriptions and assumptions stated above for predicting the average TSS concentration ($\boldsymbol{C}_\mathbf{av}$). However, the model showed overall low explanatory value (low coefficient of multiple correlation. low multiple $r^2$) and a relatively poor predictor of peak TSS (Reid et al., 2004) and is not used in these analyses.

Short-term peak sediment releases occurred during installation and removal of isolation structures (sand bags, jersey barriers, other dam structures) and bypass components (flume, pumps). Dam-and-pump construction is a particularly effective technique to cross smaller waterbodies. The larger TSS concentrations produced during fluming were mostly related to backfilling the trench, poor containment of ditch water, poor dam seals, and longer construction times associated with fluming larger waterbodies (Reid et al., 2004).

If there was a failure of isolation structures during either type of dry open-cut construction, it is assumed that the TSS generated during the failure would be similar to TSS generated during wet open-cut construction, which is included in table 4.5.3-9. Estimates of TSS concentrations produced during pipeline construction under average and peak low flow conditions are expected to be very low, primarily due to low silt and organic fractions in surface substrates which range from 6.9 percent in Shady Cove-Rogue River to 19.9 percent in Little Butte Creek fifth field watersheds (see table 4.5.3-6). Estimated average TSS concentrations produced during fluming and dam-and pump construction are equal to or slightly above background TSS estimates (2 mg/L) between 50 and 100 meters downstream from construction sites (see table 4.5.3-9).

Estimated Downstream Distance of Suspended Sediment. Ritter (1984) provided two models (minor stream crossings and major stream crossings) for estimating concentrations of suspended sediments ($C_X$, as mg/L) some distance (x) downstream from a pipeline trench being constructed across a waterbody. The model for minor crossings was based on average stream depth of 15.2 cm (6 inches) and the model for major crossings was based on average depth of 91 cm (36 inches). The mid-point between the two depths, 53.1 cm (21 inches), is assumed to differentiate minor from major streams.

Ritter's model for downstream sediment transport distance during construction across minor streams, with complete mixing of sediment particles, estimates the concentration downstream $C_X$ by:

$$C_X = C_O \, e^{-(vs / d)(x / u)}$$

Where $\mathbf{C_O}$ (mg/L) is the initial concentration of suspended solids in the water column at the trenching site, **vs** = the settling velocity (m/second) of sediment particles, **d** = stream depth (m), **u** = stream current velocity (m/second), and **x** = distance (m) downstream.

Ritter's model for downstream sediment transport distance during construction across a major stream assumes complete mixing of sediment particles within one-half the stream width (assuming a horizontal spread of the sediment plume as 0.5 cm/sec). The concentration downstream $\mathbf{C_X}$ is estimated by:

$$\mathbf{C_X = \frac{C_O}{0.5(x)(d)} e^{-(vs / (0.5d)) (u / x)}}$$

Flows expected during pipeline construction within the ODFW instream window limit the application of the major stream crossing model. The Rogue River would be classified as the only major stream but would not be crossed using dry open cut construction and is not included in the sediment entrainment and transport analysis provided in table 4.5.3-9.

Summary. TSS concentrations are essential to evaluating project-related effects on salmoninds (see section below, Suspended Sediment Effects on Fish). Estimates of TSS concentrations generated by wet open-cut and dry open-cut (flume and dam-and-pump) were modeled for 17 waterbodies within the Upper Rogue Sub-basin that would be crossed by the PCGP Project. Concentrations of TSS generated by wet open-cut construction were estimated for each of the waterbody crossing sites (see table 4.5.3-9) and adjusted, depending on use of flumed dry open-cut or dam-and-pump dry open-cut construction. Concentrations of TSS at 10, 50, and 100 meters downstream were based on Ritter's (1984) equations. Fractions of gravel, sand, silt and organics (see table 4.5.3-6) were assumed to be characteristic for each stream within the sub-basin. Average low flows were assumed (see table 4.5.3-8a and example in text) to occur during pipeline construction and used in the Reid et al. (2004) model predicting mean TSS ($\boldsymbol{C_{av}}$) generated by all pipeline instream construction activities. The $\boldsymbol{C_{av}}$ from the Reid et al. model is equivalent to $\mathbf{C_O}$ in the Ritter model (the initial concentration of suspended solids in the water column at the trenching site). Average low flows were also used for estimating concentrations, $\mathbf{C_x}$, at three distances downstream using Ritter's (1984) model for minor streams. Average peak flows during the instream construction window (see table 4.5.3-8b) were also used to estimate concentrations ($\mathbf{C_x}$) at the three distances downstream with the same $\mathbf{C_O}$ as for average low flows. The background TSS concentration was assumed to be 2 mg/L for all streams crossed by the PCGP Project during the ODFW instream construction window (see table 4.5.3-5b).

Estimated TSS concentrations downstream from flumed dry open-cut construction ranged from less than 5 mg/L to 2 mg/L (see table 4.5.3-9). Estimated TSS concentrations downstream from dam-and-pump dry open-cut construction range from about 3 mg/L to 2 mg/L (see table 4.5.3-9). Those ranges of TSS concentrations were used in Newcombe and Jensen's (1996) models estimating risks to salmonids and non-salmonids that would be associated with variable TSS concentrations and variable durations of exposure. The durations of exposure to TSS generated during dry open-cut construction at each of the 17 waterbodies simulated in table 4.5.3-9 are assumed to be similar to those described by Reid et al. (2004) occurring during installation and removal of isolation structures (temporary dams placed upstream and downstream from the workspace) and bypass structures (flume pipe, pump intake and exit conduits). Construction-related problems may occur and my cause elevated TSS concentrations downstream and for longer periods of time, including (Reid et al., 2004): 1) pump failure or insufficient capacity, 2) dam or flume failure, 3) poor dam seal, 4) poor containment of pumped ditch water, 5) inadequate maintenance of sediment control measures. Also, construction across larger waterbodies requires longer periods of instream work, large volumes of stream flow and trench dewatering, and risks of increased sediment release.

**Table 4.5.3-9**

**Estimates of Mean Total Suspended Solid (TSS) Concentrations Generated within Fifth Field Watersheds by Wet Open-Cut and Dry Open-Cut (Flume, Dam-and-Pump) Pipeline Construction Across Waterbodies Potentially Occupied by SONCC Coho within the Upper Rogue Sub-Basin during Average Low Flows and Average Peak Flows Expected Within the ODFW Instream Construction Window. TSS Concentrations, Averaged for all Stream Crossings within Fifth-Field Watersheds, Have Been Estimated at 10, 50 and 100 meters Downstream from Construction Sites.**

| Sub-basins and 5th Field Watersheds | Number of Simulated Waterbody Crossings [1] | Estimated Mean TSS (mg/L) at Construction Site (Standard Error) | | | Mean TSS (mg/L) at 10 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 50 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 100 meters Downstream [5] (Standard Error) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wet Open Cut [2] | Dry Open Cut (Flume) [3] | Dry Open Cut (Dam-Pump) [4] | Wet Open Cut<br>Low Flows<br>Peak Flows [6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows[7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows[8] | Wet Open Cut<br>Low Flows<br>Peak Flows[6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows [7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows[8] | Wet Open Cut<br>Low Flows<br>Peak Flows[6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows[7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows [8] |
| **Upper Rogue Sub-basin** | | | | | | | | | | | | | |
| Trail Creek | 2 | 107 (20.6) | 6 (0.8) | 3 (0.2) | 12 (2.7) | 2 (0.1) | 2 (0.0) | 8 (1.6) | 2 (0.1) | 2 (0.0) | 6 (1.4) | 2 (0.1) | 2 (0.0) |
| | | | | | 15 (2.6) | 3 (0.1) | 2 (0.0) | 13 (2.0) | 2 (0.1) | 2 (0.0) | 11 (1.6) | 2 (0.1) | 2 (0.0) |
| Shady Cove-Rogue River | 8 | 20 (1.1) | 3 (0.0) | 2 (0.0) | 3 (0.0) | 2 (0.0) | 2 (0.0) | 3 (0.0) | 2 (0.0) | 2 (0.0) | 2 (0.0) | 2 (0.0) | 2 (0.0) |
| | | | | | 3 (0.1) | 2 (0.0) | 2 (0.0) | 3 (0.1) | 2 (0.0) | 2 (0.0) | 3 (0.1) | 2 (0.0) | 2 (0.0) |
| Big Butte Creek | 3 | 129 (7.2) | 7 (0.3) | 3 (0.1) | 18 (0.9) | 3 (0.0) | 2 (0.0) | 13 (1.6) | 2 (0.1) | 2 (0.0) | 10 (1.4) | 2 (0.1) | 2 (0.0) |
| | | | | | 21 (0.2) | 3 (0.0) | 2 (0.0) | 17 (1.8) | 3 (0.1) | 2 (0.0) | 15 (2.1) | 2 (0.1) | 2 (0.0) |
| Little Butte Creek | 4 | 258 (92.2) | 12 (3.4) | 4 (0.8) | 46 (12.8) | 4 (0.5) | 2 (0.1) | 34 (5.7) | 3 (0.2) | 2 (0.0) | 28 (4.2) | 3 (0.2) | 2 (0.0) |
| | | | | | 52 (16.6) | 4 (0.6) | 3 (0.1) | 46 (12.6) | 4 (0.5) | 2 (0.1) | 41 (9.3) | 3 (0.3) | 2 (0.1) |

| Sub-basins and 5th Field Watersheds | Number of Simulated Waterbody Crossings [1] | Estimated Mean TSS (mg/L) at Construction Site (Standard Error) | | | Mean TSS (mg/L) at 10 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 50 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 100 meters Downstream [5] (Standard Error) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wet Open Cut [2] | Dry Open Cut (Flume) [3] | Dry Open Cut (Dam-Pump) [4] | Wet Open Cut<br>Low Flows<br>Peak Flows [6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows [7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows [8] | Wet Open Cut<br>Low Flows<br>Peak Flows [6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows [7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows [8] | Wet Open Cut<br>Low Flows<br>Peak Flows [6] | Dry Open Cut Flume<br>Low Flows<br>Peak Flows [7] | Dry Open Cut Dam-Pump<br>Low Flows<br>Peak Flows [8] |

Assumptions:

[1] All simulated waterbodies are assumed to have depths ≤ 53 cm during ODFW (2008a) instream construction windows and have been assumed to be Minor Waterbodies (see Ritter, 1984). No waterbodies with bedrock substrates are included. No waterbodies that are adjacent to but not crossed by the pipeline are included.

[2] Based on the Mean TSS model generated by <u>All Activities</u> associated with wet open-cut construction, using variable $P_f$ , the percentage of silt and clay fines materials in the watershed and $d_{50}$ = 0.25 mm or 250 µm (assumed median sediment size of the excavated material by weight) (Reid et al., 2004).

[3] TSS generated by Flumed Dry Open-Cut construction were assumed to be 3.7 percent of concentrations generated by Wet Open-Cut construction (data from Reid et al., 2004).

[4] TSS generated by Dam-and-Pump Dry Open-Cut construction were assumed to be 0.85 percent of concentrations generated by Wet Open-Cut construction (data from Reid et al., 2004)

[5] Concentrations of TSS at 10, 50 and 100 downstream were estimated for fractions of gravel, sand, silt, and organics characteristic in substrates of streams in fifth-field watersheds and settling velocities: gravel (1.6 cm diameter), vs = 90 cm/s; sand (0.025 cm diameter), vs = 3 cm/s; silt (0.0016 cm diameter), vs = 0.023 cm/s; clay (0.0004 cm diameter), vs = 0.0014 cm/s. Concentrations were added to the assumed background level of 2 mg/L.

[6] Instream average low flows and average peak flows at the time of construction (within the ODFW, 2008b recommended in-water construction periods) are assumed to be some percent of the carrying capacity flows for all of the evaluated channel sections within a specific Sub-basin; percent reduction during average flows; percent reduction during average peak flows. Sediment concentrations (Cx) at downstream distances in minor waterbody crossings (Ritter, 1984) were computed from the initial concentrations (Co) estimated by the Mean TSS model generated by <u>All Activities</u> by Reid et al., 2004. .

[7] Initial concentrations (Co) of TSS generated by Flumed Dry Open-Cut construction were assumed to be 3.7 percent of concentrations generated by Wet Open-Cut construction (Reid et al., 2004)

[8] Initial concentrations (Co) of TSS generated by Dam-and-Pump Dry Open-Cut construction were assumed to be 0.85 percent of concentrations generated by Wet Open-Cut construction (Reid et al., 2004)

Estimated average TSS concentrations produced during fluming and dam-and-pump construction are equal to or near background TSS estimates (2 mg/L) at 10, 50, and 100 meters downstream from construction sites (see table 4.5.3-9 and appendix Y). However, TSS concentrations assumed to occur during failure of isolation structures could be higher.

Suspended Sediment Effects on Coho Salmon. Newcombe and Jensen (1996) provide four additional models that have not been applied to analysis of impact of sediment to fish in the PCGP Project area because fish species for which the models were developed are not expected in the habitats for which the two models would be applicable (see species-model associations in Table 2, Newcombe and Jensen, 1996). Model 2 (adult salmonids) does not apply to coho salmon (Newcombe and Jensen, 1996) and Model 4 (eggs and larvae of salmonids and non-salmonids) does not apply to effects by this project because instream construction will not coincide with coho spawning or periods of egg incubation-fry emergence (see figure 4.5-2, above). Model 5 applies to adult estuarine non-salmonids that are particularly sensitive to effects of suspended sediments and Model 6 applies primarily to adult warmwater centrarchid species, eg. sunfish).

Input for each of the four models includes TSS concentration (mg/L) and duration (hours) of exposure to the suspended sediments. Each model has the form:

$$\mathbf{z = a + b(log_e x) + c(log_e y)}$$

where **z** = severity-of-ill-effects (SEV) score, **x** = duration of exposure in hours, **y** = concentration of suspended sediment in mg/L. Constants **a**, **b** and **c** were empirically derived for each model (see Table 3, Newcombe and Jensen, 1996):

Output from each model is severity-of-ill-effects (SEV) score ranging from 0 to 14 where SEV of 0 indicates no effects, SEV between 1 and 3 indicates behavioral effects, SEV from 4 to 8 indicates sublethal effects, and SEV from 9 through 14 indicate lethal and paralethal effects (see Table 1 in Newcombe and Jensen, 1996).

1) Behavioral Effects SEV scores: 1 = Alarm reaction; 2 = Abandonment of cover; 3 = Avoidance response
2) Sublethal Effects SEV scores: 4 = Short-term reduction in feeding rates and/or feeding success; 5 = Minor physiological stress (increase coughing rate and/or increased respiration rate); 6 = Moderate physiological stress; 7 = Moderate habitat degradation and/or impaired homing; 8 = Indications of major physiological stress (long-term reduction in feeding rate and/or feeding success, poor condition)
3) Lethal and Paralethal Effects SEV scores: 9 = Reduced growth rate and/or delayed hatching and/or reduced fish density; 10 = 0 to 20% mortality and/or increased predation and/or moderate to severe habitat degradation. 11= >20 – 40% mortality (SEV scores exceeding 11 predict increased mortality rates).

Input for each of the two models, Model 1, juvenile and adult salmonids and Model 3, juvenile salmonids, includes TSS concentration (mg/L) and duration (hours) of exposure to the concentration. Output from each model is a severity-of-ill-effects (SEV) score ranging from 0 to 14, as (see Table 1 in Newcombe and Jensen, 1996).

Reid et al., (2004) reported two flumed crossings required 23 and 51 hours of instream work while durations of four dam-and-pump crossings ranged from 9 to 41 hours. Reid et al., (2004) reported that flumed crossings averaged 64 hours of instream work (with standard error of 14.1

hours) and dam-and-pump crossing averaged 37.8 hours of instream work (with standard error of 8.4 hours). Based on these data, the assumed range of time required for flumed crossings and dam-and-pump crossings is the mean ± 2 standard errors reported for each technique by Reid et al. (2004). Consequently, estimated durations for fluming range from 36 to 96 hours (see table 4.5.3-10) and for dam-and-pump the range is from 20 to 56 hours (see table 4.5.3-11). If there is a failure of the isolation dams/structures, the durations of maximum TSS concentrations that would be similar to a wet open-cut crossing are assumed to last from 1 hour to 24 hours; the shorter durations would indicate repair of the failed structures while the longer durations would indicate completing the construction by wet open-cut.

Effects to salmonid life stages due to flumed dry open-cut construction across waterbodies that do not have bedrock substrates are included in table 4.5.3-10. The mean TSS concentration generated during flumed pipeline construction across all waterbodies within the four fifth field watersheds in Upper Rogue Sub-basin is 3 mg/L (with standard error = 0.30) 10 meters downstream from the construction site. Assuming a worst case scenario for all streams crossed during average low flow conditions (mean plus 2 standard errors) within the Upper Rogue Sub-basin and within range of SONCC coho, the TSS concentration could be as high as 4 mg/L at 10 meters downstream, declining with greater distances. During average peak flows, mean TSS concentration generated during flumed pipeline construction is 3 mg/L (with standard error = 0.37) 10 meters downstream from the construction site. During peak flows, the TSS concentration could also be as high as 5 mg/L (mean plus 2 standard errors) at 10 meters downstream. All flumed construction is assumed to be completed between 36 and 96 hours (see above).

Similarly, effects to salmonid life stages due to dam-and-pump dry open-cut construction across waterbodies that do not have bedrock substrates are included in table 4.5.3-11. The mean TSS concentration generated during dam-and-pump pipeline construction across all waterbodies within the four fifth field watersheds in Upper Rogue Sub-basin is 2 mg/L (with standard error = 0.07) 10 meters downstream from the construction site. Assuming a worst case scenario for all streams crossed (mean plus 2 standard errors) within the Upper Rogue Sub-basin and within range of SONCC coho, the TSS concentration could be 2 mg/L at 10 meters downstream. During average peak flows, mean TSS concentration generated during flumed pipeline construction is also 2 mg/L (with standard error = 0.08) 10 meters downstream from the construction site. During peak flows, the TSS concentration could be 3 mg/L (mean plus 2 standard errors) at 10 meters downstream. All dam-and-pump construction is assumed to be completed between 20 and 56 hours (see above).

Effects to SONCC Coast coho juveniles and adults due to either of the flumed dry open-cut construction and dam-and-pump dry open-cut construction procedures for waterbodies that do not have bedrock substrates are included in table 4.5.3-10 and table 4.5.3-11, respectively, for expected low flow and potential peak flow conditions during the ODFW (2008a) instream construction windows. Results from applying Model 1 for juvenile and adult coho indicate SEV scores for durations of exposure to the TSS concentrations of 4 mg/L or less would range from SEV = 4 (short-term reduction in feeding rates and/or feeding success) to SEV = 5 (minor physiological stress-increase coughing rate and/or increased respiration rate), and to SEV = 6 (moderate physiological stress) which includes the upper 95% confidence intervals (Newcombe and Jensen, 1996). Peak flows produced TSS levels nearly the same as average low flows and would generate similar SEV scores in table 4.5.3-10 and table 4.5.3-11. All expected responses by adult and juvenile salmonids to TSS produced during fluming or dam-and-pump 10 meters or more downstream would be classified as sublethal, whether during low flows or peak flows.

**Table 4.5.3-10**
**Application of Three Models for Estimating Severity of Effects to SONCC Coho 10 Meters Downstream Due to TSS Concentrations Produced by Flumed Pipeline Construction Ranging from 36 to 96 hours During Low Flow and Peak Flow Conditions**

| Model Number (and particle size) | Exposure (hours) | Average Low Flows | | | Average Peak Flows | | |
|---|---|---|---|---|---|---|---|
| | | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] |
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 36 | 3 | 4 | 5 | 3 | 4 | 5 |
| | 48 | 3 | 4 | 5 | 3 | 4 | 5 |
| | 72 | 3 | 4 | 5 | 3 | 4 | 5 |
| | 96 | 3 | 5 | 5 | 3 | 5 | 5 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 36 | 3 | 4 | 5 | 3 | 4 | 5 |
| | 48 | 3 | 4 | 5 | 3 | 4 | 5 |
| | 72 | 3 | 5 | 6 | 3 | 5 | 6 |
| | 96 | 3 | 5 | 6 | 3 | 5 | 6 |

[1] SEV scale of effects to fish (see Table 1 in Newcombe and Jensen, 1996) within range of model outputs:
Behavioral Effects: 2 = Abandonment of cover; 3 = Avoidance response
Sublethal Effects: 4 = Short-term reduction in feeding rates and/or feeding success; 5 = Minor physiological stress (increase coughing rate and/or increased respiration rate); 6 = Moderate physiological stress; 7 = Moderate habitat degradation and/or impaired homing; 8 = Indications of major physiological stress (long-term reduction in feeding rate and/or feeding success, poor condition)
Lethal and Paralethal Effects: 9 = Reduced growth rate and/or delayed hatching and/or reduced fish density; 10 = 0 to 20% mortality and/or increased predation and/or moderate to severe habitat degradation. 11= >20 – 40% mortality.
[2] Upper 95% confidence intervals on SEV scores (rounded to nearest integer) were approximated from values in Figures 1, 2, 3, and 4 in Newcombe and Jensen, 1996.

**Table 4.5.3-11**
**Application of Three Models for Estimating Severity of Effects to SONCC Coho 10 Meters Downstream Due to TSS Concentrations Produced by Dam-and-Pump Pipeline Construction Ranging from 20 to 56 hours During Low Flow and Peak Flow Conditions**

| Model Number (and particle size) | Exposure (hours) | Average Low Flows | | | Average Peak Flows | | |
|---|---|---|---|---|---|---|---|
| | | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] |
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 20 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 32 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 44 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 56 | 2 | 4 | 5 | 2 | 4 | 5 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 20 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 32 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 44 | 2 | 4 | 5 | 2 | 4 | 5 |
| | 56 | 2 | 4 | 6 | 2 | 4 | 6 |

[1] See footnotes to table 4.5.3-10.

Failures of isolation structures to exclude streamflow during fluming or dam-and-pump would result in suspended sediment entrained downstream, assumed to be similar to TSS levels generated during wet open-cut construction (mean plus 2 standard errors from table 4.5.3-9) and included in table 4.5.3-12 along with several potential durations of exposure. Scenarios of exposures of 1 hour and 6 hours could occur while work crews repair the failed isolation structures. Longer exposures of 12 and 24 hours are assumed to occur if dry open-cut construction (flume or dam-and-pump) is abandoned and the waterbody crossing is completed using wet open-cut construction. Suspended sediments concentrations of 29 mg/L during low flows and 31 mg/L during peak flows for durations of 12 to 24 hours would not produce lethal conditions for juvenile and/or adult SONCC coho but could result in moderate physiological stress (SEV = 6) but not moderate habitat degradation and/or impaired homing (if SEV = 7).

**Table 4.5.3-12**
**Application of Three Models for Estimating Severity of Effects to SONCC Coho 10 Meters Downstream due to TSS Concentrations Produced by Failure of Isolating Structures During Low Flow and Peak Flow Conditions under Different Exposure Durations**

| **Model Number** (and particle size) | **Exposure (hours)** | **Average Low Flows** TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] | | **Average Peak Flows** TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] |
|---|---|---|---|---|---|---|---|---|
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 1 | 29 | 4 | 4 | | 31 | 4 | 4 |
| | 6 | 29 | 5 | 5 | | 31 | 5 | 5 |
| | 12 | 29 | 5 | 6 | | 31 | 5 | 6 |
| | 24 | 29 | 5 | 6 | | 31 | 5 | 6 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 1 | 29 | 3 | 4 | | 31 | 3 | 4 |
| | 6 | 29 | 4 | 5 | | 31 | 4 | 5 |
| | 12 | 29 | 5 | 6 | | 31 | 5 | 6 |
| | 24 | 29 | 5 | 6 | | 31 | 5 | 6 |

[1] See footnotes to table 4.5.3-10.

FWS (Muck, 2010) incorporated the scaled SEV scores into section 7 consultations on bull trout such that SEV scores of 6 or higher would be expected to cause harassment using Model 1 (Juvenile and Adult Salmonids) and would justify a determination of “likely to adversely affect”. figure 4.5-7a provides combinations of TSS concentrations and exposures that would distinguish between determinations of “likely to adversely affect” and “not likely to adversely affect”.

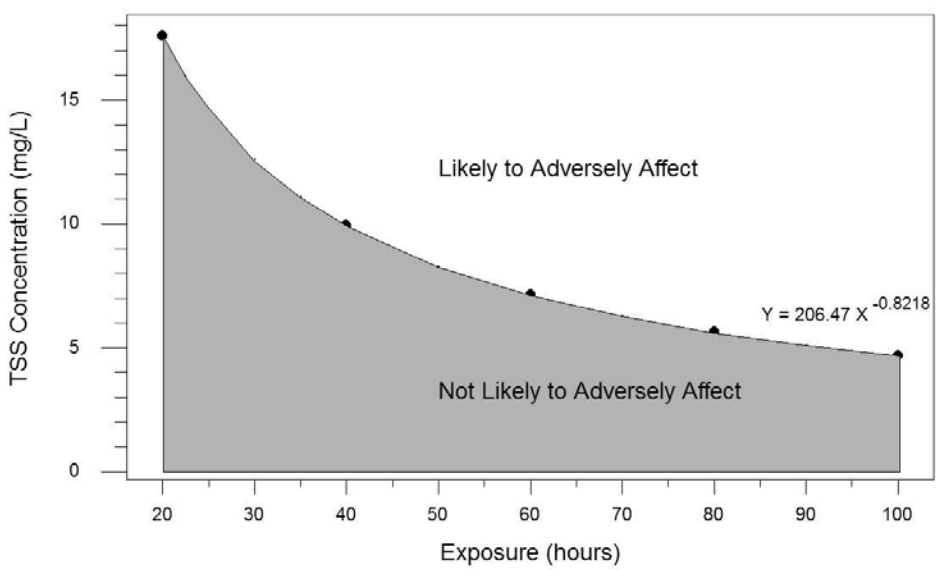



**Figure 4.5-7a**
**Combinations of TSS concentrations and Exposure that would Limit SEV Scores of 5 or Lower (Gray Area) in Model 1 (Newcombe and Jensen, 1996) with a Determination of “Not Likely to Adversely Affect” Adult and Juvenile Salmonids (Muck, 2010)**

Similarly, FWS (Muck, 2010) determined that SEV scores of 5 or higher would cause harassment with application of Model 3 (Juvenile Salmonids) and would justify a determination of “likely to adversely affect.” figure 4.5-7b provides combinations of TSS concentrations and exposures that would distinguish between determinations of “likely to adversely affect” and “not likely to adversely affect.” The same determinations of effect are assumed for coho salmon in this biological assessment.

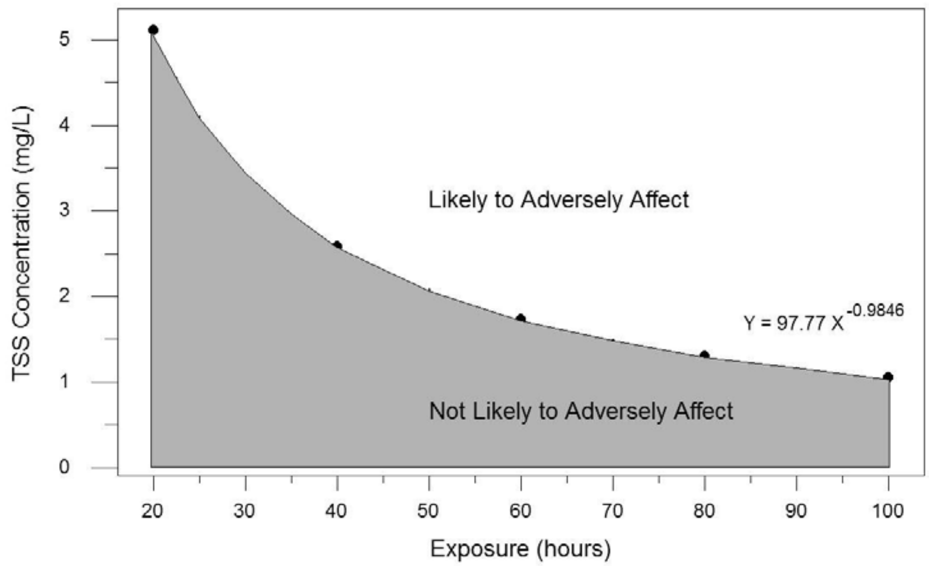
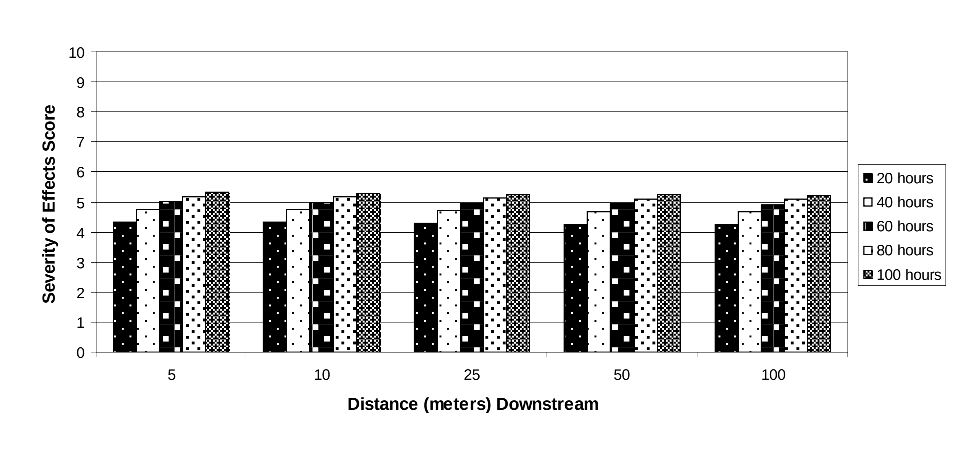



**Figure 4.5-7b**

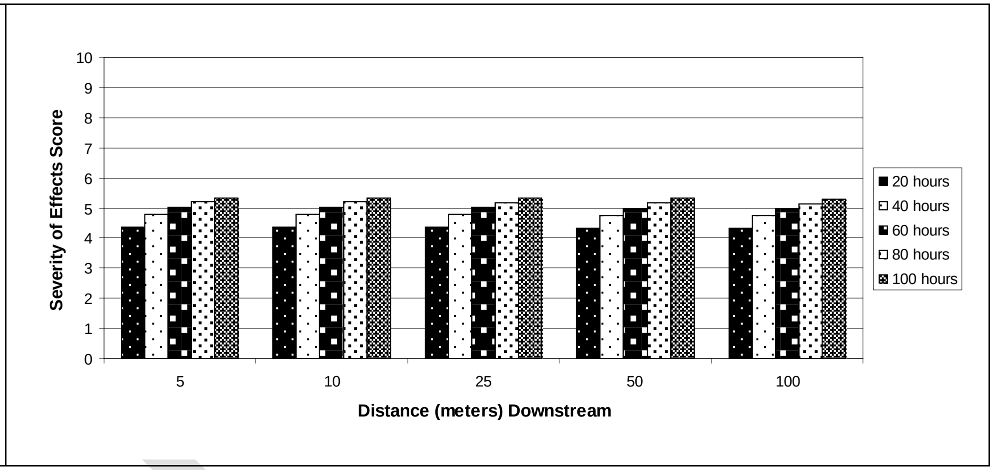
**Combinations of TSS concentrations and Exposure that would Limit SEV Scores of 4 or Lower (Gray Area) in Model 3 (Newcombe and Jensen, 1996) with a Determination of “Not Likely to Adversely Affect” Juvenile Salmonids (Muck, 2010)**

SEV scores were computed for streams within each fifth field watershed crossed within the Upper Rogue Subbasin using TSS concentrations estimated at 5, 10, 25, 50, and 100 meters downstream from pipeline construction sites and exposure durations from 20 to 100 hours which covers the expected durations required for dam-and-pump and flumed construction. Upper 95% confidence intervals, added to SEV scores, were used to evaluate potential scenarios within each fifth field watershed depending on whether Model 1 (juvenile and adult coho) or Model 3 (juvenile coho) was considered for estimated average low flows and for estimated average peak flows occurred during the period of instream construction.

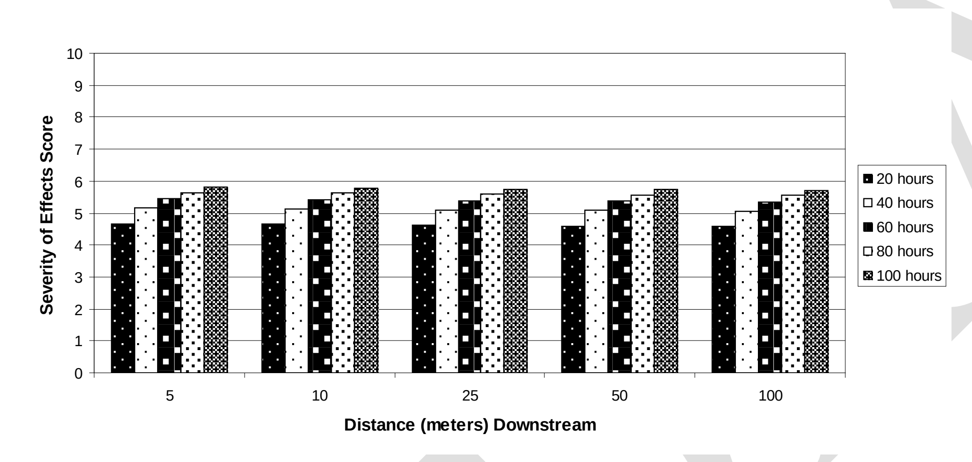
Results are shown below for TSS effects within Trail Creek (figure 4.5-8), Shady Cove-Rogue River (figure 4.5-9), Big Butte Creek (figure 4.5-10), and Little Butte Creek (figure 4.5-11) watersheds. The model outputs (SEV scores plus 95% confidence intervals) show that instream construction lasting for 20 to 40 hours would not exceed scores of 5 with Model 1 for either average low flows or average peak flows in all four watershed. Based on that model and exposures, the project would be “not likely to adversely affect” coho based on figure 4.5-7b. However, construction lasting for 20 hours or more would exceed a score of 4 with Model 3, regardless of flow rates, in all four watersheds. Based on that model and exposures, the project would be “likely to adversely affect” coho based on figure 4.5-8.



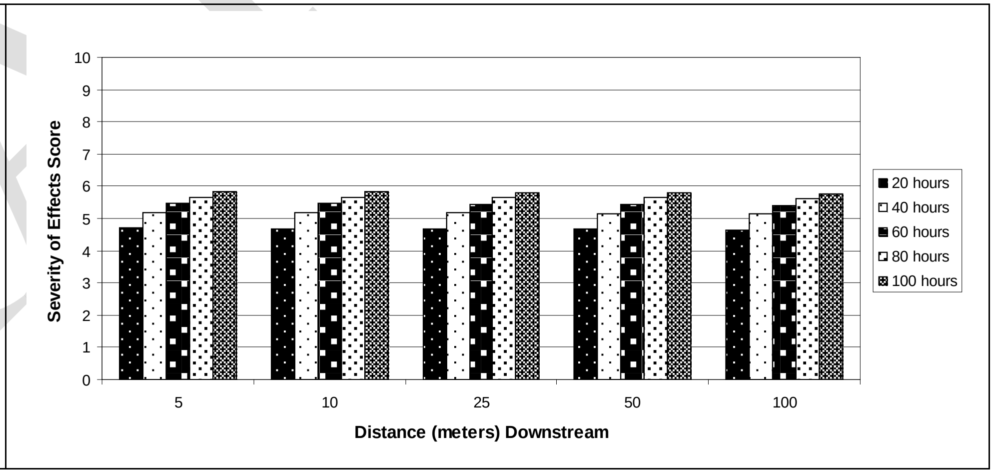

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**

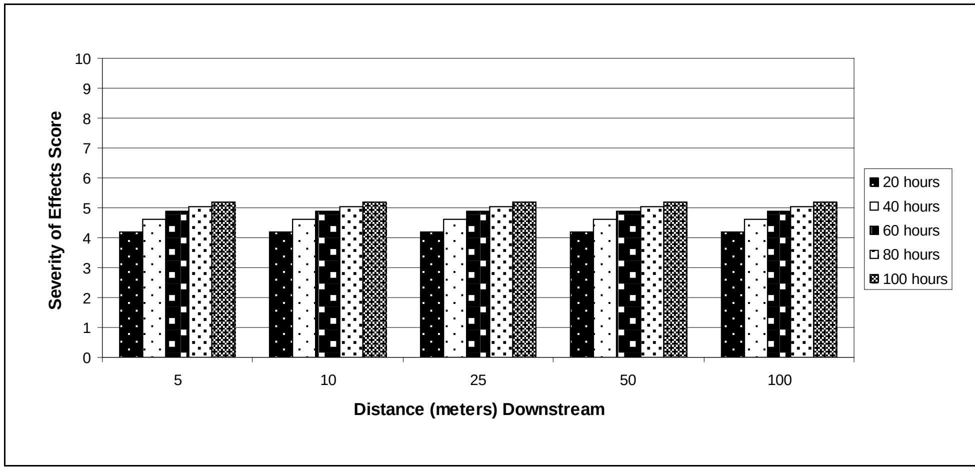



**C. Model 3, SEV Scores During Average Low Flows**

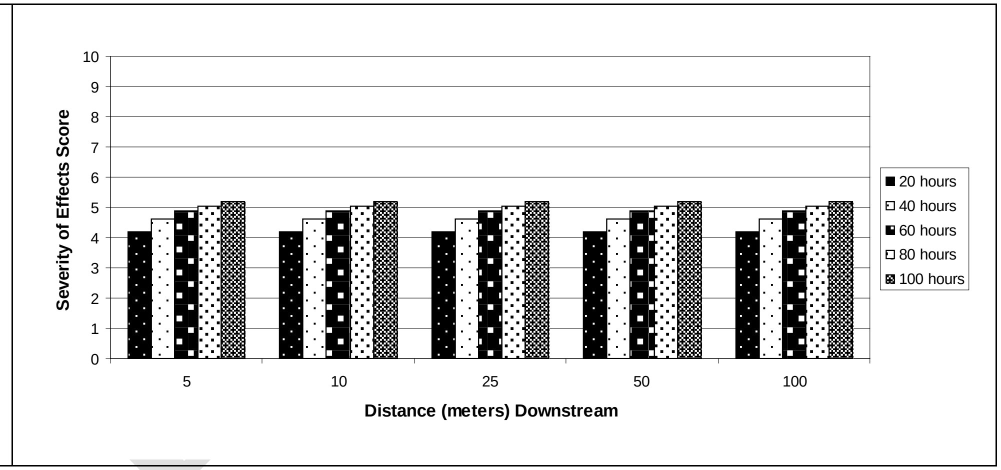



**D. Model 3, SEV Scores During Average Peak Flows.**

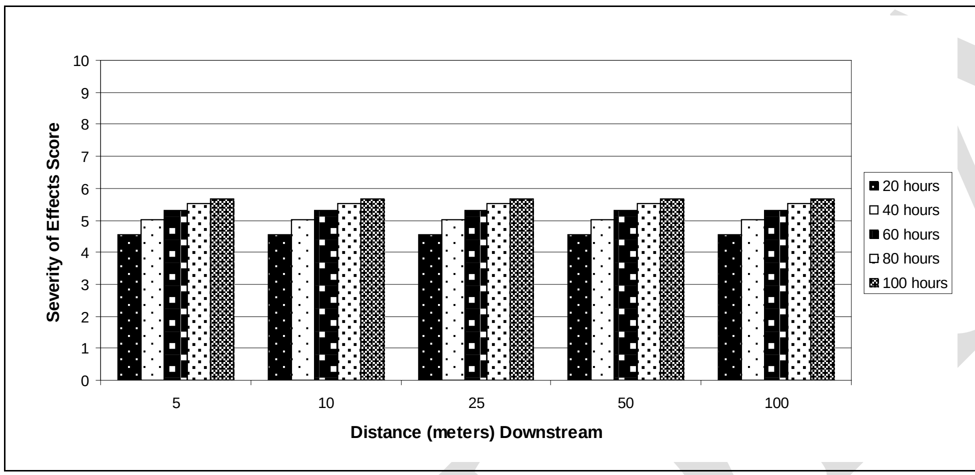
**Figure 4.5-8**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Trail Creek Watershed (HUC 1710030706) During Pipeline Construction by Fluming between June 15 and September 15. Estimated SEV Scores Include Upper 95% Confidence Intervals on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**



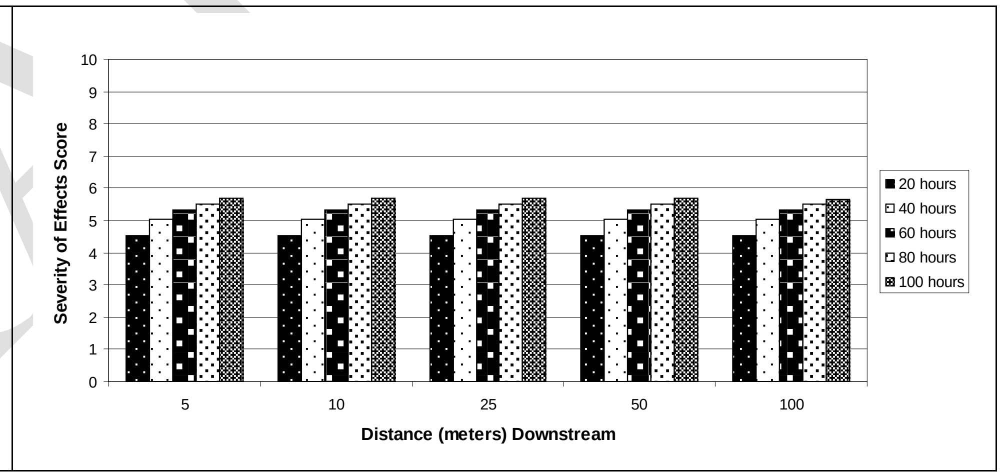

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**

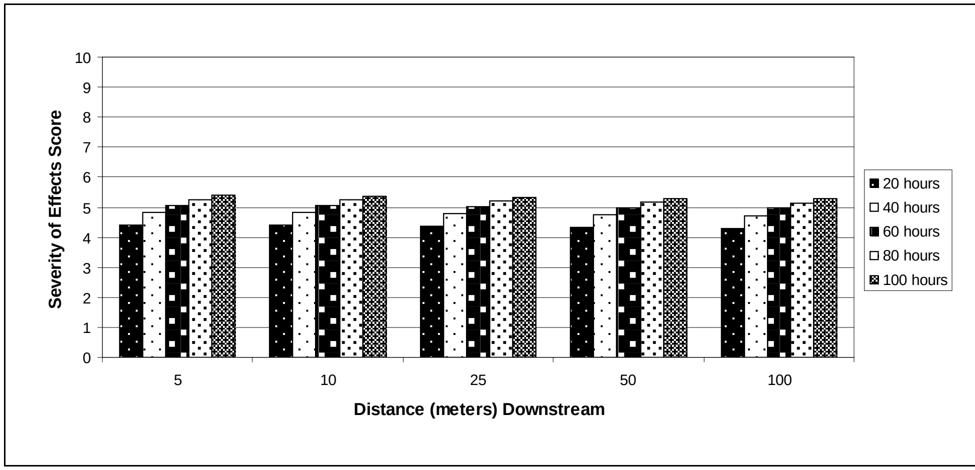



**C. Model 3, SEV Scores During Average Low Flows**

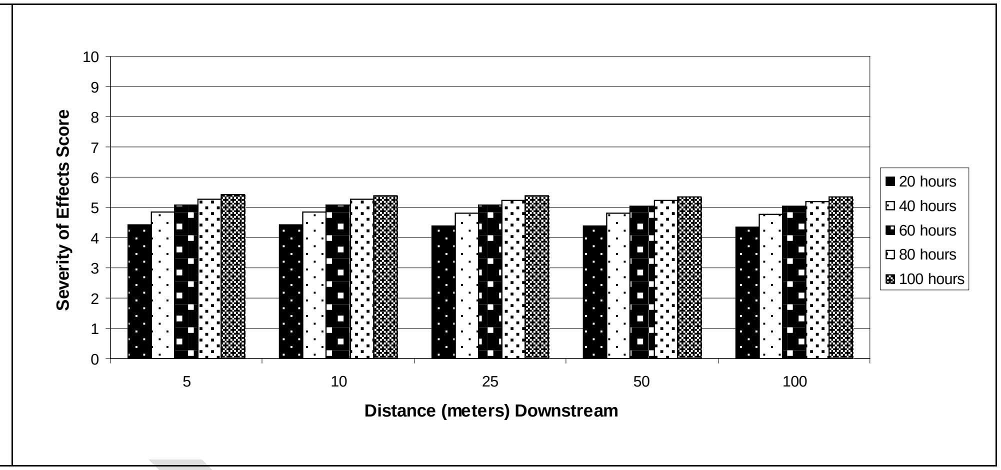



**D. Model 3, SEV Scores During Average Peak Flows.**

**Figure 4.5-9**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Shady Cove-Rogue River Watershed (HUC 1710030707) During Pipeline Construction by Fluming between June 15 and September 15. Estimated SEV Scores Include Upper 95% Confidence Intervals on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**

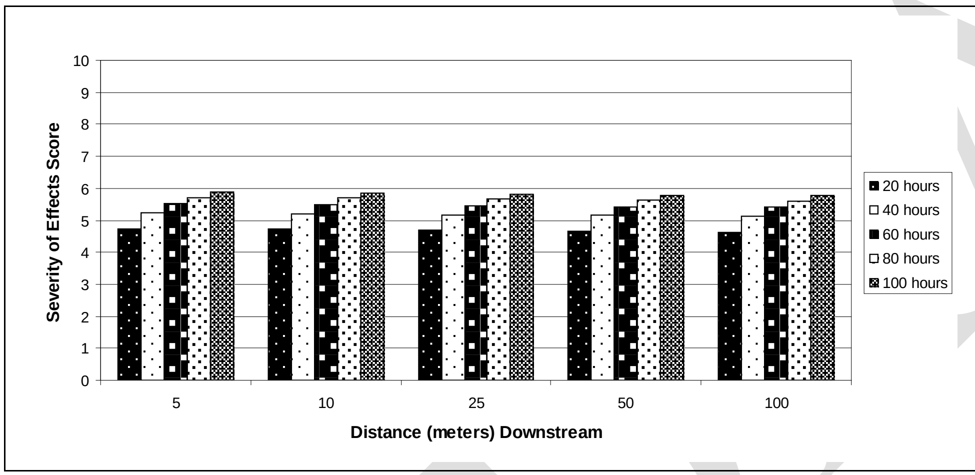



**A. Model 1, SEV Scores During Average Low Flows**

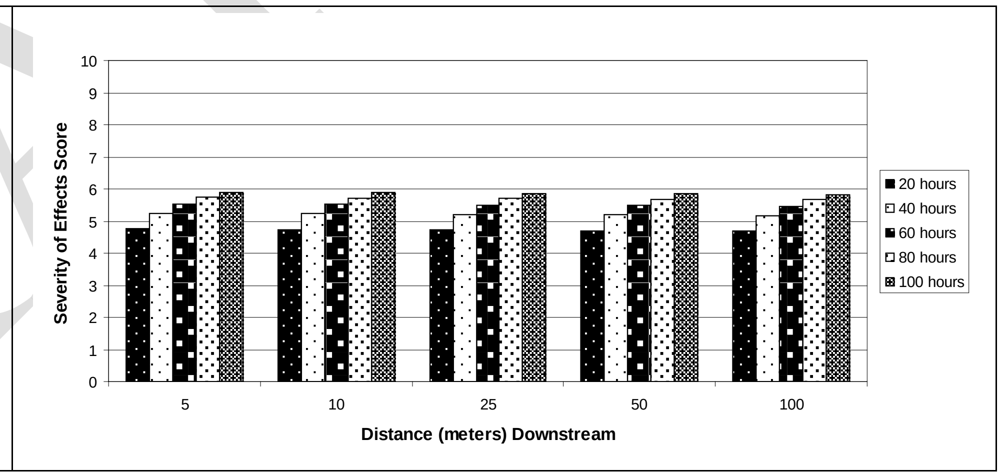



**B. Model 1, SEV Scores During Average Peak Flows.**



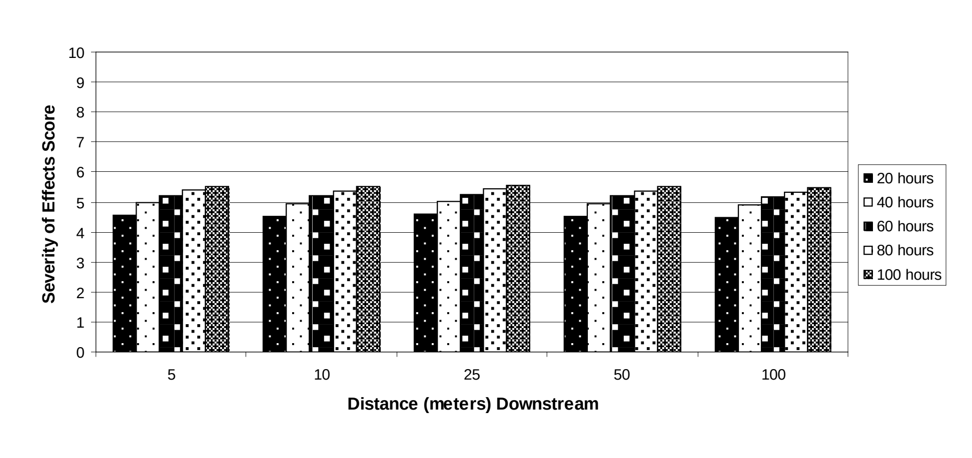



**C. Model 3, SEV Scores During Average Low Flows**

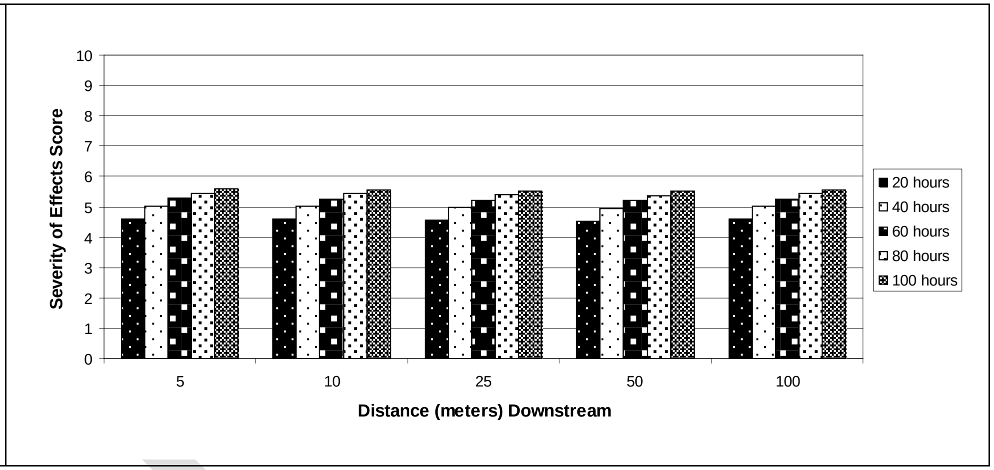



**D. Model 3, SEV Scores During Average Peak Flows.**

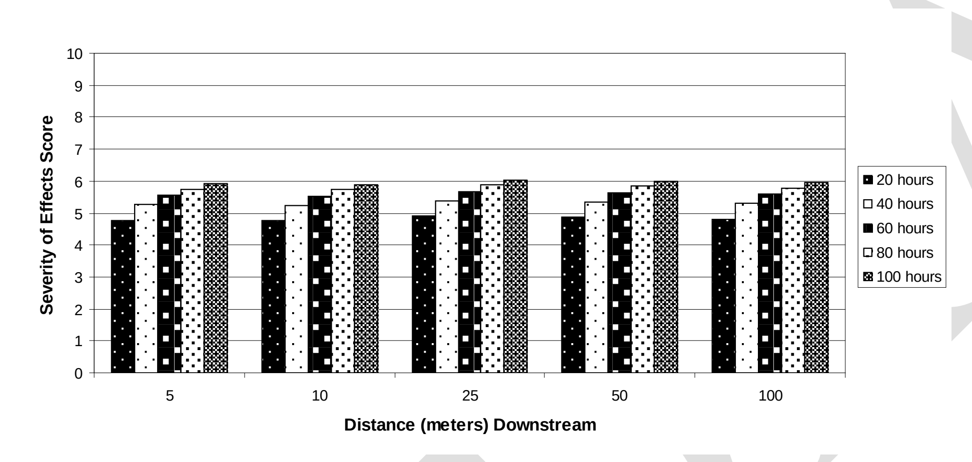
**Figure 4.5-10**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Big Butte Creek Watershed (HUC 1710030704) During Pipeline Construction by Fluming between June 15 and September 15. Estimated SEV Scores Include Upper 95% Confidence Intervals on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**



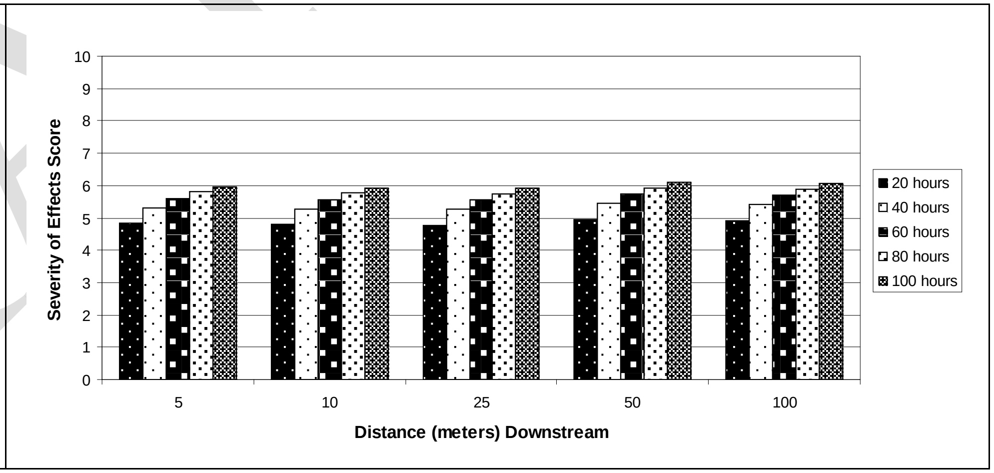

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**




**C. Model 3, SEV Scores During Average Low Flows**




**D. Model 3, SEV Scores During Average Peak Flows.**

**Figure 4.5-11**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Little Butte Creek Watershed (HUC 1710030708) During Pipeline Construction by Fluming between June 15 and September 15. Estimated SEV Scores Include Upper 95% Confidence Intervals on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**

Entrainment and Entrapment

Waterbody crossings using the "dry" crossing methods, flume or dam-and-pump, may result in some fish being entrapped in streams. Flumes and dams will be completely installed and functioning before any instream disturbance. Construction across a waterbody would take up to seven days using dry open cut methods, but less for small and intermediate streams. Once streamflow is diverted through the flume pipe, but before pipeline trenching begins, fish trapped in any water remaining in the work area between the dams would be removed and released using the Fish Salvage Plan (see appendix T). Pacific Connector will contract with either ODFW or a qualified consultant to capture the fish. Personnel that would handle and/or remove fish on federal lands would be approved by the Forest Service or the BLM or be done directly by agency personnel if approved by ODFW.

Frac-Out

Although the HDD method avoids instream impacts because it eliminates the need for instream excavation, it does not completely eliminate the possibility of impacts on aquatic resources. Pacific Connector proposes to use this method to cross the Rogue Rivers. Because HDD requires a lubricant during the process, this fluid is under pressure and there is a possibility of an inadvertent release of drilling mud or fluid (also referred to as a frac-out). Drilling mud primarily consists of water mixed with bentonite, which is a naturally occurring clay material. The only other possible additives would be nontoxic solid materials (e.g., sawdust, nut shells, bentonite pellets, or other commercially available nontoxic products) that could be needed to plug an inadvertent release.

Bentonite by itself is essentially a non-toxic drilling mud (Breteler et al., 1985; Hartman and Martin, 1984; Sprague and Logan, 1979). However, bentonite, as with any fine particulate material, can interfere with oxygen exchange by the gills of aquatic organisms (EPA, 1986). The degree of interference generally increases with water temperature (Horkel and Pearson 1976). Impacts would be localized and would normally be limited to individual fish in the immediate vicinity of the frac-out. The majority of highly mobile aquatic organisms, such as fish, would be able to avoid or move away from turbidity spots and plumes (Reid and Anderson 1999). Other less mobile or immobile organisms, such as mussels and other macroinvertebrates, would incur direct mortality. Bentonite can smother macroinvertebrates and adversely affect filter-feeders (Falk and Lawrence 1973 in Hair et al. 2002 and Land 1974 in Cameron et al. 2002). Bentonite can also exacerbate or enhance the effects of toxic compounds to fish and aquatic invertebrates if those compounds are present in aquatic habitats (Hartman and Martin 1984). Similar to other fine-grained particulates, bentonite in flowing water is more likely to remain in suspension longer than in standing water. Consequently, effects to coho salmon by a release of bentonite into a waterbody would ultimately depend on volume of the release, volume of water present, and current. Coho salmon inhabiting larger waterbodies with swift currents would be less affected by a given volume of bentonite than those inhabiting small waterbodies with no current.

The effects of an instream frac-out on spawning habitat, eggs, and juvenile survival depend on the timing of the release. If spawning habitat is nearby, redds could be affected in the vicinity of frac-out (Reid and Anderson, 1999), if not concurrently, possibly within the immediate future unless high flows flush residual bentonite. During establishment of the spawning bed, a minor addition of sediment would likely be cleaned out by the female as part of the normal preparation behavior. However, a heavy sediment load dispersing downstream could settle into spawning beds and clog interstitial spaces, reducing the amount of available spawning habitat, which could be a limiting factor in areas of already reduced habitat. When redds are active, eggs could be buried, disrupting the normal exchange of gases and metabolic wastes between the egg and water (Anderson, 1996). The impacts of sediment intrusion into the redd on larval survival are more severe during the earlier embryonic stages than following development of the circulatory system of larvae, possible because of a higher efficiency in oxygen uptake by the older fish (Bash et al., 2001). Clogging of interstitial spaces also reduces cover and food availability for juvenile salmonids (Cordone and Kelley, 1961). Benthic organisms could also be affected by burial. However, bentonite is more likely to stay in suspension and less likely to immediately settle than common bottom sediment so, in flowing water areas, effects to benthic organisms from burial from frac-out are likely to be low. The locations where any frac-out may occur are all large waterbodies, which would be affected less because of the dilution factor of large volume of water from any spill.

Potential frac-outs are more common near the HDD drill entry and exit locations; however, impacts to waterbodies are minimized by locating the drill entry and exit points away from the waterbody. The probability of a frac-out may increase when the drill bit is working nearest the surface, but is dependent on numerous factors including substrate characteristics, head pressure of the drilling mud, topography, elevation, and subsurface hydrology. Pacific Connector has designed the Klamath River HDD such that areas of greatest risk from frac-out are on uplands and not adjacent to the waterbodies where much greater depth would be achieved and frac-out potential is reduced.

According to GeoEngineers' Feasibility Analysis for pipeline construction using HDD across the Rogue River (see appendix E) the design length of the Rogue River HDD crossing is approximately 3,050 feet. The proposed entry point is located in a relatively flat, lightly wooded area east of Rogue River and west of Old Ferry Road. The exit point is located near the base of a west facing slope that forms a small butte east of the exit point. The preliminary design provides approximately 58 feet of cover at the eastern and western banks of the Rogue River. GeoEngineers' preliminary evaluation determined that the construction of the Rogue River HDD crossing is likely feasible. Additional evaluation of the hydraulic fracture and inadvertent return potential will be completed for the final design.

Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils with low shear strength or very loose granular soils. Loose and silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to dense sands and gravels and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Unfractured rock, because of its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or in formations with higher shear strength may reduce the potential for hydraulic fracturing (see appendix E).

In the event an inadvertent return occurs into the river, drilling fluid will enter the waterway causing short term, temporary water quality impacts downstream of the project area including sedimentation and turbidity. In the event drilling fluid is inadvertently released into the river, the behavioral avoidance response of SONCC coho is presumed to be triggered within the immediate vicinity of the release and the fish are expected to return and utilize the affected area shortly after the inadvertent release has been halted. If significant concentrations are found during monitoring as a result of a release, the following possible corrective measures would be taken:

1. Increase the drilling fluid viscosity in an attempt at sealing the point at which fluid is leaving the drilled hole. The drilling operation may be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.
2. If increasing the drilling fluid viscosity is ineffective, lost circulation materials (LCM) may be introduced into the hole by incorporating them in the drilling fluid and pumping the material down-hole. The drilling operation may again be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the lost circulation materials.
3. Depending on the location of the fractured zone, a steel casing may be installed that is of sufficient size to receive the largest expected down-hole tools for the crossing. This casing installation provides a temporary conduit for drilling fluids to flow while opening the remaining section of the hole to a diameter acceptable for receiving the proposed pipe sections. To alleviate future concerns with the steel casing after the HDD installation is completed, the casing is generally extracted from the hole prior to or just after completing the HDD installation. However, there have been instances when attempts at extracting the steel casing were unsuccessful.
4. In the event drilling fluid flow is not regained through the annulus of the drilled hole and a steel casing installation is not utilized, the HDD contractor may elect to install a grout mixture into the drilled hole in an attempt to seal the fractured zone. The down-hole drilling assembly is generally extracted and existing hole is re-drilled to the point at which it had previously been drilled prior to having encountered the loss of drilling fluid.
5. In addition, a grouting program may be implemented from the surface in the event that the installation of grout into the drilled hole is unsuccessful. This approach is only practical in areas where drilling rigs with vertical drilling capabilities can access the HDD alignment. If a surface grouting program is utilized, the HDD drilling assembly is extracted from down-hole. Multiple holes are then drilled vertically on either side and along the HDD alignment to allow for grout slurry to be pumped into the fracture zone where the drilling fluid had previously been lost from the drilled hole. This process can take several days to complete in order to insert the grout in a grid pattern that covers the full fractured zone, during which time the HDD operation is suspended. Upon completion of the surface grouting program, the HDD operation will resume and the pilot hole will be reestablished through the grouted formation.

In some instances, it may be determined that the existing hole encountered a zone of unsatisfactory soil material and the hole may have to be abandoned. If the hole is abandoned, it will be filled with cuttings and drilling fluid.

<u>Movement Blockage</u>

Dry open-cut construction is expected to block upstream movement by adult salmonids, as well as withinstream movements of juvenile coho. As discussed above, fish are expected to abandon cover and/or avoid turbidity plumes generated by instream construction. Instream construction would be completed prior to most upstream migrations by SONCC coho. The fluming process is expected to require from 36 to 96 hours of instream work (see table 4.5.3-10) during which migrating adult SONCC coho could be exposed to TSS concentrations that would produce SEV scores ranging from 5 (minor physiological stress with increase coughing rate and/or increased respiration rate) to 6 (moderate physiological stress).

Flumes would maintain streamflow and fish might move upstream or downstream through the flume. With the dam and pump method, fish would not be able to move upstream or downstream through the work area until the dams have been removed. Flumes and dams would be removed as soon as possible following backfilling of the trench.

With the dam and pump method, coho would not be able to move upstream or downstream through the work area until the dams have been removed. However, dam-and-pump construction is expected to require between 20 and 56 hours of instream work (see table 4.5.3-11). Dam-and-pump construction would generate lower TSS concentrations than fluming; effects to coho would be expected to range from short-term reduction in feeding rates and/or feeding success (SEV score 4) to moderate physiological stress (SEV score 6).

**Indirect Effects**

Aquatic Habit

The same approach utilizing TSS concentration and exposure to evaluate levels of risk to fish (Newcombe and Jensen, 1996) was applied to quantifying effects of sediment on fish habitat, termed the harmful alteration, disturbance or destruction (HADD) of habitat (Anderson et al., 1996). HADD risk includes concentration and exposure to sediment along with sensitivity of the habitat affected. Most likely, suspended sediment would increase embeddedness of spawning gravels with increasing habitat effects closer to the construction location.

Sediment falling out of suspension downstream from the construction location can affect freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, logjams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Based on the models for suspended sediment concentration and duration of exposure discussed above (see tables 4.5.3-10 through 4.5.3-12 and figures 4.5-8 through 4.5-11), Anderson et al. (1996) described five severity of ill effect ranks to habitat:

- SEV 3: Measured change in habitat preference.
- SEV 7: Moderate habitat degradation measured by a change in the invertebrate community.
- SEV 10: Moderately severe habitat degradation as defined by measureable reductions in the productivity of habitat for extended periods (months) or over a large area (kilometers).
- SEV 12: Severe habitat degradation as measured by long-term (years) alterations in the ability of existing habitats to support fish or invertebrates.
- SEV 14: Catastrophic or total destruction of habitat in the receiving environment.

FWS (Muck, 2010) determined that SEV scores of 5 or higher applying Model 3 would likely warrant a “likely to adversely affect” juvenile bull trout habitat although noting that abandonment of cover (SEV 2) or avoidance of habitat / change in habitat preference (SEV 3) could lead to increased predation risk and mortality if hiding cover is limited in an affected stream reach (Muck, 2010). For adult and subadult bull trout, FWS judged that abandonment of cover and avoidance may not lead to similar predation risks. Averse effects would likely occur when TSS concentrations lead to notable reduction in abundance of aquatic invertebrates and alteration in their community structure. Consequently, SEV scores (or HADD scores in Anderson et al., 1996) of 7 or higher would warrant a determination of “likely to adversely affect" adult and subadult bull trout due to indirect effects because of habitat degradation (Muck, 2010). In this biological assessment, similar levels of effect due to TSS concentrations and durations of exposure are assumed to apply to coho salmon.

The project is expected to impact salmonid habitat more than the SEV 3 level for Models 1 and 3 included in table 4.5.3-10 and table 4.5.3-11 but would not degrade habitat to the SEV 7 level, even if the upper 95% confidence levels are considered in Model 1 or Model 3 during a failure of dry open-cut construction if TSS concentrations of 29 to 31 mg/L lasted for 12 to 24 hours (see table 4.5.3-12). In cases of uninterrupted dry open-cut construction, adverse affects to coho habitats downstream are not expected.

Freshwater Stream Invertebrates

Substrates downstream from instream construction sites could be impacted by sediments. Mayflies, caddisflies, and stoneflies prefer large substrate particles in riffles and are adversely affected by fine sediment deposited in interparticulate spaces (Cordone and Kelley, 1961; Waters, 1995; Harrison et al., 2007). Fish and benthic macroinvertebrate abundances downstream of pipeline construction sites have been reported as short-term reductions (Reid and Anderson, 1999). Macroinvertebrate abundance and community composition are highly related to the degree to which substrate particles are embedded by fine material (Birtwell, 1999).

Fish emigrate from construction sites and benthic taxa drift downstream to sites where sediment deposition has not affected habitat suitability (Reid and Anderson, 1999). In Ontario, stream crossing construction using fluming produced less turbidity and sediment concentrations downstream than construction by wet open cutting streams; wet open cutting resulted in a significant decrease in aquatic invertebrates downstream three days post-construction (Baddaloo, 1978 cited in Gartman, 1984). One year after construction there were no significant differences in benthos numbers. In general, the percentage of type of stream benthos and invertebrate taxa affected by construction of the proposed pipeline would be in proportion to their abundance during the season of construction.

Rapid colonization by benthic organisms of disturbed substrate following pipeline construction has been demonstrated elsewhere. In Pennsylvania, samples taken before and 30 days after pipeline construction revealed rapid recolonization of the disturbed and newly-exposed stream substrate by benthic macroinvertebrates (Gartman, 1984). Similarly, the number and diversity of aquatic invertebrate taxa in coldwater streams in New York State were unchanged two to four years following pipeline construction from those measured prior to construction (Blais and Simpson, 1997).

Aquatic Nuisance Species

Non-indigenous aquatic species (NAS) are aquatic species that degrade aquatic ecosystem function and benefits, in some cases completely altering aquatic systems by displacing native species, degrading water quality, altering trophic dynamics, and restricting beneficial uses (Hanson and Sytsma, 2001). Currently there are 180 reported NAS in Oregon, of which 134 are documented within the USGS hydrologic basins crossed by the proposed Pacific Connector Pipeline Project (USGS, 2005). Within the Coos Bay estuary, over 67 NAS have been identified (Aquatic Nuisance Species Taskforce, 2006). All of the invertebrate NAS in the Coos Bay estuary have been introduced by ship fouling or discharge from ballast water of ocean-going vessels.

Largemouth bass and smallmouth bass, introduced as recreational species, prey on juvenile sockeye, coho, and chinook salmon (Tabor et al., 2007). Management priorities in Oregon concentrate on the species whose current or potential impacts on native species and habitats and economic and recreational activity in Oregon are known to be significant, known as aquatic nuisance species (ANS) (Hanson and Sytsma, 2001). Pacific Connector has developed BMPs to avoid the potential spread of the aquatic invasive species and pathogens of concern (see Hydrostatic Testing Plan – appendix U). If determined to be feasible for hydrostatic testing requirements, all water used in hydrostatic testing would be returned to its withdrawal source location after use; however, cascading water from one test section to another to minimize water withdrawal requirements may make it impractical to release water within the same watershed where the water was withdrawn. If it is not possible to return the water to the same water basin from where it was withdrawn, various water treatment methods would be used to disinfect water that would be transferred across water basin boundaries including screening/filtering, chlorine treatment, and discharge to upland sites. After hydrostatic test water withdrawal, all equipment used in the withdrawal process would be cleaned and sanitized to prevent the potential spread of aquatic invasives and pathogens from the use of this equipment in other waterbody sources (see appendix U).

Riparian Vegetation Removal and Modification

Aquatic resources could be affected as a result of removal of vegetation and habitat at the waterbody crossing sites as required for pipeline construction. Short-term, physical habitat disruption would occur during trenching activities. Long-term degradation of habitats could occur if the stream contours are modified in the area of the crossing; the flow patterns are changed; and if erosion of the bed, banks, or adjacent upland areas introduces sediment into the waterbody. Loss of riparian vegetation along the banks would reduce shade, potentially increasing water temperatures, remove an important source of terrestrial food for aquatic organisms, and decrease LWD and the associated reduction in habitats, and potentially increase mass failures adjacent to waterbodies.

Much of the impact to coldwater anadromous and resident fisheries by past land uses have been alterations of riparian habitats by logging, road building, agriculture, or other developments such as residences and utility corridors. A total of 105.02 acres of riparian zone habitat associated with waterbodies within range of SONCC coho ESU would be directly affected by all construction related activities. Over half of the affected vegetation (52.56 acres) would be within non-forested types but 25.26 acres of late successional-old growth forest and 24.13 acres of mid-seral forest would be removed within riparian zones (see table 4.5.3-13a). As discussed in Section 4.5.3.2- Habitat, and data presented in table 4.5.3-4, the LWD components of most aquatic habitats in watersheds occupied by SONCC coho and crossed by the PCGP Project are deficient, below benchmark conditions established by ODFW.

In forested habitats, conifer trees will be replanted within the construction right-of-way and other cleared areas outside of the 30-foot wide maintenance corridor and allowed to return to its pre-construction state. The 30-foot wide maintenance corridor centered over the pipeline will be maintained in an herbaceous/shrub state by operations during the life of the project, assumed to be 50 years (see table 4.5.3-13b). Over the long-term, 5.46 acres through riparian late successional-old growth forest and 4.25 acres through mid-seral forest would be maintained in an herbaceous/shrub state within riparian zones associated with SONCC coho (see table 4.5.3-13b).

**Table 4.5.3-13a**

**Total Terrestrial Habitat (acres) Affected/Removed[1] by Construction within Riparian Zones (One Site-Potential Tree Height Wide) Adjacent to Perennial and Intermittent Waterbodies within Range of SONCC Coho Crossed by the PCGP Project**

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| **Trail Creek (HUC 1710030706)** | | | | | | | | | | | | |
| BLM-Medford District | 0.86 | 0.62 | 0.00 | 0.00 | **1.48** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | **1.48** |
| Forest Service-Umpqua National Forest | 0.00 | 2.94 | 0.00 | 0.00 | **2.94** | 0.00 | 0.00 | 0.00 | 0.00 | 4.90 | **4.90** | **7.84** |
| Non-Federal | 2.83 | 3.18 | 0.00 | 0.00 | **6.01** | 0.00 | 0.00 | 1.05 | 0.00 | 0.22 | **1.27** | **7.28** |
| **Watershed Total** | **3.69** | **6.74** | **0.00** | **0.00** | **10.43** | **0.00** | **0.00** | **1.05** | **0.00** | **5.12** | **6.17** | **16.60** |
| **Shady Cove-Rogue River (HUC 1710030707)** | | | | | | | | | | | | |
| BLM-Medford District | 5.21 | 0.98 | 0.00 | 0.00 | **6.19** | 0.07 | 0.00 | 0.35 | 0.00 | 0.56 | **0.98** | **7.17** |
| Non-Federal | 2.35 | 4.27 | 0.49 | 0.00 | **7.11** | 0.00 | 0.34 | 5.43 | 2.53 | 0.65 | **8.95** | **16.06** |
| **Watershed Total** | **7.56** | **5.25** | **0.49** | **0.00** | **13.30** | **0.07** | **0.34** | **5.78** | **2.53** | **1.21** | **9.93** | **23.23** |
| **Big Butte Creek (HUC 1710030704)** | | | | | | | | | | | | |
| BLM-Medford District | 6.24 | 1.34 | 0.00 | 0.00 | **7.58** | 0.00 | 0.00 | 2.06 | 0.00 | 0.04 | **2.10** | **9.68** |
| Non-Federal | 0.00 | 1.84 | 0.00 | 0.00 | **1.84** | 0.09 | 0.28 | 4.38 | 1.19 | 0.58 | **6.52** | **8.36** |
| **Watershed Total** | **6.24** | **3.18** | **0.00** | **0.00** | **9.42** | **0.09** | **0.28** | **6.44** | **1.19** | **0.62** | **8.62** | **18.04** |
| **Little Butte Creek (HUC 1710030708)** | | | | | | | | | | | | |
| BLM-Medford District | 3.23 | 0.00 | 0.00 | 0.00 | **3.23** | 0.00 | 0.00 | 2.44 | 0.00 | 0.16 | **2.60** | **5.83** |
| Forest Service-Rogue River-Siskiyou National Forest | 0.75 | 0.40 | 1.57 | 0.00 | **2.72** | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | **0.32** | **3.04** |
| Non-Federal | 3.79 | 8.56 | 1.01 | 0.00 | **13.36** | 0.00 | 4.64 | 14.85 | 4.51 | 0.92 | **24.92** | **38.28** |
| **Watershed Total** | **7.77** | **8.96** | **2.58** | **0.00** | **19.31** | **0.00** | **4.64** | **17.61** | **4.51** | **1.08** | **27.84** | **47.15** |
| **All Fifth Field Watersheds and Jurisdictions** | | | | | | | | | | | | |
| BLM-Medford District | 15.54 | 2.94 | 0.00 | 0.00 | 18.48 | 0.07 | 0.00 | 4.85 | 0.00 | 0.76 | 5.68 | 24.16 |
| Forest Service-Umpqua National Forest | 0.00 | 2.94 | 0.00 | 0.00 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 4.90 | 4.90 | 7.84 |
| Forest Service-Rogue River-Siskiyou National Forest | 0.75 | 0.40 | 1.57 | 0.00 | 2.72 | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | 0.32 | 3.04 |
| **Federal Subtotal** | **16.29** | **6.28** | **1.57** | **0.00** | **24.14** | **0.07** | **0.00** | **5.17** | **0.00** | **5.66** | **10.90** | **35.04** |
| **Non-Federal Subtotal** | **8.97** | **17.85** | **1.50** | **0.00** | **28.32** | **0.09** | **5.26** | **25.71** | **8.23** | **2.37** | **41.66** | **69.98** |
| **Overall Total** | **25.26** | **24.13** | **3.07** | **0.00** | **52.46** | **0.16** | **5.26** | **30.88** | **8.23** | **8.03** | **52.56** | **105.02** |

[1] Project components considered in calculation of habitat "Removed": PCGP construction right-of-way, temporary extra work areas, aboveground facilities, and permanent and temporary access roads (PAR, TAR).

[2] Habitat Types within Riparian Zones generally categorized as: Late Successional (Mature) or Old Growth Forest (coniferous, deciduous, mixed ≥80 years old); Mid-Seral Forests (coniferous, deciduous, mixed ≥40 but ≤80 years old); Regenerating Forest (coniferous, deciduous, mixed ≥5 but ≤40 years old); Clearcut Forests; Wetland Forested, Unaltered Nonforested Habitat (grasslands, sagebrush, shrublands), and Altered Habitats (urban, industrial, residential, roads, utility corridors, quarries).

**Table 4.5.3-13b**
**Total Terrestrial Habitat (acres) within the 30-foot Wide Corridor Maintained during the PCGP Project within Riparian Zones (One Site-Potential Tree Height Wide) on Federal and Non-Federal Lands within Range of SONCC Coho Crossed by the PCGP Project**

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| **Trail Creek (HUC 1710030706)** | | | | | | | | | | | | |
| BLM-Medford District | 0.16 | 0.14 | 0.00 | 0.00 | **0.30** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | **0.30** |
| Forest Service-Umpqua National Forest | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | **0.00** |
| Non-Federal | 0.66 | 0.67 | 0.00 | 0.00 | **1.33** | 0.00 | 0.00 | 0.23 | 0.00 | 0.06 | **0.29** | **1.62** |
| **Watershed Total** | **0.82** | **0.81** | **0.00** | **0.00** | **1.63** | **0.00** | **0.00** | **0.23** | **0.00** | **0.06** | **0.29** | **1.92** |
| **Shady Cove-Rogue River (HUC 1710030707)** | | | | | | | | | | | | |
| BLM-Medford District | 1.20 | 0.17 | 0.00 | 0.00 | **1.37** | 0.01 | 0.00 | 0.12 | 0.00 | 0.11 | **0.24** | **1.61** |
| Non-Federal | 0.44 | 0.52 | 0.13 | 0.00 | **1.09** | 0.00 | 0.10 | 0.26 | 0.48 | 0.04 | **0.88** | **1.97** |
| **Watershed Total** | **1.64** | **0.69** | **0.13** | **0.00** | **2.46** | **0.01** | **0.10** | **0.38** | **0.48** | **0.15** | **1.12** | **3.58** |
| **Big Butte Creek (HUC 1710030704)** | | | | | | | | | | | | |
| BLM-Medford District | 1.18 | 0.28 | 0.00 | 0.00 | **1.46** | 0.00 | 0.00 | 0.61 | 0.00 | 0.01 | **0.62** | **2.08** |
| Non-Federal | 0.00 | 0.43 | 0.00 | 0.00 | **0.43** | 0.03 | 0.09 | 0.83 | 0.24 | 0.02 | **1.21** | **1.64** |
| **Watershed Total** | **1.18** | **0.71** | **0.00** | **0.00** | **1.89** | **0.03** | **0.09** | **1.44** | **0.24** | **0.03** | **1.83** | **3.72** |
| **Little Butte Creek (HUC 1710030708)** | | | | | | | | | | | | |
| BLM-Medford District | 0.60 | 0.00 | 0.00 | 0.00 | **0.60** | 0.00 | 0.00 | 0.78 | 0.00 | 0.01 | **0.79** | **1.39** |
| Forest Service-Rogue River-Siskiyou National Forest | 0.19 | 0.04 | 0.36 | 0.00 | **0.59** | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | **0.06** | **0.65** |
| Non-Federal | 1.03 | 2.00 | 0.28 | 0.00 | **3.31** | 0.00 | 0.96 | 3.55 | 1.17 | 0.18 | **5.86** | **9.17** |
| **Watershed Total** | **1.82** | **2.04** | **0.64** | **0.00** | **4.50** | **0.00** | **0.96** | **4.39** | **1.17** | **0.19** | **6.71** | **11.21** |
| **All Fifth Field Watersheds and Jurisdictions** | | | | | | | | | | | | |
| BLM-Medford District | 3.14 | 0.59 | 0.00 | 0.00 | 3.73 | 0.01 | 0.00 | 1.51 | 0.00 | 0.13 | 1.65 | 5.38 |
| Forest Service-Umpqua National Forest | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Forest Service-Rogue River-Siskiyou National Forest | 0.19 | 0.04 | 0.36 | 0.00 | 0.59 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.06 | 0.65 |
| **Federal Subtotal** | **3.33** | **0.63** | **0.36** | **0.00** | **4.32** | **0.01** | **0.00** | **1.57** | **0.00** | **0.13** | **1.71** | **6.03** |
| **Non-Federal Subtotal** | **2.13** | **3.62** | **0.41** | **0.00** | **6.16** | **0.03** | **1.15** | **4.87** | **1.89** | **0.30** | **8.24** | **14.40** |
| **Overall Total** | **5.46** | **4.25** | **0.77** | **0.00** | **10.48** | **0.04** | **1.15** | **6.44** | **1.89** | **0.43** | **9.95** | **20.43** |

[1] Project components considered in calculation of habitat "Removed": PCGP construction right-of-way, temporary extra work areas, aboveground facilities, and permanent and temporary access roads (PAR, TAR).

[2] Habitat Types within Riparian Zones generally categorized as: Late Successional (Mature) or Old Growth Forest (coniferous, deciduous, mixed ≥80 years old); Mid-Seral Forests (coniferous, deciduous, mixed ≥40 but ≤80 years old); Regenerating Forest (coniferous, deciduous, mixed ≥5 but ≤40 years old); Clearcut Forests; Wetland Forested, Unaltered Nonforested Habitat (grasslands, sagebrush, shrublands), and Altered Habitats (urban, industrial, residential, roads, utility corridors, quarries).

Pacific Connector has attempted to minimize impacts on riparian vegetation by minimizing the width of the standard construction right-of-way at waterbody crossings, and by maintaining a setback between waterbody banks and TEWAs in forested areas. Following construction, Pacific Connector will implement measures to replant or encourage regrowth in riparian areas, and will minimize vegetation maintenance by allowing the development of a riparian strip at least 25 feet wide to be permanently revegetated on private lands and 100 feet wide on federally-managed lands as measured from the edge of the waterbody. As required by FERC's Upland Plan, Pacific Connector consulted with the NRCS, BLM, and Forest Service regarding specific seeding dates and recommended seed mixtures for the project area (see Resource Report 7, Pacific Connector Gas Pipeline). The recommendations have been incorporated into the project-specific Erosion Control and Revegetation Plan (ECRP – see appendix F). The ECRP describes the procedures that will be implemented to minimize erosion and enhance revegetation success for the entire project.

Clearing the right-of-way would remove shading vegetation from uplands and riparian areas, exposing the land and water to increased sunlight, potentially resulting in both direct increases in water temperatures and indirect increases as water flows over the warmer land surface and eventually reaches the waterbody (Beschta and Taylor, 1988). For the waterbodies that would be crossed by HDD, the potential disturbance in riparian areas would be incidental trimming of vegetation using hand tools directly over the pipeline along a footpath. This minor clearing is required to facilitate the temporary deployment of HDD guidance (telemetry) cables along the ground during construction and to perform a leakage survey after installation and commissioning. This is a relatively small area along the riparian zone of any stream and would have minimal adverse effect on aquatic resources.

<u>Water Temperature</u>

The effects of water temperature on salmonid life stages have been extensively reviewed by McCullough (1999), Richter and Kolmes (2005), and others. Maximum water temperatures ranging from 22°C to 24°C (71.6°F to 75.2°F) limit distribution of many salmonid species. No salmonids can survive water temperatures exceeding 25°C (77°F) for extended periods (Ice, 2008). High water temperatures can cause migratory species (including anadromous salmonids) to delay upstream migration (Bjornn and Reiser, 1991), can decrease survival of spawners by increasing metabolic rates (Ice, 2008), can positively influence rates of embryo development and emergence but can negatively influence dissolved oxygen concentrations that limit rates of embryo development (Bjornn and Reiser, 1991). High temperatures inversely influence solubility of oxygen in water (Ice, 2008). Introduction of organic matter with decomposition by microorganisms reduces dissolved oxygen and, along with increased fines (suspended silt and clay) and decreased relative rate of oxygen input to water (reaeration) through reduction in stream flows (Ice, 2008), can adversely affect various salmonid life stages. Coho upstream migration water temperature requirements are for water from 7.2°C to 15.6°C, spawning requirements are for water from 4.4°C to 9.4°C, and for incubation from water from 4.4°C to 13.3°C; preferred temperature is 12.1°C and upper lethal temperatures range from 26.0°C to 28.8°C, depending on previous acclimation temperatures (Bjornn and Reiser, 1991).

Vegetative cover that provides shade, especially during summer, is one factor that regulates water temperature. Construction across waterbodies would necessitate removal of trees and riparian shrubs at the crossing locations. Available information on the effects of pipeline construction in other regions on water temperature has found no or immeasurable change. The total width of riparian area affected by shade tree removal would be small (less than 100 feet) relative to the length of any stream crossed. In one study, construction across two coldwater, fish-bearing streams in Alberta required removing forested riparian vegetation; water temperatures at construction sites and downstream did not increase above temperatures at control sites upstream from construction (Brown et al., 2002). Similarly, water temperatures measured at four coldwater streams in New York before and during pipeline construction and for 3 years following construction showed no short-term or long-term effects on water quality parameters, including water temperature, even though such effects were expected because streambank vegetation had to be cleared, which reduced shading (Blais and Simpson, 1997). In the Alberta study, the highest water temperature recorded was 66°F (19°C in August). In the New York study, the highest temperature was 79 F (26°C) sometime between August and October.

Following requests by the Forest Service, Pacific Connector modeled water temperatures on 6 different stream segments on NFS lands in the Umpqua River basin on tributaries to East Fork Cow Creek (5 crossings) and on the upper Rogue River basin on Little Butte Creek (North State Resources, 2009 ). Temperature models were run on 6 different stream segments on NFS lands in the Umpqua River basin on tributaries to East Fork Cow Creek (5 crossings) and on the upper Rogue River basin on Little Butte Creek (North State Resources, 2009). Of the three smallest streams modeled average temperature increase ranged from 1.0°C to 8.6°C right after construction. Because these streams were so small they likely also would have temperatures reduced rapidly downstream of the clearing from ground water inflow and likely would have no measurable effects on streams they flow into downstream.

As a rule, the effect of water temperature of a non-fish-bearing tributary on water temperature of a fish-bearing receiving stream is determined as the weighted mean of the two water temperatures, weight by respective volumes or instream flows. If $\mathbf{T_1}$ = temperature of tributary with $\mathbf{F_1}$ = flow rate, and $\mathbf{T_2}$ = temperature of receiving stream with $\mathbf{F_2}$ = flow rate, then the resulting water temperature $\mathbf{T_R}$ at the confluence of the two waterbodies would be,

$$\mathbf{T_R = (T_1\, F_1 + T_2\, F_2) / (F_1 + F_2).}$$

For example, Hydrofeature N is an unnamed tributary to East Fork Cow Creek crossed at MP 111.01. Pipeline construction would increase the water temperature by 8.6°C from its base temperature of 11°C (see North State Resources, 2009). The water temperature would be 19.6°C but its reported summer base flow is 0.002 cfs. ODEQ measured water temperature within East Fork Cow Creek during September 1998, reported at 13.5°C. No instream flow data are available for East Fork Cow Creek but USGS (Gage 14309500) has measured flows in West Fork Cow Creek, reporting an average flow of 11.4 cfs during September. Using those data as to illustrate how water temperatures would be combined by the weighted average, the resulting water temperature of Hydrofeature N and the receiving stream would be $\mathbf{T_R}$ = (19.6°C x 0.002 cfs + 13.5°C x 11.4 cfs) / (0.002 cfs + 11.4 cfs) = 13.501°C. The increase of water temperature in the receiving stream by the tributary water temperature would be immeasurable (in this illustration the increase would be 0.001°C).

In North State Resources (2009 ) study, two 5 and 6 foot wide streams would have estimated maximum increases ranging from 0.4 to 0.5°C with maximum temperature remaining at or below 15.6°C in the two streams just downstream of the pipeline crossing sites. Those temperatures would remain within suitable range for salmonids. For the largest stream (22 feet wide) in the study, the estimated increase was estimated to be 0.02 to 0.1°C depending on the temperature model applied. The modeled results, based on assumptions used about the rates of vegetation regrowth, determined that most temperature increase effects remained within the first 5 years, but were approaching pre-project temperatures within 10 years. Conditions at other streams along the pipeline route may vary from these due to site specific differences, but these results may be fairly representative of changes that may occur at forested streams along the route. Overall results suggest that other than the very smallest streams where fish resources would be limited, changes in temperature from vegetation removal are likely to remain small and immeasurable having unsubstantial effects on fish resources.

Similarly, GeoEngineers (2013c) modeled thermal impacts within 4th Field Watersheds where streams would be crossed by the pipeline where riparian shading vegetation would be removed within the 75-foot wide construction corridor and would be affected within the 30-foot maintenance corridor of the long term (e.g., table 4.5.3-13b). Model results show a maximum predicted increase of 0.16°C over one 75 foot clearing. The analysis showed that elevated water temperatures would return to ambient levels within a maximum distance of 25 feet downstream of the pipeline corridor, based on removal of existing riparian vegetation over a cleared corridor width of 75 feet (GeoEngineers, 2013d). The results are similar to the more geographically-limited results obtained by North State Resources (2009) which suggested more thermal impact. The conclusion drawn by GeoEngineers (2013d) was that the magnitude of thermal impact caused by pipeline construction would not be expected to cause a thermal barrier to fish migration.

Pacific Connector has proposed supplemental riparian plantings as outlined in Section 10.12 of the ECRP (see appendix F) to help ensure that the core cold-water habitat temperature criteria are not exceeded at the maximum point of impact. These measures are designed to speed up the rate of riparian area recovery and provide more effective shade immediately following construction. Plantings and vegetation regrowth in riparian areas would help moderate potential temperature increases in the short term (a few years). Pacific Connector would install supplemental transplanted trees on the Umpqua National Forest within the riparian areas of East Fork Cow Creek (i.e., 15-20 feet tall with full crowns) to increase riparian area canopy closure and placing large woody debris and boulders to create micro-topography within the wetted stream channel (see Section10.12 in the ECRP). Shading from transplanted vegetation and micro-topographic features incorporated into the final grading plan are likely to reduce the heat load enough to reduce the likelihood of measurable water temperature increases. Pacific Connector modeled the potential benefit of post project effective shade created by these mitigation measures on the Umpqua National Forest. The results of the 10-year post project modeling time step was used to predict the benefits of the mitigation measures because the trees that would be transplanted provide at least the same shade values as predicted for this time step. The predicted water temperature changes are small, with less than a 0.3°C (0.5°F) change at the point of maximum impact, with no increase at the stream network scale (North State Resources, 2009). Inclusion of the measures improves the certainty that riparian area clearance and stream channel disturbance activities within the construction right-of-way would not cause measurable water temperature increases at the maximum point of impact or at the stream network scale.

Large Woody Debris

Existing conditions associated with riparian vegetation within 5th Field Watersheds in the Upper Rogue Sub-basin crossed by the PCGP Project (see discussion related to table 4.5.3-4) are generally undesirable. There are too few large conifers along most stream reaches and LWD numbers, volume, and presence of key pieces tend to be below benchmark levels. The PCGP Project will remove 25.26 acres of late successional-old growth forest and 24.13 acres of mid-seral forest would be removed within riparian zones in watersheds occupied by SONCC coho (see table 4.5.3-13a) which would affect recruitment of LWD at those sites. Of the total riparian forest affected, 10.43 acres would be removed in the Trail Creek watershed, 12.81 acres within the Shady Cove-Rogue River watershed, 9.42 acres in the Big Butte Creek watershed, and 16.73 acres would be removed within the Little Butte Creek watershed.

A potential effect on fisheries that would result from forest clearing at pipeline crossings of waterbodies is the reduction of LWD in streams and on adjacent uplands (Harmon et al., 1986; Sedell et al., 1988). Large logs provide instream hydraulic complexity, which contributes to habitat complexity and the formation and maintenance of pools, riffles and other habitats which are critical to salmonid spawning and juvenile rearing. As the size of individual logs or accumulations of logs increases, the size and stability of pools that are created also increase (Beschta, 1983). Riparian forests that undergo harvesting of large trees take on secondary-growth characteristics and contribute lower quantities of woody debris than unmanaged, old-growth forests (Bisson et al., 1987). However, sufficiently wide, carefully managed riparian buffers that retain a full complement of ages, sizes, and species of native trees and vegetation can ensure adequate recruitment of LWD to streams (Bisson et al., 1987; Murphy and Koski, 1989).

Pacific Connector has proposed to use on-site mitigation for impacts to waterbodies by installing LWD at agency- and land owner-approved and appropriate areas within the construction right-of-way across certain waterbodies. The use of LWD as a mitigation measure for impacts associated with instream construction has been documented as an effective means of creating instream habitat heterogeneity, reducing streambank erosion, reducing sediment mobilization (Bethel and Neal, 2003), and enhancing local fish abundance (Scarborough and Robertson, 2002). Placement of LWD on the streambanks and in the streams can provide slight shade and increase bank stability, while vegetation is maturing following construction. Additionally, placement of LWD in streams or on streambanks can provide habitat for benthic invertebrates, an important food source for salmonids, and also increase habitat for forage species with the creation of pools and enhancement of the salmonid rearing potential of an area (Cederholm et al. 1997; Slaney et al., 1997).

As shown in table 4.5.3-4, LWD conditions are undesirable in all four fifth field watersheds of the Upper Rogue Sub-basin that would be crossed. Streams in the watersheds are deficient in numbers of LWD pieces per length of stream channel, deficient in volume of LWD, and deficient in numbers of key pieces (≥60 cm in diameter by ≥12 m in length) per unit of stream length. Based on those data, any addition of LWD to the watersheds would appear beneficial.

<u>Hydrostatic Testing</u>

Water would be required on a one-time basis near the end of construction to hydrostatically test the pipeline. Potential impacts associated with hydrostatic testing include entrainment of fish, reduced downstream flows, and impaired downstream uses if test water is withdrawn from surface waters, and erosion, scouring, and a release of chemical additives as a result of test water discharge. The Forest Service has also expressed concern that hydrostatic testing where the source and discharge locations were in different water basins could potentially transfer exotic organisms between basins. Pacific Connector would obtain its hydrostatic test water from commercial or municipal sources or surface water rights owners and come from lakes, impoundments, and streams, and has identified 15 potential source locations and 75 potential discharge locations for the test water (see Resource Report 1, Pacific Connector Gas Pipeline Project); all but seven potential discharge sites would be within the construction right-of-way.

Pacific Connector would minimize the potential effects of hydrostatic testing on these systems by adhering to the measures in its Hydrostatic Testing Plan (see appendix U), including screening intake hoses to prevent the entrainment of fish and other aquatic organisms, meeting NMFS screening criteria, and regulating the rate of withdrawal to avoid adverse impact on aquatic resources or downstream flows. Where test water cannot be returned to its withdrawal source, the water would be treated with a mild chlorine treatment and discharged to an upland location through a dewatering structure at a rate to prevent scour and erosion and to promote infiltration. Pacific Connector will obtain all necessary appropriations, withdrawal, and discharge permits through the Oregon Water Resources Department (OWRD). As part of the application process, OWRD provides the application(s) to ODEQ and ODFW for review.

Fuel and Chemical Spills

Fisheries habitats could be adversely affected if petroleum products were accidentally discharged into aquatic environments. Such materials are toxic to algae, invertebrates and fish. Of the products likely to be present during pipeline construction, data compiled from a wide range of sources indicate that diesel fuels and lubricating oils are considerably more toxic to aquatic organisms than other, more volatile products (gasoline) or heavier crude oil (Markarian et al., 1994). Release of diesel fuel in freshwater habitats significantly reduced aquatic invertebrate densities and species richness at least 3 miles downstream but invertebrate densities recovered within a year (Lytle and Peckarsky, 2001). Impacts to aquatic habitats that primarily affect aquatic substrates – hence spawning, incubating and rearing habitats – can remain for much longer periods (Markarian et al., 1994).

Construction equipment used to construct the pipeline across waterbodies can potentially release hydraulic fluid that include a variety of compounds those common of which are mineral oil-based, organophosphate esters, and polyalphaolefins (U.S. Department of Health and Human Services, 1997). Release from machinery can occur through faulty seals, hoses, sumps and reservoirs, or general system failure. Components of mineral oil and polyalpaolefins do appear to bioaccumulate in animals whereas larger molecular constituents in organophosphate esters can concentrate in fish, primarily partitioning in fat tissue (U.S. Department of Health and Human Services, 1997). In general, toxicity of organophosphate esters is greater than either mineral oil or polyalphaolefin-based hydraulic fluids for inhalation, oral, and dermal for humans but toxicities have not been clearly described for aquatic invertebrates or fish and would be dependent on specific chemical components (U.S. Department of Health and Human Services, 1997).

Inadvertent spills of fluids used during construction, such as fuels and lubricants, could contaminate wetland soils and vegetation. To minimize the potential for spills and any impacts from such spills, Pacific Connector's Spill Prevention, Containment, and Countermeasures Plan (SPCC Plan – see appendix L) will be implemented. In general, hazardous materials, chemicals, fuels, lubricating oils, and concrete-coating activities will be not be stored, nor will refueling operations be conducted within 150 feet of a wetland or waterbody in accordance with FERC's Wetland and Waterbody Procedures (see appendix C) and the SPCC Plan (see appendix L).

Herbicide Application

Following construction, Pacific Connector will implement a Noxious Weed Control Plan in part through the application of herbicides. Herbicides have the potential to cause toxic effects to different salmonid life stages and to other aquatic species, causing direct impacts, if used improperly. When herbicides are properly used according to label restrictions and BMPs to control noxious weeds, there is little to no chance of causing injury or mortality to fish or other aquatic organisms; the impact may be avoided or indirect.

Pacific Connector has developed an Integrated Pest Management Plan (IPM) in consultation with the Oregon Department of Agriculture, BLM and Forest Service (see Appendix I to the POD, available upon request) to address the control of noxious weeds and invasive plants across the project. The BMPs will minimize the potential spread of invasive species and minimize the potential adverse effects of control treatments.

According to the Pacific Northwest Weed Management Handbook (see Peachey et al., 2007), herbicides used in forests to control brush and weed-trees could include one of the following: 2,4-D, glyphosate, imazapyr, picloram, and ticlopyr which are applied during spring or fall dormancy although triclopyr or 2,4-D was not approved use by the Fremont-Winema National Forest (NF). Clopyralid may be used during summer to control thistles, other composites, and legumes while not damaging conifers. Only herbicides which are approved for use within treated lands (private, state, or federal) would be used. Chronic, long-term, elevated but sublethal toxic effects can lead to skin or eye irritation, headache, nausea, and possibly birth defects, genetic disorders, paralysis, cancer, and death (Tu et al., 2001). In general, most impact to waterbodies occurs from direct overspray or drift of herbicides (aerial applications) as well as leaching through soils into groundwater or as they are carried by surface/subsurface runoff (Tu et al., 2001). The ester form of herbicides is more toxic to fish and other aquatic species than salt or acid forms because esters are readily adsorbed through skin and gills. Esters are also water insoluble so that they are not diluted in waterbodies (Tu et al., 2001).

Herbicides potentially used during the project will breakdown over various periods of time, marked by the average half-life (the time it takes for the herbicide concentration to decline by 50% due to microbial metabolism –dependent on the microbial population, environmental pH, soil moisture and temperature - mineralization, and/or photolysis). Half-lives in soil and water are provided and known toxicities to bluegill sunfish (see Tu et al., 2001) although comparative toxicities to salmonids have not been found in the literature:

- 2,4-D – averages 10 day half-life in soils, less than 10 days in water. Salt formulations with low toxicity are registered for use against aquatic weeds, LC50 for bluegill sunfish = 263 mg/l.
- Glyphosate - ranges from several weeks to years, but averages two months. In water, glyphosate is rapidly dissipated through adsorption to suspended and bottom sediments, and has a half-life of 12 days to ten weeks. Some formulations with low toxicity are registered for aquatic use, LC50 for bluegill sunfish = 120 mg/l.
- Imazapyr – ranges from 1 to 5 months in soil. In aqueous solutions with photodegradation the half-life may be 2 days. It has low toxicity to fish and algae and other submerged vegetation are not affected, LC50 for bluegill sunfish >100 mg/l.
- Picloram- range from 1 month to several years in soils, average soil half-life of 90 days. LC50 for bluegill sunfish >14.5 mg/l.

- Triclopyr – average half-life in soils is 30 days but the salt formulation is water soluble and may photodegrade in several hours. LC50 for bluegill sunfish =148 mg/l.
- Clopyralid - half-life averages one to two months (40 days) but ranges up to one year. It is degraded almost entirely by microbial metabolism in soils and aquatic sediments. LC50 for bluegill sunfish =125 mg/l.

Of these herbicides, Picloram is the most toxic to bluegill sunfish and is potentially the longest persisting in soils and water. Similar attributes are expected for effects to salmonids. The potential for adverse effects to salmonids and other aquatic species by the other herbicides appear to be extremely remote, especially since application would be at least 100 feet from wetlands and waterbodies unless allowed by the appropriate agency. Pacific Connector will not use aerial herbicide applications and will not use herbicides for general brush/tree control within the 30-foot maintained easement. Given low toxicities to fish and short half-lives in soil and water, expected effects of the other herbicides to resident fish and anadromous salmonids would be discountable and insignificant.

Where weed control is necessary along the construction right-of-way, Pacific Connector's first priority will be to employ hand and mechanical methods (pulling, mowing, biological, disking, etc.) applicable to the species to prevent the spread of potential weed infestations, where feasible. To determine if an herbicide is to be used over other control methods, Pacific Connector will base the decision on weed characteristics and integrated weed management principles (USFS, 2005). If herbicides are used to control noxious weed infestations, they would be used when they are the most appropriate treatment method. Spot treatments and the use of selective herbicides would be utilized to minimize impact to native or non-target species. Pacific Connector will employ a state or federally-licensed herbicide applicator to ensure that the appropriate herbicides are utilized for the targeted weed species during its proper phenological period and at the specified rate. The applicator will ensure that the herbicides and any adjuvants[4] are used according to the labeling restrictions, and warnings, following all applicable laws and conforming to the appropriate land managing agency decision documents. The applicator will also ensure that the herbicides that are used are registered for their intended use. Permits or approvals for the use of herbicides and adjuvants on federal lands would be obtained prior to use/treatment, as detailed in the IPM (see Appendix I to the POD, available upon request).

Streambank Erosion

The clearing and grading of vegetation during construction could increase erosion along streambanks and turbidity levels in the waterbodies. The rootwad network of trees adjacent to stream supplies bank stability. Those within 25 feet of the stream are considered most important at providing the root source aiding in bank stability (Washington Department of Natural Resouces, 1997). To aid in maintaining this bank stability, Pacific Connector would cut most trees near the bank, except those in the trench line, at ground level leaving the root systems in place helping to maintain riparian stability. Roots would be removed over the trench line or from any steam banks that would need to be cut down or graded to accomplish the pipeline crossing.

[4] Adjuvant(s) are substances added to the pesticide formulation to enhance the toxicity of the active ingredient or to make the active ingredient easier to handle.

Alteration of the natural drainage ways or compaction of soils by heavy equipment near streambanks during construction may accelerate erosion of the banks, runoff, and the transportation of sediments into waterbodies. The degree of impact on aquatic organisms due to erosion would depend on sediment loads, stream velocity, turbulence, streambank composition, and sediment particle size. To minimize these impacts, Pacific Connector would use temporary equipment bridges, mats, and pads to support equipment that must cross the waterbody (perennial, intermittent, and ephemeral if water is present) or work in saturated soils adjacent to the waterbody. Pacific Connector would also install sediment barriers, such as silt fence and straw/hay bales, across the right-of-way at the edge of waterbodies throughout construction except for short periods when the removal of these sediment barriers is necessary to dig the trench, install the pipe, and restore the right-of way. Practices to minimize streambank erosion are provided in Section 5.0 in the ECRP (see appendix F).

Operation and Maintenance Activities

Once installed, maintenance of the pipeline would include activities such as aerial inspections, gas flow monitoring, visual inspection of surrounding vegetation for signs of leaks, and integrity management, which includes smart pigging to investigate the interior surface of the pipe for any signs of stress cracking, pitting, and other anomalies (see Section 13.0 in the ECRP, appendix F). All of the proposed maintenance activities would be outlined in the Operations and Maintenance plan that would be prepared according to operating regulations in U.S. Department of Transportation (DOT) 49 CFR Subpart L, Part 192 and would be completed prior to going in-service. These general maintenance activities would require only surface activities and usage of the existing right-of-way, such as insertion of the pig at one of the pig launching facilities.

The potential estuarine or stream channel disturbance would occur if an integrity issue with the pipeline were found. If this were to occur, the pipeline would need to be unearthed within the right-of-way and repair work done in-water. Within stream sites, repair work could require isolated flow from the section of pipe that is to be exposed. Typically, repairs would be made to the pipe within the right-of-way (within the trench) or, depending on the site-specific conditions and nature of the repair needed, a reroute around the affected section may be considered. Impacts would be similar to those discussed above for initial installation except on a much smaller scale, and would include all relevant BMPs and mitigation, dependent upon site conditions and land ownership. Such pipeline integrity-based in-water projects are very infrequent.

Vegetation maintenance would be limited adjacent to waterbodies to allow a riparian strip to permanently revegetate with native plant species across the entire right-of-way. To facilitate periodic pipeline corrosion/leak surveys, a corridor centered on the pipeline and up to 30 feet wide would be maintained in an herbaceous state. In addition, trees that are located within 15 feet of the pipeline and that are greater than 15 feet in height would be cut and removed from the right-of-way.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA. The Pacific Connector pipeline would not be operational until at least

2017. Consequently, the foreseeable future required for cumulative effects analysis would actually occur before implementation of the proposed action, not after its implementation, which is more often the case.

Cumulative effects to SONCC coho salmon would be generated by timber harvesting on non-federal lands. Areas of Late Successional-Old Growth (LSOG) forest have been monitored as a component of the Northwest Forest Plan (NWFP). In Oregon, LSOG was evaluated in 1996 (Moeur et al., 2005) and in 2006 (Moeur et al., 2011). Differences in areas of LSOG forests were described in the four physiographic provinces that coincide with the PCGP project; from 1996 to 2006 there was an overall net loss of LSOG on non-federal lands within the Coast Range, Klamath, Western Cascades and Eastern Cascades provinces. Within the PCGP project area and range of SONCC coho, comparisons of LSOG coverage on non-federal lands within the four watersheds in the Upper Rogue Sub-basin show similar decreases from 1996 to 2006 (see figure 4.5-12). During that period, areas of LSOG on non-federal lands declined by 74 percent within Trail Creek watershed, 78 percent within Shady Cover-Rogue River watershed, 56 percent within Big Butte Creek watershed, and declined by 9 percent within Little Butte Creek watershed.

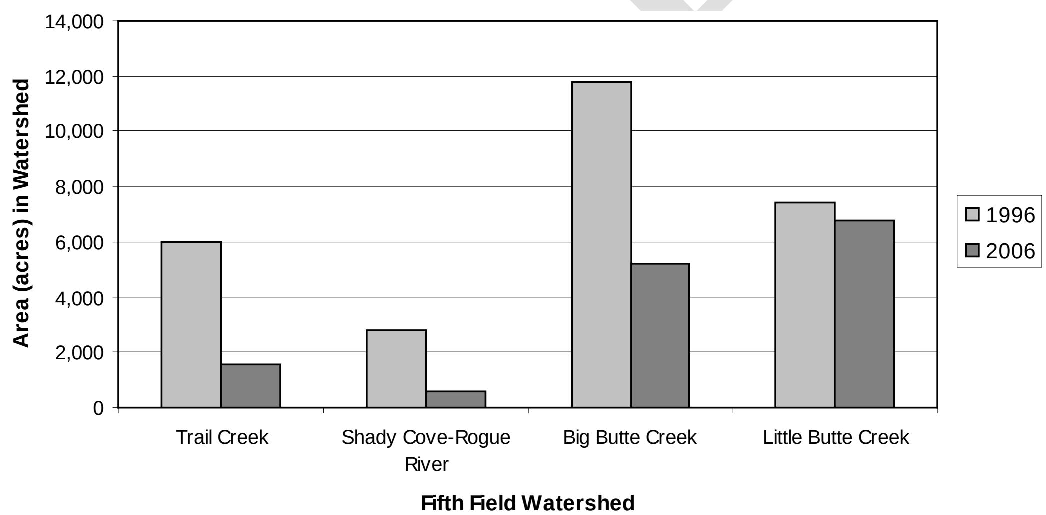



**Figure 4.5-12**
**Total Areas (acres) of Late Successional-Old Growth Forests on Non-Federal Lands in 1996 and 2006 within Four Fifth Field Watersheds within Range of SONCC coho salmon that would be Crossed by the PCGP Project. (Data from Interagency NWFP Interagency Regional Monitoring Program, 2013)**

Based on the past trend, there would be less LSOG on non-federal lands in the foreseeable future within each of the four watersheds, including less LSOG within riparian zones. Removal of additional LSOG within riparian zones on non-federal land would be a reasonably foreseeable cumulative impact. The amount of LSOG removed on non-federal land through 2016, for example, would possibly be 1) by the same percentage, or 2) at the same rate as the amounts removed between 1996 and 2006. These two scenarios are provided below in table 4.5.3-14 wherein loss at a constant annual rate predicts no LSOG left on non-federal lands by 2016 in three of the four watersheds. Alternatively, loss of LSOG by the same percent change observed between 1996 and 2006 predicts considerable declines in LSOG in 2016 but not totally eliminating it in and of the watersheds (see table 4.5.3-14).

**Table 4.5.3-14**
**Two Estimates For Areas of Late Successional-Old Growth Forest in 2016 on Non-Federal Lands In Fifth Field Watersheds Crossed by the PCGP Project**

| SONCC ESU Fifth Field Watershed | Area (acres) of LSOG on Non-Federal Land in 2006 [1] | LSOG Estimate Based on Percent Change | | LSOG Estimate Based on Rate of Change | |
|---|---|---|---|---|---|
| | | Percent Change in LSOG Since 1996 | Area (acres) of LSOG Remaining in 2016 | Rate of Change (acres per year) Since 1996 | Area (acres) of LSOG Remaining in 2016 |
| Trail Creek | 1,542 | -74.1% | 399 | -442 | 0 |
| Shady Cove-Rogue River | 604 | -78.4% | 130 | -219 | 0 |
| Big Butte Creek | 5,197 | -56.0% | 2,289 | -660 | 0 |
| Little Butte Creek | 6,759 | -9.2% | 6,135 | -69 | 6,072 |
| **Total LSOG Areas** | **14,102** | | **8,953** | | **6,072** |

[1] Data from Interagency NWFP Interagency Regional Monitoring Program, 2013

In 2016, there might be between 6,000 and 9,000 acres of LSOG within the four watersheds crossed by the PCGP project but there are no estimates for areas of LSOG within riparian zones within the watersheds. However, amounts of LSOG within the PCGP project area that would be affected by construction and amounts of LSOG that would be affected within riparian zones (eg, see table 4.5.3-13a) have been determined. We assumed that the proportions of LSOG in riparian zones to total LSOG affected by pipeline construction on non-federal lands within each watershed were representative of proportions of riparian to total LSOG on non-federal lands in each watershed. With that assumption, we computed the areas of LSOG in riparian zones on non-federal that would be removed by 2016, based on the reasonably foreseeable future estimates of remaining LSOG in table 4.5.3-14. Estimates of areas of LSOG remaining on non-federals in 2016 are provided in table 4.5.3-15, based on the percent change in LSOG since 1996 (derived in table 4.5.3-14). The estimates predict that there would have been a total of 1,711 acres of riparian LSOG on non-federal lands within all four watersheds during 2006 but, due to timber removal actions on non-federal lands (including removal of riparian LSOG) and other possible causes of removal (wildfire, disease), only 1,276 acres would remain by 2016, most of it within the Little Butte Creek watershed. Approximately 435 acres of riparian LSOG would be removed by 2016. The proposed action would contribute by removing 8.97 acres of riparian LSOG, about 2 percent, within the reasonably foreseeable future, a small portion of overall cumulative effects.

**Table 4.5.3-15**
**Potential for Cumulative Effects within Late Successional and Old Growth Riparian Forests on Non-Federal Lands within the Pacific Connector Pipeline Action Area that Coincide with the SONCC Coho Salmon ESU**

| SONCC ESU Fifth Field Watershed | Area (acres) of LSOG on Non-Federal Land in 2006 [1] | LSOG Affected by the Proposed Action on Non-Federal Land in Watershed | | | Area (acres) of Riparian LSOG on Non-Federal Land in Watershed | |
|---|---|---|---|---|---|---|
| | | Area (acres) of LSOG Affected | Area (acres) of LSOG Within Riparian Zones | Proportion of Riparian LSOG | Area (acres) of Riparian LSOG in 2006 [2] | Area (acres) of Riparian LSOG Remaining in 2016 [3] |
| Trail Creek | 1,542 | 13.73 | 2.83 | 0.21 | 318 | 82 |
| Shady Cove-Rogue River | 604 | 13.74 | 2.35 | 0.17 | 103 | 22 |
| Big Butte Creek | 5,197 | 1.55 | 0 | 0.00 | 0 | 0 |
| Little Butte Creek | 6,759 | 19.86 | 3.79 | 0.19 | 1,290 | 1,171 |
| **Total Area** | **14,102** | **48.88** | **8.97** | | **1,711** | **1,276** |

[1] Data from Interagency NWFP Interagency Regional Monitoring Program, 2013.
[2] Based on Proportion of Riparian LSOG affected by PCGP Project on Non-Federal Land
[3] Based on the Percent Change in LSOG Since 1996 in table 4.5.3-14.

ODF Administrative Rules (Chapter 629) include requirements for protecting riparian zones associated with streams of various size classes and uses on non-federal lands. RMA widths were assigned to "retain the physical components and maintain the functions necessary to accomplish the purposes and to meet the protection objectives and goals for water quality, fish, and wildlife". Specified riparian zones widths range from 100 feet for a large (average annual flow $\geq 10$ feet$^3$/second) Type F (fish use and domestic use) stream to 20 feet for a small (average annual flow $\leq 2$ feet$^3$/second) Type D (domestic water use, no fish) stream. While the ODF Administrative Rules provide some protection to fish-bearing streams, the narrower riparian zones described in the Rules are likely to provide less protective functions due to forest harvest practices on non-federal lands than harvest on federal lands.

### Critical Habitat

Eight waterbodies known to support coho within Table 4.5.3-2 that would be affected by construction of the PCGP pipeline are within designated critical habitat for coho salmon in the SONCC ESU. The effects to riparian zones associated with each waterbody in critical habitat that support coho are included in Table 4.5.3-13a. PCEs include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation (NMFS, 1999b). Each PCE defined for critical habitat would be adversely affected by the proposed action. Those effects have been quantified to the extent possible in the foregoing analyses.

## 4.5.3.4 Conservation Measures

Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to the estuary (estuarine analysis area), waterbodies, and riparian zones (riverine analysis area). Those measures have been compiled in table 2C in appendix N and apply to SONCC coho salmon.

Pacific Connector has also proposed measures to rectify, repair, rehabilitate, and otherwise reduce impact to waterbodies and riparian zones once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N.

## Erosion Control

Many of the conservation measures in table 3C in appendix N focus on erosion control to prevent sediment from entering surface waters. Temporary erosion controls would be installed immediately after vegetation clearing and grading and would be properly maintained throughout construction and reinstalled as necessary until replaced by permanent erosion controls or restoration is complete. At a minimum, the following temporary erosion control structures would be installed: temporary slope breakers, sediment barriers, mulch, and erosion control fabric.

Temporary Slope Breakers

Pacific Connector would install temporary slope breakers over the backfilled, recontoured construction right-of-way as specified in FERC staff's Plan. The outfall of each temporary slope breaker would be to a stable, well-vegetated area or to an energy-dissipating device at the end of the slope breaker off the construction right-of-way. Slope breakers reduce runoff velocity, thereby intercepting sediment and allowing it to drop out of suspension. They also can effectively divert runoff away from a disturbed site to a stable outlet (Goldman et al., 1986).

Sediment Barriers

Pacific Connector would primarily rely upon silt fence and staked hay or straw bales to confine sediment to the construction right-of-way. These structures would be used adjacent to wetland and waterbody crossings consistent with the requirements of FERC staff's Procedures. Straw bales and filter fabric (silt fence) can be used together to create a highly effective sediment barrier, a combination that compensates for the limitations of each used in isolation; straw bales provide extra support and the fabric provides greater filtering capability (Goldman et al., 1986).

All straw or hay bales used for sediment barriers would be certified as weed-free. Temporary sediment barriers would be maintained in-place until permanent revegetation measures are successful or until the upland areas adjacent to wetlands, waterbodies or roads are stabilized. The structures would be removed once vegetation in the area has been successfully restored.

Mulch

Under certain circumstances, the FERC staff's Plan requires the application of mulch to stabilize the soil surface. If it becomes necessary to delay final cleanup, including final grading and installation of permanent erosion control measures, beyond 10 days after the trench is backfilled in a specific area, Pacific Connector would apply mulch to the disturbed areas before seeding, consistent with the requirements of FERC staff's Plan. Mulch would also be applied if construction and restoration activity is interrupted for extended periods. In these cases mulch would be applied at a rate of three tons/acre on all slopes within 100 feet of waterbodies and wetlands.

A number of areas would be crossed with slopes in excess of eight percent. In these areas, mulch would be applied uniformly to cover at least 75 percent of the ground surface at a rate of two tons/acre of straw or hay or its equivalent. All straw or hay mulch would be certified weed-free.

Erosion Control Fabric

Pacific Connector would install erosion control fabric (such as jute or excelsior) on waterbody banks at the time of recontouring. The fabric would be anchored using staples or other appropriate devices. Although there are no measures specific to pipeline construction, data related to cut-and-fill slopes treated during construction of forest roads indicate varying effectiveness of different types of stabilization measures designed to control surface erosion (EPA, 2001). On fill slopes, combining straw mulch and netting decreased erosion by 99 percent. Excelsior mulch alone decreased erosion by 92 percent on fill slopes. On cut slopes, straw mulch by itself decreased erosion in a range from 32 to 97 percent (EPA, 2001). Applications of mulches and/or fabric are effective measures promoting slope stabilization until vegetation can successfully be reestablished. These measures also promote plant growth (EPA, 2001).

Cleanup and Permanent Erosion Control

Pacific Connector would make every effort to complete final cleanup of an area within ten days after backfilling the trench. Final cleanup would include final grading and installation of permanent erosion control structures. In no case would Pacific Connector delay final cleanup beyond the end of the next recommended seeding season. During final cleanup Pacific Connector would remove all construction debris and grade disturbed areas to preconstruction grades to the extent practicable. An adequate seedbed would be prepared at the conclusion of cleanup. Pacific Connector would install permanent slope breakers consistent with the requirements of FERC staff's Plan.

Fish Salvage Plan

All waterbodies that would be crossed by dry open cut construction would be done prior to adult coho salmon upstream migration, within ODFW in-stream construction windows. A Fish Salvage Plan has been provided in appendix T. The plan has been developed to minimize adverse effects to listed salmonids (SONCC coho salmon, Oregon Coast coho salmon), non-listed salmonids (Chinook salmon, steelhead, and cutthroat trout) and listed catostomids (Lost River sucker, shortnose sucker). The portions of the plan relevant to salvaging salmonids were adapted from the protocol developed by WSDOT (2014). The protocol specifies procedures to 1) isolate the work area; 2) remove fish and dewater the work area; 3) handle, hold and release fish; 4) document fish that have been captured, handled, held, and released; and 5) notify NMFS and FWS. Only trained professionals would conduct electroshocking and fish removal.

## Revegetation

As required by the FERC staff's Plan, Pacific Connector has identified procedures for the preparation and planting of live stakes or sprigs and for the planting bare root tree seedlings. Those procedures are included in appendix R. Within the range of SONCC coho salmon, construction of the Pacific Connector pipeline would remove 70.91 acres of riparian forested habitats of which 14.35 acres are late-successional (mature) old-growth, 55.61 acres are mid-seral forests, and 0.95 acre is forested wetlands. Within the Trail Creek watershed 10.43 acres of riparian forest would be removed; 12.88 acres would be removed within the Shady Cove-Rogue River watershed; 9.51 acres in the Big Butte Creek watershed and 16.73 acres in the Little Butte Creek watershed would be removed (see table 4.5.3-13a).

Existing forested riparian zones in which forest would be removed during construction would be re-planted with conifers to within 15 feet of each side of the pipeline centerline. Permanent effects – persisting longer than the assumed 50-year life of the pipeline – would occur by removing 14.35 acres of late-successional (mature) old-growth riparian forest. Even though the riparian zone would be replanted, the newly planted trees would not attain late-successional or old-growth status within 50 years. Permanent effects would also last along the 30-foot wide maintenance corridor centered on the pipeline. Those effects to former late-successional (mature) old-growth riparian forest, Mid-Seral riparian forest and other existing riparian vegetation are included in table 4.5.3-13b. Replanting conifers within each affected forested riparian zone would leave an estimated 9.75 acres of non-forested vegetation within former forested riparian zones over the long-term or permanently (see table 4.5.3-13b).

ORV Barriers

The FERC staff's Plan requires the Project to offer to each owner or manager of forested lands to install and maintain measures to control unauthorized vehicle access to the right-of-way and states that such measures may include signs; fences with locking gates; slash and timber barriers, pipe barriers, or a line of boulders across the right of way; and conifers or other appropriate trees or shrubs across the right-of-way. Slash, stumps and or logs, if available, would be placed on the right-of-way within the riparian zones to discourage ORV crossings of streams and provide carbon and nutrients if allowed by the landowner. If not allowed, Pacific Connector would discuss with the landowner the use of other methods, as noted above. At a minimum the area would be revegetated and re-seeded.

**Streambank Stability**

The root network of trees adjacent to streambanks is essential to maintaining streambank stability (WDNR 1997). Because root strength decreases significantly at distances beyond one-half the tree crown diameter, trees promoting streambank stability lie within half a tree crown diameter from the streambank. Trees within 25 feet of the streambank are assumed to promote streambank stability (WDNR 1997). Generally, trees that must be removed during construction would be cut at ground level with the roots left in place, except where located within the trenchline. Although roots would decay overtime, streambank stability would be retained by their presence until revegetation is successful.

**In-stream Gravel**

Waterbodies supporting fisheries would be backfilled with material removed from the trench with the upper 1 foot of the trench backfilled with clean gravel or native cobbles. Pacific Connector has requested a variance from Section V.C.1. of FERC staff's Procedures in fish-bearing streams that do not have gravel, cobble, or other rock substrates prior to construction. This variance was requested because many of the streams crossed by the pipeline are remote and are located in steep valley or ravine bottoms. Therefore hauling rock to these steams is impractical especially where these streams do not have gravel or cobble substrate characteristics prior to construction. The bottom and banks would be returned to preconstruction contours; banks would be stabilized; and temporary sediment barriers would be installed before returning flow to the waterbody channel.

**Large Woody Debris**

In several instances, mitigation would contribute to restoring an aquatic habitat indicator's functional level, such as placement of LWD within and/or adjacent to streams and placing LWD on floodplains, where appropriate, to provide microsites for riparian vegetation and/or vegetation protection during flood events. Placement of LWD in streams and/or on streambanks has been one focal point of recent stream rehabilitation procedures (Slaney and Martin, 1997; Cederholm et al. 1997; EPA, 2001) as well as a central consideration in the Compensatory Mitigation Plan (see appendix O).

As indicated in table 4.5.3-4, baseline watershed conditions crossed by the pipeline are lacking in LWD due to historical disturbance and LWD presence is typically below benchmark thresholds to be properly functioning. LWD is an important habitat feature providing in-stream structure, channel and habitat complexity among other benefits, and that promote salmonid productivity. Pacific Connector proposes to install LWD on-site during construction as an appropriate habitat enhancement feature to mitigate for potential pipeline impacts and to benefit watershed conditions, which are generally lacking.

LWD placement would be in addition to the Project conservation measures (see appendix N) that have been designed to minimize the potential Project effects, including utilizing dry open cut crossing methods, applying in-stream construction timing restrictions, and implementing erosion control measures and revegetation methods. Because of the overall lack of LWD in the affected watersheds, LWD also provides an appropriate mitigation model for the Project's potential waterbody crossing impacts that are temporary, short-term, and unavoidable (see Compensatory Mitigation Plan in appendix O). The LWD would also serve to mitigate for potential long-term Project impacts - impacts lasting for the 50-year life of the pipeline - such as the loss of forested riparian vegetation within the pipeline's 30-foot operational corridor (see table 4.5.3-13b). Even though the riparian zone would be replanted, the planted trees would not attain late-successional or old-growth status within 50 years. Placement of LWD would, in some measure, reduce though not eliminate the impact due to the removal of late-successional (mature) old-growth riparian forest.

For low-gradient streams, Cederholm et al. (1997) suggests using logs with diameters at least 18 inches (less in areas of low velocity) placed by vertical angling into the stream channel. Logs could be used to create a stepped-channel profile with the rootwads and encourage woody debris accumulations in pool margins. For streams with steeper gradients, they suggest that logs with smaller diameters might be used if larger logs are unavailable. Near headwaters, LWD is often suspended over the channel so that it can become functional during periods of maximum runoff. Smaller debris may be retained during those periods and help develop pools that would be functional during summer (see Cederholm et al., 1997).

Guidelines for LWD placement, provided by ODF and ODFW (1995), suggest using the following: 1) larger diameter wood pieces because they are more effective at creating pools and complex channels which improve fish populations (see table 4.5.3-16 for minimum diameter LWD per bankfull width); 2) LWD that are at least twice the length of the waterbody bankfull width (1.5 times the bankfull width if the rootwad is attached) to increase the likelihood that the LWD would remain in place; and 3) conifer logs, especially western red cedars if available, because they are more durable. In larger waterbodies, smaller diameter, shorter LWD could be used if bundled and anchored together to provide the same benefits of the longer, larger diameter LWD (ODF and ODFW 1995).

Trees classified as late-successional or old-growth are assumed to have attained heights equal to the site-potential tree heights that are included above in table 4.5.3-13a as Riparian Zone Widths. Site-potential tree heights range from 157 feet (for example, the Rogue River-Shady Cove Watershed) to 187 feet (as in the Big Butte Creek Watershed). If Douglas-fir trees in the Oregon Cascades grow in height at the rate of 20 inches per year and in diameter by 0.25 inches per year (Cox, 2008), a 20-inch tall seedling planted the year after construction of the Pacific Connector pipeline would be an estimated 85 feet tall and 12 to 13 inches in diameter (assumed dbh) after 50 years. Trees with those dimensions would provide suitable LWD for streams with bankfull widths from 0 to 10 feet but not larger streams (see table 4.5.3-16). Even in these streams recruitment of wood may be reduced as the young age of the forest would reduce recruitment from natural mortality as the rate would be less relative to older trees. But recruitment of wood is not solely dependent on natural tree mortally but includes important contributing factors such as bank erosions, disease, fires, slides, and windthrow (Reeves et al. 2003, Martin and Benda 2001, Gregory et al. 2003). LWD contribution would occur from these areas even though natural mortality contribution would be reduced.

**Table 4.5.3-16**
**Minimum Diameter LWD for Placement in Waterbody Based on Bankfull Width**

| Bankfull Width (feet) | Minimum Diameter LWD (inches) |
|---|---|
| 0 to 10 | 10 |
| 10 to 20 | 16 |
| 20 to 30 | 18 |
| Over 30 | 22 |
| Source: ODF and ODFW, 1995. | |

The Pacific Connector pipeline would actually cross 14 perennial streams within the range of SONCC ESU coho salmon. Nine of those perennial streams have existing riparian forest ranging from Mid-Seral stage (approximately 40 to 80 years old) to older late-successional and old-growth; 6.92 acres of existing riparian forest would be removed by construction. Five more perennial streams would also be crossed but construction would not affect riparian forest vegetation (see table 4.5.3-17). In addition, the PCGP project would cross 29 intermittent streams, 27 of which support riparian forest, so that 21.69 acres total of riparian forest would be removed. Two additional intermittent streams with no riparian forest would be crossed as well (see table 4.5.3-17).

To offset impact from removal of riparian trees (reducing LWD recruitment potential) and to provide an overall benefit by enhancing stream habitat with no potential for LWD recruitment, Pacific Connector proposes to place LWD at the waterbody flow types identified by watershed in table 4.5.3-17, based on the following applications:

- four pieces for each perennial stream crossed with riparian forest removed (two pieces in-stream and/or keyed into the streambank, two pieces within riparian zone on the bank);
- two pieces for each intermittent stream and unknown stream crossed with riparian forest removed (one or both LWD pieces placed in-stream, keyed into the bank, or placed on the bank);
- two pieces for each perennial, intermittent, and unknown stream crossed but with no riparian forest removed (one or both LWD pieces paced in-stream keyed into the bank, or placed on the bank); and
- one piece each for a perennial, intermittent, and unknown stream not crossed but adjacent to the construction right-of-way, with or without riparian forest removed (LWD placed on bank).

Because the construction right-of-way at stream crossings would be 75 feet wide, Pacific Connector anticipates only enough space for two pieces of LWD, preferably with rootwads attached, either placed in-stream or with stems keyed into streambanks. Unless site-specific conditions dictate otherwise, the preferable location for each in-stream LWD is downstream from the pipeline to prevent scour of the pipe. LWD would also be placed near or adjacent to streambanks within riparian zones to provide for and/or enhance microsites for riparian vegetation and/or vegetation protection during flood events.

In all, Pacific Connector proposes 116 pieces of LWD for placement within the four fifth-field watersheds that coincide with SONCC ESU coho salmon and designated critical habitat. Placement of LWD is subject to approval by each affected landowner. If a landowner rejects the proposed placement of LWD, the number of pieces that would have been applied onsite would be reserved and provided to appropriate watershed councils for their use and placement, preferably elsewhere within the affected fifth-field watershed.

Pacific Connector anticipates that during construction, in some cases, the waterbody size, landowner restrictions, or construction constraints would limit LWD placement according to the proposed LWD schedule provided in table 4.5.3-17. Further, the overall benefit of installation of LWD at some pipeline waterbody crossings (i.e., intermittent headwater streams) may not warrant LWD placement. In these situations, Pacific Connector's Environmental Inspector would record the uninstalled LWD as a deficit during construction. After construction is completed, unutilized LWD would be provided to local watershed conservation organizations or agencies for use in local enhancement projects within the affected watersheds. (Also see the discussion on the use of LWD for mitigation in Compensatory Mitigation Plan in appendix O.)

**Compensatory Mitigation**

Appendix O provides the draft Compensatory Mitigation Plan, which includes proposed projects within watersheds in the Upper Rogue Sub-Basin.

### 4.5.3.5 Determination of Effects

**Species Effects**

The Project **may affect** coho salmon in the SONCC ESU because:

- Several stages and activities of coho salmon (upstream adult migration, juvenile rearing, and juvenile out-migration) are expected to occur at various locations in the riverine analysis area during construction and operation of the proposed action.

While several project actions are not likely to cause adverse effects, those resulting effects from Project components that are **likely to adversely affect** coho salmon in the SONCC ESU include:

- Total Suspended Sediments (TSS) could adversely affect juvenile coho salmon. Exposure of juveniles to TSS concentrations during dry open-cut construction (fluming or dam-and-pump) for more than 20 hours could potentially exceed SEV 4 for 100 meters or more downstream. Such an effect could cause a short-term reduction in feeding rate and short-term reduction in feeding success.
- Exposure of juveniles to TSS concentrations during dry open-cut construction (fluming or dam-and-pump) for 40 hours of more could potentially exceed SEV 5 for 100 meters or more downstream. Such an effect could cause minor physiological stress in juvenile coho salmon.

**Table 4.5.3-17**

**Proposed Application of Large Woody Debris to Waterbodies and Riparian Zones Affected by Construction of the Proposed Action within the Range of Southern Oregon Northern California Coast Coho Salmon**

| Fifth Field Watershed | Watershed Parameter [1] | Waterbody Type | | | | | | Total in Watershed | Pieces of LWD Applied to Fifth Field Watershed [2] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Perennial | | Intermittent | | Unknown | | | | | |
| | | Crossed | Adjacent | Crossed | Adjacent | Crossed | Adjacent | | Crossed | Adjacent | Total |
| Trail Creek (HUC 1710030706) | Area (acres) of Riparian Forest | 1.95 | 0 | 5.52 | 2.94 | 0 | 0 | 10.41 | | | |
| | Total Number of Waterbodies | 2 | 0 | 4 | 1 | 0 | 0 | 7 | | | |
| | With Riparian Forest | 2 | 0 | 4 | 1 | 0 | 0 | 7 | 16 | 1 | 17 |
| | No Riparian Forest | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shady Cove-Rogue River (HUC 1710030707) | Area (acres) of Riparian Forest | 1.09 | 0 | 6.87 | 3.88 | 0 | 0 | 11.84 | | | |
| | Total Number of Waterbodies | 4 | 0 | 9 | 7 | 0 | 0 | 20 | | | |
| | With Riparian Forest | 3 | 0 | 9 | 3 | 0 | 0 | 15 | 30 | 3 | 33 |
| | No Riparian Forest | 1 | 0 | 0 | 4 | 0 | 0 | 5 | 2 | 4 | 6 |
| Big Butte Creek (HUC 1710030704) | Area (acres) of Riparian Forest | 2.87 | 0 | 5.99 | 0 | 0 | 0 | 8.86 | | | |
| | Total Number of Waterbodies | 2 | 0 | 6 | 1 | 0 | 0 | 9 | | | |
| | With Riparian Forest | 2 | 0 | 5 | 0 | 0 | 0 | 7 | 18 | 0 | 18 |
| | No Riparian Forest | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 2 | 1 | 3 |
| Little Butte Creek (HUC 1710030708) | Area (acres) of Riparian Forest | 1.01 | 0 | 3.31 | 0.4 | 0 | 0 | 4.72 | | | |
| | Total Number of Waterbodies | 6 | 0 | 10 | 3 | 0 | 0 | 19 | | | |
| | With Riparian Forest | 2 | 0 | 9 | 1 | 0 | 0 | 12 | 26 | 1 | 27 |
| | No Riparian Forest | 4 | 0 | 1 | 2 | 0 | 0 | 7 | 10 | 2 | 12 |
| **Total Fifth Field Watersheds For SONCC Coho** | Area (acres) of Riparian Forest | 6.92 | 0 | 21.69 | 7.22 | 0 | 0 | 35.83 | | | |
| | Total Number of Waterbodies | 14 | 0 | 29 | 12 | 0 | 0 | 55 | | | |
| | With Riparian Forest | 9 | 0 | 27 | 5 | 0 | 0 | 41 | 90 | 5 | 95 |
| | No Riparian Forest | 5 | 0 | 2 | 7 | 0 | 0 | 14 | 14 | 7 | 21 |
| | | | | | | | | **Total LWD** | **104** | **12** | **116** |

[1] Riparian Forest assumed to be coniferous, deciduous, or mixed forest 40 years old and older.

[2] Proposed schedule for applying LWD to different waterbody types, subject to landowner approval:

- 4 pieces for each perennial stream crossed with riparian forest removed (2 pieces instream, 2 pieces within riparian zone on the bank);
- 2 pieces for each intermittent stream and unknown stream crossed with riparian forest removed (one or both pieces placed instream or on bank);
- 2 pieces for each perennial, intermittent, and unknown stream crossed but with no riparian forest removed (one or both pieces paced instream or on bank).
- 1 piece each for perennial, intermittent, and unknown stream not crossed but adjacent to ROW with or without riparian forest removed (placed on bank).

- If a failure occurs during peak flow periods while dry open-cut construction is underway, possible effects to juvenile coho (SEV = 6) could include moderate physiological stress.
- TSS produced by dry open-cut construction methods to cross streams are estimated to temporarily affect the water columns within 10,000 feet downstream from all in-stream construction sites (not simultaneously) if peak flows occur during construction.
- Construction requiring blasting at 17 streams could cause mortality to fish by rupturing swim bladders. Adult and juvenile coho salmon would be removed and/or prevented from being within 50 feet of blasting sites to the maximum extent possible.
- Fish salvage would occur within isolated construction sites, possibly when adult and juvenile coho salmon are present. Coho salmon are considered vulnerable to electrofishing, subject to injury and mortality. Fish salvage would primarily rely on seining but may require electrofishing as a last resort, only DC or pulsed DC current would be used. Seining, electrofishing and handling may adversely affect Oregon Coast coho salmon.
- Lack of LWD is a limiting factor in most streams within range of SONCC coho salmon. Removal of Mid-Seral riparian forest (40-80 years old) would have long-term effects to recruitment of LWD and removal of Late Successional or Old-Growth forest (≥80 years old) would have permanent effects to recruitment of LWD because planted conifers would not attain those age classes within the 50-year life of the project.

**Critical Habitat Effects**

The Project **may affect** designated critical habitat for coho salmon in the SONCC ESU because the Pacific Connector pipeline crosses designated critical habitat within waterbodies of the Upper Rogue HU (17100307) below the Lost Creek, Willow Creek, and Fish Lake Dams.

Project components are **likely to adversely affect** proposed critical habitat for coho salmon in the SONCC ESU because:

- Freshwater spawning sites would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would remove substrate at crossing sites and produce turbidity downstream that could affect previously utilized redds.
- Turbidity is expected to temporarily affect the water quality within a total of 10,154 feet downstream from dry open cut construction sites (not simultaneously) generated by mobilized clay (organics) if peak flows occur during construction.
- Food resources would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would remove substrate and benthos at crossing sites and produce turbidity downstream in all streams likely to support SONCC coho salmon.
- Freshwater migration corridors would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would produce turbidity downstream and create temporary barriers to in-stream movements while construction sites are isolated.
- Approximately 105 acres of native riparian vegetation (forest, wetlands, nonforested habitats) and of altered habitat would be removed during construction within riparian zones associated with designated critical habitat. Adverse effects to riparian zones would be long-term or permanent depending on whether mid-seral riparian forests (24.13 acres) or late-successional/old-growth riparian forests (25.26 acres) are removed.

### 4.5.4 Coho Salmon (Oregon Coast ESU)

#### 4.5.4.1 Species Account and Critical Habitat

**Status**

National Marine Fisheries Service (NMFS, 1995b) conducted a status review of coho salmon in 1995 that lead to proposed listing of several evolutionarily significant units (ESUs) as threatened, including the Oregon Coast ESU, in 1995. The final listing was delayed due to disagreements about conclusions drawn from available information and the original proposal to list as threatened was withdrawn in 1997. In 1998, the District Court for Oregon determined that NMFS' 1997 withdrawal of the proposed listing status was arbitrary and capricious and vacated the determination. Following the Court decision, NMFS issued a final rule to list the Oregon Coast ESU as threatened in August 1998. That determination was based entirely on information collected prior to the proposed rule in 1997. However, the District Court set aside the 1998 final rule determining threatened status for the Oregon Coast ESU (a result of the *Alsea* ruling) and NMFS undertook an updated status review of 27 West Coast salmon ESUs in 2003, which included the coho salmon Oregon Coast ESU. During the status review, the Biological Review Team considered the uncertainty of the ESU becoming endangered. Nevertheless, NMFS again proposed listing the coho salmon Oregon Coast ESU as threatened in June 2004 based on the review (NMFS, 2006f).

In December 2004, critical habitat was also proposed. NMFS designated critical habitats for several salmon ESUs in a final rule published in September 2005 but critical habitat for the coho salmon Oregon Coast ESU was not included because there had not been a final rule listing the ESU as threatened. In that new proposed rule, the ODFW was conducting an assessment of the population viability of Oregon Coast coho salmon. From that, ODFW concluded that Oregon Coast coho salmon are "inherently resilient at low abundance" and such response would prevent extinction. With that information and other products from the ODFW *Oregon Coastal Coho Assessment*, NMFS withdrew its proposals to list Oregon Coast coho salmon as threatened and to designate critical habitat in January 2006 (NMFS 2006f). In that decision to withdraw the proposed rules, NMFS declared that listing under ESA was not warranted at the time but the decision was challenged in Oregon District Court, which ruled that NMFS' withdrawal be invalidated and remanded to NMFS (Lohn, 2007). The present listing status for the Oregon Coast coho salmon ESU is threatened with corresponding critical habitat (NMFS, 2008d). After proposing the ESU for listing, withdrawing the proposal, and re-proposing listing the ESU as threatened under scrutiny of Oregon federal district court, NMFS issued a final rule in 2011 (NMFS, 2011i) retaining the threatened listing for the coho in the Oregon Coast ESU.

**Threats**

At the time the Oregon Coast ESU was first proposed for listing as threatened in 1995, threats to West Coast salmon populations were discussed in general but were not specific to the Oregon Coast ESU. The same factors noted above as threats to coho salmon in the SONCC ESU applied to coho salmon in the Oregon Coast ESU.

NMFS published a more recent status review in 2005 (Good et al., 2005). The U.S. District Court found NMFS' 1998 decision, listing the Oregon Coast coho salmon ESU, as unlawful because the ESU includes hatchery and naturally spawned coho salmon but NMFS only considered naturally spawned fish in their decision (Lawson, 2005). Following the delisting, multiple parties petitioned NMFS to re-list all stocks within the Oregon Coast ESU as threatened based on new information about coho salmon abundance, variability in survival and abundance, threats to genetic integrity of stocks, and stochastic events including El Niño conditions and floods (Lawson, 2005).

The short-term trend in escapement of adult spawners within the Oregon Coast ESU increased substantially in 2001 and 2002, including trends within the Umpqua, Coos, and Coquille Sub-basins due to increased marine survival and considerable restrictions on ocean harvests (Lawson, 2005 and see discussion below). Alternatively, trends in short-term recruitment were less positive within the ESU, especially in the Coos and Coquille Rivers (Lawson, 2005).

In 1994, most coho salmon harvest was prohibited and has been restricted since then, though mortalities still occur coincidentally with Chinook salmon fisheries for hatchery (marked) coho salmon (Lawson, 2005). Subsequent analyses indicated that management for a proportional maximum harvest rate of 35 percent resulted in lower risk of extinction for the ESU than management for an escapement goal or quota of 200,000 spawners ESU-wide. As expected, a harvest of zero further reduces extinction risk (Lawson, 2005).

Freshwater restoration projects to improve water quality and watershed conditions have been implemented throughout the Pacific Northwest since the late 1990s (e.g., the Coastal Salmon Restoration Initiative in 1997), though measurable results would take time (Lawson 2005). Poor marine survival for Oregon coho salmon began with climatological changes detected in the mid-1970s and worsening in the 1990s. Those conditions ameliorated in the late 1990s and extend into the early 2000s so that coho salmon marine survival improved. Such fluctuations have occurred in the past as variable cycles but future cycles would likely be within the context of global warming, which would likely prohibit predictions from past conditions (Lawson, 2005).

Compared to the Oregon Coast ESU as a whole, the proportion of escapements by coho salmon produced in hatcheries to wild spawners has been quite low in the Umpqua, Coos, and Coquille Rivers (Table 71 in Lawson, 2005), though correct identification of hatchery and wild fish has been an issue in such surveys. As noted above, decreasing the proportion of hatchery spawners benefits wild stock.

**Species Recovery**

No recovery plan has been published.

**Life History, Habitat Requirements, and Distribution**

Miller and Sadro (2003) found that approximately one-half of each brood of coastal coho salmon in Winchester Creek/South Slough (which empties into Coos Bay approximately 5 miles south of the LNG terminal/Port slip area) in 1999 and 2000 moved to the estuary as sub-yearlings (age 0). A portion of these juveniles lived in the ecotone between freshwater and saline portions of the estuary for up to 8 months and then moved back upstream to overwinter. Fish that moved to the ecotone in fall and winter had a mean residency of 48 days in 1999 and 64 days in 2000. Some of these fish resided in an off-channel beaver pond. In spring, age 1 smolts had a mean residence time in the ecotone of only 18 days and a mean residence time in the estuary of 5.8 days. Coastal coho salmon smolts would not be expected to utilize the more saline waters near the LNG terminal area for the extended periods of time as they were shown to reside in the ecotone.

Radiotelemetry studies conducted by Oregon State University researchers (Schreck et al., 2002) in the Nehalem River estuary indicate that coho salmon smolts spend about 2 weeks in the estuary before moving into the ocean. Fish monitoring in Tillamook Bay (approximately 170 miles to the north) indicated that coho salmon smolts (age 1+) were rarely found in shallow edge habitat during their residency period in the bay (Ellis 1999, 2002a, 2002b). Most of the yearling smolts appear to move quickly through the estuarine environment to the ocean. ODFW seining surveys conducted at the McCullough Bridge and Trestle sampling sites in summer 2005 and 2006 did capture juvenile coho salmon (ODFW, 2006b), but coho salmon smolts are not expected to rear within the estuarine analysis area in the estuary for significant periods of time. Coho salmon smolts resided in the stream-estuary ecotone of South Slough for a range of 12 to 40 days (Miller and Sadro, 2003).

Figure 4.5-13 provides the typical timing of use for coho salmon in the estuarine analysis area and riverine analysis areas utilized by fish in the Oregon Coast ESU. Within the estuary, some coho salmon rearing occurs but most juvenile use is during migration to the ocean (Gray, 2007). During the period between October 1 and February 15 when all in-water construction would occur, juvenile coho salmon in the estuary and lower Coos River are likely to be absent but adult coho salmon would be holding and/or migrating upstream (see figure 4.5-13).

Life stage requirements of coho salmon within freshwater habitats in the Oregon Coast ESU are expected to be similar to those described above for coho salmon in the SONCC ESU (see Section 4.5.3.1). Within the entire ESU, adults generally enter coastal streams in the fall and spawn from November through possibly March. Peak spawning is during December or January (NMFS, 2004). After hatching in spring, parr inhabit areas of slow flows and spend a second winter in freshwater before outmigration to the ocean as smolts, generally March through June (NMFS, 2004).

Specific timings of life history phases for Oregon Coast coho salmon are shown in figure 4.5-13 within the in-stream portion of the pipeline project area are available for individual rivers or tributaries in the vicinity of waterbodies crossed by the Pacific Connector pipeline. Smolt outmigration in the Umpqua River mainstem and tributaries lasts from March through June, with peak outmigration from April through mid-May. Similarly, peak outmigration in the Coquille River is from late March to early May, although the duration of outmigration is shown in figure 4.5-13 to extend from mid-February to mid-June.

Peak timing of river entry by adults to the Umpqua, Coos, and Coquille is early to mid-October although adults begin entrance to all three drainages in early September through January. Spawning in the Umpqua River begins in early October, and lasts through January, peaking in November and December (see figure 4.5-13). Though not shown in figure 4.5-13, spawning in the Coos River lasts from mid-November through late January, peaking in mid December as well as in the Coquille River though spawning there lasts from mid-November through early February (Weitkamp et al., 1995, see Appendix Table C-4). In-stream construction within tributaries to the Coos, Coquille, and South Umpqua Rivers and within range of the Oregon Coast ESU would be from July 1 through September 15. Coho salmon adult upstream migration would be occurring during the end of the in-stream construction window but spawning would not yet have started. Incubation and fry emergence from gravel, juvenile rearing and juvenile out-migration would not be occurring between July 1 and September 15 (see figure 4.5-13).

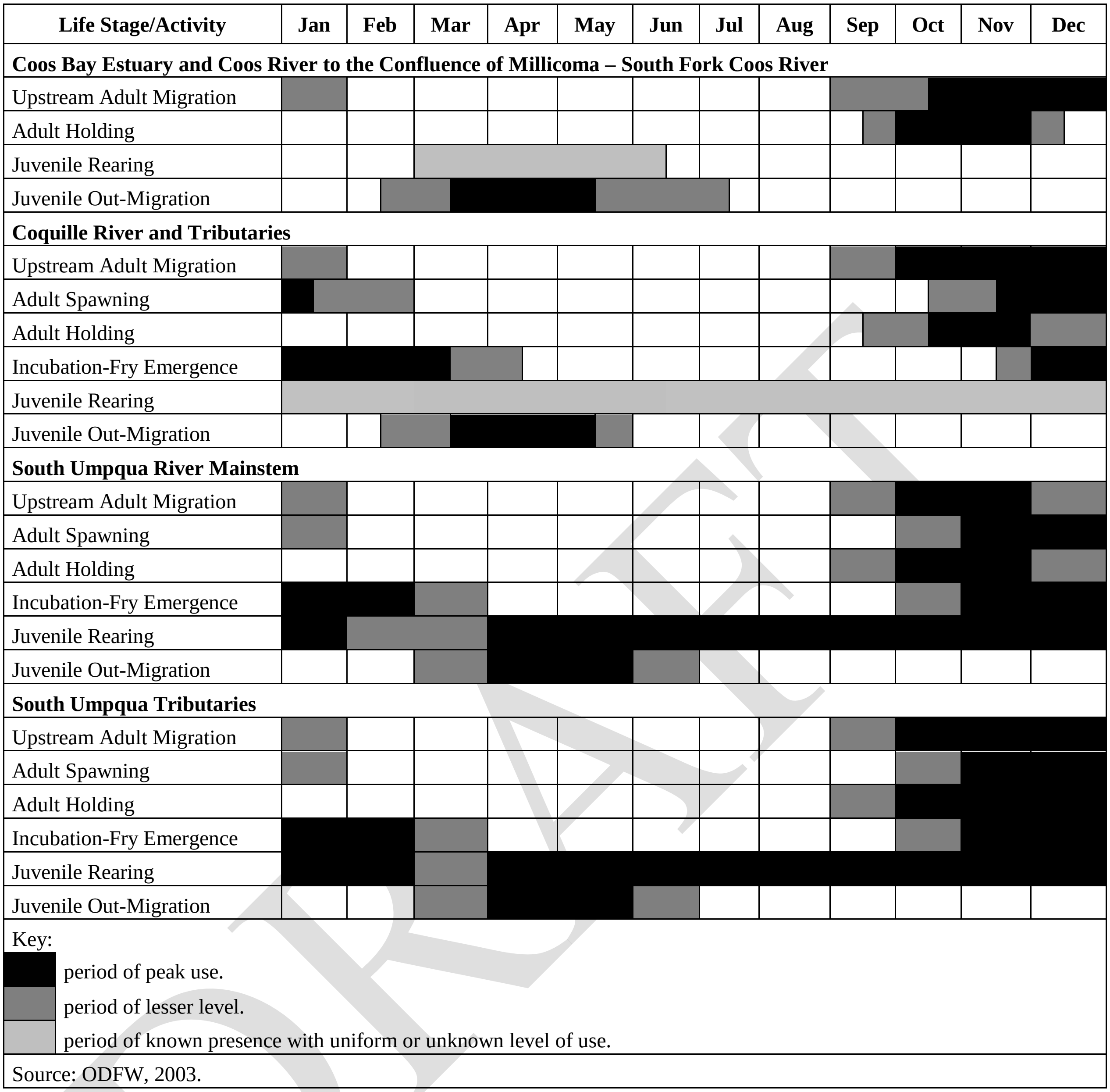



**Figure 4.5-13**
**Approximate Timing of Oregon Coast ESU Coho Salmon Use of the Coos Bay Estuary, Coos River and Tributaries, Coquille River and Tributaries, and South Umpqua River and Tributaries**

Based on genetic data and recoveries of tagged fish, the Oregon Coast coho ESU extends to Pacific Ocean tributaries from Cape Blanco north to the Columbia River. Coho in the ESU inhabit waterbodies in the following 10 fifth field watersheds that will be crossed by the PCGP: Coos Bay-Frontal Pacific Ocean (HUC 1710030403), Coquille River (HUC 1710030505), North Fork Coquille River (1710030504), East Fork Coquille River (HUC 1710030503), Middle Fork Coquille River (HUC 1710030501), Olalla Creek-Lookingglass Creek (HUC 1710030212), Clark Branch-South Umpqua River (HUC 1710030211), Myrtle Creek (HUC 1710030210), Days Creek-South Umpqua River (HUC 1710030205), and Upper Cow Creek (HUC 1710030206). Table 4.5.4-1 summarizes the number of waterbodies crossed within the PCGP Project area that are known or assumed to support Oregon Coast coho.

**Table 4.5.4-1**
**Number of Waterbodies Crossed by the PCGP Project within River Sub-basins and 5th Field Watersheds with Oregon Coast Coho ESU Designated Critical Habitat and Coho Presence (Known or Assumed).**

| Sub-basins and 5th Field Watersheds | Hydrologic Unit Code | Number of Waterbodies | | |
|---|---|---|---|---|
| | | Critical Habitat [1] | Coho Known [2] | Coho Assumed [3] |
| **Coos Sub-basin** | **17100304** | | | |
| Coos Bay-Frontal Pacific Ocean | 1710030403 | 10 | 10 | 7 |
| **Coquille Sub-basin** | **17100305** | | | |
| Coquille River | 1710030505 | 0 | 0 | 2 |
| North Fork Coquille River | 1710030504 | 3 | 3 | 0 |
| East Fork Coquille River | 1710030503 | 2 | 2 | 4 |
| Middle Fork Coquille River | 1710030501 | 1 | 1 | 0 |
| **South Umpqua Sub-basin** | **17100302** | | | |
| Olalla Creek-Lookingglass Creek | 1710030212 | 2 | 2 | 12 |
| Clark Branch-South Umpaqua River | 1710030211 | 7 | 7 | 3 |
| Myrtle Creek | 1710030210 | 3 | 3 | 2 |
| Days Creek-South Umpqua River | 1710030205 | 2 | 2 | 1 |
| Elk Creek [4] | 1710030204 | 0 | 0 | 0 |
| Upper Cow Creek | 1710030206 | 0 | 0 | 0 |
| | **Total** | 30 | 30 | 31 |

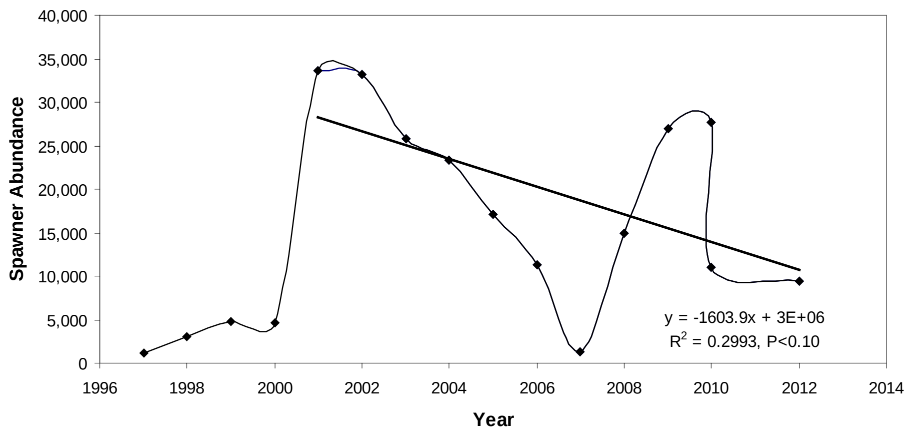
[1] NMFS, 2008e; ODFW, 2012a.
[2] Assumed presence based on connectivity to occupied stream reaches.
[3] Elk Creek Watershed would be crossed but no waterbodies would be affected within the watershed.

## Population Status

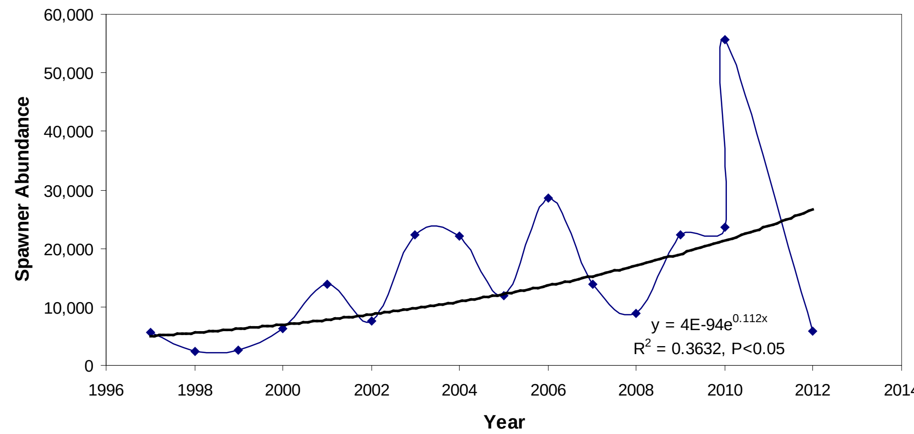
Abundance of naturally producing coho within the Coos Subbasin peaked at 33,595 spawners in 2001 but has generally diminished since then to 11,000 spawners in 2011 and to 9,400 in 2012; the declining trend in spawner abundance since 2001 is significant (see figure 4.5.4-14A).

Coho spawner abundance in the Coquille Subbasin (see figure 4.5.4-14B) and South Umpqua Subbasin (see figure 4.5.4-14C) had both been increasing at significant rates between 1997 and 2011 but declined dramatically in 2012, the fewest wild spawners since 2008 in the South Umpqua and fewest since 1999 in the Coquille Subbasin. The overall trend in total number of spawners in all three sub-basins, combined (see figure 4.5.4-14D) had likewise been increasing through 2011 but numbers of spawners in 2012 were the fewest since 2000 in the analysis area for Oregon Coast coho salmon. The same increasing trend through 2011 and decline in 2012 was apparent in all populations of the Oregon Coast ESU (ODFW, 2013).

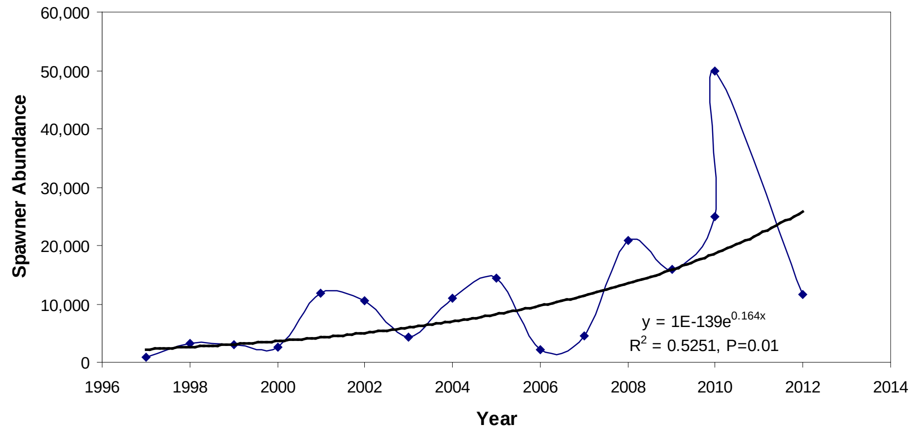
During the 20th century, there had been a prolonged decline in numbers of recruits per spawner (Weikamp et al., 1995; Good et al., 2005) wherein recruits from the return years 1997–1999 failed to replace parental spawners. Since 2000, increased marine survival rates and higher rainfall have likely contributed to a recent upswing in recruits (NMFS, 2011f; Stout et al., 2012). But that trend was interrupted during return years 2005, 2006, and 2007 as recruits again failed to replace parental spawners. Possible explanations for recent recruitment failures include the possibility that higher spawning abundance levels in recent years had reached the current carrying capacity of the degraded freshwater environment. Further, as total spawning abundance has been at highest levels since the 1950s, the total numbers of recruits remain lower than in the 1950s–1970s (NMFS, 2011f; Stout et al., 2012). These possibilities indicate that degraded freshwater habitat conditions may limit the Oregon Coast coho ESU from rebounding from another prolonged period of poor marine survival of recruits, should that occur in the future. The possibility that either of these factors, individually or together, contributed to the extreme population declines observed in 2012 has not been reported.



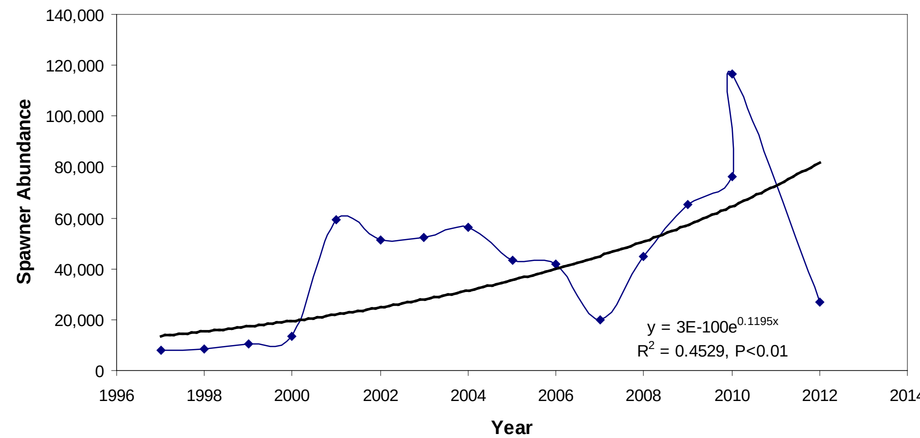

**A. Coos Sub-basin**




**B. Coquille Sub-basin**




**C. South Umpqua Sub-basin**




**D. All Sub-basins in Analysis Area**

**Figure 4.5-14**
**Estimated Abundance of Wild Adult Coho Spawners in the Oregon Coast Coho ESU, 1997 to 2012, within Three Sub-basins Crossed by the PCGP Project. (Source: ODFW, 2013)**

**Critical Habitat**

Critical habitat for the Oregon Coast coho salmon ESU was first proposed in May 1999 (NMFS 1999c). Proposed critical habitat included all river reaches accessible to Oregon Coast coho salmon ESU which were listed as threatened at the time (see discussion above). Proposed critical habitat consisted of water, substrate, and adjacent riparian zones of estuaries and rivers including those in the Umpqua (HU 17100302), Coos (HU 17100304) and Coquille (HU 17100305) HUs (NMFS 1999c). Though not specifically identified, the Coos Bay estuary would have been included. The 1999 proposal was terminated when the District Court set aside the 1998 final rule determining threatened status for the Oregon Coast ESU (see discussion above).

Following re-proposing Oregon Coast coho salmon ESU for listing as threatened in June 2004, critical habitat for the ESU was likewise re-proposed in December 2004 (NMFS, 2004). The new proposed critical habitat designated three critical habitat units that coincide with each of the three Project components: Unit 9 – South Umpqua Subbasin (HU 17100302) affected by the Pacific Connector pipeline; Unit 11 – Coos Subbasin (HU 17100304), which includes the Coos Bay estuary) affected by the Port, the LNG terminal, and the Pacific Connector pipeline; and Unit 12 – Coquille Subbasin (HU 17100305) affected by the Pacific Connector pipeline.

Similar to critical habitat designated for coho salmon in the SONCC ESU, critical habitat included stream channels laterally to the ordinary high water mark (OHWM) (or bankfull elevation or bankfull width). NMFS also defined critical habitat in estuarine and nearshore marine zones as areas contiguous with the shoreline from the extreme highwater mark out to a depth no greater that 30 meters (98 feet) below the mean low water mark (NMFS, 2004).

Within these areas, NMFS (2004) identified primary constituent elements (PCEs) of critical habitat that include sites essential to support one or more coho life stages (spawning, rearing, migration, and foraging). Those sites each are associated with physical and biological features essential coho conservations (e.g., spawning gravels, water quality, water quantity, side channels, food base). The following are PCEs for designated critical habitat for the Oregon Coast coho (NMFS, 2008d):

1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.
2. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
3. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks a) supporting juvenile and adult mobility and survival, b) supporting juvenile use of various of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and ability to reach the ocean, and c) essential for nonfeeding adults to successfully swim upstream, avoid predators, and reach spawning areas on limited energy stores.
4. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and

saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

5. Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.
6. Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Designated critical habitat for the Oregon Coast coho does not include unoccupied areas. The lateral extent of critical was defined as the width of the stream channel defined as the ordinary high-water line (NMFS, 2008d). Human actions on land outside of the stream channel can modify or degrade physical and biological features of the stream and associated PCE at the site and/or in downstream reaches of designated critical habitat.

#### 4.5.4.2 Environmental Baseline

**Analysis Area**

Three action area components are applicable to coho salmon in the Oregon Coast ESU. The first is the EEZ analysis area, which extends 200 nmi offshore from the Coos Bay Head (see figure 4.2-1, under Section 4.2.1.3 blue whale) and within the EEZ from San Diego, California, to Cape Flattery, Washington. Within the analysis area, effects to coho salmon within coastal marine waters would be associated with LNG carriers that are assumed to transect the EEZ perpendicularly - east and west - as they approach and depart from Coos Bay (see the discussion above under see under section 4.3.3.3 marbled murrelet). The second is the estuarine analysis area that was described above for marbled murrelets (see figure 4.3-6 under section 4.3.3.2 marbled murrelet). The third is a riverine analysis area similar to that described above for coho salmon in the SONCC ESU. The estuarine analysis area includes 1) operational activities by LNG carriers entering and exiting Coos Bay, 2) construction-related effects to approximately 3.1 miles downstream from the proposed LNG terminal and upstream to a point 2.2 miles from that site for potential worst-case dispersion of turbidity, as provided by Moffatt and Nichol, 2006), and 3) the 2.80-mile within-estuary route of the Pacific Connector pipeline after leaving the Weyerhaeuser Cove Pipe Yard at MP 1.7, crossing Haynes Inlet to where the pipeline emerges from the estuary at MP 4.1.

The riverine analysis area is the second component and includes two components: 1) the water column and substrate of all waterbodies crossed by the Pacific Connector pipeline from the point of crossing to the extent downstream where water quality is adversely affected by turbidity generated during construction and sediment generated by runoff from the construction right-of-way, and 2) waterbodies' associated riparian zones affected in the short-term during construction and in the long-term by operation. For coho salmon in the Oregon Coast ESU, the riverine analysis area is limited to fresh waterbodies within Coos Subbasin (HU 17100304 – figure 4.5-15A), Coquille Subbasin (HU 17100305 – figure 4.5-15B) and South Umpqua Subbasin (HU 17100302 – figure 4.5-15C).

Total suspended solid (TSS) concentrations generated during wet open-cut pipeline construction have been estimated from models developed by Reid et al. (2004). Amounts of TSS produced during dry open-cut construction (fluming, dam-and-pump) adjustments are fractions of the concentrations produced during wet-open cuts (Reid et al., 2004). Estimates of TSS produced during dry open-cut construction across waterbodies in fifth field watersheds are presented below in Section 4.5.4.3. Average sediment percentages (grain sizes including gravel, sand, silt, and organics) for streams within each fifth field watershed (see table 4.5.4-7 below in this section and table 4.5.4-12 in Section 4.5.4.3) were assumed as fractions of the TSS generated during construction and concentrations of each grain class at various distances downstream were estimated using Ritter's (1984) model for minor perennial waterbodies. Distances at which concentrations near zero (settle out of suspension) differ considerably for the different grain sizes and are dependent on water depths and stream discharge rates at the time of construction (see Table 4.5.3-7 in Section 4.5.3.3, SONCC coho). Downstream settling distances will be much greater for deeper waterbodies with high flow velocities than for shallow, slow flowing streams.

For streams within range of Oregon Coast coho that would be crossed by the PCGP project, the average downstream distance expected to near a concentration of 0 mg/L of silt (0.0016 cm diameter, 0.023 cm/sec settling velocity) during fluming is about 114 m (374 feet); the average downstream distance expected to near a concentration of 0 mg/L of clay (0.0004 cm diameter, 0.0014 cm/sec settling velocity) is about 1,500 m (4,921 feet). These estimates are for average low flows likely to occur during pipeline construction within the ODFW (2008) instream timing recommendations.

Downstream distances to reach concentrations of 0 mg/L for silt and clay mobilized by flumed construction during average peak flows would be greater. The average downstream distance expected to near a concentration of 0 mg/L of silt (0.0016 cm diameter, 0.023 cm/sec settling velocity) during fluming is about 620 m (2,034 feet); the average downstream distance expected to near a concentration of 0 mg/L of clay (0.0004 cm diameter, 0.0014 cm/sec settling velocity) is about 9,800 m (32,152 feet).

The riverine analysis area used in this biological assessment for Oregon Coast coho has been limited to downstream distances up to 32,152 feet (6.1 miles) within the affected fifth field watersheds in the range of Oregon Coast coho (see figure 4.5-15).

**Species Presence**

Based on genetic data and recoveries of tagged fish, the Oregon Coast coho ESU extends to Pacific Ocean tributaries from Cape Blanco north to the Columbia River. Coho in the ESU inhabit waterbodies in 10 fifth field watersheds that will be crossed by the PCGP (see table 4.5.4-2). An eleventh, the Elk Creek Watershed (HUC1710030204), would be crossed but no waterbodies would be affected within the watershed. The project would cross the following that are inhabited by Oregon Coast coho: Coos Bay-Frontal Pacific Ocean (HUC 1710030403), Coquille River (HUC 1710030505), North Fork Coquille River (1710030504), East Fork Coquille River (HUC 1710030503), Middle Fork Coquille River (HUC 1710030501), Olalla Creek-Lookingglass Creek (HUC 1710030212), Clark Branch-South Umpqua River (HUC 1710030211), Myrtle Creek (HUC 1710030210), Days Creek-South Umpqua River (HUC 1710030205), and Upper Cow Creek (HUC 1710030206). Upstream migrations by coho in the Middle Fork Coquille River are blocked (Bradford Falls) at River Mile 27.3, about 5.3 miles southwest of Camas Valley, OR.

**Table 4.5.4-2**
**Summary of River Sub-basins and 5th Field Watersheds Coinciding With the Proposed Pipeline Route, within Range of Oregon Encountered from West to East**

| Sub-basins and 5th Field Watersheds | Hydrologic Unit Code | Number of Waterbodies [1] | | | | |
|---|---|---|---|---|---|---|
| | | Estuary | Perennial | Intermittent | Pond [2] | Total |
| **Coos Sub-basin** | **17100304** | | | | | |
| Coos Bay-Frontal Pacific Ocean | 1710030403 | 1 | 40 | 24 | 1 | **66** |
| **Coquille Sub-basin** | **17100305** | | | | | |
| Coquille River | 1710030505 | | 5 | 1 | | **6** |
| North Fork Coquille River | 1710030504 | | 3 | 10 | | **13** |
| East Fork Coquille River | 1710030503 | | 7 | 7 | | **14** |
| Middle Fork Coquille River | 1710030501 | | 5 | 8 | | **13** |
| **South Umpqua Sub-basin** | **17100302** | | | | | |
| Olalla Creek-Lookingglass Creek | 1710030212 | | 4 | 11 | | **15** |
| Clark Branch-South Umpqua River | 1710030211 | | 6 | 13 | | **19** |
| Myrtle Creek | 1710030210 | | 5 | 5 | | **10** |
| Days Creek-South Umpqua River | 1710030205 | | 5 | 4 | | **9** |
| Elk Creek [3] | 1710030204 | | | | | **0** |
| Upper Cow Creek | 1710030206 | | 5 | 2 | | **7** |
| | **TOTAL** | **1** | **85** | **85** | **1** | **172** |

[1] includes waterbodies crossed and waterbodies not crossed but immediately adjacent to the pipeline and within the right-of-way.
[2] includes stock ponds, industrial ponds.
[3] Elk Creek Watershed would be crossed but no waterbodies would be affected within the watershed.

The pipeline would actually cross 149 of the waterbodies in table 4.5.4-3, 143 of them by dry open cutting, while the South Umpqua River would be crossed twice, once by a Direct Pipe crossing at MP 71.30 and again by a diverted open cut at MP 94.73. Kentuck Slough would be crossed by a conventional bore at MP 6.28R, Catching Slough would also be bored at MP 11.11, and the Coos River would be crossed using HDD at MP 11.13R. The Coos Bay estuary would be crossed by using a wet open cut procedure. Twenty-two of the waterbodies listed in 4.5.4-3 would not be crossed by the pipeline but are adjacent to the pipeline centerline. Blasting may be necessary to construct across 30 streams that would be crossed by dry open cut methods (see Project Description) because the streambed of each is bedrock (see table 4.5.4-3).

All affected waterbodies within the three sub-basins and 10 fifth field watersheds that are within the range of Oregon Coast coho salmon ESU proximate to the Pacific Connector pipeline are included in table 4.5.4-3. There are 172 waterbodies included in the table, of which 85 are perennial, 85 are intermittent, 1 is an estuary and another is a pond. Coho salmon are known to occur in 32 of the waterbodies and are assumed to be present in 27 others based on connectivity to perennial streams known to support coho salmon, the presence of resident salmonids, and/or information provided by fisheries biologists.

**Table 4.5.4-3**
**Waterbodies Crossed or Adjacent to the Pacific Connector Pipeline within the Coos Sub-basin (HUC 17100304), Coquille Sub-basin (HUC 17100305), and South Umpqua Sub-basin (HUC 17100302) and in the Range of the Oregon Coast Coho Salmon ESU.**

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| **Coos Sub-basin (HUC 17100304), Coos Bay-Frontal Pacific Ocean (HUC 1710030403) Fifth field Watershed [8], Coos County, Oregon** | | | | | | | |
| Coos Bay (NE026) | 1243397433543 State | 2.92R | Estuary | Wet Open-Cut | Coho | Coho Rearing, Migration | Oct 1 to Feb 15 |
| Trib. to Coos Bay (GSI026) | 1242017434500 Private | 4.89R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Kentuck Slough (EE004/GW27) | 1241795434269 Private | 6.23R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Kentuck Slough (EE005/GSP-28) | 1242068434143 Private | 6.28R | Perennial | Conventional Bore | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib to Coos Bay (NW-117/EE06) | 1241902434209 Private | 6.35R | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Willanch Creek (Denied Access 01) | 124164934037 Private | 7.99R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Willanch Slough (EE007) | 1242083434031 Private | 8.34R | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib to Willanch Slough (GDX029/EE008) | 1241601434068 | 8.43R | Perennial | Not Crossed by Centerline | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trip to Willanch Slough (GDX030) | Private | 8.48R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Willanch Slough (GDX031) | Private | 8.49R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Tributary to Coos River (GW34) | Private | 9.55R | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to Cooston Channel (Echo Creek) (SS-100-002) | 1241722433697 Private | 10.22R | Intermittent | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Coos River (SS-001-003) | Private | 10.79R | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Coos River (BSP119) | 1241999433842 (State) | 11.13R | Perennial | HDD | Coho | Coho Rearing, Migration) | Oct 1 to Feb 15 |
| Vogel Creek (SS-100-005) | Private | 11.53R | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Vogel Creek (SS-100-005 | Private | 11.58R | Perennial | Adjacent to centerline within ROW | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to Coos River ((SS-100-006) | Private | 11.77R | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Lillian Creek (SS-100-007) | Private | 11.91R | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Lillian Creek (SS-100-002a) | Private | 12.07R | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to Coos River (SS-100-008) | Private | 12.22R | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Coos River (BDX109) | 1241562433627 | 8.67 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Coos River (BDX109a) | 1241562433627 | 8.73 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Catching | 1241704433522 | 9.02 | Perennial | Dry Open-Cut | Coho | Unknown | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Slough (BSP104) | Private | | | | Assumed | | |
| Trib. to Catching Slough (BSP105) | 1241675433517 Private | 9.19 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Catching Slough (DSI003) | 1241489433510 Private | 9.33 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Catching Slough (DSP002) | 1241530433517 Private | 9.51 | Perennial | Dry Open-Cut (Streambed–bedrock) | None | None | Jul 1 to Sep 15 |
| Monkey Gulch (Denied Access 05X) | Private | 10.20 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Stock Slough (BSP088) | 1241571433361 Private | 10.32 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Pasture Pond (BL084) | Private | 10.40 | Stock pond | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Catching Slough (BSP079) | 1241572433284 Private | 11.11 | Perennial | Conventional Bore | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to Catching Slough (BDX118) | 1241553433277 Private | 11.29 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Catching Slough (BSP114) | Private | 11.47 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Catching Slough (BSP103) | 1241608433185 Private | 11.78 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Catching Slough (BSP101) | 1241655433196 Private | 11.84 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Catching Slough (BSP100) | 1241655433196 Private | 11.87 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Catching Slough (NSI041) | 1241655433196 Private | 12.05 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI092) | Private | 12.27 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI093) | Private | 12.31 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI094) | Private | 12.39 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI095) | 1241711433132 Private | 12.39 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI096) | Private | 12.41 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI097) | Private | 12.45 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib to Catching Slough (NSI098) | 1241709433122 Private | 12.52 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (BSP120) | 1241852433075 Private | 12.66 | Perennial | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (BSP121) | 1241852433075 Private | 12.68 | Perennial | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (BSP122) | 1241842433046 Private | 12.83 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (BSP125) | Private | 12.90 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough | Private | 12.97 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| (CSP031) | | | | | | | |
| Trib. to Ross Slough (CSP030) | 1241793433038 Private | 13.01 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (CSP029) | 1241778433044 Private | 13.11 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Ross Slough (CSP028) | 1241687433509 Private | 13.55 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (CSP027) | 1241761432974 Private | 13.61 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Ross Slough (CSP026) | 1241733432965 Private | 13.70 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Boone Creek (EDX078) | 1241532432789 Private | 15.71 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Boone Creek (CSI037) | 1241561432755 Private | 16.36 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Boone Creek (CSP036) | 1241561432755 Private | 16.36 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Boone Creek (CSI035) | 1241598432687 Private | 16.39 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP024) | 1241612432631 Private | 16.56 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP023) | 1241604432619 Private | 16.62 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP022) | 1241594432613 Private | 16.71 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP021) | 1241596432612 Private | 16.73 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP020) | 1241603432608 Private | 16.78 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP019) | 1241561432616 Private | 16.82 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (CSP018) | 1241606432606 Private | 16.85 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Catching Creek (BLM 17.42) | BLM – Coos Bay District | 17.42 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Catching Creek (CSP033) | 1241452433077 Private | 17.47 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing, | Jul 1 to Sep 15 |
| **Coquille Sub-basin (HUC 17100305), Coquille River (HUC 1710030505) Fifth field Watershed [8], Coos County, Oregon** | | | | | | | |
| Trib. To Cunningham Creek (BSP092) | 1241387432420 Private | 18.20 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Cunningham Creek (BSP093) | 1241469432436 Private | 18.28 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Cunningham Creek (BSP095) | 1241458432440 Private | 18.33 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Cunningham Creek (BSI096) | 1241461432438 Private | 18.48 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Cunningham Creek (NSP042) | 1242026431787 Private | 18.93 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. To Cunningham Creek (NSP043) | 1241375432355 Private | 19.06 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| **Coquille Sub-basin (HUC 17100305), North Fork Coquille River (HUC 1710030504) Fifth field Watershed [8] Coos County, Oregon** | | | | | | | |
| Trib. to Steele Creek (ESI028) | 1241154432240 BLM – Coos Bay District | 20.34 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Trib. to Steele Creek | 1241154432240 | 20.59 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| (ESI028) | BLM – Coos Bay District | | | (Streambed-bedrock) | | | |
| Trib. to Steele Creek (Denied Access 06) | Private | 20.72 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Steele Creek (Denied Access 07) | Private | 20.79 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Steele Creek (Denied Access 08) | Private | 20.94 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Steele Creek (NSP015) | 1240848432002 Private | 21.10 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Steele Creek (Denied Access 09) | Private | 21.13 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Steele Creek (ESI029) | 12410034432184 BLM-Coos Bay District | 21.36 | Intermittent | Adjacent to centerline within ROW (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| North Fork Coquille River (BSP207) | 11241417430804 Private | 23.06 | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to Middle Creek (BSI137) | 1240268431779 BLM- Coos Bay District | 27.01 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Middle Creek (BSI136) | 1240268431779 BLM- Coos Bay District | 27.02 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to Middle Creek (BSI135) | 1240268431779 BLM- Coos Bay District | 27.04 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Middle Creek (BSP133) | 1240712431628 BLM- Coos Bay District | 27.04 | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| **Coquille Sub-basin (HUC 17100305), East Fork Coquille River (HUC 1710030503) Fifth field Watershed [8], Coos County, Oregon** | | | | | | | |
| Trib. To E. Fork Coquille (BSP077) | 1240014431632 Private | 28.86 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. To E. Fork Coquille (NSI099) | 1239937431584 Private | 29.18 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. To E. Fork Coquille (BSI073) | 1241551433636 Private | 29.49 | Intermittent | Dry Open-Cut | Coho Assumed | None | Jul 1 to Sep 15 |
| Trib. To E. Fork Coquille (BSI076) | 1239946431580 Private | 29.53 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| East Fork Coquille River (BSP071) | 1240773431063 | 29.88 | Perennial | Dry Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to E. Fork Coquille (Denied Access 11) | Private | 30.21 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to E. Fork Coquille (Denied Access 12) | Private | 30.27 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To E. Fork Coquille (BSI070) | 1239583431522 BLM- Coos Bay District | 31.64 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Elk Creek (BSP057) | 1240218431116 Private | 32.40 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. To Elk Creek (BSP055) | 1239513431370 Private | 32.44 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. To Elk Creek (BSP049) | 1239524431250 Private | 32.99 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Trib. To Elk Creek (BSP050) | 1239482431284 Private | 33.02 | Perennial | Adjacent to centerline within ROW (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| South Fork Elk Creek (CSP005) | 1239778431167 Private | 34.46 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. To S. Fork Elk Creek (BSI251) | 1239155431070 BLM-Coos Bay District | 35.51 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| **Coquille Sub-basin (HUC 17100305), Middle Fork Coquille River (HUC 1710030501) Fifth field Watershed [8], Coos County, Oregon** | | | | | | | |
| Trib. to Big Creek (BLM 35.87) | 1239061430967 BLM-Coos Bay District | 35.87 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (BLM 36.48) | 1238985431032 BLM – Coos Bay District | 36.48 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (GSI025/BSI253) | 1238985431032 BLM-Coos Bay District | 36.54 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (BLM 36.85) | BLM-Coos Bay District | 36.85 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (BSI252) | 1238901431044 BLM-Coos Bay District | 36.92 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (ESI019) | 1238846431056 BLM-Coos Bay District | 37.33 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. To Big Creek (ESP020) | 1238856431054 BLM-Coos Bay District | 37.35 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Upper Rock Creek (BSP041) | 1238692429883 Private | 44.21 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| **Coquille Sub-basin (HUC 17100305), Middle Fork Coquille River (HUC 1710030501) Fifth field Watershed [8], Douglas County, Oregon** | | | | | | | |
| Deep Creek (BSP257) | 1237088430546 BLM – Roseburg District | 48.27 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Middle Fork Coquille River (BSP030) | 1241173430339 Private | 50.28 | Perennial | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Trib. to Middle Fork Coquille (GDX36/BSI066) | 1236800430537 Private | 50.45 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Belieu Creek (BSP061/GSI037) | 1236823430366 Private | 50.74 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Middle Fork Coquille (GSI038) | 1236690430555 BLM-Roseburg District | 51.02 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| **South Umpqua (HUC 17100302) Sub-basin, Olalla Creek-Lookingglass Creek (HUC 1710030212) Fifth field Watershed [8], Douglas County** | | | | | | | |
| Trib. to Shields Creek (BSI202) | 1235858430773 Private | 55.90 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Shields Creek (BSI203) | 1235796430789 Private | 55.94 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Shields Creek (Denied Access 13) | 1235757430747 Private | 56.28 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Shields Creek (Denied Access 14) | 1235785430811 Private | 56.34 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI140) | 1235535430633 Private | 57.11 | Intermittent | Dry Open-Cut (Streambed–bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI140) | 1235535430633 Private | 57.14 | Intermittent | Dry Open-Cut (Streambed–bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| Trib. to Olalla Creek (BSI138) | 1235535430633 Private | 57.31 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI147/EE012) | 1235479430651 Private | 57.84 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI151) | 1235422430690 Private | 58.20 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSP159) | 1235362430712 Private | 58.55 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Olalla Creek (BSP155) | 1234905431631 Private | 58.77 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing, Migration | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI132) | 1235250430793 Private | 59.29 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Olalla Creek (BSI129) | 1235231430834 Private | 59.65 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to McNabb Creek (NSP014) | 1235104430875 Private | 60.13 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| McNabb Creek (NSP013) | 1235187430921 Private | 60.49 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| **South Umpqua (HUC 17100302) Sub-basin, Clark Branch-South Umpqua River (HUC 1710030211) Fifth field Watershed [8], Douglas Co.** | | | | | | | |
| Kent Creek (BSP240) | 1234390431042 Private | 63.95 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Kent Creek (BSI241) | 1234490430771 Private | 63.95 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Rice Creek (BSP227) | 1234142430839 Private | 65.76 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Willis Creek (BSI230) | 1233983430694 Private | 66.87 | Intermittent | Adjacent to centerline within ROW (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Willis Creek (BSP168) | 1233989430788 Private | 66.95 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to Willis Creek (BSI169) | 1233982430692 Private | 67.00 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-011) | Private | 69.10 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-012) | Private | 69.28 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-013) | Private | 69.35 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-014) | Private | 69.57 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-015) | Private | 71.11 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| South Umpqua River (BSP026) | 1234460432680 Private | 71.30 | Perennial | Direct Pipe | Chinook, Coho | Coho Migration | Jul 1 to Aug 31 |
| Trib. to South Umpqua River (SS-100-016) | Private | 71.37 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River | Private | 71.69 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| (SS-100-017) | | | | | | | |
| Trib. to South Umpqua River (SS-100-018) | Private | 72.82 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-019) | Private | 72.96 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-021) | Private | 73.21 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua River (SS-100-020) | Private | 73.41 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Richardson Creek (SS-100-022) | Private | 74.03 | Intermittent | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| **South Umpqua (HUC 17100302) Sub-basin, Myrtle Creek (HUC 1710030210) Fifth field Watershed [8], Douglas County, Oregon** | | | | | | | |
| Bilger Creek (BSP001) | 1232578430422 Private | 76.38 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Little Lick (BSP006) | 1232235430457 Private | 77.71 | Perennial | Dry Open-Cut | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| Trib. to Little Lick Creek (BSI008) | 1232244430631 Private | 77.93 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to Little Lick Creek (BSI010) | 1232239430620 Private | 78.02 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| North Myrtle Creek (NSP037) | 1232963430229 Private | 79.12 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Trib. to North Myrtle Creek (NSP038) | 1232040430551 Private | 79.15 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho Assumed | Unknown | Jul 1 to Sep 15 |
| South Myrtle Creek (BSP172) | 1232847430231 Private | 81.19 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing, | Jul 1 to Sep 15 |
| Trib. to S. Myrtle Creek (BSP259) | 1231856430317 | 81.40 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to S. Myrtle Creek (SS-100-023) | Private | 81.45 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| Trib. to S. Myrtle Creek (SS-100-024) | Private | 81.78 | Intermittent | Adjacent to centerline within ROW | None | None | Jul 1 to Sep 15 |
| **South Umpqua (HUC 17100302) Sub-basin, Days Creek-South Umpqua River (HUC 1710030205) Fifth field Watershed [8], Douglas County** | | | | | | | |
| Wood Creek (BSP226) | 1231503429810 Private | 84.18 | Perennial | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Trib. to Fate Creek (BSI236) | 1231019429928 Private | 88.20 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| Fate Creek (BSP232) | 1231028429873 Private | 88.48 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Days Creek (BSP233) | 1231699429713 Private | 88.60 | Perennial | Dry Open-Cut (Streambed-bedrock) | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| Saint John Creek (ASP303) | 1230596429295 Private | 92.62 | Perennial | Dry Open-Cut | Coho | Coho Spawning, Rearing | Jul 1 to Sep 15 |
| South Umpqua River (ASP196) | 1234460432680 Private | 94.73 | Perennial | Diverted Open-Cut | Coho | Coho Rearing, Migration | Jul 1 to Aug 31 |
| Trib. to South Umpqua | 1230382429323 | 94.85 | Intermittent | Dry Open-Cut | Coho | Unknown | Jul 1 to Sep 15 |

| Waterbodies Crossed and Waterbody ID | Identification (LLID) and/or Jurisdiction | Pipeline Milepost (MP) | Waterbody Type | Proposed Crossing Method [1] (potential for blasting) [4] | Species Present [2] | Habitat Component Present [2] | Fishery Construction Window [3] |
|---|---|---|---|---|---|---|---|
| River (ASI193) | Private | | | | Assumed | | |
| Trib. to South Umpqua River (ASI193) | 1230382429323 Private | 95.03 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to South Umpqua (ASI190) | 1230197429036 BLM – Roseburg District | 98.46 | Intermittent | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| **South Umpqua (HUC 17100302) Sub-basin, Upper Cow Creek (HUC 1710030206) Fifth field Watershed [8], Douglas County, Oregon** | | | | | | | |
| Trib. to East Fork Cow Creek (GW014/FS-HF-C) | 1229383427835 Forest Service – Umpqua NF | 109.17 | Perennial (FS – Interpretation) | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to East Fork Cow Creek (GSI016/FS-HF-F) | 1229369427819 Forest Service – Umpqua NF | 109.33 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| East Fork Cow Creek (GSP019/FS-HF-G) | 1229918428021 Forest Service – Umpqua NF | 109.47 | Perennial | Dry Open-Cut (Streambed-bedrock) | None | None | Jul 1 to Sep 15 |
| East Fork Cow Creek (GSP022/FS-HF-G ASP297) | 1229918428021 Forest Service – Umpqua NF | 109.69 | Perennial | Adjacent to centerline within TEWA | None | None | Jul 1 to Sep 15 |
| Trib. to East Fork Cow Creek (FS-HF-J/AW298) | 1229332427779 Forest Service – Umpqua NF | 109.69 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to East Fork Cow Creek (FS-HF-K/AW299) | 1229332427781 Forest Service – Umpqua NF | 109.78 | Perennial | Dry Open-Cut | None | None | Jul 1 to Sep 15 |
| Trib. to East Fork Cow Creek (ESI068/FS-HF-N) | Forest Service – Umpqua NF | 110.98 | Intermittent | Dry Open-Cut | None | None | Jul 1 to Sep 15 |

[1] Dry open cut crossing methods include flume or dam-and-pump procedures. Dam-and-pump methods would be utilized where streambed blasting is anticipated to eliminate blasting around the flume. The dam-and-pump crossing method is the preferred crossing procedure in steep incised drainage valleys where worker safety may be compromised when placing ("threading") the pipe string under the flume pipe and where there is a risk of upsetting the flume during this operation. The dam-and-pump crossing method is also the preferred crossing method on small streams under low flow conditions during the recommended ODFW-recommended in-water work period. Pacific Connector proposes temporary/short-term fish passage restriction when completing dam-and-pump crossings within the ODFW-recommended in-water work period. Appendix M provides details of stream crossings.

[2] Oregon Department of Fish and Wildlife. 2012a. Fish Distribution Data, 1:24,000 Scale. Oregon Department of Fish and Wildlife Natural Resources Information Management Program. Online: https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata).

[3] Assumes fisheries construction windows only apply to those waterbodies flowing at the time of construction and windows do not apply to HDD crossings.

[4] Steambed bedrock based on Pacific Connector's Wetland and Waterbody delineation surveys. Streambed bedrock may require special construction techniques to ensure pipeline design depth. Special construction techniques may include rock hammering, drilling and hammering, or blasting. The need for blasting would be determined by the construction contractor and would only be initiated after ODFW blasting permits are obtained.

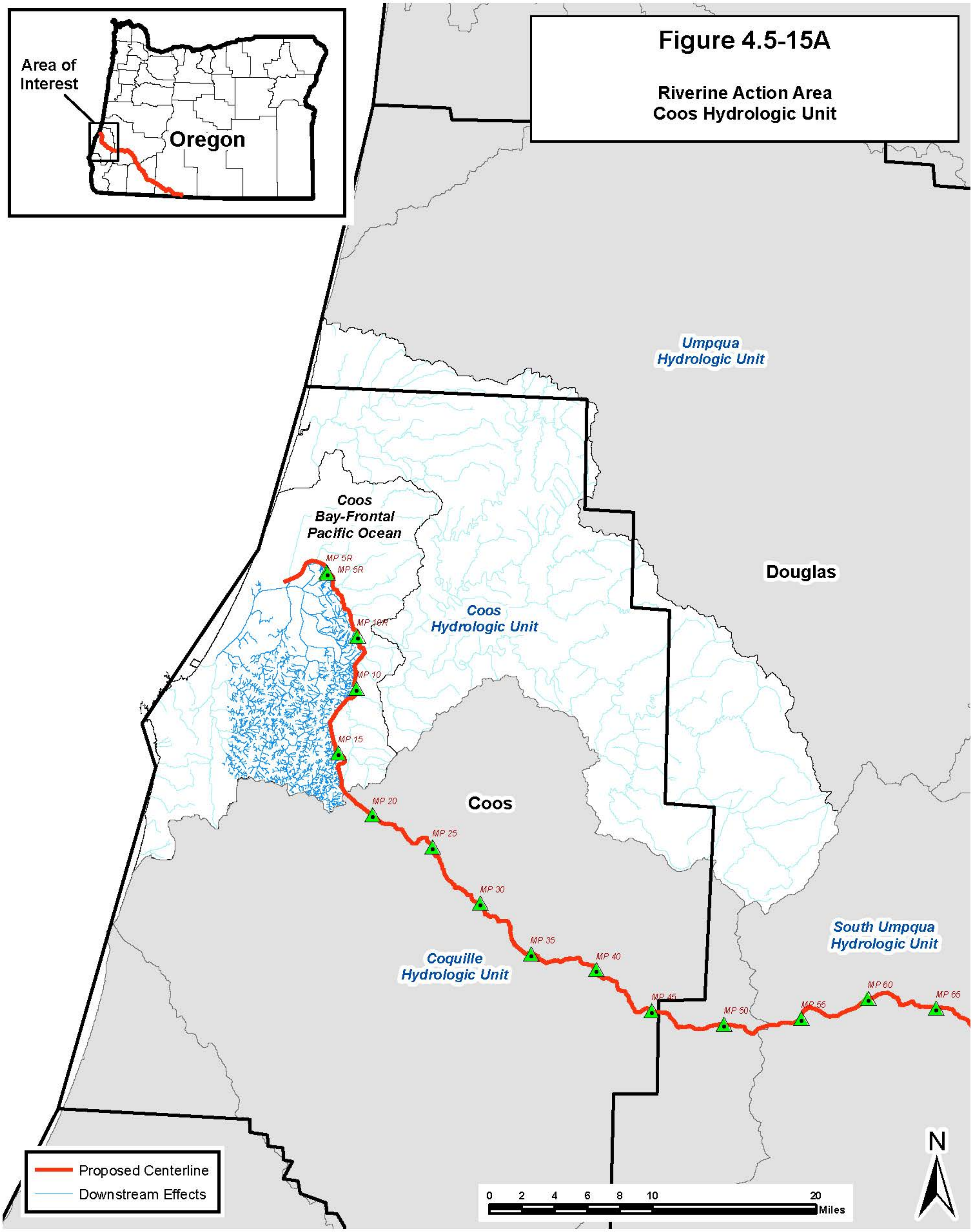


Figure 4.5-15A
Riverine Action Area
Coos Hydrologic Unit
Area of Interest
Oregon
Umpqua Hydrologic Unit
Coos Bay-Frontal Pacific Ocean
Douglas
Coos Hydrologic Unit
Coos
South Umpqua Hydrologic Unit
Coquille Hydrologic Unit
MP 5R
MP 10R
MP 10
MP 15
MP 20
MP 25
MP 30
MP 35
MP 40
MP 45
MP 50
MP 55
MP 60
MP 65
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20
Miles
N

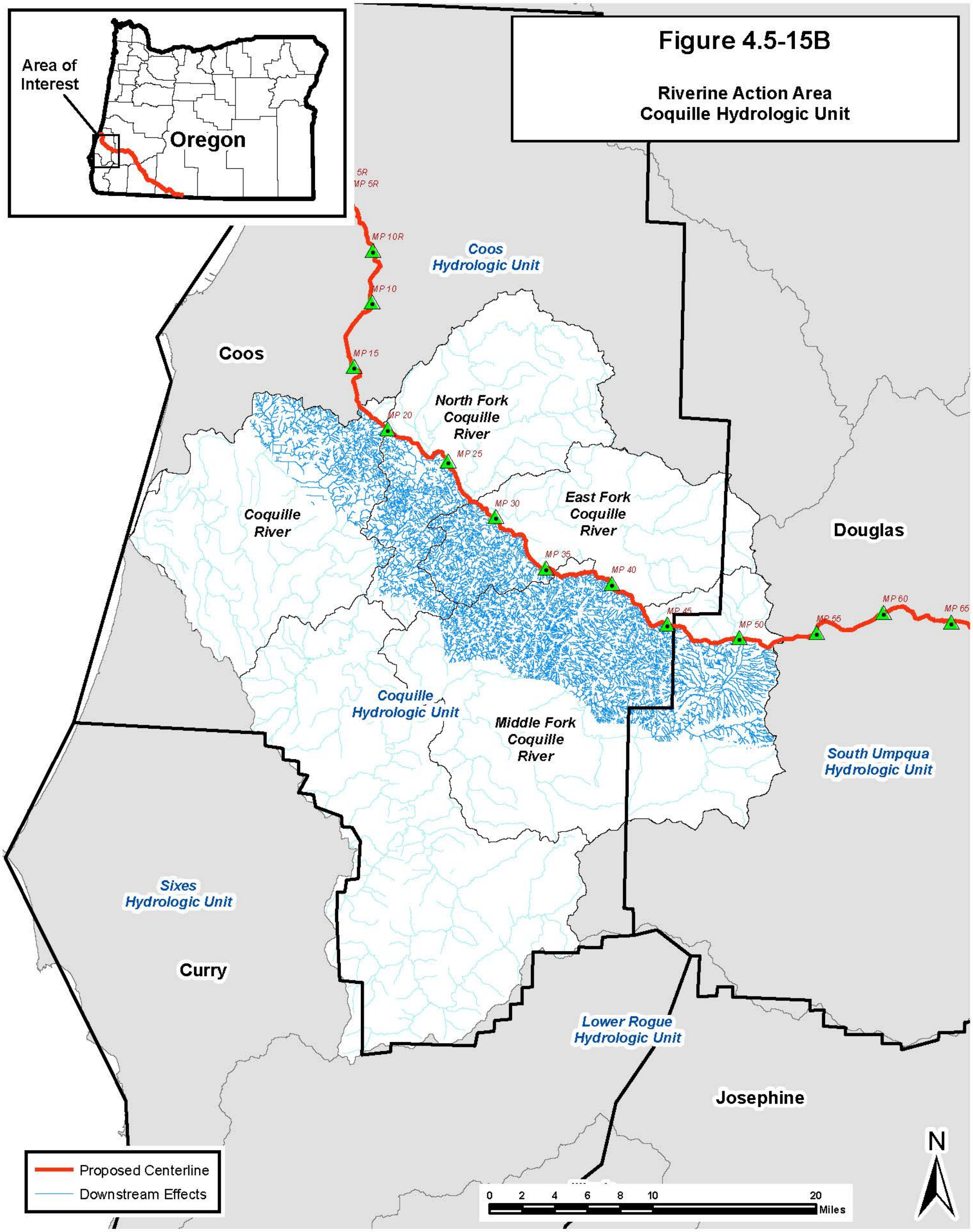


Figure 4.5-15B
Riverine Action Area
Coquille Hydrologic Unit
Area of Interest
Oregon
Coos Hydrologic Unit
Coos
North Fork Coquille River
East Fork Coquille River
Coquille River
Douglas
Coquille Hydrologic Unit
Middle Fork Coquille River
South Umpqua Hydrologic Unit
Sixes Hydrologic Unit
Curry
Lower Rogue Hydrologic Unit
Josephine
MP 5R
MP 10R
MP 10
MP 15
MP 20
MP 25
MP 30
MP 35
MP 40
MP 45
MP 50
MP 55
MP 60
MP 65
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20
Miles
N

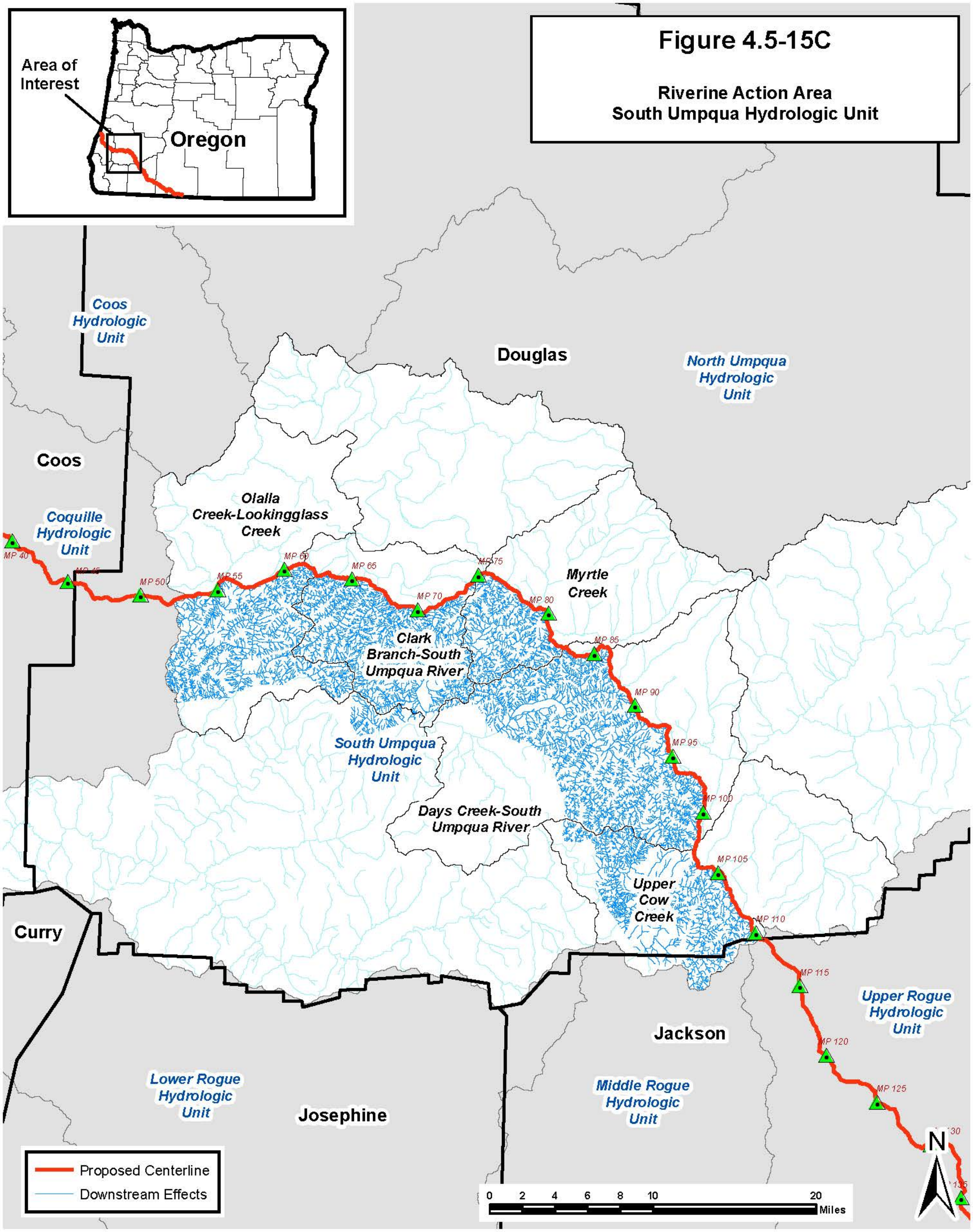


Figure 4.5-15C
Riverine Action Area
South Umpqua Hydrologic Unit
Area of Interest
Oregon
Coos Hydrologic Unit
Douglas
North Umpqua Hydrologic Unit
Coos
Coquille Hydrologic Unit
Olalla Creek-Lookingglass Creek
Myrtle Creek
Clark Branch-South Umpqua River
South Umpqua Hydrologic Unit
Days Creek-South Umpqua River
Upper Cow Creek
Curry
Jackson
Upper Rogue Hydrologic Unit
Lower Rogue Hydrologic Unit
Josephine
Middle Rogue Hydrologic Unit
MP 40
MP 45
MP 50
MP 55
MP 60
MP 65
MP 70
MP 75
MP 80
MP 85
MP 90
MP 95
MP 100
MP 105
MP 110
MP 115
MP 120
MP 125
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20
Miles
N

## Habitat

**Estuarine Habitats.** The estuarine habitat in Coos Bay along the proposed pipeline route is located in mostly shallow regions of the Haynes Inlet and in the Coos River. Tidally influenced waters extend over seven miles upstream in Catching Slough and Coos River, downstream from the location crossed by the pipeline. Tidal gates at the mouths of Kentuck Slough and Willanch Slough have changed salt water inundation and flow regimes in the lower reaches of those waterbodies. All four waterbodies will be crossed by the proposed pipeline.

Substrates within the estuary include sub-tidal (continuously submerged) and intertidal (periodically submerged by tidal action) zones. Both zones support various habitats that have been classified by type of bottom material (including rock, sand, mud, and wood/organic debris) and relative position within the estuary (aquatic bed, shore, flat, beach/bar, and tidal marsh) by Oregon Department of Land Conservation and Development (ODLCD, 1987). Sub-tidal and intertidal habitats within the Coos Bay Estuary were mapped in 1987 as a pilot project for the ODLCD Coastal Management Program Dynamic Estuary Management Information System, or DEMIS (ODLCD, 1998). The proposed pipeline route and associated work areas coincide with shallow intertidal and sub-tidal fine bottom and unconsolidated bottom habitat, with a few regions of mixed seabeds of eelgrass, attached algae, and tidal marsh.

Tidal mud flats and eelgrass beds are found on the west shore of Coos Bay; both habitats are utilized by most fish species within the bay at some time during the year (Cummings and Schwartz, 1971). Eelgrass densities in Coos Bay are greatest at relatively shallow depths, slightly above and below the mean low water level (Thom et al., 2001). Distribution of eelgrass within the estuary has apparently changed slightly since 1987 (ODLCD, 1998). Preliminary distribution of eelgrass (interpreted from infrared imagery, with some field verification) was evaluated in the vicinity of the project area during 2005 (Clinton, 2007). Eelgrass on intertidal mud flats between Glasgow Point (Kentuck Inlet) and Russell Point (Haynes Inlet) decreased since 1987 while eelgrass beds on intertidal mud and mud/sand flats extending outward from Kentuck Inlet had apparently increased.

Natural turbidity in the estuary was judged to be higher at upper bay locations, away from water influx from the ocean (Moffatt and Nichol, 2006). Turbidity (measured in Nephelometric Turbidity Units – NTUs, see turbidity discussion in Suspended Sediment, section 3.2.3.1) was evaluated at the Charleston Bridge, near the entrance to Coos Bay, and estimated as Total Suspended Solids (TSS - measured in milligrams per liter - mg/L) for modeling dredge-generated turbidity during construction of the proposed Jordan Cove Terminal (Moffatt and Nichol, 2006). At that location, turbidity varied from 3.7 to 18.1 NTU (5.7 to 45.7 mg/L) but sometimes exceeded 200 NTU.

Summaries of watershed health indicators have been reported by the Coos Watershed Association for tideland habitats accessible by Oregon Coast coho salmon (Oregon Watershed Enhancement Board, 2007). Table 4.5.4-4 provides conditions in the following three estuarine zones:

- **Tidal wetlands**: Marshes and swamps; a vegetated wetland that is periodically inundated by tidal waters. Tidal wetlands include emergent, scrub-shrub, and forested wetland types.
- **Tidal flat**: An area inundated by all high tides and exposed only at low tide. Some tidal flats have extensive growth of algae or seagrass; others are bare mud.

- **Sub-tidal zone**: Sub-tidal estuarine habitats include channel bottoms, slope bottoms, and the open water above them.

Wetland functions within the estuary have been affected by dikes, tide gates, roads and railroads, ditches, and dams that restrict tidal flows and/or have changed tidal flow patterns. Agricultural land uses have contributed to erosion of channels and, along with channel armoring, has affected vegetation diversity in wetlands, channel shading, and salmonid habitat function; tidal wetlands have also been affected excavations and disposal of dredged materials (Oregon Watershed Enhancement Board, 2007).

**Table 4.5.4-4**
**Watershed Health Indicators for Three Tidal Habitat Zones in the Coos Bay Estuary**

| Tideland Habitat Zone | Hydro-Modification | Sediment Regime | Water Quality | Vegetation Modification | Invasive Species | Habitat Loss |
|---|---|---|---|---|---|---|
| Tidal Wetlands | Limiting >40% historic wetlands modified | Limiting >40% wetlands affected by major change in sediment regime | Moderate DEQ water quality criteria met <90% of samples | Limiting 40% wetland vegetation altered by land use | Moderate Limited Invasive species impact on tidal wetland function | Limiting >40% zone with complete fill or conversion |
| Tidal Flat Zone | Limiting >40% historic tidal flats modified | Moderate 20-40% tidal flats affected by major change in sediment regime | Moderate DEQ water quality criteria met <90% of samples | N/A | Moderate Limited Invasive species impact on tidal flat function | Moderate 20-40% zone with complete fill or conversion |
| Sub-Tidal Zone | Moderate 20-40% historic zone modified | Moderate 20-40% sub-tidal zone affected by major change in sediment regime | Moderate DEQ water quality criteria met <90% of samples | N/A | Moderate Limited Invasive species impact on sub-tidal zone function | Moderate 20-40% zone with complete fill or conversion |
| Source: Oregon Watershed Enhancement Board, 2007. | | | | | | |

NMFS performed a preliminary survey of benthic invertebrates in the vicinity of the Coos Bay navigation channel in 1989 (Miller et al., 1990). The study characterized the macroinvertebrate community at 20 sites in and adjacent to the navigation channel in support of channel deepening in Coos Bay. There were 121 different invertebrate taxa identified with a mean density of 2,617 individuals/square meter ($m^2$). The highest invertebrate densities were observed in the lower bay, downstream from the LNG terminal site (CM 2 to CM 5). One of the sites (Station 11) was located in the navigation channel, immediately adjacent to the LNG terminal where 16 different taxa were identified and the mean density was 552 individuals/$m^2$. The polychaete worm, *Glycera tenuis*, dominated the taxa at this location (n=23). Nearby sampling stations also were found to support high numbers of polychaetes, including *Glycera tenuis* and *Heteropodarke heteromorpha*. *Corophium salmonis*, an amphipod important as juvenile salmonid prey, was rarely found in the study area. Total benthic invertebrate densities in Coos Bay ranged from 375 to 13,546/$m^2$ and were found to be lower than densities observed in the Umpqua River estuary (range from <200 to >50,000/$m^2$) and the Columbia River estuary (range from <1,000 to >60,000/$m^2$) (Bottom et al., 1985; Miller et al., 1989; Durkin and Emmett, 1980).

Previous studies by ODFW have shown that benthic macroinvertebrates in Coos Bay may not comprise a major portion of the diet for juvenile salmonids. Stomach contents of wild Chinook salmon and hatchery coho salmon juveniles were analyzed from July to September 1980 (Nicholas and Lorz, 1984). The survey was performed during the outmigration period for juvenile salmonids, when juveniles are expected to be abundant within the estuary. The major prey species consumed by juvenile Chinook salmon (in order of abundance) were Pacific sand lance (n=89), terrestrial insects (n=59), and decapods (e.g. crab zoea and shrimp larvae) (n=27) (Nicholas and Lorz, 1984). Only five amphipods (likely *Corophium* spp.) were identified in 143 Chinook salmon stomach samples. However, amphipods were the major prey species identified in juvenile coho salmon stomach samples (n=105). Other prey species found included terrestrial insects (n=27) and Pacific sand lance (n=25). Previous studies in Coos Bay have found that *Corophium* spp. are abundant in intertidal areas and constitute an important diet element for juvenile Chinook salmon and striped bass (USDI, 1971). Shallow water habitats near the LNG terminal/Port slip site have been mapped as habitat for *Corophium* spp (Coos County Planning Department, 1979).

Based on the presence of juvenile salmonids at nearby ODFW sampling sites, it is likely that juvenile coho and other fish species utilize the shallow water areas at the LNG terminal slip site for foraging during periods of the year. The shoreline has been mapped as potential habitat for the amphipod *Corophium* spp., which is considered an important prey species (Coos County Planning Department, 1979) and was shown to be consumed in large numbers by coho salmon (Nicholas and Lorz, 1984).

However, benthic studies conducted by NMFS within and in the vicinity of the Coos Bay navigation channel found that *Corophium salmonis* occurred in much lower densities than other Oregon estuaries (Miller et al., 1990; Bottom et al., 1985; Miller et al., 1989; Durkin and Emmett 1980). Based on site observations made in November 2006, it appears that shallower habitats at the LNG terminal site contain a higher percentage of fine substrates, and thus could support a greater abundance of benthic macroinvertebrates than had been observed within the navigation channel, which is dominated by coarser sand.

**Freshwater Habitats**. NMFS (1996) developed an approach and criteria for evaluating human-related effects to anadromous salmonid habitats which focuses on the following six pathways of potential impact: 1) water quality, 2) habitat access, 3) habitat elements, 4) channel condition and dynamics, 5) flow/hydrology, and 6) watershed condition. BLM and Forest Service developed watershed analyses, in part to meet requirements of their respective land management plans, specifically to comply with the objectives of the Aquatic Conservation Strategey (ACS) in the Northwest Forest Plan (NWFP). In addition to federal agencies, watershed assessments have been developed by local watershed councils and Oregon's natural resource agencies and are available through the Oregon Watershed Enhancement Board (OWEB). Watershed assessments provide evaluations of fish habitats and water quality and describe how natural process and human activities are affecting those resources (Governor's Watershed Enhancement Board, 1999). Available watershed analyses developed by these sources are listed in table 4.5.4-5 for the $5^{th}$ field watersheds crossed by the PCGP Project.

The various watershed documents address fish habitats but use different approaches and descriptors. Oregon Department of Fish and Wildlife (ODFW, 1997), in cooperation with other agencies, has conducted stream surveys throughout the state including streams within watersheds crossed by the PCGP Project. Four types of habitat information provide quantitative evaluations of the fish habitat condition within the various watersheds: 1) pool habitat condition, 2) riffle habitat condition, 3) woody debris habitat condition, and 4) riparian habitat condition. ODFW (Foster et al., 2001) has developed benchmark criteria for each of these habitat conditions that would represent undesirable and desirable habitat conditions. The benchmarks are provided in table 4.5.4-6 along with the various aquatic habitat conditions to which they apply.

**Table 4.5.4-5**
**Watershed Assessments Conducted by Federal and State Agencies for 5th Field Watersheds Crossed by the PCGP Project**

| Sub-basins and 5th Field Watersheds | Watershed Analysis, BLM and/or Forest Service | Watershed Assessment, Oregon Watershed Enhancement Board |
|---|---|---|
| **Coos Sub-basin** | | |
| Coos Bay-Frontal Pacific Ocean | • Catching-Beaver Watershed Analysis (BLM, 2010) | • Coos Bay Lowland Assessment and Restoration Plan (Coos Watershed Association, 2006)<br>• Catching Slough, Daniel's Creek and Heads of Tide Sub-basin Assessment and Restoration Opportunities (Coos Watershed Association, 2008) |
| **Coquille Sub-basin** | | |
| Coquille River | • Middle Main Coquille, North Coquille Mouth, Catching Creek (BLM, 1997) | • Coquille River Sub-basin Plan (Coquille Indian Tribe, 2007) |
| North Fork Coquille River | • North Fork Coquille Watershed Analysis (BLM, 2001a) | |
| East Fork Coquille River | • East Fork Coquille Watershed Analysis (BLM, 2000) | |
| Middle Fork Coquille River | • Upper Middle Fork Coquille Watershed Analysis (BLM, 1999a)<br>• Middle Fork Coquille Watershed Analysis (BLM, 2007) | |
| **South Umpqua Sub-basin** | | |
| Olalla Creek-Lookingglass Creek | • Olalla-Lookingglass Watershed Analysis (BLM, 1999b) | • Olalla/Lookingglass Watershed Assessment and Action Plan (DeVore and Geyer, 2003). |
| Clark Branch-South Umpaqua River | • Middle South Umpqua Watershed Analysis (BLM, 1999c) | • Middle South Umpqua Watershed Assessment and Action Plan (Geyer, 2003a). |
| Myrtle Creek | • Myrtle Creek Watershed Analysis and Water Quality Restoration Plan (BLM, 2002) | • Myrtle Creek Watershed Assessment and Action Plan (Geyer, 2003b) |
| Days Creek-South Umpqua River | • South Umpqua Watershed Analysis and Water Quality Restoration Plan (BLM, 2001b) | • South Umpqua River Watershed Assessment and Action Plan (Geyer, 2003c) |
| Upper Cow Creek | • Cow Creek Watershed Analysis. (Forest Service, 1995) | • Upper Cow Creek Watershed Assessment and Action Plan (Geyer, 2003d) |

Benchmark conditions are not absolute but they provide a method for comparing values of key aquatic habitat components (Foster et al., 2001) that are used in this Resource Report to establish baseline conditions within watersheds to be crossed by the PCGP Project. Pools provide refuges for fish during high and low stream flows. Pools provide slow water habitats for adults and juveniles, provide over-wintering habitat for some fish species, provide habitat during periods of low summer flows, and pools associated with large wood provide habitat complexity.

Riffles provide spawning habitats for various salmonid species that construct nests or redds in gravels of various sizes, specific to salmonid species. Sand, silt, and organic debris can reduce suitability of spawning habitats by filling pores between gravel particles that are necessary for intergravel stream flows, availability of oxygen, and for development of embryos; high percentages of sand, silt, and organic material in riffles indicate poor conditions as spawning habitat.

Riparian trees provide shade over stream channels which reduce deleterious effects of high summer water temperatures. Roots of riparian vegetation stabilize stream banks, contribute to development of bank undercutting (thermal and hiding cover), limit erosion and sedimentation from stream banks, and provide large woody debris (LWD) as an important component of the aquatic habitat. LWD, especially contributed by riparian conifers, provides cover for fish, physical habitat complexity that influences stream flows and channel diversity, and biological complexity as substrate for macroinvertebrate communities that provide food for salmonids during different life stages (Foster et al., 2001).

**Table 4.5.4-6**
**Oregon Department of Fish and Wildlife Aquatic Inventory and Analysis Project Criteria for Aquatic Habitat Conditions and Benchmarks**

| Aquatic Habitat Condition | Benchmark Level for Condition | |
|---|---|---|
| | **Undesirable** | **Desirable** |
| **Pools** | | |
| • Pool Area (% total stream area) | <10 | >35 |
| • Pool Frequency (channel widths between pools) | >20 | 5-8 |
| • Residual Pool Depth (m) | | |
| Small Streams (<7m wide) | <0.2 | >0.5 |
| Medium Streams (≥7m and <15m width) | | |
| Low Gradient (slope <3%) | <0.3 | >0.6 |
| High Gradient (slope >3%) | <0.5 | >1.0 |
| Large Streams (≥15m width) | <0.8 | >1.5 |
| • Complex Pools (pools with ≥3 LWD pieces / km of reach length) | <1 | >2.5 |
| | | |
| **Riffles** | | |
| • Width/Depth Ratio (active channel based) | | |
| East Side | >30 | <10 |
| West Side | >30 | <15 |
| • Gravel (% area) | <15 | ≥35 |
| • Silt-Sand-Organics (% area) | >20 | <10 |
| Volcanic Parent Material | >15 | <8 |
| Sedimentary Parent Material | >20 | <10 |
| Channel Gradient <1.5% | >25 | <12 |
| | | |
| **Shade** (Reach Average, Percent) | | |
| Stream Width <12 meters | | |
| West Side | <60 | >70 |
| Northeast | <50 | >60 |
| Central-Southeast | <40 | >50 |
| Stream Width >12 meters | | |
| West Side | <50 | >60 |
| Northeast | <40 | >50 |
| Central-Southeast | <30 | >40 |
| | | |
| **Large Woody Debris** | | |
| • Pieces/100m Stream Length | <10 | >20 |
| • Volume ($m^3$)/100m Stream Length | <20 | >30 |
| • "Key" Pieces (>60cm and 10m long)/100m | <1 | >3 |
| **Riparian Conifers** (30m From Both Sides of Channel) | | |
| • Number >20in DBH/1000ft Stream Length | <150 | >300 |
| • Number >35in DBH/1000ft Stream Length | <75 | >200 |

Data used to evaluate aquatic habitat conditions, reported by ODFW Aquatic Inventories Project (2011), are provided in appendix X for each stream reach included in the inventories and evaluations of benchmark conditions are summarized in tables 4.5.4-7 and 4.5.4-8, below.

Coos Sub-basin - HUC 17100304. Data available from the ODFW Aquatic Inventories Project (2011) provided aquatic habitat conditions for 37 stream reaches within the Coos Bay-Frontal Pacific Ocean 5$^{th}$ Field Watershed (HUC 710030403) surveyed between 1990 and 2002. The sampled reaches were of first, second or third order (Strahler numbers 1, 2, 3) streams with active channel widths averaging 3.2 meters and active channel heights averaging 0.6 meter.

Desirable conditions for pool habitat in surveyed reaches ranged from only 8% for pool frequency to 35% for residual pool depth (see table 4.5.4-7). In general, pool habitat conditions were undesirable or less than desirable (moderate) for most streams within the watershed. Riffle habitats were relatively abundant (68% of stream reach areas) but degraded by high levels of silt, sand and organic materials and width to depth ratios of sampled reaches tended to be high, indicative of relatively shallow wide stream channels that provide less suitable habitat than deep, narrow channels (see benchmarks in table 4.5.4-6).

Riparian conditions in streams surveyed within the Coos Bay Frontal-Pacific Ocean watershed are mostly undesirable. Trees in less than half of the reaches provide adequate shade of stream channels and the numbers of large conifer trees within surveyed riparian zones were undesirable; large conifers were absent in many of the surveyed reaches. It is not surprising that the amount of LWD, including key pieces (pieces of large wood ≥0.60 meters diameter and ≥12 meters long), is undesirable, less than benchmark. Low estimates of riparian shade is indicative of lower gradient streams and floodplains that have been altered by past land uses in the watershed. As one consequence, summer stream temperatures in lower reaches exceed levels suitable as juvenile salmonid summer rearing habitats (Coos Watershed Association, 2006). The ODFW (2008a) instream construction window for coastal tributaries is July 1 to September 15 although work in the Coos Bay Estuary and Coos River mainstem is allowed from October 1 to February 15.

The pipeline will cross Kentuck Slough and Wallanch Creek upstream from tide gates, in low gradient reaches with associated low gradient floodplains. Echo Creek will be crossed upstream from the confluence with the Coos Bay estuary, a reach that is not tidally influenced. Specific aquatic habitat conditions in those streams (Coos Watershed Association, 2006) are consistent with conditions reported for stream reaches surveyed in by ODFW Aquatic Inventories Project and summarized in table 4.5.4-7.

Stream discharges over the annual cycle are provided in figure 4.5-16 for two streams within the Coos Sub-basin, Pony Creek – a small, tidally influenced stream and tributary to Coos Bay draining a watershed 3.88 square miles, and West Fork Millacoma River – a large tributary to the Coos River, draining a 46.90-square mile watershed. Seasonal discharges in West Fork Millacoma River are representative of large and small waterbodies crossed by the PCGP Project within the Coos Sub-basin. However, flows in Pony Creek have been influenced by releases from Upper Pony Creek Reservoir since construction of the new dam, completed in 2001 (Sol Coast Consulting & Design, LLC and Parsons Brinckerhoff, 2009).

**Table 4.5.4-7**
**Aquatic Habitat Conditions from Samples Taken by ODFW in Stream Reaches within 5th Field Watersheds of the Coos Bay and Coquille Sub-basins Crossed by the PCGP Project**

| Aquatic Habitat Condition | Mean Values (with Standard Errors) in Relation to Benchmark Conditions in Surveyed Reaches (by %) of Watersheds[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coos Bay-Frontal HUC 1710030403 | | Coquille River HUC 1710030505 | | North Fork Coquille HUC 1710030504 | | East Fork Coquille HUC 1710030503 | | Middle Fork Coquille HUC 1710030501 | |
| | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions |
| **Pools** | | | | | | | | | | |
| Pool Area (% total stream area) | 31.2 (5.5) | 40.5% 32.4% | 64.2 (4.1) | 0% 88.9% | 38.6 (3.4) | 23.7% 50.0% | 34.0 (2.1) | 14.4% 47.4% | 34.4 (2.1) | 20.4% 48.3% |
| Pool Frequency (channel widths between pools) | 52.2 (12.8) | 54.1% 8.1% | 11.4 (1.8) | 11.1% 33.3% | 19.2 (3.9) | 22.4% 15.8% | 12.8 (1.5) | 16.6% 24.2% | 23.7 (5.6) | 21.8% 28.6% |
| Residual Pool Depth (m) by stream size and gradient | 0.5 (0.1) | 21.6% 35.1% | 0.5 (0.0) | 0% 44.4% | 0.5 (0.0) | 11.8% 30.3% | 0.6 (0.0) | 7.4% 47.4% | 0.5 (0.0) | 10.9% 40.8% |
| Complex Pools (pools with ≥3 LWD pieces ≥3 per km of reach length | 0.8 (0.3) | 83.8% 13.5% | 0.2 (0.1) | 88.9% 0% | 4.1 (0.7) | 48.7% 39.5% | 4.4 (0.5) | 36.8% 52.6% | 3.2 (0.4) | 52.4% 38.1% |
| **Riffles** | | | | | | | | | | |
| Width/Depth Ratio (active channel based) | 16.0 (2.7) | 24.3% 56.8% | 7.6 (1.7) | 0% 83.3% | 16.8 (1.3) | 10.5% 48.7% | 14.4 (0.9) | 4.2% 55.8% | 19.1 (1.4) | 13.6% 47.6% |
| Gravel (% of area) | 11.1 (2.4) | 67.6% 8.1% | 13.6 (2.9) | 61.1% 5.6% | 25.4 (1.4) | 15.8% 18.4% | 24.8 (1.5) | 20.0% 22.1% | 28.8 (1.5) | 19.0% 34.7% |
| Silt-Sand-Organics (% of area) by parent material and gradient[2] | 60.7 (6.2) | 75.7% 13.5% | 78.7 (3.6) | 100% 0% | 33.5 (3.1) | 48.7% 17.1% | 22.9 (1.8) | 40.0% 27.4% | 24.1 (1.4) | 48.3% 22.4% |
| **Shade** | | | | | | | | | | |
| Reach Average, % by stream width | 67.4 (4.2) | 29.7% 48.6% | 61.6 (3.8) | 38.9% 33.3% | 87.7 (1.9) | 3.9% 96.1% | 84.2 (2.6) | 8.4% 90.5% | 76.4 (2.1) | 15.0% 71.4% |
| **Large Woody Debris** | | | | | | | | | | |
| LWD Pieces/100m of Stream Length | 14.8 (2.9) | 51.4% 21.6% | 8.2 (1.7) | 72.2% 11.1% | 15.7 (1.3) | 35.5% 22.4% | 20.3 (1.5) | 23.2% 38.9% | 11.9 (1.0) | 53.7% 19.7% |
| LWD Volume ($m^3$)/100m of Stream Length | 21.8 (5.7) | 75.7% 21.6% | 10.5 (2.6) | 77.8% 5.6% | 25.9 (3.3) | 59.2% 25.0% | 52.4 (7.5) | 40.0% 44.2% | 20.2 (2.2) | 69.4% 22.4% |
| Key Pieces (≥60cm D by ≥12m L)/100m of Stream Length[3] | 0.8 (0.2) | 78.4% 8.1% | 0.3 (0.1) | 88.9% 0% | 1.2 (0.3) | 69.7% 7.9% | 1.6 (0.2) | 53.7% 14.7% | 0.7 (0.1) | 78.2% 6.1% |
| **Riparian Conifers** | | | | | | | | | | |
| Number >20in DBH/1000ft of Stream Length | 190.8 (98.3) | 81.1% 18.9% | 100.6 (77.7) | 100% 0% | 231.9 (59.3) | 65.8% 19.7% | 420.9 (106.9) | 58.9% 29.5% | 262.5 (37.9) | 61.2% 24.5% |
| Number >35in DBH/1000ft of Stream Length | 11.9 (9.3) | 94.6% 2.7% | 23.4 (23.4) | 100% 0% | 69.8 (27.8) | 84.2% 9.2% | 121.6 (28.9) | 75.8% 14.7% | 76.8 (19.7) | 82.3% 10.2% |

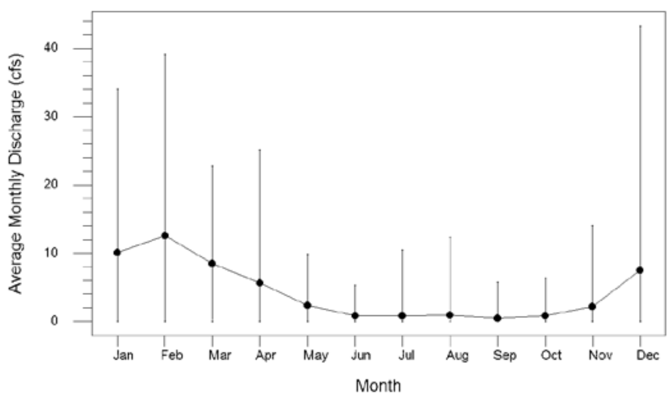
[1] Values unweighted by surveyed reach length.
[2] Assumes sedimentary parent material in all surveyed reaches.
[3] D= diameter, L = length

**Table 4.5.4-8**
**Aquatic Habitat Conditions from Samples Taken by ODFW in Stream Reaches within 5th Field Watersheds of the South Umpqua Sub-basin Crossed by the PCGP Project**

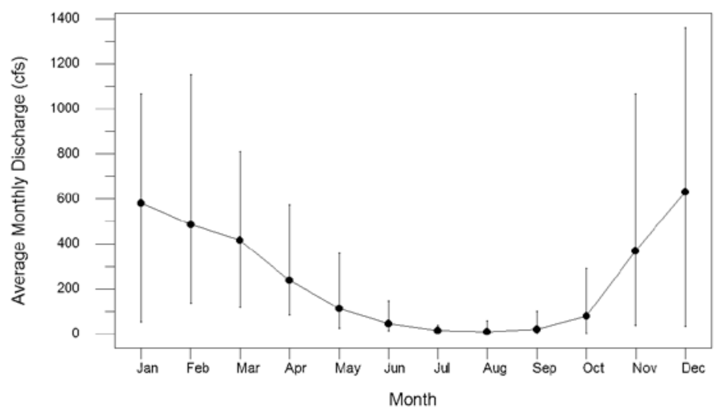
| Aquatic Habitat Condition | Mean Values (with Standard Errors) in Relation to Benchmark Conditions in Surveyed Reaches (by %) of Watersheds[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Olalla Creek-Lookingglass Creek HUC 1710030212 | | Clark Branch-South Umpqua River HUC 1710030211 | | Myrtle Creek HUC 1710030210 | | Days Creek-South Umpqua River HUC 1710030205 | | Upper Cow Creek HUC 1710030206 | |
| | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions | Mean (Standard Error) | Undesirable Desirable Conditions |
| **Pools** | | | | | | | | | | |
| Pool Area (% total stream area) | 48.3 (3.2) | 8.8% 73.7% | 25.6 (2.2) | 27.8% 26.8% | 28.5 (3.5) | 28.8% 34.6% | 20.8 (3.9) | 52.9% 26.5% | 25.3 (3.1) | 21.4% 17.9% |
| Pool Frequency (channel widths between pools) | 15.6 (5.7) | 12.3% 31.6% | 32.3 (7.1) | 34.0% 14.4% | 54.4 (21.8) | 25.0% 15.4% | 80.0 (32.0) | 47.1% 11.8% | 47.3 (18.1) | 46.4% 14.3% |
| Residual Pool Depth (m) by stream size and gradient | 0.4 (0.0) | 1.8% 12.3% | 0.4 (0.0) | 11.3% 11.3% | 0.4 (0.0) | 9.6% 23.1% | 0.3 (0.0) | 14.7% 0% | 0.4 (0.0) | 0% 21.4% |
| Complex Pools (pools with ≥3 LWD pieces ≥3 per km of reach length | 2.5 (0.6) | 61.4% 31.6% | 1.7 (0.4) | 70.1% 19.6% | 0.1 (0.0) | 96.2% 0% | 0.0 (0.0) | 97.1% 0% | 0.1 (0.0) | 94.4% 0% |
| **Riffles** | | | | | | | | | | |
| Width/Depth Ratio (active channel based) | 16.0 (1.2) | 10.5% 52.6% | 15.1 (1.0) | 4.1% 51.5% | 23.2 (2.1) | 28.8% 26.9% | 18.4 (2.5) | 14.7% 35.3% | 15.5 (2.5) | 7.1% 39.3% |
| Gravel (% of area) | 32.6 (1.5) | 3.5% 45.6% | 35.3 (1.4) | 4.1% 49.5% | 24.8 (1.7) | 15.4% 23.1% | 43.8 (3.2) | 5.9% 73.5% | 36.1 (2.4) | 3.6% 42.9% |
| Silt-Sand-Organics (% of area) by parent material and gradient [2] | 24.5 (2.2) | 36.8% 22.8% | 22.8 (1.6) | 45.4% 27.8% | 39.1 (3.0) | 15.4% 23.1% | 14.4 (1.6) | 14.7% 44.1% | 30.4 (1.7) | 60.7% 0% |
| **Shade** | | | | | | | | | | |
| Reach Average, % by stream width | 77.0 (2.1) | 8.8% 77.2% | 82.8 (1.9) | 8.2% 85.6% | 67.5 (7.0) | 32.7% 59.6% | 90.1 (6.2) | 11.8% 79.4% | 79.8 (4.4) | 7.1% 85.7% |
| **Large Woody Debris** | | | | | | | | | | |
| LWD Pieces/100m of Stream Length | 13.2 (1.3) | 47.4% 22.8% | 10.8 (1.0) | 54.6% 12.4% | 12.8 (6.1) | 80.8% 7.7% | 4.3 (1.0) | 85.3% 2.9% | 10.1 (1.1) | 57.1% 3.6% |
| LWD Volume ($m^3$)/100m of Stream Length | 20.6 (2.4) | 57.9% 24.6% | 15.4 (1.7) | 73.2% 15.5% | 17.0 (4.1) | 71.2% 15.4% | 6.4 (2.1) | 91.2% 2.9% | 17.4 (2.1) | 60.7% 17.9% |
| Key Pieces (≥60cm D by ≥12m L)/100m of Stream Length | 0.6 (0.1) | 73.7% 0% | 0.4 (0.1) | 85.5% 2.1% | 0.5 (0.1) | 80.8% 3.8% | 0.2 (0.1) | 94.1% 0% | 0.7 (0.1) | 82.1% 3.6% |
| **Riparian Conifers** | | | | | | | | | | |
| Number >20in DBH/1000ft of Stream Length | 578.6 (108.5) | 47.4% 42.1% | 300.5 (66.9) | 61.9% 24.7% | 324.0 (94.5) | 63.5% 21/2% | 138.2 (60.5) | 79.4% 11.8% | 748.9 (161.6) | 25.0% 57.1% |
| Number >35in DBH/1000ft of Stream Length | 31.7 (15.6) | 89.5% 5.3% | 108.4 (44.5) | 83.5% 10.3% | 60.2 (19.2) | 78.8% 11.5% | 24.4 (13.9) | 91.2% 2.9% | 16.7 (4.8) | 60.7% 32.1% |

[1] Values unweighted by surveyed reach length.
[2] Assumes sedimentary parent material in all surveyed reaches.
[3] D= diameter, L = length

Highest monthly discharges occur between December and April in both waterbodies along with the largest range in variability (maximum and minimum discharge for a given month). Lowest discharges occur between June and October. In all months, minimum discharges in Pony Creek were zero (see figure 4.5-16A) and minimum discharges in West Fork Millicoma River were less than 10 cubic feet per second (cfs) during July, August, September and October in some years (see Figure 4.5-16B). The ODFW (2008a) instream construction window for coastal tributaries is July 1 to September 15.




A




B

**Figure 4.5-16**
**Average Monthly Discharge (cfs) in (A) Pony Creek (USGS Gage 14324580) from 1975 to 2008, and (B) West Fork Millicoma River (USGS Gage 14324500) from 1954 to 1981. Vertical lines show maximum and minimum discharges during the periods of record.**

<u>Coquille Sub-basin - HUC 17100305.</u> ODFW, BLM, and Oregon Forest Industry Council (OFIC) surveyed 336 stream reaches in the four 5th field watersheds within the Coquille Sub-basin that will be crossed by the PCGP Project: 18 in the Coquille HUC 1710030505, 76 in the North Fork Coquille River HUC 1710030504, 95 in the East Fork Coquille River HUC 1710030503, and 147 in the Middle Fork Coquille River HUC 1710030501. Surveys were conducted during summers in different watersheds between 1990 and 2005. Conditions for aquatic habitats in the four watersheds are included in table 4.5.4-7. Sampled reaches of first through fifth order (Strahler numbers 1 through 5) streams had active channel widths averaging <3 meters and active channel heights averaging <0.6 meter.

Conditions associated with riparian vegetation are generally undesirable in each of the watersheds: there are too few large conifers along most stream reaches and LWD numbers, volume, and presence of key pieces tend to be below benchmark levels, especially for reaches in the Coquille River watershed. Pool conditions tend to more desirable than in the Coos Bay-Frontal Pacific Ocean watershed except for pool complexity formed by LWD, not surprising given the overall undesirable condition for LWD in surveyed streams. Overall, amounts of shade for reaches in the North Fork, East Fork, and Middle Fork Coquille watersheds are at desirable levels (see table 4.5.4-7), covering more than 60 to 70 percent of stream channels.

Streams in the four watersheds are mostly deep and narrow (low width/depth ratios) but spawning gravels appear to be limiting in the Coquille River watershed, less so in reaches within the other three watersheds. However, fine sediments (silt, sand, and organic materials) are present at undesirable levels within most riffle habitat units. These conditions are consistent with summaries of watershed health indicators reported by the Coquille Watershed Association for aquatic/instream habitats accessible by Oregon Coast coho salmon (Oregon Watershed Enhancement Board, 2007) in lower Coquille River, North Fork Coquille River, East Fork Coquille River, and Middle Fork Coquille River. Conditions for aquatic habitats in the watersheds are included in table 4.5.4-7.

Juvenile salmonid habitat complexity in low gradient streams requires some form(s) of shelter as large wood, pools, connected off-channel alcoves, beaver ponds, lakes, interconnected floodplains and wetlands that provide refugia and shelter from extreme water temperatures and hiding cover from predators (Oregon Watershed Enhancement Board, 2007). Spawning gravel quantities, measured by percent of riffle areas covered with gravel and gravel quality depends on embeddedness (percent of riffle areas in silt, sand, and organic fines). Waterbodies in the four watersheds within the Coquille Sub-basin that would be crossed by the pipeline are primarily limited in these and most other aquatic habitat health indicators (see table 4.5.4-9).

**Table 4.5.4-9**
**Comparisons of Aquatic Habitat Watershed Indicators in 5th Field Watersheds within the Coquille Sub-Basin that Would Be Crossed by the PCGP Project from West to East**

| 5th Field Watershed (HUC) | Winter Rearing Habitat Complexity | Summer Rearing Habitat Complexity | Spawning Gravel Quantity | Spawning Gravel Quality | Channel Modification | Large Wood | Water Quality | Water Temperature |
|---|---|---|---|---|---|---|---|---|
| Coquille River (1710030505) | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting |
| North Fork Coquille River (1710030504) | Limiting | Limiting | Moderate | Limiting | Limiting | Limiting | Moderate | Limiting |
| East Fork Coquille River (1710030503) | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting | Limiting |
| Middle Fork Coquille River (1710030501) | Limiting | Limiting | Moderate | Limiting | Limiting | Limiting | Limiting | Limiting |

Source: Oregon Watershed Enhancement Board, 2007.
Aquatic habitat categories:

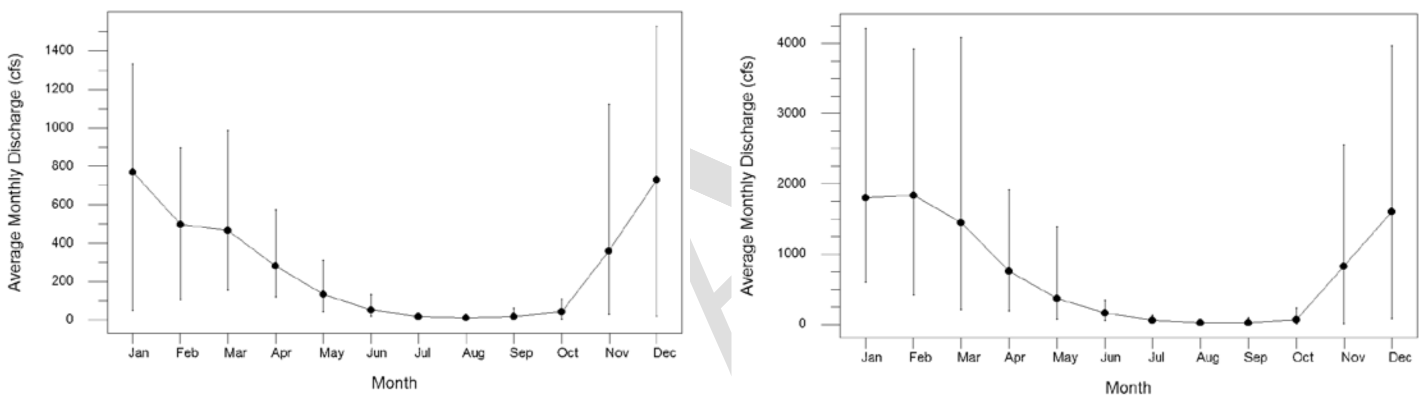
- **Limiting**: indication of degraded watershed health and a significant amount of restoration action is needed to improve watershed conditions.
- **Moderate**: indication of less than desirable watershed health and moderate to significant levels of restoration action is needed to improve watershed conditions.
- **Adequate**: indication of functional watershed health and minimal restoration activities are needed to maintain exiting watershed conditions.

Stream discharges over the annual cycle are provided in figure 4.5-17 and tributary to Coquille River draining a watershed 73.90 square miles, and Middle Fork Coquille River – a larger tributary to the Coquille River, draining a 305-square mile watershed.

Highest monthly discharges occur between November and April in both waterbodies along with the largest range in variability (maximum and minimum discharge for a given month). Lowest discharges occur between June and October. Minimum discharges in North Fork Coquille River were less than 10 cfs during August, September, and October in some years (see Figure 4.5-17A) and were less than 20 cfs during August, September, October, and November in some years in the Middle Fork (see Figure 4.5-17B). The ODFW (2008a) instream construction window for the Coquille River and tributaries is July 1 to September 15.

South Umpqua Sub-basin - HUC 17100302. The proposed pipeline route will cross five 5th field watersheds in the South Umpqua sub-basin. Between 1991 and 2010, the BLM and Umpqua Basin Fisheries Restoration Initiative surveyed 57 stream reaches in the Olalla-Lookingglass Creek watershed (HUC 1710030212), 97 reaches within the Clark Branch-South Umpqua River watershed (HUC 1710030211), 52 reaches within the Myrtle Creek watershed (HUC 1710030210), 34 reaches within the Days Creek-South Umpqua River watershed (HUC 1710030205), and 28 reaches within the Upper Cow Creek watershed (HUC 1710030206). Conditions for aquatic habitats in the five watersheds are included in table 4.5.4-8.

Stream reaches sampled in the Olalla-Lookingglass Creek watershed had significantly ($P<0.05$) more area of pool habitats than reaches in the other watersheds of the South Umpqua Sub-basin (see table 4.5.4-8). However, complex pools associated with LWD were undesirably limited (too few pieces per reach length) in most stream reaches for all six watersheds. Conditions for residual pool depths and pool frequencies were mostly intermediate (moderate), neither undesirable nor desirable for most of the sampled reaches in watersheds to be crossed by the pipeline.




**A** **B**

**Figure 4.5-17**

**Average Monthly Discharge (cfs) in (A) North Fork Coquille Fiver (USGS Gage 14326800) from 1963 to 1981, and (B) Middle Fork Coquille River (USGS Gage 14326500) from 1930 to 1946. Vertical lines show maximum and minimum discharges during the periods of record**

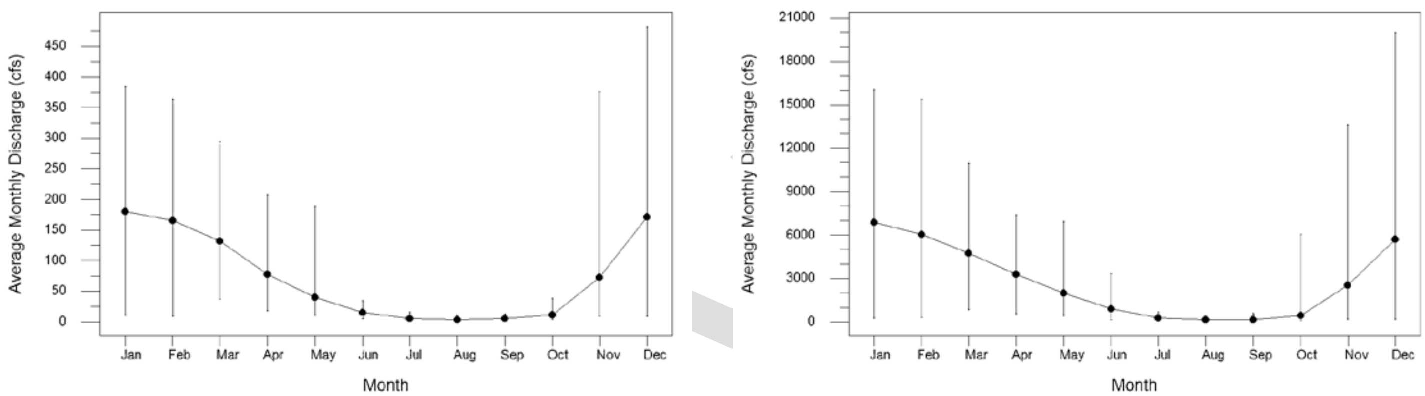
Ratios of stream widths to depths in most stream reaches in the six watersheds were generally low, more narrow and deep than wide and shallow. Areas of gravel in riffle habitats were mostly desirable or moderate conditions. Areas of fine sediments in riffles would be undesirable for the majority of stream reaches in the Upper Cow Creek watershed but at moderate or desirable conditions in reaches sampled in the other five watersheds (see table 4.5.4-8).

Shade conditions would be considered desirable for the majority of stream reaches in all six watersheds but numbers of large conifers in riparian zones were below desirable benchmark levels. LWD conditions in most stream reaches were also below desirable benchmark conditions (see table 4.5.4-8) for all of the watersheds to be crossed by the pipeline.

Stream discharges over the annual cycle are provided in figure 4.5-18 for two waterbodies within the South Umpqua Sub-basin, North Myrtle Creek – a small tributary to Myrtle Creek and the

South Umpqua River with a 54.2 square mile watershed, and the mainstem South Umpqua River with a watershed area of 1,670 square miles.

Highest monthly discharges occur between November and April in both waterbodies along with the largest range in variability (maximum and minimum discharge for a given month). Lowest discharges occur between June and October. Minimum discharges in North Myrtle Creek were less than 5 cfs during July, August, September, and October in some years (Figure 4.5-18A) and were less than 100 cfs during July, August, and September in some years in the South Umpqua River mainstem (see Figure 4.5-18B). The ODFW (2008a) instream construction window for tributaries to the South Umpqua River is July 1 to September 15 and from July 1 to August 31 for the South Umpqua River.




A B

**Figure 4.5-18**
**Average Monthly Discharge (cfs) in (A) North Myrtle Creek (USGS Gage 14311000) from 1955 to 1986, and (B) South Umpqua River (USGS Gage 14312000) from 1906 to 2011. Vertical lines show maximum and minimum discharges during the periods of record**

### Critical Habitat

Using available spatial data from ODFW on specific occupied stream reaches, NMFS developed critical habit information based on fifth field watersheds to designate specific streams as critical habitat within watersheds, including the 10 watersheds that would be crossed by the PCGP Project. Included in the designation of critical habitat for the Oregon Coast coho are estuaries associated with the watersheds, beginning at the estuary mouth, including the entrance to the Coos Bay estuary at the land end of North Jetty and South Jetty. Critical habitats for Oregon Coast coho in specific waterbodies crossed by the PCGP Project are compiled in appendix M and are summarized in table 4.5.4-1. Critical habitat includes the Coos Bay Estuary and 29 freshwater streams in which coho salmon have been documented (NMFS, 2008d with shapefiles available from FWS at http://criticalhabitat.fws.gov/crithab/; ODFW, 2012c).

### 4.5.4.3 Effects by the Proposed Action

Analyses of effects are addressed separately for the EEZ analysis area, Estuarine analysis area, and Riverine analysis area. Together, those three analysis areas comprise the action area for coho salmon in the Oregon Coast ESU

## Direct Effects – EEZ Analysis Area

Project-related effects to Oregon Coast coho would be caused by the action and occur at the same time and place, including the following direct impacts within the within the EEZ analysis area could include: 1) sediment discharge at Site F, 2) acoustic effects to coho from LNG ships transiting the EEZ, and 3) spills and releases of LNG at sea.

Turbidity at Site F

Discharge of the maintenance dredging at Site F, about 1.6 miles off the mouth of Coos Bay, would generate a turbidity plume that could affect coho adults and juveniles within the EEZ analysis area. Use of and sediment discharge at Site F were addressed in Section 4.5.1.3 for green sturgeon, above.

Site F coincides with nearshore marine areas and offshore marine areas that are components of designated critical habitat for coho salmon in the Oregon Coast ESU. It is assumed that either the existing approved permit to utilize Site F would remain valid or that the COE and EPA would be coordinating with NMFS to have offshore disposal areas, similar to and including Site F. However disposal at this site may cause short term turbidity plume that local coho salmon would avoid, potentially causing some short-term displacement of these fish. Some local burial of potential benthic food resources may also occur. Effects to coho salmon of both turbidity plume displacement and burial of potential food resources at Site F would not be substantial.

Some juvenile coho salmon may be entrained and killed during discharge of the tailings at Site F. Turbidity generated from discharge at Site F would be rapidly dissipated and may cause some short-term avoidance of the area by coho during discharge. But there is the possibility that subadult coho, if they were present directly under the sediment discharge from the barge or ship would be unable to dart out of the plume of sediment and become trapped in the sediment during active discharge. Potential adverse effects would occur to smaller subadults if they were present within the area.

In assessment of similar discharge operations off the Umpqua and Rogue Rivers (NMFS, 2009d, NMFS 2009e), NMFS noted that rearing coho juveniles from the local rivers may be unable to avoid the tailings plume during discharge and be directly killed from this operation. Overall numbers of fish however are likely very small due to season when few small fish would be present, likely dispersion of the fish, ability juvenile fish to mostly avoid the plume. Similar conditions would likely occur at Site F. Overall numbers of coho salmon affected would not be substantial. Effects to coho salmon from discharge at Site F would be of little overall change from normal maintenance dredging operations.

## Acoustic Effects

Underwater noise may affect coho salmon in the Oregon Coast ESU. LNG carriers transiting the EEZ would produce underwater noise. Underwater noise levels are expected to vary by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age - older vessels tended to be louder than newer vessels (see discussion in Section 4.2.1.3 for blue whales). Based on the general trend for higher underwater noise generated by larger vessels (McKenna et al., 2012), it is possible for many of the LNG carriers that would utilize the Jordan Cove terminal to generate more noise than the the LNG tanker built in 2003 with 138,028 $m^3$ capacity reported by Hatch et al. (2008) that produced sound levels (with 1 standard error) of 182 ± 2 dB re: 1 μPa @ 1 meter.

State agencies in Washington, Oregon, and California, along with federal agencies have developed interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a; Popper et al., 2006). Interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a) include 1) a cumulative sound exposure level ($SEL_{cum}$) of 187 dB re 1 $\mu Pa^2$ s for fishes more than 2 grams, 2) a $SEL_{cum}$ of 183 dB re 1 $\mu Pa^2$ s for fishes less than 2 grams, and 3) a single-strike peak level ($SPL_{peak}$) of 206 dB re 1 μPa for all sizes of fishes (Washington State Department of Transportation, 2011a). $SEL_{cum}$ is the cumulative sound pressure squared, integrated over time, and normalized to one second. $SEL_{cum}$ is calculated as SEL(single strike at 10 meters from the pile) + 10 Log(number of strikes). Although ship noises reported by Hatch et al. (2008) and McKenna et al. (2013) are not directly equivalent to pile driving noise, or the interim noise exposure criteria, any LNG carrier noise generated in the EEZ would be below thresholds for adverse effects to fish, including Oregon Coast coho. Noise from LNG carriers would likely increase the background noise within the EEZ, and which is occurring globally (Slabbekoorn et al., 2010). Oregon Coast coho in the EEZ might detect noise from LNG carriers but are not expected to be adversely affected by the projected since vessel traffic due to LNG carries is expected to add to the projected vessel traffic in 2017-2018 by 1.2 percent increase in shipping in coastal Oregon and Washington over the 2017-2018 estimates (see discussion in Section 4.2.1.3 for blue whales). Neither underwater noise generated during construction (see below) nor ship noises from LNG carriers transiting the EEZ are expected to adversely affect Oregon Coast coho.

Releases and Fire at Sea

Oil or LNG spills at sea or offshore are unlikely to harm coho salmon. The low amount of petroleum product on LNG vessels and low chance of LNG spill or fish contacting a spill greatly reduce chance of impacts in the marine environment from spills. Any potential spills that could occur and that could affect coho would more likely be fuels or lubricants associated with the operation of the LNG carrier. These products are kept in relatively small quantities on ships and would not result in the types of effects associated with a spill from an oil tanker.

If an unignited LNG spill were to occur along the LNG carrier transit, some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting Oregon Coast coho in the water, given the ambient water temperatures in the transit route, the adaptability of Oregon Coast coho to varying water temperatures, and their foraging patterns on benthos rather than the epipelagic or photic zone near the surface.

Characteristics of LNG released at sea were described in Section 4.2.1.3 for blue whales and Section 4.3.3.3 for marbled murrelets. At the water-vapor LNG pool interface, the cryogenically cooled LNG would begin to vaporize but, because of its relatively high density, the plume would remain at or close to the surface interface (Hightower et al., 2004). The cooling effects of the LNG plume on submerged coho salmon are unknown but are expected to be localized at the surface. Similarly, effects of a fire on prey species would likely be very limited to the ocean – LNG pool interface. Neither the LNG pool nor an ensuing fire would be expected to adversely affect coho salmon.

**Direct Effects – Estuarine Analysis Area**

Project-related effects to coho salmon in the Oregon Coast ESU would be caused by the action and occur at the same time and place, including the following direct impacts within the estuarine analysis area: 1) turbidity effects from dredging the slip and access channel, 2) turbidity effects from LNG vessel propeller wash and ship wake, 3) turbidity effects from constructing the Pacific Connector pipeline within the estuary, 4) stranding Oregon Coast coho by LNG vessel propeller wash and ship wake, 5) introduction of exotic, invasive species from ballast water, 6) entrainment and impingement of Oregon Coast coho in LNG carriers' intake port, 7) estuary water cooling during LNG carrier cargo loading, 8) potential effects by effects by operational lighting, and 9) acoustic effects to coho during LNG terminal construction.

**Timing**

In-water construction of the JCE and PCGP Project within the Coos Bay estuary is planned from October 1 through February 15 following ODFW's recommendation. Approximately one-half of each brood of coastal coho salmon in Winchester Creek/South Slough (tributaries to Coos Bay moved to the estuary as sub-yearlings (Miller and Sadro (2003). The estuary provides feeding and migratory habitat for adult and maturation habitat for juvenile coho that inhabit the ecotones between freshwater and saline portions of the estuary for up to 8 months and then moved back upstream to overwinter. By October, adult coho would likely have migrated from critical habitat in the estuary to upstream spawning habitats but the timing and progress of upstream migration could be influenced by drought and autumn precipitation. For example in fall 2011, significant rainfall did not occur until late December and adult coho held in mainstem pools for an extended period, waiting for rainfall, followed by increased discharge (ODFW, 2012d). Adult coho could be present in designated critical habitat within the estuary, coincidental with in-water construction for the JCE and PCGP Project. Principal direct impact during in-water construction would most likely be related to turbidity generated by construction of the slip, dredging the access channel, and construction of Pacific Connector's pipeline across Haynes Inlet.

**Turbidity Effects –Slip and Access Channel**

Construction of the LNG terminal slip will require the excavation and dredging of approximately 4.3 million cubic yards (cy) of material (2.3 million cy excavated and 2.0 million cy dredged) and the construction of the access channel will require the dredging of 1.3 million cy for a total of approximately 5.6 million cy (see discussion in Section 4.5.1.3, green sturgeon). The majority of the dredging for the slip will be conducted in isolation from the waters of Coos Bay. While the future slip area is being excavated and dredged, a berm will be maintained to provide complete separation of the excavation and dredging activities from the bay, resulting in no turbidity being released to the waters of Coos Bay. Dredging of the berm separating the portion of slip from the bay and the access channel will result in temporary siltation and sedimentation impacts similar to those that currently occur during maintenance dredging activities. The dredging activity will occur only during the in-water work window established by ODFW.

On average, the USACE removes approximately 550,000 cy from the bar, 200,000 cy from Channel Mile (CM) 2-12 and 150,000 cy from CM 12-15 each year. In comparison, approximately 500,000 cy will be removed in the water during the removal of the berm and dredging of the access channel. Since the duration of the dredging in the bay will be 4-6 months and only during the in-water work window from October 1 to February 15 (ODFW, 2008a), the minimal amount of turbidity created will be relatively short term and localized. Turbidity modeling demonstrated that turbidity levels dropped to near background levels beyond 200 meters (660 feet) of the dredging activity.

Turbidity was modeled for the new construction and maintenance dredging operations based on the anticipated geotechnical and environmental conditions for this project using the United States Army Corps of Engineers (USACE) DREDGE model and two dimensional numerical model Mike21 (see discussion in Section 4.5.1.3, green sturgeon). During the project construction period, the maximum modeled suspended sediment concentrations (primarily sand) produced by the DREDGE model for an open “clamshell” dredge were less than 6,000 mg/L at the dredge location and decreased to less than 50 mg/L at 200 m (approximately 660 feet). For the hydraulic cutterhead dredge the TSS levels were significantly lower with maximum of 500 mg/L in the vicinity of the dredge. The TSS concentrations decreased to a maximum of 14 mg/L at 60 meters (200 ft) away from the dredge vicinity.

During the project maintenance dredging period, the dredged material is expected to be primarily fines (mud, clay, silt). Concentration predicted with the DREDGE model for the open “clamshell” dredge were lower than during the construction stage with the maximum of 830 mg/l in vicinity of the dredge and decreasing to 125 mg/l at 200 m (approximately 660 feet). The results from the Mike21 simulations show that distribution of the generated plume depends on location of the dredge in the channel and basin area. For dredging with an open “clamshell” dredge in the channel the generated sediment plume (concentration higher than 150 mg/l) can move up to 1.2–1.9 miles from the dredging location at highest ebb or flood currents; however, the duration of such entrainment is limited by not more than a two hour period and the time average concentrations do not exceed natural ambient concentrations (10–30 mg/l) outside the dredging area. During maintenance dredging with an open “clamshell” dredge, the maximum concentrations in the generated plume do not exceed 50 mg/L. Based on these results it is not anticipated that turbidity generation at the dredging site will be an adverse effect to Oregon Coast coho.

**Turbidity Effects –Propeller Wash and Ship Wake**

Propeller wash from LNG vessels and tug boat propellers associated with the Project, as well as ship wakes breaking on shore, could cause increased erosion along the shoreline and re-suspend the eroded material within the water column. This may affect the diversity and health of the benthic community regarding food availability and feeding conditions for foraging and migrating fish species (see discussion in Section 4.5.1.3, green sturgeon).

Hydrodynamic effects from pressure field velocities measured along the sensitive shoreline from existing deep-draft vessels exceed the pressure field velocities that may be generated by future LNG carriers. The USCG has mandated that all LNG carriers be escorted by a minimum of two tractor tugs which allows the LNG carrier to transit at a lower speed than the existing vessels which transit without tug assist. Vessel velocity, rather than size, has a much greater impact on the amplitude of the pressure wave which would be less impact on coastal process at the sensitive shoreline by LNG carriers than from the existing deep-draft vessels using the estuary.

The results of the swash transport calculations generated by vessel wake effects (see discussion in Section 4.5.1.3, green sturgeon) show a small increase in wake-generated swash sediment transport at the areas of interest due to LNG carriers. The results show that the increase in swash sediment transport from combined inbound and outbound carrier traffic would not exceed six percent at Pigeon Point, eight percent at Clam Island, and five percent at the Airport sensitive shorelines. The total sediment transport for future inbound and outbound LNG carrier traffic will be less than eight percent of the existing and future wind-wave swash sediment transport. The estimated increase in swash sediment transport due to the LNG carrier traffic is a small fraction of the swash sediment transport due to the natural wind-wave conditions. This increase most likely would not be detected in a general balance of swash sediment transport due to yearly variability of wind-wave conditions and swash sediment transport. Based on these results it is not anticipated that suspended sediment generated by propeller wash and ship wake will be adverse effects to Oregon Coast coho.

**Turbidity Effects – Pipeline Construction**

Pacific Connector will construct the proposed pipeline across Haynes Inlet between October 1 and February 15, the in-water construction period recommended by ODFW (2008). It is possible that adult and/or juvenile coho would be present in the Coos Bay estuary during pipeline construction across Haynes Inlet. Construction would increase turbidity in the immediate vicinity of the construction right-of-way across Haynes Inlet but coho, if present, would be expected to avoid local turbid conditions. Natural turbidity in the Coos Bay estuary was judged to be higher at upper bay locations, away from water influx from the ocean (Moffatt and Nichol, 2006). Modeled turbidity due to dredging in Coos Bay suggests a very narrow range of elevated suspended sediment (>100 mg/L) during low tidal velocity extending a few hundred feet from the dredge, while during typical tidal cycle values were as high as 50 mg/L from 0.2 to 0.3 mile away from the dredge. Moderately low values of 25 to 50 mg/L may extend out to about 3.5 miles depending on flow, sediment, and equipment used (Moffatt and Nichol, 2006). Sediment concentrations from pipeline trenching in Haynes Inlet would be similar to winter background levels for much of the construction period and few fish would be near the highest plume concentration due to active avoidance.

Trench excavation to install the pipeline in the bay would bury, displace, or injure benthic organisms (see discussion in Section 4.5.1.3, green sturgeon). However, benthic communities on mud substrates in Coos Bay that had been disturbed by previous dredging activities recovered to pre-dredging levels in four weeks (Newell et al., 1998). Some impacts may be long-term if important habitat elements are affected, such as the effects of turbidity on eelgrass growth (Martin and Tyrrel, 2002). Based on the survey of the route in 2008, there were about 1.0 acre of eelgrass beds that will be directly affected by the construction right-of-way (including temporary extra work areas - TEWAs). Most of the area affected would be low density eel grass, and none were categorized as high-density eel grass. Approximately 0.1 percent of the total eelgrass beds present in Coos Bay would be directly disturbed from pipeline construction across Haynes Inlet (Ellis Ecological Services, 2013).

The pipeline will cross the Coos River using a HDD (see discussion, below, under Riverine Analysis Area) and will cross Catching Slough using a conventional bore. Other waterbodies within critical habitat will be crossed by dry-open cut construction between July 1 and September 15, the recommended in-water construction dates for Boone Creek, Catching Slough, Monkey Gulch, and Stock Slough (ODFW, 2008a). Sediment released during dry open-cut construction is generally restricted to short-term peaks associated with installation and removal of isolation (temporary dams) and bypass structures (see discussion, below, sediment effects under Riverine Analysis Area). Estuarine environments often have moderately elevated suspended sediment concentrations (i.e. >15 mg/L) and they are very productive (Gregory and Northcote, 1993). The amount of sediment produced by open cutting depends on multiple characteristics at the construction site including depth and width of the waterbody (effects mixing of the sediment plume in the water column), current velocity and local turbulence at the site and downstream, concentrations of suspended sediment initially at the site and at some distance downstream, particle diameter, specific weight, and settling velocity of the excavated and backfilled materials (Ritter, 1984; Reid et al., 2004). Based on sediment transport modeling, dispersal of the exposed and disturbed sediments will be very minor in intertidal areas of Haynes Inlet due to the low water velocities and sediment composition in that area and turbidity is not expected to adversely affect coho salmon.

**Stormwater Discharge at LNG Terminal**

Stormwater discharge has the potential to contain chemicals toxic to coho salmon. However the NPDES permit that the applicant would be obtained requires discharges to not modify state water quality standards of the receiving water (see discussion in Section 4.5.1.3, green sturgeon). The proposed oil and grease treatment system is designed to limit discharges of oil and grease to no more than 15 mg/l daily maximum. This system design would ultimately need approval from the State to obtain the NPDES permit (see discussion in Section 4.5.1.3, green sturgeon).

The exact levels of other runoff chemicals can not be predicted at this time. However Washington State, in a review of all of their permitted monitored stormwater discharge facilities, found that copper and zinc, two chemicals commonly of concern to aquatic organisms, were relatively high often exceeding benchmark standards (WDOE, 2009). They noted that the sources of metals pollution include oils and lubricants from motor vehicles, tire dust, brake pad dust, raw material and products, and exposed galvanized metal surfaces on buildings, fences, and equipment (see discussion in Section 4.5.1.3, green sturgeon). Juvenile coho salmon are sensitive to both copper and zinc in fairly low concentrations; downstream migrations were affected in individuals exposed to dissolved copper (Lorz et al., 1978); dissolved copper affects behaviors involved in growth reproduction, and predator avoidance all of which contribute to survival Hecht et al., 2007). Deaths of juveniles were attributed to exposure to copper and zinc when fish were challenged with seawater (Lorz et al., 1978). However, only adult and sub-adult Oregon Coast coho would potentially be exposed to metal components in stormwater discharge and exposure effects to adults are unlikely.

**Stranding from Ship Wake and Propeller Wash**

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not (see discussion in Section 4.5.1.3, green sturgeon). Size of juvenile coho in the estuary are expected to be comparable to sizes of juvenile chinook salmon (<9 cm) which became stranded by ship wakes in the Columbia River (Pearson et al., 2006); juvenile coho may be susceptible to stranding by ship wake.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds within the Coos Bay estuary have been observed to cause occasional stranding of juvenile salmon (Pearson et al., 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al., 2006) to cause stranding. In models and research conducted by the JCEP, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute to stranding of Oregon Coast coho within Coos Bay.

Exotic, Invasive Species

There are no current studies that evaluate the impact of introduced fishes on coho salmon (ODFW, 2005b). The introduced species, striped bass and shad, presents the highest risk of impact to coho salmon in the Coos Bay Estuary (ODFW, 2005b). However, navigational dredging within Coos Bay has altered salinity levels which have impacted striped bass egg and larval survival, reducing numbers and threat of striped bass predation on coho.

Loaded with water from the surrounding ports and coastal waters throughout the world, ships can carry a diverse assemblage of marine organisms in ballast water that may be foreign and exotic to the ship's port of destination. The transfer of water from port-to-port can result in aquatic biological invasions. Invasive species threaten to outcompete and exclude native species and the overall health of an ecosystem, causing algal blooms and hypoxic conditions and affecting all trophic levels resulting in a decline in biodiversity. Invasions of zebra mussel (*Dreissena polymorpha*), Chinese mitten crab (*Eriocheir sinensis*), and hydrilla (*Hydrilla verticillata*) can potentially affect Oregon Coast coho (Stout et al., 2012). For example, Oregon Coast coho smolts during out-migration consume a mudshrimp (*Upogebia pugettensis*), the major food sources in Yaquina Bay (Stout et al., 2012). These intertidal benthic invertebrates have been dramatically affected by the recently introduced isopod parasite (*Orthione griffenis*), likely introduced from Asia in the 1980s (Dumbauld et al., 2011).

Ballast water from ships' precedent ports would be emptied and exchanged with ocean seawater approximately 200 nmi offshore, at the outer edge of the EEZ. The ballast water exchange (BWE) process is mandatory under the National Ballast Water Management Program – originally established by Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and further amended by National Invasive Species Act of 1996 and National Aquatic Invasive Species Act of 2003 – amended in 2005 and again in 2007. On March 23, 2012, the USCG issued its Rule regarding Standards for Living Organisms in Ships' Ballast Water Management Discharged in U.S. Waters, which amends the existing regulations and creates a standard for the allowable concentration of living organisms in ballast water discharged in U.S. waters consistent with the International Maritime Organization's International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM Conventions). This Rule will require all vessels equipped with ballast tanks bound for (or departing) U.S. ports to utilize at least one Ballast Water Management method described in the Rule (77 FR 17254). The most likely convention given the advanced technologies used by LNG carriers will involve a complete BWE in an area 200 nautical miles from any shore prior to discharging ballast water.

LNG ships will discharge ballast concurrently with the LNG cargo loading at the LNG terminal. The amount of ballast water discharged must, at a minimum, be adequate to maintain the LNG ship in a positive stability condition and with an adequate operating draft while the LNG cargo is loaded. The ballast water discharged at the terminal will be that from 200 miles out in the open sea as occurred as part of the mandated BWE process to eliminate or minimize risks of introducing exotic, invasive species.

Entrainment and Impingement

LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is likely that some organisms small enough to pass through the screens covering the carrier's intake port will be drawn in with the cooling water and will be lost from the population in the slip area; however, it is anticipated that the effect associated with the intake of cooling water will be minimal. Juvenile fish would need to be present in the slip area near the carrier's intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen. Generally the total water intake would occur over a 24-hour period during each loading period, about 90 times per year.

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The power requirements for loading LNG in the export mode are less than those for unloading LNG in the import mode because the LNG carrier does not have to use on board LNG pumps to handle LNG cargo; hence both the LNG carrier engine requirement and the required amount of cooling water flow are reduced. For reasons discussed in Section 4.5.1.3, green sturgeon, it is anticipated that the effect associated with the intake of cooling water will be minimal. The intake velocities for the cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be impinged on the intake screen.

Water Cooling

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The engines will be running to provide power for standard hotelling activities as well as running the ballast water pumps. The activities that will require LNG carrier power and the assumptions used to develop the cooling water flow requirements are as follows:

- Hotelling operations require the generation of 1.9 MW of power during the entire time that the LNG carrier remains in the slip. The vessel is anticipated to be within the slip for a total of 17.5 hours.
- A typical auxiliary power unit for an LNG carrier is the Wartsila 34DF. This is a dual fuel (liquid and natural gas) unit that is a complete primary driver/generator package capable of being sized upwards to 6.9 MW output. Fuel to power conversion is 7,700 kilojoules (kJ) per kilowatt-hour (kWh) (kJ/kWh) (7,305 British thermal units (Btu) per kWh (Btu/kWh)). This system has an overall fuel to power efficiency of 46.7 percent, thereby resulting in the rejection of 3,893 Btu of heat into the cooling water for each kWh of power generated.

- All calculations that follow are based upon the transfer of 148,000 $m^3$ of LNG from the LNG storage tanks to the LNG carrier. The 148,000 $m^3$ carrier is set as the basis because it represents the largest vessel authorized to call on the LNG Terminal.

The total gross waste heat discharged into the slip from the cooling water stream will be due primarily from the hotelling operations (including the power required to run the ballast water discharge pumps) as the shore side LNG pumps will be used to transfer the LNG from the LNG storage tanks to the LNG carrier. The hotelling operations were assumed to be as follows:

- Hotelling Operations -17.5 total hours x 1,900 kW x 3,983 Btu/kWh = 132.5 million Btu (MMBtu). The total amount of heat discharged into the slip during each vessel call is approximately 132.5 MMBtu.

Because of the extreme differential of the temperature of the cargo in the LNG carrier (-260$^{o}$F) and that of the surrounding air and water (nominally 45$^{o}$F) there is a constant uptake of heat by the LNG carrier from its surroundings. This heat uptake is manifested by the amount of LNG cargo that changes state from liquid to vapor on a daily basis. The typical LNG carrier sees 0.25 percent of its liquid cargo converted to the gaseous state each 24 hours. In this process 219 Btu of heat is absorbed for each pound of LNG converted to vapor. This results in a total of 53 MMBtu absorbed by a typical 148,0000 $m^3$ LNG carrier during the 17.5 hours it is within the slip. Given the distribution of vessel surfaces between those surfaces in contact with water as opposed to those surfaces in contact with air it is reasonable to assume that 50 percent or more of the heat take up by the vessel is extracted from the water. This assumption is further reinforced by the fact that the heat transfer coefficient between water and steel is significantly higher than the heat transfer coefficient between air and steel. Applying this allocation of heat absorption sources results in having 26.5 MMBtu being removed from the slip by the LNG vessel during its stay. Thus a portion of the 132.5 MMBtu of thermal energy discharged into the slip from the cooling water is offset by the uptake of 26 MMBtu by the LNG vessel itself, resulting in a net heat input to the slip of 106.5 MMBtu per 148,000 $m^3$ LNG carrier call.

Analysis and numerical modeling were performed to identify potential impacts of LNG carrier cooling water discharge on water quality in the slip and adjacent area of Coos Bay. The modeling was initially performed with two different numerical models: the 3-D UM3 model and the DKHW model. The models simulate hydrodynamic mixing processes of submerged discharges and predict temperature fields and dispersion of non-conserved substances in ambient water bodies. Cooling water numerical modeling requires input of steady-state flow velocity in the modeling domain. The results of tidal flowing modeling using the SELFE model showed that ambient current velocities inside the LNG Terminal area vary, depending on tidal stage. Peak current speeds in the berth only exceed approximately 0.32 ft/sec less than two percent of the time. Therefore, for cooling water modeling, two steady state ambient flow velocities were assumed and used further in the analysis: high velocity = 0.32 ft/sec and typical velocity = 0.16 ft/sec.

The following conservative assumptions were used in the analysis. The assumptions are conservative in that a steam powered ship was used. The steam powered ships tend to be older than the newer more modern dual fuel diesel electric ships that require lower quantities of cooling water.

- LNG carriers are steam-powered with a cargo capacity of 148,000 $m^3$.

- Maximum pump capacity for main condenser cooling is 10,000 $m^3$/hr (44,030 gpm) and maximum pump capacity for LNG carrier's equipment cooling is 3,000 $m^3$/hr (13,209 gpm). Total capacity being used at a given time is typically in the range of 6,300 $m^3$/hr (27,739 gpm). For the analysis, 6,300 $m^3$/hr (27,739 gpm) was used.
- Diameter of the horizontal discharge port is 1.1 meters (3.6 feet).
- Depth of discharge port below still water is 10.0 meters (32.8 feet).
- Maximum heating of cooling water at time of discharge is 3 ºC (5.4 ºF) above ambient temperature.

Results of the modeling showed that for typical ambient flow conditions at a distance of 50 feet from the discharge point (LNG carrier sea chest), temperatures will not exceed 0.3 ºC (0.54 ºF) above the ambient temperature. This difference will decrease with further distance.

<u>Effects of Operational Lighting</u>

Localized changes in light regime have been shown to affect fish species behavior in a variety of ways (Simenstad et al., 1999; Valdimarsson et al., 1997; Tabor et al., 2004, Nightingale and Simenstad 2001). Disorientation may cause delays in migration, while avoidance responses may cause diversion of migratory routes into deeper, less protected waters. In some cases, increased light may attract both predators and potential prey species (Simenstad et al. 1999; Valdimarsson et al. 1997; Tabor et al. 2004).

Lighting at the LNG Terminal and onshore facilities would likely include a mixture of low-power fluorescent lighting and higher intensity security lighting that would primarily be located on shore, in and adjacent to the slip. When an LNG carrier is not in the berth, the lighting would be reduced to that required for security. It would be focused upon the structures and not be in proximity to the water so as to serve as an attractant or deterrent to fish species. When an LNG carrier is at the berth, it would physically block the lighting on the berth from the slip waters and, due to its proximity to the slip wall, would block the fish from getting too close to the lighting on the berth. Lighting used would be similar to that already in place at other Coos Bay facilities.

Lighting on the tug dock would be low intensity lighting for safety, providing sufficient light for personnel movements on the trestle out to the tug berth and for movement on the berth itself. There is no intention to provide lighting near the water line or high intensity lighting that would be associated with activities other than the simple berthing of the tugs at this location. The reduced lighting levels near the water would reduce or eliminate any behavioral effects to fish in the Project vicinity. Increased lighting from facility operations are not expected to significantly affect coho salmon in the Oregon Coast ESU.

**Acoustic Effects**

Underwater noise may affect coho salmon. Prior to the excavation work starting for the LNG carrier slip, an open cell sheet pile bulkhead and retaining wall will be installed. The sheetpile system will serve as a retaining wall for the shoreline on the east side and support the LNG ship loading dock and associated berthing and mooring facilities. The open cell sheet pile wall system consists of face sheetpiles for retaining the soils as well as tailwalls for anchorage of the retaining wall. All sheetpiles and tailwalls will be driven from the land while the slip construction activities are isolated from Coos Bay.

Underwater noise may be generated by driving sheet piles on land (dry piles) since some noise propagates through ground and sediments (especially through harder substrates such as rock and clay), and may transfer to the water column somewhere else (known as sound flanking). Sound in the water column would be at a lower level than at the source (Washington State Department of Transportation, 2011a) since most sound energy does not travel through water but through the sediment. There would be minimal chance that driving pilings on land could physically injure fish from the impact of percussive sound pressure in the same way as driving piles in water (see Popper, et al. 2006).

**Indirect Effects – Estuarine Analysis Area**

Project-related indirect effects to Oregon Coast coho would be caused by the action (induced by the action as human presence and use increase), and are later in time or farther removed in distance, but are still reasonably foreseeable include the following: 1) localized reduction of benthic and epibenthic invertebrates, 2) removal of eelgrass, and 3) shading the water surface by overhead structures.

**Habitat Effects –Slip and Access Channel**

Benthic and epibenthic invertebrates that presently inhabit shallow intertidal and subtidal regions within the boundaries of the proposed access channel dredging area would be removed with the dredged material. Ghost shrimp and sand shrimp (adults, juveniles and larvae), amphipods, clams, Dungeness crab, and various fish species are important prey for Oregon Coast coho. Therefore, the loss of invertebrates and vertebrates at the access channel would result in a reduction in fish food available to coho salmon in those areas affected by the Project.

As noted above, benthic communities in Coos Bay inhabiting mud substrates recovered to pre-dredging conditions in four weeks (Newell et al., 1998). Although the substrate proposed for maintenance dredging in the access channel and berth would largely be sand and silt, it is anticipated that recovery would occur within a similar time frame, resulting in only short-term effects to the benthic community and potential food resources for Oregon Coast coho.

**Habitat Effects – Pacific Connector pipeline**

Construction of the pipeline across the Haynes Inlet of Coos Bay estuary would span 2.45 miles and disturb approximately 0.068 mile of eelgrass or 2.8 percent of that amount, most of which classified as low-density eelgrass beds. Eelgrass can be adversely affected by turbidity because the depth and distribution of eelgrass is strongly associated with water clarity and depth of light penetration (Dennison and Orth, 1993; Thom et al., 1998) as well as nutrient availability (Short et al., 1995), salinity, and water temperatures (Thom et al., 2003). Construction of the pipeline across the estuary is planned from October 1 through February 15 following ODFW's recommendation. During most of that period, eelgrass in Coos Bay would be dormant, coinciding with low temperatures and short photoperiods (Fonseca et al., 1998).

Ellis Ecological Services, Inc. (2013) conducted a survey of eelgrass beds within Coos Bay along the pipeline route. Based on the survey of the route in 2013, there was 5.0 acres of eelgrass beds that will be directly affected by the construction right-of-way (including temporary extra work areas - TEWAs). Eelgrass beds were placed into three categories based on density: low, medium, and high. Most of the area affected would be low density, and none were categorized as high-density eelgrass. Approximately 0.1 percent of the total eelgrass beds present in Coos Bay would be directly disturbed from pipeline construction across Haynes Inlet (Ellis Ecological Services, 2013). During in-water pipeline installation within Coos Bay, fish and other aquatic resources could be impacted. The current pipeline route in the bay will cross 2.5 miles and disturb approximately 75.6 acres (33.2 acres of subtidal and 36.25 acres of mud/sandflats) of habitats.

**Shading Effects**

Shading from over-water structures reduces the amount of light available to phytoplankton and aquatic macrophytes. However, the area where shading LNG terminal facilities would occur is intended for industrial uses and not the creation of new habitat. The general habitat in the slip's region would not be conducive for many marine resources because of depth and steep rip/raped armored banks, so relatively few resources would likely utilize this newly created area. The water areas within the slip are being created from upland areas and therefore shading of currently un-shaded habitat would occur, and no net loss in productivity due to shading would occur. Project components that potentially could shade the new open water created by the construction of the slip include:

- At the proposed slip, the access gangway to the LNG facility is narrow and well above the water surface and would have open mesh grating. Shade produced by the gangway is expected to be biologically insignificant.
- The unloading platform for the LNG facility is 60 feet wide and would be located at an elevation of +30 feet NAVD88. Because the platform is located offshore in deep water, no shading of shallow water habitat would occur.
- The tug dock is the only structure to be built over open water portion of the newly developed slip and it is 400 feet long by 12 feet wide. Shading would be minimized by open mesh grating, which is now commonly used on piers to reduce effects to marine resources from shading.
- The tug dock would be connected from shore by a narrow gangway. The dock would be 12 feet in width and located at +12 feet NAVD88. This too would have open mesh grating to reduce shading. Consequently, shading impacts would be small and probably insignificant.

Most fish, including coho salmon, have developed countershading as an adaptation to avoid predation (Moyle and Cech 2000) from above (dark dorsal surface blends with bottom substrate) and from below (light ventral surface blends with light from the surface). Fish within a shaded area would be more easily detected by a predator, especially from below because light colored ventral surfaces would stand out against a shaded water surface. Predation potential, based on some observed fish behavior, is a concern (Nightingale and Simenstad, 2001). However actual increased occurrence in predator numbers from even substantial overwater structures has rarely been documented. Additionally review of many marina and pier studies have not documented actual increased predation at these facilities (Nightingale and Simenstad, 2001). For example, marine marina studies have found no documentation of increased concentrations of juvenile salmonid predators and some predators such as birds may be of lower abundance than under natural shoreline conditions (Cardwell et al., 1980, and Heiser and Finn, 1970, as cited in NMFS, 2005c). The extent to which any of these predators affect juvenile or adult coho salmon in shaded areas created by the proposed action is unknown. But the actions taken (open mesh grating of all structures) should reduce the probability of this occurring.

**Direct Effects – Riverine Analysis Area**

The pipeline route will cross 2.40 miles of estuarine habitat in Coos Bay and would actually cross 150 of the waterbodies in table 4.5.4-3 (summarized below in table 4.5.4-10), 144 of them by dry open cutting, while the South Umpqua River would be crossed twice, once by a Direct Pipe crossing at MP 71.30 and again by a diverted open cut at MP 94.73. Kentuck Slough would be crossed by a conventional bore at MP 6.28R, Catching Slough would also be bored at MP 11.11, and the Coos River would be crossed using HDD at MP 11.13R. The Coos Bay estuary would be crossed by using a wet open cut procedure. Twenty-two of the waterbodies listed above in 4.5.4-3 and summarized in table 4.5.4-10 would not be crossed by the pipeline but are adjacent to the pipeline centerline. Blasting may be necessary to construct across 30 streams that would be crossed by dry open cut methods (see Project Description) because the streambed of each is bedrock (see table 4.5.4-3 and table 4.5.4-10).

**Table 4.5.4-10**
**Proposed Pipeline Construction Methods for Crossing Waterbodies within Sub-basins and 5th Field Watersheds Coinciding With the Proposed Pipeline Route and coho in the Oregon Coast ESU.**

| Sub-basins and 5th Field Watersheds | Number of Waterbodies with Construction Method | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HDD or Direct Pipe | Bore | Wet Open-Cut | Diverted Open-Cut | Dry Open-Cut | Total Crossed | Adjacent Not Crossed[1] | Bedrock [2] |
| **Coos Sub-basin** | | | | | | | | |
| Coos Bay-Frontal Pacific Ocean | 1 | 2 | 1 | | 52 | **56** | 10 | 1 |
| **Coquille Sub-basin** | | | | | | | | |
| Coquille River | | | | | 6 | **6** | | 2 |
| North Fork Coquille River | | | | | 11 | **11** | 2 | 3 |
| East Fork Coquille River | | | | | 13 | **13** | 1 | 5 |
| Middle Fork Coquille River | | | | | 12 | **12** | 1 | 1 |
| **South Umpqua Sub-basin** | | | | | | | | |
| Olalla Creek-Lookingglass Creek | | | | | 15 | **15** | | 5 |
| Clark Branch-South Umpqua River | 1 | | | | 13 | **14** | 5 | 4 |
| Myrtle Creek | | | | | 8 | **8** | 2 | 3 |
| Days Creek-South Umpqua River | | | | 1 | 8 | **9** | | 5 |
| Upper Cow Creek | | | | | 6 | **6** | 1 | 1 |
| **TOTAL** | **2** | **2** | **1** | **1** | **144** | **150** | **22** | **30** |

1 Waterbodies within the construction right-of-way that will not be crossed
2 Bedrock streambeds will be crossed by dry open-cuts but may require special construction techniques to ensure pipeline design depth including rock hammering, drilling and hammering, or blasting. The need for blasting would be determined by the contractor and would only be initiated after ODFW blasting permits are obtained.

All affected waterbodies within the three sub-basins and 10 fifth field watersheds that are within the range of Oregon Coast coho salmon ESU proximate to the Pacific Connector pipeline are included in table 4.5.4-10. There are 172 waterbodies included in the table, of which 85 are perennial, 85 are intermittent, 1 is an estuary and another is a pond (see table 4.5.4-2, above).

The PCGP Project would cross 61 waterbodies which are known or presumed to be inhabited by coho salmon in the Oregon Coast ESU (see table 4.5.4-1, above). Effects by the project could occur to freshwater in-water construction activities, terrestrial/riparian habitat modification, accidental spills or leaks of hazardous materials, and periodic maintenance of the pipeline. Construction of the PCGP Project could directly and/or indirectly affect Oregon Coast coho salmon and critical habitat through one or more of the following pathways:

- Interference with key life history functions for native species.
- Acoustic shock from blasting pipe trench through bedrock streambeds or use of a track hoe or impact hammer if fish are proximate to the construction site.
- Turbidity generated during pipeline construction across waterbodies can adversely affect coho and aquatic habitats.
- Introduction and/or re-distribution of aquatic nuisance species

- Removal of riparian vegetation that can reduce shade (which could increase water temperatures), limit streambank stability, and affect recruitment of LWD.
- Accidental release of fuels and entry of other petroleum products into surface waters can adversely affect coho and other aquatic organisms.
- Application of herbicides to control noxious weeds near waterbodies may adversely affect coho.

**Timing**

Pacific Connector will cross fish-bearing waterbodies within the Oregon Coast coho ESU to prevent construction during periods of sensitive fish use and would typically allow construction only in periods of lower flow rates in streams. Within Haynes Inlet, Pacific Connector would limit pipeline trenching and other in-water activities to the October 1 through February 15 in-water work window recommended by ODFW. Timing of in-water work for the Coos Bay Estuary and Coos River (upstream to Millicoma-South Coos River confluence) is from October 1 to February 15 (ODFW, 2008a), which coincides with adult upstream migrations of coho (see figure 4.5-13, above). The ODFW (2008a) instream construction window for coastal tributaries, the Coquille River and tributaries, and tributaries to the South Umpqua River is July 1 to September 15. Instream work within the South Umpqua River mainstem is permitted from July 1 to August 31.

In general, construction of the pipeline would be timed to miss periods of major juvenile or adult migrations in freshwater based on allowed fishery construction windows, typically July 1 to mid-September for most streams, and some other dates for specific waterbodies. Timing of in-water work in aquatic habitats within the Coquille and South Umpqua sub-basins generally coincide with low flows and high water temperatures during summer and early autumn, discussed above in Section 4.5.4.2 (see figure 4.5-16, Coos Sub-basin; figure 4.5-17, Coquille Sub-basin; figure 4.5-18, and South Umpqua Sub-basin). The instream construction windows coincide with upstream adult migration by coho. Construction across waterbodies within the Coquille and South Umpqua sub-basins would be completed before spawning (see figure 4.5-13). However, juvenile coho would be present and migrating adults might be present within waterbodies flowing at the time of construction.

**Acoustic Shock**

There are 30 waterbodies within the Oregon Coast coho ESU where shallow bedrock may occur where potential blasting and/or mounted impact hammers may be required to construct a trench through bedrock substrates (see table 4.5.4-3, summarized above in table 4.5.4-10). Explosives detonated near water produce shock waves that can be lethal to fish, eggs, and larvae by rupturing swim bladders and addling egg sacs (British Columbia Ministry of Transportation, 2000). Explosives detonated underground produce two modes of seismic wave (Alaska Department of Fish and Game, ADFG, 1991), 1) body waves that are propagated as compressional primary (P) waves and shear secondary (S) waves, and 2) surface waves produced when a body wave travels to the earth surface and is reflected back. Shock waves propagated from ground to water are less lethal to fish than those from in-water explosions because some energy is reflected or lost at ground-water interface (ADFG, 1991). Peak overpressures as low as 7.2 pounds per square inch (psi) produced by blasting on a gravel/boulder beach caused 40 percent mortality in coho salmon smolts and other studies revealed 50 percent mortality in smolts with peak overpressures ranging from 19.3 to 21.0 psi (ADFG, 1991).

The best approach to protect fish species is to limit the instantaneous hydrostatic pressure change (resulting from nearby blasting) to levels below those known to be harmful to fish (see discussion above in Section 4.5.3.3 for coho salmon SONCC ESU). Pacific Connector may opt to blast across stream locations where consolidated rock makes traditional trenching methods unfeasible. Typical trench blasting scenarios use multiple 1- to 2-pound charges separated by an 8-milisecond delay to excavate the trench. With use of using 1- to 2-pound charges in rock, the set back distance (at which 2.7 psi would occur) from the blast trench to the fish habitat is between 34 and 49 feet (see Table 3, in ADFG, 1991). Blasting would be conducted within dry streambanks isolated from the water column, most likely using dam-and-pump construction to bypass water around the dry workspace.

Several approaches have been suggested to reduce risk of injury or mortality to fish in closest proximity to blasting locations (Wright and Hopky, 1998):

- deployment of bubble curtains/air curtains to disrupt the shock wave;
- deployment of noise generating devices, such as an air compressor discharge line, to scare fish away from the site; or
- removal or exclusion of fish from the work area before the blast occurs.

A Fish Salvage Plan is provided in appendix T. The plan includes measures to exclude fish and prevent them from re-entering isolated portions within waterbodies crossed for distances sufficient to avoid or minimize adverse effects by blasting bedrock in streambeds.

<u>Underwater Noise</u>

Impulsive type sounds, sound generated by pile driving for example, create stress waves in the piling material that radiate sound through the surrounding media of substrate, air, and water and may propagate outward from the source through bottom sediment (Popper and Hastings, 2009). Various studies have reported fish mortality, physical injury, auditory tissue damage, decreased viability of eggs, and decreased larval growth due to noise, mostly explosive blasts, seismic survey blasts, and air gun blasts (Hastings and Popper, 2005). State agencies in Washington, Oregon, and California, along with federal agencies have developed interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a; Popper et al., 2006, and see discussion above in Section 4.5.3.3 for coho salmon SONCC ESU). The threshold noise levels are assumed to be applicable to noise from a mounted impact hammer operating on bedrock substrates for 30 waterbodies potentially affected by the PCGP Project in the Coos, Coquille, and South Umpqua sub-basins (see table 4.5.4-9, above).

Average maximum noise produced by mounted impact hammers due to impact on substrates (eg, rock) has been reported at 90 dBA from 50 feet away in the air (see Table 7-4 in Washington State Department of Transportation, 2011a). Using a simplified conversion of dB between air and water (see footnotes and discussion above in Section 4.5.3.3 for coho salmon SONCC ESU) the noise produced by the impact hammer in air would be equivalent to about 182 dB re: 1 µPa @ 1 meter in water. However, there is no information available to determine whether that noise level would be equivalent to peak sound levels or root mean square (RMS) levels, which are the basis for evaluating potential harm to fish, particularly related to cumulative sound exposure levels caused by multiple impact hammer strikes.

Further, the estimate of noise produced by in-water use of an impact hammer in any waterbody would be influenced by water currents, water depth, and bottom material and topography, as well as configuration and materials of the river banks. The effects of these factors are unknown (Washington State Department of Transportation, 2011a). However, noise propagation in any waterbody, upstream and downstream from the construction site will be limited by the stream channels' sinuosity since the propagation is limited to straight-line distance from the source (Washington State Department of Transportation, 2011a). Noise produced by impact hammers will be much reduced if construction does not occur within the water column, similar to reduction set back distances from the blast trench to the fish habitat to reduce blast overpressures to below 2.7 psi, discussed above.

Sounds produced by a mounted impact hammer operating in dry conditions might be conducted through bedrock substrate to approach the hearing threshold of fish, as for example the Atlantic salmon, which is around 90 dB re: 1 µPa (see Figure 3 in Hastings and Popper, 2005). It is assumed that salmonids in the PCGP Project area at the time of construction will have hearing thresholds similar to Atlantic salmon. With that assumption, listed and non-listed salmonids present at the time of construction might detect the noise produced by an impact-hammer striking bedrock, but the noise is not expected to be of sufficient intensity to cause them injury as would SELs produced by pile driving.

**Suspended Sediment**

Salmonids exposed to moderate to high levels of suspended sediment for extended periods could be adversely affected. At high levels, turbidity directly affects survival and growth of salmonids and other species, interferes with gill function, and adversely affects substrate for egg development (reviewed and compiled by Bash et al., 2001). Turbidity can also reduce macrophyte cover (over the long-term) by limiting photosynthesis (Goldsborough and Kemp, 1988), as well as adversely affecting fish vision, which is a requisite for social interactions (Berg and Northcote, 1985), feeding (Vogel and Beauchamp, 1999; Gregory and Northcote, 1993), and predator avoidance (Meager et al., 2006; Miner and Stein, 1996).

Salmonids may avoid areas of increased turbidity levels at 20 mg/L suspended sediment, and possibly lower concentrations depending on length of exposure (Newcombe and Jensen, 1996). The elevated suspended sediment conditions would be short-term during pipeline installation and would not be continuous at any one location. This would reduce the chances of continuous elevated exposure for fish that may move little. Concentrations as low as 17 mg/L have been noted to potentially have some adverse effects (e.g. gill irritation, respiration) for juvenile coho salmon (Wheeler, 2008, based on Berg and Northcote, 1985). Some other studies have found varied effects including lesser effects at these concentrations, with overall effects related to both duration as well as concentration (Newcomb and Jensen, 1996).

Newcombe and Jensen (1996) compiled research from many sources that demonstrate effects to anadromous and resident salmonids by various levels of turbidity and exposure over time. The compiled information was used to develop several models of risks to salmonids and non-salmonids. Input for each of two models (Model 1, juvenile and adult salmonids; Model 3, juvenile salmonids) includes TSS concentration (mg/L) and duration (hours) of exposure to the concentration. Output from each model is a severity-of-ill-effects (SEV) score ranging from 0 to 14 where SEV of 0 indicates no effects, SEV between 1 and 3 indicates behavioral effects, SEV from 4 to 8 indicates sublethal effects, and SEV from 9 through 14 indicate lethal and paralethal effects (see Table 1 in Newcombe and Jensen, 1996).

Before the procedures can be used to evaluate effects of suspended sediment concentrations and variable durations of exposure on fish, there must be some estimate of TSS concentrations generated during construction by the PCGP Project. The following sections develop the information that will lead to estimates of TSS entrained during pipeline construction. The following sections apply to waterbodies crossed by the project, not to the 14 waterbodies (table 4.5.3-2, above) that are adjacent to the pipeline, within construction rights-of-way, and would not be crossed.

Background Turbidity and Suspended Sediment**.** Turbidity, generally reported in Nephelometric Turbidity Units (NTUs), is a measure of the lack of transparency (cloudiness) of water caused by suspended or dissolved substances which cause light to be scattered and adsorbed. Turbidity is often measured on-site using a turbidity meter that measures the scattering of light in a water sample relative to a known range turbidity standards. Turbidity is directly related to the concentration of sediments suspended in water but the relationship between turbidity and suspended sediment is complicated by sediment particle size, particle composition, and water color (Oregon Department of Environmental Quality, 2010).

GeoEngineers (2011a and 2013a) evaluated the potential risk of turbidity increasing during construction of the PCGP across waterbodies. The qualitative evaluation was based on each affected waterbody's hydroperiod, presence of erodible clay and loam soils in streambanks, presence of clay in streambed (suspended clay contributes to turbidity), long-term stability of stream channels, and level/duration of construction effort and stabilization measures likely added at the time of construction. The turbidity risk was scored from 1 (low) to 5 (high). Of 402 canals, ditches, and waterbodies evaluated, 130 were scored with a low risk (score of 1 or 2) of turbidity increase over a 24 hour period, and 272 were scored with a moderate risk (score of 3 or 4), generally due to soil erosion potential, presence of clay or mud, and/or the presence of steep slope or an incised channel that would require construction of a deep trench (GeoEngineers, 2013a). The evaluation concluded that turbidity generated during construction may exceed Oregon water quality standards for short distances and short durations downstream from each stream crossing, either coinciding with construction across perennial waterbodies or in intermittent streams coincidental with autumn precipitation.

Ambient turbidity was not addressed by GeoEngineers (2011a and 2013b). Turbidity (NTU) has been evaluated by ODEQ (2013) and retrieved from Laboratory Analytical Storage and Retrieval (LASAR) Web Application for some of the waterbodies crossed by the PCGP Project. Turbidity within individual streams may be highly variable with highest measurements reported during winter months, usually January through March (see table 4.5.4-11a). During the period coinciding with ODFW (2008a) instream construction windows, reported turbidity has been minimal in streams for which data exists (see table 4.5.4-11b).

**Table 4.5.4-11a**
**Turbidity (NTU) Records Measured by ODEQ during All Times of Year in Waterbodies Crossed by the PCGP Project in the Coos, Coquille, and South Umpqua Sub-Basins and Conversion to TSS by Available Models**

| Sub-Basin | Waterbody | Number of Records | Period of Record | Mean Turbidity (NTU) (Maximum) (Minimum) | Model Conversion to TSS (mg/L) [1] Model 1 Mean TSS (Maximum) (Minimum) | Model 2 Mean TSS (Maximum) (Minimum) | Model 3 Mean TSS (Maximum) (Minimum) | Model 4 Mean TSS (Maximum) (Minimum) |
|---|---|---|---|---|---|---|---|---|
| Coos | Kentuck Slough | 10 | 2005-2007 | 27.6 (89) (4) | 136.5 (487.1) (13.1) | 34.9 (115.0) (4.7) | 49.2 (189.6) (3.2) | 112.9 (434.8) (7.2) |
| | Willanch Creek | 1 | 1982 | 29 | 131.8 | 36.1 | 43.2 | 99.0 |
| | Catching Slough | 13 | 2005-2007 | 11.1 (39) (1) | 47.2 (186.2) (2.6) | 13.6 (49.0) (1.1) | 14.8 (63.8) (0.5) | 34.0 (146.3) (1.2) |
| Coquille | Cunningham Creek | 11 | 2001-2010 | 26.2 (82.8) (9.3) | 127.5 (447.8) (3.5) | 33.0 (106.7) (1.5) | 45.0 (172.4) (0.7) | 103.2 (395.3) (1.6) |
| | N.Fk. Coquille River | 12 | 2004-2010 | 6.9 (26.8) (2) | 26.5 (120.3) (5.8) | 8.2 (33.3) (2.3) | 7.6 (38.9) (1.3) | 17.4 (89.2) (2.9) |
| | Mid.Fk Coquille River | 13 | 2001-2010 | 12.5 (48.1) (1.2) | 53.8 (237.8) (3.3) | 15.4 (60.9) (1.4) | 17.0 (84.2) (0.7) | 38.9 (193.0) (1.5) |
| South Umpqua | Bilger Creek | 26 | 2004-2006 | 7.6 (81) (0.2) | 37.7 (436.5) (0.4) | 9.6 (104.3) (0.2) | 13.7 (167.4) (0.1) | 31.5 19384) (0.2) |
| | Clark Creek | 2 | 1994 | 1.5 (2) (1) | 4.2 (5.8) (2.6) | 1.7 (2.3) (1.1) | 0.9 (1.3) (0.5) | 2.0 (2.9) (1.2) |
| | S.Fk. Myrtle Creek | 26 | 2004-2006 | 4.5 (33) (0.7) | 17.3 (153.3) (1.6) | 5.4 (41.2) (0.7) | 5.0 (51.2) (0.3) | 11.4 (117.4) (0.7) |
| | Days Creek | 4 | 2006 | 4.3 (15) (0.5) | 16.6 (61.1) (1.2) | 5.1 (18.3 (0.5) | 4.8 (18.1) (0.2) | 10.9 (41.5) (0.5) |
| | S.Fk. Cow Creek | 1 | 1990 | 1 | 2.60 | 1.11 | 0.51 | 1.16 |

[1] Models used to convert Turbidity (T) to Suspended Solids Concentration (SSC) or Total Suspended Solids (TSS) in waterbodies crossed or proximate to the PGCP Project . Turbidity information source: Oregon Department of Environmental Quality, Laboratory Analytical Storage and Retrieval (LASAR) Web Application (Online at: http://deq12.deq.state.or.us/lasar2/default.aspx).

Model 1 (Lloyd, 1987; Lloyd et al., 1987) applicable to waters throughout Alaska: $T = 0.44\ (SSC)^{0.858}$
Model 2 (Lloyd, 1987; Lloyd et al., 1987) applicable to interior Alaskan streams: $T = 1.103\ (SSC)^{0.968}$
Model 3 (Packman et al., 1999) Rutherford Creek, King County, Washington: $\ln(TSS) = 1.32\ \ln(NTU) – 0.68$
Model 4 (Packman et al., 1999) nine streams sampled in the Puget Lowlands, Washington: $\ln(TSS) = 1.32\ \ln(NTU) + 0.15$

**Table 4.5.4-11b**
**Turbidity (NTU) Records Measured by ODEQ during ODFW Instream Construction Windows in Waterbodies Crossed by the PCGP Project and Conversion to TSS by Available Models**

| Sub-Basin | Waterbody | Number of Records | Period of Record | Mean Turbidity (NTU) (Maximum) (Minimum) | Model Conversion to TSS (mg/L) [1] | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Model 1 Mean TSS (Maximum) (Minimum) | Model 2 Mean TSS (Maximum) (Minimum) | Model 3 Mean TSS (Maximum) (Minimum) | Model 4 Mean TSS (Maximum) (Minimum) |
| South Umpqua | Bilger Creek | 10 | 2004-2006 | 0.5 (1) (0.23) | 1.2 (2.6) (0.5) | 0.6 (1.1) (0.2) | 0.2 (0.5) (0.1) | 0.5 (1.2) (0.2) |
| | South Fork. Myrtle Creek | 12 | 2004-2006 | 1.0 (1.5) (0.7) | 2.6 (4.2) (1.7) | 1.1 (1.7) (0.8) | 0.5 (0.9) (0.3) | 1.2 (2.0) (0.7) |
| | Days Creek | 2 | 2006 | 0.8 (0.9) (0.6) | 2.0 (2.4) (1.6) | 0.9 (1.0) (0.7) | 0.4 (0.5) (0.3) | 0.8 (1.0) (0.7) |

[1] See footnote to table 4.5.4-11a.

The majority of ODEQ LASAR data are turbidity (NTU) measurements taken in the field. TSS have occasionally been reported but mostly without measuring corresponding turbidity. Relationships between turbidity and suspended solid concentrations are determined on a stream-by-stream basis (Downing, 2008). However, relationships of turbidity to suspended solids have been reported for streams in Alaska (Lloyd, 1987; Lloyd et al., 1987) and streams in the Puget Lowlands (Packman et al., 1999); the models are non-linear. They produce differing estimates of TSS conversions from turbidity and conversions between models are most deviant at higher turbidity levels (see table 4.5.4-11a). At low turbidity levels (see table 4.5.4-11b), conversions of NTUs to TSS are relatively consistent. Based on these conversions, an overall background level of 2 mg/L is assumed for TSS concentrations for all streams crossed by the PCGP Project during the ODFW instream construction window. In support of that assumption, ODEQ (2010) reported that during dry seasons, background turbidity levels are relatively low and consistent in small streams throughout Oregon. A six-year ODEQ ambient monitoring study completed during dry seasons inventoried small wadeable stream sites in Oregon's eight ecoregions and found that overall median turbidity levels were approximately 1 NTU, regardless of lithology (resistant or erodible), or the degree of human disturbance. From the data provided in table 4.5.4-11b, background levels of 1 NTU would average about 2 mg/L or slightly less. A background TSS concentration of 2 mg/L during summer is also consistent with measurements reported by USGS in Myrtle Creek, Big Butte Creek, and the Rogue River mainstem during summers 1977, 1978, and 1979 (historical data provided by USDA-Forest Service).

Sediment in Streambed Substrate. ODFW (1997) conducted stream surveys throughout the state including streams within fifth-field watersheds crossed by the PCGP Project (see Habitat in Section 4.5.4.2, above). Sampled stream reaches were evaluated for 1) average percent sand, silt, and organics in the surface substrate, 2) average percent gravel in the surface substrate, 3) average percent of bedrock in the surface substrate (only reported in reaches sampled after 1999), and 4) the number of boulders ≥0.5 meter in diameter within the sampled reach. We standardized that measurement by converting numbers of boulders to boulders per meter of primary and secondary stream channel lengths. Reported values for fractions of surface area substrates were averaged for all sampled stream reaches within fifth-field watersheds crossed by the PCGP Project; averages are included in table 4.5.4-7 and table 4.5.4-8, above and in appendix X. We assumed that there are equal parts of sand, silt and organics (clay) within the reported average percent sand, silt, and organics fraction; the assumed percent of silt and clay (fine sediments) is included in table 4.5.4-12, below.

As noted, the average percent of bedrock in the surface substrate has only been reported in reaches sampled after 1999 and so summaries of the average bedrock substrate component in watersheds are incomplete or not reported. The average substrate fractions in table 4.5.4-12 were incorporated into analyses of sediment effects on salmonids without modification, even though percentages do not total 100.

We assumed that the average surface substrate fractions reported in ODFW (1997) streams surveys and averaged for all sampled streams within a fifth-field watershed are applicable to other streams in the watershed that would be crossed by the PCGP Project. Sediment generated during dry open-cut construction would most likely be surface sediments disturbed during installation and removal of isolation structures (temporary dams placed upstream and downstream from the workspace) and bypass structures (flume pipe, pump intake and exit conduits). It is not necessary to assume that surface substrate fractions are similar to excavated from the pipeline trench by a track-hoe. The use of dry open-cut construction restricts excavated sediment from entering the water column unless there is some failure of the isolation structures or seals between the stream bed and structures.

Known streambed bedrock has been determined for 30 streams proposed for crossing within the Coos, Coquille, and South Umpqua sub-basins (see table 4.5.4-3 and summarized in table 4.5.4-10) and based on Pacific Connector's Wetland and Waterbody delineation survey. If bedrock is present at the construction site, special construction techniques to ensure pipeline design depth may be required (rock hammering, drilling and hammering, and/or blasting) but only after the workspace has been isolated with temporary dams placed upstream and downstream. Dam-and-pump construction, rather than fluming, would be used at the crossing. Since presence of bedrock mostly or entirely precludes the presence of other surface substrates, other surfaces sediment fractions for streams in fifth-field watersheds in table 4.5.4-12 would not apply to streams with bedrock present.

<u>Suspended Sediment Transport</u>. In part, sediment transport in streams depends on stream channel characteristics. GeoEngineers (2011b and 2013c) developed a database on stream channel characteristics for 96 streams to be crossed by the PCGP Project (values for modeled streams in appendix Y). The streams were representative of each ecoregion and represent the range of widths/gradients and aspects of the stream crossings in each ecoregion traversed by the PCGP project. The database included (but was not limited to) the channel gradient (percent), bankfull width (feet), and streambed material (bedrock, boulder, cobble, gravel, sand, silt, mud, and clay). GeoEngineers (2012 and 2013d) developed additional stream-specific data to evaluate thermal impact on stream water temperatures due to removal of shading vegetation and increased solar loading within riparian zones during and after pipeline construction. The additional database included (but was not limited to) the wetted width (feet), bankfull width (feet), and predominant depth (feet).

**Table 4.5.4-12**
**Average Fractions of Surface Substrates by Area Reported for Sampled Stream Reaches in Fifth-Field Watersheds Crossed by the PCGP Project.** [1]

| Sub-Basin | Fifth Field Watershed | Average % Sand, Silt, Organics in Surface Substrate | Assumed % Silt and Organics in Surface Substrate [2] | Average % Gravel in Surface Substrate | Average % Bedrock in Surface Substrate [3] | Number of Boulders ≥0.5m Diameter per meter of Channel [4] |
|---|---|---|---|---|---|---|
| Coos | Coos Bay-Frontal Pacific Ocean | 60.7 | 40.5 | 11.1 | 22.7 (inc) | 0 |
| Coquille | Coquille River | 78.7 | 52.5 | 13.6 | not reported | 0 |
| | North Fork Coquille River | 33.5 | 22.3 | 25.5 | 11.2 (inc) | 0.3 |
| | East Fork Coquille River | 24.1 | 16.1 | 28.8 | 10.3 (inc) | 0.4 |
| | Middle Fork Coquille River | 22.9 | 15.3 | 24.8 | 12.6 (inc) | 0.3 |
| South Umpqua | Olalla Ck-Lookingglass Ck | 24.5 | 16.3 | 32.6 | 10.1 (inc) | 0.3 |
| | Clark Branch-S. Umpqua River | 22.8 | 15.2 | 35.3 | 10.9 (inc) | 0.2 |
| | Myrtle Creek | 39.1 | 26.1 | 24.8 | not reported | 0.1 |
| | Days Ck-S. Umpqua River | 14.4 | 9.6 | 43.8 | not reported | 0.1 |
| | Upper Cow Creek | 30.4 | 20.3 | 36.1 | not reported | 0.4 |

[1] Data from ODFW, 1997
[2] Assuming equal fractions of sand, silt, and organics
[3] Average percent of bedrock in the surface substrate has only been reported in reaches sampled after 1999
[4] Numbers of boulders counted within the reach divided by the total length (m) of primary and secondary channels within the sampled reach.

GeoEngineers data were used to estimate the stream channel cross-section shape and cross-section area. If the predominant depth was greater than ½ the bankfull width, the cross-section channel shape was assumed to be a V. If the predominant depth was less than ½ the bankfull width, the cross-section channel shape was assumed to be a trapezoid with each bank as a 1:1 slope, dependent on predominant depth. Manning's Formula (Limerinos, 1970; Arcement and Schneider, 1989) was used to estimate **Q**, the stream discharge rate (cubic feet per second):

$$\mathbf{Q = A\ (\mathit{k}/n)\ (R^{2/3})\ (S^{1/2})}$$

with estimates of **A**, the cross-sectional area of a stream (square feet or square meters), **R**, the hydraulic radius (feet or meters, where **R = A/P**, and **P** is the wetted perimeter in feet or meters), **S**, the slope of channel (vertical feet per horizontal feet), the constant ***k*** equals 1.486 if English units are used but ***k*** equals 1 with metric units, and n is Manning's roughness coefficient. Values reported by GeoEngineers, 2011b and 2012 were used to estimate **A** and **R** and **S** (where a 100 percent gradient = 1). Manning's **n** was estimated from various sources (Chow, 1959; Limerinos, 1970; Arcement and Schneider, 1989), primarily based on streambed materials and streambank conditions reported by GeoEngineers (2011b) and included in appendix Y for each stream modeled. Stream flow rate or discharge rate, **Q**, is related to cross-sectional area (**A**) and average streamflow velocity ($\mathbf{V_A}$):

$$\mathbf{Q = A\ V_A}$$

Estimates of **Q** derived with Manning's Formula are assumed to be measures of the carrying capacity (bankfull flow) of a particular channel section (Arcement and Schneider, 1989). Carrying capacities of a channel section are assumed to occur during periods of high flow, generally during winter months in the project area. Where possible, estimates of **Q** were compared to estimates of maximum instantaneous flows that could occur once every 2 years through once every 500 years, using the USGS web-based GIS hydrologic regression tool, StreamStats (see http://water.usgs.gov/osw/ streamstats/index.html). Though not every waterbody crossed by the PCGP Project has been modeled in StreamStats, those that have provided peak flow estimates (cubic feet per second, or cfs) within the same orders of magnitude (generally within the range of maximum peak flows every 2 years through peak flows every 500 years) as estimates of **Q** derived from application of Manning's Formula to the stream data compiled by GeoEngineers (2011b and 2012).

Sediment particles will be transported distances downstream (**L**, in feet or meters) based on 1) the particle size and settling velocity (**$V_S$**, - inches per second, micrometers per second – in water at 20$^{o}$C, see for example the Wentworth Grain Size Chart, USGS, 2003), 2) the average streamflow velocity, and 3) the average depth of flow (**D**, feet or meters) downstream, using the following equation (Trow Equation, see Harper and Trettel, 2002);'

$$\mathbf{L = (D\ V_A) / V_S}$$

For illustrative purposes, estimates of transport distances (**L** in feet) for various sediment particles ranging in sizes from clay to coarse gravel were provided in table 4.5.3-7, Section 4.5.3.3 under SONCC coho, for three of the waterbodies that would be crossed by the PCGP Project. Particle sizes deleterious to salmonids (250 µm or less in the models of Newcombe and Jensen, 1996, above) could settle out of suspension less than 1 meter (0.2 feet) downstream (e.g., medium sand in low flows for Tributary to Catching Creek in examples, below). Alternatively, particles could remain suspended for 200 km (100 miles) or more (very fine silt during high flows in Willis Creek).

<u>Seasonal Discharge</u>. Pipeline construction across waterbodies will occur during ODFW (2008a) instream construction windows (see discussion, above). Hydrographs of monthly discharges were provided above in Section 4.5.4.2 for the Coos Sub-basin (see figure 4.5-16); Coquille Sub-basin (see figure 4.5-17), and South Umpqua Sub-basin (see figure 4.5-18). The hydrographs show peak seasonal flows during winter months, December through February. Lowest flows occur during summer months, coinciding with the ODFW construction windows. Assuming that high winter stream flows correspond to the carrying capacities of channel sections (Arcement and Schneider, 1989), instream flows during ODFW construction windows would be some fraction of the winter flows. The fractions, included in table 4.5.4-13a and table 4.5.4-13b as a percent of winter high flow during the construction window, have been estimated for waterbodies in each of the four sub-basins based on the most recent 10-year record within USGS hydrograph data sets. Stream flows during construction windows were estimated for waterbodies in each sub-basin by reducing stream depths and affected parameters in Manning's Formula to achieve an average stream discharge rate, **Q**, that is the same as the percent (by mid-point) of high flows in table 4.5.4-13a and table 4.5.4-13b for streams in each sub-basin.

**Table 4.5.4-13a**
**Recorded High Flows During Winter and Average Flows During the ODFW Instream Construction Window in Hydrographic Data in Four Sub-basins Crossed by the PCGP Project.**

| Sub-basin | Hydrograph | High Flow (cfs) (Month) | Instream Construction Window | Average Flows (cfs) During Window | Percent of High Flow During Window | Percent Mid-Point |
|---|---|---|---|---|---|---|
| Coos | Pony Creek [1] | 17 (Feb) | Jul 1-Sep15 | 0.01 | 0.03 | 1.4 |
| | W.Fk. Millacoma River | 489 (Jan) | Jul 1-Sep15 | 13.7 | 2.8 | |
| Coquille | Mid.Fk. Coquille River | 2,220 (Feb) | Jul 1-Sep15 | 40.5 | 1.8 | 2.0 |
| | N.Fk. Coqulle River | 630 (Dec) | Jul 1-Sep15 | 14.4 | 2.3 | |
| South Umpqua | N. Myrtle Creek | 182 (Dec) | Jul 1-Sep15 | 4.8 | 2.6 | 2.8 |
| | S. Umpqua River | 6,862 (Dec) | Jul 1-Aug 31 | 196 | 2.9 | |

[1] Ten-year flows in Pony Creek were evaluated from 1992 to 2001 rather than from the most recent 10-years, 1999 to 2008, because of releases from Upper Pony Creek Reservoir since completion of the new dam in 2001.

**Table 4.5.4-13b**
**Recorded High Flows During Winter and Average Peak Flows During the ODFW Instream Construction Window in Hydrographic Data in Four Sub-basins Crossed by the PCGP Project.**

| Sub-basin | Hydrograph | High Flow (cfs) (Month) | Instream Construction Window | Average Peak Flows (cfs) During Window | Percent of High Flow During Window | Percent Mid-Point |
|---|---|---|---|---|---|---|
| Coos | Pony Creek [1] | 17 (Feb) | Jul 1-Sep15 | 0.14 | 0.8 | 9.2 |
| | W.Fk. Millacoma River | 489 (Jan) | Jul 1-Sep15 | 85.5 | 17.5 | |
| Coquille | Mid.Fk. Coquille River | 2,220 (Feb) | Jul 1-Sep15 | 132.3 | 6.0 | 8.4 |
| | N.Fk. Coqulle River | 630 (Dec) | Jul 1-Sep15 | 67.8 | 10.8 | |
| South Umpqua | N. Myrtle Creek | 182 (Dec) | Jul 1-Sep15 | 15.1 | 8.3 | 8.0 |
| | S. Umpqua River | 6,862 (Dec) | Jul 1-Aug 31 | 527.1 | 7.7 | |

[1] Ten-year flows in Pony Creek were evaluated from 1992 to 2001 rather than from the most recent 10-years, 1999 to 2008, because of releases from Upper Pony Creek Reservoir since completion of the new dam in 2001.

For example, 10-year average stream flows in the South Umpqua Sub-basin during the ODFW instream construction window are 2.8 percent of high winter flows (see table 4.5.4-13a), based on discharge data for North Myrtle Creek and South Umpqua River during December (see figure 4.5-18). Stream depths for all waterbodies within the South Umpqua Sub-basin were reduced by the same proportion. Reduced stream depths generated reduced values of **A**, **P**, and **R** in Manning's Formula. Estimates of **Q** (and $\mathbf{V_A}$) were likewise reduced for all streams in the sub-basin and were compared to **Q** generated during high winter flows. Reduction of stream depths by iteration was continued until the percent of high winter flows by average flows during the construction window was 2.8 percent for waterbodies crossed by the PCGP Project.

The same procedure was used to evaluate stream discharge rates during average peak flows that were documented in the sub-basins during instream construction windows. Peak flows were obtained from maximum daily flow data during the instream construction window and averaged for the most recent 10-year period (see table 4.5.4-13b).

<u>Sediment Generated During Pipeline Construction</u>. Modeled concentrations of TSS produced in waterbodies during wet open-cut pipeline construction were developed from empirical data collected during construction across 15 to 19 streams in North America (Reid et al., 2004). Models were developed to predict mean and peak TSS concentrations immediately downstream of pipeline construction sites. Models included TSS generated by all construction activities and by trenching, pipe lowering, and backfilling. The models predicting mean TSS generated by all activities (including trenching, pipe lowering, and backfilling) and mean TSS generated by

trenching had the highest correlation coefficients (Reid et al., 2004). The model predicting mean TSS ($C_{av}$) by all construction activities is:

$$C_{av} = 1.5 \times 10^6 \; U^{1.09} \, d_{50}^{0.95} \, P_f^{0.35} \, q^{-1}$$

where $U$ = mean flow velocity (m per second) at the crossing location during the construction period and is assumed to be equivalent to $V_A$ derived using Manning's Formula; $d_{50}$ = the median sediment size (m) of the excavated material by weight; $P_f$ = percentage of fines (silt and clay) in the excavated material (%) and is assumed to equal the percent of silt and organics in surface substrates for all streams within a given fifth-field watershed in the Coos, Coquille, and South Umpqua sub-basins tabulated in table 4.5.4-12; $q$ = the width adjusted stream flow rate where $q = Q/B$, ($m^2$ per second) with $B$ = the watercourse width (m) adjusted for a particular flow rate and $Q$ = stream flow rate ($m^3$ per second) derived using Manning's Formula. In these simulations, **Q** is related to **B** through Manning's Formula and as **B** increases numerically, **Q** also increases but at a faster numerical rate. If all other model parameters are held constant in the Reid et al. (2004) model, increased width adjusted stream flow rate, $q$ (due high flow, **Q**, and proportionally smaller watercourse widths, $B$) will decrease the TSS concentration ($C_{av}$) because $q$ is factored as $q^{-1}$ or $1/q$ in the equation. Conversely, lower $q$ values will generate higher $C_{av}$ with all other parameters in the equation held constant.

Available data do not appear suitable to estimate values for $d_{50}$. In these analyses it is assumed that $d_{50}$ = 0.00025 m (250 µm) since particles that size or less adversely affect salmonids and other fish in the evaluation procedures by Newcombe and Jensen (1996), introduced above and applied below.

In addition to developing predictive models of TSS concentrations generated by wet-open cut pipeline construction, Reid et al. (2004) measured TSS downstream from 12 flumed pipeline crossings and 23 dam-and-pump crossings (dry-open cut or isolated pipeline construction crossings) with comparisons to 11 wet open-cut construction crossings. By accounting for flow, background TSS concentrations, sampling distance downstream, and duration of construction, Reid et al. determined that mean TSS concentrations generated during dry open-cut construction for fluming were 3.7 percent of the wet open-cut concentrations and 0.85 percent of the wet open-cut concentrations for dam-and-pump construction.

Reid et al. (2004) also predicted peak TSS generated by all construction activities. The model predicting peak TSS ($C_p$) by all activities is:

$$C_p = 5.7 \times 10^5 \; U^{1.86} \, d_{50}^{0.57} \, P_f^{1.2} \, q^{-1}$$

The model has the same component descriptions and assumptions stated above for predicting the average TSS concentration ($C_{av}$). However, the model showed overall low explanatory value (low coefficient of multiple correlation. low multiple $r^2$) and a relatively poor predictor of peak TSS (Reid et al., 2004) and is not used in these analyses.

Short-term peak sediment releases occurred during installation and removal of isolation structures (sand bags, jersey barriers, other dam structures) and bypass components (flume, pumps). Dam-and-pump construction is a particularly effective technique to cross smaller waterbodies. The larger TSS concentrations produced during fluming were mostly related to backfilling the trench, poor containment of ditch water, poor dam seals, and longer construction times associated with fluming larger waterbodies (Reid et al., 2004).

If there was a failure of isolation structures during either type of dry open-cut construction, it is assumed that the TSS generated during the failure would be similar to TSS generated during wet open-cut construction, which is included in table 4.5.4-14. Estimates of TSS concentrations produced during pipeline construction under average and peak low flow conditions are expected to be highly variable primarily due to the wide range in silt and organic fractions in surface substrates which vary from 6.9 percent in Days Creek-South Umpqua River to 52.5 percent in Coquille River fifth field watersheds (see table 4.5.4-12). Estimated average TSS concentrations produced during fluming and dam-and pump construction are equal to or slightly above background TSS estimates (2 mg/L) between 50 and 100 meters downstream from construction sites (see table 4.5.3-14).

Estimated Downstream Distance of Suspended Sediment. Ritter (1984) provided two models (minor stream crossings and major stream crossings) for estimating concentrations of suspended sediments ($C_X$, as mg/L) some distance (x) downstream from a pipeline trench being constructed across a waterbody. The model for minor crossings was based on average stream depth of 15.2 cm (6 inches) and the model for major crossings was based on average depth of 91 cm (36 inches). The mid-point between the two depths, 53.1 cm (21 inches), is assumed to differentiate minor from major streams.

Ritter's model for downstream sediment transport distance during construction across minor streams, with complete mixing of sediment particles, estimates the concentration downstream $\mathbf{C_X}$ by:

$$\mathbf{C_X = C_O\, e^{-(vs/d)(x/u)}}$$

Where $\mathbf{C_O}$ (mg/L) is the initial concentration of suspended solids in the water column at the trenching site, **vs** = the settling velocity (m/second) of sediment particles, **d** = stream depth (m), **u** = stream current velocity (m/second), and **x** = distance (m) downstream.

Ritter's model for downstream sediment transport distance during construction across a major stream assumes complete mixing of sediment particles within one-half the stream width (assuming a horizontal spread of the sediment plume as 0.5 cm/sec). The concentration downstream $\mathbf{C_X}$ is estimated by:

$$\mathbf{C_X = \frac{C_O}{0.5(x)(d)}\, e^{-(vs/(0.5d))(u/x)}}$$

Flows expected during pipeline construction within the ODFW instream window limit the application of the major stream crossing model. Coos River and South Umpqua River would be classified as major streams at the time of construction but would not be crossed using dry open cut construction and are not included in the sediment entrainment and transport analysis provided in table 4.5.4-14.

Summary. TSS concentrations are essential to evaluating project-related effects on salmoninds (see section below, Suspended Sediment Effects on Fish). Estimates of TSS concentrations generated by wet open-cut and dry open-cut (flume and dam-and-pump) were modeled for 36 waterbodies within the Coos Sub-basin, 24 waterbodies within the Coquille Sub-basin, and 21 waterbodies within the South Umpqua Sub-basin that would be crossed by the PCGP Project. Concentrations of TSS generated by wet open-cut construction were estimated for each of the waterbody crossing sites (see table 4.5.4-14) and adjusted, depending on use of flumed dry open-cut or dam-and-pump dry open-cut construction. Concentrations of TSS at 10, 50, and 100 meters downstream were based on Ritter's (1984) equations. Fractions of gravel, sand, silt and organics (see table 4.5.4-12) were assumed to be characteristic for each stream within the sub-basin. Average low flows were assumed (see table 4.5.4-13a and example in text) to occur during pipeline construction and used in the Reid et al. (2004) model predicting mean TSS ($\boldsymbol{C_{av}}$) generated by all pipeline instream construction activities. The $\boldsymbol{C_{av}}$ from the Reid et al. model is equivalent to $\mathbf{C_O}$ in the Ritter model (the initial concentration of suspended solids in the water column at the trenching site). Average low flows were also used for estimating concentrations, $\mathbf{C_x}$, at three distances downstream using Ritter's (1984) model for minor streams. Average peak flows during the instream construction window (see table 4.5.4-13b) were also used to estimate concentrations ($\mathbf{C_x}$) at the three distances downstream with the same $\mathbf{C_O}$ as for average low flows. The background TSS concentration was assumed to be 2 mg/L for all streams crossed by the PCGP Project during the ODFW instream construction window (see table 4.5.4-11b and associated discussion).

Estimated TSS concentrations downstream from flumed dry open-cut construction ranged from less than 55 mg/L to 2 mg/L (see table 4.5.4-14). Estimated TSS concentrations downstream from dam-and-pump dry open-cut construction range from about 14 mg/L to 2 mg/L. Those ranges of TSS concentrations were used in Newcombe and Jensen's (1996) models estimating risks to salmonids and non-salmonids that would be associated with variable TSS concentrations and variable durations of exposure. The durations of exposure to TSS generated during dry open-cut construction at each of the 81 waterbodies simulated in table 4.5.4-14 are assumed to be similar to those described by Reid et al. (2004) occurring during installation and removal of isolation structures (temporary dams placed upstream and downstream from the workspace) and bypass structures (flume pipe, pump intake and exit conduits). Construction-related problems may occur and my cause elevated TSS concentrations downstream and for longer periods of time, including (Reid et al., 2004): 1) pump failure or insufficient capacity, 2) dam or flume failure, 3) poor dam seal, 4) poor containment of pumped ditch water, 5) inadequate maintenance of sediment control measures. Also, construction across larger waterbodies requires longer periods of instream work, large volumes of stream flow and trench dewatering, and risks of increased sediment release.

Estimated average TSS concentrations produced during fluming and dam-and-pump construction are equal to or near background TSS estimates (2 mg/L) at 10, 50, and 100 meters downstream from construction sites (see table 4.5.4-14 and appendix Y). However, TSS concentrations assumed to occur during failure of isolation structures could be higher.

**Table 4.5.4-14**

**Estimates of Mean Total Suspended Solid (TSS) Concentrations Generated within Fifth Field Watersheds by Wet Open-Cut and Dry Open-Cut (Flume, Dam-and-Pump) Pipeline Construction Across Waterbodies Potentially Occupied by Oregon Coast Coho within the Coos, Coquille, and South Umpqua Sub-Basins during Average Low Flows and Average Peak Flows Expected Within the ODFW Instream Construction Window. TSS Concentrations, Averaged for all Stream Crossings within Fifth-Field Watersheds, Have Been Estimated at 10, 50 and 100 meters Downstream from Construction Sites.**

| Sub-basins and 5th Field Watersheds | Number of Simulated Waterbody Crossings [1] | Estimated Mean TSS (mg/L) at Construction Site (Standard Error) | | | Mean TSS (mg/L) at 10 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 50 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 100 meters Downstream [5] (Standard Error) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wet Open Cut [2] | Dry Open Cut (Flume) [3] | Dry Open Cut (Dam-Pump) [4] | Wet Open Cut Low Peak Flows [6] | Dry Open Cut Flume Low Peak Flows[7] | Dry Open Cut Dam-Pump Low Peak Flows[8] | Wet Open Cut Low Peak Flows[6] | Dry Open Cut Flume Low Peak Flows [7] | Dry Open Cut Dam-Pump Low Peak Flows[8] | Wet Open Cut Low Peak Flows[6] | Dry Open Cut Flume Low Peak Flows[7] | Dry Open Cut Dam-Pump Low Peak Flows [8] |
| **Coos Sub-basin** | | | | | | | | | | | | | |
| Coos Bay-Frontal Pacific Ocean | 36 | 2,303 (202.8) | 88 (7.5) | 22 (1.7) | 875 (52.1) | 34 (1.9) | 9 (0.4) | 707 (35.2) | 28 (1.3) | 8 (0.3) | 619 (30.2) | 25 (1.1) | 7 (0.3) |
| | | | | | 1,202 (77.7) | 47 (2.9) | 12 (0.7) | 1,030 (70.0) | 40 (2.6) | 11 (0.6) | 961 (64.3) | 38 (2.4) | 10 (0.5) |
| **Coquille Sub-basin** | | | | | | | | | | | | | |
| Coquille River | 4 | 5,004 (57.9) | 188 (2.2) | 45 (0.5) | 2,394 (76.7) | 91 (2.9) | 22 (0.7) | 1,813 (172.3) | 69 (6.4) | 17 (1.5) | 1,471 (183.7) | 57 (6.8) | 15 (1.6) |
| | | | | | 2,793 (153.3) | 106 (5.7) | 26 (1.3) | 2,495 (61.7) | 95 (2.3) | 23 (0.5) | 2,367 (85.7) | 90 (3.2) | 22 (0.7) |
| North Fork Coquille River | 4 | 517 (107.8) | 21 (4.0) | 6 (0.9) | 124 (18.2) | 7 (0.7) | 3 (0.2) | 110 (17.8) | 6 (0.7) | 3 (0.2) | 101 (16.8) | 6 (0.6) | 3 (0.1) |
| | | | | | 168 (21.1) | 8 (0.8) | 3 (0.2) | 136 (18.9) | 7 (0.7) | 3 (0.2) | 126 (18.3) | 7 (0.7) | 3 (0.2) |
| East Fork Coquille River | 8 | 279 (33.8) | 12 (1.3) | 4 (0.3) | 46 (3.9) | 4 (0.1) | 2 (0.0) | 40 (4.1) | 3 (0.2) | 2 (0.0) | 36 (3.8) | 3 (0.1) | 2 (0.0) |
| | | | | | 59 (5.1) | 4 (0.2) | 2 (0.0) | 49 (3.9) | 4 (0.1) | 2 (0.0) | 47 (3.9) | 4 (0.1) | 2 (0.0) |
| Middle Fork Coquille River | 8 | 217 (28.6) | 10 (1.1) | 4 (0.2) | 35 (3.7) | 3 (0.1) | 2 (0.0) | 31 (3.8) | 3 (0.1) | 2 (0.0) | 28 (3.5) | 3 (0.1) | 2 (0.0) |
| | | | | | 47 (4.7) | 4 (0.2) | 2 (0.0) | 38 (3.9) | 3 (0.1) | 2 (0.0) | 36 (3.7) | 3 (0.1) | 2 (0.0) |

| Sub-basins and 5th Field Watersheds | Number of Simulated Waterbody Crossings [1] | Estimated Mean TSS (mg/L) at Construction Site (Standard Error) | | | Mean TSS (mg/L) at 10 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 50 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 100 meters Downstream [5] (Standard Error) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Wet Open Cut [2]** | **Dry Open Cut (Flume) [3]** | **Dry Open Cut (Dam-Pump) [4]** | **Wet Open Cut** Low Peak Flows [6] | **Dry Open Cut Flume** Low Peak Flows [7] | **Dry Open Cut Dam-Pump** Low Peak Flows [8] | **Wet Open Cut** Low Peak Flows [6] | **Dry Open Cut Flume** Low Peak Flows [7] | **Dry Open Cut Dam-Pump** Low Peak Flows [8] | **Wet Open Cut** Low Peak Flows [6] | **Dry Open Cut Flume** Low Peak Flows [7] | **Dry Open Cut Dam-Pump** Low Peak Flows [8] |
| **South Umpqua Sub-basin** | | | | | | | | | | | | | |
| Olalla Creek-Lookingglass Creek | 8 | 186 (26.9) | 9 (1.0) | 4 (0.2) | 36 (2.8) | 3 (0.1) | 2 (0.0) | 29 (2.5) | 3 (0.1) | 2 (0.0) | 27 (2.8) | 3 (0.1) | 2 (0.0) |
| | | | | | 43 (3.8) | 4 (0.1) | 2 (0.0) | 37 (3.0) | 3 (0.1) | 2 (0.0) | 34 (2.5) | 3 (0.1) | 2 (0.0) |
| Clark Branch-South Umpqua River | 1 | 113 (N/A) | 6 (N/A) | 3 (N/A) | 25 (N/A) | 3 (N/A) | 2 (N/A) | 21 (N/A) | 3 (N/A) | 2 (N/A) | 19 (N/A) | 3 (N/A) | 2 (N/A) |
| | | | | | 34 (N/A) | 3 (N/A) | 2 (N/A) | 25 (N/A) | 3 (N/A) | 2 (N/A) | 24 (N/A) | 3 (N/A) | 2 (N/A) |
| Myrtle Creek | 5 | 558 (67.5) | 23 (2.5) | 7 (0.6) | 150 (17.1) | 7 (0.6) | 3 (0.1) | 136 (16.0) | 7 (0.6) | 3 (0.1) | 127 (15.0) | 7 (0.6) | 3 (0.1) |
| | | | | | 183 (22.8) | 9 (0.8) | 4 (0.2) | 150 (18.5) | 8 (0.7) | 3 (0.2) | 143 (17.3) | 7 (0.6) | 3 (0.1) |
| Days Creek-South Umpqua River | 3 | 37 (17.7) | 3 (0.7) | 2 (0.2) | 11 (3.6) | 2 (0.1) | 2 (0.0) | 6 (0.6) | 2 (0.0) | 2 (0.0) | 5 (0.5) | 2 (0.0) | 2 (0.0) |
| | | | | | 19 (8.6) | 3 (0.3) | 2 (0.1) | 11 (4.2) | 2 (0.2) | 2 (.0) | 8 (1.9) | 2 (0.1) | 2 (0.0) |
| Upper Cow Creek | 4 | 386 (12.3) | 16 (0.5) | 5 (0.1) | 86 (2.6) | 5 (0.1) | 3 (0.0) | 75 (2.0) | 5 (0.1) | 3 (0.0) | 72 (3.2) | 5 (0.1) | 3 (0.0) |
| | | | | | 105 (4.2) | 6 (0.2) | 3 (0.0) | 88 (2.9) | 5 (0.1) | 3 (0.0) | 81 (1.9) | 5 (0.1) | 3 (0.0) |

| | | Estimated Mean TSS (mg/L) at Construction Site (Standard Error) | | | Mean TSS (mg/L) at 10 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 50 meters Downstream [5] (Standard Error) | | | Mean TSS (mg/L) at 100 meters Downstream [5] (Standard Error) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-basins and 5th Field Watersheds** | **Number of Simulated Waterbody Crossings [1]** | **Wet Open Cut [2]** | **Dry Open Cut (Flume) [3]** | **Dry Open Cut (Dam-Pump) [4]** | **Wet Open Cut<br>Low Peak Flows [6]** | **Dry Open Cut Flume<br>Low Peak Flows[7]** | **Dry Open Cut Dam-Pump<br>Low Peak Flows[8]** | **Wet Open Cut<br>Low Peak Flows[6]** | **Dry Open Cut Flume<br>Low Peak Flows [7]** | **Dry Open Cut Dam-Pump<br>Low Peak Flows[8]** | **Wet Open Cut<br>Low Peak Flows[6]** | **Dry Open Cut Flume<br>Low Peak Flows[7]** | **Dry Open Cut Dam-Pump<br>Low Peak Flows [8]** |

Assumptions:

[1] All simulated waterbodies are assumed to have depths ≤ 53 cm during ODFW (2008a) instream construction windows and have been assumed to be Minor Waterbodies (see Ritter, 1984). No waterbodies with bedrock substrates are included. No waterbodies that are adjacent to but not crossed by the pipeline are included.

[2] Based on the Mean TSS model generated by <u>All Activities</u> associated with wet open-cut construction, using variable $P_f$ , the percentage of silt and clay fines materials in the watershed and $d_{50}$ = 0.25 mm or 250 µm (assumed median sediment size of the excavated material by weight) (Reid et al., 2004).

[3] TSS generated by Flumed Dry Open-Cut construction were assumed to be 3.7 percent of concentrations generated by Wet Open-Cut construction (data from Reid et al., 2004).

[4] TSS generated by Dam-and-Pump Dry Open-Cut construction were assumed to be 0.85 percent of concentrations generated by Wet Open-Cut construction (data from Reid et al., 2004)

[5] Concentrations of TSS at 10, 50 and 100 downstream were estimated for fractions of gravel, sand, silt, and organics characteristic in substrates of streams in fifth-field watersheds and settling velocities: gravel (1.6 cm diameter), vs = 90 cm/s; sand (0.025 cm diameter), vs = 3 cm/s; silt (0.0016 cm diameter), vs = 0.023 cm/s; clay (0.0004 cm diameter), vs = 0.0014 cm/s. Concentrations were added to the assumed background level of 2 mg/L.

[6] Instream average low flows and average peak flows at the time of construction (within the ODFW, 2008b recommended in-water construction periods) are assumed to be some percent of the carrying capacity flows for all of the evaluated channel sections within a specific Sub-basin; percent reduction during average flows; percent reduction during average peak flows. Sediment concentrations (Cx) at downstream distances in minor waterbody crossings (Ritter, 1984) were computed from the initial concentrations (Co) estimated by the Mean TSS model generated by <u>All Activities</u> by Reid et al., 2004. .

[7] Initial concentrations (Co) of TSS generated by Flumed Dry Open-Cut construction were assumed to be 3.7 percent of concentrations generated by Wet Open-Cut construction (Reid et al., 2004)

[8] Initial concentrations (Co) of TSS generated by Dam-and-Pump Dry Open-Cut construction were assumed to be 0.85 percent of concentrations generated by Wet Open-Cut construction (Reid et al., 2004)

Suspended Sediment Effects on Coho Salmon. Newcombe and Jensen (1996) provide four additional models that have not been applied to analysis of impact of sediment to fish in the PCGP Project area because fish species for which the models were developed are not expected in the habitats for which the two models would be applicable (see species-model associations in Table 2, Newcombe and Jensen, 1996). Model 2 (adult salmonids) does not apply to coho salmon (Newcombe and Jensen, 1996) and Model 4 (eggs and larvae of salmonids and non-salmonids) does not apply to effects by this project because instream construction will not coincide with coho spawning or periods of egg incubation-fry emergence (see figure 4.5-13, above). Model 5 applies to adult estuarine non-salmonids that are particularly sensitive to effects of suspended sediments and Model 6 applies primarily to adult warmwater centrarchid species, eg. sunfish).

Input for each of the four models includes TSS concentration (mg/L) and duration (hours) of exposure to the suspended sediments. Each model has the form:

$$\mathbf{z = a + b(logex) + c(logey)}$$

where **z** = severity-of-ill-effects (SEV) score, **x** = duration of exposure in hours, **y** = concentration of suspended sediment in mg/L. Constants **a**, **b** and **c** were empirically derived for each model (see Table 3, Newcombe and Jensen, 1996):

Output from each model is severity-of-ill-effects (SEV) score ranging from 0 to 14 where SEV of 0 indicates no effects, SEV between 1 and 3 indicates behavioral effects, SEV from 4 to 8 indicates sublethal effects, and SEV from 9 through 14 indicate lethal and paralethal effects (see Table 1 in Newcombe and Jensen, 1996).

4) Behavioral Effects SEV scores: 1 = Alarm reaction; 2 = Abandonment of cover; 3 = Avoidance response
5) Sublethal Effects SEV scores: 4 = Short-term reduction in feeding rates and/or feeding success; 5 = Minor physiological stress (increase coughing rate and/or increased respiration rate); 6 = Moderate physiological stress; 7 = Moderate habitat degradation and/or impaired homing; 8 = Indications of major physiological stress (long-term reduction in feeding rate and/or feeding success, poor condition)
6) Lethal and Paralethal Effects SEV scores: 9 = Reduced growth rate and/or delayed hatching and/or reduced fish density; 10 = 0 to 20% mortality and/or increased predation and/or moderate to severe habitat degradation. 11= >20 – 40% mortality (SEV scores exceeding 11 predict increased mortality rates).

Input for each of the two models, Model 1, juvenile and adult salmonids and Model 3, juvenile salmonids, includes TSS concentration (mg/L) and duration (hours) of exposure to the concentration. Output from each model is a severity-of-ill-effects (SEV) score ranging from 0 to 14, as (see Table 1 in Newcombe and Jensen, 1996).

Reid et al., (2002) reported two flumed crossings required 23 and 51 hours of instream work while durations of four dam-and-pump crossings ranged from 9 to 41 hours. Reid et al., (2004) reported that flumed crossings averaged 64 hours of instream work (with standard error of 14.1 hours) and dam-and-pump crossing averaged 37.8 hours of instream work (with standard error of 8.4 hours). Based on these data, the assumed range of time required for flumed crossings and dam-and-pump crossings is the mean ± 2 standard errors reported for each technique by Reid et al. (2004). Consequently, estimated durations for fluming range from 36 to 96 hours (see table

4.5.4-15) and for dam-and-pump the range is from 20 to 56 hours (see table 4.5.4-16). If there is a failure of the isolation dams/structures, the durations of maximum TSS concentrations that would be similar to a wet open-cut crossing are assumed to last from 1 hour to 24 hours; the shorter durations would indicate repair of the failed structures while the longer durations would indicate completing the construction by wet open-cut.

Effects to salmonid life stages due to flumed dry open-cut construction across waterbodies that do not have bedrock substrates are included in table 4.5.4-15. The mean TSS concentrations generated during flumed pipeline construction across all waterbodies within the Coos Sub-basin is estimated at 12 mg/L (with standard error = 0.89), at 6 mg/L (with standard error = 1.58) in the Coquille Sub-basin, and the mean is estimated at 3 mg/L (with standard error = 0.22) in the South Umpqua Sub-basin 10 meters downstream from construction sites. During average peak flows, mean TSS concentration generated during flumed pipeline construction within the Coos Sub-basin is estimated at 29 mg/L (with standard error = 1.41), at 12 mg/L (standard error = 4.15) in the Coquille Sub-basin, and is estimated at 4 mg/L (with standard error = 0.36) in the South Umpqua Sub-basin; all estimates are for 10 meters downstream from the construction sites. All flumed construction is assumed to be completed between 36 and 96 hours (see above).

Similarly, effects to salmonid life stages due to dam-and-pump dry open-cut construction across waterbodies that do not have bedrock substrates are included in table 4.5.4-16. The mean TSS concentrations generated during dam-and-pump pipeline construction across all waterbodies within the Coos Sub-basin is estimated at 4 mg/L (with standard error = 0.20), at 3 mg/L (with standard error = 0.36) in the Coquille Sub-basin, and the mean is estimated at 4 mg/L (with standard error = 0.05) in the South Umpqua Sub-basin 10 meters downstream from construction sites. During average peak flows, mean TSS concentration generated during dam-and-pump pipeline construction within the Coos Sub-basin is estimated at 8 mg/L (with standard error = 0.32), at 4 mg/L (standard error = 0.95) in the Coquille Sub-basin, and the estimated mean is 2 mg/L (with standard error = 0.08) in the South Umpqua Sub-basin; all estimates are for 10 meters downstream from the construction sites. All dam-and-pump construction is assumed to be completed between 20 and 56 hours (see above).

Effects to Oregon Coast coho juveniles and adults due to either of the flumed dry open-cut construction and dam-and-pump dry open-cut construction procedures for waterbodies that do not have bedrock substrates are included in table 4.5.4-15 and table 4.5.4-16, respectively, for expected low flow and potential peak flow conditions during the ODFW (2008a) instream construction windows. Results from applying Model 1 for juvenile and adult coho indicates SEV scores for durations of exposure to the TSS concentrations of 20 mg/L or less would range from SEV = 5 (minor physiological stress-increase coughing rate and/or increased respiration rate), to SEV = 6 (moderate physiological stress), and SEV = 7 (moderate habitat degradation and/or impaired homing) which includes the upper 95% confidence intervals (Newcombe and Jensen, 1996). Peak flows produced TSS levels higher than average low flows, especially in the Coos and Coquille sub-basins, and would generate similar SEV scores in table 4.5.4-15 and table 4.5.4-16. All expected responses by adult and juvenile salmonids to TSS produced during fluming or dam-and-pump 10 meters or more downstream would be classified as sublethal, whether during low flows or peak flows.

**Table 4.5.4-15**

**Application of Three Models for Estimating Severity of Effects to Oregon Coast Coho 10 Meters Downstream Due to TSS Concentrations Produced by Flumed Pipeline Construction Ranging from 36 to 96 hours During Low Flow and Peak Flow Conditions**

| Model Number (and particle size) | Exposure (hours) | Average Low Flows: TSS Concentration (mg/L) | Average Low Flows: Modeled Severity of Effects (SEV) [1] | Average Low Flows: With Upper SEV (95% CI) [2] | | Average Peak Flows: TSS Concentration (mg/L) | Average Peak Flows: Modeled Severity of Effects (SEV) [1] | Average Peak Flows: With Upper SEV (95% CI) [2] |
|---|---|---|---|---|---|---|---|---|
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 36 | 20 | 5 | 6 | | 55 | 6 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 48 | 20 | 6 | 6 | | 55 | 6 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 72 | 20 | 6 | 6 | | 55 | 7 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 96 | 20 | 6 | 7 | | 55 | 7 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 36 | 20 | 5 | 6 | | 55 | 6 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 48 | 20 | 6 | 6 | | 55 | 6 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 72 | 20 | 6 | 7 | | 55 | 7 | 7 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 96 | 20 | 6 | 7 | | 55 | 7 | 7 |
| | | 2 | 4 | 6 | | 2 | 4 | 6 |

[1] SEV scale of effects to fish (see Table 1 in Newcombe and Jensen, 1996) within range of model outputs:
Behavioral Effects: 2 = Abandonment of cover; 3 = Avoidance response
Sublethal Effects: 4 = Short-term reduction in feeding rates and/or feeding success; 5 = Minor physiological stress (increase coughing rate and/or increased respiration rate); 6 = Moderate physiological stress; 7 = Moderate habitat degradation and/or impaired homing; 8 = Indications of major physiological stress (long-term reduction in feeding rate and/or feeding success, poor condition)
Lethal and Paralethal Effects: 9 = Reduced growth rate and/or delayed hatching and/or reduced fish density; 10 = 0 to 20% mortality and/or increased predation and/or moderate to severe habitat degradation. 11= >20 – 40% mortality.

[2] Upper 95% confidence intervals on SEV scores (rounded to nearest integer) were approximated from values in Figures 1, 2, 3, and 4 in Newcombe and Jensen, 1996.

**Table 4.5.4-16**
**Application of Three Models for Estimating Severity of Effects to Oregon Coast Coho 10 Meters Downstream Due to TSS Concentrations Produced by Dam-and-Pump Pipeline Construction Ranging from 20 to 56 hours During Low Flow and Peak Flow Conditions**

| Model Number (and particle size) | Exposure (hours) | Average Low Flows | | | | Average Peak Flows | | |
|---|---|---|---|---|---|---|---|---|
| | | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] | | TSS Concentration (mg/L) | Modeled Severity of Effects (SEV) [1] | With Upper SEV (95% CI) [2] |
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 20 | 6 | 4 | 5 | | 14 | 5 | 5 |
| | | 2 | 3 | 4 | | 2 | 3 | 4 |
| | 32 | 6 | 4 | 5 | | 14 | 5 | 6 |
| | | 2 | 4 | 4 | | 2 | 4 | 4 |
| | 44 | 6 | 5 | 5 | | 14 | 5 | 6 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 56 | 6 | 5 | 6 | | 14 | 5 | 6 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 20 | 6 | 4 | 5 | | 14 | 5 | 6 |
| | | 2 | 3 | 5 | | 2 | 3 | 5 |
| | 32 | 6 | 4 | 5 | | 14 | 5 | 6 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 44 | 6 | 5 | 6 | | 14 | 5 | 6 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |
| | 56 | 6 | 5 | 6 | | 14 | 5 | 6 |
| | | 2 | 4 | 5 | | 2 | 4 | 5 |

[1] See footnotes to table 4.5.4-16.

Failures of isolation structures to exclude streamflow during fluming or dam-and-pump would result in suspended sediment entrained downstream, assumed to be similar to TSS levels generated during wet open-cut construction (mean plus 2 standard errors from table 4.5.4-14) and included in table 4.5.4-17 along with several potential durations of exposure. Scenarios of exposures of 1 hour and 6 hours could occur while work crews repair the failed isolation structures. Longer exposures of 12 and 24 hours are assumed to occur if dry open-cut construction (flume or dam-and-pump) is abandoned and the waterbody crossing is completed using wet open-cut construction. Suspended sediments concentrations of 793 mg/L during low flows and 1,827 mg/L during peak flows for durations of 12 to 24 hours would not produce lethal conditions for juvenile and/or adult Oregon Coast coho but could result in moderate physiological stress (SEV = 6), moderate habitat degradation and/or impaired homing (if SEV = 7), and major physiological stress (if SEV = 8). Lethal doses (exposures to high TSS concentrations for long durations) with reduced growth rate and/or delayed hatching and/or reduced coho density (with SEV =9) could occur if failure of an isolation structure led to wet open-cut construction, principally within the Coquille Sub-basin with TSS concentrations =1,827 mg/L (mean of 1,428 + 2 standard errors) for 24 hours under either low flow or peak flow conditions.

**Table 4.5.4-17**
**Application of Two Models for Estimating Severity of Effects to Oregon Coast Coho 10 Meters Downstream due to TSS Concentrations Produced by Failure of Isolating Structures During Low Flow and Peak Flow Conditions under Different Exposure Durations**

| Model Number (and particle size) | Exposure (hours) | Average Low Flows: TSS Concentration (mg/L) | Average Low Flows: Modeled Severity of Effects (SEV) [1] | Average Low Flows: With Upper SEV (95% CI) [2] | Average Peak Flows: TSS Concentration (mg/L) | Average Peak Flows: Modeled Severity of Effects (SEV) [1] | Average Peak Flows: With Upper SEV (95% CI) [2] |
|---|---|---|---|---|---|---|---|
| **Model 1** (0.5 to 250 µm) Juvenile and Adult Salmonids | 1 | 793 | 6 | 7 | 1,827 | 7 | 7 |
| | | 5 | 2 | 3 | 5 | 2 | 3 |
| | 6 | 793 | 7 | 7 | 1,827 | 8 | 8 |
| | | 5 | 3 | 4 | 5 | 3 | 4 |
| | 12 | 793 | 8 | 8 | 1,827 | 8 | 9 |
| | | 5 | 4 | 5 | 5 | 4 | 5 |
| | 24 | 793 | 8 | 8 | 1,827 | 9 | 9 |
| | | 5 | 4 | 5 | 5 | 4 | 5 |
| **Model 3** (0.5 to 75 µm) Juvenile Salmonids | 1 | 793 | 5 | 6 | 1,827 | 6 | 7 |
| | | 5 | 2 | 3 | 5 | 2 | 3 |
| | 6 | 793 | 7 | 7 | 1,827 | 7 | 8 |
| | | 5 | 3 | 4 | 5 | 3 | 4 |
| | 12 | 793 | 7 | 8 | 1,827 | 8 | 8 |
| | | 5 | 4 | 5 | 5 | 4 | 5 |
| | 24 | 793 | 8 | 8 | 1,827 | 8 | 9 |
| | | 5 | 4 | 5 | 5 | 4 | 5 |

[1] See footnotes to table 4.5.4-16.

The South Umpqua River at MP 94.73 would be crossed using a diverted open-cut. This is similar to a dry open cut in that all in channel construction would be done in the "dry" but would require diversion of the flow to one side of the channel at a time. None of the models for sediment entrainment would apply to diverted open-cuts but TSS generated by wet open-cut construction has been used to evaluate potential effects. Juvenile and adult coho in the South Umpqua River would likely be affected by TSS concentrations less than 72 mg/L which is the mean TSS concentration plus 2 standard errors for a wet open-cut in the Days Creek-South Umpqua River Watershed (see table 4.5.4-14). Diverted open-cut could take about 14 days (336 hours) to complete. If coho were continually exposed to 72 mg/L for 336 hours, the SEV score would be SEV = 8 (indications of major physiological stress with long-term reduction in feeding rate and/or feeding success, poor condition) but that would not occur because the TSS concentration would likely be less than 72 mg/L at the construction site and fish would be able to avoid a plume of suspended sediment because construction would only occur on one side of the river at any time.

FWS (Muck, 2010) incorporated the scaled SEV scores into section 7 consultations on bull trout such that SEV scores of 6 or higher would be expected to cause harassment using Model 1 (Juvenile and Adult Salmonids) and would justify a determination of "likely to adversely affect." Figure 4.5-19 provides combinations of TSS concentrations and exposures that would distinguish between determinations of "likely to adversely affect" and "not likely to adversely affect."

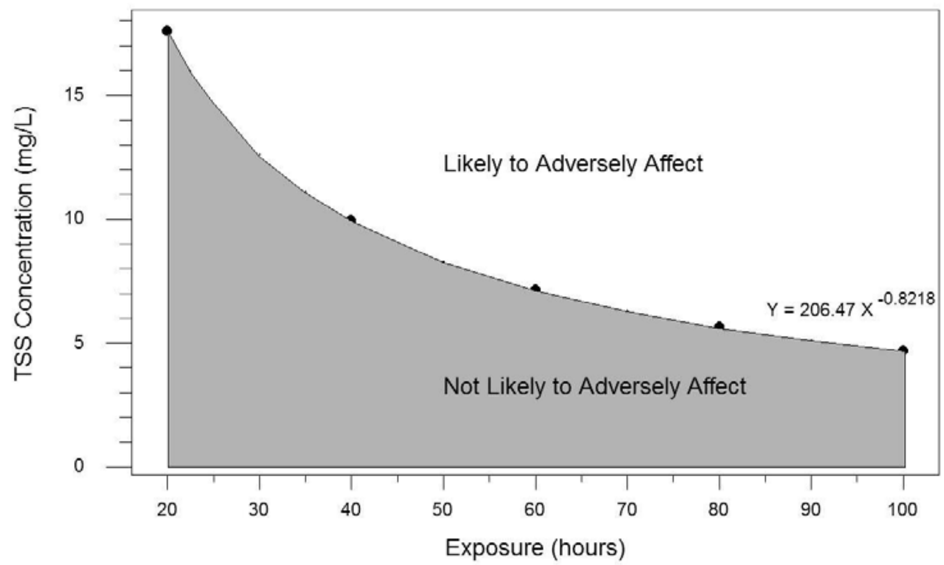



**Figure 4.5-19**
**Combinations of TSS concentrations and Exposure that would Limit SEV Scores of 5 or Lower (Gray Area) in Model 1 (Newcombe and Jensen, 1996) with a Determination of "Not Likely to Adversely Affect" Adult and Juvenile Salmonids (Muck, 2010)**

Similarly, FWS (Muck, 2010) determined that SEV scores of 5 or higher would cause harassment with application of Model 3 (Juvenile Salmonids) and would justify a determination of "likely to adversely affect." Figure 4.5-20 provides combinations of TSS concentrations and exposures that would distinguish between determinations of "likely to adversely affect" and "not likely to adversely affect." The same determinations of effect are assumed for coho salmon in this biological assessment.

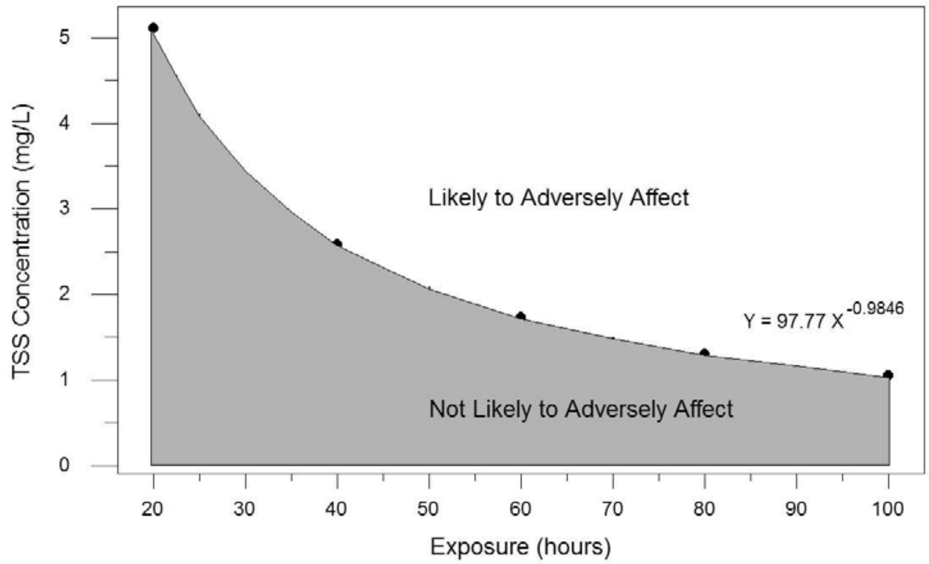
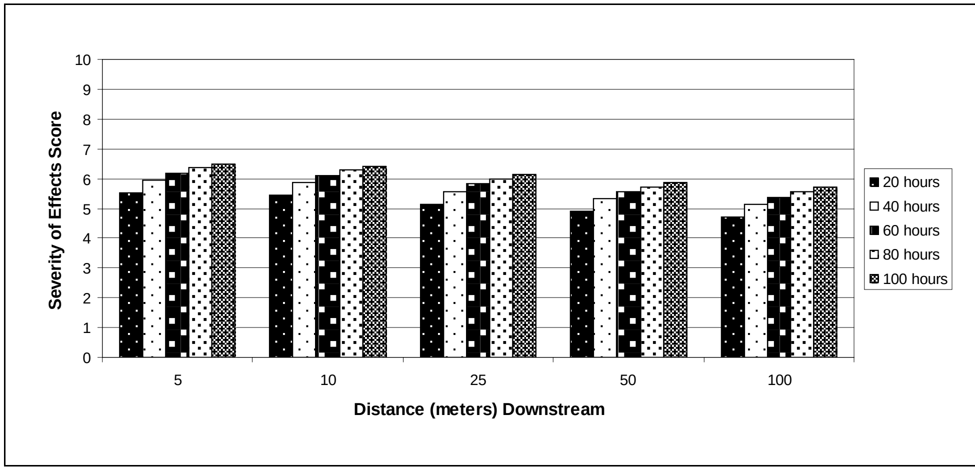


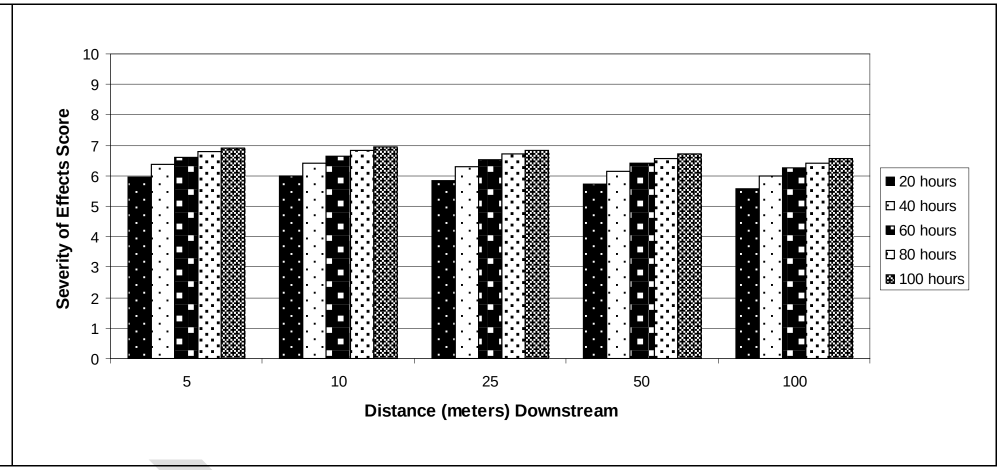

**Figure 4.5-20**
**Combinations of TSS concentrations and Exposure that would Limit SEV Scores of 4 or Lower (Gray Area) in Model 3 (Newcombe and Jensen, 1996) with a Determination of "Not Likely to Adversely Affect" Juvenile Salmonids (Muck, 2010)**

SEV scores were computed for streams within each fifth field watershed crossed within the Coos, Coquille, and South Umpqua sub-basins using TSS concentrations estimated at 5, 10, 25, 50, and 100 meters downstream from pipeline construction sites and exposure durations from 20 to 100 hours which covers the expected durations required for dam-and-pump and flumed construction. Upper 95% confidence intervals, added to SEV scores, were used to evaluate potential scenarios within each fifth field watershed depending on whether Model 1 (juvenile and adult coho) or Model 3 (juvenile coho) was considered for estimated average low flows and for estimated average peak flows occurred during the period of instream construction.

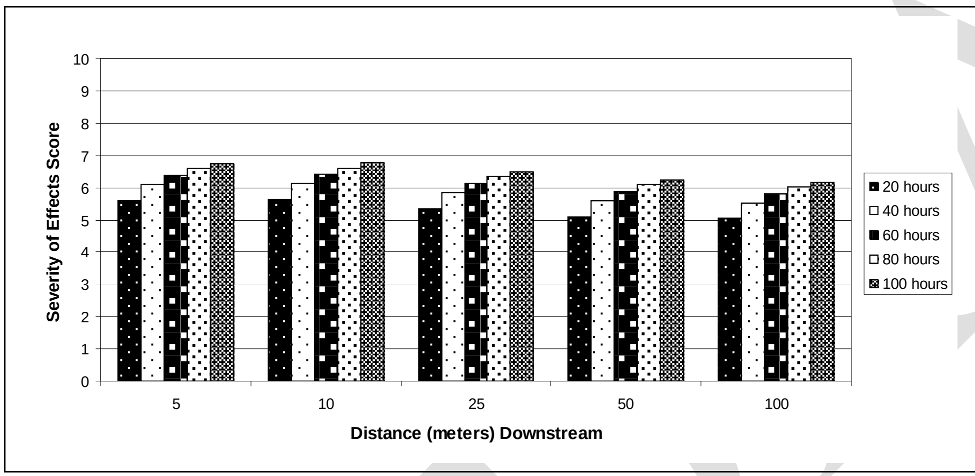
Results are shown below for TSS effects in fifth field watersheds within the Coos Sub-basin (figure 4.5-21), the Coquille Sub-basin (see figure 4.5-22 through figure 4.5-25), and the South Umpqua Sub-basin (see figure 4.5-26 through figure 4.5-30). The model outputs (SEV scores plus 95% confidence intervals) for the Coos Bay-Frontal Pacific Ocean Watershed (Figure 4.5-21), Coquille River Watershed (see figure 4.5-22), North Fork Coquille River Watershed (see figure 4.5-23), East Fork Coquille River Watershed (see figure 4.5-24), Middle Fork Coquille River Watershed (see figure 4.5-25), Olalla Creek-Lookingglass Creek Watershed (see figure 4.5-26), Myrtle Creek Watershed (figure 4.5-28), and Upper Cow Creek Watershed (see figure 4.5-30) show that instream construction lasting for 20 to 40 hours could exceed scores of 5 with Model 1 for both average low flows or average peak flows in all four watershed. Based on that model and exposures, the project would be "likely to adversely affect" coho based on figure 4.5-19. However, construction lasting for 20 hours or more would exceed a score of 4 with Model 3, regardless of flow rates, in all four watersheds. Based on that model and exposures, the project would be "likely to adversely affect" juvenile coho based on figure 4.5-20.



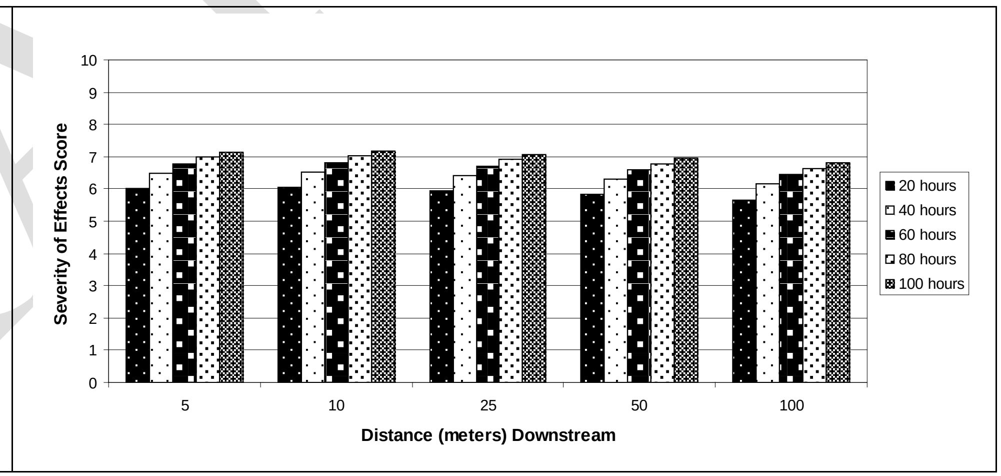

A. Model 1, SEV Scores During Average Low Flows




B. Model 1, SEV Scores During Average Peak Flows.

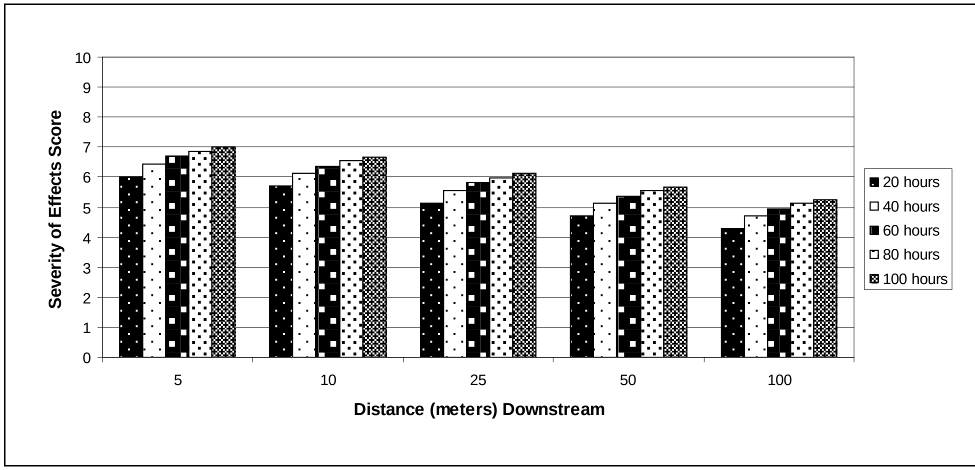


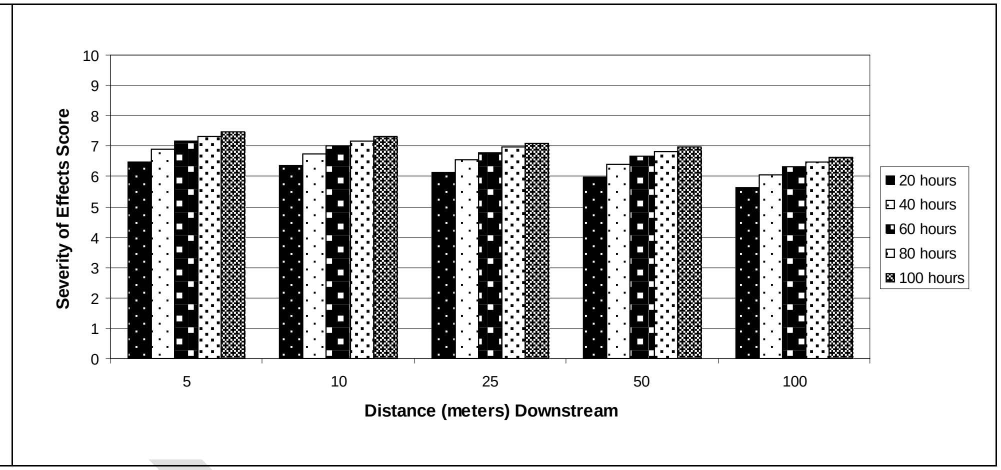

C. Model 3, SEV Scores During Average Low Flows




D. Model 3, SEV Scores During Average Peak Flows.

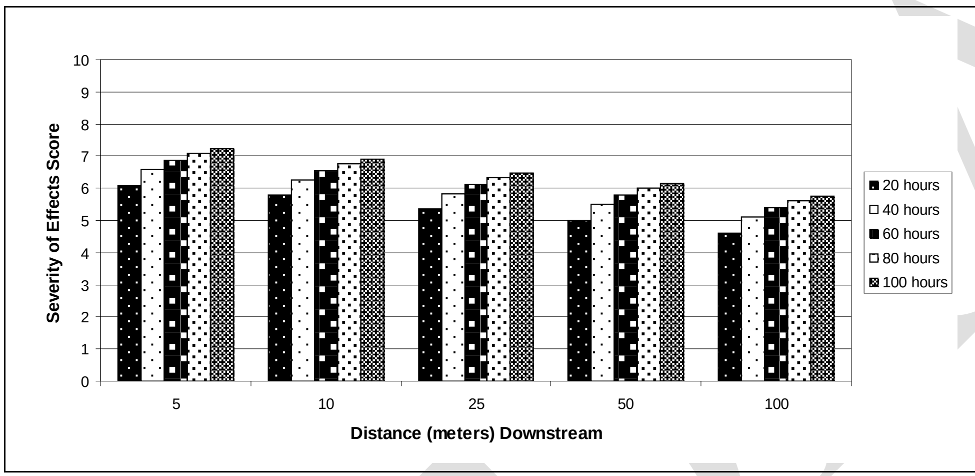
**Figure 4.5-21**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Coos Bay-Frontal Pacific Ocean Watershed (HUC 1710030403) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**

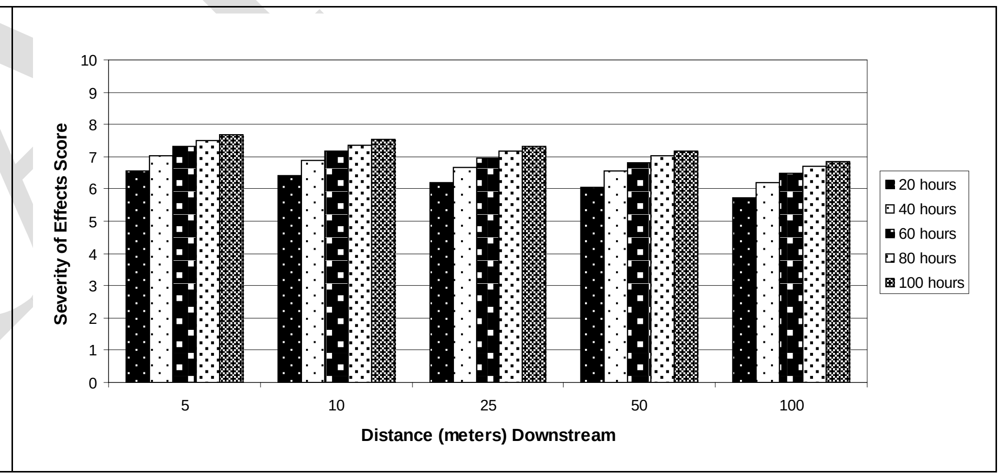



**A. Model 1, SEV Scores During Average Low Flows**

**B. Model 1, SEV Scores During Average Peak Flows.**

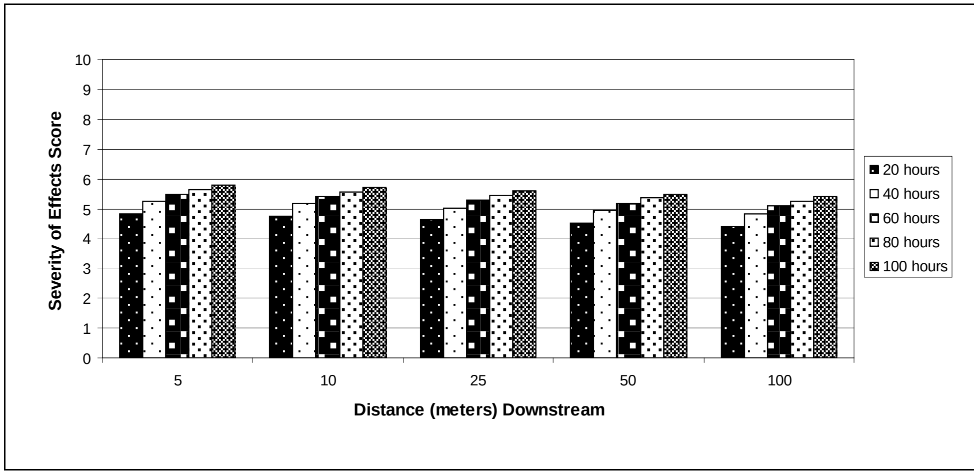


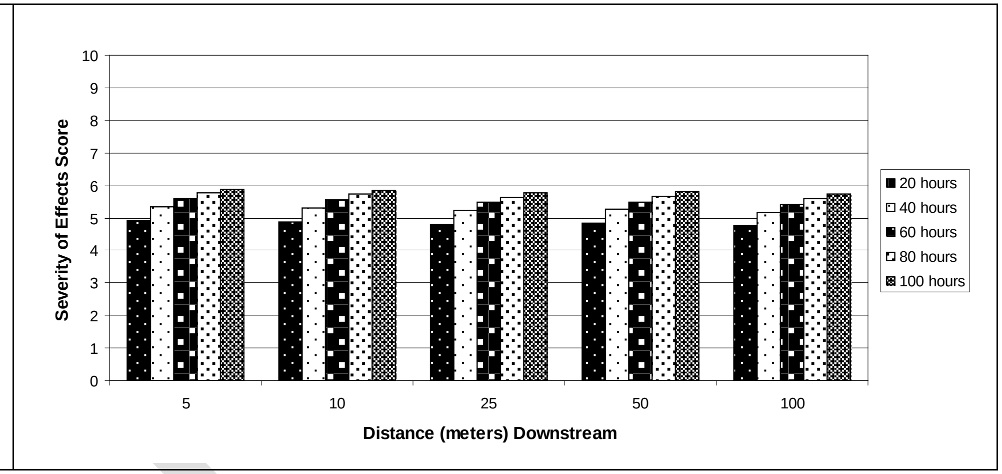




**C. Model 3, SEV Scores During Average Low Flows**

**D. Model 3, SEV Scores During Average Peak Flows.**

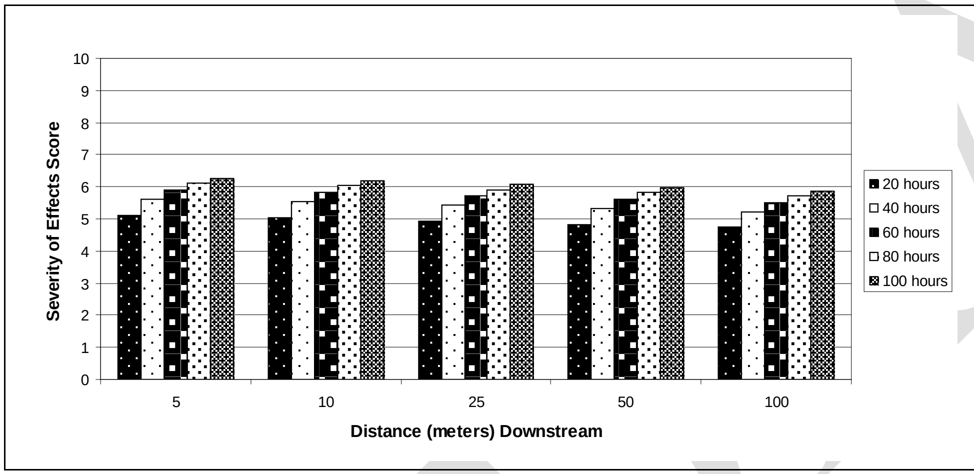
**Figure 4.5-22**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Coquille River Watershed (HUC 1710030505) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**

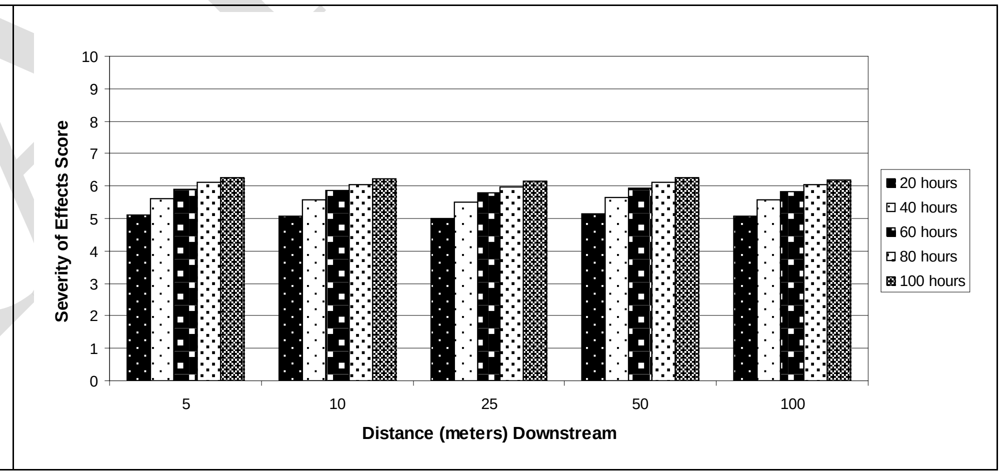



**A. Model 1, SEV Scores During Average Low Flows**

**B. Model 1, SEV Scores During Average Peak Flows.**



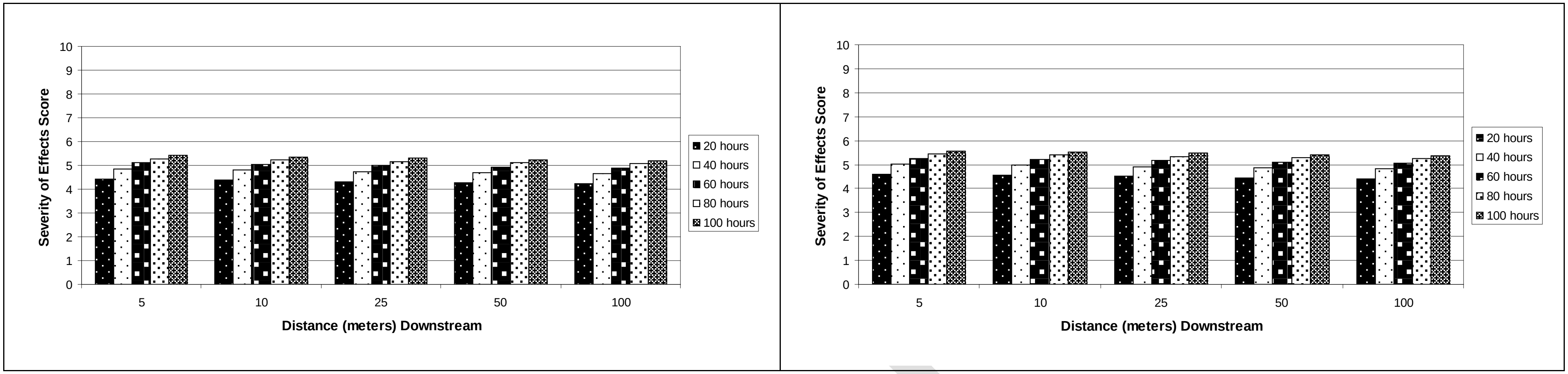




**C. Model 3, SEV Scores During Average Low Flows**

**D. Model 3, SEV Scores During Average Peak Flows.**

**Figure 4.5-23**

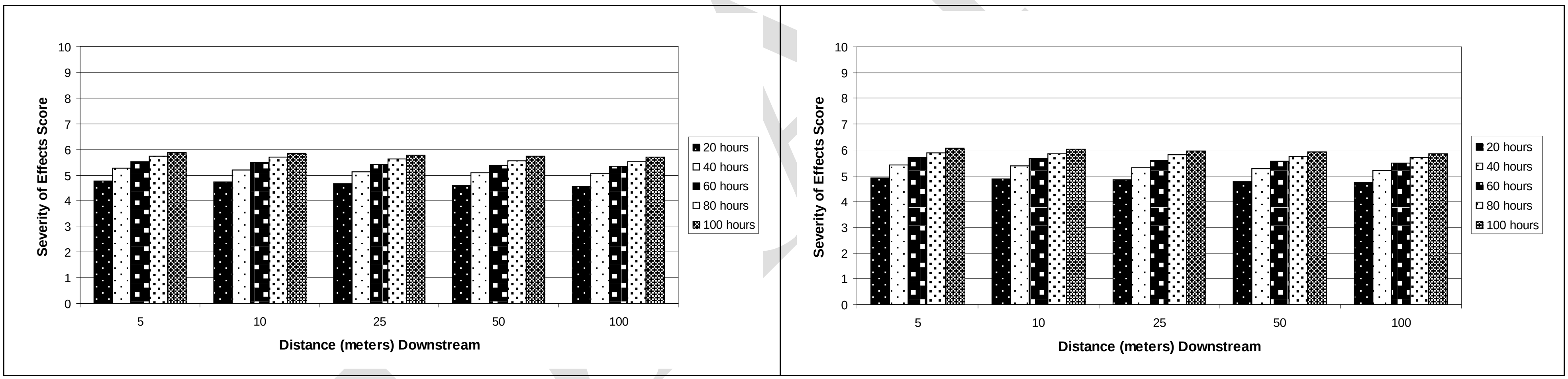
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the North Fork Coquille River Watershed (HUC 1710030504) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows.**




**A. Model 1, SEV Scores During Average Low Flows**

**B. Model 1, SEV Scores During Average Peak Flows.**

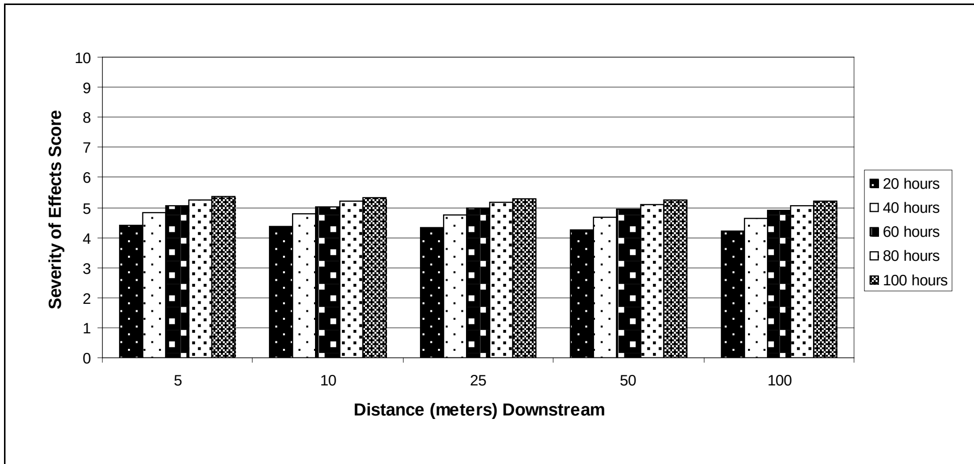




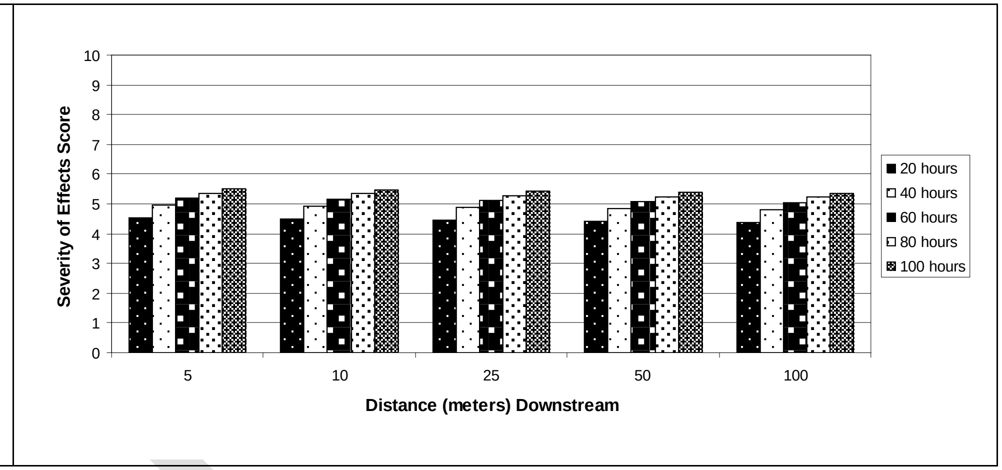

**C. Model 3, SEV Scores During Average Low Flows**

**D. Model 3, SEV Scores During Average Peak Flows.**

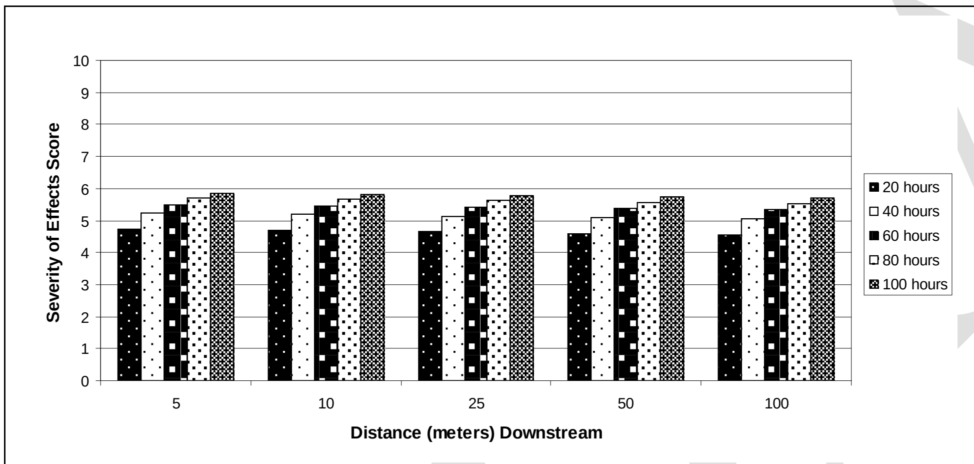
**Figure 4.5-24**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the East Fork Coquille River Watershed (HUC 1710030503) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**



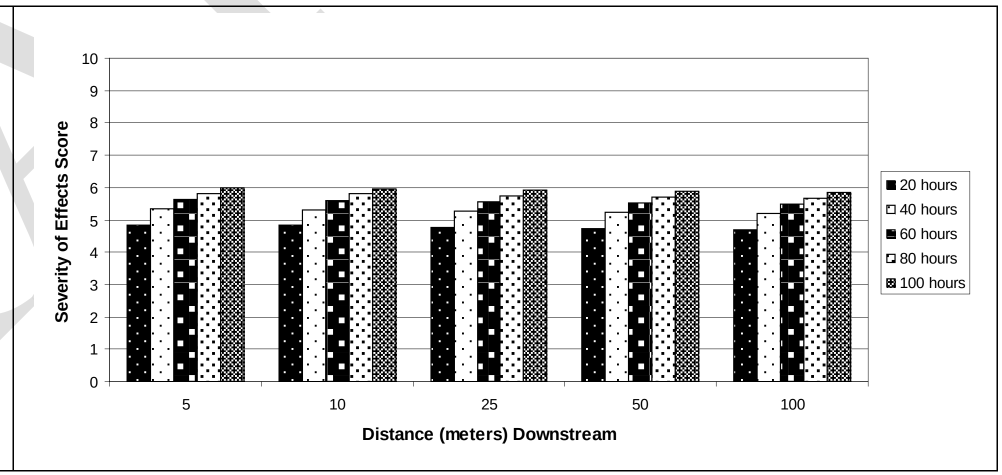

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**



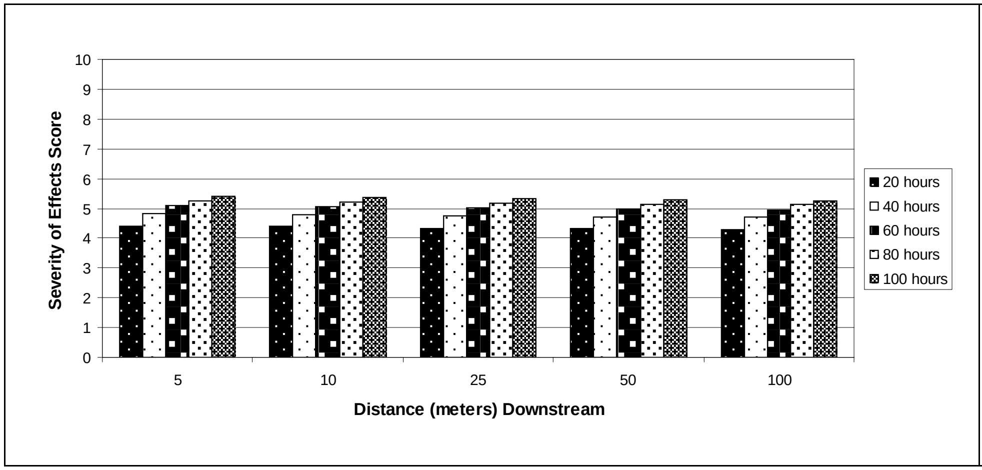

**C. Model 3, SEV Scores During Average Low Flows**



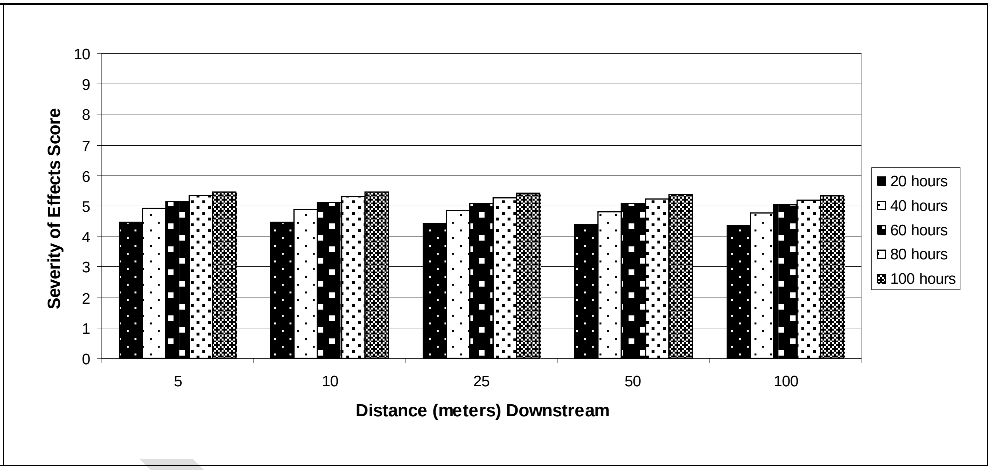

**D. Model 3, SEV Scores During Average Peak Flows.**

**Figure 4.5-25**

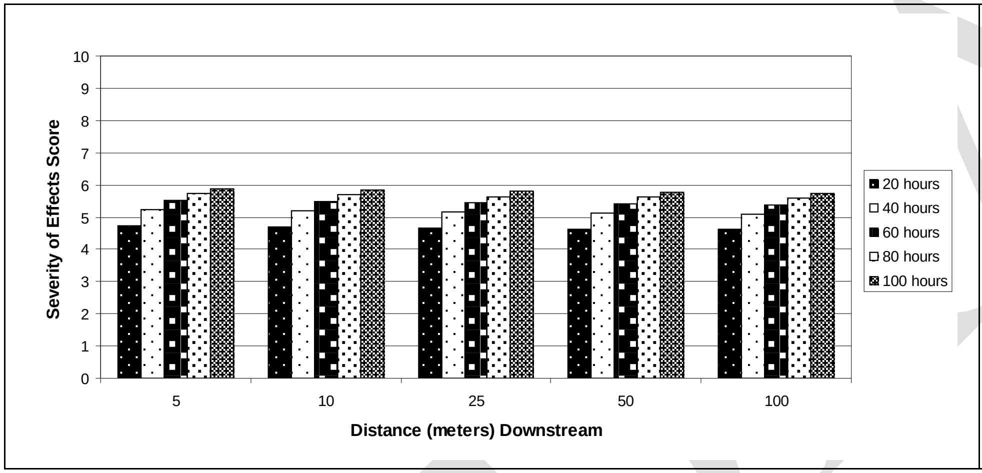
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Middle Fork Coquille River Watershed (HUC 1710030501) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**



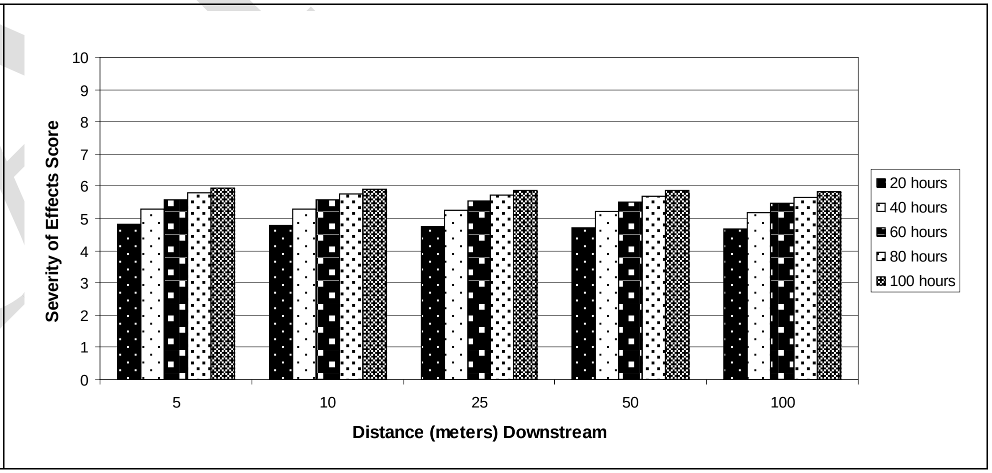

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**

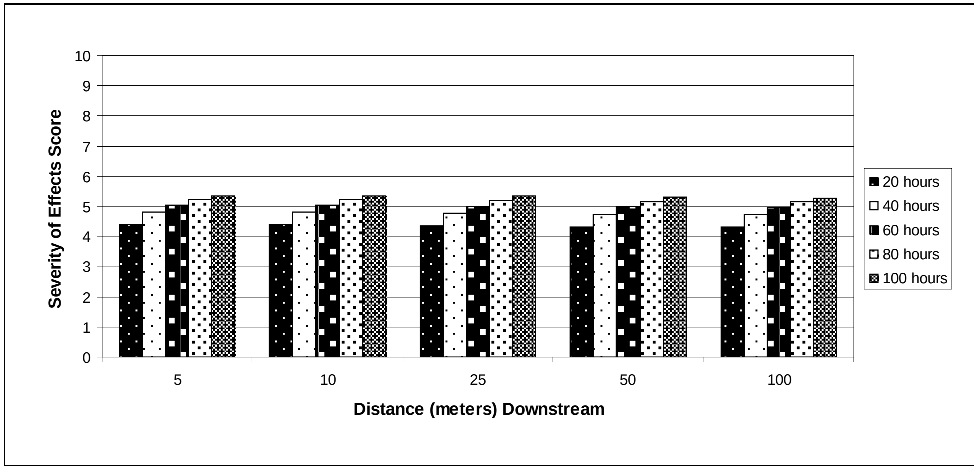



**C. Model 3, SEV Scores During Average Low Flows**

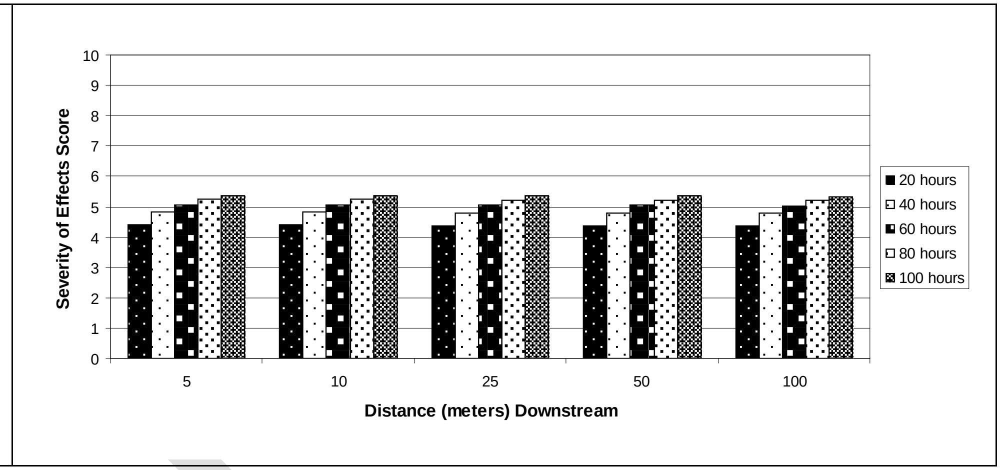



**D. Model 3, SEV Scores During Average Peak Flows.**

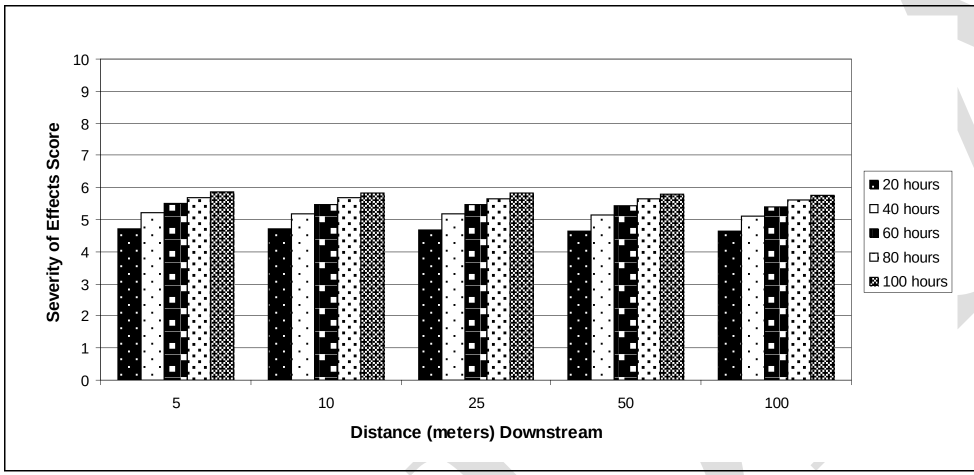
**Figure 4.5-26**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Olalla Creek-Lookingglass Creek Watershed (HUC 1710030212) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**



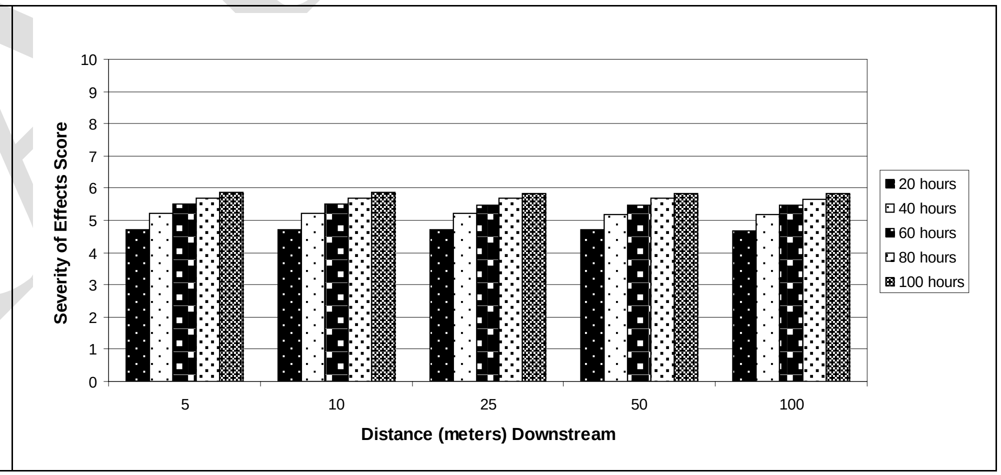

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**



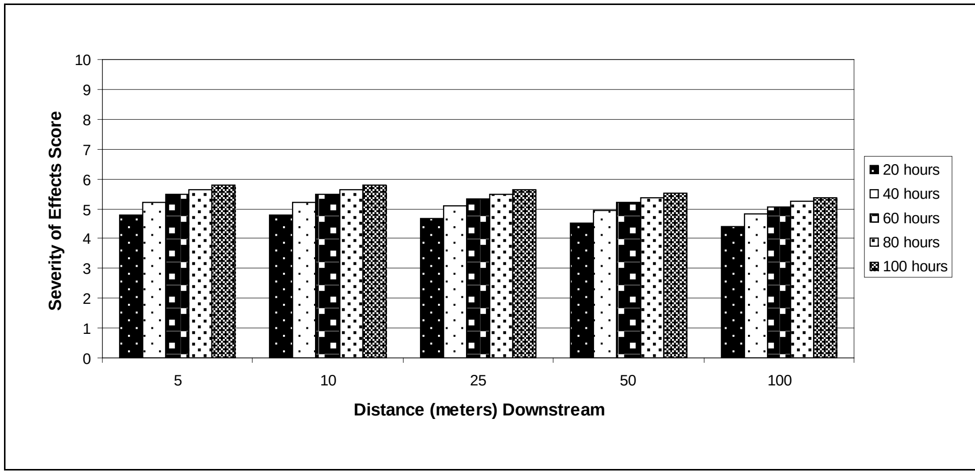

**C. Model 3, SEV Scores During Average Low Flows**



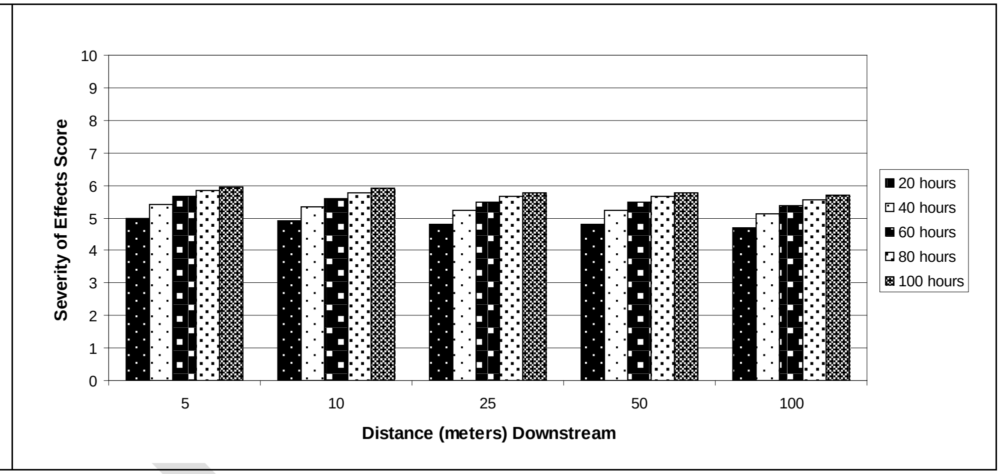

**D. Model 3, SEV Scores During Average Peak Flows.**

**Figure 4.5-27**

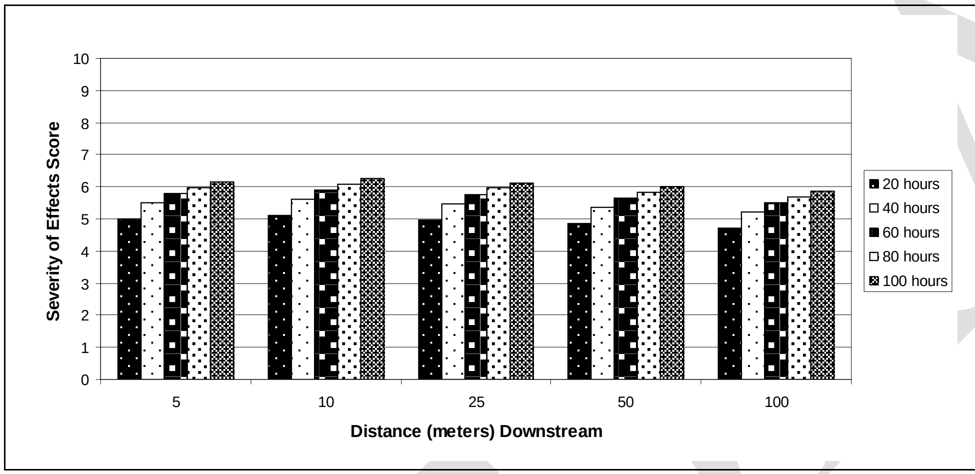
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Clark Branch-South Umpqua River Watershed (HUC 1710030211) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include thw Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**



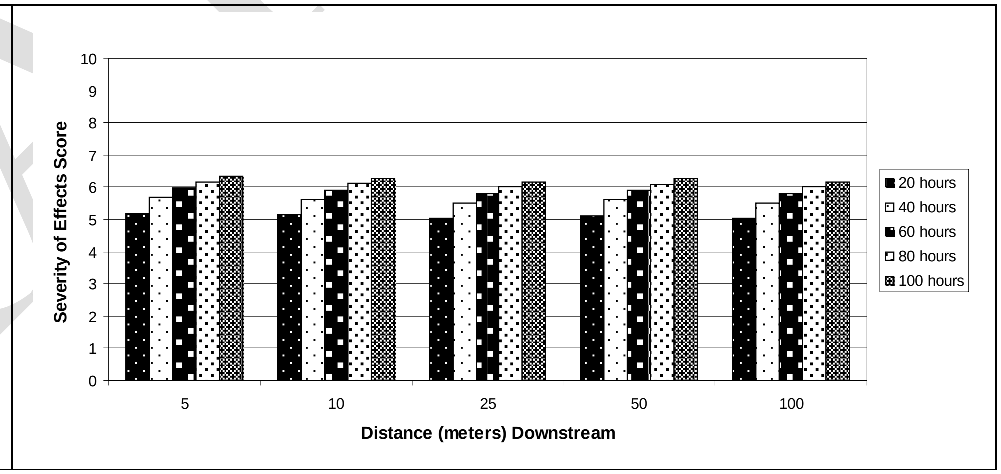

**A. Model 1, SEV Scores During Average Low Flows**




**B. Model 1, SEV Scores During Average Peak Flows.**

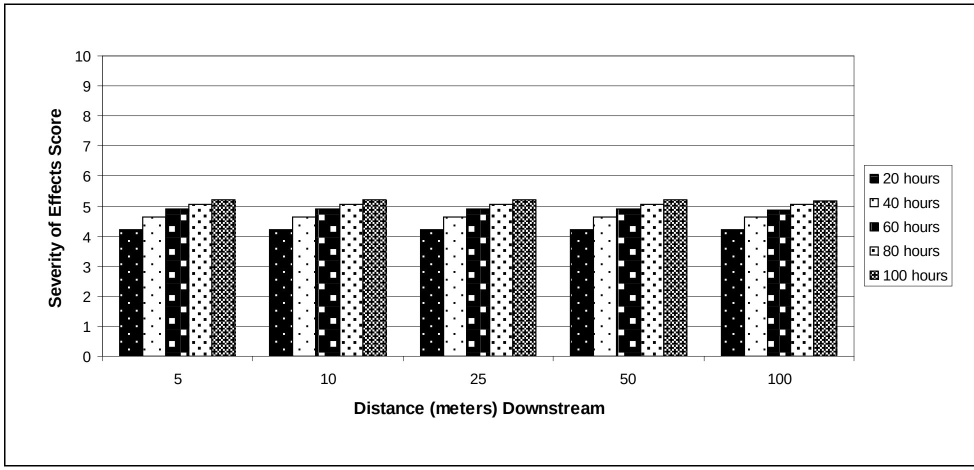



**C. Model 3, SEV Scores During Average Low Flows**

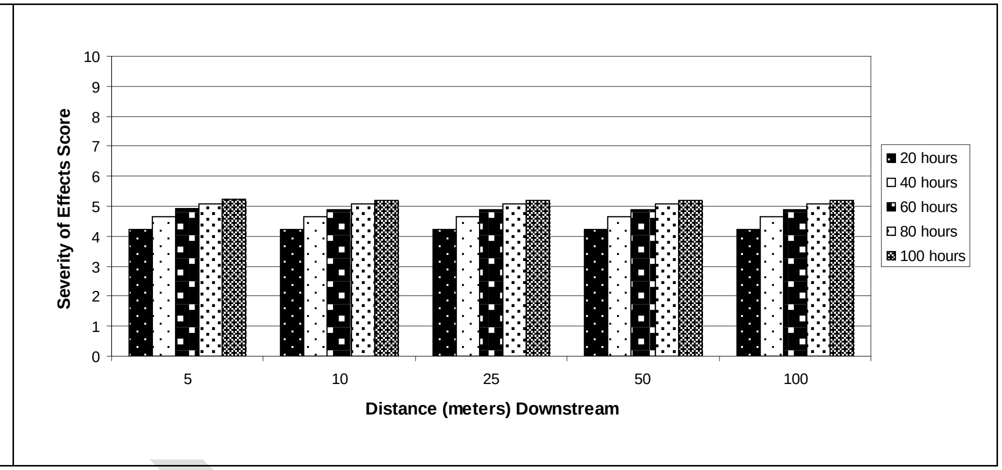



**D. Model 3, SEV Scores During Average Peak Flows.**

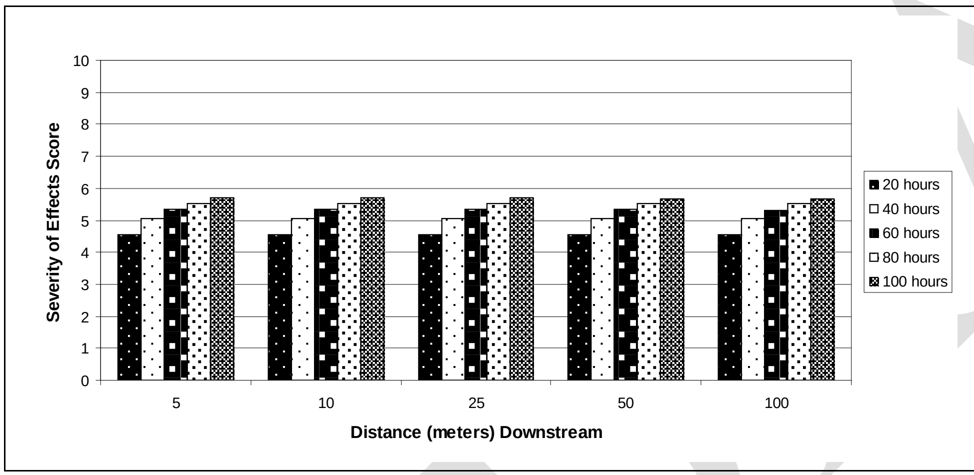
**Figure 4.5-28**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Myrtle Creek Watershed (HUC 1710030210) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**



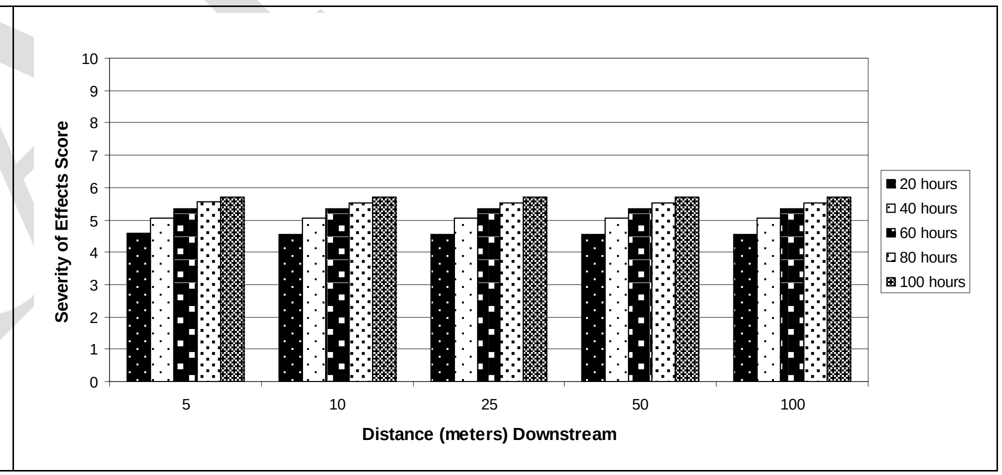

A. Model 1, SEV Scores During Average Low Flows




B. Model 1, SEV Scores During Average Peak Flows.

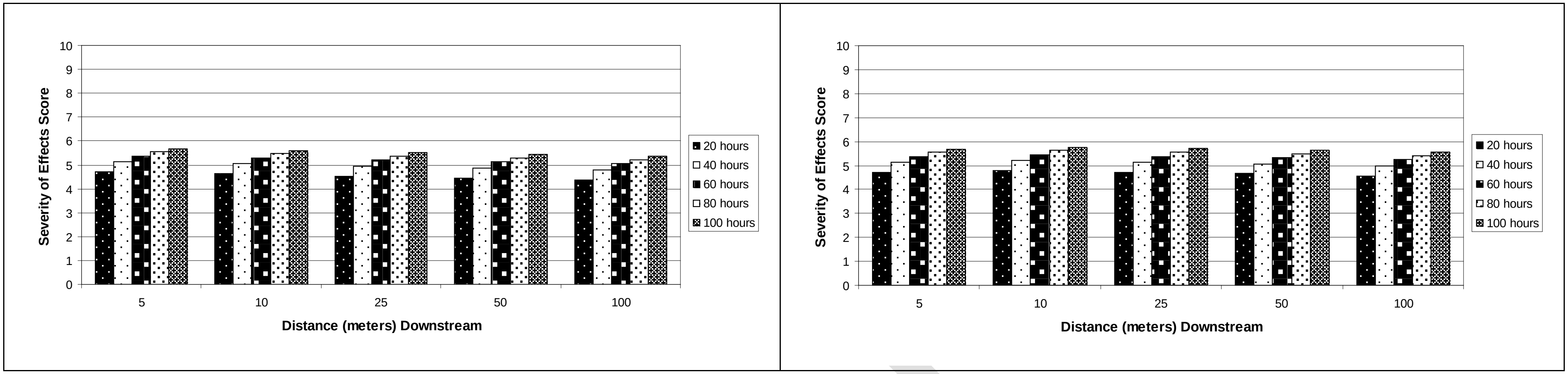



C. Model 3, SEV Scores During Average Low Flows



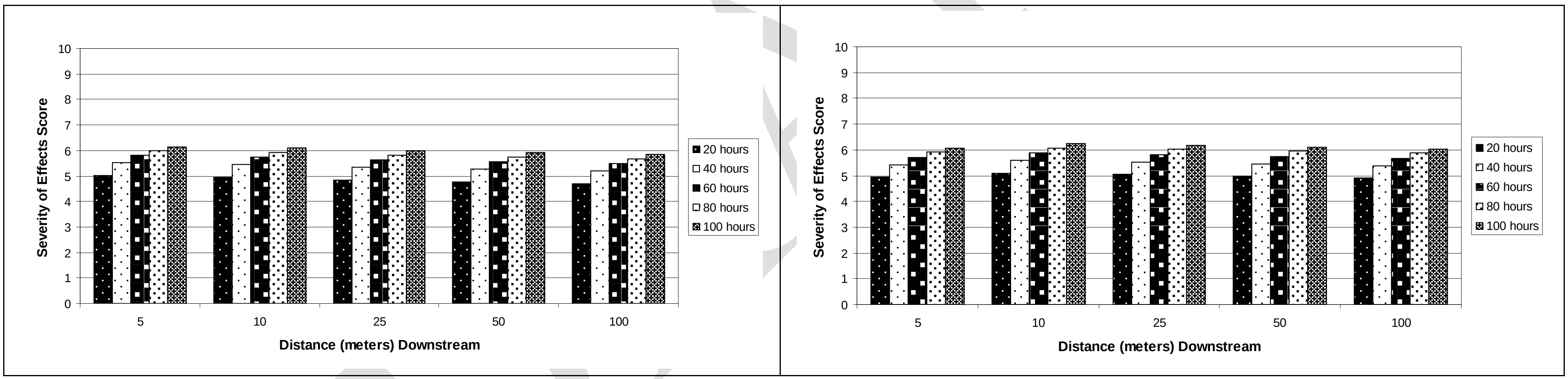

D. Model 3, SEV Scores During Average Peak Flows.

**Figure 4.5-29**
**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Days Creek-South Umpqua River Watershed (HUC 1710030205) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**




A. Model 1, SEV Scores During Average Low Flows

B. Model 1, SEV Scores During Average Peak Flows.




C. Model 3, SEV Scores During Average Low Flows

D. Model 3, SEV Scores During Average Peak Flows.

**Figure 4.5-30**

**Severity of Effects Expected for Coho Salmon in Occupied Steams within the Upper Cow Creek Watershed (HUC 1710030206) During Pipeline Construction by Fluming between July 1 and September 15. Estimated SEV Scores Include Upper 95% Confidence Interval on Output for Model 1 (Figures A and B, Juvenile and Adult Salmonids) and Model 3 (Figures C and D, Juvenile Salmonids) in Newcombe and Jensen (1996) for Five Exposure Durations (hours) During Periods of Low and Peak Flows**

Entrainment and Entrapment

Waterbody crossings using the “dry” crossing methods, flume or dam-and-pump, may result in some fish being entrapped in streams. Flumes and dams will be completely installed and functioning before any instream disturbance. Construction across a waterbody would take up to seven days using dry open cut methods, but less for small and intermediate streams. Once streamflow is diverted through the flume pipe, but before pipeline trenching begins, fish trapped in any water remaining in the work area between the dams would be removed and released using the Fish Salvage Plan (see appendix T). Pacific Connector will contract with either ODFW or a qualified consultant to capture the fish. Personnel that would handle and/or remove fish on federal lands would be approved by the Forest Service or the BLM or be done directly by agency personnel if approved by ODFW.

Frac-Out

Although the HDD method avoids instream impacts because it eliminates the need for instream excavation, it does not completely eliminate the possibility of impacts on aquatic resources. Pacific Connector proposes to use this method to cross the Coos River. Because HDD requires a lubricant during the process, this fluid is under pressure and there is a possibility of an inadvertent release of drilling mud or fluid (also referred to as a frac-out). Drilling mud primarily consists of water mixed with bentonite, which is a naturally occurring clay material. The only other possible additives would be nontoxic solid materials (e.g., sawdust, nut shells, bentonite pellets, or other commercially available nontoxic products) that could be needed to plug an inadvertent release.

Direct Pipe construction would be used to cross the South Umpqua River at MP 71.30. Direct Pipes are completed using an articulated, steerable microtunnel boring machine (MTBM) mounted on the leading end of the product pipe or casing which is jacked into position using a pipe thrusting machine mounted at or near the ground surface. Soil and rock are excavated by the cutting head and removed through pressurized slurry pipes to the launching pit at a rate that is balanced with the advance rate of the machine, as the MTBM and pipe are jacked through the formation. A pipe thrusting machine located in or near the launching pit provides the necessary force to advance the product pipe and provide the face pressure required for excavation. Small sections of pipe are welded to the back of subsequent sections after each section is advanced. Friction between the pipe and surrounding soil can create significant resistance during Direct Pipe installation. To reduce the frictional resistance, over cutting is employed to create a small annular space between the pipe and external soil. The over cut is typically on the order of 1 to 2 inches. The use of bentonite slurry helps reduce the frictional resistance between the pipe and soil as well as reducing the risk of collapse of the annulus around the pipe. Bentonite lubrication is typically added from the launch seal and from a specialized lubrication ring located behind the MTBM and in front of the jacking pipe. According to GeoEngineers’ Technology Overview for Direct Pipe (see appendix E), the bentonite lubrication system used to lubricate the annulus between the product pipe and the excavation is introduced at a relatively low pressure reducing the potential for hydraulic fracture and inadvertent drilling fluid returns. Because the excavated hole is continuously supported and the risk of hydraulic fracture is low, the Direct Pipe alignment can be designed much shallower than is typical for HDD.

Bentonite by itself is essentially a non-toxic drilling mud (Breteler et al., 1985; Hartman and Martin, 1984; Sprague and Logan, 1979). However, bentonite, as with any fine particulate material, can interfere with oxygen exchange by the gills of aquatic organisms (EPA, 1986). The degree of interference generally increases with water temperature (Horkel and Pearson 1976). Impacts would be localized and would normally be limited to individual fish in the immediate vicinity of the frac-out. The majority of highly mobile aquatic organisms, such as fish, would be able to avoid or move away from turbidity spots and plumes (Reid and Anderson 1999). Other less mobile or immobile organisms, such as mussels and other macroinvertebrates, would incur direct mortality. Bentonite can smother macroinvertebrates and adversely affect filter-feeders (Falk and Lawrence 1973 in Hair et al. 2002 and Land 1974 in Cameron et al. 2002). Bentonite can also exacerbate or enhance the effects of toxic compounds to fish and aquatic invertebrates if those compounds are present in aquatic habitats (Hartman and Martin 1984). Similar to other fine-grained particulates, bentonite in flowing water is more likely to remain in suspension longer than in standing water. Consequently, effects to coho salmon by a release of bentonite into a waterbody would ultimately depend on volume of the release, volume of water present, and current. Coho salmon inhabiting larger waterbodies with swift currents would be less affected by a given volume of bentonite than those inhabiting small waterbodies with no current.

The effects of an instream frac-out on spawning habitat, eggs, and juvenile survival depend on the timing of the release. If spawning habitat is nearby, redds could be affected in the vicinity of frac-out (Reid and Anderson, 1999), if not concurrently, possibly within the immediate future unless high flows flush residual bentonite. During establishment of the spawning bed, a minor addition of sediment would likely be cleaned out by the female as part of the normal preparation behavior. However, a heavy sediment load dispersing downstream could settle into spawning beds and clog interstitial spaces, reducing the amount of available spawning habitat, which could be a limiting factor in areas of already reduced habitat. When redds are active, eggs could be buried, disrupting the normal exchange of gases and metabolic wastes between the egg and water (Anderson, 1996). The impacts of sediment intrusion into the redd on larval survival are more severe during the earlier embryonic stages than following development of the circulatory system of larvae, possible because of a higher efficiency in oxygen uptake by the older fish (Bash et al., 2001). Clogging of interstitial spaces also reduces cover and food availability for juvenile salmonids (Cordone and Kelley, 1961). Benthic organisms could also be affected by burial. However, bentonite is more likely to stay in suspension and less likely to immediately settle than common bottom sediment so, in flowing water areas, effects to benthic organisms from burial from frac-out are likely to be low. The locations where any frac-out may occur are all large waterbodies, which would be affected less because of the dilution factor of large volume of water from any spill.

Potential frac-outs are more common near the HDD drill entry and exit locations; however, impacts to waterbodies are minimized by locating the drill entry and exit points away from the waterbody. The probability of a frac-out may increase when the drill bit is working nearest the surface, but is dependent on numerous factors including substrate characteristics, head pressure of the drilling mud, topography, elevation, and subsurface hydrology. Pacific Connector has designed the Klamath River HDD such that areas of greatest risk from frac-out are on uplands and not adjacent to the waterbodies where much greater depth would be achieved and frac-out potential is reduced.

According to GeoEngineers' Feasibility Analysis for pipeline construction using HDD across the Coos River (see appendix E) the design length of the Coos River HDD crossing is approximately 1,602 feet. The proposed entry point is located approximately 500 from the north bank of the

Coos River; the exit point is approximately 650 feet from the south bank. The entry and exit points allow for adequate depth beneath the Coos River. The preliminary design provides a minimum of 43.6 feet of cover below the Coos River. GeoEngineers' preliminary evaluation determined that the construction of the Coos River HDD crossing is likely feasible. Additional evaluation of the hydraulic fracture and inadvertent return potential will be completed for the final design.

Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils with low shear strength or very loose granular soils. Loose and silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to dense sands and gravels and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Unfractured rock, because of its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or in formations with higher shear strength may reduce the potential for hydraulic fracturing (see appendix E).

In the event an inadvertent return occurs into the river, drilling fluid will enter the waterway causing short term, temporary water quality impacts downstream of the project area including sedimentation and turbidity. In the event drilling fluid is inadvertently released into the river, the behavioral avoidance response of Oregon Coast coho is presumed to be triggered within the immediate vicinity of the release and the fish are expected to return and utilize the affected area shortly after the inadvertent release has been halted. If significant concentrations are found during monitoring as a result of a release, the following possible corrective measures would be taken:

5. Increase the drilling fluid viscosity in an attempt at sealing the point at which fluid is leaving the drilled hole. The drilling operation may be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.
6. If increasing the drilling fluid viscosity is ineffective, lost circulation materials (LCM) may be introduced into the hole by incorporating them in the drilling fluid and pumping the material down-hole. The drilling operation may again be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the lost circulation materials.
7. Depending on the location of the fractured zone, a steel casing may be installed that is of sufficient size to receive the largest expected down-hole tools for the crossing. This casing installation provides a temporary conduit for drilling fluids to flow while opening the remaining section of the hole to a diameter acceptable for receiving the proposed pipe sections. To alleviate future concerns with the steel casing after the HDD installation is completed, the casing is generally extracted from the hole prior to or just after completing the HDD installation. However, there have been instances when attempts at extracting the steel casing were unsuccessful.
8. In the event drilling fluid flow is not regained through the annulus of the drilled hole and a steel casing installation is not utilized, the HDD contractor may elect to install a grout mixture into the drilled hole in an attempt to seal the fractured zone. The down-hole drilling assembly is generally extracted and existing hole is re-drilled to the point at which it had previously been drilled prior to having encountered the loss of drilling fluid. 5. In addition, a grouting program may be implemented from the surface in the event that the installation of grout into the drilled hole is unsuccessful. This approach is only

practical in areas where drilling rigs with vertical drilling capabilities can access the HDD alignment. If a surface grouting program is utilized, the HDD drilling assembly is extracted from down-hole. Multiple holes are then drilled vertically on either side and along the HDD alignment to allow for grout slurry to be pumped into the fracture zone where the drilling fluid had previously been lost from the drilled hole. This process can take several days to complete in order to insert the grout in a grid pattern that covers the full fractured zone, during which time the HDD operation is suspended. Upon completion of the surface grouting program, the HDD operation will resume and the pilot hole will be reestablished through the grouted formation.

In some instances, it may be determined that the existing hole encountered a zone of unsatisfactory soil material and the hole may have to be abandoned. If the hole is abandoned, it will be filled with cuttings and drilling fluid.

**Movement Blockage**

Dry open-cut construction is expected to block upstream movement by adult salmonids, as well as withinstream movements of juvenile coho. As discussed above, fish are expected to abandon cover and/or avoid turbidity plumes generated by instream construction. Instream construction would be completed prior to most upstream migrations by Oregon Coast coho. The fluming process is expected to require from 36 to 96 hours of instream work (see table 4.5.4-15) during which migrating adult Oregon Coast coho could be exposed to TSS concentrations that would produce SEV scores ranging from 5 (minor physiological stress with increase coughing rate and/or increased respiration rate) to 6 (moderate physiological stress) and possibly 7 moderate habitat degradation and/or impaired homing).

Flumes would maintain streamflow and fish might move upstream or downstream through the flume. With the dam and pump method, fish would not be able to move upstream or downstream through the work area until the dams have been removed. Flumes and dams would be removed as soon as possible following backfilling of the trench.

With the dam and pump method, coho would not be able to move upstream or downstream through the work area until the dams have been removed. However, dam-and-pump construction is expected to require between 20 and 56 hours of instream work (see table 4.5.4-16). Dam-and-pump construction would generate lower TSS concentrations than fluming; effects to coho would be expected to range from short-term reduction in feeding rates and/or feeding success (SEV score 4) to moderate physiological stress (SEV score 6). All expected responses by adult and juvenile salmonids to TSS produced during fluming or dam-and-pump 10 meters or more downstream would be classified as sublethal, whether during low flows or peak flows.

At one crossing of the South Umpqua River, a diverted open cut crossing would be used. This is similar to a dry open cut in that all in channel construction would be done in the “dry” but would require diversion of the flow to one side of the channel at a time. This method could take about 14 days to complete per site. Because one channel would be open during the entire crossing, no passage of fish would be impeded and no fish removal would be required.

**Indirect Effects**

<u>Aquatic Habit</u>

The same approach utilizing TSS concentration and exposure to evaluate levels of risk to fish (Newcombe and Jensen, 1996) was applied to quantifying effects of sediment on fish habitat, termed the harmful alteration, disturbance or destruction (HADD) of habitat (Anderson et al., 1996). HADD risk includes concentration and exposure to sediment along with sensitivity of the habitat affected. Most likely, suspended sediment would increase embeddedness of spawning gravels with increasing habitat effects closer to the construction location.

Sediment falling out of suspension downstream from the construction location can affect freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, logjams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Based on the models for suspended sediment concentration and duration of exposure discussed above (see tables 4.5.4-15 through 4.5.4-17 and figures 4.5-21 through 4.5-30), Anderson et al. (1996) described five severity of ill effect ranks to habitat:

SEV 3: Measured change in habitat preference.
SEV 7: Moderate habitat degradation measured by a change in the invertebrate community.
SEV 10: Moderately severe habitat degradation as defined by measureable reductions in the productivity of habitat for extended periods (months) or over a large area (kilometers).
SEV 12: Severe habitat degradation as measured by long-term (years) alterations in the ability of existing habitats to support fish or invertebrates.
SEV 14: Catastrophic or total destruction of habitat in the receiving environment.

FWS (Muck, 2010) determined that SEV scores of 5 or higher applying Model 3 would likely warrant a "likely to adversely affect" juvenile bull trout habitat although noting that abandonment of cover (SEV 2) or avoidance of habitat / change in habitat preference (SEV 3) could lead to increased predation risk and mortality if hiding cover is limited in an affected stream reach (Muck, 2010). For adult and subadult bull trout, FWS judged that abandonment of cover and avoidance may not lead to similar predation risks. Averse effects would likely occur when TSS concentrations lead to notable reduction in abundance of aquatic invertebrates and alteration in their community structure. Consequently, SEV scores (or HADD scores in Anderson et al., 1996) of 7 or higher would warrant a determination of "likely to adversely affect" adult and subadult bull trout due to indirect effects because of habitat degradation (Muck, 2010). In this biological assessment, similar levels of effect due to TSS concentrations and durations of exposure are assumed to apply to coho salmon.

The project is expected to impact salmonid habitat more than the SEV 3 level for Models 1 and 3 included in table 4.5.4-15 and table 4.5.4-16. The project would degrade habitat to the SEV 7 level with the upper 95% confidence levels or above in Model 1 or Model 3 during a failure of dry open-cut construction if TSS concentrations of 793 to 1,827 mg/L lasted for one hour or more (see table 4.5.4-17). In cases of uninterrupted dry open-cut construction, adverse affects to coho habitats downstream are not expected.

**Freshwater Stream Invertebrates**

Substrates downstream from instream construction sites could be impacted by sediments. Mayflies, caddisflies, and stoneflies prefer large substrate particles in riffles and are adversely affected by fine sediment deposited in interparticulate spaces (Cordone and Kelley, 1961; Waters, 1995; Harrison et al., 2007). Fish and benthic macroinvertebrate abundances downstream of pipeline construction sites have been reported as short-term reductions (Reid and Anderson, 1999). Macroinvertebrate abundance and community composition are highly related to the degree to which substrate particles are embedded by fine material (Birtwell, 1999).

Fish emigrate from construction sites and benthic taxa drift downstream to sites where sediment deposition has not affected habitat suitability (Reid and Anderson, 1999). In Ontario, stream crossing construction using fluming produced less turbidity and sediment concentrations downstream than construction by wet open cutting streams; wet open cutting resulted in a significant decrease in aquatic invertebrates downstream three days post-construction (Baddaloo, 1978 cited in Gartman, 1984). One year after construction there were no significant differences in benthos numbers. In general, the percentage of type of stream benthos and invertebrate taxa affected by construction of the proposed pipeline would be in proportion to their abundance during the season of construction.

Rapid colonization by benthic organisms of disturbed substrate following pipeline construction has been demonstrated elsewhere. In Pennsylvania, samples taken before and 30 days after pipeline construction revealed rapid recolonization of the disturbed and newly-exposed stream substrate by benthic macroinvertebrates (Gartman, 1984). Similarly, the number and diversity of aquatic invertebrate taxa in coldwater streams in New York State were unchanged two to four years following pipeline construction from those measured prior to construction (Blais and Simpson, 1997).

Aquatic Nuisance Species

Non-indigenous aquatic species (NAS) are aquatic species that degrade aquatic ecosystem function and benefits, in some cases completely altering aquatic systems by displacing native species, degrading water quality, altering trophic dynamics, and restricting beneficial uses (Hanson and Sytsma, 2001). Currently there are 180 reported NAS in Oregon, of which 134 are documented within the USGS hydrologic basins crossed by the proposed Pacific Connector Pipeline Project (USGS, 2005). Within the Coos Bay estuary, over 67 NAS have been identified (Aquatic Nuisance Species Taskforce, 2006). All of the invertebrate NAS in the Coos Bay estuary have been introduced by ship fouling or discharge from ballast water of ocean-going vessels.

Largemouth bass and smallmouth bass, introduced as recreational species, prey on juvenile sockeye, coho, and chinook salmon (Tabor et al., 2007). Management priorities in Oregon concentrate on the species whose current or potential impacts on native species and habitats and economic and recreational activity in Oregon are known to be significant, known as aquatic nuisance species (ANS) (Hanson and Sytsma, 2001). Pacific Connector has developed BMPs to avoid the potential spread of the aquatic invasive species and pathogens of concern (see Hydrostatic Testing Plan – appendix U). If determined to be feasible for hydrostatic testing requirements, all water used in hydrostatic testing would be returned to its withdrawal source location after use; however, cascading water from one test section to another to minimize water withdrawal requirements may make it impractical to release water within the same watershed where the water was withdrawn. If it is not possible to return the water to the same water basin from where it was withdrawn, various water treatment methods would be used to disinfect water that would be transferred across water basin boundaries including screening/filtering, chlorine treatment, and discharge to upland sites. After hydrostatic test water withdrawal, all equipment used in the withdrawal process would be cleaned and sanitized to prevent the potential spread of aquatic invasives and pathogens from the use of this equipment in other waterbody sources (see appendix U).

Riparian Vegetation Removal and Modification

Aquatic resources could be affected as a result of removal of vegetation and habitat at the waterbody crossing sites as required for pipeline construction. Short-term, physical habitat disruption would occur during trenching activities. Long-term degradation of habitats could occur if the stream contours are modified in the area of the crossing; the flow patterns are changed; and if erosion of the bed, banks, or adjacent upland areas introduces sediment into the waterbody. Loss of riparian vegetation along the banks would reduce shade, potentially increasing water temperatures, remove an important source of terrestrial food for aquatic organisms, and decrease LWD and the associated reduction in habitats, and potentially increase mass failures adjacent to waterbodies.

Much of the impact to coldwater anadromous and resident fisheries by past land uses have been alterations of riparian habitats by logging, road building, agriculture, or other developments such as residences and utility corridors. A total of 292.65 acres of riparian zone habitat associated with waterbodies within range of Oregon Coast coho ESU would be directly affected by all construction related activities. Less than half of the affected vegetation (142.50 acres) would be within non-forested types but 14.35 acres of late successional-old growth forest and 55.61 acres of mid-seral forest would be removed within riparian zones (see table 4.5.4-18a). As discussed in Section 4.5.4.2- Habitat, and data presented in table 4.5.4-7 and table 4.5.4-8, the LWD components of most aquatic habitats in watersheds occupied by Oregon Coast coho and crossed by the PCGP Project are deficient, below benchmark conditions established by ODFW.

In forested habitats, conifer trees will be replanted within the construction right-of-way and other cleared areas outside of the 30-foot wide maintenance corridor and allowed to return to its pre-construction state. The 30-foot wide maintenance corridor centered over the pipeline will be maintained in an herbaceous/shrub state by operations during the life of the project, assumed to be 50 years (see table 4.5.4-18b). Over the long-term, 3.39 acres through riparian late successional-old growth forest and 12.45 acres through mid-seral forest would be maintained in an herbaceous/shrub state within riparian zones associated with Oregon Coast coho (see table 4.5.4-18b).

Pacific Connector has attempted to minimize impacts on riparian vegetation by minimizing the width of the standard construction right-of-way at waterbody crossings, and by maintaining a setback between waterbody banks and TEWAs in forested areas. Following construction, Pacific Connector will implement measures to replant or encourage regrowth in riparian areas, and will minimize vegetation maintenance by allowing the development of a riparian strip at least 25 feet wide to be permanently revegetated on private lands and 100 feet wide on federally-managed lands as measured from the edge of the waterbody. As required by FERC's Upland Plan, Pacific Connector consulted with the NRCS, BLM, and Forest Service regarding specific seeding dates and recommended seed mixtures for the project area (see Resource Report 7, Pacific Connector Gas Pipeline). The recommendations have been incorporated into the project-specific Erosion Control and Revegetation Plan (ECRP – see appendix F). The ECRP describes the procedures that will be implemented to minimize erosion and enhance revegetation success for the entire project.

**Table 4.5.4-18a**
**Total Terrestrial Habitat (acres) Affected/Removed[1] by Construction within Riparian Zones (One Site-Potential Tree Height Wide) Adjacent to Perennial and Intermittent Waterbodies within Range of Oregon Coast Coho Crossed by the PCGP Project**

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| **Coos Bay Frontal Pacific Ocean (HU 1710030403)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.00 | 0.15 | 0.25 | 0.00 | **0.40** | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | **0.03** | **0.43** |
| Non-Federal | 0.83 | 10.33 | 36.42 | 2.93 | **50.51** | 0.86 | 18.33 | 0.17 | 13.87 | 37.85 | **71.08** | **121.59** |
| **Watershed Total** | **0.83** | **10.48** | **36.67** | **2.93** | **50.91** | **0.86** | **18.33** | **0.17** | **13.87** | **37.88** | **71.11** | **122.02** |
| **Coquille River(HU 1710030505)** | | | | | | | | | | | | |
| Non-Federal | 0.36 | 0.75 | 7.57 | 0.00 | **8.68** | 0.00 | 0.00 | 0.00 | 0.00 | 0.39 | **0.39** | **9.07** |
| **Watershed Total** | **0.36** | **0.75** | **7.57** | **0.00** | **8.68** | **0.00** | **0.00** | **0.00** | **0.00** | **0.39** | **0.39** | **9.07** |
| **North Fork Coquille River (HU 1710030504)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 1.09 | 7.24 | 0.00 | 0.00 | **8.33** | 0.00 | 0.01 | 0.00 | 0.57 | 0.88 | **1.46** | **9.79** |
| Non-Federal | 0.00 | 4.77 | 7.90 | 0.00 | **12.67** | 0.00 | 0.05 | 0.00 | 2.30 | 0.78 | **3.13** | **15.80** |
| **Watershed Total** | **1.09** | **12.01** | **7.90** | **0.00** | **21.00** | **0.00** | **0.06** | **0.00** | **2.87** | **1.66** | **4.59** | **25.59** |
| **East Fork Coquille River(HU 1710030503)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.61 | 0.00 | 1.19 | 0.00 | **1.80** | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | **0.93** | **2.73** |
| Non-Federal | 0.15 | 2.71 | 9.17 | 1.11 | **13.14** | 0.00 | 0.01 | 0.00 | 2.08 | 0.68 | **2.77** | **15.91** |
| **Watershed Total** | **0.76** | **2.71** | **10.36** | **1.11** | **14.94** | **0.00** | **0.01** | **0.00** | **2.08** | **1.61** | **3.70** | **18.64** |
| **Middle Fork Coquille River (HU 1710030501)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 2.92 | 0.00 | 2.85 | 1.02 | **6.79** | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | **0.80** | **7.59** |
| BLM-Roseburg District | 0.91 | 1.80 | 0.10 | 0.00 | **2.81** | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | **0.25** | **3.06** |
| Non-Federal | 1.01 | 2.31 | 1.24 | 0.26 | **4.82** | 0.00 | 0.00 | 0.00 | 3.71 | 0.03 | **3.74** | **8.56** |
| **Watershed Total** | **4.84** | **4.11** | **4.19** | **1.28** | **14.42** | **0.00** | **0.00** | **0.00** | **3.71** | **1.08** | **4.79** | **19.21** |
| **Olalla Creek-Lookingglass Creek (HU 1710030212)** | | | | | | | | | | | | |
| Non-Federal | 1.29 | 2.68 | 1.24 | 0.00 | **5.21** | 0.00 | 0.28 | 0.08 | 13.90 | 0.20 | **14.46** | **19.67** |
| **Watershed Total** | **1.29** | **2.68** | **1.24** | **0.00** | **5.21** | **0.00** | **0.28** | **0.08** | **13.90** | **0.20** | **14.46** | **19.67** |
| **Clark Branch-South Umpqua River (HU 1710030211)** | | | | | | | | | | | | |
| Non-Federal | 0.00 | 5.87 | 1.34 | 0.00 | **7.21** | 0.00 | 0.01 | 15.30 | 0.57 | 1.20 | **17.08** | **24.29** |
| **Watershed Total** | **0.00** | **5.87** | **1.34** | **0.00** | **7.21** | **0.00** | **0.01** | **15.30** | **0.57** | **1.20** | **17.08** | **24.29** |
| **Myrtle Creek (HU 1710030210)** | | | | | | | | | | | | |
| Non-Federal | 1.46 | 7.53 | 2.35 | 0.00 | **11.34** | 0.00 | 0.15 | 0.47 | 13.67 | 0.82 | **15.11** | **26.45** |
| **Watershed Total** | **1.46** | **7.53** | **2.35** | **0.00** | **11.34** | **0.00** | **0.15** | **0.47** | **13.67** | **0.82** | **15.11** | **26.45** |

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| **Days Creek-South Umpqua River (HU 1710030205)** | | | | | | | | | | | | |
| BLM-Roseburg District | 1.14 | 0.00 | 0.48 | 0.00 | **1.62** | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | **0.11** | **1.73** |
| Non-Federal | 0.51 | 6.00 | 1.34 | 0.00 | **7.85** | 0.00 | 0.13 | 3.17 | 5.55 | 1.66 | **10.51** | **18.36** |
| **Watershed Total** | **1.65** | **6.00** | **1.82** | **0.00** | **9.47** | **0.00** | **0.13** | **3.17** | **5.55** | **1.77** | **10.62** | **20.09** |
| **Upper Cow Creek (HU 1710030206)** | | | | | | | | | | | | |
| Forest Service-Umpqua National Forest | 2.07 | 3.47 | 1.43 | 0.00 | **6.97** | 0.09 | 0.00 | 0.00 | 0.00 | 0.56 | **0.65** | **7.62** |
| **Watershed Total** | **2.07** | **3.47** | **1.43** | **0.00** | **6.97** | **0.09** | **0.00** | **0.00** | **0.00** | **0.56** | **0.65** | **7.62** |
| **All Fifth Field Watersheds and Jurisdictions** | | | | | | | | | | | | |
| BLM-Coos Bay District | 4.62 | 7.39 | 4.29 | 1.02 | **17.32** | 0.00 | 0.01 | 0.00 | 0.57 | 2.64 | **3.22** | **20.54** |
| BLM-Roseburg District | 2.05 | 1.80 | 0.58 | 0.00 | **4.43** | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | **0.36** | **4.79** |
| Forest Service-Umpqua National Forest | 2.07 | 3.47 | 1.43 | 0.00 | **6.97** | 0.09 | 0.00 | 0.00 | 0.00 | 0.56 | **0.65** | **7.62** |
| **Federal Subtotal** | **8.74** | **12.66** | **6.30** | **1.02** | **28.72** | **0.09** | **0.01** | **0.00** | **0.57** | **3.56** | **4.23** | **32.95** |
| **Non-Federal Subtotal** | **5.61** | **42.95** | **68.57** | **4.30** | **121.43** | **0.86** | **18.96** | **19.19** | **55.65** | **43.61** | **138.27** | **259.70** |
| **Overall Total** | **14.35** | **55.61** | **74.87** | **5.32** | **150.15** | **0.95** | **18.97** | **19.19** | **56.22** | **47.17** | **142.50** | **292.65** |

[1] Project components considered in calculation of habitat "Removed": PCGP construction right-of-way, temporary extra work areas, aboveground facilities, and permanent and temporary access roads (PAR, TAR).

[2] Habitat Types within Riparian Zones generally categorized as: Late Successional (Mature) or Old Growth Forest (coniferous, deciduous, mixed ≥80 years old); Mid-Seral Forests (coniferous, deciduous, mixed ≥40 but ≤80 years old); Regenerating Forest (coniferous, deciduous, mixed ≥5 but ≤40 years old); Clearcut Forests; Wetland Forested, Unaltered Nonforested Habitat (grasslands, sagebrush, shrublands), and Altered Habitats (urban, industrial, residential, roads, utility corridors, quarries).

**Table 4.5.4-18b**
**Total Terrestrial Habitat (acres) within the 30-foot Wide Corridor Maintained during the PCGP Project within Riparian Zones (One Site-Potential Tree Height Wide) on Federal and Non-Federal Lands within Range of Oregon Coast Coho Crossed by the PCGP Project**

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| **Coos Bay Frontal Pacific Ocean (HU 1710030403)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.00 | 0.06 | 0.07 | 0.00 | **0.13** | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | **0.01** | **0.14** |
| Non-Federal | 0.22 | 2.47 | 8.85 | 0.77 | **12.31** | 0.28 | 2.93 | 0.01 | 2.68 | 1.00 | **6.90** | **19.21** |
| **Watershed Total** | **0.22** | **2.53** | **8.92** | **0.77** | **12.44** | **0.28** | **2.93** | **0.01** | **2.68** | **1.01** | **6.91** | **19.35** |
| **Coquille River (HU 1710030505)** | | | | | | | | | | | | |
| Non-Federal | 0.00 | 0.18 | 2.10 | 0.00 | **2.28** | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | **0.02** | **2.30** |
| **Watershed Total** | **0.00** | **0.18** | **2.10** | **0.00** | **2.28** | **0.00** | **0.00** | **0.00** | **0.00** | **0.02** | **0.02** | **2.30** |
| **North Fork Coquille River (HU 1710030504)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.31 | 1.85 | 0.00 | 0.00 | **2.16** | 0.00 | 0.00 | 0.00 | 0.06 | 0.01 | **0.07** | **2.23** |
| Non-Federal | 0.00 | 1.34 | 1.33 | 0.00 | **2.67** | 0.00 | 0.02 | 0.00 | 0.52 | 0.07 | **0.61** | **3.28** |
| **Watershed Total** | **0.31** | **3.19** | **1.33** | **0.00** | **4.83** | **0.00** | **0.02** | **0.00** | **0.58** | **0.08** | **0.68** | **5.51** |
| **East Fork Coquille River (HU 1710030503)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.30 | 0.00 | 0.31 | 0.00 | **0.61** | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | **0.15** | **0.76** |
| Non-Federal | 0.06 | 0.63 | 1.88 | 0.24 | **2.81** | 0.00 | 0.01 | 0.00 | 0.23 | 0.11 | **0.35** | **3.16** |
| **Watershed Total** | **0.36** | **0.63** | **2.19** | **0.24** | **3.42** | **0.00** | **0.01** | **0.00** | **0.23** | **0.26** | **0.50** | **3.92** |
| **Middle Fork Coquille River (HU 1710030501)** | | | | | | | | | | | | |
| BLM-Coos Bay District | 0.79 | 0.00 | 0.62 | 0.19 | **1.60** | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | **0.44** | **2.04** |
| BLM-Roseburg District | 0.25 | 0.46 | 0.00 | 0.00 | **0.71** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | **0.71** |
| Non-Federal | 0.36 | 0.66 | 0.26 | 0.04 | **1.32** | 0.00 | 0.00 | 0.00 | 0.93 | 0.01 | **0.94** | **2.26** |
| **Watershed Total** | **1.40** | **1.12** | **0.88** | **0.23** | **3.63** | **0.00** | **0.00** | **0.00** | **0.93** | **0.45** | **1.38** | **5.01** |
| **Olalla Creek-Lookingglass Creek (HU 1710030212)** | | | | | | | | | | | | |
| Non-Federal | 0.21 | 0.78 | 0.15 | 0.00 | **1.14** | 0.00 | 0.10 | 0.03 | 3.28 | 0.04 | **3.45** | **4.59** |
| **Watershed Total** | **0.21** | **0.78** | **0.15** | **0.00** | **1.14** | **0.00** | **0.10** | **0.03** | **3.28** | **0.04** | **3.45** | **4.59** |
| **Clark Branch-South Umpqua River (HU 1710030211)** | | | | | | | | | | | | |
| Non-Federal | 0.00 | 1.34 | 0.25 | 0.00 | **1.59** | 0.00 | 0.01 | 3.13 | 0.03 | 0.10 | **3.27** | **4.86** |
| **Watershed Total** | **0.00** | **1.34** | **0.25** | **0.00** | **1.59** | **0.00** | **0.01** | **3.13** | **0.03** | **0.10** | **3.27** | **4.86** |
| **Myrtle Creek (HU 1710030210)** | | | | | | | | | | | | |
| Non-Federal | 0.23 | 0.91 | 0.34 | 0.00 | **1.48** | 0.00 | 0.05 | 0.09 | 1.51 | 0.07 | **1.72** | **3.20** |
| **Watershed Total** | **0.23** | **0.91** | **0.34** | **0.00** | **1.48** | **0.00** | **0.05** | **0.09** | **1.51** | **0.07** | **1.72** | **3.20** |
| **Days Creek-South Umpqua River (HU 1710030205)** | | | | | | | | | | | | |
| BLM-Roseburg District | 0.07 | 0.00 | 0.04 | 0.00 | **0.11** | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | **0.06** | **0.17** |

| Fifth Field Watershed (Hydrologic Unit Code) and Landowner | Forest Habitat [2] | | | | | Other Habitat [2] | | | | | | Total Riparian Zone Impact (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Late Successional Old Growth Forest | Mid-Seral Forest | Regenerating Forest | Clearcut, Forest | Forest Total | Forested Wetland | Nonforested Wetland | Unaltered Nonforested Habitat | Agriculture | Altered Habitat | Other Total | |
| Non-Federal | 0.03 | 0.89 | 0.29 | 0.00 | **1.21** | 0.00 | 0.07 | 0.58 | 0.89 | 0.16 | **1.70** | **2.91** |
| **Watershed Total** | **0.10** | **0.89** | **0.33** | **0.00** | **1.32** | **0.00** | **0.07** | **0.58** | **0.89** | **0.22** | **1.76** | **3.08** |
| **Upper Cow Creek (HU 1710030206)** | | | | | | | | | | | | |
| Forest Service-Umpqua National Forest | 0.56 | 0.88 | 0.40 | 0.00 | **1.84** | 0.00 | 0.01 | 0.00 | 0.00 | 0.17 | **0.18** | **2.02** |
| **Watershed Total** | **0.56** | **0.88** | **0.40** | **0.00** | **1.84** | **0.00** | **0.01** | **0.00** | **0.00** | **0.17** | **0.18** | **2.02** |
| **All Fifth Field Watersheds and Jurisdictions** | | | | | | | | | | | | |
| BLM-Coos Bay District | 1.40 | 1.91 | 1.00 | 0.19 | **4.50** | 0.00 | 0.00 | 0.00 | 0.06 | 0.61 | **0.67** | **5.17** |
| BLM-Roseburg District | 0.32 | 0.46 | 0.04 | 0.00 | **0.82** | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | **0.06** | **0.88** |
| Forest Service-Umpqua National Forest | 0.56 | 0.88 | 0.40 | 0.00 | **1.84** | 0.00 | 0.01 | 0.00 | 0.00 | 0.17 | **0.18** | **2.02** |
| **Federal Subtotal** | **2.28** | **3.25** | **1.44** | **0.19** | **7.16** | **0.00** | **0.01** | **0.00** | **0.06** | **0.84** | **0.91** | **8.07** |
| **Non-Federal Subtotal** | **1.11** | **9.20** | **15.45** | **1.05** | **26.81** | **0.28** | **3.19** | **3.84** | **10.07** | **1.58** | **18.96** | **45.77** |
| **Overall Total** | **3.39** | **12.45** | **16.89** | **1.24** | **33.97** | **0.28** | **3.20** | **3.84** | **10.13** | **2.42** | **19.87** | **53.84** |

[1] Project components considered in calculation of habitat "Removed": PCGP construction right-of-way, temporary extra work areas, aboveground facilities, and permanent and temporary access roads (PAR, TAR).

[2] Habitat Types within Riparian Zones generally categorized as: Late Successional (Mature) or Old Growth Forest (coniferous, deciduous, mixed ≥80 years old); Mid-Seral Forests (coniferous, deciduous, mixed ≥40 but ≤80 years old); Regenerating Forest (coniferous, deciduous, mixed ≥5 but ≤40 years old); Clearcut Forests; Wetland Forested, Unaltered Nonforested Habitat (grasslands, sagebrush, shrublands), and Altered Habitats (urban, industrial, residential, roads, utility corridors, quarries).

Clearing the right-of-way would remove shading vegetation from uplands and riparian areas, exposing the land and water to increased sunlight, potentially resulting in both direct increases in water temperatures and indirect increases as water flows over the warmer land surface and eventually reaches the waterbody (Beschta and Taylor, 1988). For the waterbodies that would be crossed by HDD, the potential disturbance in riparian areas would be incidental trimming of vegetation using hand tools directly over the pipeline along a footpath. This minor clearing is required to facilitate the temporary deployment of HDD guidance (telemetry) cables along the ground during construction and to perform a leakage survey after installation and commissioning. This is a relatively small area along the riparian zone of any stream and would have minimal adverse effect on aquatic resources.

**Water Temperature**

The effects of water temperature on salmonid life stages have been extensively reviewed by McCullough (1999), Richter and Kolmes (2005), and others. Maximum water temperatures ranging from 22°C to 24°C (71.6°F to 75.2°F) limit distribution of many salmonid species. No salmonids can survive water temperatures exceeding 25°C (77°F) for extended periods (Ice, 2008). High water temperatures can cause migratory species (including anadromous salmonids) to delay upstream migration (Bjornn and Reiser, 1991), can decrease survival of spawners by increasing metabolic rates (Ice, 2008), can positively influence rates of embryo development and emergence but can negatively influence dissolved oxygen concentrations that limit rates of embryo development (Bjornn and Reiser, 1991). High temperatures inversely influence solubility of oxygen in water (Ice, 2008). Introduction of organic matter with decomposition by microorganisms reduces dissolved oxygen and, along with increased fines (suspended silt and clay) and decreased relative rate of oxygen input to water (reaeration) through reduction in stream flows (Ice, 2008), can adversely affect various salmonid life stages. Coho upstream migration water temperature requirments are for water from 7.2$^{o}$C to 15.6$^{o}$C, spawning requirements are for water from 4.4$^{o}$C to 9.4$^{o}$C, and for incubation from water from 4.4$^{o}$C to 13.3$^{o}$C; preferred temperature is 12.1$^{o}$C and upper lethal temperatures range from 26.0$^{o}$C to 28.8$^{o}$C, depending on previous acclimation temperatures (Bjornn and Reiser, 1991).

Vegetative cover that provides shade, especially during summer, is one factor that regulates water temperature. Construction across waterbodies would necessitate removal of trees and riparian shrubs at the crossing locations. Available information on the effects of pipeline construction in other regions on water temperature has found no or immeasurable change. The total width of riparian area affected by shade tree removal would be small (less than 100 feet) relative to the length of any stream crossed. In one study, construction across two coldwater, fish-bearing streams in Alberta required removing forested riparian vegetation; water temperatures at construction sites and downstream did not increase above temperatures at control sites upstream from construction (Brown et al., 2002). Similarly, water temperatures measured at four coldwater streams in New York before and during pipeline construction and for 3 years following construction showed no short-term or long-term effects on water quality parameters, including water temperature, even though such effects were expected because streambank vegetation had to be cleared, which reduced shading (Blais and Simpson, 1997). In the Alberta study, the highest water temperature recorded was 66°F (19°C in August). In the New York study, the highest temperature was 79 F (26°C) sometime between August and October.

Following requests by the Forest Service, Pacific Connector modeled water temperatures on 6 different stream segments on NFS lands in the Umpqua River basin on tributaries to East Fork

Cow Creek (5 crossings) and on the upper Rogue River basin on Little Butte Creek (North State Resources, 2009). Temperature models were run on 6 different stream segments on NFS lands in the Umpqua River basin on tributaries to East Fork Cow Creek (5 crossings) and on the upper Rogue River basin on Little Butte Creek (North State Resources, 2009). Of the three smallest streams modeled average temperature increase ranged from 1.0$^{o}$C to 8.6$^{o}$C right after construction. Because these streams were so small they likely also would have temperatures reduced rapidly downstream of the clearing from ground water inflow and likely would have no measurable effects on streams they flow into downstream.

As a rule, the effect of water temperature of a non-fish-bearing tributary on water temperature of a fish-bearing receiving stream is determined as the weighted mean of the two water temperatures, weight by respective volumes or instream flows. If $\mathbf{T_1}$ = temperature of tributary with $\mathbf{F_1}$ = flow rate, and $\mathbf{T_2}$ = temperature of receiving stream with $\mathbf{F_2}$ = flow rate, then the resulting water temperature $\mathbf{T_R}$ at the confluence of the two waterbodies would be,

$$\mathbf{T_R = (T_1\ F_1 + T_2\ F_2) / (F_1 + F_2).}$$

For example, Hydrofeature N is an unnamed tributary to East Fork Cow Creek crossed at MP 111.01. Pipeline construction would increase the water temperature by 8.6$^{o}$C from its base temperature of 11$^{o}$C (see North State Resources, 2009). The water temperature would be 19.6$^{o}$C but its reported summer base flow is 0.002 cfs. ODEQ measured water temperature within East Fork Cow Creek during September 1998, reported at 13.5$^{o}$C. No instream flow data are available for East Fork Cow Creek but USGS (Gage 14309500) has measured flows in West Fork Cow Creek, reporting an average flow of 11.4 cfs during September. Using those data as to illustrate how water temperatures would be combined by the weighted average, the resulting water temperature of Hydrofeature N and the receiving stream would be $\mathbf{T_R}$ = (19.6$^{o}$C x 0.002 cfs + 13.5$^{o}$C x 11.4 cfs) / (0.002 cfs + 11.4 cfs) = 13.501$^{o}$C. The increase of water temperature in the receiving stream by the tributary water temperature would be immeasurable (in this illustration the increase would be 0.001$^{o}$C).

In the North State Resources (2009 ) study, two streams, 5- and 6- feet wide would have estimated maximum temperature increases ranging from 0.4 to 0.5$^{o}$C with maximum temperature remaining at or below 15.6$^{o}$C in the two streams just downstream of the pipeline crossing sites. Those temperatures would remain within suitable range for salmonids. For the largest stream (22 feet wide) in the study, the estimated increase was estimated to be 0.02 to 0.1$^{o}$C depending on the temperature model applied. The modeled results, based on assumptions used about the rates of vegetation regrowth, determined that most temperature increase effects remained within the first 5 years, but were approaching pre-project temperatures within 10 years. Conditions at other streams along the pipeline route may vary from these due to site specific differences, but these results may be fairly representative of changes that may occur at forested streams along the route. Overall results suggest that other than the very smallest streams where fish resources would be limited, changes in temperature from vegetation removal are likely to remain small and immeasurable having unsubstantial effects on fish resources.

Similarly, GeoEngineers (2013c) modeled thermal impacts within 4$^{th}$ Field Watersheds where streams would be crossed by the pipeline where riparian shading vegetation would be removed within the 75-foot wide construction corridor and would be affected within the 30-foot maintenance corridor of the long term (e.g., see table 4.5.4-18b, above). Model results show a maximum predicted increase of 0.16°C over one 75 foot clearing. The analysis showed that elevated water temperatures would return to ambient levels within a maximum distance of 25 feet downstream of the pipeline corridor, based on removal of existing riparian vegetation over a cleared corridor width of 75 feet (GeoEngineers, 2013c). The results are similar to the more geographically-limited results obtained by North State Resources (2009) which suggested more thermal impact. The conclusion drawn by GeoEngineers (2013c) was that the magnitude of thermal impact caused by pipeline construction would not be expected to cause a thermal barrier to fish migration.

Pacific Connector has proposed supplemental riparian plantings as outlined in Section 10.12 of the ECRP (see appendix F) to help ensure that the core cold-water habitat temperature criteria are not exceeded at the maximum point of impact. These measures are designed to speed up the rate of riparian area recovery and provide more effective shade immediately following construction. Plantings and vegetation regrowth in riparian areas would help moderate potential temperature increases in the short term (a few years). Pacific Connector would install supplemental transplanted trees on the Umpqua National Forest within the riparian areas of East Fork Cow Creek (i.e., 15-20 feet tall with full crowns) to increase riparian area canopy closure and placing large woody debris and boulders to create micro-topography within the wetted stream channel (see Section10.12 in the ECRP). Shading from transplanted vegetation and micro-topographic features incorporated into the final grading plan are likely to reduce the heat load enough to reduce the likelihood of measurable water temperature increases. Pacific Connector modeled the potential benefit of post project effective shade created by these mitigation measures on the Umpqua National Forest. The results of the 10-year post project modeling time step was used to predict the benefits of the mitigation measures because the trees that would be transplanted provide at least the same shade values as predicted for this time step. The predicted water temperature changes are small, with less than a 0.3°C (0.5°F) change at the point of maximum impact, with no increase at the stream network scale (North State Resources, 2009). Inclusion of the measures improves the certainty that riparian area clearance and stream channel disturbance activities within the construction right-of-way would not cause measurable water temperature increases at the maximum point of impact or at the stream network scale.

**Large Woody Debris**

Existing conditions associated with riparian vegetation within 5$^{th}$ Field Watersheds in the Upper Rogue Sub-basin crossed by the PCGP Project (see discussion related to table 4.5.4-7 and table 4.5.4-8) are generally undesirable. There are too few large conifers along most stream reaches and LWD numbers, volume, and presence of key pieces tend to be below benchmark levels. The PCGP Project will remove 14.35 acres of late successional-old growth forest and 55.61 acres of mid-seral forest would be removed within riparian zones in watersheds occupied by Oregon Coast coho (see table 4.5.4-18a) which would affect recruitment of LWD at those sites. Of the total riparian forest affected, 11.31 acres would be removed in the Coos Sub-basin, 26.63 acres within the Coquille Sub-basin, and 32.02 acres would be removed within the South Umpqua Sub-basin.

A potential effect on fisheries that would result from forest clearing at pipeline crossings of waterbodies is the reduction of LWD in streams and on adjacent uplands (Harmon et al., 1986; Sedell et al., 1988). Large logs provide instream hydraulic complexity, which contributes to habitat complexity and the formation and maintenance of pools, riffles and other habitats which are critical to salmonid spawning and. As the size of individual logs or accumulations of logs increases, the size and stability of pools that are created also increase (Beschta, 1983). Riparian forests that undergo harvesting of large trees take on secondary-growth characteristics and contribute lower quantities of woody debris than unmanaged, old-growth forests (Bisson et al., 1987). However, sufficiently wide, carefully managed riparian buffers that retain a full complement of ages, sizes, and species of native trees and vegetation can ensure adequate recruitment of LWD to streams (Bisson et al., 1987; Murphy and Koski, 1989).

Pacific Connector has proposed to use on-site mitigation for impacts to waterbodies by installing LWD at agency- and land owner-approved and appropriate areas within the construction right-of-way across certain waterbodies. The use of LWD as a mitigation measure for impacts associated with instream construction has been documented as an effective means of creating instream habitat heterogeneity, reducing streambank erosion, reducing sediment mobilization (Bethel and Neal, 2003), and enhancing local fish abundance (Scarborough and Robertson, 2002). Placement of LWD on the streambanks and in the streams can provide slight shade and increase bank stability, while vegetation is maturing following construction. Additionally, placement of LWD in streams or on streambanks can provide habitat for benthic invertebrates, an important food source for salmonids, and also increase habitat for forage species with the creation of pools and enhancement of the salmonid rearing potential of an area (Cederholm et al. 1997; Slaney et al., 1997).

As shown in table 4.5.4-7 and table 4.5.4-8, LWD conditions are undesirable in all four fifth field watersheds of the Upper Rogue Sub-basin that would be crossed. Streams in the watersheds are deficient in numbers of LWD pieces per length of stream channel, deficient in volume of LWD, and deficient in numbers of key pieces (≥60 cm in diameter by ≥12 m in length) per unit of stream length. Based on those data, any addition of LWD to the watersheds would appear beneficial.

**Hydrostatic Testing**

Water would be required on a one-time basis near the end of construction to hydrostatically test the pipeline. Potential impacts associated with hydrostatic testing include entrainment of fish, reduced downstream flows, and impaired downstream uses if test water is withdrawn from surface waters, and erosion, scouring, and a release of chemical additives as a result of test water discharge. The Forest Service has also expressed concern that hydrostatic testing where the source and discharge locations were in different water basins could potentially transfer exotic organisms between basins. Pacific Connector would obtain its hydrostatic test water from commercial or municipal sources or surface water rights owners and come from lakes, impoundments, and streams, and has identified 15 potential source locations and 75 potential discharge locations for the test water (see Resource Report 1, Pacific Connector Gas Pipeline Project); all but seven potential discharge sites would be within the construction right-of-way.

Pacific Connector would minimize the potential effects of hydrostatic testing on these systems by adhering to the measures in its Hydrostatic Testing Plan (see appendix U), including screening intake hoses to prevent the entrainment of fish and other aquatic organisms, meeting NMFS screening criteria, and regulating the rate of withdrawal to avoid adverse impact on aquatic resources or downstream flows. Where test water cannot be returned to its withdrawal source, the water would be treated with a mild chlorine treatment and discharged to an upland location through a dewatering structure at a rate to prevent scour and erosion and to promote infiltration. Pacific Connector will obtain all necessary appropriations, withdrawal, and discharge permits through the Oregon Water Resources Department (OWRD). As part of the application process, OWRD provides the application(s) to ODEQ and ODFW for review.

**Fuel and Chemical Spills**

Fisheries habitats could be adversely affected if petroleum products were accidentally discharged into aquatic environments. Such materials are toxic to algae, invertebrates and fish. Of the products likely to be present during pipeline construction, data compiled from a wide range of sources indicate that diesel fuels and lubricating oils are considerably more toxic to aquatic organisms than other, more volatile products (gasoline) or heavier crude oil (Markarian et al., 1994). Release of diesel fuel in freshwater habitats significantly reduced aquatic invertebrate densities and species richness at least 3 miles downstream but invertebrate densities recovered within a year (Lytle and Peckarsky, 2001). Impacts to aquatic habitats that primarily affect aquatic substrates – hence spawning, incubating and rearing habitats – can remain for much longer periods (Markarian et al., 1994).

Construction equipment used to construct the pipeline across waterbodies can potentially release hydraulic fluid that include a variety of compounds those common of which are mineral oil-based, organophosphate esters, and polyalphaolefins (U.S. Department of Health and Human Services, 1997). Release from machinery can occur through faulty seals, hoses, sumps and reservoirs, or general system failure. Components of mineral oil and polyalpaolefins do appear to bioaccumulate in animals whereas larger molecular constituents in organophosphate esters can concentrate in fish, primarily partitioning in fat tissue (U.S. Department of Health and Human Services, 1997). In general, toxicity of organophosphate esters is greater than either mineral oil or polyalphaolefin-based hydraulic fluids for inhalation, oral, and dermal for humans but toxicities have not been clearly described for aquatic invertebrates or fish and would be dependent on specific chemical components (U.S. Department of Health and Human Services, 1997).

Inadvertent spills of fluids used during construction, such as fuels and lubricants, could contaminate wetland soils and vegetation. To minimize the potential for spills and any impacts from such spills, Pacific Connector's Spill Prevention, Containment, and Countermeasures Plan (SPCC Plan – see appendix L) will be implemented. In general, hazardous materials, chemicals, fuels, lubricating oils, and concrete-coating activities will be not be stored, nor will refueling operations be conducted within 150 feet of a wetland or waterbody in accordance with FERC's Wetland and Waterbody Procedures (see appendix C) and the SPCC Plan (see appendix L).

**Herbicide Application**

Following construction, Pacific Connector will implement a Noxious Weed Control Plan in part through the application of herbicides. Herbicides have the potential to cause toxic effects to different salmonid life stages and to other aquatic species, causing direct impacts, if used improperly. When herbicides are properly used according to label restrictions and BMPs to control noxious weeds, there is little to no chance of causing injury or mortality to fish or other aquatic organisms; the impact may be avoided or indirect.

Pacific Connector has developed an Integrated Pest Management Plan (IPM) in consultation with the Oregon Department of Agriculture, BLM and Forest Service (see Appendix I to the POD, available upon request) to address the control of noxious weeds and invasive plants across the project. The BMPs will minimize the potential spread of invasive species and minimize the potential adverse effects of control treatments.

According to the Pacific Northwest Weed Management Handbook (see Peachey et al., 2007), herbicides used in forests to control brush and weed-trees could include one of the following: 2,4-D, glyphosate, imazapyr, picloram, and ticlopyr which are applied during spring or fall dormancy although triclopyr or 2,4-D was not approved use by the Fremont-Winema National Forest (NF). Clopyralid may be used during summer to control thistles, other composites, and legumes while not damaging conifers. Only herbicides which are approved for use within treated lands (private, state, or federal) would be used. Chronic, long-term, elevated but sublethal toxic effects can lead to skin or eye irritation, headache, nausea, and possibly birth defects, genetic disorders, paralysis, cancer, and death (Tu et al., 2001). In general, most impact to waterbodies occurs from direct overspray or drift of herbicides (aerial applications) as well as leaching through soils into groundwater or as they are carried by surface/subsurface runoff (Tu et al., 2001). The ester form of herbicides is more toxic to fish and other aquatic species than salt or acid forms because esters are readily adsorbed through skin and gills. Esters are also water insoluble so that they are not diluted in waterbodies (Tu et al., 2001).

Herbicides potentially used during the project will breakdown over various periods of time, marked by the average half-life (the time it takes for the herbicide concentration to decline by 50% due to microbial metabolism –dependent on the microbial population, environmental pH, soil moisture and temperature - mineralization, and/or photolysis). Half-lives in soil and water are provided and known toxicities to bluegill sunfish (see Tu et al., 2001) although comparative toxicities to salmonids have not been found in the literature:

- 2,4-D – averages 10 day half-life in soils, less than 10 days in water. Salt formulations with low toxicity are registered for use against aquatic weeds, LC50 for bluegill sunfish = 263 mg/l.
- Glyphosate - ranges from several weeks to years, but averages two months. In water, glyphosate is rapidly dissipated through adsorption to suspended and bottom sediments, and has a half-life of 12 days to ten weeks. Some formulations with low toxicity are registered for aquatic use, LC50 for bluegill sunfish = 120 mg/l.
- Imazapyr – ranges from 1 to 5 months in soil. In aqueous solutions with photodegradation the half-life may be 2 days. It has low toxicity to fish and algae and other submerged vegetation are not affected, LC50 for bluegill sunfish >100 mg/l.
- Picloram- range from 1 month to several years in soils, average soil half-life of 90 days. LC50 for bluegill sunfish >14.5 mg/l.
- Triclopyr – average half-life in soils is 30 days but the salt formulation is water soluble and may photodegrade in several hours. LC50 for bluegill sunfish =148 mg/l.
- Clopyralid - half-life averages one to two months (40 days) but ranges up to one year. It is degraded almost entirely by microbial metabolism in soils and aquatic sediments. LC50 for bluegill sunfish =125 mg/l.

Of these herbicides, Picloram is the most toxic to bluegill sunfish and is potentially the longest persisting in soils and water. Similar attributes are expected for effects to salmonids. The potential for adverse effects to salmonids and other aquatic species by the other herbicides appear to be extremely remote, especially since application would be at least 100 feet from wetlands and waterbodies unless allowed by the appropriate agency. Pacific Connector will not use aerial herbicide applications and will not use herbicides for general brush/tree control within the 30-foot maintained easement. Given low toxicities to fish and short half-lives in soil and water, expected effects of the other herbicides to resident fish and anadromous salmonids would be discountable and insignificant.

Where weed control is necessary along the construction right-of-way, Pacific Connector's first priority will be to employ hand and mechanical methods (pulling, mowing, biological, disking, etc.) applicable to the species to prevent the spread of potential weed infestations, where feasible. To determine if an herbicide is to be used over other control methods, Pacific Connector will base the decision on weed characteristics and integrated weed management principles (Forest Service, 2005). If herbicides are used to control noxious weed infestations, they would be used when they are the most appropriate treatment method. Spot treatments and the use of selective herbicides would be utilized to minimize impact to native or non-target species. Pacific Connector will employ a state or federally-licensed herbicide applicator to ensure that the appropriate herbicides are utilized for the targeted weed species during its proper phenological period and at the specified rate. The applicator will ensure that the herbicides and any adjuvants are used according to the labeling restrictions, and warnings, following all applicable laws and conforming to the appropriate land managing agency decision documents. The applicator will also ensure that the herbicides that are used are registered for their intended use. Permits or approvals for the use of herbicides and adjuvants on federal lands would be obtained prior to use/treatment, as detailed in the IPM (see Appendix I to the POD, available upon request).

**Streambank Erosion**

The clearing and grading of vegetation during construction could increase erosion along streambanks and turbidity levels in the waterbodies. The rootwad network of trees adjacent to stream supplies bank stability. Those within 25 feet of the stream are considered most important at providing the root source aiding in bank stability (Washington Department of Natural Resouces, 1997). To aid in maintaining this bank stability, Pacific Connector would cut most trees near the bank, except those in the trench line, at ground level leaving the root systems in place helping to maintain riparian stability. Roots would be removed over the trench line or from any steam banks that would need to be cut down or graded to accomplish the pipeline crossing.

Alteration of the natural drainage ways or compaction of soils by heavy equipment near streambanks during construction may accelerate erosion of the banks, runoff, and the transportation of sediments into waterbodies. The degree of impact on aquatic organisms due to erosion would depend on sediment loads, stream velocity, turbulence, streambank composition, and sediment particle size. To minimize these impacts, Pacific Connector would use temporary equipment bridges, mats, and pads to support equipment that must cross the waterbody (perennial, intermittent, and ephemeral if water is present) or work in saturated soils adjacent to the waterbody. Pacific Connector would also install sediment barriers, such as silt fence and straw/hay bales, across the right-of-way at the edge of waterbodies throughout construction except for short periods when the removal of these sediment barriers is necessary to dig the trench, install the pipe, and restore the right-of way. Practices to minimize streambank erosion are provided in Section 5.0 in the ECRP (see appendix F).

**Operation and Maintenance Activities**

Once installed, maintenance of the pipeline would include activities such as aerial inspections, gas flow monitoring, visual inspection of surrounding vegetation for signs of leaks, and integrity management, which includes smart pigging to investigate the interior surface of the pipe for any signs of stress cracking, pitting, and other anomalies (see Section 13.0 in the ECRP – appendix F). All of the proposed maintenance activities would be outlined in the Operations and Maintenance plan that would be prepared according to operating regulations in U.S. Department of Transportation (DOT) 49 CFR Subpart L, Part 192 and would be completed prior to going in-service. These general maintenance activities would require only surface activities and usage of the existing right-of-way, such as insertion of the pig at one of the pig launching facilities.

The potential estuarine or stream channel disturbance would occur if an integrity issue with the pipeline were found. If this were to occur, the pipeline would need to be unearthed within the right-of-way and repair work done in-water. Within stream sites, repair work could require isolated flow from the section of pipe that is to be exposed. Typically, repairs would be made to the pipe within the right-of-way (within the trench) or, depending on the site-specific conditions and nature of the repair needed, a reroute around the affected section may be considered. Impacts would be similar to those discussed above for initial installation except on a much smaller scale, and would include all relevant BMPs and mitigation, dependent upon site conditions and land ownership..

Vegetation maintenance would be limited adjacent to waterbodies to allow a riparian strip to permanently revegetate with native plant species across the entire right-of-way. To facilitate periodic pipeline corrosion/leak surveys, a corridor centered on the pipeline and up to 30 feet wide would be maintained in an herbaceous state. In addition, trees that are located within 15 feet of the pipeline and that are greater than 15 feet in height would be cut and removed from the right-of-way.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA. The Pacific Connector pipeline would not be operational until at least 2017. Consequently, the foreseeable future required for cumulative effects analysis would actually occur before implementation of the proposed action, not after its implementation, which is more often the case.

Cumulative effects to Oregon Coast coho salmon would be generated by timber harvesting on non-federal lands. Areas of Late Successional-Old Growth (LSOG) forest have been monitored as a component of the Northwest Forest Plan (NWFP). In Oregon, LSOG was evaluated in 1996 (Moeur et al., 2005) and in 2006 (Moeur et al., 2011). Differences in areas of LSOG forests were described in the four physiographic provinces that coincide with the PCGP project showed an overall decline on all lands; from 1996 to 2006 there was an overall net loss of LSOG on non-federal lands within the Coast Range (-17.1 percent), Klamath Mountains (-6.7 percent), Western Cascades (-10.8 percent), and Eastern Cascades (-12.6 percent) provinces (see Table 7 in Moeur et al., 2011). Most of the losses in LSOG on federal lands were attributed to large fire events including the 2002 Biscuit Fire in the Klamath Mountains, the 2003 B&B Fire in the Western Cascades, and the 2003 B&B Fire and Davis Fire in the Eastern Cascades (Moeur et al, 2011). However, losses associated with wildfire were negligible on non-federal lands. Most of the decline in LSOG on non-federal lands was due to timber harvest, primarily concentrated in the Oregon Coast Range province (see Table 7 in Moeur et al., 2003)

Within the PCGP project area and range of Oregon Coast coho, comparisons of LSOG coverage on non-federal lands within the four of the fifth field watersheds in the Coos and Coquille sub-basins show opposite trends from 1996 to 2006; the only apparent loss of LSOG occurred within the Middle Fork Coquille River Watershed (see figure 4.5-31).

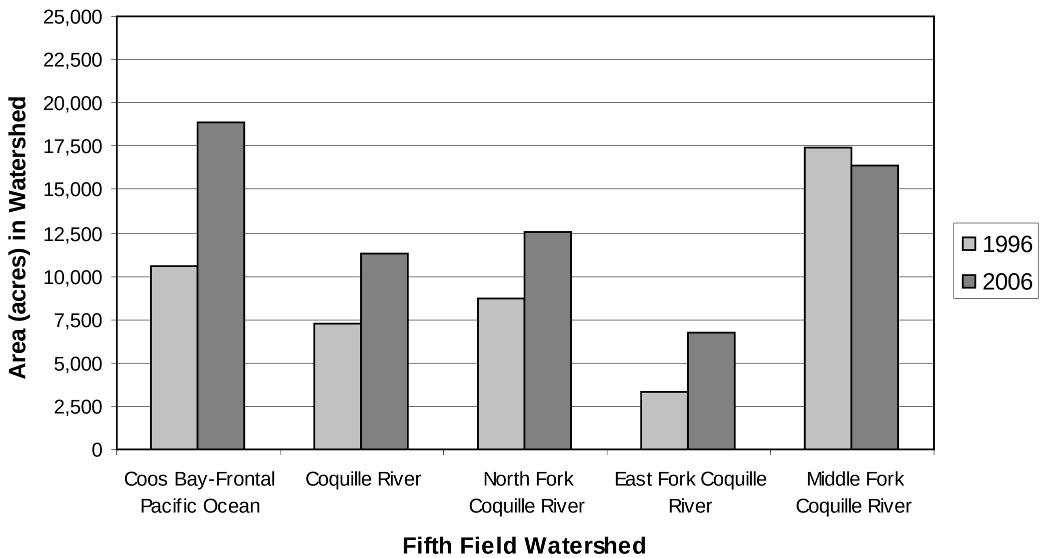



**Figure 4.5-31**
**Total Areas (acres) of Late Successional-Old Growth Forests on Non-Federal Lands in 1996 and 2006 within Five Fifth Field Watersheds (Coos and Coquille Sub-basins) within Range of Oregon Coast Coho Salmon that would be Crossed by the PCGP Project. (Data from Interagency NWFP Interagency Regional Monitoring Program, 2013)**

During the period from 1996 to 2006, areas of LSOG on non-federal lands increased by 78 percent within Coos Bay-Frontal Pacific Ocean watershed, by 57 percent within Coquille River watershed, by 46 percent within North Fork Coquille River watershed, and increased by 103 percent in the East Fork Coquille River watershed. LSOG declined by 6 percent within Middle Fork Coquille River watershed. All five fifth field watersheds are within the Oregon Coast Range Province in which there was a 17.1 percent decline of LSOG primarily due to timber harvest. The disparity between the overall decline of LSOG in the Coast Range province and increase of LSOG in the four fifth field watersheds is unexplained but may be due to measurement errors, mapping errors, and/or differences in detection or definition of LSOG between 1996 and 2006. Regardless, we use comparisons of LSOG from 1996 to 2006 to estimate cumulative effects the in the Coos and Coquille sub-basins in the reasonably foreseeable future w.

Comparisons of LSOG coverage on non-federal lands within four of the fifth field watersheds in the South Umpqua Sub-basin show declining trends from 1996 to 2006; the only apparent increase in LSOG occurred within the Olalla Creek-Lookingglass Creek Watershed (see figure 4.5-32). During the period from 1996 to 2006, areas of LSOG on non-federal lands increased by 36 percent within Olalla Creek-Lookingglass Creek watershed, but decreased by 54 percent within the Clark Branch-South Umpqua River watershed, decreased by 55 percent within the Myrtle Creek watershed, decreased by 54 percent in the Days Creek-South Umpqua River Watershed, and decreased by 91 percent in the Upper Cow Creek Watershed.

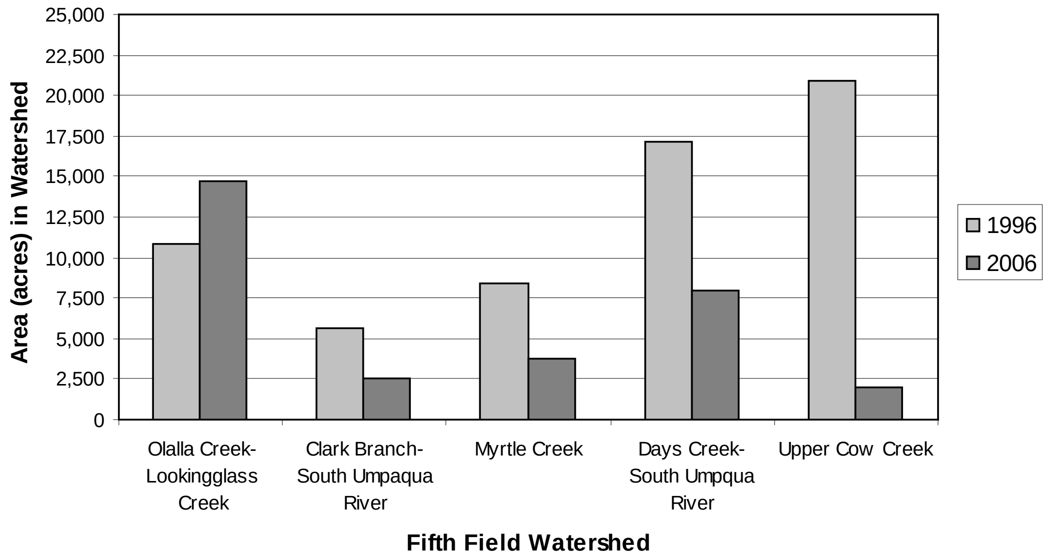



**Figure 4.5-32**
**Total Areas (acres) of Late Successional-Old Growth Forests on Non-Federal Lands in 1996 and 2006 within Five Fifth Field Watersheds (South Umpqua Sub-basin) within Range of Oregon Coast Coho Salmon that Would Be Crossed by the PCGP Project. (Data from Interagency NWFP Interagency Regional Monitoring Program, 2013)**

Based on the past trend there would be more LSOG on non-federal lands in the foreseeable future in half of the watersheds and less LSOG on the other half of watersheds affected by the PCGP project that are within range of coho salmon in the Oregon Coast ESU. Increased LSOG within riparian zones may be possible. Removal of additional LSOG within riparian zones on non-federal land would be more of a reasonably foreseeable cumulative impact. The amount of LSOG gain or loss on non-federal land through 2016, for example, would possibly be: 1) by the same percentage, or 2) at the same rate as the amounts that changed between 1996 and 2006. These two scenarios are provided below in table 4.5.4-19 wherein change (gain or loss) at a constant annual rate predicts no LSOG left on non-federal lands by 2016 in three of the watersheds. Alternatively, change of LSOG by the same percent change observed between 1996 and 2006 predicts considerable increases in LSOG in 2016 on five watersheds with decreases on five others but not totally eliminating LSOG within any of the watersheds (see table 4.5.4-19).

**Table 4.5.4-19**
**Two Estimates For Areas of Late Successional-Old Growth Forest in 2016 on Non-Federal Lands in Fifth Field Watersheds Crossed by the PCGP Project within Range of Oregon Coast Coho**

| Oregon Coast ESU Fifth Field Watershed | Area (acres) of LSOG on Non-Federal Land in 2006 [1] | LSOG Estimate Based on Percent Change | | LSOG Estimate Based on Rate of Change | |
|---|---|---|---|---|---|
| | | Percent Change in LSOG Since 1996 | Area (acres) of LSOG Remaining in 2016 | Rate of Change (acres per year) Since 1996 | Area (acres) of LSOG Remaining in 2016 |
| Coos Bay-Frontal Pacific Ocean | 18,835 | 78.4% | 33,608 | 828 | 27,114 |
| Coquille River | 11,357 | 56.6% | 17,781 | 410 | 15,461 |
| North Fork Coquille River | 12,602 | 45.5% | 18,335 | 394 | 16,543 |
| East Fork Coquille River | 6,698 | 102.8% | 13,582 | 339 | 10,093 |
| Middle Fork Coquille River | 16,392 | -5.8% | 15,435 | -102 | 15,375 |
| Olalla Creek-Lookingglass Creek | 14,690 | 35.7% | 19,942 | 387 | 18,559 |
| Clark Branch-South Umpqua River | 2,588 | -54.0% | 1,191 | -304 | 0 |
| Myrtle Creek | 3,740 | -55.4% | 1,667 | -465 | 0 |
| Days Creek-South Umpqua River | 7,924 | -53.7% | 3,670 | -919 | 0 |
| Upper Cow Creek | 1,938 | -90.7% | 130 | -1,894 | 0 |
| Total LSOG Areas | **96,764** | | **125,341** | | **103,145** |

[1] Data from Interagency NWFP Interagency Regional Monitoring Program, 2013

In 2016, there might be between 103,000 and 125,000 acres of LSOG within the ten fifth field watersheds crossed by the PCGP project within range of Oregon Coast coho but there are no estimates for areas of LSOG within riparian zones within the watersheds. However, amounts of LSOG within the PCGP project area that would be affected by construction and amounts of LSOG that would be affected within riparian zones (e.g., see table 4.5.4-18a) have been determined. We assumed that the proportions of LSOG in riparian zones to total LSOG affected by pipeline construction on non-federal lands within each watershed were representative of proportions of riparian to total LSOG on non-federal lands in each watershed. With that assumption, we computed the areas of LSOG in riparian zones on non-federal that would change (as a gain or loss) by 2016, based on the reasonably foreseeable future estimates of remaining LSOG in table 4.5.4-19. Estimates of areas of riparian LSOG present on non-federal lands in 2016 are provided in table 4.5.4-20, based on the percent change in LSOG since 1996 (derived in table 4.5.4-19). The estimates predict that there would have been a total of 20,281 acres of riparian LSOG on non-federal lands within all ten watersheds during 2006 but there would be a net gain of nearly 8,000 acres of riparian LSOG in 2016 in spite of likely timber removal actions on non-federal lands (including removal of riparian LSOG) and other possible causes of removal (wildfire, disease). However, estimates of riparian LSOG within six watersheds indicate losses between 2006 and 2016. The proposed action would remove 7.68 acres of riparian LSOG within the ten watersheds in range of the Oregon Coast coho, about 0.03 percent of the amount of riparian LSOG projected to be present in 2016, within the reasonably foreseeable future, and a small portion of overall cumulative effects.

**Table 4.5.4-20**
**Potential for Cumulative Effects within Late Successional and Old Growth Riparian Forests on Non-Federal Lands within the Pacific Connector Pipeline Action Area that Coincide with the Oregon Coast Coho Salmon ESU**

| SONCC ESU Fifth Field Watershed | Area (acres) of LSOG on Non-Federal Land in 2006 [1] | LSOG Affected by the Proposed Action on Non-Federal Land in Watershed | | | Area (acres) of Riparian LSOG on Non-Federal Land in Watershed | |
|---|---|---|---|---|---|---|
| | | Area (acres) of LSOG Affected | Area (acres) of LSOG Within Riparian Zones | Proportion of Riparian LSOG | Area (acres) of Riparian LSOG in 2006 [2] | Area (acres) of Riparian LSOG Present in 2016 [3] |
| Coos Bay-Frontal Pacific Ocean | 18,835 | 7.46 | 0.83 | 0.11 | 2,096 | 3739 |
| Coquille River | 11,357 | 0.36 | 0.36 | 1.00 | 11,357 | 17785 |
| North Fork Coquille River | 12,602 | 0.71 | 0 | 0.00 | 0 | 0 |
| East Fork Coquille River | 6,698 | 2.33 | 0.15 | 0.06 | 431 | 874 |
| Middle Fork Coquille River | 16,392 | 3.95 | 1.01 | 0.26 | 4,191 | 3948 |
| Olalla Creek-Lookingglass Creek | 14,690 | 19.80 | 1.29 | 0.07 | 957 | 1299 |
| Clark Branch-South Umpqua River | 2,588 | 7.57 | 0 | 0.00 | 0 | 0 |
| Myrtle Creek | 3,740 | 8.90 | 1.46 | 0.16 | 614 | 274 |
| Days Creek-South Umpqua River | 7,924 | 32.12 | 0.51 | 0.02 | 126 | 58 |
| Upper Cow Creek | 1,938 | 7.88 | 2.07 | 0.26 | 509 | 47 |
| Total Area | **96,764** | **91.08** | **7.68** | | **20,281** | **28,024** |

[1] Data from Interagency NWFP Interagency Regional Monitoring Program, 2013.
[2] Based on Proportion of Riparian LSOG affected by PCGP Project on Non-Federal Land
[3] Based on the Percent Change in LSOG Since 1996 in table 4.5.4-19.

ODF Administrative Rules (Chapter 629) include requirements for protecting riparian zones associated with streams of various size classes and uses on non-federal lands. RMA widths were assigned to "retain the physical components and maintain the functions necessary to accomplish the purposes and to meet the protection objectives and goals for water quality, fish, and wildlife". Specified riparian zones widths range from 100 feet for a large (average annual flow ≥ 10 $feet^3$/second) Type F (fish use and domestic use) stream to 20 feet for a small (average annual flow ≤ 2 $feet^3$/second) Type D (domestic water use, no fish) stream. While the ODF Administrative Rules provide some protection to fish-bearing streams, the narrower riparian zones described in the Rules are likely to provide less protective functions due to forest harvest practices on non-federal lands than harvest on federal lands.

### Critical Habitat

The Coos Bay Estuary and 29 freshwater streams known to support coho within table 4.5.4-1 are designated critical habitat for Oregon Coast coho. The effects to riparian zones associated with each waterbody in critical habitat that support coho are included in table 4.5.4-18a. PCEs include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation (NMFS, 2008d). Each PCE defined for critical habitat would be adversely affected by the proposed action. Those effects have been quantified to the extent possible in the foregoing analyses including effects within the EEZ analysis area, the estuarine analysis area, and the riverine analysis area.

Project effects to freshwater spawning sites would likely occur prior to coho spawning in the year of construction and there would be no effects to spawning, incubation, and larval development by suspended sediment although project-generated sediment could increase gravel embeddeness downstream. Those effects would depend on precipitation and instream flow (potential freshets) following construction that would likely flush fines downstream The project would remove small areas of riparian forest that would provide recruitment of LWD. The project would temporarily decrease water quality downstream from construction sites by entrainment of sediments. In all instances, habitat suitability (HADD) would temporarily decrease. Construction of the pipeline across Haynes Inlet and dredging of the Coos Bay shipping channel would decrease water quality and affect cover (aquatic vegetation, eelgrass). Disposal of dredged spoils at Site F could cause effects to the nearshore marine environment, similar to assumed effects that are associated with current maintenance dredging. LNG carriers could affect offshore marine areas of critical habitat if spills or releases at sea occurred and possible limited effects due to vessel noise.

#### 4.5.4.4 Conservation Measures

Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to the estuary (estuarine analysis area), waterbodies, and riparian zones (riverine analysis area). Those measures have been compiled in table 2C in appendix N and apply to Oregon Coast coho salmon.

Pacific Connector has also proposed measures to rectify, repair, rehabilitate, and otherwise reduce impact to waterbodies and riparian zones once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N.

**Erosion Control**

Many of the conservation measures in table 3C in appendix N focus on erosion control to prevent sediment from entering surface waters. Temporary erosion controls would be installed immediately after vegetation clearing and grading and would be properly maintained throughout construction and reinstalled as necessary until replaced by permanent erosion controls or restoration is complete. At a minimum, the following temporary erosion control structures would be installed: temporary slope breakers, sediment barriers, mulch, and erosion control fabric.

**Temporary Slope Breakers**

Pacific Connector would install temporary slope breakers over the backfilled, recontoured construction right-of-way as specified in FERC staff's Plan. The outfall of each temporary slope breaker would be to a stable, well-vegetated area or to an energy-dissipating device at the end of the slope breaker off the construction right-of-way. Slope breakers reduce runoff velocity, thereby intercepting sediment and allowing it to drop out of suspension. They also can effectively divert runoff away from a disturbed site to a stable outlet (Goldman et al., 1986).

**Sediment Barriers**

Pacific Connector would primarily rely upon silt fence and staked hay or straw bales to confine sediment to the construction right-of-way. These structures would be used adjacent to wetland and waterbody crossings consistent with the requirements of FERC staff's Procedures. Straw bales and filter fabric (silt fence) can be used together to create a highly effective sediment barrier, a combination that compensates for the limitations of each used in isolation; straw bales provide extra support and the fabric provides greater filtering capability (Goldman et al., 1986).

All straw or hay bales used for sediment barriers would be certified as weed-free. Temporary sediment barriers would be maintained in-place until permanent revegetation measures are successful or until the upland areas adjacent to wetlands, waterbodies or roads are stabilized. The structures would be removed once vegetation in the area has been successfully restored.

**Mulch**

Under certain circumstances, the FERC staff's Plan requires the application of mulch to stabilize the soil surface. If it becomes necessary to delay final cleanup, including final grading and installation of permanent erosion control measures, beyond 10 days after the trench is backfilled in a specific area, Pacific Connector would apply mulch to the disturbed areas before seeding, consistent with the requirements of FERC staff's Plan. Mulch would also be applied if construction and restoration activity is interrupted for extended periods. In these cases mulch would be applied at a rate of three tons/acre on all slopes within 100 feet of waterbodies and wetlands.

A number of areas would be crossed with slopes in excess of eight percent. In these areas, mulch would be applied uniformly to cover at least 75 percent of the ground surface at a rate of two tons/acre of straw or hay or its equivalent. All straw or hay mulch would be certified weed-free.

**Erosion Control Fabric**

Pacific Connector would install erosion control fabric (such as jute or excelsior) on waterbody banks at the time of recontouring. The fabric would be anchored using staples or other appropriate devices. Although there are no measures specific to pipeline construction, data related to cut-and-fill slopes treated during construction of forest roads indicate varying effectiveness of different types of stabilization measures designed to control surface erosion (EPA, 2001). On fill slopes, combining straw mulch and netting decreased erosion by 99 percent. Excelsior mulch alone decreased erosion by 92 percent on fill slopes. On cut slopes, straw mulch by itself decreased erosion in a range from 32 to 97 percent (EPA, 2001). Applications of mulches and/or fabric are effective measures promoting slope stabilization until vegetation can successfully be reestablished. These measures also promote plant growth (EPA, 2001).

**Cleanup and Permanent Erosion Control**

Pacific Connector would make every effort to complete final cleanup of an area within ten days after backfilling the trench. Final cleanup would include final grading and installation of permanent erosion control structures. In no case would Pacific Connector delay final cleanup beyond the end of the next recommended seeding season. During final cleanup Pacific Connector would remove all construction debris and grade disturbed areas to preconstruction grades to the extent practicable. An adequate seedbed would be prepared at the conclusion of cleanup. Pacific Connector would install permanent slope breakers consistent with the requirements of FERC staff's Plan.

**Fish Salvage Plan**

All waterbodies that would be crossed by dry open cut construction would be done prior to adult coho salmon upstream migration, within ODFW in-stream construction windows. A Fish Salvage Plan has been provided in appendix T. The plan has been developed to minimize adverse effects to listed salmonids (SONCC coho salmon, Oregon Coast coho salmon), non-listed salmonids (chinook salmon, steelhead, and cutthroat trout) and listed catostomids (Lost River sucker, shortnose sucker). The portions of the plan relevant to salvaging salmonids were adapted from the protocol developed by WSDOT (2014). The protocol specifies procedures to 1) isolate the work area; 2) remove fish and dewater the work area; 3) handle, hold and release fish; 4) document fish that have been captured, handled, held, and released; and 5) notify NMFS and FWS. Only trained professionals would conduct electroshocking and fish removal.

**Revegetation**

As required by the FERC staff's Plan, Pacific Connector has identified procedures for the preparation and planting of live stakes or sprigs and for the planting bare root tree seedlings. Those procedures are included in appendix R. Within the range of Oregon Coast coho salmon, construction of the Pacific Connector pipeline would remove 69.96 acres of riparian forested habitats of which 14.35 acres are late-successional (mature) old-growth, 55.61 acres are mid-seral forests, and 0.95 acre is forested wetlands (see table 4.5.4-14a).

Existing forested riparian zones in which forest would be removed during construction would be re-planted with conifers to within 15 feet of each side of the pipeline centerline. Permanent effects – persisting longer than the assumed 50-year life of the pipeline – would occur by removing 14.35 acres of late-successional (mature) old-growth riparian forest. Even though the riparian zone would be replanted, the newly planted trees would not attain late-successional or old-growth status within 50 years. Permanent effects would also last along the 30-foot wide maintenance corridor centered on the pipeline. Those effects to former late-successional (mature) old-growth riparian forest, Mid-Seral riparian forest and other existing riparian vegetation are included in table 4.5.4-18b. Replanting conifers within each affected forested riparian zone would leave an estimated 16.12 acres of non-forested vegetation within former forested riparian zones over the long-term or permanently (see table 4.5.4-18b).

**ORV Barriers**

The FERC staff's Plan requires the Project to offer to each owner or manager of forested lands to install and maintain measures to control unauthorized vehicle access to the right-of-way and states that such measures may include signs; fences with locking gates; slash and timber barriers, pipe barriers, or a line of boulders across the right of way; and conifers or other appropriate trees or shrubs across the right-of-way. Slash, stumps and or logs, if available, would be placed on the right-of-way within the riparian zones to discourage ORV crossings of streams and provide carbon and nutrients if allowed by the landowner. If not allowed, Pacific Connector would discuss with the landowner the use of other methods, as noted above. At a minimum the area would be revegetated and re-seeded.

**Streambank Stability**

The root network of trees adjacent to streambanks is essential to maintaining streambank stability (WDNR 1997). Because root strength decreases significantly at distances beyond one-half the tree crown diameter, trees promoting streambank stability lie within half a tree crown diameter from the streambank. Trees within 25 feet of the streambank are assumed to promote streambank stability (WDNR 1997). Generally, trees that must be removed during construction would be cut at ground level with the roots left in place, except where located within the trenchline. Although roots would decay overtime, streambank stability would be retained by their presence until revegetation is successful.

**In-stream Gravel**

Waterbodies supporting fisheries would be backfilled with material removed from the trench with the upper 1 foot of the trench backfilled with clean gravel or native cobbles. Pacific Connector has requested a variance from Section V.C.1. of FERC staff's Procedures in fish-bearing streams that do not have gravel, cobble, or other rock substrates prior to construction. This variance was requested because many of the streams crossed by the pipeline are remote and are located in steep valley or ravine bottoms. Therefore hauling rock to these steams is impractical especially where these streams do not have gravel or cobble substrate characteristics prior to construction. The bottom and banks would be returned to preconstruction contours; banks would be stabilized; and temporary sediment barriers would be installed before returning flow to the waterbody channel.

**Large Woody Debris**

In several instances, mitigation would contribute to restoring an aquatic habitat indicator's functional level, such as placement of LWD within and/or adjacent to streams and placing LWD on floodplains, where appropriate, to provide microsites for riparian vegetation and/or vegetation protection during flood events. Placement of LWD in streams and/or on streambanks has been one focal point of recent stream rehabilitation procedures (Slaney and Martin, 1997; Cederholm et al. 1997; EPA, 2001) as well as a central consideration in the Compensatory Mitigation Plan (see appendix O).

As indicated in table 4.5.4-7 and table 4.5.4-8, baseline watershed conditions crossed by the pipeline are lacking in LWD due to historical disturbance and LWD presence is typically below benchmark thresholds to be properly functioning. LWD is an important habitat feature providing in-stream structure, channel and habitat complexity among other benefits, and that promote salmonid productivity. Pacific Connector proposes to install LWD on-site during construction as an appropriate habitat enhancement feature to mitigate for potential pipeline impacts and to benefit watershed conditions, which are generally lacking.

LWD placement would be in addition to the Project conservation measures (see appendix N) that have been designed to minimize the potential Project effects, including utilizing dry open cut crossing methods, applying in-stream construction timing restrictions, and implementing erosion control measures and revegetation methods. Because of the overall lack of LWD in the affected watersheds, LWD also provides an appropriate mitigation model for the Project's potential waterbody crossing impacts that are temporary, short-term, and unavoidable (see Compensatory Mitigation Plan in appendix O). The LWD would also serve to mitigate for potential long-term Project impacts - impacts lasting for the 50-year life of the pipeline - such as the loss of forested riparian vegetation within the pipeline's 30-foot operational corridor (see table 4.5.3-13b, above). Even though the riparian zone would be replanted, the planted trees would not attain late-successional or old-growth status within 50 years. Placement of LWD would, in some measure, reduce though not eliminate the impact due to the removal of late-successional (mature) old-growth riparian forest.

For low-gradient streams, Cederholm et al. (1997) suggests using logs with diameters at least 18 inches (less in areas of low velocity) placed by vertical angling into the stream channel. Logs could be used to create a stepped-channel profile with the rootwads and encourage woody debris accumulations in pool margins. For streams with steeper gradients, they suggest that logs with smaller diameters might be used if larger logs are unavailable. Near headwaters, LWD is often suspended over the channel so that it can become functional during periods of maximum runoff. Smaller debris may be retained during those periods and help develop pools that would be functional during summer (see Cederholm et al., 1997).

Guidelines for LWD placement, provided by ODF and ODFW (1995), suggest using the following: 1) larger diameter wood pieces because they are more effective at creating pools and complex channels which improve fish populations (see table 4.5.4-21 for minimum diameter LWD per bankfull width); 2) LWD that are at least twice the length of the waterbody bankfull width (1.5 times the bankfull width if the rootwad is attached) to increase the likelihood that the LWD would remain in place; and 3) conifer logs, especially western red cedars if available, because they are more durable. In larger waterbodies, smaller diameter, shorter LWD could be used if bundled and anchored together to provide the same benefits of the longer, larger diameter LWD (ODF and ODFW 1995).

Trees classified as late-successional or old-growth are assumed to have attained heights equal to the site-potential tree heights that are included above in table 4.5.4-18a as Riparian Zone Widths. Site-potential tree heights range from 225 feet (for example, the Coos Bay-Frontal Pacific Ocean Watershed) to 164 feet (as in the Days Creek-South Umpqua Rover Watershed). If Douglas-fir trees in the Oregon Cascades grow in height at the rate of 20 inches per year and in diameter by 0.25 inches per year (Cox, 2008), a 20-inch tall seedling planted the year after construction of the Pacific Connector pipeline would be an estimated 85 feet tall and 12 to 13 inches in diameter (assumed dbh) after 50 years. Trees with those dimensions would provide suitable LWD for streams with bankfull widths from 0 to 10 feet but not larger streams (see table 4.5.4-21). Even in these streams recruitment of wood may be reduced as the young age of the forest would reduce recruitment from natural mortality as the rate would be less relative to older trees. But recruitment of wood is not solely dependent on natural tree mortally but includes important contributing factors such as bank erosions, disease, fires, slides, and windthrow (Reeves et al. 2003, Martin and Benda 2001, Gregory et al. 2003). LWD contribution would occur from these areas even though natural mortality contribution would be reduced.

**Table 4.5.4-21**
**Minimum Diameter LWD for Placement in Waterbody Based on Bankfull Width**

| Bankfull Width (feet) | Minimum Diameter LWD (inches) |
|---|---|
| 0 to 10 | 10 |
| 10 to 20 | 16 |
| 20 to 30 | 18 |
| Over 30 | 22 |
| Source: ODF and ODFW, 1995. | |

The Pacific Connector pipeline would actually cross 79 perennial streams within the range of Oregon Coast ESU coho salmon. Forty-two of those perennial streams have existing riparian forest ranging from Mid-Seral stage (approximately 40 to 80 years old) to older late-successional and old-growth; 28.77 acres of existing riparian forest would be removed by construction. Thirty-seven more perennial streams would also be crossed but construction would not affect riparian forest vegetation (see table 4.5.4-22). In addition, the PCGP project would cross 73 intermittent streams, 47 of which support riparian forest, so that 61.08 acres total of riparian forest would be removed. Twenty-six additional intermittent streams with no riparian forest would be crossed as well (see table 4.5.4-22).

To offset impact from removal of riparian trees (reducing LWD recruitment potential) and to provide an overall benefit by enhancing stream habitat with no potential for LWD recruitment, Pacific Connector proposes to place LWD at the waterbody flow types identified by watershed in table 4.5.4-22, based on the following applications:

- four pieces for each perennial stream crossed with riparian forest removed (two pieces in-stream and/or keyed into the streambank, two pieces within riparian zone on the bank);
- two pieces for each intermittent stream and unknown stream crossed with riparian forest removed (one or both LWD pieces placed in-stream, keyed into the bank, or placed on the bank);
- two pieces for each perennial, intermittent, and unknown stream crossed but with no riparian forest removed (one or both LWD pieces paced in-stream keyed into the bank, or placed on the bank); and
- one piece each for a perennial, intermittent, and unknown stream not crossed but adjacent to the construction right-of-way, with or without riparian forest removed (LWD placed on bank).

Because the construction right-of-way at stream crossings would be 75 feet wide, Pacific Connector anticipates only enough space for two pieces of LWD, preferably with rootwads attached, either placed in-stream or with stems keyed into streambanks. Unless site-specific conditions dictate otherwise, the preferable location for each in-stream LWD is downstream from the pipeline to prevent scour of the pipe. LWD would also be placed near or adjacent to streambanks within riparian zones to provide for and/or enhance microsites for riparian vegetation and/or vegetation protection during flood events.

In all, Pacific Connector proposes 405 pieces of LWD for placement within the ten fifth-field watersheds that coincide with Oregon Coast ESU coho salmon and designated critical habitat. Placement of LWD is subject to approval by each affected landowner. If a landowner rejects the proposed placement of LWD, the number of pieces that would have been applied onsite would be reserved and provided to appropriate watershed councils for their use and placement, preferably elsewhere within the affected fifth-field watershed.

Pacific Connector anticipates that during construction, in some cases, the waterbody size, landowner restrictions, or construction constraints would limit LWD placement according to the proposed LWD schedule provided in table 4.5.4-22. Further, the overall benefit of installation of LWD at some pipeline waterbody crossings (i.e., intermittent headwater streams) may not warrant LWD placement. In these situations, Pacific Connector's Environmental Inspector would record the uninstalled LWD as a deficit during construction. After construction is completed, unutilized LWD would be provided to local watershed conservation organizations or agencies for use in local enhancement projects within the affected watersheds. (Also see the discussion on the use of LWD for mitigation in Compensatory Mitigation Plan in appendix O.)

**Compensatory Mitigation**

Appendix O provides the draft Compensatory Mitigation Plan which includes proposed mitigation projects within watersheds in the Coos, Coquille, and South Umpqua Sub-Basins.

**Table 4.5.4-22**
**Proposed Application of Large Woody Debris to Waterbodies and Riparian Zones**
**Affected by Construction of the Proposed Action within the Range of Oregon Coast Coast Coho Salmon**

| Fifth Field Watershed | Watershed Parameter | Waterbody Type | | | | | | Total in Watershed | Pieces of LWD Applied to Fifth Field Watershed [1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Perennial | | Intermittent | | Unknown | | | | | |
| | | Crossed | Adjacent | Crossed | Adjacent | Crossed | Adjacent | | Crossed | Adjacent | Total |
| Coos Bay-Frontal Pacific Ocean (HU 1710030403) | Area (acres) of Riparian Forest | 2.97 | 0 | 3.77 | 0.56 | 0 | 0 | 7.30 | | | |
| | Total Number of Waterbodies | 37 | 3 | 19 | 4 | 0 | 0 | 63 | | | |
| | With Riparian Forest | 10 | 0 | 6 | 1 | 0 | 0 | 17 | 52 | 1 | 53 |
| | No Riparian Forest | 27 | 3 | 13 | 3 | 0 | 0 | 46 | 80 | 6 | 86 |
| Coquille River (HU 1710030505) | Area (acres) of Riparian Forest | 0.75 | 0 | 0 | 0 | 0 | 0 | 0.75 | | | |
| | Total Number of Waterbodies | 5 | 0 | 1 | 0 | 0 | 0 | 6 | | | |
| | With Riparian Forest | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 4 |
| | No Riparian Forest | 4 | 0 | 1 | 0 | 0 | 0 | 5 | 10 | 0 | 10 |
| North Fork Coquille River (HU 1710030504) | Area (acres) of Riparian Forest | 0.96 | 0.16 | 9.69 | 1.12 | 0 | 0 | 11.93 | | | |
| | Total Number of Waterbodies | 2 | 1 | 8 | 2 | 0 | 0 | 13 | | | |
| | With Riparian Forest | 1 | 1 | 7 | 2 | 0 | 0 | 11 | 18 | 3 | 21 |
| | No Riparian Forest | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 4 | 0 | 4 |
| East Fork Coquille River (HU 1710030503) | Area (acres) of Riparian Forest | 2.02 | 0 | 0.85 | 0 | 0 | 0 | 2.87 | | | |
| | Total Number of Waterbodies | 6 | 1 | 7 | 0 | 0 | 0 | 14 | | | |
| | With Riparian Forest | 5 | 0 | 5 | 0 | 0 | 0 | 10 | 30 | 0 | 30 |
| | No Riparian Forest | 1 | 1 | 2 | 0 | 0 | 0 | 4 | 6 | 1 | 7 |
| Middle Fork Coquille River (HU 1710030501) | Area (acres) of Riparian Forest | 5.41 | 0 | 2.89 | 0 | 0 | 0 | 8.30 | | | |
| | Total Number of Waterbodies | 5 | 0 | 8 | 0 | 0 | 0 | 13 | | | |
| | With Riparian Forest | 5 | 0 | 7 | 0 | 0 | 0 | 12 | 34 | 0 | 34 |
| | No Riparian Forest | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 2 |
| Olalla Creek-Lookingglass Creek (HU 1710030212) | Area (acres) of Riparian Forest | 2.82 | 0 | 1.16 | 0 | 0 | 0 | 3.98 | | | |
| | Total Number of Waterbodies | 4 | 0 | 11 | 0 | 0 | 0 | 15 | | | |
| | With Riparian Forest | 4 | 0 | 6 | 0 | 0 | 0 | 10 | 28 | 0 | 28 |
| | No Riparian Forest | 0 | 0 | 5 | 0 | 0 | 0 | 5 | 10 | 0 | 10 |

| Fifth Field Watershed | Watershed Parameter | Waterbody Type: Perennial Crossed | Perennial Adjacent | Intermittent Crossed | Intermittent Adjacent | Unknown Crossed | Unknown Adjacent | Total in Watershed | Pieces of LWD Applied to Fifth Field Watershed [1]: Crossed | Adjacent | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Clark Branch-South Umpqua River (HU 1710030211) | Area (acres) of Riparian Forest | 1.01 | 0 | 3.31 | 0.4 | 0 | 0 | 4.72 | | | |
| | Total Number of Waterbodies | 6 | 0 | 10 | 3 | 0 | 0 | 19 | | | |
| | With Riparian Forest | 2 | 0 | 9 | 1 | 0 | 0 | 12 | 26 | 1 | 27 |
| | No Riparian Forest | 4 | 0 | 1 | 2 | 0 | 0 | 7 | 10 | 2 | 12 |
| Myrtle Creek (HU 1710030210) | Area (acres) of Riparian Forest | 5.48 | 0 | 0.5 | 2.84 | 0 | 0 | 8.82 | | | |
| | Total Number of Waterbodies | 5 | 0 | 3 | 2 | 0 | 0 | 10 | | | |
| | With Riparian Forest | 5 | 0 | 2 | 2 | 0 | 0 | 9 | 24 | 2 | 26 |
| | No Riparian Forest | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 2 |
| Days Creek-South Umpqua River (HU 1710030205) | Area (acres) of Riparian Forest | 4.69 | 0 | 2.94 | 0 | 0 | 0 | 7.63 | | | |
| | Total Number of Waterbodies | 5 | 0 | 4 | 0 | 0 | 0 | 9 | | | |
| | With Riparian Forest | 5 | 0 | 3 | 0 | 0 | 0 | 8 | 26 | 0 | 26 |
| | No Riparian Forest | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 2 |
| Upper Cow Creek (HU 1710030206) | Area (acres) of Riparian Forest | 2.66 | 0.22 | 1.9 | 0 | 0 | 0 | 4.78 | | | |
| | Total Number of Waterbodies | 4 | 1 | 2 | 0 | 0 | 0 | 7 | | | |
| | With Riparian Forest | 4 | 1 | 2 | 0 | 0 | 0 | 7 | 20 | 1 | 21 |
| | No Riparian Forest | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Fifth Field Watersheds For Oregon Coast Coho** | Area (acres) of Riparian Forest | 28.77 | 0.38 | 27.01 | 4.92 | 0 | 0 | 61.08 | | | |
| | Total Number of Waterbodies | 79 | 6 | 73 | 11 | 0 | 0 | 169 | | | |
| | With Riparian Forest | 42 | 2 | 47 | 6 | 0 | 0 | 97 | 262 | 8 | 270 |
| | No Riparian Forest | 37 | 4 | 26 | 5 | 0 | 0 | 72 | 126 | 9 | 135 |
| | | | | | | | **Total LWD** | | **388** | **17** | **405** |

[1] Proposed schedule for applying LWD to different waterbody types, subject to landowner approval:

- 4 pieces for each perennial stream crossed with riparian forest removed (2 pieces instream, 2 pieces within riparian zone on the bank);
- 2 pieces for each intermittent stream and unknown stream crossed with riparian forest removed (one or both pieces placed instream or on bank);
- 2 pieces for each perennial, intermittent, and unknown stream crossed but with no riparian forest removed (one or both pieces paced instream or on bank).
- 1 piece each for perennial, intermittent, and unknown stream not crossed but adjacent to ROW with or without riparian forest removed (piece placed on bank).

### 4.5.4.5 Determination of Effects

**Species Effects**

The Project **may affect** coho salmon in the Oregon Coast ESU because:

- Several stages and activities of coho salmon (upstream adult migration, juvenile rearing, and juvenile out-migration) are expected to occur at various locations in the riverine analysis area during construction and operation of the proposed action.
- Several stages and activities of coho salmon (juveniles, adults) are expected to occur within the estuarine analysis area during construction and operation of the proposed action.
- Adult coho salmon area expected to occur within the EEZ analysis area during operation of the proposed action.

While several project actions are not likely to cause adverse effects, those resulting effects from Project components that are **likely to adversely affect** coho salmon in the Oregon Coast ESU include:

- Discharge of maintenance dredge spoils off shore at Site F would generate a turbidity plume that could affect coho adults and juveniles within the EEZ analysis area.
- Juvenile coho may be susceptible to stranding by LNG carrier wakes within the estuarine analysis area.
- Short-term effects to the benthic community and potential food resources for Oregon Coast coho would be affected by dredging the proposed access channel in Coos Bay.
- Construction of the proposed pipeline would affect aquatic vegetation (eelgrass), the benthic community, and potential food resources for Oregon Coast coho during construction across Haynes Inlet.
- Total Suspended Sediments (TSS) could adversely affect juvenile coho salmon. Exposure of juveniles to TSS concentrations during dry open-cut construction (fluming or dam-and-pump) for more than 20 hours could potentially exceed SEV 4 for 10 to 100 meters or more downstream. Such an effect could cause a short-term reduction in feeding rate and short-term reduction in feeding success.
- Exposure of juveniles to TSS concentrations during dry open-cut construction (fluming or dam-and-pump) for 40 hours of more could potentially exceed SEV 5 for 10 to 100 meters or more downstream. Such an effect could cause minor physiological stress in juvenile coho salmon.
- If a failure occurs during peak flow periods while dry open-cut construction is underway, possible effects to juvenile coho (SEV = 6) could include moderate physiological stress.
- TSS produced by dry open-cut construction methods to cross streams are estimated to temporarily affect the water columns within 32,152 feet downstream from some in-stream construction sites (not simultaneously) if peak flows occur during construction.
- TSS concentrations generated during dry open-cut construction and if failure of isolation structures occur, would adversely affect freshwater habitats by changing coho habitat preferences (SEV = 3) or causing moderate habitat degradations (SEV = 7).
- Construction requiring blasting at 30 streams could cause mortality to fish by rupturing swim bladders. Adult and juvenile coho salmon would be removed and/or prevented from being within 50 feet of blasting sites to the maximum extent possible.

- Fish salvage would occur within isolated construction sites, possibly when adult and juvenile coho salmon are present. Coho salmon are considered vulnerable to electrofishing, subject to injury and mortality. Fish salvage would primarily rely on seining but may require electrofishing as a last resort, only DC or pulsed DC current would be used. Seining, electrofishing and handling may adversely affect Oregon Coast coho salmon.
- Lack of LWD is a limiting factor in most streams within range of Oregon Coast coho salmon. Removal of Mid-Seral riparian forest (40-80 years old) would have long-term effects to recruitment of LWD and removal of Late Successional or Old-Growth forest (≥80 years old) would have permanent effects to recruitment of LWD because planted conifers would not attain those age classes within the 50-year life of the project.

**Critical Habitat Effects**

The Project **may affect** designated critical habitat for coho salmon in the EEZ analysis area, within the estuarine analysis area, and within the riverine analysis area for the Oregon Coast ESU because construction and operation of the LNG terminal and LNG carriers will occur and the Pacific Connector pipeline crosses designated critical habitat within waterbodies of the Coos, Coquile, and South Umpqua sub-basins.

Project components are **likely to adversely affect** proposed critical habitat for coho salmon in the Oregon Coast ESU because:

- Discharge of maintenance dredge spoils off shore at Site F would generate a turbidity plume that could affect coho adults and juveniles within the EEZ analysis area.
- Juvenile coho may be susceptible to stranding by LNG carrier wakes within the estuarine analysis area.
- Short-term effects to the benthic community and potential food resources for Oregon Coast coho would be affected by dredging the proposed access channel in Coos Bay.
- Construction of the proposed pipeline would affect aquatic vegetation (eelgrass), the benthic community, and potential food resources for Oregon Coast coho during construction across Haynes Inlet.
- Freshwater spawning sites would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would remove substrate at crossing sites and produce turbidity downstream that could affect previously utilized redds.
- Turbidity is expected to temporarily affect the water quality within a total of 32,152 feet downstream from some dry open cut construction sites (not simultaneously) generated by mobilized clay (organics) if peak flows occur during construction.
- TSS concentrations generated during dry open-cut construction and if failure of isolation structures occur, would adversely affect freshwater habitats by changing coho habitat preferences (SEV = 3) or causing moderate habitat degradations (SEV = 7).
- Food resources would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would remove substrate and benthos at crossing sites and produce turbidity downstream in all streams likely to support Oregon Coast coho salmon.
- Freshwater migration corridors would potentially be affected over the short-term by dry open cut and diverted open cut construction methods that would produce turbidity

downstream and create temporary barriers to in-stream movements while construction sites are isolated.

A total of 292.65 acres of riparian zone habitat associated with waterbodies within range of Oregon Coast coho ESU would be directly affected by all construction related activities. Adverse effects to riparian zones would be long-term or permanent depending on whether mid-seral riparian forests (55.61 acres) or late-successional/old-growth riparian forests (14.35 acres) are removed.

### 4.5.5 Lost River Sucker

#### 4.5.5.1 Species Account and Critical Habitat

**Status**

The Lost River sucker was listed as a federally endangered species on July 18, 1988 (FWS 1988). The Lost River sucker was listed as endangered because of the loss of habitat and access to historical range, resulting in a declining population. A 5-year review was released in July 2007 that recommended down listing the Lost River sucker from endangered to threatened status (FWS 2007g). However, no formal proposal to down list the species to threatened status has been made.

**Threats**

Lost River suckers and shortnose suckers were considered together in the final rule listing both as endangered species. Numerous factors in both species' decline were cited by FWS (1988) including historical over-fishing, dams limiting upstream movements and access to spawning habitats, introduction of non-native species that compete (fathead minnows) and prey on suckers (yellow perch, bullheads, largemouth bass, and various lepomid sunfish), and degradation of water quality due to livestock grazing, agriculture, and timber harvest. Pollution in Upper Klamath Lake has lead to algal blooms with increased mortality of suckers when oxygen depletions occur due to eutrophication. Status assessments conducted in 2001 and 2002 (FWS, 2002c) concluded that the Lost River sucker was threatened by the following: 1) drastically reduced adult populations and reduction in range; 2) extensive habitat loss, degradation, and fragmentation; 3) small or isolated adult populations as a result of dams; 4) poor water quality; 5) lack of sufficient recruitment; 6) entrainment into irrigation and hydropower diversions; 7) hybridization with the other native Klamath sucker species; 8) potential competition with introduced exotic fishes; and 9) lack of regulatory protection.

FWS (2007g) published a more recent status review of Lost River suckers in 2007. Recent habitat loss (wetlands in the upper Klamath Basin) has been minor and numerous habitat restoration projects have resulted in some positive population response by Lost River suckers. Nevertheless, poor water quality in Upper Klamath Lake and the Lost River continues, particularly during summers when high temperatures combined with nutrient loading from pumping diked wetlands and runoff from farms, roads, and other sources as well as from lake sediments create hypereutrophic conditions which lead to depletions of dissolved oxygen and fish die-offs (FWS, 2007g). Populations declined prior to listing due to habitat loss of approximately 75 percent of historic range, restricted access to spawning habitat, overharvest, and increased rates of mortality resulting from entrainment in water management structures and severely impaired water quality. Populations in Upper Klamath Lake have chronically low recruitment, reduced survivorship of adult fish, and reduced age-class diversity. Length-frequency analysis suggests that the last substantial recruitment to the spawning population occurred during the late 1990s (FWS, 2012g).

**Species Recovery**

Actions described in the recovery plan that would aid in the delisting of the Lost River sucker include improving habitat conditions through rehabilitating riparian areas and improving land management practices in the Klamath Basin watershed, developing and achieving water quality and quantity goals, and improving fish passage, spawning habitat, and other habitat conditions.

A recovery plan for Lost River sucker and short-nose sucker was finalized on March 17, 1993 (FWS 1993b). Since then there has been substantial amounts of additional information, prompting recent revision of the recovery plan (FWS, 2012g). The recovery program goal is to stop the population decline and enhance Lost River sucker and shortnose sucker populations so that ESA protection is no longer necessary.

At the time of listing, population declines were related to loss or degradation of spawning, rearing, and adult habitats. Only about 25 percent of the original habitat remains. Reductions in habitat quality compound the effects of reduced habitat quantity and availability on Lost River sucker and shortnose sucker abundance. In addition to habitat, factors currently limiting species recovery include high mortality of larvae and juveniles due to reduced rearing habitat, entrainment in water management structures, poor water quality, and adverse effects (predation, competition) from non-native, introduced fish species. Adult populations are limited by extremely limited recruitment to the population as well as high levels of stress and mortality associated with severely impaired water quality. As a whole the species are potentially limited by the lack of habitat connectivity (FWS, 2012g).

Demographic-based objectives include increasing larval production, individual survival and recruitment to spawning populations, and ultimately increasing abundance in spawning populations. The objectives of restoring spawning and nursery habitat, expanding reproduction, reducing the negative impacts from water quality on all life stages, clarifying the effects of other species on all life stages, reducing entrainment, and establishing auxiliary populations comprise the threats-based objectives. The recovery strategy is intended to produce and document healthy, self-sustaining populations by reduction of mortality, restoration of habitat, including spawning, larval and juvenile habitats, and increasing connectivity between spawning and rearing habitats. It also involves ameliorating adverse effects of degraded water quality, disease, and non-native fish. The plan provides areas of emphasis and guidelines to direct recovery actions (FWS, 2012g). There are two recovery units for Lost River suckers, the Upper Klamath Lake Unit and Lost River Basin Unit (FWS, 2012g). Upper Klamath Lake Unit includes all Lost River suckers within lake, tributaries to Upper Klamath Lake, and reservoirs within the Klamath River including Keno Reservoir and populations below Keno Reservoir. The Lost River Basin Recovery Unit includes Clear Lake Reservoir and tributaries including Willow Creek and Boles Creek, (FWS, 2012g). The Lost River is not included in designated critical habitat.

**Life History, Habitat Requirements, and Distribution**

Lost River suckers are native to the Lost River and Upper Klamath River Basin but have adapted to lake habitats and are now a lake-dwelling fish that migrates into streams to spawn (Moyle, 2002). It is a long-lived species, reaching ages over 30 years. Historically, Lost River suckers were found in the Lost River watershed, Tule Lake, Lower Klamath Lake, and Sheepy Lake. The present distribution of the Lost River sucker includes Upper Klamath Lake and its tributaries, Clear Lake Reservoir and its tributaries, Tule Lake and the Lost River up to Anderson-Rose Dam, the Klamath River downstream to Copco Reservoir, and probably Iron Gate Reservoir. In the Upper Klamath Lake watershed, the Lost River sucker spawning runs are primarily limited to Sucker Springs in Upper Klamath Lake, and the Sprague and Williamson Rivers. Spawning runs also occur in the Wood River and in Crooked Creek in this watershed. An additional run may occur in Sheepy Lake in the Lower Klamath Lake watershed and spawning has been documented in the Clear Lake watershed (FWS, 1988 and 1993b).

Although sucker spawning habitat in the Lost River is very limited, U.S. Bureau of Reclamation (Reclamation, 2007) has documented sucker spawning below Anderson-Rose Dam, in Big Springs near Bonanza and at the terminal end of the West Canal as it spills into the Lost River. Suitable spawning habitats with riffle areas and rocky substrates include the spillway area below Malone Dam, immediately upstream of Keller Bridge, immediately below Big Springs in the Lost River, below Harpold Dam, and adjacent to Station 48 (Reclamation, 2007). Suckers are primarily bottom dwellers, remaining within 1 foot of bottom substrates. Water depths and turbidity provide cover in lakes while pools and overhanging banks provide cover features in streams. In Tule Lake, most depths are less than 1 meter and adult suckers are confined to the few locations where depths exceed 1 meter (Reclamation, 2007). During periods of deteriorating water quality, especially in Upper Klamath Lake, adult suckers may utilize shallow waters with suitable water quality even though they may be more vulnerable to predators (Reclamation, 2007).

Most spawning by Lost River suckers lasts from late February to early June in the larger tributaries of inhabited lakes (FWS, 2007g). River spawning habitat in riffles or runs with gravel or cobble substrate, with moderate flows, and in water 8 to 50 inches deep. Some Lost River suckers have been noted to spawn in lakes, particularly at springs occurring along the shorelines (FWS, 2007g). Each Lost River sucker female may produce between 44,000 and 236,000 eggs in a single spawning season; larger, older females produce more eggs and contribute more to recruitment than younger females (Reclamation, 2007).

Larval Lost River suckers are present in Upper Klamath Lake from the beginning of May through mid-July. During that period, larvae utilize protective emergent vegetation along lake shorelines which provides cover from predators, currents and turbulence, and are areas of concentrated prey including zooplankton, macroinvertebrates, and periphyton (Reclamation, 2007). Similar relationships within the Lost River watershed, including Tule Lake and Lost River, have not be studied but are assumed to be similar to those in Upper Klamath Lake (Reclamation, 2007).

By mid-summer larval suckers have become juveniles, which, in Upper Klamath Lake, tend to occupy shoreline habitats less than 4 feet deep with and without emergent vegetation and/or shoreline vegetation. Abundance of juvenile suckers in the lake declines dramatically during late summer and early autumn. Some of the decline is due to emigration of juveniles into the Link River and parallel canals at the outlet of Upper Klamath Lake (Reclamation, 2007). Adult suckers (and presumably subadults) in Upper Klamath Lake tend to inhabit deeper (>1 meter) waters in the northern half of the lake (Reclamation, 2007). But, when water quality deteriorates in the north end of the lake during mid-summer with lower concentrations of dissolved oxygen, adult Lost River and shortnose suckers migrate to relatively shallow waters in Pelican Bay along the west shore (Reclamation, 2007). Similar seasonal movements have not been described for suckers inhabiting Tule Lake and the Lost River although reproduction has been documented in Tule Lake and is suspected to occur in the Lost River.

In the Upper Klamath Sub-basin (HUC 18010206) they are found in the Klamath River as far downstream as Copco Reservoir (RM 199) and possibly Iron Gate Reservoir (RM 191). The PCGP pipeline would cross the Klamath River at RM 249. In the Lost Sub-basin, they are found in the Lost River mainstem and Clear Lake Reservoir (Moyle, 2002). In the project vicinity, Lost River suckers spawn in the Lost River and are present in John C. Boyle Reservoir, downstream from the pipeline crossing at RM 225 (National Research Council, 2004). In addition to collections of Lost River suckers in J.C. Boyle Reservoir, ORBIC (2012) cites records of collections in Lake Ewauna and in the Lost River Diversion Channel connecting the Klamath River (at RM 249.8) to the Lost River at the Lost River Diversion Dam, approximately 10 river miles downstream from the PCGP crossing of the Lost River at RM 9.5.

Historically, Lost River suckers migrated upstream from Tule Lake (in California) to spawn near Bonanza. Currently, Lost River suckers migrate a short distance from Tule Lake to spawn in the Lost River below Anderson-Rose Diversion Dam (RM 17.4) south of Merrill and approximately 7.6 river miles from the pipeline crossing of the Lost River (ORBIC, 2012). Suckers also spawn below Malone Dam, downstream from Clear Lake, also in California.

**Population Status**

The Lost River sucker population in Upper Klamath Lake was estimated between 11,000 and 23,000 at the time of the Final Rule listing the species as endangered (FWS, 1988). That estimate was probably inaccurate although adults in Upper Klamath Lake and Clear Lake (in California) probably number in the tens of thousands (FWS, 2007g). There had been several die-offs during the 1990s which affected the spawning population of older adults in Upper Klamath Lake. Current information indicates possible increased recruitment of males and females with only slight population growth in the portion of the population normally spawning along the lakeshore of Upper Klamath Lake and low recruitment continues as major concern (FWS, 2007g). Limited information indicates declines of large adult suckers in Clear Lake (FWS, 2007g). Lost River suckers are known to be present in J.C. Boyle Reservoir, Copco Reservoir, and Iron Gate Reservoir but reproduction in any of the reservoirs is unknown and they are not abundant in any of the three reservoirs (Reclamation, 2007).

In the past, the Lost River was probably important spawning habitat for Lost River suckers migrating upstream from Tule Lake. Now, Lost River is highly modified, used primarily for distributing irrigation water and impaired by surface runoff and agricultural drainage (Reclamation, 2007). For several years there was no indication that Lost River or shortnosed suckers continued to inhabit Tule Lake but in 1991 both species were observed spawning below Anderson-Rose Dam, and sampling at Tule Lake in the early 1990s determined that small populations of both species were present (Reclamation, 2007). Lost River sucker spring-spawning abundance in 2007 is estimated to be 56 percent and 75 percent of 2002 abundances for males and females respectively, although the exact abundances are unknown and the spawner abundance relative to an earlier are estimates of population change rather than population size (FWS, 2012g). Tagging studies conducted on Lost River and shortnose suckers in Gerber Reservoir and Clear Lake (both impoundments are connected to the Lost River below Gerber Dam and Clear Lake Dam, respectively) indicate that numbers of large adult suckers of both species have declined since 2000. Declines in large adult Lost River suckers have been particularly pronounced in Clear Lake, possibly due to poor recruitment from younger age classes prior to 2000 (Barry et al., 2007).

### Critical Habitat

Critical habitat for the Lost River sucker and shortnose sucker was proposed by FWS in 1994 which included the majority of known populations of Lost River suckers (FWS, 1994a): Critical habitat for Lost River and shortnose suckers was re-proposed in 2011 and designated in 2012 (FWS, 2012h). In the PCGP Project area, designated critical habitat for Lost River and shortnose sucker (Unit 1 in Klamath County) includes the Link River, Lake Ewauna, and the Klamath River downstream to Keno. Unit 2 in Klamath and Lake Counties, Oregon and Modoc County California includes Clear Lake Reservoir and tributaries and Gerber Reservoir and tribuaries but does not include the Tule Lake and its tributary, the Lost River. For reasons described above (blockage by Anderson Rose Diversion Dam), neither provides spawning habitats or supports viable self-sustaining populations of Lost River or shortnose suckers (FWS, 2012h).

Primary constituent elements of critical habitat include (FWS, 2012h):

1. Water. Areas with sufficient water quantity and depth within lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity. Water must have varied depths to accommodate each life stage: Shallow water (up to 3.28 ft (1.0 m)) for larval life stage, and deeper water (up to 14.8 ft (4.5 m)) for older life stages. The water quality characteristics should include water temperatures of less than 82.4 °F (28.0 °C); pH less than 9.75; dissolved oxygen levels greater than 4.0 mg/L; low levels of microcystin; and un-ionized ammonia (less than 0.5 mg/L). Elements also include natural flow regimes that provide flows during the appropriate time of year or, if flows are controlled, minimal flow departure from a natural hydrograph.
2. Spawning and rearing habitat. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 4.3 ft (1.3 m) with adequate stream velocity to allow spawning to occur. Areas containing emergent vegetation adjacent to open water, provides habitat for rearing and facilitates growth and survival of suckers, as well as protection from predation and protection from currents and turbulence.
3. Food. Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

## 4.5.5.2 Environmental Baseline

### Analysis Area

The riverine analysis area includes two components: 1) the water column and substrate of all waterbodies crossed by the Pacific Connector pipeline from the point of crossing to the extent downstream where water quality is adversely affected by turbidity generated during construction and sediment generated by runoff from the construction right-of-way, and 2) waterbodies' associated riparian zones affected in the short-term during construction and in the long-term by operation. For Lost River suckers, the riverine analysis area is limited to fresh waterbodies within the Upper Klamath Sub-basin (HUC 18010206 – figure 4.5-33A) and Lost Sub-basin (HUC 18010204 figure 4.5-33B).

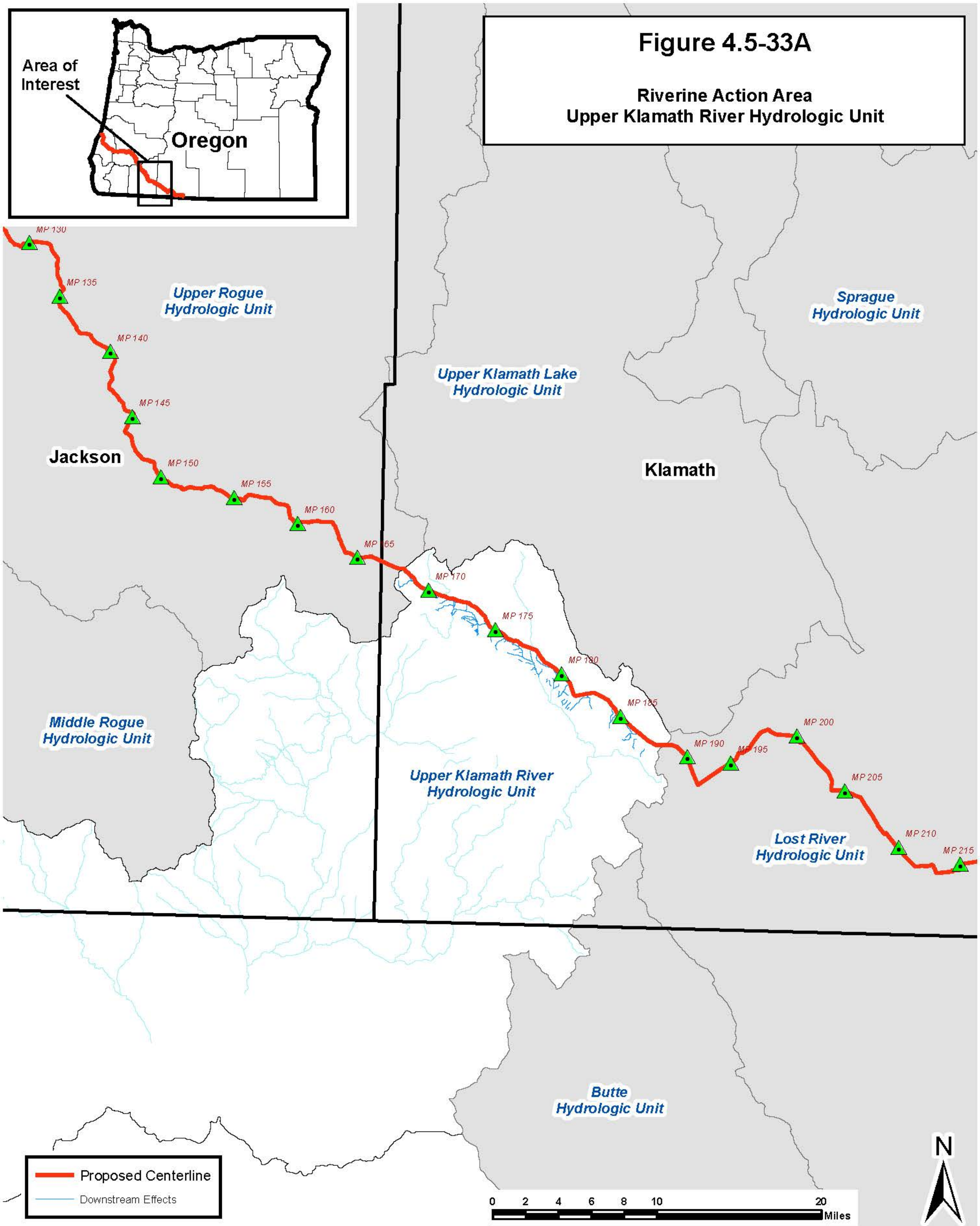


Figure 4.5-33A
Riverine Action Area
Upper Klamath River Hydrologic Unit
Area of Interest
Oregon
Upper Rogue Hydrologic Unit
Upper Klamath Lake Hydrologic Unit
Sprague Hydrologic Unit
Jackson
Klamath
Middle Rogue Hydrologic Unit
Upper Klamath River Hydrologic Unit
Lost River Hydrologic Unit
Butte Hydrologic Unit
MP 130
MP 135
MP 140
MP 145
MP 150
MP 155
MP 160
MP 170
MP 175
MP 190
MP 200
MP 205
MP 210
MP 215
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20
Miles
N

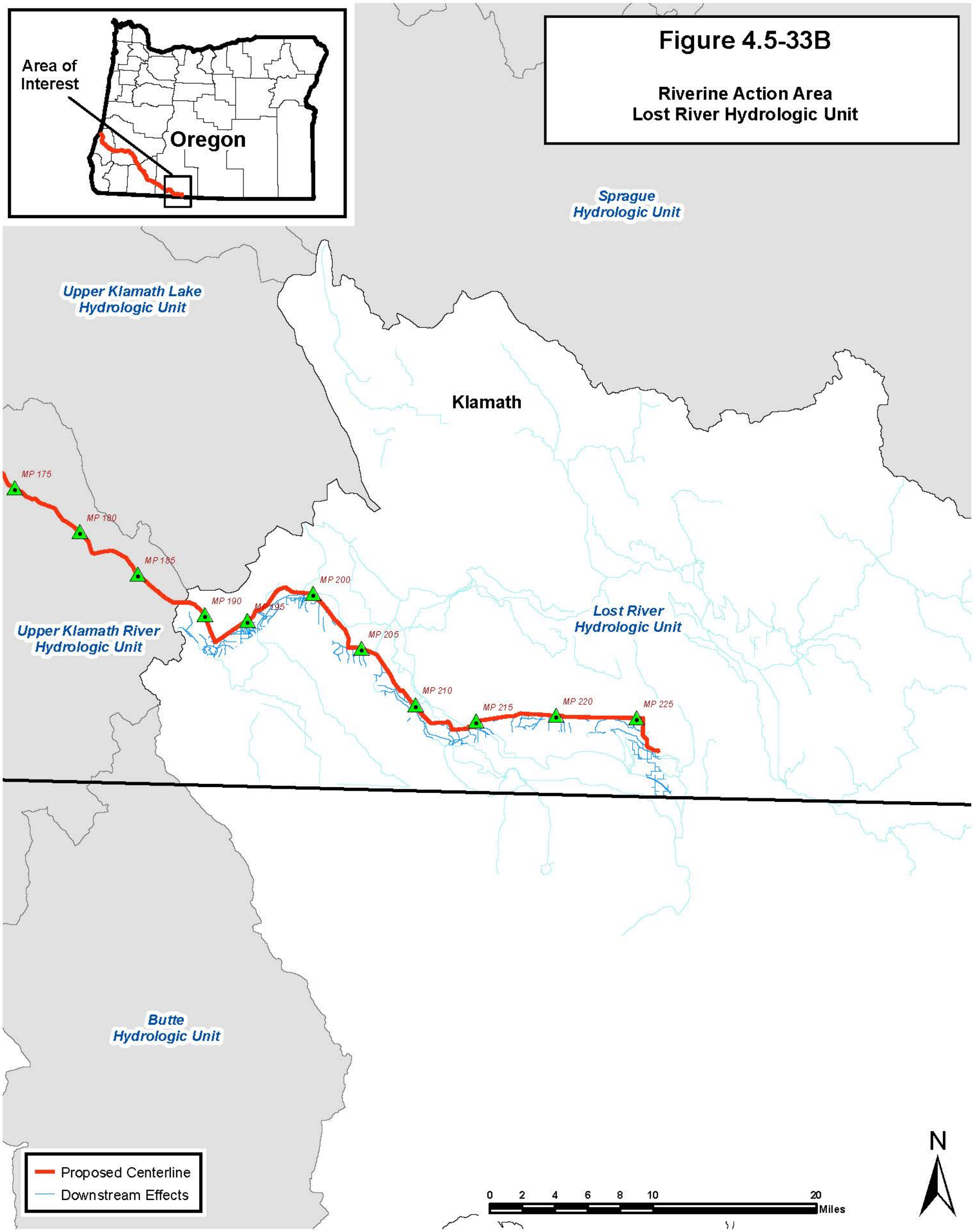


Figure 4.5-33B
Riverine Action Area
Lost River Hydrologic Unit
Area of Interest
Oregon
Sprague Hydrologic Unit
Upper Klamath Lake Hydrologic Unit
Klamath
Lost River Hydrologic Unit
Upper Klamath River Hydrologic Unit
Butte Hydrologic Unit
MP 175
MP 180
MP 185
MP 190
MP 200
MP 205
MP 210
MP 215
MP 220
MP 225
Proposed Centerline
Downstream Effects
0 2 4 6 8 10 20 Miles
N

**Species Presence**

Within the Project area, the Lost River sucker has been documented within the Klamath River from Klamath Falls to Keno Reservoir, located 4.3 and 15.1 miles upstream of the Pacific Connector pipeline Project area and riverine analysis area, consecutively. The PCGP pipeline would cross the Klamath River at RM 249. The sucker is also known from Tule Lake Sump and Clear Lake in northern California, which are connected by the Lost River. Tule Lake sumps are at the lower terminus of the Lost River and the population in Tule Lake is isolated from upstream spawning areas by multiple dams including blockage by the Anderson-Rose Dam.

Historically, Tule Lake supported large populations of Lost River suckers but much of the historical lakebed area has been drained and transformed to agriculture and portions were engineered to receive high runoff flows from the Klamath River via the Lost River Diversion Channel and Lost River (Hodge and Buettner, 2009). Dams constructed on the Lost River, including the Lost River Diversion Dam, Anderson Rose Diversion Dam, Malone Dam, and Harpold Dam have blocked suckers from accessing spawning areas upstream in the Lost River. Currently, sucker spawning migrations are limited to the Lost River below the Anderson Rose Diversion Dam. Lost River suckers migrate a short distance from Tule Lake to spawn in the Lost River below Anderson-Rose Diversion Dam (RM 17.4) south of Merrill and approximately 7.6 river miles from the pipeline crossing of the Lost River (ORBIC, 2012).

Very little water flows in the Lost River below the diversion dam except during the winter and early spring. During the irrigation season, all flows are diverted at Anderson Rose Diversion Dam into the J-Canal for irrigation deliveries to the Tule Lake Irrigation District (Hodge and Buettner, 2009). From 2006 to 2008, FWS and Reclamation placed gravels below the diversion dam and released flows from mid-April to early June to entice suckers to migrate from Tule Lake and spawn in the lower Lost River. Lost River suckers and shortnose suckers sporadically spawned in the graveled riffle area below the Anderson Rose Diversion Dam and sucker larvae were documented in the Lost River during 2006 although they may have derived from Upper Klamath Lake, the Upper Lost River, and/or Clear Lake. Reclamation salvages suckers from J-Canal, which drains into Tule Lake suggesting that some entrained fish move into Tule Lake (Hodge and Buettner, 2009).

Tagged Lost River suckers spawning in the lower Lost River peaked from April 23 to May 17 and from May 27 to June 5 (Hodge and Buettner, 2009). Most of the suckers that migrated into the Lost River from Tule Lake moved to below the Anderson Rose Diversion Dam and spawn there. Larval suckers were present from May 30 to July 22, 2008. The population of Lost River suckers in Tule Lake Sump is probably in the low thousands of individuals which is higher than documented in the early 1990s (Hodge and Buettner, 2009). Currently, Tule Lake functions only as a sink for Lost River sucker populations (FWS, 2012h).

Regular spawning occurs in the Upper Klamath Lake and in Clear Lake Reservoir. Recruitment is low for the spawning population in Upper Klamath Lake. Clear Lake Reservoir, in California, supports a sustaining population of Lost River suckers which is critical to the species' recovery (FWS, 2012g; Barry et al, 2009). Growth rates for adult Lost River suckers are greater in Clear Lake than in Upper Klamath Lake, possibly due to younger individuals present in Clear Lake (Barry et al., 2009). Suckers spawn in Willow Creek, a tributary to Clear Lake Reservoir, during February and March when water temperatures range from $4^{o}$C to $12^{o}$C and larva emigrate down Willow Creek into Clear Lake from late March to mid-April (Perkins and Scoppettone, 1996).

There is limited evidence of a resident population of Lost River suckers in the Lost River above Malone Dam in the Langell Valley, Oregon (FWS, 2012h). However, Lost River suckers are prevented from accessing historically occupied habitats in Lost River mainstem and lower Lost River from Clear Lake Reservoir by Malone Dam.

**Habitat**

Dams continue to limit passage and sucker migration, impose isolation of subpopulations, and decrease available spawning habitats which have has raised the possibility of facilitating hybridization between several sucker species (Reclamation, 2007). Dams may also cause stream channel changes, alter water quality, and provide habitat for exotic fish that prey on suckers or compete with them for food and habitat (Reclamation, 2007). Although there are seven major dams in the Klamath Basin that may affect the migration patterns of listed suckers, only the Link River Dam has been recently equipped with a fish ladder that was designed specifically for sucker passage (Reclamation, 2007). Fish ladders are present at J.C. Boyle and Keno dams and, although suckers have been observed to use the ladders, they were not designed for sucker passage and generally are inadequate for sucker passage (ReclamationReclamation, 2007).

Lost River suckers continue to inhabit the Klamath River above Keno. Fish may enter the Klamath River from Upper Klamath Lake by passing through the gates at Link River Dam. Lost River suckers that survive passing through the hydroelectric facilities either die due to poor summer water quality conditions or pass downstream into the Klamath Reservoirs. At that point, fish are unlikely to return and believed to be lost from the breeding population (FWS, 2007g). The Pacific Connector pipeline would cross the Klamath River using HDD.

Adverse water quality is the most critical threat to the Lost River Sucker (FWS 2007g). Klamath River and Klamath Lake have been designated as water quality impaired, including for nutrient loads which are enhanced by drainage of irrigation water from agricultural lands adjacent to Klamath Lake. Construction of dikes and drainage systems converted wetlands to agricultural use. Soils high in organic content were subject to mineralization processes which released nutrients into the aquatic system, especially phosphorous and nitrogen (Rykbost and Charlton, 2001).

High levels of phosphorous in Klamath Lake have lead to extreme eutrophication events that promote algal blooms dominated by the blue-green algae, *Aphanizomenon flos-aquae* that reach or nearly reach theoretical biological maxima (National Research Council, 2004). As a consequence, portions of Upper Klamath Lake develop conditions of oxygen depletion or are anoxic, and accumulate high concentrations of ammonia which has resulted in mass mortality of fish, including adult suckers (National Research Councils, 2004). Lost River suckers are likely to experience high mortality if exposed to one or more of the following: pH $\geq$ 9.8, ammonia (unionized) concentration $\geq$ 0.34 mg/L, water temperatures $\geq 29.4^{o}$C ($\geq 85^{o}$F), and dissolved oxygen concentration $\leq$ 2.3 mg/L (Bellerud and Saiki, 1995).

No assessments have been conducted for either of the two $5^{th}$ field watersheds that will be crossed by the PCGP Project in the Lost Sub-basin: Lake Ewauna-Klamath River (HUC 1801020412) and Mills Creek-Lost River (HUC 1801020409). Likewise, no stream reaches have been sampled under ODFW's Aquatic Inventories Project in the watersheds. Nevertheless, modifications and degradation of aquatic habitats have been documented by FWS (1993b and 2012g), U.S. Geological Survey - USGS (Dileanis et al., 1996), U.S. Bureau of Reclamation (Reclamation, 2007), and the National Research Council (2004), among others.

Dams limit passage and fish migration, impose isolation of subpopulations, and decrease available spawning habitats (Reclamation, 2007). Klamath River and Klamath Lake have been designated as water quality impaired, including for nutrient loads which are enhanced by drainage of irrigation water from agricultural lands adjacent to Klamath Lake. Construction of dikes and drainage systems converted wetlands to agricultural use. Soils high in organic content were subject to mineralization processes which released nutrients into the aquatic system, especially phosphorous and nitrogen (Rykbost and Charlton, 2001). Sediment accumulation rates in Upper Klamath Lake indicate substantial annual increases since the late 1880s due to deforestation, drainage of wetlands, agriculture, livestock production and irrigation (Reclamation, 2007).

High levels of phosphorous in Klamath Lake have lead to extreme eutrophication events that promote algal blooms dominated by the blue-green algae, *Aphanizomenon flos-aquae* that reach or nearly reach theoretical biological maxima (National Research Council, 2004). As a consequence, portions of Upper Klamath Lake develop conditions of oxygen depletion or are anoxic and accumulate high concentrations of ammonia which has resulted in mass mortality of fish (National Research Council, 2004).

There are no recent long-term water discharge data for waterbodies in the Lost River watershed. The A Canal connects the Link River to the Lost River via the B Canal. According to USGS Gage 11507200, there is no flow in the A Canal between November and March (see figure 4.5-34), consistent with periods of water diversions from the Klamath River, discussed above.

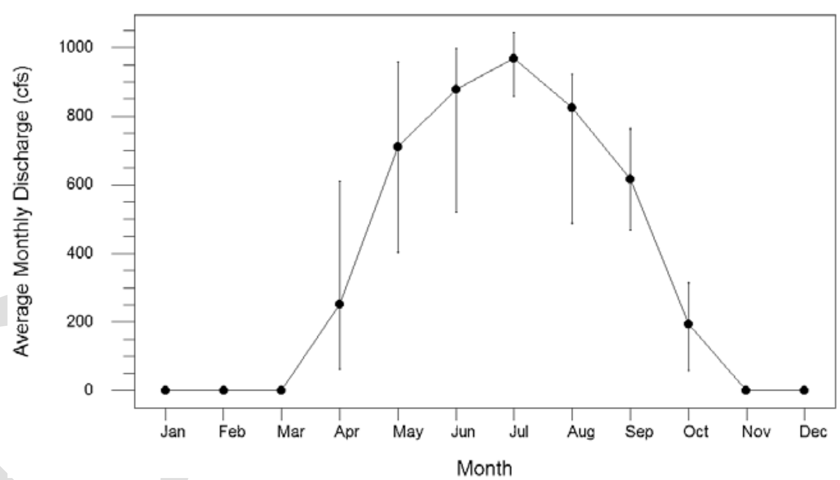



**Figure 4.5-34**
**Average Monthly Discharge in the A Canal (USGS Gage 11507200) from 1960 to 1981. Vertical lines show maximum and minimum discharges for months during the periods of record.**

### Critical Habitat

Designated critical habitat for the Lost River sucker is present within the Project area. The PCGP pipeline would cross the Klamath River at RM 249 which is within critical habitat Unit 1, Klamath County (FWS, 2012h). Unit 1 includes Upper Klamath Lake and Agency Lake, together with some wetland habitat; portions of the Williamson and Sprague Rivers; Link River; Lake Ewauna; and the Klamath River from the outlet of Lake Ewauna downstream to Keno Dam. Primary constituent elements include (FWS, 2012h, abbreviated from above):

1. Water. Areas with sufficient water quantity and depth within lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity.
2. Spawning and rearing habitat. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 1.3 m (4.3 feet) with adequate stream velocity to allow spawning to occur. Areas identified in PCE1 containing emergent vegetation adjacent to open water, provides habitat for rearing and for growth and survival of suckers.
3. Food. Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

Critical habitat Unit 2 includes Clear Lake Reservoir and its principal tributary, Willow Creek. Unit 2 does not coincide with the Project area.

#### 4.5.5.3 Effects by the Proposed Action

### Direct Effects

Timing

Pacific Connector anticipates beginning construction in the Klamath Basin area (MPs 188 to 228) in fourth quarter 2015 or early 2016. The Klamath River (MP 199.38) and the Lost River (MP 212.05) are the only perennial waterbodies crossed by the PCGP Project on Construction Spread 5. The ODFW (2008a) allows instream construction in the Klamath River (above Keno) from July 1 to January 31 and in the Lost River (below Bonanza) from July 1 to March 31. Pacific Connector would cross the Klamath River using HDD crossing methods between July and October. Upland rig-up and preparation are the only HDD activities that would occur outside the recommended ODFW instream construction window. The Lost River would be crossed by dry-open crossing methods during the ODFW-recommended crossing window (July 1 to March 31). One other intermittent drainage that would be crossed at MP 188.9 also has an ODFW-recommended crossing window between July 1 and January 31, but this minor headwater waterbody is expected to be dry at the time of construction.

There are 13 waterbodies between MPs 216.10 and 225.07 that have an ODFW-recommended construction window from July 1 to March 31. These 13 waterbodies are intermittent drainages which would be crossed using dry open-cut crossing methods if flowing at the time of construction. Although seven of the intermittent drainage are presumed to provide habitat for Lost River sucker or shortnose sucker, the PCGP Project's crossing locations are not expected to provide suitable habitat conditions for these species and all of the minor intermittent waterbodies are expected to be dry at the time of construction (see figure 3.2-3).

Fish Salvage

Suckers as a group (family Catostomidae) appears to be susceptible to many of the same deleterious effects from electroshocking that were described above for salmonids (Snyder, 2004). Although records of the effects by electroshock to Lost River suckers have not been compiled, responses by river carpsucker, longnose sucker, white suckers and razorback sucker among others indicate that they are particularly susceptible to spinal injuries and hemorrhages by electrofishing (Snyder, 2004).

Reclamation recently completed construction of fish screen at the entrance to the A-Canal in the forebay of Upper Klamath Lake to reduce high rates of sucker entrainment at this diversion site. Reclamation routinely lowers water levels in the forebay to reduce DO stress. As that takes place, Reclamation salvages all fish in the forebay of the fish screen facility using backpack electrofishers and beach seines and then returns all collected fish to Upper Klamath Lake. This annual salvage procedure alleviates potential mass mortality of all fish at the fish screen as water is removed (Reclamation, 2007).

In addition, Reclamation has salvaged fish from canals throughout the Klamath Project each fall since 1991 following dewatering using electofishing techniques (Reclamation, 2008). Reclamation has noted that if electrofishing is found to injure juvenile suckers, they would pursue other techniques to salvage fish (Reclamation, 2008). Sucker mortalities (Lost River suckers, shortnose suckers, and Klamath largescale suckers) do occur during salvage operations, whether due to electrofishing stress or to low levels of dissolved oxygen (for example, Peck, 2000 and 2001). But the protocol to be used during this Project would use a variety of netting (e.g. beach seining, dip netting) before using electrofishing methods to reduce this potential impact (see Conservation Methods below for details).

Acoustic Shock

There will be no blasting or use of mounted hydraulic impact hammer to cross the Lost River. Use of back-hoes for dry open-cut construction will not produce sound levels to cause harm to Lost River suckers, as discussed for coho in Section 3.2.3.2.

**Indirect Effects**

Turbidity

Potential impacts to fisheries by dry open-cutting were discussed above in section 4.5.1.3 Coho (SONCC ESU). As noted in that discussion, dry open-cutting (fluming, dam-and-pump, or some combination of the two) generates small amounts of turbidity compared to wet open-cut procedures. However, adult suckers appear to prefer deep, turbid water but are often forced to utilize shallow, clear water if forced to during degraded water quality conditions in the summer (National Research Council, 2004). The amounts of turbidity generated by dry open-cut construction are not expected to adversely affect Lost River suckers if they are within the Lost River, several hundred feet downstream from the construction site.

Riparian Vegetation

Because HDD would be used to cross the Klamath River, only 0.75 acre within the Klamath River riparian zone (extending 117 feet or one site-potential tree height from each river bank) would be affected. No forested riparian vegetation would be affected. Construction across the Lost River would disturb approximately 2.72 acres within the riparian zone (extending 119 feet from each river bank). Similar to the Klamath River, no forest riparian vegetation would be affected or removed and all effects would be to agricultural land.

Water Temperature

No riparian vegetation would be removed that otherwise would provide shade. Consequently, water temperature would not be affected by construction. Lost River suckers are susceptible to water temperatures $\geq 85^{o}$F (Bellerud and Saiki, 1995). Summertime water temperatures in Upper

Klamath Lake often reach 86$^{o}$F which coincide with or are caused by baseflows of major rivers and small streams (Bortleson and Fretwell 1993).

Frac-Out

The HDD installation method is considered an effective technique for avoiding in-stream impacts by eliminating the need for in-stream excavation (Reid and Anderson, 1998; Reid et al., 2004). Even with this technique, there is a potential for impact as a result of the HDD process. Drilling requires use of a drilling mud for lubrication of the bit and removal of cuttings. A non-toxic, biodegradable bentonite clay mixture makes up drilling mud. Because the drilling mud is under pressure during drilling, if the bit encounters substrate fractures or channels, it is possible for bentonite to escape from the hole (termed a "frac-out"). Bentonite can escape to the surface through fractures in the drilled substrate. Bentonite is non-toxic to aquatic organisms but as with any fine particulate material, it can interfere with oxygen exchange by gills and the degree of interference generally increases with water temperature (see review and discussion of bentonite effects on aquatic organisms under Coho, Oregon Coast ESU, above).

Potential frac-outs are more common near the HDD drill entry and exit locations; however, impacts to waterbodies are minimized by locating the drill entry and exit points away from the waterbody. The probability of a frac-out may increase when the drill bit is working nearest the surface, but is dependent on numerous factors including substrate characteristics, head pressure of the drilling mud, topography, elevation, and subsurface hydrology. Pacific Connector has designed the Klamath River HDD such that areas of greatest risk from frac-out are on uplands and not adjacent to the waterbodies where much greater depth would be achieved and frac-out potential is reduced.

According to GeoEngineer's Feasibility Analysis for pipeline construction using HDD across the Klamath River (see appendix E) the design length of the Klamath River HDD crossing is approximately 2,300 feet. The proposed entry point is located in an open agricultural field on the east side of the Klamath River. The exit point is located in an open area on the west side of the river. The preliminary design provides approximately 60 feet of cover below the bottom of the river. There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment. Additional evaluation of the hydraulic fracture and inadvertent return potential will be completed for the final design.

Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils with low shear strength or very loose granular soils. Loose and silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to dense sands and gravels and very stiff to hard silts and clays have a low to moderate hydraulic fracture potential. Unfractured rock, because of its high shear strength, typically has a low potential for hydraulic fracture. HDD installations with greater depth or in formations with higher shear strength may reduce the potential for hydraulic fracturing (see appendix E).

In the event an inadvertent return occurs into the river, drilling fluid will enter the waterway causing short term, temporary water quality impacts downstream of the project area including sedimentation and turbidity. Sediments discharged into aquatic systems have the potential, depending on the concentrations, to wear down fish gills and impair fish vision making it difficult to feed and also making the fish more susceptible to predation. However, these effects typically occur after relatively long-term exposure to concentrated sedimentation. If drilling fluid accumulates in the substrate, it can adversely impact the quality and quantity of aquatic habitat available for aquatic species including salmonid spawning habitat and benthic macroinvertebrate rearing habitat. Drilling fluid that accumulates in the substrate may cover up food sources and smother fish eggs and other aquatic life in the riverbed. However, significant impacts to substrate from inadvertent returns are not likely in large river systems because of the anticipated high volumes and velocities within large rivers.

The rheologic properties of drilling fluid allow it to remain suspended within the water column for prolonged periods of time and would likely settle out in very slow moving water downstream of the release. The distance of expected transport would likely prevent significant concentrations of the fluid from accumulating in one area of the Klamath River. In the event drilling fluid is inadvertently released into the river, the behavioral avoidance response of Lost River sucker is presumed to be triggered within the immediate vicinity of the release and the fish are expected to return and utilize the affected area shortly after the inadvertent release has been halted. If significant concentrations are found during monitoring as a result of a release, the following possible corrective measures would be taken:

1. Increase the drilling fluid viscosity in an attempt at sealing the point at which fluid is leaving the drilled hole. The drilling operation may be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.
2. If increasing the drilling fluid viscosity is ineffective, lost circulation materials (LCM) may be introduced into the hole by incorporating them in the drilling fluid and pumping the material down-hole. The drilling operation may again be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the lost circulation materials.
3. Depending on the location of the fractured zone, a steel casing may be installed that is of sufficient size to receive the largest expected down-hole tools for the crossing. This casing installation provides a temporary conduit for drilling fluids to flow while opening the remaining section of the hole to a diameter acceptable for receiving the proposed pipe sections. To alleviate future concerns with the steel casing after the HDD installation is completed, the casing is generally extracted from the hole prior to or just after completing the HDD installation. However, there have been instances when attempts at extracting the steel casing were unsuccessful.
4. In the event drilling fluid flow is not regained through the annulus of the drilled hole and a steel casing installation is not utilized, the HDD contractor may elect to install a grout mixture into the drilled hole in an attempt to seal the fractured zone. The down-hole drilling assembly is generally extracted and existing hole is re-drilled to the point at which it had previously been drilled prior to having encountered the loss of drilling fluid. 5. In addition, a grouting program may be implemented from the surface in the event that the installation of grout into the drilled hole is unsuccessful. This approach is only practical in areas where drilling rigs with vertical drilling capabilities can access the HDD alignment. If a surface grouting program is utilized, the HDD drilling assembly is extracted from down-hole. Multiple holes are then drilled vertically on either side and along the HDD alignment to allow for grout slurry to be pumped into the fracture zone where the drilling fluid had previously been lost from the drilled hole. This process can take several days to complete in order to insert the grout in a grid pattern that covers the full fractured zone, during which time the HDD operation is suspended. Upon completion

of the surface grouting program, the HDD operation will resume and the pilot hole will be reestablished through the grouted formation.

In some instances, it may be determined that the existing hole encountered a zone of unsatisfactory soil material and the hole may have to be abandoned. If the hole is abandoned, it will be filled with cuttings and drilling fluid.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

Within the action area, 100 percent of all lands are non-federal within the John C. Boyle Reservoir-Klamath River watershed, 99 percent are non-federal lands within the Lake Ewauna-Klamath River watershed, and 94 percent are non-federal lands within the Mills Creek-Lost River fifth-field watershed. Degradation of water quality due to livestock grazing, agriculture, and timber harvest has resulted in severe pollution in Upper Klamath Lake. That in turn has lead to algal blooms with increased mortality of suckers when oxygen depletions occur due to eutrophication particularly during summers when high temperatures combined with nutrient loading from pumping diked wetlands and runoff from farms. Past actions that have lead to increased mortality have been due to private enterprise on private lands. Cumulative impact to Lost River suckers and shortnose suckers would include those same or similar actions which are reasonably foreseeable during the next 4 years. Cumulative impact from non-federal actions on non-federal lands would actually occur before implementation of the proposed action, not after its implementation which is more often the case. Therefore, the proposed Project could potentially contribute to cumulative effects for this species.

**Critical Habitat**

Designated critical habitat for the Lost River sucker is present within the Project area. The PCGP pipeline would cross the Klamath River at RM 249 which is within critical habitat Unit 1, Klamath County (FWS, 2012h). Unit 1 includes Upper Klamath Lake and Agency Lake, together with some wetland habitat; portions of the Williamson and Sprague Rivers; Link River; Lake Ewauna; and the Klamath River from the outlet of Lake Ewauna downstream to Keno Dam. Primary constituent elements could be affected during the HDD across the Klamath River if a frac-out occurred with release of bentonite into the water column; the same effects to critical habitat that were described as Indirect Effects, above, would occur.

Only 0.75 acre assumed to be within the Klamath River 100-year floodplain would be affected by construction and nearly all of that area is in an existing industrial facility.

#### 4.5.5.4 Conservation Measures

Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to waterbodies and riparian zones. Those measures have been compiled in table 2C in appendix N and apply to Lost River suckers.

Pacific Connector has also proposed measures and to rectify, repair, and rehabilitate and otherwise reduce impact to waterbodies and riparian zones once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N.

Fish Salvage

Lost River suckers can potentially occur within the construction right-of-way on the Lost River at the time of construction. Since the Lost River would be crossed using dry open-cut technology, fish salvage procedures (see section 4.5.1.4 in coho SONCC ESU) may occur while fish, including Lost River suckers, are within isolated construction sites. Since suckers in general appear to be vulnerable to electroshocking, Pacific Connector's fish salvage plan in the Lost River may have to avoid use of electroshock, relying instead on seining and dip netting as described in section 4.5.1.4.

A Fish Salvage Plan has been provided in appendix T. The plan has been developed to minimize adverse effects to listed salmonids (SONCC coho, Oregon Coast coho), non-listed salmonids (Chinook salmon, steelhead, cutthroat trout) and listed catostomids (Lost River sucker, shortnose sucker). The portions of the plan relevant to salvaging salmonids were adapted from the protocol developed by Washington State Department of Transportation (2011b). The protocol specifies procedures to 1) isolate the work area, 2) removing fish and dewatering the work area, 3) handling, holding and releasing fish, and 4) documenting fish that have been captured, handled, held and released and notification to NMFS and FWS. The same protocol would generally be followed during salvage of Klamath Basin suckers. However, salvage operations within the crossing where these suckers may be present would include the latest Handling Guidelines for Klamath Basin Suckers (Reclamation, 2008). These guidelines may be updated frequently. Some of the main factors in handling are the requirement of having a 0.5 percent saline solution of un-chlorinated well water to place any captured listed sucker in should it be collected during fish salvage operations. Aeration would also be supplied and the container a sucker is placed into would have been coated with a commercially available slime coat. Fish would be retained in this solution until released upstream of the capture site unless otherwise indicated through agreement with FWS.

Instream Gravel

Pipeline trenches across the Lost River and other perennial waterbodies within the Upper Klamath River Sub-basin and Lost River Sub-basin would be backfilled with material removed from the trench with the upper 1-foot of the trench backfilled with clean gravel or native cobbles of a size appropriate for resident fish, including suckers. The bottom and banks would be returned to preconstruction contours; banks would be stabilized; and temporary sediment barriers would be installed before returning flow to the waterbody channel.

Streambank Restoration

Pacific Connector's Erosion Control and Revegetation Plan (ECRP – see appendix F) describes the measures that will be used to stabilize streambanks crossed by the pipeline. Pacific Connector would not use riprap to stabilize streambanks. The alignment of the pipeline has been designed at waterbody crossings to be as perpendicular to the axis of the waterbody channel, as engineering and routing constraints allow, minimizing streambank disturbance and avoiding parallel stream alignments or multiple stream crossings. Immediately after installation of a waterbody crossing, the contours of the streambed, shoreline, and streambanks will be restored to preconstruction configurations (i.e., contour/elevations) to restore the physical integrity/condition of these features and to minimize the loss of stream complexity.

Pacific Connector has completed a scour analysis for the project that will be used to ensure that appropriate pipeline burial depths and cover design parameters beneath channel streambeds and adjacent floodplains are utilized, so that the effects on natural stream processes will be avoided or minimized. The project's scour analysis, which was completed by GeoEngineers, was included in Pacific Connector's June 2013 FERC Certificate application.

Pacific Connector will install erosion control fabric (such as jute or excelsior) on streambanks at the time of recontouring. The fabric will be anchored using staples or other appropriate devices. The erosion control fabric to be used on streambanks will be designed for the proposed use and will be approved by Pacific Connector's Environmental Inspectors (EIs).

Consistent with FERC's Wetland and Waterbody Procedures (Section V.C.3.), during streambank restoration/recontouring, the streambanks will be returned to their preconstruction contours or to a stable configuration. The Lost River is included in the application of the conservation measure. Streambank revegetation measures, including supplemental riparian planting procedures are also outlined in Section 10.0 of the ECRP. Riparian zones associated with the Klamath River and Lost River are on land owned by the State of Oregon. Riparian Zones for all other waterbodies crossed that are within range of the Lost River sucker are on private lands. The shrubs and trees planted at each site will be determined at the time of planting based on the moisture regimes and site-specific conditions at each planting location and landowner requirements.

#### 4.5.5.5 Determination of Effects

**Species Effects**

The Project **may affect** Lost River suckers because:

- Lost River suckers occur within the Upper Klamath Sub-basin and Lost Sub-basin which would be affected during construction of the proposed action.

While several project actions are not likely to cause adverse effects, those resulting effects from Project components that are **likely to adversely affect** Lost River suckers include:

- The remote possibility that Lost River suckers could occur within the Lost River when it would be crossed by the Pacific Connector pipeline.
- There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment across the Klamath River
- Adults and juveniles subject to fish salvage within the isolated construction site at the Lost River could be injured or killed if electroshocking is used and stressed if seining is used. Incidental take of a Lost River sucker is possible.

**Critical Habitat Effects**

The Project **may affect** designated critical habitat for the Lost River sucker because:

- There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment across the Klamath River.

### 4.5.6 Shortnose Sucker

#### 4.5.6.1 Species Account and Critical Habitat

**Status**

The shortnose sucker was listed as a federally endangered species on July 18, 1988 (FWS 1988). The shortnose sucker was listed as endangered because of the loss of habitat and access to historical range, resulting in a declining population. A 5-year review was released in July 2007 that recommended down listing the shortnose sucker from endangered to threatened status (FWS 2007h). However, no formal proposal to down list the species to threatened status has been made.

**Threats**

Lost River suckers and shortnose suckers were considered together in the final rule listing both as endangered species. Numerous factors in both species' decline were cited by FWS (1988) including historical over-fishing, dams limiting upstream movements and access to spawning habitats, introduction of non-native species that compete (fathead minnows) and prey on suckers (yellow perch, bullheads, largemouth bass, and various lepomid sunfish), and degradation of water quality due to livestock grazing, agriculture, and timber harvest. Pollution in Upper Klamath Lake has lead to algal blooms with increased mortality of suckers when oxygen depletions occur due to eutrophication. Status assessments conducted in 2001 and 2002 (FWS, 2002c) concluded that the Lost River sucker was threatened by the following: 1) drastically reduced adult populations and reduction in range; 2) extensive habitat loss, degradation, and fragmentation; 3) small or isolated adult populations as a result of dams; 4) poor water quality; 5) lack of sufficient recruitment; 6) entrainment into irrigation and hydropower diversions; 7) hybridization with the other native Klamath sucker species; 8) potential competition with introduced exotic fishes; and 9) lack of regulatory protection.

FWS (2007h) published a more recent status review of Lost River suckers in 2007. Recent habitat loss (wetlands in the upper Klamath Basin) has been minor and numerous habitat restoration projects have resulted in some positive population response by Lost River suckers. Nevertheless, poor water quality in Upper Klamath Lake and the Lost River continues, particularly during summers when high temperatures combined with nutrient loading from pumping diked wetlands and runoff from farms, roads, and other sources as well as from lake sediments create hypereutrophic conditions which lead to depletions of dissolved oxygen and fish die-offs (FWS, 2007h). Populations declined prior to listing due to habitat loss of approximately 75 percent of historic range, restricted access to spawning habitat, overharvest, and increased rates of mortality resulting from entrainment in water management structures and severely impaired water quality. Populations in Upper Klamath Lake have chronically low recruitment, reduced survivorship of adult fish, and reduced age-class diversity. Length-frequency analysis suggests that the last substantial recruitment to the spawning population occurred during the late 1990s (FWS, 2012g).

**Species Recovery**

Actions described in the recovery plan that would aid in the delisting of the shortnose sucker include improving habitat conditions through rehabilitating riparian areas and improving land management practices in the Klamath Basin watershed, developing and achieving water quality and quantity goals, and improving fish passage, spawning habitat, and other habitat conditions.

A recovery plan for Lost River sucker and short-nose sucker was finalized on March 17, 1993 (FWS 1993b). Since then there has been substantial amounts of additional information, prompting recent revision of the recovery plan (FWS, 2012g). The recovery program goal is to stop the population decline and enhance Lost River sucker and shortnose sucker populations so that ESA protection is no longer necessary.

At the time of listing, population declines were related to loss or degradation of spawning, rearing, and adult habitats. Only about 25 percent of the original habitat remains. Reductions in habitat quality compound the effects of reduced habitat quantity and availability on Lost River sucker and shortnose sucker abundance. In addition to habitat, factors currently limiting species recovery include high mortality of larvae and juveniles due to reduced rearing habitat, entrainment in water management structures, poor water quality, and adverse effects (predation, competition) from non-native, introduced fish species. Adult populations are limited by extremely limited recruitment to the population as well as high levels of stress and mortality associated with severely impaired water quality. As a whole the species are potentially limited by the lack of habitat connectivity (FWS, 2012e).

Demographic-based objectives include increasing larval production, individual survival and recruitment to spawning populations, and ultimately increasing abundance in spawning populations. The objectives of restoring spawning and nursery habitat, expanding reproduction, reducing the negative impacts from water quality on all life stages, clarifying the effects of other species on all life stages, reducing entrainment, and establishing auxiliary populations comprise the threats-based objectives. The recovery strategy is intended to produce and document healthy, self-sustaining populations by reduction of mortality, restoration of habitat, including spawning, larval and juvenile habitats, and increasing connectivity between spawning and rearing habitats. It also involves ameliorating adverse effects of degraded water quality, disease, and non-native fish. The plan provides areas of emphasis and guidelines to direct recovery actions (FWS, 2012e).

There are two recovery units for shortnose suckers, the Upper Klamath Lake Unit and Lost River Basin Unit (FWS, 2012g). Upper Klamath Lake Unit includes all Lost River suckers within lake, tributaries to Upper Klamath Lake, and reservoirs within the Klamath River including Keno Reservoir and populations below Keno Reservoir. The Lost River Basin Recovery Unit includes Clear Lake Reservoir and tributaries including Willow Creek and Boles Creek, (FWS, 2012e). The Lost River is not included in designated critical habitat.

**Life History, Habitat Requirements, and Distribution**

Shortnose suckers are native to the Upper Klamath River Basin and Lost River Basin but have adapted to lake habitats and spawn in larger tributary rivers associated with lakes (Moyle, 2002), generally from February through early May. Larval stages persist from May through July (Reclamation, 2007). Although Lost River suckers may live to 43 years old, shortnose suckers are shorter-lived, surviving to 25 years old but females attain sexual maturity at 4 years old while Lost River sucker females are sexually mature at 6 to 9 years old (Reclamation, 2007). Shortnose sucker females may produce 72,000 eggs per spawning season, generally fewer than Lost River suckers.

River spawning habitat occurs in riffles or runs with gravel or cobble substrate, with moderate flows, and in water 4 to 51 inches deep. Shortnose suckers have historically spawned in lakes, particularly at springs occurring along the shorelines (FWS 2007h). Currently, shortnose suckers are found in Upper Klamath Lake and its tributaries, Klamath River downstream to Iron Gate Reservoir, Clear Lake Reservoir and its tributaries, Gerber Reservoir and its tributaries, the Lost River, and Tule Lake. In the Upper Klamath Lake watershed, shortnose sucker spawning runs are primarily limited to the Sprague and Williamson Rivers, although spawning runs may also be present in the Wood River and in Crooked Creek. Shortnose sucker spawning has also been recorded in the Clear Lake watershed (FWS, 1988) and Gerber Reservoir watershed (FWS, 1994a). Adult and juvenile shortnose suckers prefer turbid, highly productive but shallow lakes that are cool in the summer, with adequate dissolved oxygen, and water that is moderately alkaline (FWS, 2007h).

As discussed for Lost River suckers, a small population of several hundred adult shortnose suckers exists in Tule Lake. Shortnose suckers have resident populations in both lake and some riverine habitats, including Lost River, Willow Creek, and other tributaries of Clear Lake and Gerber Reservoir (Reclamation, 2007). Shortnose suckers have been documented spawning below Anderson-Rose Dam, in Big Springs near Bonanza and at the terminal end of the West Canal as it spills into the Lost River. Suitable spawning habitats with riffle areas and rocky substrates include the spillway area below Malone Dam, immediately upstream of Keller Bridge, immediately below Big Springs in the Lost River, below Harpold Dam, and adjacent to Station 48 (Reclamation, 2007). Seasonal movements of shortnose suckers are similar to those described above for Lost River suckers.

**Population Status**

At the time of the Final Rule, estimates of the shortnose sucker population could not be made. Nevertheless, there was very little recruitment to the population and that, plus mortality from fish die-offs and fishing, indicated a declining trend (FWS, 2007h). Continued efforts to estimate shortnose sucker populations have been based on several approaches which indicate a declining population with nearly no measurable recruitment in Upper Klamath Lake and limited survival of adults past the age of sexual maturity. Shortnose suckers attain sexual maturity when 4 to 6 years old and survival after entering the spawning population was estimated at only 3.6 years indicating insufficient time for reproduction to sustain the population (FWS, 2007h).

For several years there was no indication that shortnose suckers continued to inhabit Tule Lake but in 1991 both sucker species were observed spawning below Anderson-Rose Dam, and sampling at Tule Lake in the early 1990s determined that small populations of the two species were present (Reclamation, 2007). Estimates of shortnose sucker annual survival rates in Upper Klamath Lake between 1995 and 2004 indicate that the population is likely to be decreasing, although the survival estimates appear to be imprecise (Reclamation, 2007).

For several years there was no indication that Lost River or shortnosed suckers continued to inhabit Tule Lake but in 1991 both species were observed spawning below Anderson-Rose Dam, and sampling at Tule Lake in the early 1990s determined that small populations of both species were present (Reclamation, 2007). Shortnose sucker spring-spawning abundance in 2007 is estimated to be 42 percent and 48 percent of 2001 abundances for males and females respectively, although the exact abundances are unknown and the spawner abundance relative to an earlier are estimates of population change rather than population size (FWS, 2012g). Tagging studies conducted on Lost River and shortnose suckers in Gerber Reservoir and Clear Lake (both impoundments are connected to the Lost River below Gerber Dam and Clear Lake Dam, respectively) indicate that numbers of large adult suckers of both species have declined since

2000. Declines in large adult shortnose suckers have been particularly pronounced in Clear Lake, possibly due to poor recruitment from younger age classes prior to 2000 (Barry et al., 2009).

### Critical Habitat

Critical habitat for the Lost River sucker and shortnose sucker was proposed by FWS in 1994 which included the majority of known populations of Lost River suckers (FWS, 1994a): Critical habitat for Lost River and shortnose suckers was re-proposed in 2011 and designated in 2012 (FWS, 2012h). In the PCGP Project area, designated critical habitat for Lost River and shortnose sucker (Unit 1 in Klamath County) includes the Link River, Lake Ewauna, and the Klamath River downstream to Keno. Unit 2 in Klamath and Lake Counties, Oregon and Modoc County California includes Clear Lake Reservoir and tributaries and Gerber Reservoir and tribuaries but does not include the Tule Lake and its tributary, the Lost River. For reasons described above (blockage by Anderson Rose Diversion Dam), neither provides spawning habitats or supports viable self-sustaining populations of Lost River or shortnose suckers (FWS, 2012h).

Primary constituent elements of critical habitat include (FWS, 2012f):

1. Water. Areas with sufficient water quantity and depth within lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity. Water must have varied depths to accommodate each life stage: Shallow water (up to 3.28 ft (1.0 m)) for larval life stage, and deeper water (up to 14.8 ft (4.5 m)) for older life stages. The water quality characteristics should include water temperatures of less than 82.4 °F (28.0 °C); pH less than 9.75; dissolved oxygen levels greater than 4.0 mg/L; low levels of microcystin; and un-ionized ammonia (less than 0.5 mg/L). Elements also include natural flow regimes that provide flows during the appropriate time of year or, if flows are controlled, minimal flow departure from a natural hydrograph.
2. Spawning and rearing habitat. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 4.3 ft (1.3 m) with adequate stream velocity to allow spawning to occur. Areas containing emergent vegetation adjacent to open water, provides habitat for rearing and facilitates growth and survival of suckers, as well as protection from predation and protection from currents and turbulence.
3. Food. Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

## 4.5.6.2 Environmental Baseline

### Analysis Area

The riverine analysis area includes two components: 1) the water column and substrate of all waterbodies crossed by the Pacific Connector pipeline from the point of crossing to the extent downstream where water quality is adversely affected by turbidity generated during construction and sediment generated by runoff from the construction right-of-way; and 2) waterbodies' associated riparian zones affected in the short-term during construction and in the long-term by operation. For shortnose suckers, the riverine analysis area is limited to fresh waterbodies within the Upper Klamath Sub-basin (HUC 18010206 – figure 4.5-33A) and Lost Sub-basin (HUC 18010204 figure 4.5-33B).

**Species Presence**

Currently, shortnose suckers are found in Upper Klamath Lake and its tributaries, Klamath River downstream to Iron Gate Reservoir, Clear Lake Reservoir and its tributaries, Gerber Reservoir and its tributaries, the Lost River, and Tule Lake. Shortnose sucker spawning has also been recorded in the Clear Lake watershed (FWS, 1988) and Gerber Reservoir watershed (FWS, 1994). In the Upper Klamath Sub-basin (HUC 18010206) they are found in the Klamath River as far downstream as Copco Reservoir and possibly Iron Gate Reservoir. In the Lost Sub-basin, they are found in the Lost River mainstem below Anderson Rose Diversion Dam, above Malone Dam, and in Clear Lake Reservoir (Moyle, 2002).

In the project vicinity, shortnose suckers spawn in the Lost River and are present in John C. Boyle Reservoir, downstream from the pipeline crossing at RM 225 (National Research Council, 2004). In addition to collections of Lost River suckers in J.C. Boyle Reservoir, ORBIC (2012) cites records of spawning in the Link River. They have been documented from Lake Ewauna and in the Lost River Diversion Canal. Currently, Lost River suckers migrate a short distance from Tule Lake to spawn in the Lost River below Anderson-Rose Diversion Dam (RM 17.4) south of Merrill and approximately 7.6 river miles from the pipeline crossing of the Lost River (ORBIC, 2012). Suckers also spawn in the Lost River below Malone Dam, downstream from Clear Lake. A population inhabits the Tule Lake sumps at the terminus of the Lost River (FWS, 2007f). That population is isolated from upstream spawning habitats in the Lost River by the Anderson-Rose Dam and the population is not self-sustaining (FWS, 2007h).

Within the Project area, the shortnose sucker has been documented within the Klamath River from Klamath Falls to Keno Reservoir, located 4.3 and 15.1 miles upstream of the Pacific Connector pipeline Project area and riverine analysis area, consecutively. The PCGP pipeline would cross the Klamath River at RM 249. The sucker is also known from Tule Lake Sump and Clear Lake in northern California, which are connected by the Lost River. Tule Lake sumps are at the lower terminus of the Lost River and the population in Tule Lake is isolated from upstream spawning areas by multiple dams including blockage by the Anderson-Rose Dam.

**Habitat**

Dams continue to limit passage and sucker migration, impose isolation of subpopulations, and decrease available spawning habitats which have has raised the possibility of facilitating hybridization between several sucker species (Reclamation, 2007). Dams may also cause stream channel changes, alter water quality, and provide habitat for exotic fish that prey on suckers or compete with them for food and habitat (Reclamation, 2007). Although there are seven major dams in the Klamath Basin that may affect the migration patterns of listed suckers, only the Link River Dam has been recently equipped with a fish ladder that was designed specifically for sucker passage (Reclamation, 2007). Fish ladders are present at J.C. Boyle and Keno dams and, although suckers have been observed to use the ladders, they were not designed for sucker passage and generally are inadequate for sucker passage (Reclamation, 2007).

The Link River Dam regulates water flows downstream to Lake Euwana, Keno Reservoir, and the Klamath River. The river gates on the dam do not protect fish from becoming entrained and numerous juvenile suckers are drawn through the dam gates. Shortnose suckers that survive passing through the hydroelectric facilities either die due to poor summer water quality conditions or pass downstream into the Klamath Reservoirs. At that point, fish cannot return and are believed to be lost from the breeding population (FWS, 2007h). The Pacific Connector pipeline would cross the Klamath River using HDD.

Adverse water quality is the most critical threat to the shortnose sucker (FWS, 2007h). Klamath River and Klamath Lake have been designated as water quality impaired, including for nutrient loads which are enhanced by drainage of irrigation water from agricultural lands adjacent to Klamath Lake. Construction of dikes and drainage systems converted wetlands to agricultural use. Soils high in organic content were subject to mineralization processes which released nutrients into the aquatic system, especially phosphorous and nitrogen (Rykbost and Charlton, 2001).

High levels of phosphorous in Klamath Lake have lead to extreme eutrophication events that promote algal blooms dominated by the blue-green algae *Aphanizomenon flos-aquae* that reach or nearly reach theoretical biological maxima (National Research Council, 2004). As a consequence, portions of Upper Klamath Lake develop conditions of oxygen depletion or are anoxic, and accumulate high concentrations of ammonia which has resulted in mass mortality of fish, including adult suckers (National Research Council, 2004). Shortnose suckers are likely to experience high mortality if exposed to one or more of the following: pH $\geq$ 9.8, ammonia (unionized) concentration $\geq$ 0.34 mg/L, water temperatures $\geq 29.4^{o}$C ($\geq 85^{o}$F), and dissolved oxygen concentration $\leq$ 2.3 mg/L (Bellerud and Saiki, 1995).

No assessments have been conducted for either of the two $5^{th}$ field watersheds that will be crossed by the PCGP Project in the Lost Sub-basin: Lake Ewauna-Klamath River (HUC 1801020412) and Mills Creek-Lost River (HUC 1801020409). Likewise, no stream reaches have been sampled under ODFW's Aquatic Inventories Project in the watersheds. Nevertheless, modifications and degradation of aquatic habitats have been documented by FWS (1993 and 2012), U.S. Geological Survey - USGS (Dileanis et al., 1996), U.S. Bureau of Reclamation (Reclamation, 2007), and the National Research Council (2004), among others.

Dams limit passage and fish migration, impose isolation of subpopulations, and decrease available spawning habitats (Reclamation, 2007). Klamath River and Klamath Lake have been designated as water quality impaired, including for nutrient loads which are enhanced by drainage of irrigation water from agricultural lands adjacent to Klamath Lake. Construction of dikes and drainage systems converted wetlands to agricultural use. Soils high in organic content were subject to mineralization processes which released nutrients into the aquatic system, especially phosphorous and nitrogen (Rykbost and Charlton, 2001). Sediment accumulation rates in Upper Klamath Lake indicate substantial annual increases since the late 1880s due to deforestation, drainage of wetlands, agriculture, livestock production and irrigation (Reclamation, 2007).

High levels of phosphorous in Klamath Lake have lead to extreme eutrophication events that promote algal blooms dominated by the blue-green algae, *Aphanizomenon flos-aquae* that reach or nearly reach theoretical biological maxima (National Research Council, 2004). As a consequence, portions of Upper Klamath Lake develop conditions of oxygen depletion or are anoxic and accumulate high concentrations of ammonia which has resulted in mass mortality of fish (National Research Council, 2004).

There are no recent long-term water discharge data for waterbodies in the Lost River watershed. The A Canal connects the Link River to the Lost River via the B Canal. According to USGS

Gage 11507200, there is no flow in the A Canal between November and March (see figure 4.5-34, above), consistent with periods of water diversions from the Klamath River, discussed above.

### Critical Habitat

Designated critical habitat for the Lost River sucker is present within the Project area. The PCGP pipeline would cross the Klamath River at RM 249 which is within critical habitat Unit 1, Klamath County (FWS, 2012h). Unit 1 includes Upper Klamath Lake and Agency Lake, together with some wetland habitat; portions of the Williamson and Sprague Rivers; Link River; Lake Ewauna; and the Klamath River from the outlet of Lake Ewauna downstream to Keno Dam. Primary constituent elements include (FWS, 2012h, abbreviated from above):

1. Water. Areas with sufficient water quantity and depth within lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity.
2. Spawning and rearing habitat. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 1.3 m (4.3 feet) with adequate stream velocity to allow spawning to occur. Areas identified in PCE1 containing emergent vegetation adjacent to open water, provides habitat for rearing and for growth and survival of suckers.
3. Food. Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

Critical habitat Unit 2 includes Clear Lake Reservoir and its principal tributary, Willow Creek. Unit 2 does not coincide with the Project area.

### 4.5.6.3 Effects by the Proposed Action

### Direct Effects

Timing

Pacific Connector anticipates beginning construction in the Klamath Basin area (MPs 188 to 228) in fourth quarter 2015 or early 2016. The Klamath River (MP 199.38) and the Lost River (MP 212.05) are the only perennial waterbodies crossed by the PCGP Project on Construction Spread 5. The ODFW (2008) allows instream construction in the Klamath River (above Keno) from July 1 to January 31 and in the Lost River (below Bonanza) from July 1 to March 31. Pacific Connector would cross the Klamath River using HDD crossing methods between July and October. Upland rig-up and preparation are the only HDD activities that would occur outside the recommended ODFW instream construction window. The Lost River would be crossed by dry-open crossing methods during the ODFW-recommended crossing window (July 1 to March 31). One other intermittent drainage that would be crossed at MP 188.9 also has an ODFW-recommended crossing window between July 1 and January 31, but this minor headwater waterbody is expected to be dry at the time of construction.

There are 13 waterbodies between MPs 216.10 and 225.07 that have an ODFW-recommended construction window from July 1 to March 31. These 13 waterbodies are intermittent drainages which would be crossed using dry open-cut crossing methods if flowing at the time of construction. Although seven of the intermittent drainage are presumed to provide habitat for Lost River sucker or shortnose sucker, the PCGP Project's crossing locations are not expected to provide suitable habitat conditions for these species and all of the minor intermittent waterbodies are expected to be dry at the time of construction (see figure 3.2-3).

Fish Salvage

Suckers as a group (family Catostomidae) appear to be susceptible to many of the same deleterious effects from electroshocking that were described above for salmonids (Snyder, 2004). Although records of the effects by electroshock to shortnose suckers have not been compiled, responses by river carpsucker, longnose sucker, white suckers and razorback sucker among others indicate that they are particularly susceptible to spinal injuries and hemorrhages by electrofishing (Snyder, 2004).

Reclamation has salvaged fish from canals throughout the Klamath project each fall since 1991 following dewatering using electrofishing techniques (Reclamation, 2008). Sucker mortalities (shortnose suckers, Lost River suckers and Klamath largescale suckers) do occur during salvage operations, whether due to electrofishing stress or to low levels of dissolved oxygen (for example, Peck, 2000 and 2001). But the protocol to be used during this Project would use a variety of netting (e.g. beach seining, dip netting) before using electrofishing methods to reduce this potential impact (see Conservation Methods below for details).

Acoustic Shock

There will be no blasting or use of mounted hydraulic impact hammer to cross the Lost River. Use of back-hoes for dry open-cut construction will not produce sound levels to cause harm to shortnose suckers.

**Indirect Effects**

Turbidity

Potential impacts to fisheries by dry open-cutting were discussed above in section 4.4.1.3 Coho (SONCC ESU). As noted in that discussion, dry open-cutting (fluming, dam-and-pump, or some combination of the two) generates small amounts of turbidity compared to wet open-cut procedures. However, adult suckers appear to prefer deep, turbid water but are often forced to utilize shallow, clear water if forced to during degraded water quality conditions in the summer (National Research Council, 2004). The amounts of turbidity generated by dry open-cut construction are not expected to adversely affect shortnose suckers if they are within the Lost River, several hundred feet downstream from the construction site.

Riparian Vegetation

Because HDD would be used to cross the Klamath River, only 0.75 acre within the Klamath River riparian zone (extending 117 feet or one site-potential tree height from each river bank) would be affected. No forested riparian vegetation would be affected. Construction across the Lost River would disturb approximately 2.72 acres within the riparian zone (extending 119 feet from each river bank). Similar to the Klamath River, no forest riparian vegetation would be affected or removed and all effects would be to agricultural land.

Water Temperature

No riparian vegetation would be removed that otherwise would provide shade. Consequently, water temperature would not be affected by construction. Shortnose suckers are susceptible to water temperatures $\geq 85^{o}$F (Bellerud and Saiki, 1995) but prefer water temperatures $60^{o}$F to $77^{o}$F (FWS, 2007l). Summertime water temperatures in Upper Klamath Lake often reach $86^{o}$F which coincide with or are caused by baseflows of major rivers and small streams (Bortleson and Fretwell, 1993).

Frac-Out

The HDD installation method is considered an effective technique for avoiding in-stream impacts by eliminating the need for in-stream excavation (Reid and Anderson, 1998; Reid et al., 2004). Even with this technique, there is a potential for impact as a result of the HDD process. Drilling requires use of a drilling mud for lubrication of the bit and removal of cuttings. A non-toxic, biodegradable bentonite clay mixture makes up drilling mud. Because the drilling mud is under pressure during drilling, if the bit encounters substrate fractures or channels, it is possible for bentonite to escape from the hole (termed a "frac-out"). Bentonite can escape to the surface through fractures in the drilled substrate. Bentonite is non-toxic to aquatic organisms but as with any fine particulate material, it can interfere with oxygen exchange by gills and the degree of interference generally increases with water temperature (see review and discussion of bentonite effects on aquatic organisms under Coho, Oregon Coast ESU, above).

Potential frac-outs are more common near the HDD drill entry and exit locations; however, impacts to waterbodies are minimized by locating the drill entry and exit points away from the waterbody. As discussed for Lost River suckers, above, GeoEngineer's Feasibility Analysis for pipeline construction using HDD across the Klamath River (see appendix E) the design length of the Klamath River HDD crossing is approximately 2,300 feet. The proposed entry point is located in an open agricultural field on the east side of the Klamath River. The exit point is located in an open area on the west side of the river. The preliminary design provides approximately 60 feet of cover below the bottom of the river. There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment. Additional evaluation of the hydraulic fracture and inadvertent return potential will be completed for the final design.

If drilling fluid accumulates in the substrate, it can adversely impact the quality and quantity of aquatic habitat available for aquatic species including salmonid spawning habitat and benthic macroinvertebrate rearing habitat. Drilling fluid that accumulates in the substrate may cover up food sources and smother fish eggs and other aquatic life in the riverbed. However, significant impacts to substrate from inadvertent returns are not likely in large river systems because of the anticipated high volumes and velocities within large rivers. As discussed above for Lost River suckers, if drilling fluid is inadvertently released into the Klamath River and significant concentrations are found during monitoring as a result of a release, the following possible corrective measures would be taken:

1. Increase the drilling fluid viscosity in an attempt at sealing the point at which fluid is leaving the drilled hole. The drilling operation may be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the higher viscosity drilling fluid.
2. If increasing the drilling fluid viscosity is ineffective, lost circulation materials (LCM) may be introduced into the hole by incorporating them in the drilling fluid and pumping the material down-hole. The drilling operation may again be suspended for a short period (i.e. overnight) to allow the fractured zone to become sealed with the lost circulation materials.
3. Depending on the location of the fractured zone, a steel casing may be installed that is of sufficient size to receive the largest expected down-hole tools for the crossing. This

casing installation provides a temporary conduit for drilling fluids to flow while opening the remaining section of the hole to a diameter acceptable for receiving the proposed pipe sections. To alleviate future concerns with the steel casing after the HDD installation is completed, the casing is generally extracted from the hole prior to or just after completing the HDD installation. However, there have been instances when attempts at extracting the steel casing were unsuccessful.

4. In the event drilling fluid flow is not regained through the annulus of the drilled hole and a steel casing installation is not utilized, the HDD contractor may elect to install a grout mixture into the drilled hole in an attempt to seal the fractured zone. The down-hole drilling assembly is generally extracted and existing hole is re-drilled to the point at which it had previously been drilled prior to having encountered the loss of drilling fluid. 5. In addition, a grouting program may be implemented from the surface in the event that the installation of grout into the drilled hole is unsuccessful. This approach is only practical in areas where drilling rigs with vertical drilling capabilities can access the HDD alignment. If a surface grouting program is utilized, the HDD drilling assembly is extracted from down-hole. Multiple holes are then drilled vertically on either side and along the HDD alignment to allow for grout slurry to be pumped into the fracture zone where the drilling fluid had previously been lost from the drilled hole. This process can take several days to complete in order to insert the grout in a grid pattern that covers the full fractured zone, during which time the HDD operation is suspended. Upon completion of the surface grouting program, the HDD operation will resume and the pilot hole will be reestablished through the grouted formation.

In some instances, it may be determined that the existing hole encountered a zone of unsatisfactory soil material and the hole may have to be abandoned. If the hole is abandoned, it will be filled with cuttings and drilling fluid.

**Cumulative Effects**

FWS and NMFS describe cumulative effects (50 CFR § 402.02) as the result of future actions by state or private entities, not involving federal actions, but reasonably certain to occur in the action area considered in this biological assessment. Future federal actions that are unrelated to the proposed action are not considered here because they require separate consultation pursuant to section 7 of the ESA.

Within the action area, 100 percent of all lands are non-federal within the John C. Boyle Reservoir-Klamath River watershed, 99 percent are non-federal lands within the Lake Ewauna-Klamath River watershed, and 94 percent are non-federal lands within the Mills Creek-Lost River fifth-field watershed. Degradation of water quality due to livestock grazing, agriculture, and timber harvest has resulted in severe pollution in Upper Klamath Lake. That in turn has lead to algal blooms with increased mortality of suckers when oxygen depletions occur due to eutrophication particularly during summers when high temperatures combined with nutrient loading from pumping diked wetlands and runoff from farms. Past actions that have lead to increased mortality have been due to private enterprise on private lands. Cumulative impact to Lost River suckers and shortnose suckers would include those same or similar actions which are reasonably foreseeable during the next 4 years. Cumulative impact from non-federal actions on non-federal lands would actually occur before implementation of the proposed action, not after its implementation which is more often the case. Therefore, the proposed Project could potentially contribute to cumulative effects for this species.

**Critical Habitat**

Designated critical habitat for the shortnose sucker is present within the Project area. The PCGP pipeline would cross the Klamath River at RM 249 which is within critical habitat Unit 1, Klamath County (FWS, 2012h). Unit 1 includes Upper Klamath Lake and Agency Lake, together with some wetland habitat; portions of the Williamson and Sprague Rivers; Link River; Lake Ewauna; and the Klamath River from the outlet of Lake Ewauna downstream to Keno Dam. Primary constituent elements could be affected during the HDD across the Klamath River if a frac-out occurred with release of bentonite into the water column; the same effects to critical habitat that were described as Indirect Effects, above, would occur.

Only 0.75 acre assumed to be within the Klamath River 100-year floodplain would be affected by construction and nearly all of that area is in an existing industrial facility.

#### 4.5.6.4 Conservation Measures

Conservation measures have been proposed by Pacific Connector to minimize construction and operation impact to waterbodies and riparian zones. Those measures have been compiled in table 2C in appendix N,and apply to shortnose suckers.

Pacific Connector has also proposed measures and to rectify, repair, and rehabilitate and otherwise reduce impact to waterbodies and riparian zones once construction of the Pacific Connector pipeline is complete. Those measures have been compiled in table 3C in appendix N.

**Fish Salvage**

Shortnose suckers can potentially occur within the construction right-of-way on the Lost River at the time of construction. A Fish Salvage Plan has been provided in appendix T. The plan has been developed to minimize adverse effects to listed salmonids (SONCC coho, Oregon Coast coho), non-listed salmonids (Chinook salmon, steelhead, cutthroat trout) and listed catostomids (Lost River sucker, shortnose sucker). The portions of the plan relevant to salvaging salmonids were adapted from the protocol developed by by Washington State Department of Transportation (2011b). The protocol specifies procedures to 1) isolate the work area, 2) removing fish and dewatering the work area, 3) handling, holding and releasing fish, and 4) documenting fish that have been captured, handled, held and released and notification to NMFS and FWS. The same protocol generally would be followed during salvage of Klamath Basin suckers. However salvage operations within the crossing where these sucker may be present would include the latest Handling Guidelines for Klamath Basin Suckers (Reclamation, 2008). These guidelines may be updated frequently. Some of the main factors in handling are the requirement of having a 0.5 percent saline solution of un-chlorinated well water to place any captured listed sucker in should it be collected during fish salvage operations. Aeration would also be supplied and the container a sucker is placed into would have been coated with a commercially available slime coat. Fish would be retained in this solution until released upstream of the capture site unless otherwise indicated through agreement with FWS.

<u>Instream Gravel</u>

Pipeline trenches across the Lost River and other perennial waterbodies within the Upper Klamath River Sub-basin and Lost River Sub-basin would be backfilled with material removed from the trench with the upper 1-foot of the trench backfilled with clean gravel or native cobbles of a size appropriate for resident fish, including suckers. The bottom and banks would be returned to preconstruction contours; banks would be stabilized; and temporary sediment barriers would be installed before returning flow to the waterbody channel.

Streambank Restoration

Pacific Connector's Erosion Control and Revegetation Plan (ECRP – see appendix F) describes the measures that will be used to stabilize streambanks crossed by the pipeline. Pacific Connector would not use riprap to stabilize streambanks. The alignment of the pipeline has been designed at waterbody crossings to be as perpendicular to the axis of the waterbody channel, as engineering and routing constraints allow, minimizing streambank disturbance and avoiding parallel stream alignments or multiple stream crossings. Immediately after installation of a waterbody crossing, the contours of the streambed, shoreline, and streambanks will be restored to preconstruction configurations (i.e., contour/elevations) to restore the physical integrity/condition of these features and to minimize the loss of stream complexity.

Pacific Connector has completed a scour analysis for the project that will be used to ensure that appropriate pipeline burial depths and cover design parameters beneath channel streambeds and adjacent floodplains are utilized, so that the effects on natural stream processes will be avoided or minimized. The project's scour analysis, which was completed by GeoEngineers, was included in Pacific Connector's June 2013 FERC Certificate application.

Pacific Connector will install erosion control fabric (such as jute or excelsior) on streambanks at the time of recontouring. The fabric will be anchored using staples or other appropriate devices. The erosion control fabric to be used on streambanks will be designed for the proposed use and will be approved by Pacific Connector's Environmental Inspectors (EIs).

Consistent with FERC's Wetland and Waterbody Procedures (Section V.C.3.), during streambank restoration/recontouring, the streambanks will be returned to their preconstruction contours or to a stable configuration. The Lost River is included in the application of the conservation measure. Streambank revegetation measures, including supplemental riparian planting procedures are also outlined in Section 10.0 of the ECRP. Riparian zones associated with the Klamath River and Lost River are on land owned by the State of Oregon. Riparian Zones for all other waterbodies crossed that are within range of the Lost River sucker are on private lands. The shrubs and trees planted at each site will be determined at the time of planting based on the moisture regimes and site-specific conditions at each planting location and landowner requirements.

#### 4.5.6.5 Determination of Effects

**Species Effects**

The Project **may affect** shortnose suckers because:

- Shortnose suckers occur within the Upper Klamath River Sub-basin and Lost River Sub-basin which would be affected during construction of the proposed action.

While several project actions are not likely to cause adverse effects, those resulting effects from Project components that are **likely to adversely affect** shortnose suckers include:

- There is a possibility that shortnose suckers could occur within the Lost River when it would be crossed by the Pacific Connector pipeline.

- There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment across the Klamath River
- Adults and juveniles subject to fish salvage within the isolated construction site at the Lost River could be injured or killed if electroshocking is used and stressed if seining is used. Incidental take of a shortnose sucker is possible.

**Critical Habitat Effects**

The Project **may affect** designated critical habitat for the shortnose sucker because:

- There may be a moderate risk of hydraulic fracture and inadvertent returns near the entry and exit points and also along the eastern portion of the alignment due to the silts observed along the proposed alignment across the Klamath River.

## 4.6 INVERTEBRATES

### 4.6.1 Vernal Pool Fairy Shrimp

#### 4.6.1.1 Species Account and Critical Habitat

**Status**

On September 19, 1994, the final rule to list the vernal pool fairy shrimp as threatened was published in the Federal Register (FWS 1994b).

**Threats**

The FWS identified significant threats to vernal pool fairy shrimp including destruction, modification, or curtailment of the species' habitat or range within California. The final rule made no distinction for specific vernal pool fairy shrimp habitats in the Agate Desert/Jackson County area in Southern Oregon because the species was not discovered there until 1998. The vegetation and land use in the Oregon habitat range, however, are similar to those of northern California's inland valleys (FWS 2005d). The FWS determined that the shrimp was imperiled throughout its then-known range by rapid urbanization, agricultural conversion, ORV use, and man-made changes in hydrologic patterns. In many cases, vernal pool complexes inhabited by the shrimp occurred on private land in areas of proposed or ongoing road, utility, residential, and commercial developments. Additionally, the FWS was concerned that landowners were likely to knowingly destroy the vernal pool habitat (FWS 1994b).

Other factors noted as threats to vernal pool fairy shrimp in the final rule include stochastic events, which have disproportionate effects on small isolated populations and may result in extirpations of some. Pools and pool complexes supporting fairy vernal pool shrimp are usually small, and unforeseen natural and man-caused catastrophic events threaten the elimination of some sites (FWS 1994b).

In a 5-year review of the vernal pool fairy shrimp, FWS determined threats to the species have not decreased since the time of listing in 1994 (FWS, 2007j). The loss and modification of vernal pool habitat due to urban development and infrastructure construction continue to be primary threats to the shrimp. The Medford region, where the species is found in Southern Oregon near the Pacific Connector pipeline area, grew by 29.5 percent between 1990 and 2000 (FWS, 2007j), although population growth slowed somewhat to 18.6 perecent between 2000 and

2010 (Oregon.gov, 2012). Other ongoing threats include agricultural conversion, altered hydrology, cessation of grazing or overgrazing, stochastic extinction, hybridization, contaminants, drought and climate change, and other human-cause impacts (FWS 2007i). In their *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (FWS 2005d), FWS listed commercial and industrial development, agricultural conversion, utility projects, and recreational use as direct threats on vernal pool habitats in Oregon (FWS, 2005d).

**Species Recovery**

A final recovery plan was completed in 2012 (FWS, 2012i) for vernal pool species within the Rogue River and Illinois Valleys that are federally listed or have federal species of concern designation. This plan includes more Oregon-specific direction for recovery of the vernal pool fairy shrimp than *The Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (FWS 2005d) provided. The recovery plan addresses large-flowered woolly meadowfoam, Cook's lomatium, and vernal pool fairy shrimp as well as six plant species of concern, and the hairy water flea.

The recovery goal specific to the vernal pool fairy shrimp is:

- Contribute to the recovery of the vernal pool fairy shrimp as stated in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (FWS 2005d).

The recovery objectives included in the recovery plan are:

- Stabilize and protect populations so further decline in species status and range are prevented.
- Minimize or eliminate the threats that caused the species to be listed and any newly identified threats.
- Conduct research necessary to refine downlisting and recovery criteria.
- Promote natural ecosystem processes and functions by protecting and conserving intact vernal pool-mounded prairie complexes and seasonally wet meadows within the recovery planning area.

The recovery plan includes the following delisting criteria for vernal pool fairy shrimp in the Klamath Mountina Region:

- At least 80 percent (9 of 11) of the occurrences within the Klamath Mountain Region (Rogue Valley) have been protected.
- At least 85 percent of suitable vernal pool habitat within the Klamath Mountain Vernal Pool Region has been protected.
- Habitat management and monitoring plans that facilitate maintenance of vernal pool ecosystem function and population viability have been developed and implemented for all protected habitat.
- Cyst banking actions have been completed for the vernal pool fairy shrimp.
- Status surveys, 5-year status reviews, and population monitoring show vernal pool fairy shrimp populations within the Klamath Mountain Vernal Pool Region are viable (self-sustaining) and have been maintained (stable, increasing, or showing only minor declines from high population levels) for a 10-year monitoring period.

The recommended recovery and long-term conservation actions are:

1. Protect vernal pool, wet meadow, and sloped mixed-conifer forest habitats.
2. Manage, restore, and monitor vernal pool and wet meadow habitat.
3. Conduct rangewide population status surveys.
4. Conduct research essential to the conservation and recovery of the species.
5. Enhance public awareness and participation in the recovery of the species.
6. Develop a post-delisting monitoring plan.

**Life History, Habitat Requirements, and Distribution**

This freshwater crustacean inhabits vernal pools, or seasonal wetlands that fill with water during fall and winter rains, in California and southwestern Oregon. They are known to occupy a variety of vernal pool habitats, from small, clear, sandstone rock pools to large, turbid, alkaline, grassland valley floor pools. Vernal pools in which the shrimp has been collected have water temperatures ranging from 40° to 73°F, with low to moderate amounts of salinity or total dissolved solids (FWS 2005d). Individuals hatch from cysts during winter storms and require water temperatures of 50°F or lower to hatch. The time to maturity and reproduction is dependent on temperature, ranging between 18 and 147 days, with a mean of 39.7 days. The shrimp can die when water temperatures rise to about 75°F. Flooding and wildlife movement within vernal pool complexes allow the shrimp to disperse between individual pools, indicating that vernal pool fairy shrimp populations are defined by entire pool complexes, rather than individual pools (FWS, 2007i).

Vernal pool fairy shrimp are found in 27 counties across the Central Valley and Coast ranges of California, and the inland valleys of southern California and southern Oregon (FWS 2003c). The shrimp was relatively recently discovered (1998) in Oregon at two distinct vernal pool habitats: on alluvial fan terraces associated with Agate-Winlo soils on the Agate Desert, and in the Table Rocks area on Randcore-Shoat soils underlain by lava bedrock (FWS 2005d). In Oregon, the vernal pool fairy shrimp is associated with the same vernal pool habitats as the large-flowered woolly meadowfoam and Cook’s lomatium plant species (discussed below). The Agate Desert comprises the northern extent of the vernal pool fairy shrimp’s range (2005d).

**Population Status**

The vernal pool fairy shrimp occurs in seaonally wet (autumn or winter) pools in the Agate Desert, White City, and Table Rocks areas in the Rogue Valley of Jackson County, Oregon, as well as various localities in the Central Valley and Coast Ranges of California (FWS, 2012i). The historical distribution is not known, especially in Oregon where it was recently discovered in 1998. Therefore, distribution can only be inferred from the loss of vernal pool habitat, which calculates to an approximate 75 percent decline in the vernal pool fairy shrimp population in the Agate Desert in Jackson County, Oregon (FWS 2005d). Additionally, over 40 percent of the vernal pool habitats remaining in Oregon have been degraded. Vernal pool fairy shrimps have been documented in 50 percent of the pools sampled in the Agate Desert Preserve, which is the highest percentage compared with other locales where the species is found (i.e., California and Denman Wildlife Management Area) (FWS 2005d).

**Critical Habitat**

Within the Rogue Valley, 7,574 acres have been designated as critical habitat for the vernal pool fairy shrimp within the following quadrangles in Jackson County: Shady Cove, Eagle Point, Boswell Mountain, Brownsboro, and Sams Valley (FWS 2003c). When determining areas of critical habitat for the vernal pool fairy shrimp, FWS focused on the principal biological or physical Primary Constituent Elements (PCEs) that are essential to the conservation of the species (FWS 2003c). Specifically, FWS (2003c) determined that two essential PCEs would apply to all critical habitat designated for vernal pool fairy shrimp. They are:

1) Vernal pools, swales, and other ephemeral wetland features of needed size and depth that become inundated during winter rains and hold water for the time necessary for life cycle completion, including but not limited to, Northern Hardpan, Northern Claypan, Northern Volcanic Mud Flow, and Northern Basalt Flow vernal pools; and,
2) The geographic, topographic, and edaphic features that support systems of hydrologically interconnected pools, swales, and other ephemeral wetlands and depressions within a matrix of surrounding uplands that together form what are known as vernal pool complexes (FWS, 2003c).

#### 4.6.1.2 Environmental Baseline

**Analysis Area**

In a general sense, a similar analysis area to the botanical analysis area that is described below for plant species (see Applegate's milk-vetch, section 4.2.1.2) applies to vernal pool fairy shrimp. That is, effects by the Project to vernal pool fairy shrimp could extend 200 feet from the perimeter of five proposed pipeyard storage areas that are located within the Vernal Pool Complex – Agate Desert, Jackson County, Oregon and shown in figure 4.6-1.

**Species Presence**

Six pipe storage yards are proposed within the Eagle Point and Sams Valley quadrangles where ten designated critical habitat units are within 3 miles of the proposed yards. Two proposed yards are adjacent to two critical habitat units (CHU's), identified as VERFS 3A and 3B (FWS 2006g). Surveys have documented vernal pool fairy shrimp in CHUs in Oregon, as well as adjacent to the project area in VERFS 3A and 3B (ORBIC, 2012); the most recent observations were in 2004 and 2005 where 15 to 25 percent of the vernal pools sampled were occupied by fairy shrimp (ORBIC, 2012).

No specific surveys have been conducted for the vernal pool fairy shrimp along the proposed construction right-of-way in the project area. Surveys in potentially suitable vernal pool habitat would be conducted two seasons prior to Project construction, following the interim FWS survey protocol (FWS, 1996b) in expected habitat and by a certified surveyor (see section 4.6.1.4, below). However, potential suitable vernal pool habitat was identified and surveyed at or adjacent to three pipe storage yards for large-flowered woolly meadowfoam and Cook's lomatium, where survey access permission was granted (SBS, 2008a): Rogue Aggregates, Medford Industrial Park, and habitat adjacent to Burrill Lumber (totaling 257.5 acres; table 4.6.1-1). Vernal pool fairy shrimp may be expected in the same habitat, where suitable vernal pool habitat was identified.

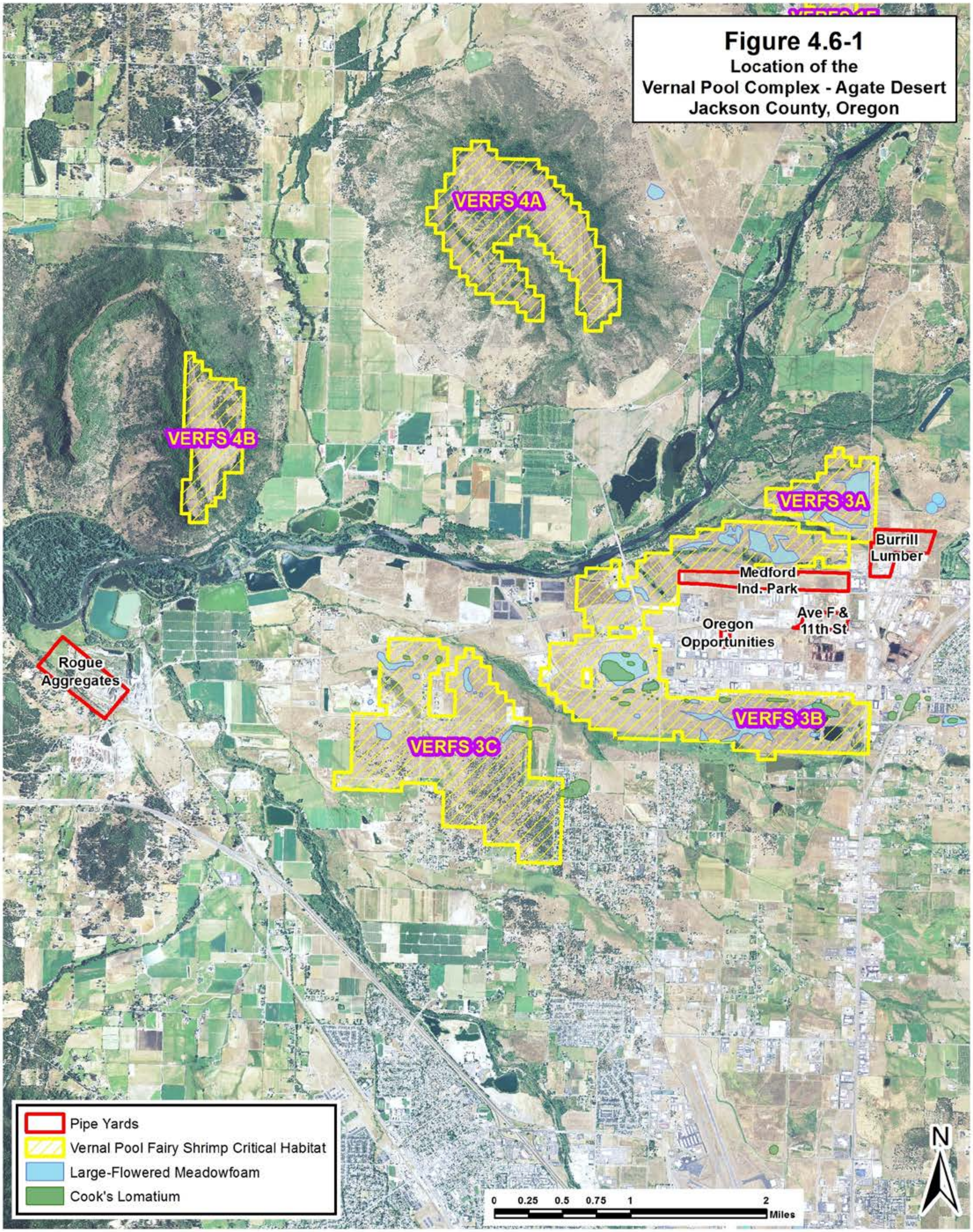


Figure 4.6-1
Location of the
Vernal Pool Complex - Agate Desert
Jackson County, Oregon
VERFS 4A
VERFS 4B
VERFS 3A
VERFS 3B
VERFS 3C
Burrill Lumber
Medford Ind. Park
Oregon Opportunities
Ave F & 11th St
Rogue Aggregates
Pipe Yards
Vernal Pool Fairy Shrimp Critical Habitat
Large-Flowered Meadowfoam
Cook's Lomatium
0 0.25 0.5 0.75 1 2
Miles
N

**Table 4.6.1-1**

**Summary of Proposed Pipe Storage Yards Considered for Use in Jackson County**

| PipeStorage Yard | Size (Acres) | General Description | Wetland and Waterbody Features (taken from RR2) | T&E Botanical Survey (SBS, 2007) |
|---|---|---|---|---|
| Burrill Lumber | 64.11 | Old lumber mill/log yard | Small shallow depressions support hydrophytic species from seasonal ponding. Ponding likely due to past soils soil compaction from previous site landuse. A drainage ditch crosses through the yard from north to south. | Species Surveyed: None – no vernal pool habitat.<br>Surveys Required: None – no vernal pool habitat.<br>No suitable habitat for species associated with vernal pools. Only suitable vernal pool habitat occurs in 65-acre taxlot adjacent to this storage yard that was surveyed for Cook's lomatium and large-flowered woolly meadowfoam. |
| Burrill Real Estate – Medford Industrial Park | 92.05 | Existing industrial park | Narrow wetland ditched drainages along southern, western, and eastern edges and two bisecting the site. Seasonal wetland mosaic in western portion of yard. The drainage features would be matted to cross and the wetlands would be avoided by project activities. | Species Surveyed: Cook's lomatium, Large-flowered woolly meadowfoam.<br>Surveys Required: Vernal pool fairy shrimp<br>Seventeen small, low quality vernal pools mostly in the eastern portion of this site. Remaining portion is used as industrial storage where habitat is disturbed and modified with areas of seasonal saturation. Three ditches associated with vernal pool habitat.<br>This yard was not considered suitable habitat for large-flowered woolly meadowfoam due to high level of surface disturbance/soil compaction, but was considered habitat for Cook's lomatium since that species can handle more disturbance. |
| Avenue F and 11th Street | 26.16 | Industrial business and vacant leveled lot | No wetlands or streams. | Species Surveyed: none – landowner denial.<br>Surveys Required: Cook's lomatium, large-flowered woolly meadowfoam.<br>Potential habitat identified on SW and SE margins of yard, although initial review indicates modified, disturbed unsuitable habitat; area actively used by industry and shows no sign of seasonal saturation.<br>Although this yard was not considered suitable habitat for large-flowered woolly meadowfoam or vernal pool fairy shrimp, surveys for large-flowered woolly meadowfoam will be conducted concurrently with Cook's lomatium when permission is granted. |
| Oregon Opportunities | 5.18 | Undeveloped/vacant lot in industrial park | Seasonal emergent wetland is present along railroad tracks on north end of site. Temporary construction mats or geotextile fabric and gravel padding would be used as a temporary access pad to railroad tracks if offloading pipe is necessary. | Species Surveyed: none – landowner denial.<br>Surveys Required: Cook's lomatium, large-flowered woolly meadowfoam.<br>Potential habitat on north and south end identified for surveys. Initial review indicates unsuitable habitat used as industrial storage with no indication of seasonal saturation.<br>Although this yard was not considered suitable habitat for large-flowered woolly meadowfoam or vernal pool fairy shrimp, surveys for large-flowered woolly meadowfoam will be conducted concurrently with Cook's lomatium when permission is granted. |
| Rogue Aggregates | 111.02 | Active aggregate quarry and processing facility and undeveloped land | No wetlands present. Several small ephemeral streams cross the site; the function of these drainages would not be affected by project activities. North end of site within floodplain. | Species Surveyed: Cook's lomatium, Large-flowered woolly meadowfoam<br>Surveys Required: none – no vernal pool habitat suitable for vernal pool fairy shrimp.<br>No suitable vernal pool habitat for the listed species. Mixture of pasture, mixed hardwoods, a gravel pit, and two ephemeral streams. |

**Habitat Surveyed**

As noted above, Siskiyou BioSurvey conducted botanical surveys within 257.5 acres on three proposed pipe yard storage yards near or in the analysis area (Rogue Aggregates, Medford Industrial Park, and habitat adjacent to Burrill Lumber). Of the 257.5 acres surveyed within the three pipe storage yards, 95.4 acres were found to be suitable vernal pool habitat for Cook's lomatium within Medford Industrial Park. No habitat was considered suitable for large-flowered woolly meadowfoam within the pipe storage yards or within the 200-foot survey buffer. Rogue Aggregates, a proposed pipe storage yard totaling 111.0 acres was surveyed, but no potential vernal pool or seasonal wetland habitat was identified. The site includes a mixture of pasture, mixed hardwoods, a gravel pit, and two ephemeral streams. Also, no suitable habitat for species associated with vernal pools was identified within Burrill Lumber pipe storage yard. Only 17 small, low quality vernal pools and two ditches in Medford Industrial Park were identified as potential suitable habitat for vernal pool fairy shrimp.

Two other areas no longer considered for potential pipe storage yard use were surveyed for large-flowered woolly meadowfoam and Cook's lomatium, and considered potential suitable habitat for vernal pool fairy shrimp. These yards included: one 65-acre taxlot (Maplot #361W17600) adjacent to the proposed 64.1-acre Burrill Lumber Yard that contained five acres of high quality and one acre of low quality vernal pool habitat over 900 feet from proposed Burrill Lumber Yard, and 24 acres of suitable vernal pool habitat located on the Avenue C and 7th Street/Elite Cabinet & Doors Yard that includes disturbed seasonally saturated or seasonal wetland habitat that has been filled and graded in the past (SBS, 2008a).

Two additional pipe storage yards totaling 31.3 acres were not surveyed – Avenue F and 11th Street and Oregon Opportunities (permission for access was denied), of which 4.9 acres of habitat within those pipe storage yards may have potential vernal pool habitat based on aerial photo interpretation and a "drive-by assessment". Avenue F and 11th Street is a 26-acre taxlot that appears to be modified, disturbed habitat that is actively used as industrial land, and shows no sign of seasonal saturation except for possible vernal pool habitat on the southwest and southeast margins of the yard. Oregon Opportunities includes five acres that appear to also have been previously disturbed; the site is unsuitable habitat and is currently used as an industrial storage area with no indication of seasonal saturation. Possible low quality vernal pool habitat exists on the north and south margins of the yard, although there is no sign of seasonal saturation. The proposed pipe storage yards are both highly modified and were not expected to support suitable habitat for vernal pool fairy shrimp.

Nine vernal pools (approximately 0.2 acre) within and adjacent to the proposed right-of-way that are on private lands (MPs 145.34 and 145.40) may also provide suitable habitat for the vernal pool fairy shrimp, although this area is outside of the known range for vernal pool fairy shrimp, but within the correct soils type for the Agate Desert vernal pool habitat. Surveys in potentially suitable vernal pool habitat would be conducted two seasons prior to Project construction, following the interim FWS survey protocol (FWS, 1996b) in expected habitat and by a certified surveyor (see section 4.6.1.4, below).

According to the recovery plan (FWS, 2012i), approximately 3,650 acres of vernal pool fairy shrimp habitat is considered for inclusion within the Agate Desert Wetland Conservation Plan. Approximately 568 acres (16 percent) are in the development category, 1,325 acres (36 percent) are in the protection category, and 1,757 acres (48 percent) are in the incentive for conservation category. The 568 acres slated for development would likely be permanently lost and the fate of the 1,757 acres in the incentive category may depend on funding of conservation incentive programs. None of the 7,500 acres of vernal pool fairy shrimp critical habitat is included in the development category. Approximately 1,200 acres of fairy shrimp critical habitat are included in the protection category with another 1,000 acres included in the incentive category (FWS, 2012i).

**Critical Habitat**

Two proposed pipe storage yards, Burrill Lumber and Burrill Real Estate – Medford Industrial Park, are located in industrial yards that are adjacent to two vernal pool fairy shrimp critical habitat units, VERFS 3A and 3B, in the Shady Cove quadrangle in Jackson County.

- Burrill Lumber (adjacent to VERFS 3A): Burrill Lumber proposed pipe storage yard is an old lumber mill and log yard with existing industrial structures on the south-western portion of the proposed 64 acre yard. This yard is separated from critical habitat unit VERFS 3A by an existing road (Agate Road). In the portion of the yard not recently used for industrial purposes, small shallow depressions are present that support hydrophytic species during seasonal ponding. Ponding is likely due to past soil compaction from previous site land uses and is not considered suitable habitat for federally listed vernal pool species associated with the vernal pool complexes in designated critical habitat units adjacent to this 64 acre lot including, vernal pool fairy shrimp, Cook's lomatium, and large-flowered woolly meadowfoam (SBS, 2008a). A drainage ditch crosses through the yard from north to south. Botanical surveys conducted in 2007 for Cook's lomatium and large-flowered woolly meadowfoam did not locate either species within this storage yard (SBS, 2008a).
- Burrill Real Estate – Medford Industrial Park (adjacent to VERFS 3B): Medford Industrial proposed pipe storage yard (92 acres) is a previously disturbed and modified industrial park located between an existing, paved road (Avenue G) and designated critical habitat unit VERFS 3B. Narrow wetland ditched drainages occur along the southern, western, and eastern edges of the industrial park and two wetland ditches bisect the site. A mosaic of 17 small, low quality seasonal wetlands are located in the eastern portion of the proposed yard, as well as three ditches with potential connections to vernal pool habitat. The remaining portion of the yard is used for industrial storage. Botanical surveys conducted in 2008 for Cook's lomatium and large-flowered woolly meadowfoam did not locate either species within this storage yard (SBS, 2008a).

Pacific Connector intends to avoid using areas within pipe storage yards that may have vernal pool fairy shrimp. If vernal pool fairy shrimp (or other ESA botanical species associated with vernal pools) is identified in previously surveyed or unsurveyed proposed pipe storage yards when access is granted through the FERC Certificate process, Pacific Connector would avoid using that section of the yard.

### 4.6.1.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Because of the rarity of vernal pool fairy shrimp, any direct or indirect impact resulting in species take or habitat loss would be a significant hindrance to its recovery. Direct effects include possible disturbance to pools from driving or storing equipment or pipes near or on pools or wetlands. Those actions could directly destroy or disturb vernal pool fairy shrimp cysts (during the dry season) or live shrimp (during the wet season). The proposed action in pipe storage yards near vernal pool habitats would occur on lands where past heavy industrial uses have occurred. Pacific Connector would avoid using the portion of the pipe storage yard that has suitable or potentially suitable habitat for vernal pool fairy shrimp, similar to actions taken within the 65-acre taxlot adjacent to Burrill Lumber Yard (with 5 acres of high quality suitable vernal pool habitat), and pipe storage yard Avenue C and 7th Street (24 acres of lower quality vernal pool habitat). As a result, no direct effects to vernal pool fairy shrimp or their potential habitat within pipe storage yards are expected.

Indirect effects to vernal pool fairy shrimp and their habitat could occur with increased road use to access the pipe storage yards that are adjacent or in the vicinity of suitable or potentially suitable habitat. Increased road use and the associated dust created might impact vernal pool habitat as dust settles, affecting vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, temperature). Project use of pipe storage yards (i.e., potential soil compaction by heavy equipment) adjacent to, or in the vicinity of suitable or potentially suitable habitat, may indirectly affect hydrology upon which vernal pools and associated vegetation are dependent. Indirect effects to hydrology could be expected within 527 feet of suitable or potentially suitable vernal pool habitat since at least 20 acres of habitat is considered essential for intact hydrology (see primary constituent element discussion for large-flowered woolly meadowfoam and Cook's lomatium – FWS, 2010b) and 527 feet is the radius of a circle with an area of 20 acres. Also, road use adjacent to or in the vicinity of suitable or potentially suitable vernal pool fairy shrimp habitat may increase the introduction of non-native, weedy species that could compete with native plant species associated with the vernal pool fairy shrimp.

No indirect effects are expected from use of Burrill Lumber pipe storage yard or roads accessing that yard to the five acres of high quality vernal pool habitat located on the northeast corner of the 65-acre taxlot (Maplot #361W17600) since it is located over 900 feet from the perimeter of the proposed Burrill Lumber Yard with a small drainage between the habitat and the industrial area.

Surveys for vernal pool fairy shrimp have not been conducted at 17 seasonal wetlands and saturated areas identified within Medford Industrial Park pipe storage yard as potential habitat, nor within potential habitat identified in nine vernal pools within and adjacent to the proposed right-of-way (MPs 145.34 and 145.40). While the pools at Medford Industrial Park are currently low quality vernal pool fairy shrimp habitat, the species is capable of occupying artificial seasonal wetland habitats (Vollmar, 2002). Also, vernal pools identified along the right-of-way are outside the range of vernal pool fairy shrimp, but may be capable of supporting vernal pool fairy shrimp because the soils are appropriate. Therefore, without surveys to confirm non-occupancy, direct effects from pipe storage yard activities or construction of the pipeline to vernal pool fairy shrimp and their habitat are possible. The two remaining unsurveyed pipe storage yards (Avenue F and 11th Street and Oregon Opportunities) both appear to have no potential vernal pool or seasonal wetland habitat; therefore, no direct or indirect effects are expected at these sites.

**Critical Habitat**

Vernal pool fairy shrimp are dependent on seasonal fluctuations, absence or presence of water during specific times of the year, duration of inundation, and the rate of drying of their habitats to support seed germination, cyst hatching, growth, maturation, reproduction, and dispersal, and the appropriate periods of dry-down for seed and cyst dormancy necessary for their survival (FWS, 2003c). The FWS (2003c) identified two primary constituent elements that were considered when designating critical habitat that considers soil moisture and aquatic environment required, as well as upland areas that may be associated with maintaining the aquatic and drying phases of the vernal pool or complexes. Vernal pools on the Agate Desert Preserve in the vicinity of proposed pipe storage yards in Jackson County, Oregon, generally consist of remnant parcels of disturbed or degraded vernal pool habitat and are threatened by indirect effects of adjacent land use, including alteration of hydrology (FWS, 2007i). Williamson et al. (2005 cited in FWS, 2007m) indicate that surface or subsurface changes to water flow could have deleterious effects on vernal pool ecosystem function protected areas within or adjacent to altered watersheds. Rains et al. (2006 cited in FWS, 2007i) also indicate that small changes in local land use may have considerable impacts on vernal pools and their hydrology. Hydrology can also be altered by non-native grasses that occur commonly in vernal pool complexes.

Two proposed pipe storage yards (Burrill Lumber and Medford Industrial Park) are located adjacent to two vernal pool fairy shrimp critical habitat units – VERFS 3A and VERFS 3B, consecutively. Although critical habitat lies adjacent to the proposed pipe storage yards, no direct impacts from the proposed action are anticipated since equipment and pipe storage would not occur near or on pools or wetlands located in the critical habitat units, nor would traffic to and from the pipe storage yards drive near or on pools within the designated critical habitat units. Possible indirect effects to the critical habitat units may occur as a result of increased road use to access the pipe storage yards that are adjacent to the critical habitat units (Avenues C, F, G, and Antelope and Agate Roads) and use of Medford Industrial Park pipe storage yard that is directly adjacent to critical habitat unit VERFS 3B. Increased road use and the associated dust created, might impact vernal pool habitat as dust settles, affecting associated vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, and temperature). Use of the Medford Industrial Park yard that includes ground disturbance such as leveling may alter hydrology in vernal pools in critical habitat unit VERS 3B, possibly affecting the frequency or amount of water in adjacent vernal pools, or altering the upland hydrology for which vernal pools and associated vegetation are dependent.

Indirect effects to hydrology could be expected within 527 feet of suitable or potentially suitable vernal pool habitat within VERFS 3B (527 feet is the radius of a 20-acre circle) since at least 20 acres of habitat surrounding a vernal pool site is considered essential for intact hydrology (see proposed primary constituent element discussion for large-flowered woolly meadowfoam and Cook's lomatium – FWS, 2010a). Additionally, use of the roads adjacent to the critical habitat units and the pipe storage yards, themselves, may increase the introduction of non-native, weedy species and contribute to ground/soil compactions which could affect local hydrological connectivity.

Applying conservation measures identified below (section 4.6.1.4) and use/alteration/restoration of pipe storage yards should minimize effects to the timing, duration, magnitude, or quality of hydrological connections to an off-site vernal pool and/or federally-listed vernal-pool obligate species.

#### 4.6.1.4 Conservation Measures

Pacific Connector has eliminated the 26.4-acre Avenue C and 7th Street-Elite Cabinet & Door Pipe Storage Yard, which contained potential vernal pool habitat, from further consideration for Project use to avoid potential effects to vernal pool habitat. Pacific Connector also would not use the 65-acre taxlot (Maplot #361W17600) which was surveyed adjacent to the Burrill Lumber Yard and contains five acres of high quality and one acre of low quality vernal pool habitat.

Once Pacific Connector has determined if Medford Industrial Park would be used for storage of pipe for the Pacific Connector pipeline, surveys for this species would be conducted per FWS interim survey protocol (FWS, 1996b) in expected habitat by a certified surveyor (applying either two full wet season surveys completed within a 5-year period or two consecutive seasons of one full wet season survey and one dry season survey, or visa versa) two seasons prior to Project use. Surveys would also be conducted for vernal pool fairy shrimp within the nine vernal pools identified within and adjacent to the construction right-of-way (MPs 145.34-145.40) two seasons prior to construction. Surveys would not commence until permission is provided by the FWS. Surveys have not been conducted yet to minimize "take" of the species, which could potentially occur if the shrimp are present (per protocol – survey and collect specimens). If this species is noted during survey efforts, Pacific Connector would implement proper sedimentation control barriers (FWS, 2005d) to minimize potential impacts to vernal pool fairy shrimp and associated vernal pools would be avoided. Pacific Connector would also ensure that use of the yards or construction of the pipeline would not affect surface drainage or current hydrologic conditions to adjacent areas if survey results confirm the presence of vernal pool fairy shrimp or if a yard is adjacent to potential suitable habitat or designated critical habitat.

#### 4.6.1.5 Determination of Effects

**Listed Species**

The Project **may affect** vernal pool fairy shrimp because:

- Potential suitable habitat for vernal pool fairy shrimp could be within one site considered for pipe storage (Medford Industrial Park). However, the species has not been surveyed at this site.

The Project is **likely to adversely affect** vernal pool fairy shrimp because:

- Use of the Medford Industrial Park Yard, even if found to not support vernal pool fairy shrimp, is expected to indirectly affect fairy shrimp if they are 527 feet away, possibly in designated critical habitat, since intact hydrologic connections between the yard and vernal pools could potentially be impacted by surface disturbances and/or soil compaction by heavy machinery.

**Critical Habitat**

A **may affect** determination is warranted for vernal pool fairy shrimp critical habitat because:

- The project occurs adjacent to designated vernal pool fairy shrimp critical habitat.
- The project may result in habitat impacts within adjacent designated critical habitat.

A **likely to adversely affect** determination is warranted for vernal pool fairy shrimp critical habitat because:

- The proposed action could potentially adversely modify geographic, topographic, and edaphic features that support systems of hydrologically interconnected pools, swales, and other ephemeral wetlands and depressions within a matrix of surround uplands (PCE 2) through surface disturbances and/or soil compaction by heavy machinery within the Medford industrial Park Yard at least 527 feet away from designated critical habitat unit VERFS 3B.

## 4.7 PLANTS

### 4.7.1 Applegate's Milk-vetch

#### 4.7.1.1 Species Account and Critical Habitat

**Status**

Applegate's milk-vetch was listed as endangered on July 28, 1993 (FWS, 1993c). It was believed to be extinct until its rediscovery in 1983 and at the time of listing was only known from two extant sites.

**Threats**

In the five year review of Applegate's milk-vetch, FWS identified continued destruction, modification or curtailment of its habitat or range, and loss of habitat through competition with non-native weeds as the principal threats to the species survival (FWS, 2009c). Extensive agricultural use had extirpated at least one Applegate's milk-vetch population in Klamath Country, Oregon. Road construction near Klamath Falls eliminated both plants and habitat. At the time of the listing, potential commercial and road development on private land threatened to destroy "probably the only viable population left" of the plant (FWS, 1993c: 40549). In Oregon's Klamath Wildlife Management Area, overgrazing by rabbits and fire and flood management schemes endangered an already waning Applegate's milk-vetch population (FWS, 1993c).

According to FWS Applegate's milk-vetch Recovery Plan (1998b), habitat loss and modification due to development and hydrologic manipulation continue to threaten Applegate's milk-vetch. Portions of the Ewauna Flat population have been destroyed by urban development on private land and more are at risk because they occupy properties zoned industrial. Construction of ditches and dikes in the Klamath Basin alter the hydrologic character of Applegate's milk-vetch habitat. These changes could result in lethally dry conditions, or may indirectly impact the species by introducing drought-tolerant and exotic plants (FWS, 1998b).

Several other factors were identified in the decision to list the Applegate's milk-vetch. Overutilization for commercial, recreational, and scientific purposes was seen as a potential threat at the time of listing because the rare plants are easily accessible by road. FWS identified predation from rabbits and cattle as obstacles to the plant's survival (FWS, 1993c). Additionally, because of the small number of populations, limited gene pool, and small number of plants in general, the FWS determined that potential for extinction from stochastic events (fires or floods) is a threat to the species (FWS, 1993c).

**Species Recovery**

The recovery plan was drafted with the ultimate goal to increase the stability of Applegate's milk-vetch so that it can be down-listed. The two main objectives of the recovery plan (FWS, 1998b) are to:

- Increase the species' representation from the current three areas to at least six areas with a minimum of two populations occurring at each of the recovery areas; and
- Develop management strategies that provide for long-term stability.

In order to achieve the two objectives, the recovery plan recommends the following actions:

- Conserve natural and introduced Applegate's milk-vetch populations.
- Develop long-term, off-site seed storage.
- Conduct research on population sustainability, population establishment and augmentation techniques, efficacy of habitat management strategies, and the plant's edaphic and hydrologic requirements.
- Develop and implement an outreach program.

The 5-year review of Applegate's milk-vetch (FWS, 2009c) reports that since the recovery plan was published, three new occurrences of Applegate's milk-vetch have been found. The review states that recovery critereia should be modified to include oppurtunities to achieve self-sustaining populations at the newly discovered sites. Specifically, the 5-year review suggests that Applegate's milk-vetch will be considered for downlisting to threatened status when (FWS, 2009c):

> "At least two natural and/or introduced self-sustaining populations are preserved in each of the three recovery areas (Ewauna Flat, Miller Island, and Worden), for a total of six or more populations in habitat permanently secured and managed for the benefit of the species. A minimum of 4,500 reproductive plants is needed for a recovery area to meet the downlisting threshold. Self-sustaining populations are defined as containing a minimum of 1,500 reproductive plants, plus sufficient individuals in younger age classes to suggest population stability or growth".

As of 2007, Applegate's milk-vetch population establishment techniques had not been successful and additional transplantation methods were being investigated (Gisler, 2002; ORBIC, 2007). FWS recommends further research on the impacts of weed competition on Applegate's milk-vetch, pollination and self-fertilization processes, and herbivory and predation processes (FWS, 1998b).

**Life History, Habitat Requirements, and Distribution**

Soils in typical Applegate's milk-vetch habitats are characterized as being gray in color, slightly alkaline, with a shallow water table and groundwater with a relatively high salinity due to periodic flooding and evaporation (TNC, 1999). Applegate's milk-vetch grows only in flat-lying, seasonally moist, alkaline soils with underlying clay hardpans. The underlying clay hardpans provide seasonal soil moisture, saturation and retention, forming a hydrological regime which may be a requirement for dry summer months when flowering and seeding occur (FWS 1998b). Alkaline soils may support mycorrhizal fungi and rhizobium bacteria beneficial to the survival and growth of the milk-vetch (FWS, 1998b). As with other plants growing under extreme conditions of alkalinity, heavy metals, and/or salinity, Applegate's milk-vetch may benefit from alkaline soils to help reduce competition from other species (FWS, 1998b).

The vegetative community in which Applegate's milk-vetch sites occurs is classified as interior alkali grassland (TNC, 1999). The species' habitat was historically characterized by sparse, native bunch grasses and patches of bare soil, allowing for some seed dispersal by wind. Today, dense coverage of the habitat by introduced grasses and weeds means seed dispersal is highly localized, with most seedling establishment found adjacent to mature plants (FWS, 1998b). Flowering usually begins in early June and ends in August. Reproduction takes place exclusively by seeds, which are shed soon after flowering. Pollination is thought to be mediated by butterflies (*Lycaedes argyrognomon* and *Plebejus Melissa*) and polylectic bees (Yamamoto, 1985), although the plant is also capable of seed production through self-fertilization.

Since the publication of the recovery plan in 1998, there have been numerous cooperative efforts made by Oregon Department of Agriculture, ORBIC, TNC, the FWS, and private landowners to conduct inventories forApplegate's milk-vetch throughout most of its historical range. The plant is endemic to Klamath County, Oregon (FWS, 1998b), is adapted to a narrow range of environmental conditions, and is known only in the Lower Klamath Basin (the plain containing Lower Klamath Lake), near the City of Klamath Falls in southern Oregon. Three new sites discovered since publication of the recovery plan include the Collins tract, the Klamath Falls Airport, and the Washburn Way-Railroad track (FWS, 2009c).

**Population Status**

At the time of the recovery plan in 1998, there were three known extant populations in Klamath County, numbering about 12,000 plants (FWS 1998b). As of 2008, the last published data available, the number of individuals was estimated to be 33,800 plants on six known sites (FWS 2009). Table 4.7.1-1 provides a summary of Applegate's population status at the time of federal listing in 1993, the draft recovery plan in 1998, and status as of 2008 (FWS, 2009c).

Local populations (table 4.7.1-1) range from nine plants in the Worden site to thousands of plants in two current extant sites (Klamath Airport and Collins Tract sites). Multi-year trend data has been collected at the Nature Conservancy Preserve site near Ewauna Lake. These data document a dramatic downward decline in the subpopulation from 30,000 to 2,000 plants during the five years 2003 to 2008 (FWS, 2008i in SBS, 2008a).

**Table 4.7.1-1**

**Summary of Applegate's Milk-vetch Population Status by Site at the Time of Federal Listing (1993), Publication of the Recovery Plan (1998), and as of 2008**

| Site Name | Ownership | Number of Plants at Time of Listing (1993) | Number of Plants at Time of Recovery Plan (1998) | 2007 Survey | 2008 Survey | Current Status |
|---|---|---|---|---|---|---|
| Ewauana Flat Preserve | The Nature Conservancy | Up to 30,000 plants | Approximately 11,500 plants | Partial Survey (see 2008) | Approximately 2,197 plants (2007/2008 surveys) | Declining |
| Miller Island | State of Oregon | 30 to 80 plants | Fewer than 500 plants | 38 plants | 112 plants | Unknown |
| Keno | Private | Historical (extirpated) | Historical (extirpated) | Historical (extirpated) | Historical (extirpated) | Extirpated |
| Worden | Private | Undiscovered | 3 plants | Extirpated | 9 plants | Unknown |
| Collins Tract | Private | Undiscovered | Undiscovered | Thousands of plants (area not counted) | 10,143 plants | Unknown |
| Klamath Falls Airport | City of Klamath Falls | Undiscovered | Undiscovered | Approximately 1,000 plants (area not completely surveyed) | 21,049 plants | Unknown |
| Washburn Way-Railroad | Private | Undiscovered | Undiscovered | Approximately 100 plants | 307 plants | Unknown |
| Klamath Falls | Private | Believed to have been extirpated | 13 plants found in 1994 | Extirpated site (developed) | Extirpated | Extirpated |

Source: FWS, 2008j in SBS, 2008a.

### Critical Habitat

Critical habitat has not been designated for Applegate's milk-vetch.

## 4.7.1.2 Environmental Baseline

### Analysis Area

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. That area corresponds to areas that were surveyed for sensitive and listed plant species during surveys conducted between 2007 and 2013. The survey areas were expanded beyond the 400-foot width to include TEWAs, UCSAs associated with the construction right-of-way, rock source and disposal sites, and proposed storage yards on federal or state lands that have potential for listed plant species. Under these criteria, nearly all of the proposed Pacific Connector pipeline route in Douglas and Jackson Counties was designated for survey and is included in the botanical analysis area. In Klamath County, a large area of private land was included for on-the-ground evaluation in order to detect small areas of potential habitat for Applegate's milk-vetch.

**Species Presence**

Herbarium records indicate that a known historical population, now presumed extirpated (ORBIC, 2012), occurred in the vicinity of the proposed pipeline alignment (MP 190.9 to MP 192.3); it was last reported in 1937, approximately 2 miles east of the town of Keno, Oregon (about 10 miles southwest of Klamath Falls; see the Keno Site included in table 4.7.1-1). Efforts to relocate this species in the area have been unsuccessful (ORBIC, 2012; FWS 1998b). Plants have been documented north and south of the proposed pipeline alignment (MP 195.5 to MP 196.7) across the Klamath River from and adjacent to the Lower Klamath National Wildlife Refuge and State Wildlife Area. The last observations were in 2010 with the site ranked as one with excellent estimated viability (ORBIC, 2012). Estimates of more than 10,000 plants at multiple sites in the area were made in 2008 (ORBIC, 2012). The closest mapped population of Applegate's milkvetch to the proposed project construction right-of-way is approximately 60 feet away. All sub-populations in this complex are on private land (including the Collins Tract Site, see Habitat Surveyed, below).

**Habitat Surveyed**

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for Applegate's milk-vetch within the proposed pipeline project area, including existing roads identified for access to the construction right-of-way. Aerial photographs (summer 2005) and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for Applegate's milk-vetch. The same methods have been applied to determine areas of suitable habitat in new locations where the proposed pipeline right-of-way has been relocated.

A total of 687.3 acres have been identified as potential habitat requiring surveys within the current project alignment including a 200-foot buffer (table 4.7.1-2). Of this habitat, 612.1 acres were allowed access to survey (297.2 acres within the project area) of which 131.7 acres (77 acres within the project area) were considered suitable habitat for Applegate's milk-vetch. All potential habitats are located within Klamath County between MPs 190.9 and 214.4.

Approximately 76.2 acres (49.8 acres within the project area) of potentially suitable habitat for Applegate's milkvetch was denied access by the landowner and would need to be surveyed prior to construction for complete surveys of this ecoregion. If the assumption is made that a similar percent of that area is suitable as documented within the rest of the area surveyed, then approximately 17 acres (22 percent of 76.2 acres, or 11 acres within the project area) is probably suitable Applegate's milk-vetch.

| Table 4.7.1-2<br><br>Summary of Potential Suitable Applegate's Milk-vetch Habitat within the FEIS-Revised Route and Botanical Analysis Area | | | |
|---|---|---|---|
| | **Area (acres) Included** | | |
| **Surveyed Area Type and Years Surveyed** | **FEIS ROW/ Access Roads** | **200-foot Botanical Analysis Area [1] (Outside of ROW)** | **Total** |
| **Area Identified for Survey (Potential Habitat)** | 346.8 | 340.5 | 687.3 |
| **Area Surveyed to Protocol** | | | |
| 2007 | 167.1 | 226.4 | 393.5 |
| 2007 and 2008 | 74.7 | 42.5 | 117.2 |
| 2008 | 31.0 | 15.4 | 46.4 |
| 2008 and 2013 | 5.1 | 1.6 | 6.7 |
| 2013 | 19.3 | 29.0 | 48.3 |
| **Totals** | **297.2** | **314.9** | **612.1** |
| **Area of Confirmed Potential Habitat** | | | |
| 2007 | 8.6 | 6.8 | 15.4 |
| 2007 and 2008 | 49.1 | 30.9 | 80.0 |
| 2008 | 14.2 | 15.4 | 29.6 |
| 2008 and 2013 | 5.1 | 1.6 | 6.7 |
| 2013 | 0 | 0 | 0 |
| **Totals** | **77.0** | **54.7** | **131.7** |
| **Area not Surveyed (access/ early grazing/ reroute / storage yards)** | 49.8 | 26.4 | 76.2 |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

<u>Documented Locations</u>

Three locations with Applegate's milk-vetch plants were documented by SBS during surveys in 2007 and 2008 (see table 4.7.1-3, SBS, 2008). Currently 38.3 acres of Applegate's milk-vetch habitat (with plants present) coincide with the current project alignment and 200 foot buffer: 17.8 acres within the proposed ROW and 20.5 acres outside of the ROW but within the 200-foot buffer.

| Table 4.7.1-3<br><br>Summary of Applegate's Milk-vetch Locations [1]. | | |
|---|---|---|
| **Milepost** | **Year Located** | **Site Description** |
| 195.35-195.95 | 2008 | 4.1 acres, JWTR LLC |
| 195.49-195.85 | 2008 | 14.1 acres, Collins Tract |
| 196.29 -196.79 | 2007, 2008 | 20.1 acres, Collins Tract |

Note:
[1] Locations and acreages are for discoveries **within** the 200-foot botanical analysis area.

Collins Tract

The Collins Tract site located within and adjacent to the botanical analysis area was first discovered in 1998 (table 4.7.1-1), and field surveys conducted by ORBIC in 2007 discovered two large sub-population, each several acres in size (Roninger, 2008). Expanded survey efforts by FWS and SBS in 2008 discovered several sub-populations clusters in the Collins Tract site, including plants within the FERC-filed construction right-of-way between MP 195.35 and 196.5 (Roninger, 2008; SBS, 2008a). In 2008, the entire Collins Tract was found to contain 10,133 plants on 32.3 acres within a larger 250-acre area (see figure 4.7-1). The 19 individual sub-population clusters ranged from a single plant to thousands of plants. There were seven sub-population clusters that occured within the botanical analysis area. The large sub-populations of Applegate's milk-vetch located at Collins Tract site was in habitat slightly different than other known populations: soil was less alkaline and not associated with the usual vegetative structure (i.e., very little or no rabbitbrush present). Also, weeds present within this area include cheatgrass, mouse barley, and sweet clover (see July 24, 2008 meeting minutes). In 2013, 55.0 acres were surveyed around the Collins Tract (and other areas), but no Applegate's milk-vetch were observed (SBS, 2013).

Although the Collins Tract site was discovered in 1998, the expansion of the sites sub-population was documented in 2007 and by definition in the 1998 Recovery Plan (FWS, 1998b) the site would be considered a self-sustaining population with a minimum of 1,500 reproductive plants with individuals in younger age classes, suggesting population stability and growth. However, additional monitoring of this site is required to verify population sustainability over time.

### Critical Habitat

Critical habitat has not been designated for Applegate's milk-vetch.

### 4.7.1.3 Effects by the Proposed Action

### Direct and Indirect Effects

In June and July 2008, FWS and SBS documented 10,133 plants within the Collins Tract site coinciding with and adjacent to the botanical analysis area. Of those locations, 592 plants were located within various components of the pervious FERC-filed route. Since very few sites of this species exist in Klamath County, and total numbers of individual plants for this species are relatively low, any loss of plants would be significant. The 1998 Recovery Plan identifies the small numbers and limited distribution as a threat because the possibility of extirpation due to random mortality events is increased (FWS, 1998b). Pacific Connector met with several members of the Habitat Quality Subtask Group on July 24, 2008 to discuss impacts to the documented plants and provide recommendations of how to avoid or minimize impact to these plants). In response to recommendations and discussions with agencies, Pacific Connector rerouted the proposed alignment north of its FERC-filed route to wetter soils to avoid individual plants documented during surveys in 2008, as well as more suitable habitat. As a result, use of the currently proposed route would avoid removal of documented plants and no direct impact to individual plants is expected (see figure 4.7-1).

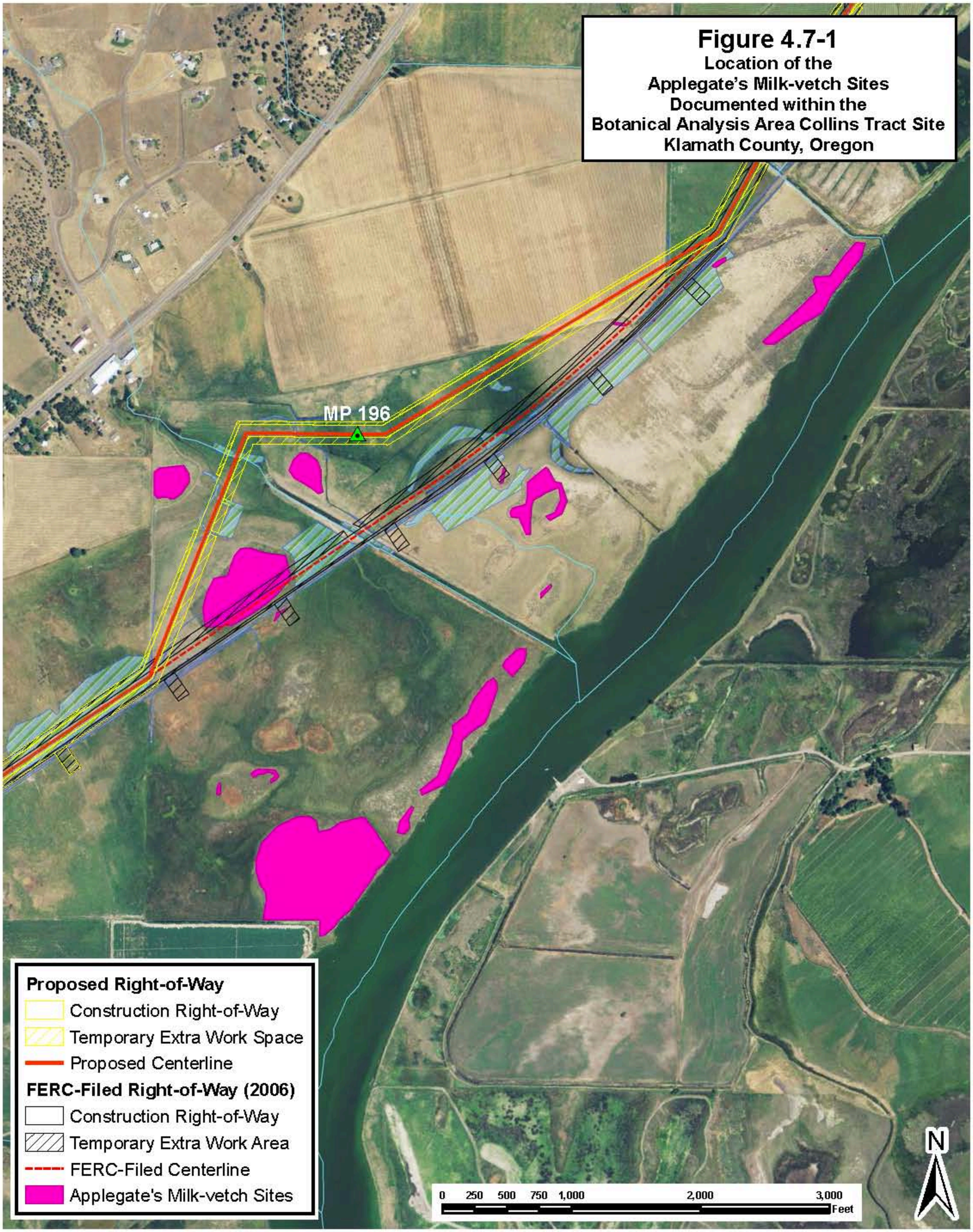


Figure 4.7-1
Location of the
Applegate's Milk-vetch Sites
Documented within the
Botanical Analysis Area Collins Tract Site
Klamath County, Oregon
MP 196
Proposed Right-of-Way
Construction Right-of-Way
Temporary Extra Work Space
Proposed Centerline
FERC-Filed Right-of-Way (2006)
Construction Right-of-Way
Temporary Extra Work Area
FERC-Filed Centerline
Applegate's Milk-vetch Sites
0 250 500 750 1,000 2,000 3,000
Feet
N

Records of Applegate's milkvetch provided by ORBIC (2012), FWS, and SBS in 2008 north and south of MPs 195.5 and 195.8, and possibly other sites within unsurveyed habitat, may also be indirectly impacted as a result of habitat alteration. Indirect impacts are likely to include: 1) changes in hydrology and soil characteristics, 2) an increase in invasive weeds, 3) alterations of vegetation cover and species composition. Such alterations in suitable habitat would likely cause an increase in weedy grasses and forbs. Competition from invasive weeds may limit the establishment and recovery of Applegate's milk-vetch (FWS, 1998b). Impacts to suitable habitat are expected to negatively affect the recovery of the plant. Very little suitable habitat still exists in the Klamath Basin, and the impacted habitat within the analysis area is therefore expected to represent a significant percentage of the total suitable habitat (SBS, 2008c).

After construction, Pacific Connector would restore the construction right-of-way back to approximate original contours and reseed using a species mix recommended by FWS and appropriate for this area of the pipeline project. Operational impacts would include monitoring and treatment for noxious weeds. No other maintenance impacts are expected within the range of Applegate's milk-vetch because the permanent easement would be maintained in an herbaceous/shrub state, similar to suitable habitat for Applegate's milk-vetch.

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where Applegate's milk-vetch occurs on private lands throughout the botanical analysis area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, wherever they may occur. However, the Pacific Connector pipeline would mitigate for any pipeline impacts to Applegate's milk-vetch.

**Critical Habitat**

No critical habitat would be impacted by the proposed action. Critical habitat has not been designated for Applegate's milk-vetch.

#### 4.7.1.4 Conservation Measures

The only protected Applegate milkvetch populations in the area are those at the Klamath Wildlife Area and Klamath Falls Airport. The proposed pipeline route is within one of the largest private land populations of this species, the Collins Tract, which contains greater than 10,000 plants. The FWS has been exploring conservation agreements with the Collins Company to protect the Collins Tract population. To avoid removing individual plants within the Collins Tract site, Pacific Connector rerouted the original FERC-filed alignment north around other documented sites and in the lower elevations and wetter soils to minimize potential of unforeseen impacts to the plants or its habitat (see draft EIS-revised route). The location of the draft EIS-revised route was recommended by attendees at the July 24, 2008 Habitat Quality Subtask Group meeting. Additionally, TEWAs identified to discharge extra water within the trench were eliminated or moved to avoid impacting smaller plant groups (see figure 4.7-1).

Applegate's milk-vetch is a trailing perennial herb that begins flowering in early June and ends in August. Reproduction takes place exclusively by seeds, which are shed soon after flowering.

Participants of the July 24, 2008 meeting indicated that constructing within this area would be better in the winter than spring or summer to avoid the critical growing, flowering, and seeding cycle of this species. Within the range of Applegate's milk-vetch, Pacific Connector would construct from September 15 in Year 1 through April 30 in Year 2 (see figures 3.2-1 and 3.2-3), which would minimize impact to these critical life cycles.

During winter construction, Pacific Connector would use wetland mats in the travel area between MPs 195.35 to 196.50 where necessary to prevent rutting in saturated areas or to minimize soil compaction and protect existing plants that may be present but not documented. Additionally, Pacific Connector would segregate topsoil from trench spoil to maintain the soil seed bank, as well as maintain microrhyzoids with which the species' root system is associated. After construction, the construction right-of-way would be restored to its original contours and reseeded with an appropriate seed mixture recommended by FWS prior to the following growing season.

To control the potential noxious weed invasion Pacific Connector would implement the procedures outlined in their Noxious Weed Control Plan (section 12.0) provided in the ECRP (see appendix F).

When Pacific Connector acquires access to the construction right-of-way, surveys would be conducted in potential habitat (previously surveyed or unsurveyed) and additional plants located during surveys would be avoided, if feasible. Measures of avoidance may include necking down the construction right-of-way in that area, excluding a portion of an identified temporary extra work space or pipe storage yard, or erecting a protective fence to avoid impact to plants from construction debris. If it is determined that avoidance is not possible, participants of the July 24, 2008 Habitat Quality Subtask Group suggested digging up the plant(s), transplanting, and monitoring; however, Applegate's milk-vetch is difficult to transplant because of the long (approximately five-foot) tap root. Also, no or minimal successful out-planting has been recorded in greenhouses or other locations. Prior to construction, Pacific Connector would collect and bag seeds in June and/or July if plants are identified within the proposed alignment and provide seeds to a suggested repository. If permission is granted by the property owner, Pacific Connector would use the collected seed to plant outside of the permanent right-of-way after construction.

#### 4.7.1.5 Determination of Effects

**Listed Species**

The Project **may affect** Applegate's milk-vetch because:

- Suitable habitat is available within the botanical analysis area.
- Individual plants have been located within the analysis area during survey efforts.

The Project is **likely to adversely affect** Applegate's milk-vetch because:

- Potential suitable habitat occurs along the proposed route and comprehensive surveys have not been conducted in all areas; therefore it is possible that unidentified plants occur within the proposed construction right-of-way and work space.
- Grazing had occurred prior to surveying one area of potential habitat and plants may be located at that site.

- Unidentified plants could occur within unsurveyed habitat, where landowner denied survey permission.

**Critical Habitat**

Critical habitat has not been designated for Applegate's milk-vetch.

### 4.7.2 Gentner's Fritillary

#### 4.7.2.1 Species Account and Critical Habitat

**Status**

Gentner's fritillary was listed as endangered on December 10, 1999 (FWS, 1999b). The reddish-flowered lily's origin may be a recent hybrid but is considered a valid species. It is found in small, scattered locations in Jackson and Josephine counties in Oregon, with one small population recently discovered in northern California (FWS, 2003d).

**Threats**

A key factor in FWS listing Gentner's fritillary was the present or threatened destruction, modification, or curtailment of its habitat and range. FWS identified residential and utility development and agricultural conversion as the causes for these destroyed locations in its relatively isolated population. At that time, 73 percent of the known plants were in a central core area within a seven-mile radius of the Jacksonville Cemetery. FWS noted that habitat loss due to ongoing or future development might occur at 42 percent of the occupied sites (19 plots—all within the central core area) (FWS, 1999b).

Loss of habitat is still a major threat to Gentner's fritillary. In the species' recovery plan (2003d) FWS identified agricultural, urban and residential development, timber harvest, and recreation as ongoing threats to the very narrow geographic range of the plant. The areas most threatened are on private lands. Habitat conversion due to fire suppression continues to be a problem for the endangered species, as well as weed and non-native plant proliferation, and herbicide use. The plant is endangered by the very structure of its remaining populations, which are scattered, isolated, and small in size and number. These small pockets of the plant are at high risk of decline because they lack reserves to ward off stochastic loss, overutilization for commercial and recreational purposes, diseases, climatic shifts, herbivory, localized natural disturbances, and decrease in genetic diversity (FWS, 1999b and 2003d).

**Species Recovery**

A species recovery plan was released by FWS in 2003 (FWS, 2003d). The objective of the recovery plan is to remove threats to the extent that Gentner's fritillary is no longer in danger of extinction and can be downlisted or delisted. To meet the objective, the plan requires the establishment, management, and maintenance of a minimum of eight *Fritillaria* management areas, with at least two distributed within each of four recovery units described in the recovery plan. The recommended recovery actions are listed below:

- Provide private landowners with information on identification and management of habitat to maintain *Fritillaria gentneri*.
- Establish a minimum of eight *Fritillaria* management areas.
- Conduct surveys and research essential to conservation and recovery.
- Develop off-site germplasm banks to maintain reproductive materials.

- Review and revise recovery plan as needed, based on accumulation of new data.

The plan creates four recovery units for Gentner's fritillary to delineate areas that are considered necessary for the viability and recovery of the plant. The recovery strategies for the units include rehabilitation of habitat, restoration of historical sites, and augmentation of existing populations including expansion into nearby suitable habitat (FWS, 2003d). Recovery units are considered individually necessary to the long-term viability of the species. The proposed pipeline coincides with Recovery Unit 3 in northeastern Jackson County.

**Life History, Habitat Requirements, and Distribution**

Gentner's fritillary is often found in grassland habitats within, or on the edge of dry, mixed forest types where overstory can be dominated by Oregon white oak, madrone, Douglas-fir, and ponderosa pine. It occurs at a wide range of elevations, from 1,000 to 5,100 feet, in the rural foothills of the Rogue River Valley of Josephine and Jackson counties (FWS, 2003d and SBS, 2008b). It is usually associated with shrubs that provide protection from the wind and sun.

The perennial reproduces clonally by means of numerous small bulblets that break off larger bulbs and form new plants. Sexual reproduction appears to be a sporadic or episodic event for the plant, although observations suggest hummingbirds and some species of bees may pollinate the plant. Blooming season usually lasts from April through May, and the plant must reach a minimum size before flowering (FWS, 2003d).

The distribution of Gentner's fritillary is characterized by distinct clusters. The species is highly localized, with the populations occurring within a 30-mile radius of Jacksonville Cemetery in Jacksonville, Oregon, with approximately 45 percent of the plants occurring within an 11-mile radius.

**Population Status**

It is often difficult to census populations of Gentner's fritillary because individuals can remain dormant for one or more years underground and not flower. Also, flowering plants can be grazed by deer or cattle before identification and counting can be performed and sometimes it cannot be distinguished from other non-flowering and co-occurring *Fritilleria* species, such as scarlet fritillary or chocolate lily (FWS, 2003d). In 2001, Gentner's fritillary was estimated at 1,696 flowering individuals in Jackson and Josephine counties, and just south of the border in California (FWS, 2003d). A more recent informal count indicates a total number of about at least 3,000 mature, flowering plants in 109 population sites (SBS, 2008b). Most Gentner's fritillary sites include a small number of individual plants, ranging from one to 450 individual plants (mean of 16 plants). The largest number of plants occurs on BLM lands, with 1,653 counted in 2005 during annual monitoring of 56 known sites (SBS, 2008b). Inventories on other monitored sites counted 940 plants on private lands in Jacksonville (SBS, 2008b) and 424 at Pickett Creek (Thorpe et al., 2006 in SBS, 2008b).

**Critical Habitat**

Critical habitat has not been designated for Gentner's fritillary.

#### 4.7.2.2 Environmental Baseline

**Analysis Area**

A botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. That area corresponds to areas that were surveyed for sensitive and listed plant species in 2007, 2008 and 2013. See section 4.7.1.2 above for the full botanical analysis area description.

**Species Presence**

The analysis area crosses the species' range approximately from MP 116.96 through 154.22. Twenty-one sites occur within 10 miles of the proposed route (ORBIC, 2012). The proposed pipeline crosses Gentner's fritillary Recovery Unit 3, which is one of four clusters of fritillary sites proposed for conservation management within the 2003 recovery plan. Populations within Recovery Unit 3 are considered to have low vigor (BLM, 2007 in SBS 2008a). One of the most vigorous plant populations in Recovery Unit 3 is closest to the botanical analysis area, located 1.2 miles southeast of MP 134.4 in the Obenchain Mountain area within the BLM Medford District (Friedman, 2006; ORBIC, 2012; SBS, 2008a). However, recent observations at the site reported 19 plants (the observed population in good vigor) in 2005 but just 1 plant in 2009 with the population rated as poor viability (ORBIC, 2012). Pipe storage yards in Jackson County are located more than 3 miles away from several documented populations in Sam's Valley (Friedman, 2006). None of the previously known sites mentioned above are located within the botanical analysis area but are part of the recovery unit located within the analysis area.

**Habitat Surveyed**

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for Gentner's fritillary within the botanical analysis area, including existing roads identified for access to the construction right-of-way. Aerial photographs from summer, 2005 and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for Gentner's fritillary. The same methods were used to determine potential suitable habitat coinciding with new realignments of the project corridor.

A total of 1,738.1 acres have been identified as potential suitable habitat requiring surveys within the current project alignment and associated 200 foot botanical analysis area (see table 4.7.2-1, and detail below under Jackson County Pipeyards). Of this habitat, 1,495.1 acres were permitted survey access (544.6 acres within the project area). A total of 189.7 acres were surveyed on access roads located outside of the current project alignment and outside the 200-foot wide botanical analysis area. The habitat is located within the Rogue Valley Foothills region, Pacific Connector pipeline MP 116.96 through MP 154.22.

Of the 1,495.1 acres of potential habitat allowed for survey access, 1,231.5 acres (449.9 acres within the project area) were considered suitable habitat for Gentner's fritillary. Habitat suitability was qualitatively assessed based on Gentner's fritillary habitat analysis conducted in Oregon by SBS in 2001. Habitat found to be "suitable" in the surveys included areas with some of the characteristics detailed in the Life History, Habitat Requirements, and Distribution section above (SBS, 2008a).

Approximately 243 acres (73.3 acres within the project area) of potentially suitable habitat for this species was denied access by the landowner and would need to be surveyed prior to construction for complete surveys of this eco-region. If the assumption is made that a similar percent of that area is suitable as documented within the rest of the area surveyed, then approximately 200 acres (82 percent of 243 acres, or 60 acres within the project area) is likely to be suitable fritillary habitat.

**Table 4.7.2-1**

**Summary of Potential Suitable Gentner's Fritillary Habitat within the FEIS-Revised Route and the Botanical Analysis Area.**

| Surveyed Area Type and Years Surveyed | Area (acres) Included | | |
|---|---|---|---|
| | FEIS ROW/ Access Roads | 200-foot Botanical Analysis Area [1] (Outside of ROW) | Total |
| **Area Identified for Survey (Potential Habitat)** | 617.9 | 1120.2 | 1738.1 |
| **Area Surveyed to Protocol** | | | |
| 2007 | 64.4 | 116.6 | 181 |
| 2007 and 2008 | 448.4 | 765.5 | 1213.9 |
| 2008 | 16.5 | 40.7 | 57.2 |
| 2010 and 2011 | 8.9 | 16.3 | 25.2 |
| 2013 | 6.4 | 11.4 | 17.8 |
| **Totals** | **544.6** | **950.5** | **1495.1** |
| **Area of Confirmed Potential Habitat** | | | |
| 2007 | 32.8 | 55.8 | 88.6 |
| 2007 and 2008 | 390.4 | 673.3 | 1063.7 |
| 2008 | 11.4 | 24.8 | 36.2 |
| 2010 and 2011 | 8.9 | 16.3 | 25.2 |
| 2013 | 6.4 | 11.4 | 17.8 |
| **Totals** | **449.9** | **781.6** | **1231.5** |
| **Area not Surveyed (access/ early grazing/ reroute / storage yards)** | **73.3** | **169.7** | **243.0** |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

<u>Pacific Connector Gentner's Fritillary Surveys</u>

Two years of surveys are advised to conduct a complete survey for and detect Gentner's fritillary because mature plants do not flower every year and the basal leaves are identical to scarlet fritillary, a species with no special status. Five sites were located during survyes conducted from 2008 to 2013 (table 4.7.2-2).

During the first year of surveys from April 13 to April 30, 2007, surveys were conducted on 181 acres of the current proposed alignment's botanical analysis area (64.4 acres within the project area). No plants were found.

During 2008 (including resurveying the 2007 areas) surveys on 1,213.9 acres (448.4 acres within the current project alignment) between April 26 and May 20, this Gentner's fritillary was located at three sites. One Gentner's fritillary plant was located approximately 0.38 mile north of MP

128.05 near Indian Creek and 50 feet below a four-wheel drive road proposed for access to the construction right-of-way (EAR 128.05 north of the proposed construction right-of-way).

Two additional medium-sized fritillary species (*Fritillaria* sp.) leaves were located nearby at MP 128.1. Unless flowering, however, it is difficult to identify the leave as those of Gentner's fritillary. A second site was approximately one mile west of MP 128.8 which was discovered during surveys of an existing access road (EAR 128.05 south of the proposed construction right-of-way) approximately 100 feet from the access road. This population consists of four individual plants located in a 20 meter area just above the high water line of Indian Creek and no other leaves were located. The third site supported a flowering Gentner's fritillary plant (with no leaves) located near MP 142.10 just within a TEWA (TEWA 142.07-N).

There were additional fritillary species (*Fritillaria* sp.) with leaves located within 150 feet of the flowering site within TEWA 142.07-N and construction right-of-way, as well as two other flowering fritillary species (scarlett fritillary and chocolate lily). It is possible that some of the leaves located within this area could be Gentner's fritillary and therefore a larger area that includes all the leaves encountered in 2008 is considered part of the population area (approximately 0.83 acres) (see figure 4.7-2).

In spring 2011, a single plant was identified outside of the project corridor, but witin the 200-foot botanical analysis area at MP 128.1. In 2013, 23.2 acres were surveyed between MPs 128.8 and 129.4. One plant location was recorded at MP 129, outside of the TEWA, but within the 200-foot botanical analysis area.

The five sites identified within the botanical analysis area are 0.4 to 11.2 miles from each other and therefore are not considered a "population center" by the recovery plan definition (four or more locations occur within 0.3-mile of each other – FWS, 2003d). Also, these sites are about six aerial miles from other known sites and therefore could not be considered part of those population centers. However, it might be considered that these sites are part of a deme within Recovery Unit 3 – "a scattered population of individuals with the potential to exchange genetic material on occasion", because the documented sites are within 9.3 miles of other identified populations, a maximum distance that distribution of plant clusters has been documented (FWS, 2003d).

**Table 4.7.2-2**

**Summary of Gentner's Fritillary Locations**.

| Milepost | Year Located | Site Description |
|---|---|---|
| 128.05 and 128.1 | 2008 | On Indian Creek access road, 50' below road; nearby site recorded non-flowering plants. |
| 128.1 | 2011 | Located 46' from TEWA 128.01-W. Out of ROW but within 200'vegetation buffer. |
| 128.8 | 2008 | Located 100 feet from proposed access road EAR-128.05. |
| 129.1 | 2013 | Out of ROW but within 200'vegetation buffer. |
| 142.1 | 2008 | Flowering plant located within TEWA 142.07-N. |

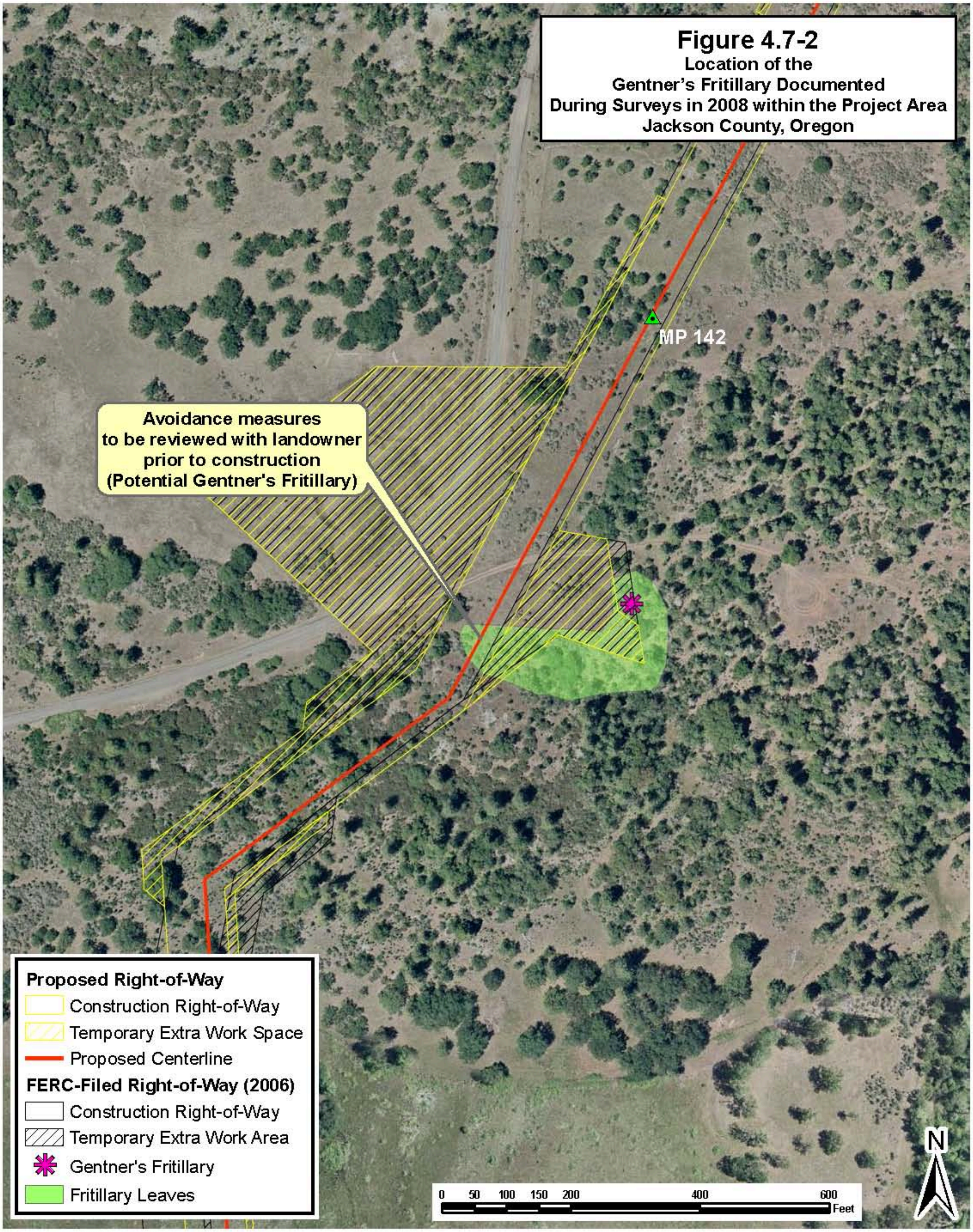


Figure 4.7-2
Location of the
Gentner's Fritillary Documented
During Surveys in 2008 within the Project Area
Jackson County, Oregon
MP 142
Avoidance measures
to be reviewed with landowner
prior to construction
(Potential Gentner's Fritillary)
Proposed Right-of-Way
Construction Right-of-Way
Temporary Extra Work Space
Proposed Centerline
FERC-Filed Right-of-Way (2006)
Construction Right-of-Way
Temporary Extra Work Area
Gentner's Fritillary
Fritillary Leaves
0 50 100 150 200 400 600
Feet
N

### Critical Habitat

Critical habitat has not been designated for Gentner's fritillary.

### 4.7.2.3 Effects by the Proposed Action

### Direct and Indirect Effects

Five new Gentner's fritillary locations (eight plants total) were identified within the PCGP Project area during surveys conducted between spring 2008 and 2013. Since only five sites of this species have been located by Pacific Connector within Recovery Unit 3, and total individual plants for this species are relatively low (a reason for federal listing), any loss of plants would be significant.

No direct effects are expected at sites located 50 and 100 feet from a proposed existing access road (MPs 128.05 and 128.10), or at the two sites located within the 200 foot botany zone but outside of the project corridor at MP 128.1 and MP 129.1. The site at MP 128.8 is located 100 feet from an access road. At the other site, SBS documented one flowering Gentner's fritillary plant and several other *Fritillaria* sp. leaves within TEWA 142.07-N and construction right-of-way. Because this site consists of a single plant or perhaps a small cluster of plants, it is more vulnerable to extirpation due to even small-scale losses of habitat or plants (FWS, 2003d). Pacific Connector met with several members of the Habitat Quality Subtask Group on July 24, 2008 to discuss impacts to the documented plant(s) and provide recommendations of how to avoid or minimize impact to these plants (see July 24, 2008 meeting minutes). Participants of this meeting recommended that no direct impacts occur to this site. In response to recommendations and discussions, Pacific Connector has determined that a minor route adjustment of the proposed alignment is feasible to avoid the identified potential Gentner's fritillary sub-population, including the unidentified *Fritilleria* sp. leaves. Also, Pacific Connector removed a portion of TEWA 142.07-N that would directly impact the flowering Gentner's fritillary plant. The revised proposed route avoids removal of the documented plants and *Fritilleria* sp. leaves, and as a result, no direct impact to individual plants documented during surveys is expected (see figure 4.7-2). Pacific Connector anticipates conducting additional surveys of this area to verify species and/or locate additional *Fritilleria* sp.

Since Gentner's fritillary does not flower every year and remains dormant underground for one or more years, it is very possible that not all plants within the suitable habitat in the PCGP Project area were documented during the 2-year survey effort. Therefore, there is a good likelihood that construction activity within identified suitable habitat could remove individual plants, resulting in a direct impact to this species.

Approximately 618 acres (table 4.7.2-1) of suitable or potentially suitable (unsurveyed) habitat between MP 117.0 and 154.2 would be disturbed (removed/modified) by construction of the proposed pipeline resulting in an indirect impact to Gentner's fritillary. Indirect impacts are likely to include: 1) changes in hydrology and soil characteristics, 2) an increase in invasive weeds, 3) alterations of vegetation cover and species composition. Such alterations in suitable habitat would likely cause an increase in weedy grasses and forbs. Competition from invasive weeds may limit the establishment and recovery of Gentner's fritillary (FWS, 2003d); however, the impacted habitat in the analysis area represents a very small percentage of total suitable habitat in the species' range (SBS, 2008b), and so disturbance to the habitat should not impede recovery of the species. To control the potential noxious weed invasion, Pacific Connector would implement the procedures outlined in their Noxious Weed Control Plan (section 12.0) provided in the ECRP (see appendix F).

Operation and maintenance of the proposed pipeline would occur within suitable Gentner's fritillary habitat. Vegetation within the 30-foot operational corridor would be periodically maintained using mowing, cutting, trimming, and herbicides (selectively). Maintenance activities are expected to occur approximately every 3 to 5 years depending on growth rate. However, these activities should not have an adverse affect on Gentner's fritillary because maintenance activities, if necessary, would occur after the critical growing and flowering season. If noxious weed infestation occurs within the permanent easement, selective use of herbicides or mechanical treatments would be used to control weed within proximity to the species. Pacific Connector's protection procedures are outlined in the Noxious Weed Control Plan (Section 12.0 in the ECRP - appendix F).

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where Gentner's fritillary occurs on private lands throughout the action area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, wherever they may occur. However, the Pacific Connector pipeline would mitigate for any Project impacts to Gentner's fritillary.

**Critical Habitat**

No critical habitat would be impacted by the proposed action. Critical habitat has not been designated for Gentner's fritillary.

### 4.7.2.4 Conservation Measures

The objective within each established recovery unit is to have at least 750 flowering plants to downgrade its status to threatened or 1,000 plants to delist the species, monitored biannually for at least 15 years. This recovery unit total may consist of many management areas within each recovery unit, including management areas as small as five flowering plants. Maintaining the subpopulations or population clusters within each recovery unit is important to preserve the genetic diversity within the species, ensure its long-term viability, and reduce the vulnerability of the species to extirpation from random catastrophic events (FWS, 2003d). To avoid all direct impact to the flowering plant documented in 2008 within the FERC-filed route, Pacific Connector has modified TEWA 142.07-N (see figure 4.7-2). To reduce the possibility of eliminating a genetic source of Gentner's fritillary within Recovery Unit 3, Pacific Connector has identified a feasible route to avoid the unidentified *Fritillaria* sp. leaves located within TEWA 142.07. Pacific Connector will conduct additional surveys to verify *Fritilleria* sp., as well as identify any additional flowering plants or *Fritilleria* sp. leaves that should be considered within a route adjustment, prior to consulting with the private landowner regarding a minor route adjustment.

Pacific Connector assumes the potential habitat identified for Gentner's fritillary (surveyed and not surveyed) would be accessible prior to construction of the pipeline. When Pacific Connector acquires access to the construction right-of-way, surveys would be conducted in potential habitat and plants located during surveys would be avoided, if feasible. FWS would be notified of survey results and, if present, the avoidance/conservation measures (including compensatory mitigation) to be taken would be discussed with FWS staff. Measures of avoidance may include necking down the construction right-of-way in that area, excluding a portion of an identified TEWA or pipe storage yard, or erecting a protective fence to avoid impact to plants from construction debris. If it is determined that avoidance is not possible, propagation of collected bulblets followed by offsite cultivation for population augmentation could be a viable conservation measure (SBS, 2008a). This procedure might include (SBS, 2008a):

- identification and tagging plants for propagation during spring flowering (April in lower elevation, May in higher elevations);
- collection of bulblets during dormant season (late summer to fall-August through November);
- cultivation of bulblets off-site; or
- replanting of grown-out bulbs in subsequent years' dormant season.

Transplanting mature, dormant whole bulbs is another possible conservation measure. However, because recent propagation work has focused on augmenting populations, as opposed to moving plants to avoid disturbance, success with transplanting bulbs is not known. Based on that work, it appears reasonable to similarly identify and tag mature plants in the spring, then move and plant the mature bulbs in the fall in suitable habitat nearby. In this scenario, bulbs might need to be stored after the fall bulb harvest and construction disturbance period until the replanting period in the fall of the following year (SBS, 2008a). The associated small bulblets could be grown out to further enhance the recovery site. A conservation easement could be established to compensate for lost habitat and tied to potential transplant projects regardless of whether plants were found in the construction right-of-way or not.

Although the seed of some fritillaries appears to germinate quite easily, germination of seed collected from Gentner's fritillary has rarely been documented. Difficulties in collecting an adequate supply of viable seed, combined with potentially poor germination and seedling survival, currently make propagation from seed a poor method for creating transplants. Attempts to germinate seed at Berry Botanic Garden were not successful, and no reports of germination exist in the available horticultural literature (SBS, 2008b).

Replanting of an area adjacent to the disturbance zone is possible with the propagation techniques discussed above. Replanting adjacent areas of undisturbed areas (with cultivated bulbs or simply moving mature bulbs) requires identification of suitable Gentner's fritillary habitat. Transplanting mature bulbs requires no time for growing out plants, but would require storage of the mature bulbs during construction (i.e. between harvesting in late summer/fall year one, and replanting the following year during late summer/fall). Harvesting of rice-grain bulblets requires additional time to grow out the rice-grain bulblets to sizable plants. Both techniques require harvesting and replanting bulbs in the late summer/fall season, during the dormant season.

For each Gentner's fritillary potential population to be disturbed, the choice of suitable habitat for proposed re-establishment requires consideration of: 1) the proximity of mother plant location to the re-establishment area, 2) the proximity of the established Gentner's fritillary populations within Recovery Unit 3, 3) the proximity and number of individual plants in the closest Gentner's fritillary Management Unit of Recovery Unit 3, 4) the ownership status of the re-establishment location; 5) the quality of the habitat in the proposed reestablishment area, i.e. site characteristics such as level of habitat disturbance, soils, topography, aspect, slope, plant community/vegetation, and weed infestation.

Additionally, about 60 percent of the construction right-of-way that was formerly considered as suitable habitat could be returned to and maintained as suitable habitat through the planting of associated compatible native species, with monitoring for and control of invasive species.

Invasive weed species could affect the existence, establishment, or recovery of Gentner's fritillary. Pacific Connector would monitor and control invasive weed species within the permanent right-of-way; however, some herbicidal treatment of invasive weed species could pose a threat to this species depending on the season of use and type of herbicide used. To minimize impacts to this species, Pacific Connector would either use a dicot-specific herbicide or general herbicide outside of the growing season of Gentner's fritillary. If treatment is necessary within the growing season, Pacific Connector would use triclopyr, a chemical that has little effect on grasses and other monocots including Gentner's fritillary (FWS, 2003d). For more details on the control of potential noxious weed invasions, Pacific Connector's protection procedures are outlined in the Noxious Weed Control Plan in Section 12.0 in the ECRP (see appendix F).

**Mitigation**

Additional mitigation measures for individual Gentner's fritillary plants, if identified within the unsurveyed portions of the proposed route, would be addressed through the Gentner's Fritillary Mitigation Plan (see Appendix O).

In addition, Pacific Connector has agreed to fund a BLM mitigation proposal for *Fritillaria gentneri* to compensate for potential threats to *Fritillaria gentneri* populations located on BLM lands and for potential impacts to non-flowering plants along the pipeline route (see Appendix O – Attachment 1). The BLM mitigation would include augmenting sites at a secure location as a recovery action towards downlisting or delisting the species. The Cobleigh Road *Fritillaria gentneri* ACEC site was proposed as an ACEC for protection and recovery of *Fritillaria gentneri*. This site lies within Recovery Area 3, which includes other populations located along the pipeline route. The ACEC contains more than a dozen documented *Fritillaria gentneri* populations across 1,146 acres. Flowering plant counts in this recovery unit have never reached 750 for downlisting or 1,000 for delisting, but the BLM and Oregon Department of Agriculture are currently using the area for bulb collection and outplanting.

Augmentation would include bulb collection and outplanting. The proposed restoration project would consist of collecting bulblets from existing populations, increasing bulblet numbers to 2,000 through propagation in the greenhouse, planting the bulblets at 4 different locations with 500 bulblets at each site, and monitoring the bulblets for three years. The BLM would add funding to an existing Assistance Agreement with the Oregon Department of Agriculture to conduct the augmentation activities.

### 4.7.2.5 Determination of Effects

**Listed Species**

The Project **may affect** Gentner's fritillary because:

- Suitable habitat is available within the analysis area.
- Individual plants have been located within the analysis area during survey efforts.

The Project is **likely to adversely affect** Gentner's fritillary because:

- Not all potential suitable habitat was surveyed due to landowner access denial.
- Gentner's fritillary does not flower every year, and has been documented to not flower for several years; therefore, it is possible that the two years of surveys conducted for this flower did not locate this species.
- *Fritillaria* sp. leaves were documented within and adjacent to the proposed project and without flowers, it is nearly impossible to determine if those leaves belong to Gentner's fritillary or another *Fritillaria* species.

**Critical Habitat**

Critical habitat has not been designated for Gentner's fritillary.

### 4.7.3 Large-Flowered Woolly Meadowfoam

#### 4.7.3.1 Species Account and Critical Habitat

**Status**

The large-flowered woolly meadowfoam was listed as endangered on November 7, 2002 (FWS 2002d). A recovery plan was developed (FWS, 2012i) for vernal pool species within the Rogue River Valley that are federally listed or have federal species of concern designation, including large-flowered woolly meadowfoam.

**Threats**

A major factor in FWS listing the large-flowered woolly meadowfoam was the present or threatened destruction, modification, or curtailment of its habitat and range. Due to recent rapid population increases in the region, the primary threats to the plant's habitat and range in the Agate Desert (Jackson County, Oregon) are industrial, commercial, and residential development and their residual road and utility construction and maintenance (FWS, 2011e). These important residual impacts include mowing, herbicide use, firebreak construction, and hydrologic alteration (mostly for agriculture).

Grazing can have a mixed effect on large-flowered wooly meadowfoam. The effect of grazing on suitable habitat depends on how the grazing is managed. There are various reports showing how grazing practices can positively or negatively affect native plant species' richness (Marty 2005). Marty's (2005) study indicates that wet season grazing resulted in a decrease of native forb species at vernal pool edge habitat, but year-round grazing actually improved species' richness.

Although disease (fungus), herbivory, and the meadowfoam fly (*Scaptomyza apicalis)* have been identified as potential problems, no data other than casual observations exist to suggest that these factors pose a substantial threat to the species at this point in time (FWS, 2012i).

Because of the enduring population and development pressures on the species' limited habitat and range, it is presumed that the final rule factors in determining its endangered status remain as significant ongoing threats to the species.

**Species Recovery**

The Recovery Plan for Rogue and Illinois Valley Vernal Pool and and Wet Meadow Ecosystems (FWS, 2012i) identifies nine core areas for protection in the Rogue Valley. The recovery plan addresses large-flowered woolly meadowfoam, Cook's lomatium, and vernal pool fairy shrimp, as well as six plant species of concern and the hairy water flea. Approximately 98 percent of known large-flowered woolly meadowfoam populations occur on designated critical habitat for the vernal pool fairy shrimp (FWS, 2006g). The recovery objectives for the large-flowered woolly meadowfoam include:

- Stabilize and protect populations of the the listed species in core areas so further decline in species's status and range are prevented.
- Minimize or eliminate the threats that caused the species to be listed, and any other newly identified threats, in order to be able to delist the species.
- Conduct research necessary to refine downlisting and recovery criteria.
- Ensure long-term conservation.
- Promote natural ecosystem processes and functions by protecting and conserving, in identified core areas, intact vernal pool-mounded prairie complexes and seasonally wet serpentine-derived grassland meadows, sloped mixed-conifer forest openings, and shrub dominated plant communities within the recovery planning area.

Delisting criteria specific to large-flowered woolly meadowfoam:

- At least 17 of 18 occurrences for large-flowered woolly meadowfoam (approximately 95 percent of documented/extant occurrences) should be protected in conservation oriented ownership (i.e., land that is formally secured from habitat loss and degradation by way of conservation easements, formal agreements, conservation banks, or public or conservation group ownership). For occurrences that have become extirpated, reintroduced or introduced populations may be substituted. Introduced or newly discovered populations outside of currently known core areas may be substituted if the FWS deems them equivalent in their contribution to recovery.
- At least 95 percent of suitable vernal pool habitat acreage within each Priority 1 core area for the species and at least 90 percent of suitable vernal pool habitat acreage within each Priority 2 core area for the species has been protected from development. All suitable habitat must include soils and hydrology that support the plant species.
- Conservation oriented management plans for each protected core area are developed to guide protection and conservation following establishment of protected status such as a conservation easement or transfer of ownership to land trusts or government entities. Each management plan should be operational as soon as possible, as funding and staff time allow.
- Additional species occurrences identified through future site assessments, GIS, other analyses, or status surveys, and that are determined essential to recovery, are protected. Status surveys, 5-year status reviews, and population monitoring show achievement of self-sustaining species populations as confirmed through species monitoring and status surveys in each protected occurrence.
- Seeds from each core area of the two species are in storage as insurance against the risk of extirpations and to ensure that genetic lines are preserved. Seed banking is also necessary in order to complete the reintroductions or introductions that can contribute to meeting recovery criteria.

**Life History, Habitat Requirements, and Distribution**

The large-flowered woolly meadowfoam is an annual herb endemic to the Agate Desert area in southern Oregon. It grows on the wetter, inner edges of vernal pools mostly in the Rogue River Valley. Vernal pool-mounded prairie habitats sustain wet soils needed for growth and flowering, and the shallow pools provide for nutlet dispersal during the annual's relatively short life cycle (FWS 2006g). The plant is capable of self-fertilization and self-pollination. Flowering occurs between March and May, with flowers producing nutlets. These nutlets may be dispersed by water, normally only short distances. Thus, it is likely that they do not disperse beyond their pool or swale of origin.

Large-flowered woolly meadowfoam occupies a limited portion of the Rogue Valley. The plant typically occurs in areas mapped with Agate-Winlo soils (FWS, 2012i). There are no significant ecological, genetic, or geographic barriers separating the 21 extant and historical large-flowered woolly meadowfoam occurrences, apart from agricultural and rural development and road systems. All known populations of large-flowered woolly meadowfoam comprise approximately 177 hectares (440 acres), and are grouped into nine core areas that are separated by at least 1 kilometer (0.7 miles). In the Rogue River Valley, large-flowered woolly meadowfoam is found in the same vernal pool habitats as Cook's lomatium and the vernal pool fairy shrimp.

**Population Status**

At the time of listing in 2002, there were 15 known occurrences of large-flowered woolly meadowfoam. At the time of the release of the Draft Recovery Plan in 2006, 22 occurrences were known. Currently, 23 occurrences are known (FWS, 2011e). Portions of 12 occur on public lands, on conservation easements, or on lands managed by The Nature Conservancy (FWS, 2009d) and thus are protected from development. The population of this species fluctuates annually depending on precipitation and temperature, and so fluctuating populations at the various sites of occurrence have a broad range of approximately 100 to 100,000 (FWS 2006g).

**Critical Habitat**

Critical habitat was designated on July 21, 2010, including eight critical habitat units in Jackson County totaling 2,363 hectares (5,840 acres) (FWS, 2010e). The primary constituent elements for large-flowered woolly meadowfoam critical habitat include:

1) Vernal pools or ephemeral wetlands and the adjacent upland margins of these depressions that hold water for a sufficient length of time to sustain large-flowered woolly meadowfoam, growth, and reproduction, between elevations of 1,220 to 1,540 feet, a minimum of 20 acres, and associated with specific dominant native plants (FWS, 2010e).
2) The hydrologically and ecologically functional system of interconnected pools, ephemeral wetlands, or depressions within a matrix of surrounding uplands that together form vernal pool complexes within the greater watershed.
3) Silt, loam, and clay soils that are of alluvial origin, with a 0 to 3 percent slope, primarily classified as Agate– Winlo complex soils, but also including Coker clay, Carney clay, Provig–Agate complex soils, and Winlo very gravelly loam soils.
4) No or negligible presence of competitive, nonnative, invasive plant species.

Eight critical habitat units have been designated for the large-flowered woolly meadowfoam in Jackson County, of which two units are shared by the designated critical habitat for Cook's lomatium (White City and Whetstone Creek, see below). Critical habitat units RV6 and RV8 are within the vicinity of White City, Oregon, where five proposed pipe storage yards for the PCGP Project are located.

#### 4.7.3.2 Environmental Baseline

##### Analysis Area

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. That area corresponds to areas that were surveyed for sensitive and listed plant species in 2007 and 2008. The botanical analysis area also applies to known or potential habitats for endemic vernal pool obligate species. Effects by the Project to vernal pool obligates could extend 200 feet from the perimeter of five proposed pipeyard storage areas that are located within the Vernal Pool Complex – Agate Desert, Jackson County, Oregon and shown in figure 4.6-1 under Vernal Pool Fairy Shrimp, above.

##### Species Presence

There are multiple historical records of large-flowered woolly meadowfoam within the Shady Cove-Rogue River watershed – HUC 1710030707 (ORBIC, 2012) through which the proposed pipeline passes for approximately 8.4 miles, from MP 121.77 to MP 130.15. The closest record is a population with poor viability, last observed in 1982 approximately 3.6 miles southwest of the proposed route. Other, more distant populations were extant in the 1980's and 1990's but also rated with poor viability by ORBIC (2012). Populations in the watershed that were found and evaluated within the past fifteen years were rated with excellent viability but those are more than 6 miles from the proposed route.

Five pipe storage yards have been proposed within the range of large-flowered woolly meadowfoam in the Agate Desert in Jackson County. Two of the proposed pipe storage yards (Burrill Lumber and Medford Industrial Park) are adjacent or in close proximity to four critical habitat subunits RV6A, RV6B, RV6C, and RV6D where nine sites of large-flowered woolly meadowfoam have been previously documented (Friedman, 2006). Two other proposed storage yards (Oregon Opportunities and Ave F and 11$^{th}$ St.) are located within 0.5 mile of critical habitat subunits RV6A and RV6B. The known large-flowered woolly meadowfoam sites range from 200 feet to 2,880 feet from the proposed pipe storage yards. The closest known large-flowered woolly meadowfoam sites to Rogue Aggregates pipe storage yard are greater than 1.5 miles away.

Pacific Connector Large-flowered Woolly Meadowfoam Surveys

SBS conducted surveys for large-flowered woolly meadowfoam at three of the five potential pipe storage yards where survey permission was granted: Burrill Lumber, Rogue Aggregates, and Medford Industrial Park (SBS, 2008a). No plants were located within the three proposed pipe storage yards.

Two other areas were surveyed for large-flowered woolly meadowfoam: one 65-acre taxlot (Maplot #361W17600) adjacent to the proposed 64.1-acre Burrill Lumber Yard that contained five acres of high quality (and one acre of low quality vernal pool habitat over 900 feet from proposed Burrill Lumber Yard), and 24 acres of suitable vernal pool habitat located on the Avenue C and 7$^{th}$ Street/Elite Cabinet & Doors Yard that includes disturbed seasonally saturated or seasonal wetland habitat that has been filled and graded in the past (SBS, 2008a). On the 65-

acre taxlot, four small patches (36 plants) of large-flowered woolly meadowfoam were found more than 900 feet northeast of the Burrill Lumber proposed storage yard. Three patches occur on the edges of vernal pools in a quarter-acre area in an undisturbed corner of the property, and one patch is 400 feet to the south, outside of the vernal pool area in a heavily modified swale (SBS, 2008a). The site is located on a portion of the property that has not been heavily modified (SBS, 2007; see figure 4.6-1). The plants located are suspected to be part of a larger large-flowered woolly meadowfoam population located to the east within critical habitat subunit RV6D. Since discovery of the plants, Pacific Connector is not considering the 65 acre taxlot (Maplot #361W17600) for use as a pipe storage yard.

Two other proposed yards, Avenue F and 11th Street and Oregon Opportunities, have not been surveyed due to landowner denial. Initial reviews of habitat via aerial photography and "drive-by" have identified approximately five acres of potential low quality vernal pool habitat on the margins of both of these yards. It is expected that once surveyed, this habitat would be determined not suitable for large-flowered woolly meadowfoam.

### Habitat

None of the the 257.5 acres identified as potentially suitable large-flowered woolly meadowfoam habitat surveyd by SBS in the three pipe storage yards (Burrill Lumber, Medford Industrial Park, and Rogue Aggregates) was considered suitable for large-flowered woolly meadowfoam (table 4.7.3-1).

**Table 4.7.3-1**

**Summary of Potential Habitat and Survey Status for Large-Flowered Woolly Meadowfoam**

| Surveyed Area | Area (acres) Included | | |
|---|---|---|---|
| | FEIS ROW/ Access Roads | 200-foot Botanical Analysis Area [1] (Outside of ROW) | Total |
| **Area of Potential Habitat** (Jackson County Pipe Storage Yards) | 262.4 | 0 | **262.4** |
| **Area of Known Suitable Habitat** (known from surveys) | 0 | 0 | **0** |
| **Areas Surveyed to Protocol** (proposed route) | 257.5 | 0 | **257.5** |
| **Area Not Surveyed** (access denied) | 4.9 | 0 | **4.9** |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

Suitable and occupied large-flowered woolly meadowfoam habitat also exists within proposed critical habitat subunits adjacent or in proximity to the Burrill Lumber and Medford Industrial Park pipe storage yards (see critical habitat discussion, below).

### Critical Habitat

Two of the eight designated critical habitat units for large-flowered woolly meadowfoam are within the vicinity of five proposed pipe storage yards: RV6, which consists of 8 subunits and is approximately 1,829 acres, and RV8 that is approximately 850 acres. Both consist of intact vernal pool-mounded prairie and swale habitats (FWS, 2010b). Four of eight RV6 subunits – RV6A, RV6B, RV6C, and RV6D – are near or adjacent to proposed yards. RV8 is over 1.4 miles from the closest pipe storage yard, and is located between the proposed Rogue Aggregates and the other four pipe storage yards (see figure 4.6-1). Except for subunit RV6D, the other RV6 subunits and RV8 unit coincide with designated critical habitat for vernal pool fairy shrimp: VERFS 3A, 3B, and 3C.

#### 4.7.3.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Possible direct effects to large-flowered woolly meadowfoam include possible disturbance to pools from driving or storing equipment or pipes near or on pools or wetlands with this species. The proposed action in pipe storage yards near vernal pool habitats would occur on lands where past heavy industrial uses, soil grading, and compaction have occurred. Surveys conducted for the proposed project has not identified any plants or suitable habitat for the large-flowered woolly meadowfoam. Also, proposed pipe storage yards that have not been surveyed to-date but have been evaluated by other means (including Avenue F and 11th Street and Oregon Opportunities yards) are not expected to contain suitable habitat for this species. If future surveys identify potential suitable habitat or large-flowered woolly meadowfoam plants within the two unsurveyed pipe storage yards, Pacific Connector would avoid using the portion of the pipe storage yard, similar to actions taken within the 65-acre taxlot adjacent to Burrill Lumber Yard with 5 acres of high quality suitable vernal pool habitat, and pipe storage yard Avenue C and 7th Street that had 24 acres of lower quality vernal pool habitat. No direct effects to large-flowered woolly meadowfoam or their potential habitat within pipe storage yards are expected.

Indirect effects to large-flowered woolly meadowfoam and their habitat could occur with increased road use to access the pipe storage yards that are adjacent or in the vicinity of suitable or potentially suitable habitat. Increased road use and the associated dust created might impact vernal pool habitat as dust settles, affecting vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, temperature). Project use of pipe storage yards (i.e., potential soil compaction from heavy equipment use) adjacent to, or in the vicinity of suitable or potentially suitable habitat, may indirectly affect hydrology upon which vernal pools and associated vegetation are dependent. Indirect effects to hydrology could be expected within 527 feet (the radius of a 20 acre circle) of suitable or potentially suitable vernal pool habitat since at least 20 acres of habitat is considered essential for intact hydrology (see primary constituent element discussion for large-flowered woolly meadowfoam and Cook's lomatium – FWS, 2010a). Effects could include altering hydrologic processes, such as runoff patterns as a result of soil compaction, as well as increased seeding of non-native invasive plant species (PCEs 1 and 4). However, any potential compaction that may occur at the yard would likely be insignificant because of the previous industrial use, soil grading and compaction, and implementation of the Noxious Weed Control Plan (section 12.0) provided in the ECRP (see appendix F) would reduce spread of noxious species.

Thirty-six large-flowered woolly meadowfoam plants were documented during surveys in 2007 over 900 feet from proposed pipe storage yard Burrill Lumber in the northeast corner of an adjacent 65-acre taxlot (Maplot #361W17600). However, indirect impacts to these plants and their habitat, including hydrology, is not expected to occur from activities associated with the proposed Burrill Lumber Yard because the yard is located over 900 feet from the vernal pool habitat and the large-flowered woolly meadowfoam plants located in the northeast corner of the adjacent taxlot (Maplot #361W17600).

Indirect impacts to suitable and occupied habitat located within the critical habitat units adjacent to or in the proximity of the Burrill Lumber and Medford Industrial Park pipe storage yards is possible, and discussed further in the critical habitat section, below.

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where large-flowered woolly meadowfoam occurs on private lands throughout the action area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, where ever they may occur. However, the Pacific Connector pipeline would mitigate for any Project impacts to large-flowered woolly meadowfoam.

**Critical Habitat**

Large-flowered woolly meadowfoam is dependent on vernal pool or ephemeral wetland complexes, including upland hydrological features, that provide enough water for a sufficient length of time in the winter months to allow meadowfoam to germinate, grow, and reproduce. Vernal pool complexes that this species are dependent on have been threatened by residential, urban, and commercial development, agricultural development, road construction and maintenance, aggregate mining, incompatible grazing practices, off-road vehicle use, vandalism, encroachment by nonnative plants, and herbivory by gophers and voles. Such threats can 1) cause damage to the clay pan layer and allow moisture to drain from the vernal pools or wet meadow habitats that the plants depend upon for reproduction and survival, 2) alter hydrology, or 3) introduce nonnative plants that can outcompete and displace native plant species and may inhibit successful germination of seeds (FWS, 2010e). To protect biological and physical features the meadowfoam depends on, FWS (2010e) has designated eight critical habitat units for this species, of which two units (RV6 and RV8) are within the vicinity of five proposed storage yards in Jackson County, Oregon.

Three of the designated critical habitat subunits, RV6A, RV6B, and RV6C are adjacent to Burrill Lumber and Medford Industrial Park pipe storage yards. Although designated critical habitat lies adjacent to the proposed pipe storage yards, no direct impacts from the proposed action are anticipated since equipment and pipe storage would not occur near or on pools or wetlands located in the critical habitat subunits, nor would traffic to and from the pipe storage yards drive near or on pools within the critical habitat units. Additionally, nine plant sites previously located in areas proposed as critical habitat units RV6B and RV6C are at least 200 feet from the proposed storage yards (Friedman, 2006), so no direct impact to those plant sites are expected. Another subunit, RV6D is located approximately 900 feet north of Burrill Lumber pipe storage yard where survey efforts in 2007 located large-flowered woolly meadowfoam. Previous surveys had also documented plant sites north of this storage yard. Direct effects to critical habitat subunit RV6D are not expected.

Possible indirect effects to the designated critical habitat units in the vicinity of the six pipe storage yards may occur as a result of increased road use to access the pipe storage yards that are adjacent to the critical habitat units (Avenues C, F, G, and Antelope and Agate Roads) and use of Medford Industrial Park pipe storage yard that is directly adjacent to critical habitat subunit RV6B. Increased road use and the associated dust created might impact large-flowered woolly meadowfoam critical habitat as dust settles, affecting associated vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, and temperature). Primary constituent element 1 specifies that at least 20 acres are essential for intact hydrology. A circle with an area of 20 acres has a radius of 527 feet. Indirect impact to critical habitat units adjacent to pipe storage yards may be expected by actions affecting hydrology at least 527 feet away. Use of the Medford Industrial Park yard that includes ground disturbance such as soil compaction by heavy machinery may alter hydrology in vernal pools in critical habitat unit RV6B, possibly affecting the frequency or amount of water in adjacent vernal pools, or altering the upland hydrology upon which vernal pools and associated vegetation are dependent. Additionally, use of the roads adjacent to the critical habitat units and the pipe storage yards, themselves, may increase the introduction of non-native, weedy species. Primary constituent element 4 specifies that no or negligible presence of competitive nonnative invasive plant species be present for the continued survival and recovery of large-flowered woolly meadowfoam.

Critical habitat unit RV8 is located greater than 1.4 miles from proposed pipe storage yards in Jackson County. The project is not expected to directly or indirectly affect this critical habitat unit.

Applying conservation measures identified below, the use/alteration/restoration of pipe storage yards should not result in modifications in the timing, duration, magnitude, or quality of hydrological connections to an off-site vernal pool and/or federally-listed vernal-pool obligate species. Additionally, measures taken to minimize the introduction and spread of noxious weeds outlined in the ECRP and Project's compensatory mitigation plan would ensure that competition from nonnative species in adjacent critical habitat units remains negligible.

#### 4.7.3.4 Conservation Measures

Pacific Connector would not use the 65-acre taxlot (Maplot #361W17600) which was surveyed adjacent to the Burrill Lumber Yard and contains five acres of high quality and one acre of low quality vernal pool habitat where large-flowered woolly meadowfoam plants were identified during survey efforts.

Once Pacific Connector has determined if Oregon Opportunities and Avenue F and 11th Street pipe storage yards would be used for storage of pipe for the Pacific Connector pipeline and is granted permission to survey those yards through the FERC Certificate process, surveys for large-flowered woolly meadowfoam will be conducted within the 1.9 acres of potential low quality vernal pool habitat. Pacific Connector would not use portions of those proposed pipe storage yards if large-flowered woolly meadowfoam plants or highly suitable habitat is identified, similar to actions taken for the pipe storage yards no longer considered (the 65-acre property adjacent to Burrill Lumber yard).

Pacific Connector would implement proper sedimentation control barriers (FWS 2005d) to minimize potential impacts to identified large-flowered woolly meadowfoam plants and highly suitable habitat. Additional mitigation measures for large-flowered woolly meadowfoam, if identified, are addressed through the Compensatory Mitigation Plan. Such measures could include application of Integrated Weed Management to control existing noxious weeds and prevent new infestations within and adjacent to occupied and potential habitats similar to that recommended for Kincaid's lupine (BLM et al. 2008). Integrated Weed Management in those areas supporting large-flowered woolly meadowfoam could include (BLM et al. 2008, page 13):

- Hand pulling and cutting noxious weeds.
- Mechanical treatments such as mowing prior to seed development.
- Application of an appropriate herbicide treatment for noxious weeds using application methods during the correct phonological periods and using pertinent Best Management Practices to avoid potential effects to large-flowered woolly meadowfoam.
- Cleaning all mechanical equipment and inspecting to insure no noxious weed plant parts are present prior to equipment use within or proximate to large-flowered woolly meadowfoam habitat.
- Flaming with propane burners or hot water treatment of herbaceous noxious weeds.
- Planting desirable grasses, forbs and shrubs to prevent invasion of noxious weeds and invasive non-native species, however the yards would be return to their previous industrial use after temporary use by Pacific Connector.

#### 4.7.3.5 Determination of Effects

**Listed Species**

The Project **may affect** large-flowered woolly meadowfoam because:

- Suitable habitat may be available within the analysis area in 4.9 unsurveyed acres identified as potential low quality vernal pool habitat.

The Project is **likely to adversely affect** large-flowered woolly meadowfoam because

- Use of the Medford Industrial Park Yard, even if it does not support the species, potentially could indirectly affect large-flowered woolly meadowfoam and vernal pools if they are 527 feet away, possibly in proposed critical habitat, since intact hydrologic connections between the yard and vernal pools might be impacted by additional soil compaction by heavy machinery.

**Critical Habitat**

The Project **may affect** designated critical habitat for large-flowered woolly meadowfoam because:

- The project occurs adjacent to large-flowered woolly meadowfoam critical habitat.
- The project may result in habitat impacts within adjacent critical habitat units.

A **likely to adversely affect** determination is warranted for large-flowered woolly meadowfoam critical habitat because:

- The proposed action could potentially adversely modify habitat areas at least 527 feet away that provide sufficient buffer protection from adjacent development and weed sources, continuous nonfragmented habitat and intact hydrology (PCE 1 and 4). Effects from surface disturbances and/or soil compaction by heavy machinery within the

Medford industrial Park Yard would be at least 527 feet away from critical habitat unit RV6B.

### 4.7.4 Cook's Lomatium

#### 4.7.4.1 Species Account and Critical Habitat

**Status**

Cook's lomatium was listed as endangered on November 7, 2002 under the authority of the Endangered Species Act. A recovery plan was developed for vernal pool species within the Rogue River Valley that are federally listed or have federal species of concern designation, including Cook's lomatium.

**Threats**

A major factor in FWS listing Cook's lomatium was the present or threatened destruction, modification, or curtailment of its habitat and range. Due to recent rapid population increases in the region, the primary threats to habitat and range are industrial, commercial, and residential development and their residual road and utility construction and maintenance. These important residual impacts include mowing, herbicide use, firebreak construction, and hydrologic alteration (mostly for agriculture), and some mining. FWS also found that competition from introduced grass species and grazing can reduce or eliminate populations (FWS, 2002d).

Vandalism, in the form of intentional disregard or dismantling of signage or fencing intended to protect certain wetland areas from unauthorized ORV use, and subsequent damage resulting from that use, has resulted in negative effects on the hydrology of the habitat for Cook's lomatium (for example, by altering the surface hydrology, resulting in excess or a lack of hydrology in otherwise suitable habitat).

The effect of grazing on suitable habitat depends on how the grazing is managed. There are various reports showing how grazing practices can positively or negatively affect native plant species' richness (Marty 2005). Marty's (2005) study indicates that wet season grazing resulted in a decrease of native forb species at vernal pool edge habitat, but year-round grazing actually improved species' richness.

Although disease (fungus) and herbivory have been identified as potential problems, no data other than casual observations exist to suggest that these factors pose a substantial threat to the species at this point in time (FWS, 2012a).

Because of the continuing population and development pressures on the limited Cook's lomatium habitat and range, it is presumed that the final rule factors in determining its endangered status remain as significant ongoing threats to the species.

**Species Recovery**

According to the recovery plan, approximately 20 percent of known Cook's lomatium populations occur on designated critical habitat for the vernal pool fairy shrimp. Three core areas occur in the Rogue River Valley Recovery Unit and 13 core areas occur in the Illinois Valley Recovery Unit. The two units are geographically distinct, and it is thought that the populations have genetically adapted to each habitat. At least 95 percent of suitable vernal pool and wet meadow habitat acreage within each Priority 1 core area and 85 percent within one Priority 2 core area in would be required for downlisting (FWS 2006g).

The recovery plan addresses large-flowered woolly meadowfoam, Cook's lomatium, and vernal pool fairy shrimp as well as six plant species of concern and the hairy water flea. Delisting criteria included in the 2012 recovery plan specific to Cook's lomatium include:

- At least 33 of 36 occurrences for Cook's lomatium (approximately 95 percent of documented/extant occurrences) should be protected in conservationoriented ownership (i.e., land that is formally secured from habitat lossand degradation by way of conservation easements, formal agreements, conservation banks, or public or conservation group ownership). For occurrences that have become extirpated, reintroduced or introduced populations may be substituted. Introduced or newly discovered populations outside of currently known core areas may be substituted if the Service deems them equivalent in their contribution to recovery.
- At least 95 percent of suitable vernal pool habitat acreage within each Priority 1 core area for the species and at least 90 percent of suitable vernal pool habitat acreage within each Priority 2 core area for the species has been protected from development. All suitable habitat must include soils and hydrology that support the plant species.
- Conservation oriented management plans for each protected core area are developed to guide protection and conservation following establishment of protected status such as a conservation easement or transfer of ownership to land trusts or government entities. Each management plan should be operational as soon as possible, as funding and staff time allow.
- Additional species occurrences identified through future site assessments, GIS, other analyses, or status surveys, and that are determined essential to recovery, are protected. Status surveys, 5-year status reviews, and population monitoring show achievement of self-sustaining species populations as confirmed through species monitoring and status surveys in each protected occurrence.
- Seeds from each core area of the two species are in storage as insurance against the risk of extirpations and to ensure that genetic lines are preserved. Seed banking is also necessary in order to complete the reintroductions or introductions that can contribute to meeting recovery criteria.

**Life History, Habitat Requirements, and Distribution**

Cook's lomatium is a small perennial in the parsley family. Its range is on seasonally wet soils limited to two areas: 1) along vernal pools in the Agate Desert area of the Rogue River Valley, Jackson County, and 2) in alluvial floodplains within the Illinois River Valley area near Cave Junction, Josephine County. The Jackson County populations occur in vernal pool habitats within a 20,510-acre landform known as the Agate Desert. Located on the floor of the Rogue River basin north of Medford, the Agate Desert is characterized by shallow, Agate-Winlow complex soils, a relative lack of trees, sparse prairie vegetation, and agates commonly found on the soil surface. Fire may maintain suitable habitat because shrubs such as manzanita and scotch broom compete for sun and space in the Illinois Valley and an historical fire regime is thought to have prevented such shrubs from encroaching on Cook's lomatium habitat (FWS, 2006g).

Plants in the Agate Desert are found on the margins and bottoms of vernal pools with standing water from December to April or May. The plant flowers from late March to May and is pollinated entirely by insects. Each flowering stalk produces either primarily male or female flower clusters (FWS 2006g). In the Rogue River Valley, Cook's lomatium is found in the same vernal pool habitats as the large-flowered woolly meadowfoam and the vernal pool fairy shrimp.

The Josephine County populations occur on seasonally wet soils in the Illinois Valley. These populations are found in deep clay loam soils, in open wet meadows and along roadsides adjacent to meadows and oak woodlands. These seasonally wet areas are similar to the vernal pools of the Agate Desert, but lack that region's distinctive mound and swale topography. The Illinois Valley soils are partially derived from serpentine formations that occur on surrounding slopes and hilltops.

**Population Status**

In the Rogue River Valley, which is crossed by the proposed Pacific Connector pipeline area, the Cook's lomatium is estimated at 34,000 plants in 13 populations (FWS 2006g, FWS, 2011, FWS, 2012a).

**Critical Habitat**

Critical habitat for Cook's lomatium was designated on July 21, 2010, including three critical habitat units in Jackson County, totaling 924 hectares (2,282 acres), and 13 critical habitat units in Josephine County, totaling 1,621 hectares (4,007 acres) (FWS, 2010e). The proposed Project occurs within and adjacent to the Agate Desert complex; therefore discussion will focus on this geographic area.

When determining areas for critical habitat for the Cook's lomatium in the Agate Desert, FWS focused on the biological or physical primary constituent elements that are essential to the conservation of the species. The primary constituent elements for Cook's lomatium critical habitat include:

1) Vernal pools or ephemeral wetlands and the adjacent upland margins of these depressions that hold water for a sufficient length of time to sustain Cook's lomatium, growth, and reproduction, between elevations of 1,256 to 1,600 feet, a minimum of 20 acres, and associated with specific dominant native plants (FWS, 2010e).
2) The hydrologically and ecologically functional system of streams, slopes, and wooded systems that surround and maintain seasonally wet alluvial meadows underlain by relatively undisturbed ultramafic soils within the greater watershed.
3) Silt, loam, and clay soils that are of ultramafic and nonultramafic alluvial origin, with a 0 to 40 percent slope, classified as Abegg gravelly loam, Brockman clay loam, Copsey clay. Cornutt–Dubakel complex, Dumps, Eightlar extremely stony clay, Evans loam, Foehlin gravelly loam, Josephine gravelly loam, Kerby loam, Newberg fine sandy loam, Pearsoll–Rock outcrop complex, Pollard loam, Riverwash, Speaker–Josephine gravelly loam, Takilma cobbly loam, or Takilma Variant extremely cobbly loam.
4) No or negligible presence of competitive, nonnative, invasive plant species.

Sixteen critical habitat units have been designated for the Cook's lomatium in Jackson and Josephine Counties, of which two units (White City and Whetstone Creek) are shared by the designated critical habitat for large-flowered woolly meadowfoam (FWS, 2010e - see above). Within the vicinity of White City, Oregon, where five proposed pipe storage yards for the PCGP Project are located, critical habitat units RV6 and RV8 have been designated.

### 4.7.4.2 Environmental Baseline

**Analysis Area**

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. The botanical analysis area also includes all TEWAs, rock source and disposal sites, and proposed storage yards that have potential for listed plant species. That area corresponds to areas that were surveyed for sensitive and listed plant species in 2007 and 2008. See Section 4.7.1.2 The botanical analysis area also applies to known or potential habitats for endemic vernal pool obligate species. Effects by the Project to vernal pool obligates could extend 200 feet from the perimeter of five proposed pipeyard storage areas that are located within the Vernal Pool Complex – Agate Desert, Jackson County, Oregon and shown in figure 4.6-1 under Vernal Pool Fairy Shrimp, above.

**Species Presence**

Multiple locations of Cook's lomatium have been documented in the Agate Desert, in and around White City, Jackson County. The closest population to theproposed pipeline right-of-of way is 10.3 miles to the west of MP 145.7 (ORBIC, 2012). However, five proposed pipe storage yards occur within the Agate Desert and near vernal pool habitat. Several patches of Cook's lomatium have been documented in Ken Denman State Game Management Reserve and Agate Desert Preserve, 0.37 mile south of proposed pipe storage yard Oregon Opportunities and 0.26 mile south of the proposed Avenue C and 7$^{th}$ Street yard (Friedman 2006) (see figure 4.6-1). The landscape between the proposed yards and Cook's lomatium locations is now developed with multiple industrial sites on both sides of Avenue C, Antelope Road, and Avenue A, all of which intervene.

**Surveyed Habitat**

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for Cook's lomatium within the botanical analysis area, including existing roads identified for access to the construction right-of-way, and associated impact areas like pipeyards. Aerial photographs (summer 2005) and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for Cook's lomatium. The same methods were used to determine potential suitable habitat coinciding with new realignments of the project corridor.

A total of 228.7 acres have been identified as potential suitable habitat requiring surveys within the proposed pipe storage yards (see table 4.7.4-1) for which access was allowed to survey 226.8 acres. Of the 226.8 acres of potential habitat that was surveyed, 118.0 acres were considered suitable habitat for Cook's lomatium. Habitat found to be "suitable" in the surveys included areas with some of the characteristics detailed in the Life History, Habitat Requirements, and Distribution section above (SBS, 2008a).

**Table 4.7.4-1**

**Summary of Potential Suitable Cook's Lomatium within Pipe Storage Yards**

| **Survey Area Type and Years Surveyed** | **FEIS ROW/ Pipe Yards Area (acres)** |
|---|---|
| **Area Identified for Survey** | 228.7 |
| **Area Surveyed to Protocol** | |
| 2007 | 117.5 |
| 2008 | 92.0 |
| **Visual Survey Only** | 17.3 |
| **Total** | **226.8** |
| **Area of Confirmed Potential Habitat** | |
| 2007 | 23.3 |
| 2008 | 92.0 |
| **Visual Survey Only** | 2.7 |
| **Total** | **118.0** |
| **Area not Surveyed (access denied)** | **1.9** |

<u>Construction Right-of Way.</u>

Surveys were conducted along the proposed pipeline near MP 145.3 where Agate-Winlow soils occur, even though this habitat is outside the range of the species. No Cook's lomatium plants were documented.

<u>Jackson County Pipe Yards</u>

SBS conducted surveys for Cook's lomatium at four of the six potential pipe storage yards where survey permission was granted: Burrill Lumber, Rogue Aggregates, Avenue C and 7th Street/Elite Cabinet & Doors and Medford Industrial Park (SBS, 2008a). No plants were located within the four proposed pipe storage yards, however there were 24 acres of suitable vernal pool habitat located on the Avenue C and 7th Street/Elite Cabinet & Doors Yard, including disturbed seasonally saturated or seasonal wetland habitat that has been filled and graded in the past (SBS, 2008a).

One large lot, a 65-acre taxlot (Maplot #361W17600) adjacent to the proposed 64.1-acre Burrill Lumber Yard, was surveyed for Cook's lomatium and found to contain five acres of high quality (and one acre of low quality vernal pool habitat over 900 feet from the proposed Burrill Lumber Yard). Two other proposed yards, Avenue F and 11th Street yard and Oregon Opportunities yard have not been surveyed due to landowner denial. Initial reviews of habitat via aerial photography and "drive-by" have identified approximately 1.9 acres of potential low quality Cook's lomatium vernal habitat on the margins of the Avenue F and 11th Street yard. No habitat within the potential Oregon Opportunities yard were identified during the visual reconnaissance. At the present, the expectation is that surveys would confirm that the habitat would not be suitable for Cook's lomatiun.

Suitable and occupied Cook's lomatium habitat also exists within proposed critical habitat subunits near or adjacent to proposed pipe storage yards in Jackson County (see critical habitat discussion, below).

**Critical Habitat**

Two of the 16 designated critical habitat units for Cook's lomatium are within the vicinity of six proposed pipe storage yards: RV6, which consists of four subunits identified as habitat for lomatium and is approximately 1,503 acres, and RV8 that is approximately 896 acres, of which both consist of intact vernal pool-mounded prairie and swale habitats (FWS, 2009c). One of four RV6 subunits – RV6A – is near or adjacent to proposed yards, whereas RV8 is located between proposed pipe storage yard Rogue Aggregates and the other five pipe storage yards, over 1.4 miles from the closest pipe storage yard. Designated RV6A subunit and RV8 unit coincide with designated critical habitat for vernal pool fairy shrimp: the southern and western portion of VERFS 3B and VERFS 3C.

#### 4.7.4.3 Effects by the Proposed Action

**Direct and Indirect Effects**

Possible direct effects to Cook's lomatium include possible disturbance to pools from driving on or storing equipment or pipes near or on pools or wetlands associated with this species. In 2007 and 2008, surveys were conducted on 226.8 acres of potentially suitable Cook's lomatium habitat at four pipe storage yards in Jackson County (Burrill Lumber, Medford Industrial Park, Avenue C and 7$^{th}$ Street/Elite Cabinet & Doors, and Rogue Aggregates), and along a portion of the proposed centerline (between MPs 145.3 and 145.5) outside of the known range of the plant but within appropriate Agate-Winlo soils. Approximately 118.0 acres of habitat surveyed was considered suitable habitat for Cook's lomatium within Medford Industrial Park pipe storage yard and the 200-foot survey buffer adjacent to the construction right-of-way between MPs 145.3 and 145.5. Direct impact to suitable habitat identified within Medford Industrial Park is possible. No Cook's lomatium plants were located; therefore, no direct effects to Cook's lomatium plants are expected as a result of the proposed action.

Indirect effects to Cook's lomatium plants and their habitat could occur with increased road use to access the pipe storage yards that are adjacent or in the vicinity of suitable or potentially suitable habitat. Increased road use and the associated dust created might impact vernal pool habitat as dust settles, affecting vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, temperature). Project use of pipe storage yards (i.e., potential soil compaction by heavy equipment use) adjacent to, or in the vicinity of suitable or potentially suitable habitat, may indirectly affect hydrology upon which vernal pools and associated vegetation are dependent. Indirect effects to hydrology could be expected if such disturbances to ground and/or soils occurred within 527 feet of suitable or potentially suitable vernal pool habitat. The distance of potential effects is based on FWS' (2010e) estimate that at least 20 acres of habitat surrounding a vernal pool site is considered essential for intact hydrology (see primary constituent element discussion for large-flowered woolly meadowfoam and Cook's lomatium – FWS, 2010; 527 feet is the radius of a circle with an area of 20-acre). Such effects could again include altering hydrologic processes, such as runoff patterns as a result of soil compaction, as well as increased seeding of non-native invasive plant species (PCEs 1 and 4). However, any potential compaction that may occur at the proposed yards would likely be insignificant because of the previous industrial use, soil grading and compaction, and implementation of the Noxious Weed Control Plan (section 12.0) provided in the ECRP (see appendix F) would reduce spread of noxious species. .

Surveys for Cook's lomatium have not been conducted on 1.9 acres of potential suitable habitat identified at the Avenue F and 11th Street proposed yard site that had survey access denied. Pacific Connector would avoid portions of those yards if surveys identify suitable Cook's lomatium habitat or plants. Therefore, no direct impact to unsurveyed habitat or unidentified plants is expected. However, indirect impacts may be possible.

Potential impact to 119.9 acres (118.0 acres known, 1.9 acres unsurveyed) of Cook's lomatium suitable habitat from use of the proposed storage yards and pipeline construction is not likely to affect the recovery of the species, because the area only accounts for 0.5 percent of Cook's lomatium sub-range (20,510 acres, total).

Indirect impacts to suitable habitat located within the critical habitat subunit RV6A adjacent to or in proximity of Medford Industrial Park pipe storage yard is possible and discussed further in the critical habitat section, below.

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where Cook's lomatium occurs on private lands throughout the action area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, where ever they may occur. However, the Pacific Connector pipeline would mitigate for any Project impacts to Cook's lomatium.

**Critical Habitat**

Cook's lomatium within the Agate Desert complex is dependent on vernal pool or ephemeral wetland complexes, including upland hydrological features, that provide enough water for a sufficient length of time in the winter months to allow lomatium to germinate, grow, and reproduce. Vernal pool complexes that this species are dependent on have been threatened by residential, urban, and commercial development, agricultural development, road construction and maintenance, aggregate mining, incompatible grazing practices, off-road vehicle use, vandalism, encroachment by nonnative plants, and herbivory by gophers and voles. Such threats can 1) cause damage to the clay pan layer and allow moisture to drain from the vernal pools or wet meadow habitats that the plants depend upon for reproduction and survival, 2) alter hydrology, or 3) introduce nonnative plants that can outcompete and displace native plant species and may inhibit successful germination of seeds (FWS, 2009d). To protect biological and physical features Cook's lomatium depends on, FWS (2010e) has designated 16 critical habitat units for this species in Jackson and Josephine Counties, of which two units (RV6 and RV8) are within the vicinity of five proposed storage yards in Jackson County, Oregon.

A portion of one of the critical habitat subunits, RV6A is adjacent to the western edge of Medford Industrial Park pipe storage yard. Although critical habitat lies adjacent to the proposed pipe storage yard, no direct impacts from the proposed action are anticipated since equipment and pipe storage would not occur near or on pools or wetlands located in the critical habitat subunit, nor would traffic to and from the pipe storage yards drive near or on pools within the critical habitat unit. Several patches of Cook's lomatium have been previously documented in Denman Wildlife Management Area and Agate Desert Preserve in critical habitat subunit RV6A, but are located in the southern portion of the critical habitat subunit at least 0.25 mile south of Oregon Opportunities pipe storage yard (Friedman, 2006), so no direct impact to those plant sites are expected. Possible indirect effects to the critical habitat units in the vicinity of the five pipe storage yards may occur as a result of increased road use to access the pipe storage yards that are adjacent or within the vicinity of the critical habitat units (Avenues C, F, G, and Antelope and Agate Roads). Increased road use and the associated dust created might impact Cook's lomatium critical habitat as dust settles, affecting associated vegetation and vernal pool physical or chemical properties (pH, water quality, turbidity, sedimentation, and temperature). Primary constituent element 1 specifies that at least 20 acres are essential for intact hydrology. A circle with an area of 20 acres will have a radius of 527 feet. Indirect impact to critical habitat units adjacent to pipe storage yards may be expected by actions affecting hydrology at least 527 feet away. Use of the Medford Industrial Park yard that includes ground disturbance such as soil compaction by heavy machinery may alter hydrology in vernal pools in critical habitat unit RV6A, possibly affecting the frequency or amount of water in adjacent vernal pools, or altering the upland hydrology upon which vernal pools and associated vegetation are dependent. Indirect effects to hydrology could be expected if such disturbances to ground and/or soils occurred within 527 feet of suitable or potentially suitable vernal pool habitat. Additionally, use of the roads adjacent to the critical habitat units and the pipe storage yards, themselves, may increase the introduction of non-native, weedy species. Primary constituent element 4 specifies that no or negligible presence of competitive nonnative invasive plant species be present for the continued survival and recovery of Cook's lomatium.

Critical habitat unit RV8 is located greater than 1.5 miles from the pipe storage yards in Jackson County. The project is not expected to directly or indirectly affect this critical habitat unit. Applying conservation measures identified below (section 4.7.5.4) and use/alteration/restoration of pipe storage yards should not result in modifications in the timing, duration, magnitude, or quality of hydrological connections to an off-site vernal pool and/or federally-listed vernal-pool obligate species. Additionally, measures taken to minimize the introduction and spread of noxious weeds outlined in the ECRP and Project's compensatory mitigation plan would ensure that competition from nonnative species in adjacent critical habitat units remains negligible.

#### 4.7.4.4 Conservation Measures

Pacific Connector would not use the 65-acre taxlot (Maplot #361W17600) which was surveyed adjacent to the Burrill Lumber Yard and contains five acres of high quality and one acre of low quality vernal pool habitat.

Once Pacific Connector has determined if Oregon Opportunities and Avenue F and 11th Street pipe storage yards would be used for storage of pipe for the Pacific Connector pipeline and is granted permission to survey those yards through the FERC Certificate process, surveys for Cook's lomatium will be conducted within the 1.9 acres of potential low quality vernal pool habitat. Pacific Connector would not use portions of those proposed pipe storage yards if Cook's lomatium plants or highly suitable habitat is identified, similar to actions taken for the pipe storage yards no longer considered for pipe storage use (the 65-acre property adjacent to Burrill Lumber yard).

Pacific Connector would implement proper sedimentation control barriers (FWS 2005d) to minimize potential impacts to identified Cook's lomatium plants and highly suitable habitat. Additional mitigation measures for Cook's lomatium, if identified, are addressed through the Project's Compensatory Mitigation Plan. Such measures could include application of Integrated Weed Management to control existing noxious weeds and prevent new infestations within and adjacent to occupied and potential habitat similar to that recommended for Kincaid's lupine (BLM et al., 2008). Integrated Weed Management in those areas supporting Cook's lomatium could include (BLM et al., 2008, page 13):

- Hand pulling and cutting noxious weeds.
- Mechanical treatments such as mowing prior to seed development.
- Application of an appropriate herbicide treatment for noxious weeds using application methods during the correct phonological periods and using pertinent Best Management Practices to avoid potential effects to Cook's lomatium.
- Clean all mechanical equipment and inspect to insure no noxious weed plant parts are present prior to equipment use within or proximate to Cook's lomatium habitat.
- Flaming with propane burners or hot water treatment of herbaceous noxious weeds.
- Planting desirable grasses, forbs and shrubs to prevent invasion of noxious weeds and invasive non-native species; however the yards would be return to their previous industrial use after temporary use by Pacific Connector.

#### 4.7.4.5 Determination of Effects

**Listed Species**

The Project **may affect** Cook's lomatium because:

- Potential suitable habitat is available within the analysis area.

The Project is **not likely to adversely affect** Cook's lomatium because:

- Surveyed suitable habitat at proposed pipe storage yards in Jackson County and along the proposed pipeline did not document Cook's lomatium.
- Pacific Connector would avoid using portions of proposed pipe storage yards with high-quality vernal pool habitat.
- Effects to suitable habitat by the proposed action are likely to be insignificant (impact does not reach a level where take occurs) to the point where no meaningful measurement, detection, or evaluation of impact would be possible.
- Sedimentation barriers would be used, as appropriate, to prevent run-off and changes in hydrology.
- Conservation measures have been developed to avoid or minimize impacts to future plants identified during surveys prior to pipeline construction.
- Known sites within the vicinity of the project are further than 0.25 miles from proposed pipe storage yards.

Unsurveyed habitat is low quality vernal pool habitat located over 0.25 miles from known sites with no apparent hydrologic connectivity.

**Critical Habitat**

The Project **may affect** designated critical habitat for Cook's lomatium:

- The project occurs adjacent to Cook's lomatium critical habitat.
- The project may result in habitat impacts within adjacent critical habitat units.

Project components are **not likely to adversely** affect Cook's lomatium critical habitat because:

- The proposed action is not expected to adversely modify habitat areas that provide buffer protection from adjacent development and weed sources, continuous non-fragmented habitat, and intact hydrology (PCE 1 and 4). Effects from surface disturbances and/or soil compaction by heavy machinery within the Medford Industrial park Yard are already present, and would be at least 527 feet away from critical habitat unit RV6A.

### 4.7.5 Kincaid's Lupine

#### 4.7.5.1 Species Account and Critical Habitat

**Status**

Kincaid's lupine was listed as threatened on January 25, 2000 (FWS, 2000b). A recovery outline for the species was released in 2006 (FWS 2006h) a draft recovery plan was published in August 2008 (FWS, 2008e), a five year review was completed in 2010 (FWS, 2010c), and a final recovery plan was published in 2010 (FWS, 2010d).

**Threats**

The three major threats to Kincaid's lupine populations are habitat loss, competition from non-native plants, and elimination of historical disturbance regimes (Wilson et al., 2003, FWS, 2010b). The present or threatened destruction, modification, or curtailment of the Kincaid's lupine habitat and range is a major factor for listing in the final rule. Human alteration of the plant's native prairie in Oregon's Willamette Valley has destroyed over 99 percent of its habitat (FWS 2000c). At the time of listing there were 88 remnants of the native prairie habitat, with Kincaid's lupine occurring at 54 sites. Eighty percent of this remaining prairie habitat is rapidly disappearing because of agricultural practices, development activities, forestry practices, grazing, roadside maintenance, and commercial Christmas tree farming (FWS, 2000c). The remaining Kincaid's lupine populations in prairie habitat are essentially relegated to small, isolated patches of habitat. Habitat loss is likely to continue as private lands are developed.

Most prairie sites require frequent disturbances to hold back the natural succession of trees and shrubs. Before settlement by Euro-Americans, the regular occurrence of fire maintained the open prairie habitats essential to Kincaid's lupine. The loss of a regular disturbance regime, primarily fire, has resulted in the decline of prairie habitats through succession by native trees and shrubs, and has allowed the establishment of numerous non-native grasses and forbs. At the time of federal listing, 83 percent of upland prairie Kincaid's lupine sites were estimated to be succeeding to forest (FWS, 2000c; FWS, 2008e).

In Douglas County, Kincaid's lupine has been found in open woodlands and meadows, often near roads, and associated with Pacific madrone, incense cedar and Douglas-fir with open canopies (FWS, 2008e). Those populations appear to tolerate more shade than populations in the Willamette Valley (BLM et al., 2008). Kincaid's lupine habitat in forested sites is subject to similar alterations from natural succession: fire suppression activities result in increased canopy closure and cover of woody species that contribute to the decline in Kincaid's lupine forested habitat (FWS, 2006i).

The Willamette Valley continues to be an important population center for urban, rural, transportation, commercial and agricultural activities. Ongoing threats to Kincaid's lupine habitat and range presumably mirror the factors listed in FWS's 2000 final rule. These ongoing threats include: further habitat loss or fragmentation due to agriculture, development, and forest practices; herbicide use; disease and predation; invasion of prairie habitats by non-native species; encroachment of trees and shrubs into prairie habitats; elimination of natural disturbance regimes; inbreeding as a result of isolated and fragmented populations (FWS 2008e); and habitat vandalism, which is an uncommon occurrence, but could further reduce habitat function and destroy individual plants (FWS, 2008e, FWS 2010c). Changes in the natural hydrology of a site, such as by ditching or draining a wet prairie, can alter the annual duration of soil saturation, which in turn affects the species composition of the site. Hydrological alterations have been a pervasive factor in the reduction of native species in the Willamette Valley (Finley, 1995; FWS, 2010c).

**Species Recovery**

A final recovery plan for the prairie species of western Oregon, including Kincaid's lupine, was published on January 1, 2010 and includes recovery objectives to delist Kincaid's lupine (FWS, 2010d). Ten recovery zones were established for Kincaid's lupine, of which Douglas County is considered its own recovery zone. Since the clonal or clumping growth pattern of Kincaid's lupine creates a challenge for estimating and monitoring number of plants, the recovery plan provides population targets in terms of foliar cover (measure of the area occupied by the plants).

Within Douglas County where the Project is proposed, the Douglas County Recovery Zone has a recovery goal of a minimum of two populations covering at least 5,000 square meters (1.25 acres) and not be separated by more than 2.0 miles (FWS, 2010f). Additionally, monitoring of these populations should show evidence of reproduction by flowering, seed set, or presence of seedlings, and remain stable or increase in size for a period of at least 15 years. Habitat for Kincaid's lupine populations should be managed to provide high-quality habitat that is protected on lands managed by a government agency or private conservation agreement, and is monitored and controlled from threats to the species (FWS, 2010f). Recovery actions for Kincaid's lupine include:

- Evaluate the status of extant populations.
- Manage population sites to minimize woody plant succession and reduce the threat of competition from nonnative plants, including mowing in late summer (August or September) after the plants have become dormant, and elimination of invasive species with careful and appropriate application of herbicides or mechanical control methods.
- Restore connectivity among populations, establishing subpopulations within 2 miles of each other.
- Augment or reintroduce populations and restore habitat to achieve population targets.
- Monitor populations and trends.
- Monitor prairie quality at all population sites.
- Collect and bank seeds.

**Life History, Habitat Requirements, and Distribution**

Kincaid's lupine is a long-lived perennial herb inhabiting native prairies and foothills (FWS, 2000c). The plant was historically found from Lewis County, Washington in the north, south to the foothills of Douglas County, Oregon; however, most of the known and historical populations are found in Oregon's Willamette Valley (FWS, 2006i).

In Douglas County, Kincaid's lupine appears to tolerate more shaded conditions, where it occurs at sites with canopy cover of 50 to 80 percent. In contrast to the open prairie habitats of the more northerly populations, tree and shrub species dominate the sites in Douglas County including Douglas-fir, California black oak, Pacific madrone, ponderosa pine, incense cedar, hairy manzanita, and poison oak (FWS, 2006i).

Kincaid's lupine does not appear to actually reproduce (i.e., form new, physiologically independent individuals) except by sexual means. Individual clones can be several centuries old (FWS, 2005e; Kaye, 2008) and become quite large with age, producing many flowering stems. Excavations and morphological patterns suggest that plants 33 feet or more apart can be interconnected by below-ground stems and such clones can exceed 66 feet across. Because of vegetative (clonal) growth pattern it is difficult to distinguish individuals; counting individual "plants" and monitoring the size of populations is challenging. Instead, monitoring agencies have used a grid pattern and counted stems or leaves to assess density rather than attempt to count "individuals."

Flowering typically ranges from April through June. Pollinators include small native bumblebees, solitary bees, and occasionally, European honey bees. Insect pollination appears to be critical for successful seed production. Seeds are dispersed from fruits that open explosively upon drying (FWS, 2006i). Kincaid's lupine is also a host plant for the endangered Fender's blue butterfly (FWS, 2008e).

**Population Status**

Prior to Euro-American settlement, Kincaid's lupine was likely well-distributed throughout the prairies of western Oregon and southwestern Washington. Today, fragmentation, degradation, and elimination of natural prairie habitat has resulted in existing populations that are widely separated by expanses of unsuitable habitat (FWS, 2008d). Most of the known extant populations are found in Oregon's Willamette Valley. At the time of listing, approximately 91 percent (51 of 54 sites) of the occupied sites were on private lands and therefore were considered to be at a higher risk of extirpation (FWS, 2008e). Kincaid's lupine is currently known at about 164 sites, comprising about 246 hectares (608 acres) (FWS, 2010b).

**Critical Habitat**

Almost 600 acres of critical habitat were designated on November 30, 2006 in Benton, Lane, Polk, and Yamhill Counties, Oregon, and Lewis County, Washington (FWS, 2006i). The designation did not include Douglas County where conservation agreements were established to formally document the intent to protect, conserve, and contribute to the recovery by implementing recovery actions for Kincaid's lupine and its habitat (see the subsection below).

The PCEs of critical habitat are: 1) the habitat components that provide early seral upland prairie and oak savanna habitat with a mosaic of low growing grasses, forbs, and spaces to establish seedlings or new vegetative growth, with an absence of dense canopy vegetation providing sunlight for individual and population growth and reproduction; and 2) the presence of insect pollinators with available corridors between lupine patches to allow unrestricted movement of pollinators (FWS, 2006i).

Management activities that could adversely modify critical habitat are those that alter PCEs to an extent that the conservation value for Kincaid's lupine is appreciably reduced (FWS, 2006i).

These activities that may affect critical habitat include, but are not limited to: 1) removal or destruction of prairie habitat supporting Kincaid’s lupine populations by grading, leveling, plowing, mowing, burning, motorized equipment operation, or herbicide spraying; and 2) actions that further isolate or reduce genetic interchange among populations within a unit or between subunits, including road construction and expansion, housing and building development, and infrastructure construction (FWS, 2006i).

Conservation Agreements

Roseburg BLM District, Umpqua National Forest, and FWS completed a programmatic conservation agreement for Kincaid’s lupine in Douglas County, which specifies the following goals (BLM et al., 2006):

1. Maintain stable populations by protecting and restoring habitats.
2. Reduce threats to the species on BLM and USFS lands.
3. Promote larger functioning metapopulations, with increased population size and genetic diversity.
4. Meet the recovery criteria in the Recovery Outline for the species (FWS, 2006i).

A Conservation Agreement was also signed with three private timber companies in Douglas County including Lone Rock Timber Management Company, Roseburg Forest Products and Seneca Jones Timber Company. This Voluntary *Agreement for Kincaid’s Lupine (Lupinus Sulphureus Spp. kincaidii) In Douglas County (2006)* includes reporting guidelines and an agreement for road maintenance and minimizing disturbance along roads. The objective of the Voluntary Agreement is “to promote functioning meta-populations”, including coordinating propagation activities for establishing new sites and extending known populations.

In March 2008, a management plan for Kincaid’s lupine in Douglas County was developed between the Roseburg BLM District, the Umpqua National Forest, and the FWS, addressing the populations and habitat of Kincaid’s lupine on BLM and NFS lands in Douglas County (BLM et al. 2008). Kincaid’s lupine occurs on 14 sites within Douglas County of which nine are on federal lands: eight on BLM land (Roseburg District) and one on the Umpqua National Forest (BLM et al. 2008).

### 4.7.5.2 Environmental Baseline

#### Analysis Area

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. The botanical analysis area also includes all TEWAs, rock source and disposal sites, and proposed storage yards either on federal or state lands or that have potential for listed plant species. That area corresponds to areas that were surveyed for sensitive and listed plant species from 2007 through 2013. See section 4.7.1 Applegate’s Milk-vetch above, for the full botanical analysis area description. Portions of the botanical analysis area that coincide with Kinkaid’ lupine are included in figures 4.7-3, 4.7-4, and 4.7-5.

#### Species Presence

Records obtained from ORBIC (2012) indicate Kincaid’s lupine had been previously located at eleven sites within 2.5 miles of the proposed Pacific Connector pipeline. The three closest sites are: 1) 10 clumps located 1.5 miles northeast of MP 56.0 in 1999 - plants were within a 200 square-foot area but with poor estimated viability, 2) 400 to 4,000 plants within four sites occupying approximately 3 acres located 2.2 miles southwest of MP 96.0 in 2003 with excellent estimated viability, and 3), about 100 to 200 plants in one acre located in 1992 approximately 1.5 miles east of MP 98.9 with fair estimated viability. Herbarium records indicate that one extinct population (1979) occurred near the 1992 documented site, approximately 1.7 miles east of MP 98.9 and 0.25 mile from the other 1992 population.

**Surveyed Habitat**

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for Kincaid's lupine within the botanical analysis area, including existing roads identified for access to the construction right-of-way. Aerial photographs (summer 2005) and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for Kincaid's lupine. The same methods were used to determine potential suitable habitat coinciding with new realignments of the project corridor.

A total of 3,009.3 acres have been identified as potential suitable habitat requiring surveys within the current project alignment and 200-foot botanical analysis area (see table 4.7.5-1). Of this habitat, 2,054.8 acres were permitted survey access (1,102.6 acres within the project area). A total of 151.2 acres of access roads located outside of the ROW and 200-foot botanical buffer were identified for surveys. Surveys have been completed on 134.5 acres of access roads, while no survyes have been conducted on the remaining 16.7 acres due to denied access. All habitat is located within Pacific Connector pipeline MP's 46.91 through 104.10, as well as at proposed storage yards. The potential suitable habitat includes both meadow (typically non-native pasture) and forested upland Kincaid's lupine habitats.

Of the 2,054.8 acres of potential habitat with access allowed for surveys, 954.5 acres (729.3 acres within the project area) were considered suitable habitat for Kincaid's lupine. Habitat suitability was qualitatively assessed based on Kincaid's lupine habitat analysis conducted in Oregon by SBS in 2001. Habitat found to be "suitable" in the surveys included areas with some of the characteristics detailed in the Life History, Habitat Requirements, and Distribution section above (SBS, 2008a).

Approximately 954.5 acres of potentially suitable habitat for this species (512.5 acres within the project area) were denied access by the landowner and would need to be surveyed prior to construction for complete surveys of this eco-region. If the assumption is made that a similar percent of that area is suitable, as documented within the rest of the area surveyed, then approximately 678 acres (71 percent of 955 acres, or 364 acres within the project area) are probably suitable Kincaid's lupine habitat.

| Table 4.7.5-1<br><br>**Summary of Potential Suitable Kincaid's Lupine Habitat within the FEIS-Revised Route and Botanical Analysis Area.** | | | |
|---|---|---|---|
| | **Area (acres) Included** | | |
| **Surveyed Area Type and Years Surveyed** | **FEIS ROW/ Access Roads** | **200-foot Botanical Analysis Area [1] (Outside of ROW)** | **Total** |
| **Area Identified for Survey (Potential Habitat)** | 1,615.1 | 1,394.2 | 3,009.3 |
| **Area Surveyed to Protocol** | | | |
| 2007 | 888.4 | 652.6 | 1,541 |
| 2008 | 30.2 | 3.4 | 33.6 |
| 2010 | 18.4 | 21.1 | 39.5 |
| 2013 | 165.6 | 275.1 | 440.7 |
| **Totals** | **1,102.6** | **952.2** | **2,054.8** |
| **Area of Confirmed Potential Habitat** | | | |
| 2007 | 605.3 | 440.1 | 1,045.4 |
| 2008 | 5.0 | 3.4 | 8.4 |
| 2010 | 9.2 | 2.9 | 12.1 |
| 2013 | 109.8 | 275.1 | 384.9 |
| **Totals** | **729.3** | **721.5** | 1,450.8 |
| **Area not Surveyed (access denied)** | **512.5** | **442.0** | **954.5** |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

### Documented Occurrences

Surveys located three populations in the proposed analysis area (see table 4.7.5-2): two in western and one in eastern Douglas County (also see figures 4.7-3, 4.7-4, and 4.7-5).

| Table 4.7.5-2<br><br>**Summary of Kincaid's Lupine Locations**. | | |
|---|---|---|
| **Milepost** | **Year Located** | **Site Description** |
| 57.84-57.92 | 2007/2008 | Along centerline near MP 57.9; in right-of-way and continuing south of right-of-way at MP 57.85 - 57.90 |
| 59.6 | 2007/2008 | Outside of the construction zone and 200 foot analysis area (location would only affect any new TEWA space in that area). |
| 96.48-96.9 | 2007/2008 | in right-of-way and in access roads south of the right-of-way |

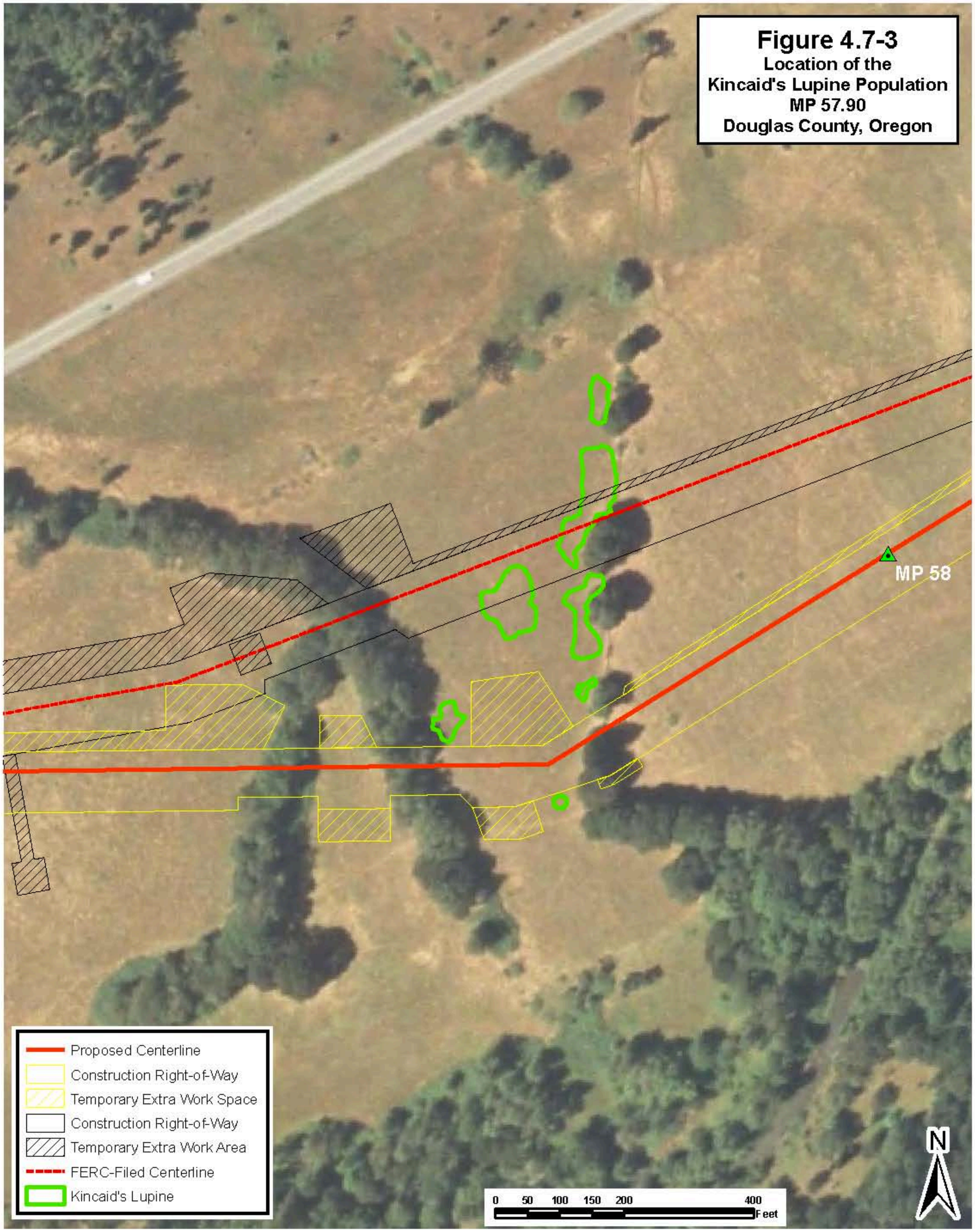


Figure 4.7-3
Location of the
Kincaid's Lupine Population
MP 57.90
Douglas County, Oregon
MP 58
Proposed Centerline
Construction Right-of-Way
Temporary Extra Work Space
Construction Right-of-Way
Temporary Extra Work Area
FERC-Filed Centerline
Kincaid's Lupine
0
50
100
150
200
400
Feet
N

Figure 4.7-4
Location of the
Kincaid's Lupine Population
MP 59.60
Douglas County, Oregon
Proposed Centerline
Construction Right-of-Way
Temporary Extra Work Space
Kincaid's Lupine
0
50
100
150
200
400
Feet
N

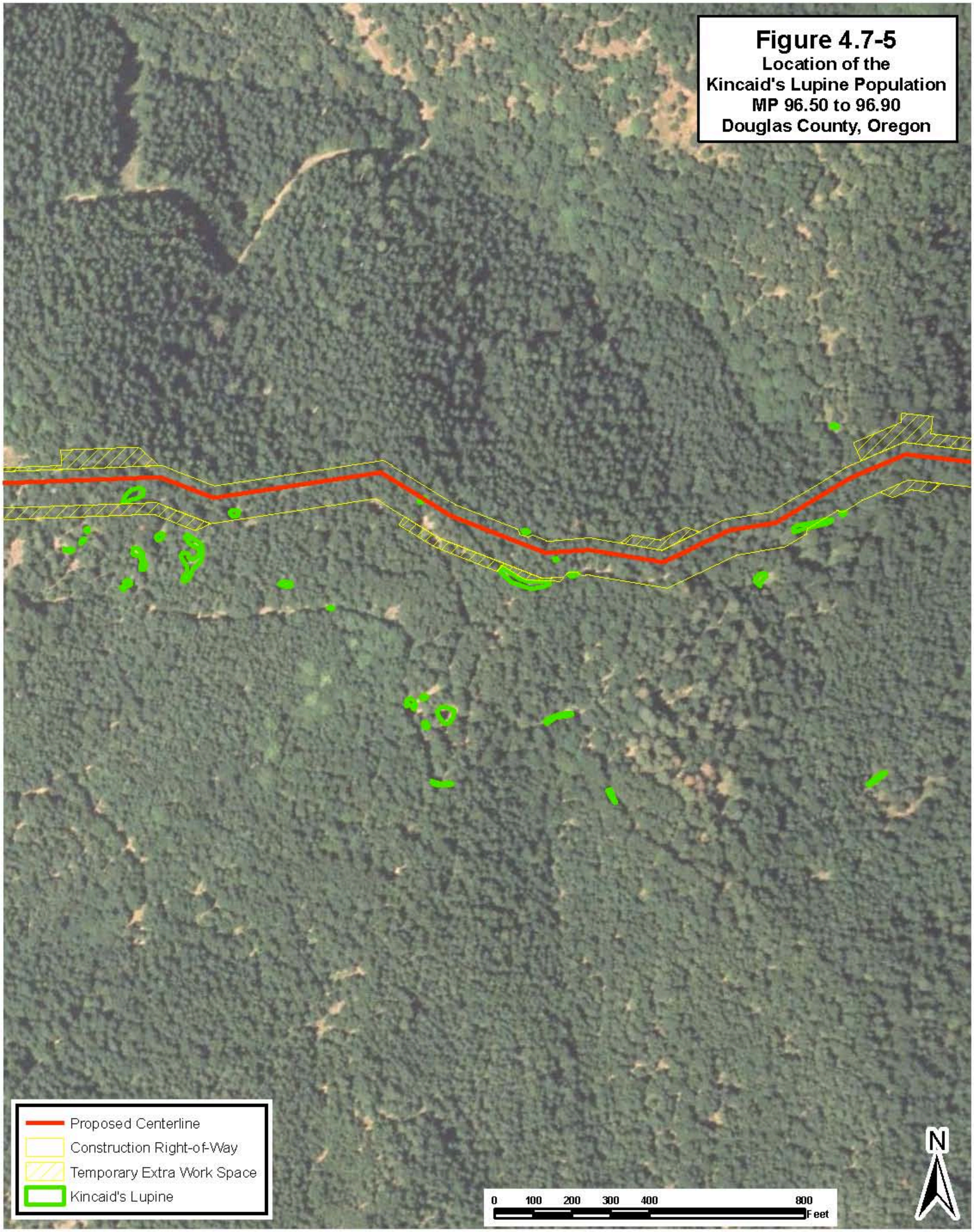


Figure 4.7-5
Location of the
Kincaid's Lupine Population
MP 96.50 to 96.90
Douglas County, Oregon
Proposed Centerline
Construction Right-of-Way
Temporary Extra Work Space
Kincaid's Lupine
0
100
200
300
400
800
Feet
N

The first site in western Douglas County is located within the FERC-filed route between MP 57.84 and MP 57.92 on private land. Approximately 179 plants were found at this site within seven sub-populations covering approximately 0.6 acre of area scattered within an approximately 4 acre area in pasture habitat (approximately 15 percent cover). Subpopulations or patches range in size from 1 to 54 plants and are anywhere from 20 feet to 177 feet from each other. Plant counts were made by considering all stems in close proximity as one plant. This site is approximately 2.1 miles from a known site 1.5 miles northeast of MP 56.0, and approximately 1.6 miles southwest of the second site located during surveys in 2007 near MP 59.60 (figure 4.7-3).

A second site was located on private land approximately 300 feet north of MP 59.60 and approximately 225 feet north of TEWA 59.30-N. McNabb Creek Road, an identified existing access road (EAR 59.62) runs nearby the site, approximately 43 and 85 feet to the south and west. This site includes approximately 66 plants within 2 clumps or subpopulations (clonal groups) covering approximately 0.5 acre scattered in a 2-acre area on a flat grazed pasture (approximately 25 percent cover). This site is approximately 2.7 miles southeast of the known site, north of MP 56.0 and 1.6 miles east of the site with 179 plants that was documented in 2007 near MP 57.84 and 57.92 (figure 4.7-4).

A third Kincaid's lupine site was found between MPs 96.5 and 96.9 and on access roads south of MPs 96.7 to 96.9. The population occurs on private timberland two miles south of the South Fork Umpqua River on a ridgeline east of Stouts Creek. The plants are all located on loam soils in a young mid-seral mixed conifer and hardwood forest. Plants were located in canopy gaps and, less regularly, under closed canopy (mostly under ponderosa pine trees) and in openings along four-wheel drive roads. Approximately 1,083 plants were located within 28 subpopulations or patches scattered within a 20-acre area. In all, plants occurred on an approximate total area of 0.6 acre (approximately 29 percent cover). The 28 patches ranged in size from 1 plant to 258 plants in a 0.4 acre area. This documented site is approximately 2.5 miles northeast and 2.7 miles northwest of previously known sites documented in 2003 and 1992, consecutively (figure 4.7-5).

**Critical Habitat**

The proposed action would not affect any of the PCEs identified because no critical habitat for Kincaid's lupine is present within the analysis area.

### 4.7.5.3 Effects by the Proposed Action

**Direct and Indirect Effects**

The report published on the Biology of Kincaid's lupine, (Wilson et al. 2003) indicates that Kincaid's lupine spreads extensively by physiologically-interdependent clones interspersed across large distances in the population, making it challenging to distinguish genetically distinct individual plants. Any estimates of number of individuals impacted by the proposed action are subject to broad margins of error. Because even broadly separated clones share resources through caudices, removal of stems from the population may destroy other connected members of the plant, increasing the number of plants taken. There is no evidence to date that clones can survive when separated from the remainder of the plant. Therefore, removing any individuals from small populations like those documented during survey efforts, would likely decrease their potential survival and ability to colonize available habitats.

An important related concern is that these populations may consist of significantly fewer genetically distinct plants than estimated, due to clonal growth. Kincaid's lupine depends on sexual reproduction to replace individual plants that may succumb to numerous threats, to augment populations and to spread into suitable habitat. Such out-crossing plants require a large number of genetically distinct individuals as well as adequate pollinators to maintain genetic diversity and avoid negative effects of inbreeding depression, which may already be impacting these small remnant populations.

The three new populations of Kincaid's lupine identified during surveys in 2007 on private lands at MPs 57.84 through 57.92, 59.60, and 96.48 through 96.9 along Pacific Connector's FERC-filed route are too small to meet the minimum viable population size specified in the FWS recovery plan (either by estimated number of plants or by density within a coverage area). The newly found populations, however, may be contributing to other known meta-populations and recovery plan objectives, and removal of these plants may contribute negatively toward recovery.

The population at MP 57.9 totals 0.6 acre within a 4-acre area (15 percent cover) and the population at MP 59.6 is approximately 0.5 acre within a 2-acre area (25 percent cover). Total cover at these population locations is high due to the vigor and age of the plants. These sites are approximately 2.1 to 2.7 miles from an extant site with plants of low vigor near Ten Mile, but far from other known sites, so are unlikely to be part of an eventual meta-population for meeting Recovery Plan goals (FWS 2008e). They do, however, contribute significantly to the "additional" population goals. These sites are unique for Douglas County in that they occupy Valley-Floor pasture/meadow habitats similar to Willamette Valley populations but very different from the other Douglas County populations. As a result, plants identified during survey efforts may be preserving high value genetic information and diversity.

The population near MP 95.6 is an important element in the recognized Stouts Creek-Callahan Ridge meta-population. It is approximately 2.5 miles east/northeast of the large known population cluster on BLM and Roseburg Timber lands at Stouts Creek, and approximately 2.7 miles west/northwest from the population on USFS and private land at Callahan Ridge, and approximately 3.7 miles from the population at Callahan Meadows. It occurs in a central location between these populations thus forming an important genetic link and increases the possibility of developing a successful South Umpqua "meta-population" to further achieve recovery goals. The population consists of 28 patches within an area of 20 acres, occurring in transitory and natural openings in 45-year old forest. The total cumulative area of the patches documented is approximately 0.57 acre (2.9 percent total cover), with the largest patch covering 0.09 acre. This population could be considered quite significant in meeting the goals of the South Umpqua meta-population.

Direct Impacts

Pacific Connector met with several members of the Habitat Quality Subtask Group on July 24, 2008 to discuss impacts to documented plants and get recommendations on how to avoid or minimize impacts (see July 24, 2008 meeting minutes). One of the biggest concerns the group had was fragmenting the population because the patches were located close enough (within 33 feet of each other) that they could be interconnected by below-ground stems. Therefore, Pacific Connector rerouted the proposed pipeline route south of six of the seven patches documented (see figure 4.7-3), completely avoiding all aboveground documented Kincaid's lupine patches. Subpopulation 7 (1 plant) located south of the proposed route is 150 to 190 feet from the other documented sites and is most likely not a part or clone of the other plants and should not be affected by dissecting below-ground stems. No direct impacts to the subpopulations located aboveground at this site are expected.

No direct effects are expected at the second site near MP 59.60 documented north of TEWA 59.30-N because the site is at least 200 feet from proposed pipeline components. Direct impact from use of the existing access road is also not expected.

The third site between MPs 96.5 and 96.9 documented 1,064 plants within 28 subpopulations. A total of 138 plants (within 8 patches) were located within the FERC-filed construction right-of-way and 80 plants (within 3 patches) within the FERC-filed TEWAs and UCSAs, representing approximately 20.5 percent of the discovered population at this site. Because the FERC-filed route is located on a narrow ridgeline, there are no feasible routing alternatives to realign the pipeline to completely avoid this documented population. Therefore, to minimize impacts to this population, Pacific Connector has modified the construction right-of-way and TEWA 96.66-W, avoiding impacts to 61 plants within three subpopulations and partially avoiding plants within a fourth subpopulation by narrowing the construction right-of-way (see figure 4.7-5, revised proposed route). Approximately 157 plants are expected to be directly impacted; however, because of the rhizomatous nature of the plant, more plants may be impacted by translocation of a partial plant clone. A number of the identified subpopulations (totaling 58 plants) occur along the identified access roads in this area, including EAR 96.29 and EAR 96.67. Project activities on these existing roads during pipeline construction could include filling pot-holes, blading/grading, and brushing, and may directly impact the documented Kincaid's lupine plants. However, Pacific Connector's EIs would ensure that potential impacts to the lupine plants along the proposed access roads are avoided or minimized during any necessary maintenance activities by flagging and fencing the known populations and monitoring maintenance activities during construction.

It is possible that clones of Kincaid's lupine could become reestablished within the construction right-of-way. Pacific Connector would monitor revegetation success in the areas of the restored Kincaid's lupine populations between MPs 57.84 - 57.92 and MPs 96.5 - 96.9 annually for five years after construction. Monitoring would include inspection between those mileposts for any new growths of Kincaid's lupine. If any are found, no mowing would be conducted. The five-year monitoring period is longer than FERC's three-year monitoring period requirement for sensitive areas such as wetlands (see Section VI. D. 3. of FERC's 2003 Wetland and Waterbody Construction and Mitigation Procedures). Monitoring would be completed by a qualified botanist and would be scheduled in June to coincide with the optimal time for plant identification. Pacific Connector also has an agreement in principle with the Forest Service which includes 125.3 acres of meadow restoration on the Umpqua National Forest within the Elk Creek and Days Creek South Umpqua River watershed that will benefit native species including Kincaid's Lupine and which should compensate for any potential effects caused by maintenance of the 30-foot right-of-way.

Indirect Impacts

Indirect impacts to documented patches of lupine are possible from the proposed pipeline, including impacts from heavy dust created during construction activities, sub-surface disturbance to underground stems, and from invasive plants occurring on pipeline route. Approximately 1,394.2 acres of the 3,009.3 acres identified as potential habitat occur outside of the proposed construction work areas, of which 721.5 acres of the 952.2 acres surveyed were determined suitable for Kincaid's lupine (76 percent suitable) during 2007 and 2008 surveys. Approximately 442 acres were outside the proposed construction work areas but within the botanical analysis area and were not surveyed due to denial of access by land owners. Of that unsurveyed area, 336 acres (76 percent of 442 acres) could contain suitable Kincaid's lupine habitat.

Within the known or estimated suitable habitat within the entire botanical analysis area (721.5 acres), Kincaid's lupine plants were documented at three sites on approximately 1.7 acres (see discussion above), or 0.24 percent of habitat surveyed. Therefore, it can be estimated that approximately 0.8 acre of the 336 acres not surveyed within the 200-foot botanical analysis area may be occupied by Kincaid's lupine. Plants located within the 0.8 acre estimated as occupied could also be indirectly affected by the Project. This estimate of 0.8 acre is different from the estimate of 0.34 acres that would be affected by direct impact, above.

Indirect impacts include habitat alteration of 1,057.5 acres (721.5 known plus 336 acres estimated) known or estimated acres of suitable Kincaid's lupine habitat that occur within the botanical analysis area. Indirect impacts are likely to include: 1) changes in hydrology and soil characteristics, 2) an increase in invasive weeds, and 3) alterations of vegetation cover and species composition. Changes in the natural hydrology of a site, such as by ditching or draining a wet prairie, can alter the annual duration of soil saturation, which in turn affects the species composition of the site. The potential for soil compaction along the construction right-of-way could occur from heavy equipment use and repeated vehicle traffic. Soil compaction can alter soil hydrologic conductivities, decreasing soil infiltration rates and available water contents, and increase runoff rates. Pacific Connector's Erosion Control and Revegetation Plan (see Appendix F - Sections 4.2.3, 10.3 and 10.4) describes the mitigation measures that would be implemented during restoration to alleviate potential soil compaction along the right-of-way to ensure revegetation success and to minimize any potential effects to Kincaid's lupine. Such alteration in Kincaid's lupine meadow habitats would likely cause an increase in weedy grasses and forbs. In Kincaid's lupine forested habitat, a decrease in overstory canopy cover and subsequent shift to early seral vegetation associated with logging is expected. A reduction in canopy cover alone (i.e. without the ground disturbance associated with logging activities) could result in an improvement to forested Kincaid's lupine habitat, especially within the population documented between MPs 96.5 and 96.9 that were generally located within canopy gaps of late regenerating/early mid-seral forest and along transitional roadsides. Kincaid's lupine is very sensitive to habitat loss, competition from nonnative plants, and elimination of historical disturbance regimes (and resulting competition from increased vegetation cover), all of which have contributed to the decline of Kincaid's lupine populations.

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where Kincaid's lupine occurs on private lands throughout the action area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, where ever they may occur. However, the Pacific Connector pipeline would mitigate for any Project impacts to Kincaid's lupine.

**Critical Habitat**

No critical habitat would be affected by the proposed action.

### 4.7.5.4 Conservation Measures

Because the removal of any Kincaid's lupine plants may hinder the recovery, and eventual down-listing of the species, Pacific Connector has taken action to avoid or minimize impacts to the populations of Kincaid's lupine that were located during survey efforts near MPs 57.84 to 57.92, 59.60, and 96.5 to 96.9. These measures included altering the proposed route, removing or minimizing proposed TEWAs, and/or minimizing the construction right-of-way (see figures 4.8-3, 4-8-4, and 4.8-5, revised proposed route). At the site between FERC-filed MPs 57.84 and 57.92, all direct impacts to that population were avoided through a reroute. The FERC-filed route near the site between MPs 96.5 and 96.9 follows a narrow ridge-line and no feasible alternate route was available to completely avoid impacting the documented plants at this site. Therefore, Pacific Connector minimized the construction right-of-way and modified TEWAs to avoid directly impacting some Kincaid's lupine patches. Also at this site, subpopulations identified along the existing access roads (EARs 96.29 and 96.67) would be flagged by a qualified botanist prior to Project activities in the area and Pacific Connector's EIs would clearly fence the road edges adjacent to these subpopulations to minimize potential disturbance from road use and maintenance activities. Traffic identified to use EAR 96.67 would be instructed to stay within the construction right-of-way rather than using portions of the road outside of the construction right-of-way with adjacent Kincaid's lupine patches. Similar measures described above would be applied to other areas of the proposed pipeline where survey access was denied, if other Kincaid's lupine populations are identified during survey efforts once Pacific Connector is granted survey access through the FERC certificate process. For additional detail, see the Draft Mitigation Plan for Kincaid's lupine submitted as part of the draft Compensatory Mitigation Plan in appendix O.

Not all documented plants or patches of Kincaid's lupine would be avoided at the site located between MPs 96.5 and 96.9, or possibly at other populations identified if Pacific Connector is granted survey access permission on all unsurveyed parcels. To off-set this impact, plant salvage and seed collection would be attempted. While salvage and re-planting of existing plants would be attempted, there is no guarantee that it would be successful since recent Kincaid's lupine propagation work has focused on augmenting populations, rather than moving plants to avoid disturbance. To date, efforts to establish new populations of Kincaid's lupine using seeds and transplants have met with mixed success. The earliest recorded efforts to establish plants in the field were made by Ingersoll (Gisler 2004). In this study, only five percent of 150 seedlings sown in April 1992 survived the first year. Direct seeding with pre-scarified seeds proved more successful, with 68 percent survival through the first growing season. Kaye (2008) states that germinating and growing Kincaid's lupine seedlings in nursery environments consistently results in large sized plants, although transplanted seedlings typically require three years in the field to assess success (i.e. to achieve flowering plants). Therefore, transplanting mature but dormant plants may be a possible, more viable option, since Kaye (2008) does not advise transplanting of adult plants immediately, nor during the growing season. To increase success in transplanting, a likely timeline might include: 1) identify and tag adult plants during flowering season (May to June); 2) dig up dormant plants during fall (October to December); 3) pot dormant plants and maintain in nursery environment for at least one year to condition plants; and 4) plant out plants during the fall (October to December). Collected seeds would also be provided to a certified seed repository (possibly the Berry Botanic Garden Seed Bank for Range and Endangered Plants, Portland, Oregon) for long-term storage and for use in establishing transplants (BLM et al. 2008).

If Pacific Connector receives approval from the landowner between MPs 96.5 and 96.9, a qualified botanist would attempt to salvage the Kincaid's lupine plants that cannot be avoided within the construction right-of-way in the fall prior to construction to transplant off-site (e.g., adjacent to the proposed project) in suitable habitat openings. The salvaged plants would be temporarily potted and moved to a nursery to condition for a minimum of one year, as recommended by FWS. The feasibility of salvaging and successfully transplanting the salvaged plants is expected to be difficult because of the lupine's vegetative growth pattern (clonal) that renders it difficult to distinguish individuals. Excavations and morphological patterns suggest that plants 33 feet or more apart can be interconnected by below-ground stems, and that clones can exceed 66 feet across (FWS, 2005e; Kaye, 2008). Therefore, the ability to efficiently and successfully complete plant salvage efforts would be determined during the salvaging efforts by Pacific Connector's environmental staff and the salvaging botanist.

Seed collection of Kincaid's lupine from the populations between MPs 96.5 and 96.9, as well as other populations that could be identified on unsurveyed parcels where Pacific Connector has been granted survey access through the FERC Certificate process, would be completed in the 2 years prior to construction after flowering and when the seeds have developed and matured. Seed collection is proposed for 2 years because of the species' low seed production (Gisler 2004). The collected seed would either be provided to a certified repository (i.e., The Berry Botanic Garden) or would be replanted within or adjacent to the construction right-of-way during restoration efforts on suitable BLM lands where future protection can be managed or on private lands where a conservation easement has been acquired. If planting is to occur on the construction right-of-way, it would occur outside the 30-foot maintained easement. For additional detail, see the Draft Mitigation Plan for Kincaid's lupine in appendix O.

Pacific Connector assumes the identified potential habitat for Kincaid's lupine (surveyed and not surveyed) would be accessible prior to construction of the pipeline. When Pacific Connector acquires access to the construction right-of-way, it would conduct surveys in potential habitat and plants located during surveys would be avoided, if possible. Measures of avoidance may include minor alignment reroutes, necking down the construction right-of-way in that area, excluding a portion of an identified temporary extra work space or pipe storage yard, or erecting a protective fence to avoid impact to plants from construction debris, similar to actions taken at the previously identified Kincaid's lupine sites documented within the project area. If it is determined that avoidance is not possible, replanting an area may be considered, either on-site or off-site to supplement conservation agreements and recovery goals. Augmentation of known populations is possible. Approximately 1,468 acres of suitable Kincaid's lupine habitat occur along the proposed pipeline corridor within the botanical analysis area. Appropriate habitat within those acres would need to be selected and assessed.

Additional suitable habitat may exist outside of the botanical analysis area on private land or federal ownership. Appropriate habitat within any private or federal (i.e. non-analysis area) ownership would need to be identified and assessed. Considerations for appropriate habitat include quality of habitat, soil and hydrology characteristics, level of weed infestation, similar habitat/plant community (meadow habitat or forest habitat), proximity to the Kincaid's lupine seed source area, proximity to historical Kincaid's lupine population sites, the ownership status of the site and the ability to protect the site from disturbance. Additional considerations include the proximity of the selected site to the metapopulations within the Douglas County Recovery Unit, and the number of individuals in those metapopulations.

The population at MP 57.9 is a high-value valley floor habitat and would need to be augmented within suitable nearby valley floor habitat. All potential out-planting sites along the right-of way are on private lands and would require a conservation easement or purchase of the land.

The population at MP 96.5 is in upland forest in transitory openings and natural openings and could possibly be augmented by outplantings on BLM land approximately 0.4 mile to the north (T.30S R.3W S.35 SE1/4 of SE ¼) as well as outplantings within the population to augment sub-populations that occur in natural openings. The latter would require a conservation easement.

Additional mitigation measures for the impacts to individual Kincaid's lupine plants would be addressed through the Compensatory Mitigation Plan (see appendix O). Such measures could include application of Integrated Weed Management (BLM et al., 2008) to control existing noxious weeds and prevent new infestations within and adjacent to occupied and potential habitats. Competition with invasive species (Himalayan blackberry, oxeye daisy, grasses, Scotch boom) have been the biggest threat to maintaining or reestablishing Kincaid's lupine in some locations (Thorpe and Massatti, 2008; Thorpe et al. 2009). Integrated Weed Management in those areas could include (BLM et al. 2008, page 13):

- Hand pulling and cutting noxious weeds.
- Mechanical treatments such as mowing prior to seed development.
- Application of an appropriate herbicide treatment for noxious weeds using application methods during the correct phonological periods and using pertinent Best Management Practices to avoid potential effects to Kincaid's lupine.
- Clean all mechanical equipment and inspect to insure no noxious weed plant parts are present prior to equipment use within Kincaid's lupine habitat.
- Flaming with propane burners or hot water treatment of herbaceous noxious weeds.
- Planting desirable grasses, forbs and shrubs to prevent invasion of noxious weeds and invasive non-native species.

Other measures could include planting native forbs and shrubs adjacent to Kincaid's lupine populations to encourage a variety of pollinating insects. Controlling canopy cover in occupied or potential wood habitats could also stimulate growth of existing clones if shading is judged to be a limiting factor.

**Mitigation**

Mitigation for proposed damage to these populations are detailed in the Compensatory Mitigation Plan (see appendix O) and would include the collection of seeds and attempted salvage and transplanting of plants from the population between MPs 96.5 to 96.9. However, harvesting seeds from any population may negatively impact that population's ability to produce new individuals. Also, these Douglas County populations may host unique genetic resources that could contribute to the genetic viability for a restored population. Seeds from other sources, such as from the Willamette Valley populations could be used, but may lack locally adapted genotypes required for successful establishment and growth in Douglas County. Future propagation efforts for the taxon as a whole would likely depend on availability of seed sources from all extant populations. With so little known about genetics in this taxon, it is important to maintain all extant populations.

#### 4.7.5.5 Determination of Effects

**Listed Species**

The Project **may affect** Kincaid's lupine because:

- Suitable habitat is present within the analysis area.
- Individual plants have been located within the analysis area during survey efforts.

The Project is **likely to adversely affect** Kincaid's lupine because:

- Individual plants would be removed.
- Indirect impacts are expected to documented or suspected plants outside of the construction right-of-way and along proposed access roads.
- Trenching activities associated with the proposed pipeline could impact below-ground stems and the expected impact to extant plants is unknown.
- Potential suitable habitat has not been surveyed due to landowner access denial.

**Critical Habitat**

A **no effect** determination is warranted for Kincaid's lupine because:

- The pipeline does not occur within designated Kincaid's lupine critical habitat.

### 4.7.6 Western Lily

#### 4.7.6.1 Species Account and Critical Habitat

**Status**

The western lily was listed as endangered on August 17, 1994 (FWS, 1994c), and a final recovery plan (FWS, 1998c) was released four years later.

**Threats**

In the final rule to classify the western lily as an endangered species, FWS identified agricultural conversion and use, urban and rural development on public and private lands, and forest encroachment as threats that destroy, modify, or curtail the plant's habitat or range. The western lily occupies a very limited range of habitat near the coasts of Oregon and Northern California. Coincidentally, these areas are desirable regions for private land residential development and the plant's habitat during the time of listing was threatened by intense pressure from this current and future development. FWS noted that overutilization for commercial and recreation uses, disease, predation, grazing, and other natural or manmade factors affecting the plant are threats to the western lily's continued existence (FWS, 1994c).

The ongoing threat of development includes creation of new cranberry bogs, residential development, utility and road construction and maintenance, land clearing and drainage for livestock grazing, fire suppression, agricultural plowing, and logging. Lily populations are directly affected by these developments, but are also impacted by the activities on surrounding lands because of degraded hydrological conditions. FWS considers competitive exclusion by shrubs and trees to be the most significant long-term threat to the western lily (FWS, 1998c).

**Species Recovery**

The recovery plan for western lily identifies six recovery areas. When at least 20 viable populations (a viable population consists of 1,000 flowering plants) distributed among these six areas are protected and managed, the western lily can be downlisted to threatened. In coastal areas within Oregon where the lily occurs, the recovery plan recommends that all conifers and alders within 33 feet of the plants be removed to minimize vegetative succession surrounding the population. Additionally, the recovery plan suggests posting coded signs so that accidental destruction of plants through excavation or herbicide treatments do not occur (FWS, 1998c).

The objective of the recovery plan is to stabilize and protect existing occupied sites as viable populations so that the species can be downlisted or delisted in the future. To achieve the objective, the following steps are recommended (FWS 1998c):

- On-site conservation that manages the habitat in appropriate seral stages (i.e., prevents or reverses encroachment by trees and shrubs).
- Off-site conservation by reintroducing or augmenting populations from seeds.
- Conduct and encourage public outreach.

Six recovery areas have been identified within the range of the western lily. These areas are not defined geographically, but are positioned between known extant sites or historical sites. The proposed pipeline and LNG terminal occurs within Recovery Area 1, within which four extant populations and one "unknown status" population occur.

**Life History, Habitat Requirements, and Distribution**

Western lily is present in 31 small, widely separated populations inhabiting sphagnum bogs, coastal scrub and prairie, and other poorly drained soils along the coast of southern Oregon and northern California. Western lilies have an extremely restricted distribution within 2 miles of the coast from Hauser, Coos County, Oregon to Loleta, Humboldt County, California. The plant occurs in seven widely separated regions along the coast within 4 miles of the Pacific Ocean. Such populations are densely clumped and mostly on isolated wetlands that are fewer than 10 acres (FWS 1994c and 1998c).

Western lily is known to occur from early successional fens and coastal scrub habitat in northwestern California to southwest Oregon (Kal,t 2006). Habitats with which this species is associated include coastal bluff scrub, coastal prairie, and openings in coastal coniferous forest dominated by Sitka spruce, including freshwater marshes and swamps (CNDDB, 2005). In Oregon, western lily emerges in late March or early April and flowers in late June or July (Imper, 2003). The species grows in soils that are described as both well-drained or poorly drained and have a significant layer of organic topsoil. The soil profile also includes an iron or clay-confining layer which serves to perch moisture late in the growing season (Imper, 2003). Species typically associated with western lily include Sitka spruce, Pacific reed grass, willows, false lily-of-the-valley, and evergreen huckleberry (Imper, 2003).

## Population Status

At the time of the species recovery plan (1998), western lily had been extirpated from 18 of an estimated 55 sites. Twenty-eight sites had been surveyed (FWS, 1998c). Since 1998, the number and size of populations has declined, with current populations found on nine extant sites in Oregon and seven in California (Imper, 2008 cited in SBS, 2008b).

## Critical Habitat

Critical habitat has not been designated for western lily.

### 4.7.6.2 Environmental Baseline

## Analysis Area

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. That area corresponds to areas that were surveyed for sensitive and listed plant species in 2007 and 2008. A limited area of private lands in Coos County immediately adjacent to Coos Bay was included as potential habitat for western lily. See section 4.7.1.2 above for the full botanical analysis area description. On the JCEP LNG Terminal site the analysis area includes the project footprint and potential habitat for western lily extending north from the footprint to the Trans-Pacific Highway and in potential habitat approximately 300 feet west of the proposed slip and LNG storage tank sites.

## Species Presence

The botanical analysis area crosses the plant's range from approximately MP 0 to MP 11.5 (SBS, 2008b). The closest known western lily occurrence is approximately 5.2 miles northeast of the JCEP LNG Terminal site and South Dunes Powerplant site at Hauser Bog (ORBIC, 2012). The occurrence is on Blacklock soils which are found on marine deposits, are deep, poorly drained with high organic content. In 2009, there were 494 plants observed at the site although the population was rated as poor estimated viability (ORBIC, 2012). At the time of listing in 1994, there were 43 plants reported flowering (although based on an incomplete survey – FWS, 2009d). Western lilies at the Hauser Bog site sustain inundation because they grow on mounds that allow bulbs to remain above high water (FWS, 2009d); high groundwater has been implicated in mortality of western lilies at other sites (FWS, 2009d).

Other extant populations of western lily are present south of the JCEP LNG terminal at Bastendorff Bog Preserve (7.8 miles), Sunset Bay State Park (8.7 miles), and several sites within Shore Acres State Park (9.6 miles) (FWS, 1998c). Western lilies in those populations have been rated with excellent or good estimated viabilities except for the population at Sunset Bay State Park which last observed in 2004 and ranked with poor viability (ORBIC, 2012). The western lily has not been documented within the project botanical analysis area (ORBIC, 2012).

## Surveyed Habitat

<u>Jordan Cove Western Lily Surveys</u>

Western lily surveys were conducted in the vicinity of the JCEP LNG terminal and slip area within habitat identified as suitable for this species during the floristically appropriate season in 2006 and again in 2013 (see SHN, 2013). The 2013 surveys included potential habitats within the analysis area (described above) north of the proposed South Dunes Power Plant site to the Trans Pacific Highway.

Botanical reconnaissance assessments in the vicinity of the LNG terminal and slip were conducted in 2005 and 2006 and included evaluations of aerial photography and on-site surveys that initially covered 42 acres on and adjacent to the Roseburg property, which includes the LNG terminal site. Suitable habitat for western lily was found to be limited due to lack of appropriate substrate. The soil types on-site are dune land, Heceta fine sands, Waldport fine sands, and Walport-Heceta fine sands. All of those soils are derived from Eolian deposits rather than marine terrace deposits. Based on soil types present within the study area and the species' moisture requirements, suitable low to moderate quality habitat within the study area is limited to the freshwater wetlands on site that have a significant organic layer within the soil profile. The soil profile within the wetland habitat at and surrounding Jordan Lake lacks the amount of significant organic accumulations that were observed in a section of the Northcentral Wetland and Henderson Marsh.

All freshwater wetlands within the project footprint were reviewed for potential western lily habitat. Wetland sites where fill has been placed were also searched, as they could contain pockets of native soils. Wetlands created for industrial uses (sludge ponds) or estuarine habitats were not included in the surveys, as they would not contain the habitat necessary for the species. Focused surveys for western lily were conducted at 11 sites adjacent to or coinciding with the Project footprint, including the South Dunes Powerplant site, on July 8, 9, 10, and 11, 2013 (SHN, 2013). Sites included freshwater wetlands as far north as the border the Trans Pacific Parkway. Two sites were in disturbed habitat along Jordan Cove Road and the Trans Pacific Parkway and two sites were on highly degraded habitat located on fill that functions as a drainage for surrounding industrial sites. No western lilies were observed during any surveys conducted on the JCEP LNG Terminal site and South Dunes Powerplant site (SHN, 2013).

<u>Pacific Connector Western Lily Surveys</u>

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for western lily within the botanical analysis area, including existing roads identified for access to the construction right-of-way. Aerial photographs (summer 2005) and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for western lily. The same methods were used to determine potential suitable habitat coinciding with new realignments of the project corridor.

A total of 37.6 acres have been identified as potential suitable habitat requiring surveys within the current project alignment and 200 foot botanical analysis area (see table 4.7.6-1). Of that potential habitat, access was allowed to survey 36.1 acres (including 13.7 acres within the project area). An additional 9.3 acres of potential suitable habitat was surveyed adjacent to the Noah Butte access road, but no suitable habitat was located. All potential suitable habitats are located within Pacific Connector pipeline MP 4.15 through MP 11.42, and are all in Coos County.

Of the 36.1 acres of potential habitat that was surveyed, none were considered suitable habitat for western lily. Approximately 1.5 acres (0.2 acres within the project area) of potentially suitable habitat for this species was denied access by the landowner and would need to be surveyed prior to construction for complete surveys of this eco-region. Given the unsuitable habitat conditions surveyed in adjacent areas, the 1.5 acres remaining to be surveyed (see table 4.7.6-1) are not expected to provide suitable habitat for western lily. No western lilies have been observed during surveys conducted on accessible potential habitat and the chance that western lilies occur on the unsurveyed 1.5 acres (0.2 acres within the project area) is judged to be highly unlikely.

**Table 4.7.6-1**

**Summary of Potential Suitable Western Lily Habitat within the FEIS-Revised Route and Botanical Analysis Area**

| Surveyed Area Type and Years Surveyed | Area (acres) Included: FEIS ROW | Area (acres) Included: 200-foot Botanical Analysis Area [1] (Outside of ROW) | Area (acres) Included: Total |
|---|---|---|---|
| **Area Identified for Survey (Potential Habitat)** | 13.9 | 23.7 | 37.6 |
| **Area Surveyed to Protocol** | | | |
| 2007 | 13.0 | 21.1 | 34.1 |
| 2013 | 0.7 | 1.3 | 2.0 |
| **Totals** | **13.7** | **22.4** | **36.1** |
| **Area of Confirmed Potential Habitat** | | | |
| 2007 | 0.0 | 0.0 | 0.0 |
| 2013 | 0.0 | 0.0 | 0.0 |
| **Totals** | **0.0** | **0.0** | **0.0** |
| **Area not Surveyed (access denied)** | **0.2** | **1.3** | **1.5** |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

### Critical Habitat

No critical habitat has been designated for western lily.

## 4.7.6.3 Effects by the Proposed Action

### Direct and Indirect Effects

No direct effects to western lily are expected as a result of the proposed action because surveys conducted at the JCEP LNG Terminal site, the South Dunes Powerplant site, and along the PCGP pipeline route did not locate any plants. Known western lily sites and plants are at least 5 miles from the botanical analysis area.

Approximately 37.6 acres of potential habitat within the botanical analysis area has been identified as potential western lily habitat, of which 36.1 acres have been surveyed. None of the surveyed habitat was found to have suitable conditions to support western lily. A small portion of potential habitat remains to be surveyed; the chance that western lilies occur on the unsurveyed 1.5 acres (0.2 acres within the project area) is judged to be highly unlikely.

Review of NRCS soil survey data, indicates that the potential suitable habitat areas along the proposed PCGP route does not have the combination of the soil characteristics (i.e., deep, poorly drained marine deposits with high organic content) that support the known western lily populations.  Furthermore, the upland proposed route is within a narrow range of the plant, which has been relatively well-explored botanically, and no plants identified (FWS, 1998c).  Since suitable habitat has not been previously identified within the proposed route and suitable habitat is not expected to be present in the proposed route, the Pacific proposed route is not expected to impact western lily.  However, that will be confirmed once Pacific Connector is granted survey access permission on the unsurveyed parcel and surveys for western lily can be completed.

**Cumulative Effects**

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs.  Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where western lily occurs on private lands throughout the action area.  Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant.  Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, where ever they may occur.  However, the Pacific Connector pipeline would mitigate for any pipeline impacts to western lily.

**Critical Habitat**

Critical habitat has not been designated for western lily.

#### 4.7.6.4 Conservation Measures

If the Project is approved, Pacific Connector would have access to the identified potential habitat for western lily shortly prior to construction of the pipeline.  When Pacific Connector acquires access to the construction right-of-way, surveys would be conducted in previously unsurveyed potential habitat and any plants located during surveys would be avoided, if feasible.  Measures of avoidance may include necking down the construction right-of-way in that area, excluding a portion of an identified temporary extra work space or pipe storage yard, or erecting a protective fence to avoid impact to plants from construction debris.  If a population is documented within the revised proposed route and seed is needed to augment the population, the Berry Botanic Garden has a few collections of western lily seed, including populations within Recovery Area 1 where the proposed pipeline is located (FWS, 1998c).  The FWS would be provided all survey results.

#### 4.7.6.5 Determination of Effects

**Listed Species**

The Project **may affect** western lily because:

- Known populations occur within 10 miles of the botanical analysis area.
- Potential suitable habitat is available within the analysis area.

The Project is **not likely to adversely affect** western lily because:

- Surveys of potential western lily habitat at the JCEP LNG terminal site, at the South Dunes Powerplant site, and along the PCGP proposed pipeline route did not document

western lily nor did the surveys identify suitable western lily habitats within the botanical analysis area.
- Initial reviews of soils at potential suitable habitat sites that have not been surveyed do not appear to be suitable to support western lily plants.
- The closest known population of western lily is located 5.2 miles northeast of the JCEP LNG Terminal site at Hauser Bog.
- Surveys in potentially suitable habitat identified within the FEIS-revised proposed route (1.5 acres) would occur prior to ground disturbing activities; if plants are identified, conservation measures developed to avoid or minimize impacts to future plants would be applied.
- Given current knowledge that the species is absent and suitable habitat would not be affected and there is no reason to expect that future surveys would identify western lily plants, project effects to the species are currently insignificant and discountable.

**Critical Habitat**

Critical habitat has not been designated for western lily.

### 4.7.7 Rough Popcornflower

#### 4.7.7.1 Species Account and Critical Habitat

**Status**

The rough popcornflower was listed as endangered on January 25, 2000 (FWS, 2000d).

**Threats**

At the time of listing in the FWS final rule, the rough popcornflower was threatened by the destruction, modification, or curtailment of its wetland habitat and range. The species was then limited to 17 small, isolated habitat patches. Areas supporting the rough popcornflower were threatened by hydrological alterations (including ditching and wetland fill), livestock grazing, agricultural land conversion, non-native vegetation invasion, forest succession and canopy cover, residential and commercial development.

Predation and other natural or manmade factors are also threats identified in the endangered status listing. These factors include herbicide and pesticide use, chemical spills and runoff from roads, roadside maintenance, habitat vandalism, and grazing. Overgrazing likely contributed to declining numbers throughout its historical range. Livestock grazing in spring and summer months can cause the most damage. When flowers and seed heads are grazed, the reproductive output for the year is destroyed. However, FWS notes in the final rule that grazing in the fall, during the plant's dormant stage; can be a benefit by reducing the growth of weedy competitors (FWS 2000d). The small, isolated populations also make the species vulnerable to disease outbreaks, weak genetic viability, adverse pollinator activity, and random environmental events.

Since the publication of the final rule for rough popcornflower, the potential for further development in the plant's habitat remains the most urgent threat. Habitat destruction and fragmentation from residential, commercial, and agricultural development continues as the Sutherlin, Oregon area expands. Competitive exclusion by other wetland vegetation is another major threat to the plant. Other ongoing threats include, forest succession, overgrazing by livestock, chemical spills and fire along roadsides, herbicide use, wetland infill, and the intentional destruction of suitable habitat and plants (FWS, 2003e).

**Species Recovery**

A recovery plan was developed in 2003 (FWS, 2003e). To ensure that the rough popcornflower was conserved throughout its range in the North Umpqua system, three recovery units were created. Part of the recovery plan also involves a goal of nine reserves, each containing a minimum of 5,000 plants, distributed across the three recovery units of Calapooya Creek, Sutherlin Creek, and Yoncalla Creek (FWS, 2003e). However, all the units identified occur north of the proposed Pacific Connector pipeline and the Project is not expected to affect these units.

The objective of the recovery plan is to reduce threats and increase population viability until the rough popcornflower can be downlisted. The recommended steps are as follows:

- Conserve and manage a minimum of nine reserves within three recovery units.
- Practice ex-situ conservation.
- Research factors that threaten the recovery of the species.
- Provide outreach services for owners of reserve populations and the general public.

**Life History, Habitat Requirements, and Distribution**

The rough popcornflower is currently found in seasonal wet meadows or wet prairies in poorly drained clay or silty clay loam soils at elevations ranging from 100 to 900 feet. Deep, poorly drained soils provide a high-to-surface-level water table from November to May, when rough popcornflowers' seedlings germinate and overwinter as submerged rosettes. In these areas, the rough popcornflower is often observed in the deeper sections of shallow meadow pools that lack significant shade, and are associated with typical marshland sedge and grasses (FWS, 2003e).

Rough popcornflower generally blooms from June through July. Rough popcornflower grows in scattered groups and reproduces largely by insect-aided cross-pollination and partially by self-pollination (FWS, 2008f). The herbaceous plant occurs in the vicinity of Sutherlin and Yoncalla, mostly on private lands in the Umpqua River drainage (FWS, 2003e).

**Population Status**

There are 15 known naturally-occurring extant sites of the Rough popcornflower within its limited range, as found in the Oregon Natural Heritage Program database. In addition to the naturally occurring populations, rough popcornflower transplants have been introduced at two sites on the BLM North Bank Habitat Management Area (FWS, 2003e). Five population patches are considered protected, two of which are on State of Oregon lands managed by The Nature Conservancy as part of the Popcorn Swale Preserve (FWS, 2003e).

**Critical Habitat**

Critical habitat has not been designated for the rough popcornflower.

### 4.7.7.2 Environmental Baseline

**Analysis Area**

A botanical analysis area applies to the extent of Project-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline. The botanical analysis area also includes all TEWAs, rock source and disposal sites, and proposed storage yards either on federal or state lands or that have potential for listed plant species. That area corresponds to areas that were surveyed for sensitive and listed plant species in 2007 and 2008. See section 4.7.1.2 Applegate's Milk-vetch above, for the full botanical analysis area description.

**Species Presence**

This species has only been documented in northern Douglas County. As of 2010, there were 14 extant occurrences of rough popcornflower distributed from Yoncalla Creek near Rice Hill, south to Sutherlin Creek near Wilbur (FWS, 2010g). The patches along Sutherlin Creek are within the Lower Noth Umpqua River watershed (HUC 171003011) and extend from inside the city of Sutherlin to the south for four miles. The closest rough popcorn occurrence occurrence to the proposed pipeline route is 17.5 miles north of MP 68.

However, there are historical records of rough popcorn flowers near two proposed pipeyards. One record is of a population of 300 to 500 plants when first observed in 1983, but fewer than 50 plants were observed in 1998. The population was proximate to the proposed Sutherlin John Murphy pipe yard, an 85.48 acre site in the city of Sutherlin, Orgon. In 1998 there were very few plants remaining and the site was being drained; the expectation then was that complete extirpation was imminent (ORBIC, 2012). The 1998 record is west of Taylor Road in Sutherlin while the Sutherlin John Murphy Pipe Yard is east of Taylor Road, a major thoroughfare in the city. Although the 1998 record is 120 feet across the road from the John Murphy yard property edge, that portion of the property is covered by the North Douglas Log Ponds. The 1998 record is >1,000 feet from the actual asphalt surfaced yard associated with the former John Murphy Plywood Mill.

Currently the proposed pipeyard is an active laminated beam factory on private land. The proposed yard site would not be used unless the factory closed prior to pipeline construction. If the site is used for pipe storage, only the existing paved portions of the site would be used which amount to 31.3 acres. The North Douglas Log Ponds are still present at the southern portion of the property and wetland habitat may be present, providing suitable conditions similar to suitable habitat in shallow meadow pools that lack significant shade, and associated with typical marshland sedge and grasses. The periphery of the poposed Sutherlin John Murphy pipe yard has not been surveyed for rough popcornflower.

The second record is of an historical population located between railroad tracks that parallel Interstate 5 and Sutherlin Creek. The site was last observed in 1998 with plants present but the population was rated with fair or poor estimated viability (ORBIC, 2012). The rough popcornflower population occurred in a wetland swale on both sides of a private driveway and had been impacted by fall livestock grazing. It was noted that grazing during spring would destroy the population (ORBIC, 2012). There is no information indicating that the population has persisted.

That site is adjacent to an 8.76 acre parcel proposed for use as the Old Highway 99 pipe yard. Approximately 4.9 acres of the proposed yard site are graveled and currently provide storage as an equipment auction business. A small 1.2 acre pond is present south of the gravel yard surface and separates the yard from the historic population of rough popcornflower to the south. As with the Sutherlin Jack Murphy yard, the proposed Old Highway 99 yard site would not be used unless the business closed prior to pipeline construction. If the site is used for pipe storage, only the existing 4.9-acre gravelled portion of the site would be used. The periphery of the poposed Old Highway 99 pipe yard has not been surveyed for rough popcornflower.

**Surveyed Habitat**

Pacific Connector Rough Popcornflower Surveys (2007)

Prior to beginning field surveys in 2007 for the Pacific Connector pipeline, botanists with SBS conducted a habitat review to identify potential habitat and delineate survey areas for rough popcorn flower within the botanical analysis area, including existing roads identified for access to the construction right-of-way. Aerial photographs (summer 2005) and knowledge of regional landscape and biological features (soils, geology, topography, elevation, target species habitat, and plant community habitat) were used to determine potential habitat for rough popcorn flower. The same methods were used to determine potential suitable habitat coinciding with new realignments of the project corridor.

A total of 41.6 acres have been identified as potential suitable habitat requiring surveys within the current project alignment and 200-foot botanical analysis area (see table 4.7.7-1). Of this habitat, access was allowed to survey on 11.7 acres (3.3 acres within the project area). A total of 22.1 acres of unassessed habitat are located on pipeyards. Potential suitable habitat is located within Pacific Connector pipeline MP 51.7 through MP 66.96, all in Douglas County.

Of the 11.7 acres of potential habitat with allowed access to survey, 3.4 acres (1.0 acre within the project area) were considered suitable habitat for rough popcornflower. Habitat found to be "suitable" in the surveys included areas with some of the characteristics detailed in the Life History, Habitat Requirements, and Distribution section above (SBS, 2008a).

Approximately 29.9 acres (24.3 acres within the project area) of potentially suitable habitat for this species was denied access by the landowner and would need to be surveyed prior to construction for complete surveys of this eco-region. If the assumption is made that a similar percent of that area is suitable as documented within the rest of the area surveyed, then approximately 3.0 acres (10 percent of 29.9 acres, or 2.4 acres within the project area) is probably suitable popcorn flower habitat. No rough popcorn flower individuals were located during surveys conducted in 2007.

| Table 4.7.7-1<br><br>Summary of Potential Suitable Rough Popcornflower within the FEIS-Revised Route and Botanical Analysis Area. | | | |
|---|---|---|---|
| | **Area (acres) Included** | | |
| **Surveyed Area Type and Years Surveyed** | **FEIS ROW** | **200-foot Botanical Analysis Area** [1] **(Outside of ROW)** | **Total** |
| **Area Identified for Survey (Potential Habitat)** | 27.6 | 14.0 | 41.6 |
| **Area Surveyed to Protocol** | | | |
| 2007 | 3.3 | 8.3 | 11.6 |
| 2013 | 0.0 | 0.1 | 0.1 |
| **Totals** | **3.3** | **8.4** | **11.7** |
| **Area of Confirmed Potential Habitat** | | | |
| 2007 | 1.0 | 2.3 | 3.3 |
| 2013 | 0.0 | 0.1 | 0.1 |
| **Totals** | **1.0** | **2.4** | 3.4 |
| **Area not Surveyed (access denied)** | **24.3** | **5.6** | **29.9** |

**Note:**
[1] The botanical analysis area applies to the extent of pipeline-related effects on listed plant species within a general 400-foot-wide corridor, 200 feet on each side of the proposed Pacific Connector pipeline centerline.

### Critical Habitat

Critical habitat has not been designated for this species.

## 4.7.7.3 Effects by the Proposed Action

### Direct and Indirect Effects

Surveys conducted within potential suitable rough popcornflower habitat did not locate any plants; therefore, no direct effects to rough popcornflower plants are expected as a result of the proposed action. Potential wetland habitat for the species may be present at the periphery of two proposed pipe yard but surveys have not been conducted at those sites. Based on the current businesses occupying the proposed Sutherlin John Murphy pipe yard and proposed Old Highway 99 pipe yard sites, neither would be used for pipe storage if the businesses are present at the time of project initiation. In that circirmstance, there would be no project-related effects to rough popcornflower. If either or both proposed pipe yards will be used by the project, surveys along the perimeters of the paved or graveled surfaces that are adjacent to standing water would be conducted.

### Cumulative Effects

ESA plant species do not have federal protection in Oregon on private lands except in instances where a federal permit is required or a federal action occurs. Outside of the surveyed area for the Pacific Connector pipeline, it is unknown where rough popcornflower occurs on private lands throughout the action area. Therefore, it is impossible to determine if there are reasonably foreseeable actions which might occur on private lands, which could impact the plant. Given the lack of protections under ESA and Oregon statutes, all federally listed plants on private lands must be considered at risk of adverse effects, where ever they may occur. However, the Pacific Connector pipeline would mitigate for any Project impacts to rough popcornflower.

**Critical Habitat**

No critical habitat has been designated.

### 4.7.7.4 Conservation Measures

No measures to conserve rough popcornflower have been included in the proposed action.

### 4.7.7.5 Determination of Effects

**Listed Species**

The Project **may affect** rough popcornflower because:

- Historical populations occur in the vicinity of two proposed pipe storage yards.
- Potential suitable habitat might be present within the 200-foot botanical analysis area extending from the perimeter of either yard.

The Project is **not likely to adversely affect** rough popcornflower because:

- It does not appear likely that either yard would be used for the project, based on current occupancies of the properties.
- Suitable wetland habitats within the 200-foot botanical analysis area surrounding either yard may be present, but no historica populations of rough popcornflower have been reported in the analysis areas.
- Surveys in potentially suitable habitat identified within the botanical analysis areas surrounding the two proposed yards would occur prior to ground disturbing activities; if plants are identified, conservation measures developed to avoid or minimize impacts to future plants would be applied.
- Given current use of the two proposed pipe yards, no rough popcornflowers are present within portions that would be used for pipe storage and there is no reason to expect that future surveys would identify rough popcornflowers within the botanical analysis area surrounding the yards. Project effects to the species are currently insignificant and discountable.

**Critical Habitat**

Critical habitat has not been designated for rough popcornflower.

## 5.0 INTERDEPENDENT AND INTERRELATED EFFECTS

The ESA, as amended, described interrelated actions as those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration" (50 § CFR 402.02).

For the LNG component, unless analyzed differently by FERC, the South Dunes Power Plant would not be included in the EIS. However, the disturbance area necessary to construct the power plant was included in the environmental analysis in the Jordan Cove Resource Reports provided to FERC. The power plant connects directly to the LNG component but does not affect the configuration and location of the LNG component. The power plant is outside of FERC's jurisdiction as the siting, construction, and operation of this facility is under the jurisdiction of the State of Oregon Energy Facility Siting Council. The power lines that connect the power plant to the LNG component are located within a corridor that is under the FERC's jurisdiction. The power plant is being privately developed by Jordan Cove; it has no federal financing or guarantees. Prior to construction of the power plant, a federal permit will be required for wetlands from previous activities on the site that are affected by the site closure plan that was previously approved by the ODEQ; no federal lands would be involved.

For the Pacific Connector pipeline component, interrelated/interdependent facilities would include local power and telephone service to the compressor station and meter stations. Exisiting local facilities are available at each of the aboveground facility locations. There are no permits required of Pacific Connector for purchase power or telephone service to the Klamath Compressor Station, Clarks Branch Meter Station, or Jordan Cove Meter Station, and there are no additional impacts on environmental resources beyond those already accounted for by Pacific Connector and Jordan Cove in their respective FERC Certificate applications.

The PCGP Project scope currently includes interconnections with three interstate gas transmission pipeline systems. Two of the systems are Gas Transmission Northwest and Ruby Pipeline, which would have interconnects at the proposed Klamath Compressor Station site (MP 228.13), where both these pipeline systems have existing below and aboveground facilities. The PCGP Project would also interconnect with Northwest Pipeline's Grants Pass Lateral at the proposed Clarks Branch Meter Station (MP 71.46). All facilities and actions necessary to effectuate these interconnections are under FERC's jurisdiction.

# 6.0 ESSENTIAL FISH HABITAT

The Sustainable Fisheries Act of 1996 amended the Magnuson-Stevens Act and requires federal agencies, in part, to consult with the NMFS about activities that may adversely affect EFH (NMFS, 1997a). The Magnuson-Stevens Act established guidelines for Regional Fishery Management Councils to identify and describe EFH in Fishery Management Plans (FMPs) to responsibly manage exploited fish and invertebrate species in federal waters. The Pacific Fishery Management Council (PFMC) has developed four FMPs that address EFH for managed species in the Pacific Connector pipeline area, (PFMC, 2004; PFMC, 1998; and PFMC, 1999).

The Magnuson-Stevens Act describes EFH as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity (NMFS, 1997a). The Magnuson-Stevens Act provides these additional definitions:

- "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate.
- "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities.
- "Necessary" means the habitat required to support a sustainable fishery and the managed species contribution to a healthy ecosystem.
- "Spawning, breeding, feeding, or growth to maturity" covers the full life cycle of a species.

There are four federal fishery management plans and associated essential fish habitats that coincide with the EEZ analysis area, the estuarine analysis area, and several riverine analysis areas that were defined in the introduction to Section 4.0 of the Biological Assessment for this Proposed Action. The four fisheries managed by the PFMC are highly migratory species, coastal pelagic species, groundfish, and Pacific Coast salmon.

## 6.1 HIGHLY MIGRATORY SPECIES

### 6.1.1 Essential Fish Habitat

Highly migratory species occur within the EEZ analysis area (from the coast seaward to 200 nmi) and beyond since they migrate considerable distances across oceans to feed and reproduce. Highly migratory species defined by the Pacific Fishery Management Council include tunas (5 species), sharks (5 species), billfish/swordfish (2 species), and the dorado (also called dolphinfish or mahi-mahi). However, highly migratory species and their various life stages are not uniformly distributed within the EEZ analysis area. Species' life cycles included in table 6.1.1-1 have been separated by their distributions in the EEZ north of 37$^{o}$N latitude (north of Monterey Bay, California) and/or south of 37$^{o}$N. Within the EEZ analysis area, the earliest life stages for most highly migratory species occur south of Monterey Bay (South of 37$^{o}$N latitude in table 6.1.1-1).

**Table 6.1.1-1**
**Highly Migratory Fish Species Managed by the Pacific Fishery Management Council For Which Essential Fish Habitat Has Been Identified and May Occur Within the Proposed Action EEZ Analysis Area**

| Common Name/Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within the EEZ Analysis Area North of 37°N Latitude | | | | | Distribution within the EEZ Analysis Area South of 37°N Latitude | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs | Larvae | Neonate-Early Juvenile [2] | Late Juvenile - Sub-adults [2] | Adult | Eggs | Larvae | Neonate-Early Juvenile [2] | Late Juvenile - Sub-adults [2] | Adult |
| Common thresher shark *Alopias vulpinus* | Epipelagic, neritic, and oceanic waters off beaches, in shallow bays, open coast bays and offshore, in near surface waters. Feeds primarily on northern anchovy, Pacific hake, Pacific mackerel, and sardine. | | | | | X | | | X | X | X |
| Pelagic thresher shark *Alopias pelagicus* | Epipelagic and predominantly oceanic waters. Associates with sea surface temperatures of 21°C or warmer. Nothing known of diet. | | | | | | | | | X | X |
| Bigeye thresher shark *Alopias superciliosus* | Coastal and oceanic waters in epi- and mesopelagic zones. Little known of diet; presumably feeds on pelagic fishes and squids. | | | | | X | | | | X | X |
| Blue shark *Prionace glauca* | Epipelagic and oceanic waters. Feeds on northern anchovy, Pacific hake, squid, spiny dogfish, herring, flatfishes. | | | X | X | X | | | X | X | X |
| Shortfin mako shark *Isurus oxyrinchus* | Oceanic and epipelagic waters. Reportedly feed on mackerel, sardine, bonito, anchovy, tuna, other sharks, swordfish, and squid. | | | X | X | X | | | X | X | X |
| Albacore *Thunnus alalunga* | Oceanic, epipelagic waters. Feed opportunistically. Younger fish may aggregate in vicinity of upwelling fronts to feed. | | | X | | X | | | X | | X |
| Bigeye Tuna *Thunnus obesus* | Oceanic, epipelagic, and mesopelagic waters. Nothing known of diet. | | | | | | | | X | | X |
| Northern bluefin tuna *Thunnus thynnus* | Juvenile-oceanic, epipelagic waters. Major part of diet is northern anchovy. | | | X | | | | | X | | |
| Skipjack tuna *Katsuwonus pelamis* | Adult-oceanic, epipelagic waters. Major part of diet are pelagic red crab and northern anchovy. | | | | | X | | | | | X |
| Yellowfin tuna *Thunnus albacares* | Juvenile-oceanic, epipelagic waters. Diet on pelagic red crab and northern anchovy. | | | | | | | | X | | |
| Striped marlin *Tetrapturus audax* | Adult-oceanic, epipelagic waters. Preferred water temperature bounded by 20-25°C. Diet includes Pacific saury, northern anchovy, Pacific sardine, jack mackerel, squid, and pelagic red crab. | | | | | | | | | | X |
| Broadbill swordfish *Xiphias gladius* | Oceanic, epipelagic, and mesopelagic waters. Food species not documented. | | | X | | X | | | X | | X |
| Dorado *Coryphaena hippurus* | Epipelagic and predominantly oceanic waters. Prefers sea temperatures 20°C and higher during warm water incursions. Diet unknown. | | | | | | | | X | | X |

[1] PFMC 2007.
[2] All juvenile life stages are combined for species other than sharks.

### 6.1.2 Analysis of Effects

Analyses of effects to EFH for highly migratory species by the proposed action have been provided in multiple sections in the BA. For Highly Migratory Species EFH, Project effects are expected to be associated with accidental spills and releases at sea by LNG carriers transiting at least 50 nmi offshore within the EEZ from south to north (San Diego to Coos Bay) and from LNG carriers approaching Coos Bay from the west through the 200 nmi-wide EEZ.

Oil spills at sea or offshore might directly harm highly migratory fish species. The quantity of oil and other petroleum products on board an LNG vessel are low (fuels or lubricants associated with the operation of the LNG carrier) relative to oil tankers, so any spill is likely to be small and the chance of any spill remote. A total of about 90 LNG vessel trips would occur annually when spills may occur along the route. As reported by Pacific States/British Columbia annual reports, the number of oil spills reported from fishing and other harbor marine vessels ranged from 9 to 65 per year, fairly infrequent for the large number of marine vessels in that area.

An LNG spill is very unlikely to impact highly migratory fish. If an unignited LNG spill were to occur along the LNG carrier transit route in the areas where this species is located, the LNG would float on the water until it vaporizes would not have an adverse effect on this species, unless individuals come in direct contact with the LNG. Should a fish directly contact the LNG when it is first released, before any warming occurs, could have its flesh frozen as the temperature is very low (-260$^0$C). The chance of this occurring would be extremely remote as it would require a fish to be at or above the water surface at the direct point of LNG spill. Some cooling of the upper water layers closest to the LNG spill would be expected, but would not likely cause the overall water column to cool to the point of affecting the fish species in the water, given the ambient water temperatures in the transit route. If the vapor from an LNG spill were to come in contact with an ignition source, the resulting fire would burn back to the spill source and would affect species on the water or in the area that come in direct contact with the fire. Fish in the water would not be affected as the fire would be above the water in the area of the spill where the vaporized LNG is flammable. LNG density as a gas (mostly methane) is less than air and would rise above the water as it turns to vapor. In either case of lower or higher water temperatures based on the spill scenario, mobile fish species would move out of the area until the water temperatures return to normal.

Additionally the chances of an LNG spill are remote. Considering the double-hulled construction of LNG carriers and the outstanding operating and safety record of LNG carriers, the probability of any incidents that could result in the loss of LNG cargo, are extremely low. LNG carriers have been operating commercially since 1959. Since then there have been more than 38,000 LNG carrier voyages covering more than 60 million miles and transported a total of 1.5 billion cubic meters of LNG. Currently, approximately 196 LNG carriers safely transport more than 287 million cubic meters of LNG annually to ports around the world. There have been approximately 11 reportable incidents between 1979 and 2006 worldwide. Since LNG has not been transported to or from the Pacific Northwest, no data are available. However, due to the double hulls of LNG carriers, none of the incidents that have occurred with LNG carriers have resulted in the loss of LNG cargo or other significant petroleum based spills.

Additional details of effects have been included for mammals (whales in sections 4.2.1.3, 4.2.2.3, 4.2.3.3, 4.2.4.3, 4.2.5.3, 4.2.6.3, and 4.2.7.3), reptiles (sea turtles in sections 4.4.1.3, 4.4.2.3, 4.4.3.3, and 4.4.4.3), and fish (Southern DPS North American green sturgeon in section

4.5.1.3, Southern DPS Pacific eulachon in section 4.5.2.3, and Oregon Coast coho salmon ESU in section 4.5.4.3).

**Conservation Measures**

Measures to minimize effects to listed whales would likewise minimize potential accidental spills and releases at sea which could affect EFH within the EEZ analysis area. Those measures include 1) LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port; and 2) spills or releases of LNG at sea would not cause the water column to cool to the point of affecting highly migratory fish species in the water.

### 6.1.3 Effects Determination

The proposed action **would not adversely affect** EFH for highly migratory species because accidental spills and releases at sea, if they should occur, are not expected to diminish water quality within the EEZ analysis area.

## 6.2 COASTAL PELAGIC SPECIES

### 6.2.1 Essential Fish Habitat

Coastal pelagic species also occur from the ocean surface to depths of 1,000 m (547 fm) within the EEZ analysis area but distributions of several species tend to be in relatively shallow water closer to shore, including the estuarine analysis area. Coastal pelagic species include four fin fish – northern anchovy, Pacific sardine, Pacific (chub) mackerel, and jack mackerel – and the invertebrate market squid. Coastal pelagic species occur near the ocean surface and are not associated with substrates. EFH for coastal pelagic species also includes portions of the water column where sea surface temperatures range between 50°F (near the United States/Mexico maritime boundary) and 79°F (seasonally and annually variable) (PFMC, 2006).

All life stages for each of the coastal pelagic species are expected to occur within the EEZ analysis area and adults of most species are expected within the estuarine analysis area (table 6.2.1-1). Northern anchovies are the only coastal pelagic species for which all life stages are likely to utilize the estuarine analysis area (table 6.2.1-1). Site F, off the mouth of Coos Bay, also contains at least juvenile and adult stages of both northern anchovy and Pacific mackerel, based primarily on trawl samples at this dredge discharge site (table 6.2.1-1) Within the Coos Bay estuary, northern anchovies are expected to be transient users of eelgrass (Phillips 1984). Eelgrass provides indirect benefits to these species by contributing to productivity in the estuary, and eelgrass drift may provide cover for coastal pelagic species (Nightengale and Simenstad, 2001).

**Table 6.2.1-1**
**Coastal Pelagic Fish Species Managed by the Pacific Fishery Management Council For Which Essential Fish Habitat Has Been Identified and May Occur Within the Proposed Action Estuarine Analysis Area and EEZ Analysis Area**

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area | | | | Distribution within EEZ Analysis Area | | | | Site F Presence [2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs | Larvae | Juvenile | Adult | Eggs | Larvae | Juvenile | Adult | Juvenile | Adult |
| Pacific sardine Sardinops sagax | Pelagic commercially-harvested schooling fish that inhabits coastal subtropical and temperate waters. Occur in estuaries, but more commonly near shore and offshore. Highly mobile, moving seasonally along the coast. More abundant in Oregon during the summer and warm water years. Spawning occurs year-round (spatially and seasonally dependent on temperature) in loosely aggregated schools in the upper 50 yards of the water column, generally 30-90 miles offshore. Major prey species for commercially valuable and endangered fish species. | | | ? | X | X | X | X | X | | |
| Northern anchovy Engraulis mordax | Often in schools near the surface. Spawning occurs every month, especially in late winter and early spring (February – April). Overwinter in mixed layer temperatures. Nearshore habitats support most of the juvenile population. Eat phytoplankton or zooplankton by either filter-feeding or biting. Considered a valuable source of food for endangered fish and bird species. | X | X | X | X | X | X | X | X | X | X |
| Pacific (chub) mackerel Scomber japonicus | Pelagic for all life stages. Adults commonly found in shallow banks with increased abundance from July to November. Spawning peaks April through July in California. | | | ? | ? | X | X | X | X | ? | ? |
| Jack Mackerel Trachurus symmetricus | Pelagic schooling fish that range widely. Diet on large zooplankton, juvenile squid, and anchovy. They are more available on offshore banks in late spring, summer and early fall than during the remainder of the year. Much of their range lies outside the 200 mile EEZ. | | | | X | X | X | X | X | | |
| Market Squid Loligo opalescens | Prefer oceanic salinities and rarely found in bays, estuaries, or near river mouths. Spawning occurs year-round. They are important as forage foods for many species. | | X | X | X | X | X | X | X | | |

[1] PFMC, 2007b
[2] Source Hinton and Emmett, 1994, and assumed based on species characteristics

## 6.2.2 Analysis of Effects

Analyses of effects to EFH for coastal pelagic species by the proposed action have been provided in multiple sections in the BA. For EFH within the EEZ analysis area, Project effects are expected to be associated with accidental spills and releases at sea by LNG carriers transiting at least 50 nmi offshore within the EEZ from south to north (from San Diego to Coos Bay) and from LNG carriers approaching Coos Bay from the west through the 200 nmi-wide EEZ. These effects have been discussed under Highly Migratory species in Section 6.2.1 above. Additional details of effects have been included for mammals (whales in sections 4.2.1.3, 4.2.2.3, 4.2.3.3, 4.2.4.3, 4.2.5.3, 4.2.6.3, and 4.2.7.3), reptiles (sea turtles in sections 4.4.1.3, 4.4.2.3, 4.4.3.3, and 4.4.4.3), and fish (Southern DPS North American green sturgeon in section 4.5.1.3, Southern DPS Pacific eulachon in section 4.5.2.3, and Oregon Coast coho salmon ESU in section 4.5.4.3).

Within the estuarine analysis area of Coos Bay, Project effects to coastal pelagic species are expected to be associated with effects to eelgrass habitats; short-term turbidity produced by construction of LNG carrier berth, access channel, and Pacific Connector pipeline; entrainment of larvae, juveniles and adults by hydraulic dredging and ballast and cooling water expulsion; acoustic effects from ship noise, effects of operational lighting and wakes associated with LNG carriers; effects of facilitated predation by shading from over-water structures; introduction of exotic species; and windblown sand from stockpiles. Those effects have been included for Southern DPS green sturgeon in section 4.5.1.3 and Oregon Coast ESU coho salmon in section 4.5.4.3.

Eelgrass Habitat

Construction of the pipeline across the Haynes Inlet of Coos Bay estuary would span 2.5 miles and disturb approximately 0.068 mile of eelgrass or 2.8 percent of that amount, most of which classified as low-density eelgrass beds (see discussion in Section 4.5.4.3, Oregon Coast coho). Construction of the pipeline across the estuary is planned from October 1 through February 15 following ODFW’s recommendation. During most of that period, eelgrass in Coos Bay would be dormant, coinciding with low temperatures and short photoperiods (Fonseca et al., 1998).

Ellis Ecological Services, Inc. (2013) conducted a survey of eelgrass beds within Coos Bay along the pipeline route. Based on the survey of the route in 2013, there was 5.0 acres of eelgrass beds that will be directly affected by the construction right-of-way (including temporary extra work areas - TEWAs). Eelgrass beds were placed into three categories based on density: low, medium, and high. Most of the area affected would be low density, and none were categorized as high-density eelgrass. Approximately 0.1 percent of the total eelgrass beds present in Coos Bay would be directly disturbed from pipeline construction across Haynes Inlet (Ellis Ecological Services, 2013).

Entrainment and Impingement

LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is expected that a high portion of juvenile larval stages of fish and invertebrates entrained or impinged would suffer mortality. Ballast and cooling water intake could be highly variable depending on multiple factors but could range from about 64 to 285 thousand $m^3$ per vessel offloading trip. The details of how entrainment may affect coastal pelagic species is similar to that of Groundfish EFH resources (Section 6.3.2), which is presented in more detail. Juvenile or larval fish would need to be present in the slip area near the LNG carrier’s intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen. Generally the total water intake would occur over a 24-hour period during each loading period, about 90 times per year.

The LNG ships will also re-circulate water for engine cooling while loading LNG at the berth. The power requirements for loading LNG in the export mode are less than those for unloading LNG in the import mode because the LNG carrier does not have to use on board LNG pumps to handle LNG cargo; hence both the LNG carrier engine requirement and the required amount of cooling water flow are reduced. For reasons discussed in Section 4.5.1.3, green sturgeon, it is anticipated that the effect associated with the intake of cooling water will be minimal. The intake velocities for the cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals and reptiles or amphibians) will be impinged on the intake screen. Overall, the loss of marine fish including coastal pelagic fish and their prey resources, relative to numbers in Coos Bay, would be very small, but lacking specific data is difficult to estimate.

Stranding from Ship Wake and Propeller Wash

Fish stranding can occur when fish become caught in a vessel's wake and are deposited on shore by the wave generated by the vessel wake. Stranding typically results in mortality unless another wave carries the fish back into the water. A series of interlinked factors act together to produce stranding during vessel traffic and may include water surface elevations, with low tides more likely to result in strandings than high tide; beach slope, with strandings more likely on low gradients than high; wake characteristics influenced by vessel size, hull form, depth underwater (draught), and speed; and biological factors, such as numbers of small fish present near the shoreline and whether fish are strong swimmers or not (see discussion in Section 4.5.1.3, green sturgeon). Size of juvenile coho in the estuary are expected to be comparable to sizes of juvenile chinook salmon (<9 cm) which became stranded by ship wakes in the Columbia River (Pearson et al., 2006); juvenile coho may be susceptible to stranding by ship wake.

Ship wakes produced by deep-draft vessels traveling at speeds greater than the estimates for LNG carrier speeds within the Coos Bay estuary have been observed to cause occasional stranding of juvenile salmon (Pearson et al., 2006); however, no strandings were observed as a result of vessels traveling at speeds under 9 knots (10.4 mph). The hull geometry of the LNG carriers is such that bow wakes are minimized, especially at the slower speeds of 4 to 6 knots that would occur during most of the transit route through Coos Bay. Therefore, the LNG carriers would be traveling at speeds less than that observed (Pearson et al., 2006) to cause stranding. In models and research conducted by the JCEP, wave heights produced by LNG carrier traffic would not exceed that of normal conditions in Coos Bay and overall waves would contribute to a small portion of the total waves that occur in the bay. In addition, the LNG carriers would be arriving and leaving at high tide, which is a period when gently sloping beaches are mostly covered and less likely dewatered from waves. Considering that LNG marine traffic would enter and leave at high slack tide, have low vessel speeds, and wave height would be in normal range, it appears unlikely that the Project would contribute to stranding of coastal pelagic species within Coos Bay.

Turbidity Effects –Propeller Wash and Ship Wake

Propeller wash from LNG vessels and tug boat propellers associated with the Project, as well as ship wakes breaking on shore, could cause increased erosion along the shoreline and re-suspend the eroded material within the water column. This may affect the diversity and health of the benthic community regarding food availability and feeding conditions for foraging and migrating fish species (see discussion in Section 4.5.1.3, green sturgeon).

Hydrodynamic effects from pressure field velocities measured along the sensitive shoreline from existing deep-draft vessels exceed the pressure field velocities that may be generated by future LNG carriers. The USCG has mandated that all LNG carriers be escorted by a minimum of two tractor tugs which allows the LNG carrier to transit at a lower speed than the existing vessels which transit without tug assist. Vessel velocity, rather than size, has a much greater impact on the amplitude of the pressure wave which would be less impact on coastal process at the sensitive shoreline by LNG carriers than from the existing deep-draft vessels using the estuary.

The results of the swash transport calculations generated by vessel wake effects (see discussion in Section 4.5.1.3, green sturgeon) show a small increase in wake-generated swash sediment transport at the areas of interest due to LNG carriers. The results show that the increase in swash sediment transport from combined inbound and outbound carrier traffic would not exceed six percent at Pigeon Point, eight percent at Clam Island, and five percent at the Airport sensitive shorelines. The total sediment transport for future inbound and outbound LNG carrier traffic will be less than eight percent of the existing and future wind-wave swash sediment transport. The estimated increase in swash sediment transport due to the LNG carrier traffic is a small fraction of the swash sediment transport due to the natural wind-wave conditions. This increase most likely would not be detected in a general balance of swash sediment transport due to yearly variability of wind-wave conditions and swash sediment transport. Based on these results it is not anticipated that suspended sediment generated by propeller wash and ship wake will be adverse effects to coastal pelagic species within Coos Bay.

Underwater Noise

Underwater noise may affect coastal pelagic species. LNG carriers transiting the EEZ would produce underwater noise. Underwater noise levels are expected to vary by ship type and also by vessel length, gross tonnage, vessel speed, and to some extent, vessel age - older vessels tended to be louder than newer vessels (see discussion in Section 4.2.1.3 for blue whales). Based on the general trend for higher underwater noise generated by larger vessels (McKenna et al., 2013), it is possible for many of the LNG carriers that would utilize the Jordan Cove terminal to generate more noise than the loudest container ship reported by McKenna et al. (2013), reported at >188 dB re: 1 µPa @ 1 meter.

State agencies in Washington, Oregon, and California, along with federal agencies have developed interim noise exposure threshold criteria for pile driving effects on fish (Washington State Department of Transportation, 2011a; Popper et al., 2006). Although ship noise reported by McKenna et al. (2013) is not directly equivalent to pile driving noise (see discussions in Section 4.5.4.3 for Oregon Coast coho), or the interim noise exposure criteria, any LNG carrier noise generated in the EEZ would be below thresholds for adverse effects to fish. Noise from LNG carriers would likely increase the background noise within the EEZ, and which is occurring globally (Slabbekoorn et al., 2010). Fish in the EEZ or Coos Bay Estuary might detect noise from LNG carriers but are not expected to be adversely affected by the projected since vessel traffic due to LNG carries is expected to add to the projected vessel traffic in 2017-2018 by 1.2 percent increase in shipping in coastal Oregon and Washington over the 2017-2018 estimates (see discussion in Section 4.2.1.3 for blue whales). Underwater noise generated by LNG carriers transiting the EEZ and estuary is not expected to adversely affect coastal pelagic species within Coos Bay.

Effects of Operational Lighting

Localized changes in light regime have been shown to affect fish species behavior in a variety of ways (see discussion in Section 4.5.1.3, green sturgeon). Lighting at the LNG Terminal and onshore facilities would likely include a mixture of low-power fluorescent lighting and higher intensity security lighting that would primarily be located on shore, in and adjacent to the slip. When an LNG carrier is not in the berth, the lighting would be reduced to that required for security. It would be focused upon the structures and not be in proximity to the water so as to serve as an attractant or deterrent to fish species. When an LNG carrier is at the berth, it would physically block the lighting on the berth from the slip waters and, due to its proximity to the slip wall, would block the fish from getting too close to the lighting on the berth. Lighting used would be similar to that already in place at other Coos Bay facilities.

Lighting on the tug dock would be low intensity lighting for safety, providing sufficient light for personnel movements on the trestle out to the tug berth and for movement on the berth itself. The reduced lighting levels near the water would reduce or eliminate any behavioral effects to fish in the Project vicinity. Increased lighting from facility operations is not expected to adversely affect coastal pelagic species within Coos Bay.

Water Cooling

The LNG ships will re-circulate water for engine cooling while loading LNG at the berth. The engines will be running to provide power for standard hotelling activities as well as running the ballast water pumps (see discussion discussion in Section 4.5.1.3, green sturgeon). The total gross waste heat discharged into the slip from the cooling water stream will be due primarily from the hotelling operations (including the power required to run the ballast water discharge pumps) as the shore side LNG pumps will be used to transfer the LNG from the LNG storage tanks to the LNG carrier.

Because of the extreme differential of the temperature of the cargo in the LNG carrier (-260$^{o}$F) and that of the surrounding air and water (nominally 45$^{o}$F) there is a constant uptake of heat by the LNG carrier from its surroundings. Analysis and numerical modeling were performed to identify potential impacts of LNG carrier cooling water discharge on water quality in the slip and adjacent area of Coos Bay. The modeling was initially performed with two different numerical models: the 3-D UM3 model and the DKHW model. The models simulate hydrodynamic mixing processes of submerged discharges and predict temperature fields and dispersion of non-conserved substances in ambient water bodies. Cooling water numerical modeling requires input of steady-state flow velocity in the modeling domain. For cooling water modeling, two steady state ambient flow velocities were assumed and used further in the analysis: high velocity = 0.32 ft/sec and typical velocity = 0.16 ft/sec.

The following conservative assumptions were used in the analysis. The assumptions are conservative in that a steam powered ship was used. The steam powered ships tend to be older than the newer more modern dual fuel diesel electric ships that require lower quantities of cooling water.

- LNG carriers are steam-powered with a cargo capacity of 148,000 m$^3$.
- Maximum pump capacity for main condenser cooling is 10,000 m$^3$/hr (44,030 gpm) and maximum pump capacity for LNG carrier's equipment cooling is 3,000 m$^3$/hr

(13,209 gpm). Total capacity being used at a given time is typically in the range of 6,300 $m^3$/hr (27,739 gpm). For the analysis, 6,300 $m^3$/hr (27,739 gpm) was used.

- Diameter of the horizontal discharge port is 1.1 meters (3.6 feet).
- Depth of discharge port below still water is 10.0 meters (32.8 feet).
- Maximum heating of cooling water at time of discharge is 3 ºC (5.4 ºF) above ambient temperature.

Results of the modeling showed that for typical ambient flow conditions at a distance of 50 feet from the discharge point (LNG carrier sea chest), temperatures will not exceed 0.3 ºC (0.54 ºF) above the ambient temperature. This difference will decrease with further distance. Water cooling while loading LNG at the berth by LNG is not expected to adversely affect coastal pelagic species within Coos Bay.

Turbidity Effects – Slip and Access Channel

Construction of the LNG terminal slip will require the excavation and dredging of approximately 4.3 million cubic yards (cy) of material (2.3 million cy excavated and 2.0 million cy dredged) and the construction of the access channel will require the dredging of 1.3 million cy for a total of approximately 5.6 million cy (see discussion in Section 4.5.1.3, green sturgeon). The majority of the dredging for the slip will be conducted in isolation from the waters of Coos Bay. While the future slip area is being excavated and dredged, a berm will be maintained to provide complete separation of the excavation and dredging activities from the bay, resulting in no turbidity being released to the waters of Coos Bay. Dredging of the berm separating the portion of slip from the bay and the access channel will result in temporary siltation and sedimentation impacts similar to those that currently occur during maintenance dredging activities. The dredging activity will occur only during the in-water work window established by ODFW.

On average, the USACE removes approximately 550,000 cy from the bar, 200,000 cy from Channel Mile (CM) 2-12 and 150,000 cy from CM 12-15 each year. In comparison, approximately 500,000 cy will be removed in the water during the removal of the berm and dredging of the access channel. Since the duration of the dredging in the bay will be 4-6 months and only during the in-water work window from October 1 to February 15 (ODFW, 2008), the minimal amount of turbidity created will be relatively short term and localized. Turbidity modeling demonstrated that turbidity levels dropped to near background levels beyond 200 meters (660 feet) of the dredging activity.

Turbidity was modeled for the new construction and maintenance dredging operations based on the anticipated geotechnical and environmental conditions for this project using the United States Army Corps of Engineers (USACE) DREDGE model and two dimensional numerical model Mike21 (see discussion in Section 4.5.1.3, green sturgeon). During the project construction period, the maximum modeled suspended sediment concentrations (primarily sand) produced by the DREDGE model for an open “clamshell” dredge were less than 6,000 mg/L at the dredge location and decreased to less than 50 mg/L at 200 m (approximately 660 feet). For the hydraulic cutterhead dredge the TSS levels were significantly lower with maximum of 500 mg/L in the vicinity of the dredge. The TSS concentrations decreased to a maximum of 14 mg/L at 60 meters (200 ft) away from the dredge vicinity.

During the project maintenance dredging period, the dredged material is expected to be primarily fines (mud, clay, silt). Concentration predicted with the DREDGE model for the open “clamshell” dredge were lower than during the construction stage with the maximum of 830 mg/l in vicinity of the dredge and decreasing to 125 mg/l at 200 m (approximately 660 feet). The results from the Mike21 simulations show that distribution of the generated plume depends on location of the dredge in the channel and basin area. For dredging with an open “clamshell” dredge in the channel the generated sediment plume (concentration higher than 150 mg/l) can move up to 1.2–1.9 miles from the dredging location at highest ebb or flood currents; however, the duration of such entrainment is limited by not more than a two hour period and the time average concentrations do not exceed natural ambient concentrations (10–30 mg/l) outside the dredging area.

During maintenance dredging with an open “clamshell” dredge, the maximum concentrations in the generated plume do not exceed 50 mg/L. Estuarine environments often have moderately elevated suspended sediment concentrations (i.e. >15 mg/L) and they are very productive (Gregory and Northcote, 1993). The amount of sediment produced by open cutting depends on multiple characteristics at the construction site including depth and width of the waterbody (effects mixing of the sediment plume in the water column), current velocity and local turbulence at the site and downstream, concentrations of suspended sediment initially at the site and at some distance downstream, particle diameter, specific weight, and settling velocity of the excavated and backfilled materials (Ritter, 1984; Reid et al., 2004). Based on sediment transport modeling, dispersal of the exposed and disturbed sediments will be very minor in intertidal areas of Haynes Inlet due to the low water velocities and sediment composition in that area. Based on this information it is not anticipated that turbidity generation at the dredging site will be an adverse affect to coastal pelagic species within Coos Bay.

Additionally, discharge of maintenance dredging spoils, at the EPA-approved Site F clean maintenance dredge spoils discharge location off the mouth of Coos Bay, would have Project effects associated with turbidity plume and short-term burial of potential prey resources. The turbidity plume would cause short-term avoidance (e.g., hours) of the discharge area, and briefly reduce primary production. Some short-term loss of benthic invertebrates from burial (weeks/months) would occur but the extent of the area would be extremely small relative to amount of this habitat available. Also, the site is low in diversity of organisms. The site has been approved partly for its minimal effects to recourses from discharge of clean (hazardous substance free) sediment.

**Conservation Measures**

Measures to minimize effects to listed whales would likewise minimize potential accidental spills and releases at sea which could affect EFH within the EEZ analysis area. Those measures include: 1) LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port, and 2) spills or releases of LNG at sea would not cause the water column to cool to the point of affecting coastal pelagic fish species in the water.

Measures to minimize effects to listed coho salmon and green sturgeon would likewise minimize potential effects to EFH within the estuarine analysis area. Coastal pelagic species are not estuarine resident species and utilize Coos Bay on a seasonal basis, primarily in summer months. Construction is planned within the period from October 1 through February 15 following ODFW’s recommendation and would coincide with a period when fewest coastal pelagic species are expected to be present. Effects to food resources and eelgrass habitats would be minimized by construction from October 1 through February 15 when eelgrass within Coos Bay is dormant.

Turbidity within Coos Bay and Haynes Inlet, produced by construction of the slip, access channel, and Pacific Connector pipeline would be short-term, relatively confined to elongated plumes, and is expected to quickly dissipate to turbidity levels generally associated with winter tides and storm wave action.

### 6.2.3 Effects Determination

The proposed action **may adversely affect** EFH for coastal pelagic species in the short term from loss of eelgrass areas until the mitigation beds and pipeline areas regrowth occurs. Also the disposal of dredge material at Site F would temporarily bury potential food resources for coastal pelagic fish. Additionally, juvenile larval stages of fish could be entrained or impinged and suffer mortality. Accidental spills and releases at sea, if they should occur, and Project construction within the Coos Bay estuary are not expected to diminish water quality or substrates within the EEZ analysis area or the estuarine analysis area.

## 6.3 GROUNDFISH

### 6.3.1 Essential Fish Habitat

There are over 80 species of groundfish, most of which live at or near the ocean bottom, and are managed under the Pacific Coast Groundfish Management Plan (PFMC, 2008). Many groundfish species occur within the EEZ and estuarine analysis areas. The Groundfish Fishery Management Plan includes EFH within the waters and substrates at "depths less than or equal to 3,500 m (1,914 fm) to mean higher high water level (MHHW) or the upriver extent of saltwater intrusion, defined as upstream and landward to where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow" (PFMC, 2005).

Not every groundfish species is expected to occur within the proposed action estuarine analysis area and/or the EEZ analysis area. Species' distributions, based on mapped habitat suitability probabilities for spatial occurrences by different life stages (Appendix B-4 in PFMC 2006), were used to evaluate likely species' occurrences within either analysis area. The results of that evaluation are summarized in table 6.3.1-1.

Site F, centered 1.6 miles off the mouth of Coos Bay, also is inhabited by groundfish, including an estimated 18 species, with some adult and juvenile stages assumed or known to be present. This includes 5 species of rockfish and 10 of flatfish, including speckled sanddab, which was the most abundant in trawl surveys of the area (Hinton and Emmett, 1994, see table 6.2.1-1).

**Table 6.3.1-1**
**Groundfish Species Managed by the Pacific Fishery Management Council for which Essential Fish Habitat Has Been Identified and May Occur Within the Proposed Action Estuarine Analysis Area and EEZ Analysis Area**

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| Soupfin shark *Galeorhinus galeus* | Coastal-pelagic species associated with the bottom, inhabiting bays, muddy shallows and offshore up to 225 fathoms (fm). Adult males occur in deeper waters and females usually at less than 30 fm. From dense shoals, migrating north in the summer and south in the winter. Mating occurs in the spring. | | | L | M | | | H | H | | |
| Spiny dogfish *Squalus acanthias* | An inner shelf-mesobenthal species with a depth range of 0 to 677 fm. Common in inland seas and shallow bays. Seasonal migrations occur within preferred temperature range. | | | L | H | | | H | H | | |
| Leopard shark *Triakis semifasciata* | Inhabits enclosed muddy bays, flat sandy areas, mud flats, sandy and muddy bottoms strewn with rock near reefs and kelp beds. Common in littoral waters and around jetties and piers. Pupping and feeding/rearing grounds in estuaries and shallow coast waters. Found at depths up to 50 fm, common at 0 to 2 fm. | | | H | H | | | H | H | | |
| Big skate *Raja binoculata* | Inhabits inner and outer shelf areas, particularly on soft bottom sediments. Either associated with silty sediment, or with sediment consisting of a mixture of mud, sand, gravel, and cobble. Found at depths up to 55 fm. | U | | U | U | H | | H | H | | X |
| California skate *Raja inornata* | Usually occur in habitats with muddy bottoms. Juveniles are associated with soft bottom sediments. Common in inshore waters and shallow bays; sometimes in deep water. | H | | U | H | H | | H | H | | |
| Longnose skate *Raja rhina* | Occurs on the bottom inner and outer shelf areas, usually less than about 175 fathoms deep. Juveniles and adults are associated with soft bottom sediments with combinations of mud and cobble near high relief structures. | L | | L | U | H | | H | H | | |
| Pacific cod *Gadus macrocephalus* | Adults and juveniles prefer mud, sand, and clay. Usually found near bottom, with a wide depth range of 7 to 300 fm. Spawning occurs from the late fall to early spring. Larvae and small juveniles are pelagic, large juveniles and adults are parademersal. | L | U | U | U | H | H | M | L | | X |
| Pacific grenadier (rattail) *Coryphaenoides acrolepis* | Commercial species that inhabits the continental slope. Highest densities occur on the sandy bottoms of abyssal plains. Migrations have not been documented, but larger fish are found in deeper water. Larvae are pelagic | H | H | U | U | H | H | L | H | | |
| Pacific whiting (hake) *Merluccius productus* | Inhabits euhaline waters of the continental shelf. Juveniles reside in shallow coastal waters, bays, and inland seas and move deeper as they get older. Highly migratory. Spawns from December through March, perhaps more than once per season. | U | | U | H | H | | U | H | | |
| Spotted ratfish *Hydrolagus colliei* | Found near the bottom, from close inshore to about 500 fm. Abundant in cold waters at moderate depths. Feed on mollusks, crustaceans and fishes; also echinoderms and worms. Fishers are reputed to fear the jaws of the ratfish more than they do the dorsal spine. | U | | U | U | H | | H | H | | |
| Rougheye rockfish | Usually found on the bottom in deep, offshore waters with soft substrata, frequenting | | | U | U | | | H | L | | |

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| *Sebastes aleutianus* | boulders and at slopes greater than 20 degrees. Depths range from 14 to 478 fm. | | | | | | | | | | |
| Pacific Ocean Perch *Sebastes alutus* | This commercially important schooling fish is abundant offshore, often found along submarine canyons, depressions, pinnacles, and seamounts. Depth ranges from surface to 451 fm (most occur in 80 to 200 fm). | | U | U | U | | H | H | M | | |
| Kelp rockfish *Sebastes atrovirens* | Inhabiting shallow waters, adults are primarily residential in kelp forests and on the bottom near rocky areas and are considered parademersal. Common at depths of 5 to 7 fm, but found up to 25 fm with a distribution mostly off the coast of California. | | | | U | | | | H | | |
| Brown rockfish *Sebastes auriculatus* | Display strong reef fidelity with a distribution from Gulf of Alaska to Baja California. Bottom dwellers of shallow waters. Juveniles usually live in shallower water than adults. Maintain small home ranges on high-relief rocky reefs and common at less than 55 fm. | — | — | — | — | — | — | — | — | | |
| Aurora rockfish *Sebastes aurora* | Adults and juveniles are found in soft- and hard- bottom habitats on the continental slope/basin. Distribution ranges from Vancouver Island, British Columbia to Cedros Island, Baja California. Depth ranges from 68 to 420 fm. | | U | U | U | | H | H | H | | |
| Redbanded rockfish *Sebastes babcocki* | Thought to associate with both soft substrata and hard-bottom substrata, and in crevices between boulders. This deepwater species has been caught in the 50 to 342 fm range and is found from Amchitka Island, Alaska to San Diego, California. | | | | U | | | | H | | |
| Silvergray rockfish *Sebastes brevispinis* | Inhabits the outer shelf-mesobenthal zone on a variety of rocky-bottom habitats. Found at the surface to 205 fm, from the Bering Sea to Baja California. | | | | U | | | | L | | |
| Shortraker rockfish *Sebastes borealiz* | Deepwater species inhabiting the middle shelf to the mesobenthal slope and common on the bottom from 100 to 478 fm. Distribution from the Aleutian Islands and down to Point Conception, California | | | | U | | | | H | | |
| Gopher rockfish *Sebastes carnatus* | These are shallow-water benthic fish that inhabit rocky reefs, kelp beds, and sandy areas near reefs. Common depth from surface to 9 fm and mostly limited to the California coast. | | U | U | U | | H | H | H | | |
| Copper rockfish *Sebastes caurinus* | Occur in nearshore waters, from the surface to 100 fm. Found on or near natural rocky reefs, boulder fields, artificial reefs, oil platforms and rockpiles; usually directly on the bottom with reefs or kelp bed areas. May move inshore to release their young. | | | | U | | | | H | | |
| Greenspotted rockfish *Sebastes chlorostictus* | Associated with soft-bottom habitats and also with rock outcrops, reefs, caves, and crevices. Range is from Washington to Baja California with depths 27-150 fm | | | U | U | | | H | L | | |
| Black and yellow rockfish *Sebastes chrysomelas* | Inhabits holes and crevices in rocky areas. Found in intertidal areas and depths to 20 fm. | | U | U | U | | H | M | M | | |
| Starry rockfish *Sebastes constellatus* | Usually found on reefs. Viviparous, with planktonic larvae and pelagic juvenlies. Limited distribution along the California coast from north of San Franciscon to Baja. Depth ranges from 13 – 150 fm. | | | U | U | | | U | M | | |
| Darkblotched rockfish *Sebastes crameri* | Adults are associated with muddy areas near cobble or boulders. Found at depths of 14 to 328 fm from the Bering Sea to Catalina Island, California. | | U | U | U | | H | H | H | | |

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| Splitnose rockfish *Sebastes diploproa* | Associated with offshore mud habitats near isolated rock cobble and boulder fields. Most common at 50 to 250 fm. Young occur in shallow water, often at the surface under drifting kelp, algae, and seagrass. Emigration from surface waters occurs primarily in May and June. | | H | U | U | | H | H | H | | |
| Greenstriped rockfish *Sebastes elongatus* | Prefers a mixture of mud and rock bottom and found at depths of 14 to 232 fm. Distribution from Alaska to Baja California. | | | U | U | | | H | H | | |
| Widow rockfish *Sebastes entomelas* | All life stages are pelagic, but older juveniles and adults are associated with hard bottoms among rocks. This important commercial fish ranges from near Kodiak Island, Alaska to Todos Santos Bay in Baja California; from surface to 300 fm. | | | U | U | | | H | M | | |
| Pink rockfish *Sebastes eos* | Demersal, inhabiting rocky bottoms in isolated areas from Southern Oregon to Central Baja California. Depth range from 40 to 200 fm. | | | | U | | | | H | | |
| Yellowtail rockfish *Sebastes flavidus* | They are considered a middle shelf-mesobenthal species most common near the bottom. This schooling rockfish has a range from Unalaska Island, Alaska to San Diego, California and is found from the surface down to 300 fm. | | | U | U | | | H | H | | X |
| Chilipepper rockfish *Sebastes goodei* | Most commonly associated with deep, high-relief rocky areas and along cliffs. A commercially important species in California found at the surface to 232 fm. | | | L | U | | | H | H | X | |
| Rosethorn rockfish *Sebastes helvomaculatus* | Adults are mostly found in muddy areas adjacent to boulders, cobble, or rock. Depth range from 40 to 300 fm. Limited distribution from Alaska to Baja California. | | | | U | | | | L | | |
| Squarespot *rockfish* *Sebastes hopkinsi* | They are reef-associated, in areas with cobble and have a depth range of 2 to 120 fm. | | | U | U | | | H | H | | |
| Shortbelly rockfish *Sebastes jordani* | Can be found in large schools, offshore and off smooth bottom areas near the shelf break and sharp drop-offs. Depths of 0 to 191 fm. | | | | U | | | | H | | |
| Cowcod *Sebastes levi* | Adults are primarily found over high-relief rocky areas. Juveniles prefer soft bottom habitats and those consisting of low-relief rocks. Mostly found off California at depths of 11 to 200 fm. | | | U | U | | | H | L-M | | |
| Quillback rockfish *Sebastes maliger* | A common, shallow-water benthic species, from subtidal depths to 150 fm. Young occur along shores and adults usually in deeper waters. | | | U | | | | H | | | |
| Black rockfish *Sebastes melanops* | Adults inhabit midwater and surface areas over-high relief rocky reefs, in and around kelp beds, boulder fields, pinnacles, and artificial reefs. Larvae and young juveniles are pelagic. | | | M | U | | | H | H | | |
| Blackgill rockfish *Sebastes melanostomus* | An aggregate species, usually inhabiting deep rocky-or hard-bottom habitats along steep dropoffs. Larvae inhabit the upper mixed layer of water, juveniles are pelagic (associated with flat bottoms) and migrate shoreward. Spawn from January to June. | | U | U | U | | H | H | H | | |
| Vermilion rockfish *Sebastes miniatus* | Found over rocks, along drop-offs, and over hard bottom. Adults inhabit rocky reefs at depths of 8 to 150 fm. Larvae are pelagic and found near the surface for three to four | | | | U | | | | H | X | |

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| | months, and are frequently associated with algae. | | | | | | | | | | |
| Blue rockfish *Sebastes mystinus* | Strong affinity for kelp forests. Adults inhabit midwater and surface areas around high relief rocky areas, within and round the kelp colony, and around artificial reefs. Common depth range of 33 to 167 fm. Larvae and early stage juveniles are pelagic, and older individuals are semi-demersal or demersal. | | L | U | U | | H | H | H | | |
| China rockfish *Sebastes nebulosus* | Occur both inshore and along the open coast from 1 to 75 fm. Most Juveniles are pelagic, but adults are sedentary, associated with rocky reefs or cobble. They are residential and associated the bottom, crevices, and kelp beds. | | | U | U | | | H | H | | |
| Tiger rockfish *Sebastes nigrocinctus* | Found at depths of 5 to 150 fm. Juveniles are pelagic, common near water surface with algae mats and plants. Adults are semi-demersal. Often found in caves, off cliffs, and on floors. Solitary, may be territorial. | | | | U | | | | H | | |
| Speckled rockfish *Sebastes ovalis* | They occur in midwater over rocks and are also found near the bottom on reefs and among boulders. Depths range from 17 to 200 fm. | | | U | U | | | H | H | | |
| Bocaccio *Sebastes paucispinis* | Benthic juveniles and adults are found around vertical relief; over sand-mud bottoms with little relief; and in areas with mixtures of rocks and boulders, rock ridges, and rocks and boulders among mud. Most common at depths of 40 to 175 fm. Larvae and small juveniles are pelagic; large juveniles and adults are semi-demersal. | | L | U | U | | H | H | M | X | |
| Canary rockfish *Sebastes pinniger* | Most abundant above hard bottoms, usually 50 to 110 fm. In its southern range, it is a reef associated species. Larvae and juveniles are pelagic. Young of the year can be found in tide pools, and can be associated with artificial reefs and interfaces between mud and rock. Juveniles descend deeper as they mature. Capable of large latitudinal movements. | | | U | U | | | H | H | | |
| Redstripe rockfish *Sebastes prorigger* | Generally found off the bottom over both high- and low-relief rocky areas. Depths range from 7 to 232 fm (most common at 70 to 150 fm.) | | | | U | | | | H | | |
| Grass rockfish *Sebastes rastrelliger* | Common in nearshore rocky areas, along jetties, and in kelp and eelgrass. Residential species at shallow depths. | | | U | U | | | H | H | | |
| Yellowmouth rockfish *Sebastes reedi* | Found over rough bottoms from the Northern Gulf of Alaska to the south of Crecent City, California, with a depth range from 75 to 200 fm. More common at 100 to 200 fm. | | | U | U | | | H | M | | |
| Rosy rockfish *Sebastes rosaceus* | These fish are solitary bottom-dwellers found over hard, high-relief areas and at low-relief spots among rocks and sand. Depths range from 27 to 150 fm. | | | U | U | | | H | H | | |
| Yelloweye rockfish *Sebastes ruberrimus* | Inhabits rocky reefs and boulder fields from Prince William Sound, Alaska to Ensenada, Baja California. An important commercial species ranging from 8 to 300 fm. | | | U | U | | | H | H | | |
| Flag rockfish *Sebastes rubrivinctus* | These demersal fish inhabit rocky areas and have a depth range of 0 to 302 meters. | | | U | U | | | M | H | | |
| Bank rockfish *Sebastes rufus* | Juveniles are parademersal and prefer mixed mud and rock habitats. Adults can be found on rocky reefs, among boulder fields, cobble, and mixed mud-rock bottoms. Depths range | | | U | U | | | H | L | | |

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| | from 17 to 135 fm. | | | | | | | | | | |
| Stripetail rockfish *Sebastes saxicola* | A dominant soft-bottom fish. Pelagic juveniles, with a narrow depth range of 27 to 30 fm, are associated with sandy bottoms. Adult depth ranges from 5 to 299 fm (most common 80-150 fm). | | | U | U | | | H | H | X | |
| Sharpchin rockfish *Sebastes zacentrus* | An outer shelf-mesobenthal species preferring mud and cobble and mud and boulder substrata. Found at depths from 14 to 260 fm. | | U | U | U | | H | H | M | | |
| Shortspine thornyhead *Sebastolobus alascanus* | Juveniles occupy shallower waters than adults, usually over muddy bottoms near rocks. Adults are found on muddy bottoms and bottoms with mud and cobble/boulder mixes. A deepwater species, found at 10 to 833 fm. | | | U | U | | | H | H | | |
| Longspine thornyhead *Sebastolobus altivelis* | Juvenile and adults are demersal and occupy the sediment surface, preferably sand or mud. A deepwater species, found often at 110 to 960 fm. | | | U | U | | | H | H | | |
| Cabezon *Scorpaenichthys marmoratus* | Most abundant in estuaries where all life stages may be present. Found intertidally or in shallow subtidal areas in a variety of habitats, often in the vicinity of kelp beds, jetties, oil platforms, isolated rocky reefs or pinnacles, and shallow tide pools. Mostly utilize rocky bottoms and cobble substrata. | | | | U | | | | H | | |
| Sablefish *Anoplopoma fimbria* | Inner shelf-bathybenthal commercial species. Eggs, larvae, and young juveniles are pelagic. Older-juveniles and adults are benthopelagic on soft bottoms, commonly with mud and sea urchins. Often migratory, wide-ranging depths from 170 fm to 1000 fm. Spawning occurs in the late fall and early winter in waters at depths >167 fm. | L | U | U | U | H | H | H | H | | |
| Lingcod *Ophiodon elongatus* | Occupy the estuarine-mesobenthic zone, from intertidal areas to 266 fm. Mostly inhabit slopes of submerged banks with seaweed, kelp and eelgrass beds. Spawning occurs from December through April, 2-5 fm below mean lower low water over rocky reefs in areas with a swift current. | H | U | U | U | H | H | H | H | X | |
| Finescale codling (mora) *Antimora microlepis* | Inhabits the lower regions of the continental slope between 437 fm and 980 fm. Whether or not the species migrates extensively or uses the North American west coast slopes only as feeding areas is not known. | | | | U | | | | H | | |
| Kelp greenling *Hexagrammos decagrammus* | High affinity for rocky banks near dense algae or kelp beds, or in kelp beds. Larvae and small juveniles are pelagic, adults are demersal (but not usually below 11 fm). Juveniles associated with rocky reefs and microalgae. Newly hatched larvae move out of estuaries or shallow nearshore areas into open water. Spawning occurs in the fall. | | M | | U | | H | | M | | |
| Pacific sanddab *Citharichthys sordidus* | Inhabit s inner continental shelf along the West Coast. Most abundant in 20 to 50 fm. Small juveniles prefer silty sand substrata and adults prefer sand and coarser sediments and low-relief rock bottoms. Spawning occurs late winter through summer. | | | | U | | | | H | X | X |
| Arrowtooth flounder *Atheresthes stomias* | Eggs and larvae are palegic and juveniles and adults are demersal. Juveniles and adults are usually found on sand or sandy gravelly substrata, but occasionally over rock-relief sponge bottoms. Migrate from shallow-water summer feeding grounds on the continental shelf to | H | H | U | U | H | H | H | H | | X |

| Common Name Scientific Name | Life Cycle and Habitat Associations [1] | Distribution within Estuarine Analysis Area [2] | | | | Distribution within EEZ Analysis Area [2] | | | | Site F Presence [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Eggs [3] | Larvae [3] | Juvenile [3] | Adult [3] | Juvenile | Adult |
| | deep-water spawning grounds over the continental shelf. Spawning occurs in the winter. | | | | | | | | | | |
| Petrale Sole *Eopsetta jordani* | Juveniles and adults are demersal. Adults migrate seasonally between deep-water winter spawning areas to shallower, spring feeding grounds. Found on sand and mud bottoms from 10 to 300 fm. Most abundant at 30 to 70 fm from April through October and at 150 to 250 fm during winter. | | | U | U | | | H | H | X | X |
| Rex sole *Glyptocephalus zachirus* | Abundant on sandy, muddy, and gravely bottoms. Also in complexes of mud and boulders. Cold temperate, upper-slope, outer-shelf flatfish with pelagic eggs and larvae. Move inshore in summer and offshore for spawning in winter and early spring. | | | U | U | | | H | H | X | X |
| Flathead sole *Hippoglossoides elassodon* | These sole inhabit soft, silty or muddy bottoms from 0 to 575 fm. (common 55 to 135 fm). They can also be associated with mud mixed with gravel or sand. | | | U | U | | | L | L | X | X |
| Dover sole *Microstomus pacificus* | Innershelf-mesobenthal commercially caught species, mostly in waters <273 fm. Adults and juveniles have high affinity for soft bottoms of fine mud and sand. Commonly associated with mud and sea urchins. Eggs are epipelagic, larvae are epi-mesopelagic, and juveniles and adults are demersal. Spawning occurs in the spring near the bottom of the water. Females and juveniles migrate offshore to deeper waters in the fall. | | | U | U | | | H | H | | |
| English sole *Parophrys vetulus* | Shallow-water, soft-bottom, marine and estuarine environments. Spawning occurs in winter to early spring over soft-bottom mud strata, depths of 27-38 fm. Eggs and larvae are pelagic and adults are demersal | | M | L | L | | H | H | H | X | X |
| Starry flounder *Platichthys stellatus* | Occur in the inner continental shelf and shallow sublittoral communities. Older individuals occur from 75 miles upstream to the outer continental shelf. Juveniles prefer sandy to muddy substrata. Spawning occurs in late winter-early spring in estuaries or sheltered inshore bays with less than 25 fm. | L | | U | L | H | | H | H | X | X |
| Rock sole *Pleuronectes bilineatus* | Juveniles and adults are demersal and found primarily in shallow water bays and over the continental shelf on rocky, pebbly, or sandy bottoms form 0 to 200 fm. Most are caught in 20 to 40 fm. | | | | U | | | | H | X | X |
| Curlfin sole *Pleuronichthys decurrens* | Curlfin are found on soft bottoms from 4 to 291 fm, but usually are found in shallower waters. | | | | L | | | | H | | |
| Sand sole *Psettichthys melanostictus* | High affinity to shallow waters with sandy/muddy substrate. Spawning occurs in winter and spring near shore. Larvae and small juveniles are pelagic and transported to estuaries by tidal current. | | M | U | U | | H | H | H | X | X |

<u>a/</u> Life Cycle and Habitat Association: Froese and Pauly, 2008; ODFW, 2008; NMFS, 2005d; PFMC, 2005; PFMC, 2004; Orr, et al., 1998; PFMC 1998; Kostow, 1995.
<u>b/</u> Life Stages Distribution: Ground Fish Species' Distribution based on Habitat Suitability Probability Maps, Appendix B-4 (PFMC, 2005); McCain et al., 2005.
<u>c/</u> "U" indicates unlikely occurrence; "L" –Low probability; "M"—Moderate probability; "H"—High probability; "—" indicates no PFMC distribution data available.
<u>d/</u> X=collected in samples or assumed to be present based on known habitat use (Sources: Hinton and Emmett, 1994)

### 6.3.2 Analysis of Effects

Analysis of effects to EFH for groundfish species by the proposed action have been provided in multiple sections in the BA. For EFH within the EEZ analysis area, Project effects are expected to be associated with accidental spills and releases at sea by LNG carriers transiting at least 50 nmi offshore within the EEZ from south to north (from San Diego to Coos Bay), from LNG carriers approaching Coos Bay from the west through the 200 nmi-wide EEZ, and from tugs hauling sand barges between Coos Bay and San Francisco Bay 12 nmi or more offshore. These effects have been discussed under Highly Migratory species in section 6.2.1 above Additional details of effects have been included for mammals (whales in sections 4.2.1.3, 4.2.2.3, 4.2.3.3, 4.2.4.3, 4.2.5.3, 4.2.6.3, and 4.2.7.3), reptiles (sea turtles in sections 4.4.1.3, 4.4.2.3, 4.4.3.3, and 4.4.4.3), and fish (Southern DPS North American green sturgeon in section 4.5.1.3, Southern DPS Pacific eulachon in section 4.5.2.3, and Oregon Coast coho salmon ESU in section 4.5.4.3).

Within the estuarine analysis area of Coos Bay, Project effects to groundfish species are expected to be associated with effects to eelgrass habitats; short-term turbidity produced by construction of the slip, access channel and Pacific Connector pipeline; entrainment of larvae, juveniles and adults by hydraulic dredging and ballast and cooling water withdrawal; acoustic effects due to pile driving; effects of operational lighting and wakes associated with LNG carriers, effects of facilitated predation by shading from over-water structures; introduction of exotic species; and windblown sand from stockpiles sources.

Ballast and cooling water intake by LNG carriers during the 24-hour offloading period could result in organism entrainment or impingement. An approved screening system is currently not planned (see Oregon Coastal Coho salmon). Even with an approved screening plan zooplankton, phytoplankton, planktonic shellfish larvae, and ichthyoplankton (larval fish and fish eggs) would be subject to entrainment in this ballast and cooling water.

Of the EFH species that inhabit Coos Bay, species with planktonic/pelagic eggs and larvae include: English sole, rex sole, sand sole, starry flounder, lingcod, cabezon and possibly boccacio. There is limited information on the densities of ichythoplankton, zooplankton, phytoplankton and planktonic shellfish larvae for Coos Bay, but it can be expected that large numbers of these life stages would be entrained during seasonal periods of high abundance. These planktonic life stages are widely dispersed within the estuary. Miller and Shanks (2005) collected a total of 35 species of ichthyoplankton in Coos Bay, the most abundant species of which were penpoint gunnel, northern anchovy, rosylip sculpin, Pacific sardine, and surf smelt. These five species consistently comprised >70 percent of the total catch. All of these species are small, abundant, forage species. Miller and Shanks (2005) found that at both ocean-dominated and up-estuary sites in Coos Bay, the majority of the catch occurred from October 1 to May 31, although the seasonal difference was less marked within the estuary than it was at the estuary mouth.

There are limited additional data on type, size, and organism distribution in the Coos Bay estuary, especially near the proposed slip. Jordan Cove has therefore developed a study plan and begun conducting studies to determine this information. The studies period would be during the 3 years prior to and during slip construction. These studies began in August 2009 and are nearly completed through the first year of data collection. The studies are intended to determine background species numbers, as well as their timing and distribution around the slip area. This plan and results will be presented to NMFS and FWS, and the approach and findings will be discussed with them. The goal would be to establish numerical estimates of likely entrainment and following this, if necessary, provide compensatory mitigation. Preliminary results of plankton sampling (Shanks et al. 2010) have been sent to FERC. The study results to date address zooplankton including larval fish.

Direct loss of young life stages may have an effect on production of older individuals. EPA (2004) examined the effects of entrainment by California power plants on marine fish and shellfish. The document developed natural mortality information by life stage of common marine and estuarine species or groups of species present in the California coastal region. Many of the species groups are common to the Coos Bay area. This information supplies an additional indication that loss of early life stages because of high natural mortality, would not markedly reduce later life stages. Table 6.3.2-1 shows the relative survival percent from one life stage to the next up to age 2, and overall percent survival from larval to age 1 and 2, based on the EPA (2004) document. For most taxa less than one percent of larvae would be expected to survive to age 1, as the highest rate of mortality occurs in early life stages. Adult or harvestable populations of a fish species are also affected by many factors (e.g., currents, food, temperature, usable habitat) that are generally independent of numbers or survival of early life stages. Overall, the loss of marine fish including groundfish and their prey resources from entrainment, relative to numbers in Coos Bay, would be small based on the information discussed.

**Table 6.3.2-1**
**Selected Survival Values by Life Stage of Pacific Marine Species or Groups of Species that May Be Present in the Project Area used by EPA (2004) for Power Plant's Entrainment and Impingement Studies in California Coastal Waters.**

| Taxa Group/Species [2] | Percent Survival by Life Stages [1] | | | | |
|---|---|---|---|---|---|
| | Larvae to Juvenile | Juvenile to Age 1 | Age 1 to Age 2 | Larvae to Age 1 | Larvae to Age 2 |
| Anchovies | 0.03% | 12.00% | 49.66% | <0.01% | <0.01% |
| Longfin Smelt | 0.17% | 40.01% | 51.17% | 0.07% | 0.03% |
| Pacific Herring | 0.90% | 50.01% | 62.31% | 0.45% | 0.28% |
| Other Forage Fish | 0.05% | 27.53% | 19.79% | 0.01% | 0.00% |
| Flounder | 0.19% | 31.98% | 69.56% | 0.06% | 0.04% |
| Rockfish | 36.79% | 36.79% | 80.65% | 13.53% | 10.92% |
| Cabezon | 1.87% | 40.01% | 26.18% | 0.75% | 0.20% |
| Sculpins | 2.26% | 40.01% | 65.70% | 0.90% | 0.59% |
| Dungeness Crab | 30.12% | 30.12% | 60.65% | 9.07% | 5.50% |
| Commercial Shrimp | 4.98% | 11.53% | 11.53% | 0.57% | 0.07% |
| Forage Shrimp | 0.31% | 41.85% | 33.29% | 0.13% | 0.04% |
| Average | 7.06% | 32.90% | 48.23% | 2.32% | 1.607% |
| Median | 0.90% | 36.79% | 51.17% | 0.45% | 0.07% |

1 Values based on natural mortality rates by life stage
2 Groups include multiple species defined in Appendix B1 of EPA (2004)

Evaluation of entrainment effects at some similar projects concluded substantial effects were unlikely. Environmental assessment studies conducted at the KeySpan LNG in Rhode Island (FERC 2005) and the El Paso Energy Bridge LNG facility in the Gulf of Mexico (Coast Guard 2003) off the coast of Louisiana have addressed the issue of entrainment of ichthyoplankton organisms in ballast water and other consumptive water uses. In both cases, they concluded that the losses of eggs and larvae when converted to adult equivalents were small and largely limited to small forage species. Based on the species composition of ichthyoplankton in Coos Bay (Miller and Shanks, 2005; Shanks et al., 2010), and the small portion of total bay water used, similar conclusions in Coos Bay would be likely, indicating unsubstantial adverse effect to EFH species.

The potential for fish stranding loss from vessel wake for groundfish would be similar to those discussed for coastal pelagic species (see section 6.2.2 and discussion in Section 4.5.1.3 for green sturgeon). While more species and life stages would be present year round in the Coos Bay for groundfish than coastal pelagic species their susceptibility to stranding and loss from vessel wake should not be markedly different than those discussed in the other subsections. Overall effects to groundfish EFH from vessel wakes would therefore be minimal and discountable for similar reasons noted in these two subsections.

Groundfish resources may be affected through direct mortality or short term increased susceptibility to predation from acoustic shock waves caused by impact hammer pile driving. But, as discussed for coastal pelagic species, acoustic effects of pile driving to groundfish EFH would be unsubstantial due to the use of a bubble curtain (reducing affect zone to about 3 m) and limited number of piles being driven (likely only 8, up to 24).

As noted in Section 4.5.1.3, green sturgeon, increased suspended sediment would occur from both dredging for the new facility and pipeline construction crossing of Coos bay. The result would be similar to that noted for coastal pelagic species (see section 6.2.2) and would be some short term adverse effects (primarily avoidance) to EFH of groundfish species during construction of the slip and the installation of the pipeline.

Of particular concern to groundfish is the potential increase for bioavailability of contaminants due to sediment suspension during construction and operation of the proposed action. Findings made in 2004 by the COE from sampling conducted within the Coos Bay Navigation Channel (COE, 2005) indicate that resuspension of sediments associated with the dredging for the access channel should not result in significant increases in the bioavailability of contaminants to fish and fish food organisms within the Project area.

Many groundfish EFH species are known to occur within the Estuary either seasonally or year-round. Project activities are likely to have the greatest impact on flatfish residents of the lower bay, including English sole and starry flounder. Access channel dredging would convert 16.8 acres of shallow water habitat to deepwater habitat. Juvenile English sole and starry flounder are typically found in shallow water near shore in estuarine environments. Therefore, the conversion from shallow water to deep water habitat would represent a reduction in habitat quality and quantity over existing conditions. Dredging is not expected to cause a significant change in sediment grain size. Flatfish species are expected to return to the area after dredging is completed. Most EFH rockfish species in the lower bay prefer rocky reef habitat and do not commonly utilize sand/mud substrates that would be affected by dredging. Juvenile lingcod and adult cabazon and boccacio are known to utilize sandy flats habitat and would suffer some loss of habitat. However, the sandy habitats that would be lost are common within the primary action area. It is anticipated that groundfish species would be able to relocate to nearby suitable habitats.

Indirect effects, as defined for EFH consultations under 50 CFR 600.810, require an assessment of the short-term disturbance of food organisms for groundfish and coastal pelagic species. Substrate disturbances caused by the proposed activities would be primarily limited to the access channel dredge prism, but would also include benthic habitats affected by the turbidity plume within the estuarine analysis area. The groundfish EFH species primarily feed on small fish and benthic invertebrates while the coastal pelagic EFH species forage on phytoplankton and zooplankton. Turbidity increases may cause a small reduction in prey abundance and decrease foraging efficiencies for species that forage in the water column.

The eelgrass proposed for removal by the proposed action may provide foraging and nursery habitat for various groundfish species. The loss of 1 acre of low to moderate density eelgrass during construction of the pipeline across Haynes Inlet would adversely affect EFH for some species. Turbidity effects on eelgrass habitats within the primary action area would be minimal due to scheduling dredging outside the blooming season (when eelgrass is dormant).

Construction of the Pacific Connector pipeline within the Coos Bay estuary may directly affect 5.0 acres of eelgrass beds by the construction right-of-way (including TEWAs). Of the three density categories of eelgrass found in the survey (low, medium and high) no high density was found and the majority was low density (Ellis Ecological Services 2013). Some (not quantified) of the eelgrass has been identified as Japanese or dwarf eelgrass (*Zostera japonica*), an introduced species which may compete with native eelgrass (*Z. marina*). The largest and most contiguous beds of submerged grasses are located in both the lower and upper bay, in the North and South Sloughs, and in Haynes Inlet. Total eelgrass area within Coos Bay was estimated to be about 1,400 acres in 1997 (ODLCD, 1998). While current abundance may differ, overall portion of important eelgrass habitat directly affected is very small. Due to the lack of large eelgrass beds within the estuarine analysis area, turbidity increases are not expected to significantly impact eelgrass populations in the lower bay. However, this region would take time to regrow the following year and may take additional plantings to be successful for full restoration. So, in the short term, some eelgrass habitat would be lost.

Water quality impacts would be short-term and defined by the turbidity plume, which would be subject to prevailing tidal conditions. Based on previous turbidity modeling efforts, the turbidity plume is not expected to exceed the boundaries of the primary action area (Moffatt and Nichol 2006a). No significant turbidity increases are expected in Jordan Cove or Pony Slough, which are important alcove habitats that may be utilized by EFH species. Dredging of the access channel is not expected to cause resuspension of sediment contaminants that could harm EFH species.

Discharge of the maintenance dredging at Site F, about 1.6 miles off the mouth of Coos Bay, would generate a turbidity plume that could affect ground fish within the EEZ analysis area. Site F is about 2,700 acres and ranges from 25 to 150 feet deep. Approximately 37,700 cy is the total maintenance dredging volume expected at year 1 and 34,600 cy is the total maintenance dredging volume expected at year 10. In the first 10 years, an approximate total of 360,000 cy would be removed and in the next 10 years approximately 330,000 cy would be removed for an approximate total of 690,000 cy in comparison to the earlier prediction of 1.75 million cy. This is a substantial reduction in volume which in turn will reduce the demand for disposal space at Site F. The original estimate for the frequency of dredging was every two years. Now, with the additional information from the modeling, the recommended future maintenance dredging requirements are approximately 115,000 cy would need to be dredged every three years for the first 9-12 years (10 years approximately) and after 10 years it would be safe to reduce the volume of dredging to some values in the range of 115,000 to 160,000 cy with a frequency of five years between dredging events.

Turbidity generated from discharge at Site F would be rapidly dissipated and may cause some short-term avoidance of the area by ground fish during discharge. But there is the possibility that fish, if they were present directly under the sediment discharge from the barge or ship, would be unable to dart out of the plume of sediment and become trapped in the sediment during active discharge. Potential adverse effects would occur to smaller subadults if they were present within the area. In addition, some short-term loss of benthic invertebrates from burial (weeks/months) would occur, but the extent of the area would be extremely small relative to amount of this habitat available. Also, the site is low in diversity and abundance of organisms. The site has been approved partly for its minimal effects to recourses from discharge of clean (hazardous substance free) sediment here.

**Conservation Measures**

Measures to minimize effects to listed whales would likewise minimize potential accidental spills and releases at sea which could affect EFH within the EEZ analysis area. Those measures include: 1) LNG carriers approaching the Port of Coos Bay would be traveling slowly and escorted by tractor tugs from 50 nmi offshore to the Port, and 2) spills or releases of LNG at sea would not cause the water column to cool to the point of affecting coastal pelagic fish species in the water.

Measures to minimize effects to listed Oregon Coast coho salmon and green sturgeon would likewise minimize potential effects to EFH within the estuarine analysis area. Groundfish species primarily utilize Coos Bay on a seasonal basis, mostly during summer months. Construction is planned within the period from October 1 through February 15 following ODFW's recommendation and would coincide with a period when fewest groundfish species are expected to be present. Effects to food resources and eelgrass habitats would be minimized by construction from October 1 through February 15 when eelgrass within Coos Bay is dormant.

Turbidity within Coos Bay and Haynes Inlet, produced by construction of the slip, access channel, and Pacific Connector pipeline would be short-term, relatively confined to elongated plumes, and is expected to quickly dissipate to turbidity levels generally associated with winter tides and storm wave action.

### 6.3.3 Effects Determination

The proposed action **may adversely affect** EFH for groundfish species in the short term from loss of eelgrass areas until the mitigation beds and pipeline areas regrowth occurs. Also the disposal of dredge material at Site F would temporarily bury potential food resources for groundfish. Additionally, juvenile larval stages of fish could be entrained or impinged and suffer mortality. Accidental spills and releases at sea, if they should occur, and Project construction within the Coos Bay estuary are not expected to diminish water quality or substrates within the EEZ analysis area or the estuarine analysis area.

## 6.4 PACIFIC SALMON

### 6.4.1 Essential Fish Habitat

EFH for Pacific salmon includes estuaries, nearshore marine water, and waters extending out to the 200 nmi-wide EEZ of the coast of Washington, Oregon, and in California north of Point Conception. It also includes freshwater and substrates associated with streams, lakes, ponds, wetlands and other waterbodies that were historically accessible to salmon. EFH excludes habitats upstream from longstanding impassible barriers (waterfalls) and upstream from impassible barriers (dams) identified by PFMC (1999).

EFH for chinook and coho salmon has been designated within the following watersheds that coincide with the proposed action riverine analysis areas: South Umpqua River (HUC 17100302), Coos River (HUC 17100304), Coquille River (HUC 17100305), and Upper Rogue River (HUC 17100307). Essential fish habitat for chinook salmon and coho salmon is also present in the Upper Klamath River (HUC 18010206) in California and Oregon but construction of multiple dams on the mainstem Klamath River have made upstream areas impassible to anadromous fish (Hamilton et al., 2005). Habitats within the Project Area upstream from the Iron Gate Dam are not currently accessible to coho or Chinook salmon. , but the Oregon Fish and Game Commission in July 2008 authorized the study of reintroduction of anadromous fish into the Klamath River system in Oregon.

Coho salmon within the Upper Rogue River (HUC 17100307) watershed are within the SONCC ESU and their threatened status, environmental baseline, Project effects and determination of effects under ESA (species effects and effects to designated critical habitat) were addressed in Section 4.4.1. Likewise, coho within the South Umpqua River (HUC 17100302), Coos River (HUC 17100304), Coquille River (HUC 17100305) watersheds are within the Oregon Coast ESU, listed as threatened and with designated critical habitat under ESA, were similarly evaluated in section 4.5.1. EFH for coho in both ESUs is present within several proposed action riverine analysis areas, as well as the estuarine and EEZ analysis area (Oregon Coast coho).. Likewise, EFH for Chinook salmon in the Oregon Coast and SONCC ESUs, is present within the same analyses areas as for coho although neither Chinook salmon ESU is listed under ESA.

Specific timings of life history phases for fall-run Chinook salmon within the estuarine and riverine analysis areas are shown in figure 6.4-1. Spawning does not occur within the Coos Bay estuary or the analysis area included for Coos River. Spawning does occur within the Coquille River and tributaries, in the Rogue River mainstem and tributaries, as well as the South Umpqua River mainstem and tributaries.

Whereas adult coho in the SONCC ESU and Oregon Coast ESU begin upstream migrations in September, fall Chinook salmon in some watersheds begin as early as mid-July (Coos River and Coquille River) or early August. Similar to coho, fall Chinook salmon in the South Umpqua River begin upstream migrations in early September. Spawning in the South Umpqua mainstem is as early as mid-September but begins in October within tributaries to the South Umpqua. Spawning in the Rogue River mainstem and tributaries also begins in October (see figure 6.4-1).

Specific timings of life history phases for spring-run Chinook salmon within the riverine analysis areas are shown in figure 6.4-2. No life-phase timing of spring Chinook salmon is reported for the Coos Bay estuary or Coos River. Spawning does occur in the Coquille River and tributaries from September through mid-November. Spawning also occurs within the Rogue River mainstem and tributaries in October and November as well as in the South Umpqua River mainstem from mid-September through January and in its tributaries from October through mid-January (see figure 6.4-2).

### 6.4.2 Analysis of Effects

Within the 200 nmi-wide EEZ, effects by the proposed action to coho salmon and Chinook salmon EFH within the analysis area are expected to be associated with accidental spills and releases at sea by LNG carriers transiting at least 50 nmi offshore within the EEZ from south to north (from San Diego to Coos Bay), from LNG carriers approaching Coos Bay from the west through the 200 nmi-wide EEZ, and from tugs hauling sand barges between Coos Bay and San Francisco Bay 12 nmi or more offshore. These effects have been discussed under Highly Migratory Species in section 6.2.1 above. Additional effects about these spills are noted in the in sections for Oregon Coast coho salmon ESU in Sections 4.5.4.3 and Southern DPS green sturgeon in Section 4.5.1.3. Likewise, effects to coho salmon within the estuarine analysis area (Oregon Coast ESU) were described in Section 4.5.4.3 and are applicable to other coho salmon and similar for Chinook salmon EFH. Various life stages of fall Chinook salmon are expected within the Coos Bay estuary throughout the year (see figure 6.4-1). During the period when within-water construction is planned, October 1 through February 15, adult fall-run Chinook salmon would be holding within Coos Bay and migrating upstream within the Coos River (see figure 6.4-1).

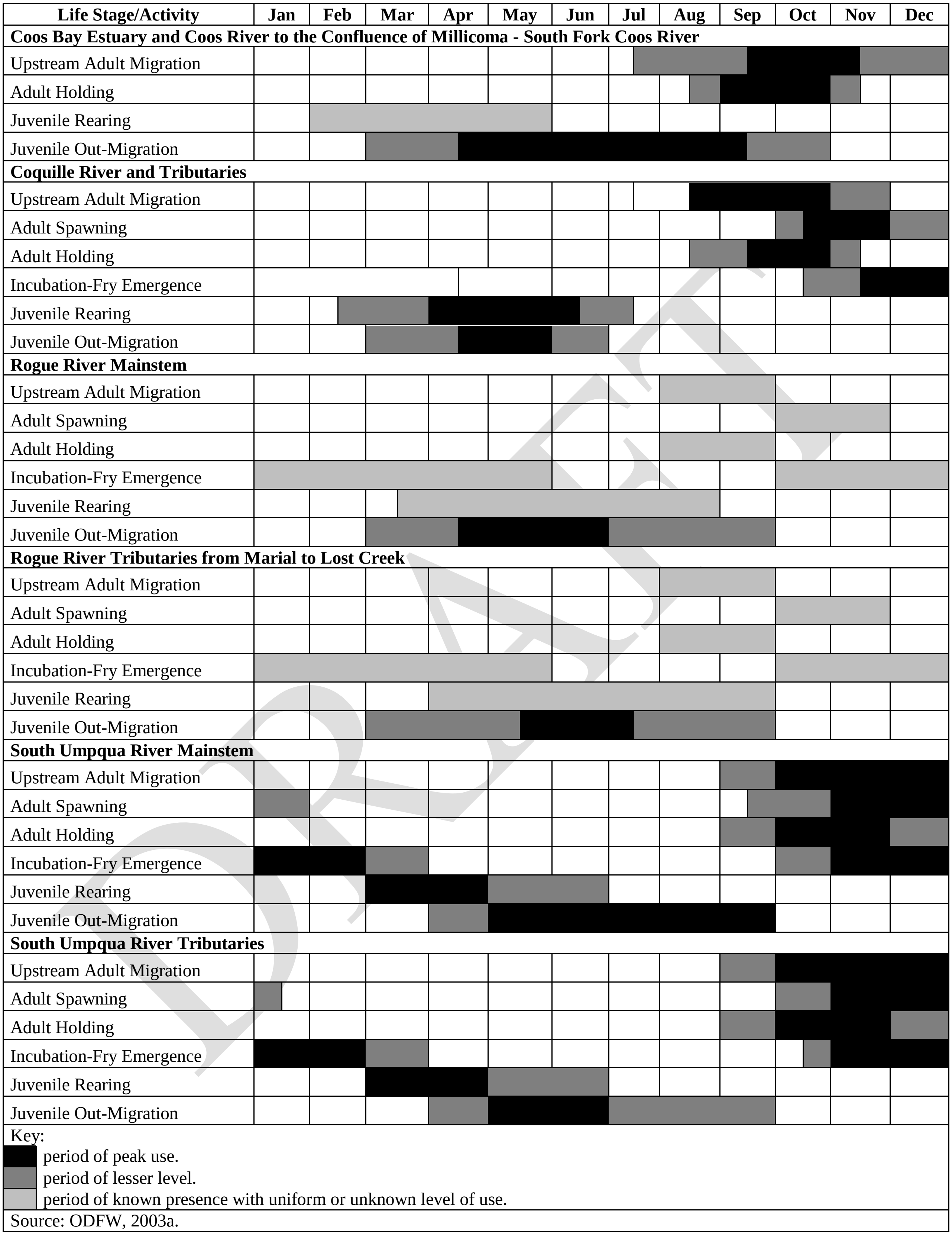





**Figure 6.4-1**
**Approximate Timing of Fall Chinook Salmon Use of Streams and Estuaries in the Pacific Connector Pipeline Area**

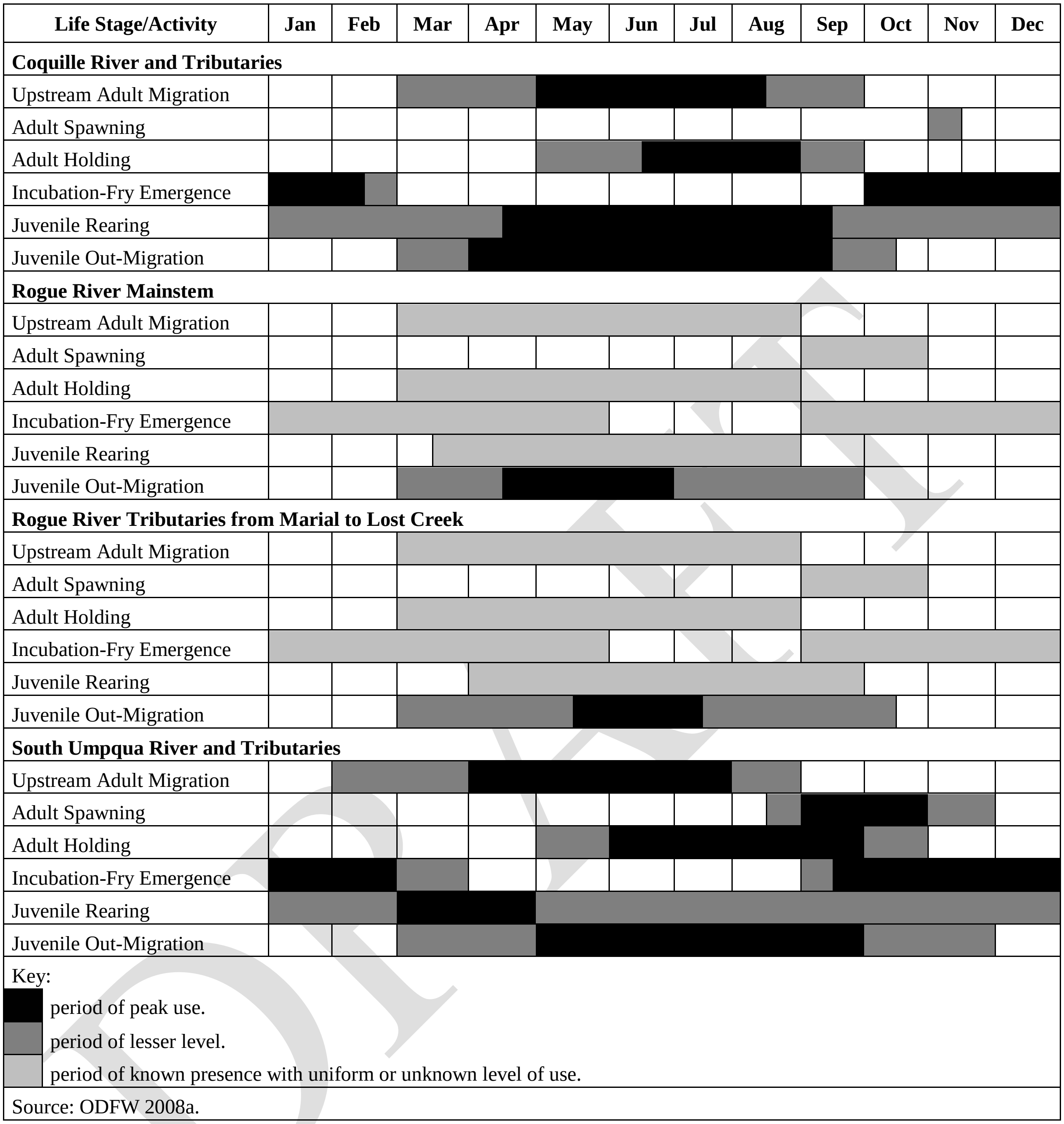



**Figure 6.4-2**
**Approximate Timing of Spring Chinook Salmon Use of Streams in the Pacific Connector Pipeline Area**

Construction within Coos Bay is likely to increase local turbidity over the short-term while adult Chinook salmon are present. Juvenile Chinook salmon may also be present in the estuarine analysis area during construction. However, Chinook salmon smolts appear to be more tolerant to high levels of suspended sediments than juvenile coho salmon coho since $LC_{50}$ values for smolts exposed for 96 hours were found to be 11,000 mg/L (Ross, 1982) compared to $LC_{50}$ of 509 mg/L for coho salmon coho smolts (Stober et al., 1981). However effects still remain for Chinook salmon juveniles from turbidity. Similarly, effects, distance, and effective area of downstream turbidity produced during instream construction, within freshwater EFH, that were described and analyzed above for coho salmon are not expected to specifically apply to fall or spring Chinook salmon.

Construction of the LNG bay and the pipeline route would cause some initial loss of eelgrass habitat, an important food and rearing environment for juvenile coho and Chinook salmon. While mitigation would replace some of the lost habitat from the dredging of the LNG facility it would take time for the replacement area to develop. Also regrowth of eelgrass in the region of the Coos Bay pipeline dredging would take time to reestablish and may require additional plantings causing a short term loss of this habitat.

LNG carriers would re-circulate water while loading LNG at the berth and the amount of cooling water to be re-circulated is a function of the propulsion system for the vessels. Once the LNG fleet has been identified, cooling water flow rates and the amount of water required can be further addressed. It is likely that some organisms small enough to pass through the screens covering the carrier's intake port will be drawn in with the cooling water and will be lost from the population in the slip area; however, it is anticipated that the effect associated with the intake of cooling water will be minimal. Juvenile fish would need to be present in the slip area near the carrier's intake screens and be small enough to fit through the sea chests which are covered with screens composed of 4.5 mm thick bars spaced 24 mm apart and located approximately 32 feet below the water line, or 5.6 feet from the keel of the LNG carrier. The intake velocities for cooling water are low enough that it is not anticipated that any larger organisms (fish, marine mammals, or invertebrates) would be impinged on the intake screen.

Near and offshore marine areas that supply potential food sources for salmon near Coos Bay may be affected by disposal of dredge spoils at Site F, a 2,700-acre clean dredge disposal site centered 1.6 miles off the mouth of Coos Bay (discussed above in Section 6.3.2 for ground fish). Disposal would initially bury benthic and epibenthic non-mobile organisms and cause a short-term turbidity plume both within Coos Bay during dredging and at the discharge locations. While this site has been used by COE for disposal since 1986, the Project would increase the frequency and quantity of disposal at this site. Effects to EFH for Pacific salmon would be similar to those described for Oregon Coast coho salmon (Section 4.5.4.3), for both other coho salmon and juvenile Chinook salmon, including short-term displacement of fish near the tailings plume and short-term loss of deeper water potential benthic food resources.

The potential for fish stranding loss from vessel wake in Coos Bay for coho salmon was assessed in Section 4.5.4.3 and concluded to be discountable because of several factors. Most of those factors also apply to juvenile Chinook salmon in Coos Bay. However age 0 Chinook salmon in the lower Columbia River system have been found to be more susceptible to stranding than juvenile coho salmon in this system (Pearson et al., 2006). It has been observed in net sampling studies in the lower Columbia River that age 0 Chinook salmon appear to be more oriented to the shoreline areas than age 1 Chinook salmon or coho salmon (Johnsen and Sims 1973, Dawley et al. 1986). While age 0 Chinook salmon are more susceptible to stranding, partly because of their apparent distribution, the procedures to be used for vessel traffic in Coos Bay such, as low vessels speed and travel at high tide only, have been found to reduce to insignificant the loss of even age 0 Chinook salmon in the lower Columbia River (Hinton and Emmett, 1994). The outer mile of the channel, where vessel speed would be the highest would appear to be a region of greatest potential stranding from large waves generated by vessels. However area is also a region of naturally higher waves due to its proximity to the ocean (Wagner et al., 1990), so ship wake is likely to be much lower effect than natural conditions relative to frequency and magnitude of shore waves. Also although data for Coos Bay is not specifically available radio tagging studies of juvenile salmonids in the Columbia River suggest that even age 0 Chinook salmon tended to be more commonly offshore when they are approaching the marine environment near the mouth of the Columbia River (Carter et al. 2009). This behavior, if it occurs in Coos Bay, would reduce further the chance of age 0 Chinook salmon from being stranded from vessel wakes. Overall stranding potential is higher for age 0 Chinook salmon in Coos Bay from vessel wake than other salmonids but available information suggests stranding of all juvenile salmonids would not be substantial. Overall effects to Pacific salmon EFH from vessel wakes would therefore be minimal and discountable for reasons noted in above.

Instream construction in all watersheds (Coos, Coquille, South Umpqua, and Upper Rogue) within which there is EFH for fall and/or spring Chinook salmon would coincide with upstream migration, adult spawning, adult holding, incubation and fry emergence, juvenile rearing, and/or juvenile out-migration for one or both runs of Chinook salmon (figures 6.4-1 and 6.4-2).

**Conservation Measures**

Measures to minimize effects to listed coho salmon and green sturgeon would likewise minimize potential effects to EFH within the estuarine analysis area. The Conservation Measures (see appendix N) and the Compensatory Mitigation Plan (see appendix O) described are also applicable to EFH and would satisfy requirements pursuant to Section 305(b)(4)(A) of the MSA. Overall, the proposed conservation measures are expected to increase habitat value within the lower bay and provide long-term benefits to EFH species managed under the MSA but short term habitat effects remain. Conservation measures applied to freshwater EFH would provide long-term benefits, particularly instream and riparian zone installations of LWD.

### 6.4.3 Effects Determination

Effects to freshwater Pacific Coast Salmon EFH by the proposed action **may adversely affect** riverine habitats by impacting substrates and water quality over the short-term and by removal of riparian vegetation which could affect water quality over the long-term. Additionally, the Project may adversely affect the estuarine and nearshore marine sites in the short term from loss of important eelgrass habitat until it reestablishes after dredging and restoration in the bay and benthic food resources in the offshore disposal Site F. Also juvenile salmon may be trapped in the ocean tailings discharge while disposal occurs at Site F. Additionally, juvenile salmon stages could be entrained or impinged and suffer mortality from water withdrawal.

## 7.0 LITERATURE CITED


Agness, A.M. 2006. Effects and Impacts of Vessel Activity on the Kittlitz's Murrelet (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. M.S. Thesis, University of Washington, Seattle, WA.

Agness, A,.M., K.M. Marshall, J.F. Piatt, H.A.,. J.C., and G.R. Vanblaricom. 2013. Energy Cost of Vessel Disturbance to Kittlitz's Murrelets *Brachyramphus brevirostris*. Marine Ornithology 41:1-9.

Alaska Department of Fish and Game. 1991. Rationale for Blasting Standards (11 AAC 95) Developed to Prevent Explosive Injury to Fish. Alaska Department of Natural Resources Office of Habitat Management and Permitting. Online at: http://www.dnr.state.ak.us/habitat/explosives.htm.

Alice Berge & Associates. 2006. Jordan Cove Fisheries Report. Prepared for SHN Consulting Engineers and Geologists by Alice Berge & Associates, LLC, Ferndale, CA.

Allen, B.M. and R.P. Angliss. 2011. Alaskan Marine Mammal Stock Assessments. US Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-234.

Allen, J.K., M.L. Peterson, G.V. Sharrad, D.L. Wright, and S.K. Todd. 2012. Radiated Noise from Commercial Ships in the Gulf of Maine: Implications for Whale/Vessel Collisions. Journal of Acoustic Society of America 132(3):EL229-EL235.

American Cetacean Society. 2004. American Cetacean Society Fact Sheet. ORCA (Killer Whale). Online at: http://www.acsonline.org/factpack/orca/killer-whale.pdf.

Anderson, J.W., J.M. Neff, B.A. Cox, H.E. Tatem, and G.M. Hightower. 1974. Characteristics of Dispersions and Water-soluble Extracts of Crude and Refined Oils and their Toxicity to Estuarine Crustaceans and Fish. Marine Biology. 27:75–88.

Anderson, P.G. 1996. Sediment Generation from Forestry Operations and Associated Effects on Aquatic Ecosystems. Proceedings of the Forest-Fish Conference: Land Management Practices Affecting Aquatic Ecosystems, May 1-4, 1996. Calgary, Alberta.

Anderson, P.G., B.R. Taylor, and G.C. Balch. 1996. Quantifying the Effects of Sediment Release on Fish and their Habitats. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2346. Available online: http://publications.gc.ca/collections/collection_2007/dfo-mpo/Fs97-4-2346E.pdf

André, M., and E. Degollada. 2003. Effects of Shipping Noise on Sperm Whale Populations. Abstract: 17th Annual Conference of the European Cetacean Society, Las Palmas de Gran Canaria.

Andrew, R.K., B.M. Howe, and J.A. Mercer. 2011. Long-time Trends in Ship Traffic Noise for Four Sites off the North American West Coast. Journal of the Acoustical Society of America 129(2):642-651.

Andrew, R.K., B.M. Howe, J.A. Mercer, and M.A. Dzieciuch. 2002. Ocean Ambient Sound: Comparing the 1960s with 1990s for a Receiver Off the California Coast. Acoustics Research Letters Online-ARLO 3:65-70.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J.D. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, L.S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehering, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutierrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2006. Status and Trend in Demography of Northern Spotted Owls, 1985-2003. Wildlife Monographs. 163: 1-48.

Antunes-Kenyon, S.E. and G. Kennedy. 2004. A Review of the Toxicity and Environmental Fate of Triclopyr. Massachusetts Department of Agricultural Resources. Accessed online: http://www.mass.gov/agr/pesticides/water/Aquatic/triclopyr_final.pdf.

Aquatic Nusiance Species Taskforce. 2006. Aquatic Nuisance Species Impacts. Accessed online: http://www.anstaskforce.gov/impacts.php.

Arcement, G.J., and V.R. Schneider. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. U.S Geological Survey Water-Supply Paper 2339. Accessed online: http://www.fhwa.dot.gov/bridge/wsp2339.pdf.

Arneson, R.J. 1976. Seasonal Variation in Tidal Dynamics, Water Quality, and Sediments in the Coos Bay Estuary. Unpublished M.S. Thesis. Oregon State University, Corvallis, OR.

Audubon Society of Portland. 2013. Heceta Bank. Online at: http://audubonportland.org/local-birding/iba/iba-map/heceta

Avian Power Line Interaction Committee (APLIC). 2012. Reducing Avian Collisions with Power Lines. The State of The Art in 2012. Edison Electric Institute and Avian Power Line Interaction Committee, Washington, D.C.

Awbrey, F.T. and A.E. Bowles. 1990. The Effects of Aircraft Noise and Sonic Booms on Raptors: A Preliminary Model and a Synthesis on the Literature on Disturbance. U.S. Air Force, Patterson Air Force Base, OH.

Baddaloo, E.G. 1978. An Assessment of Effects of Pipeline Activity in Streams in the Durham and Northumberland Counties of Ontario. Journal of Canadian Society of Petroleum Geologists 4:2-10.

Baker, W.L., and G.K. Dillon. 2000. Plant and Vegetation Responses to Edges in the Southern Rocky Mountains. Pages 221-245 in R.L. Knight, F.W. Smith, S.W. Buskirk, W.H Romme, and W.L. Baker (editors). Forest Fragmentation in the Southern Rocky Mountains. University Press of Colorado, Boulder, CO.

Baldwin, R.A. 2009. Use of Maximum Entropy Modeling in Wildlife Research. Entropy. 11: 854–866.

Barlow, J. 2010. Cetacean Abundance in the California Current Estimated from a 2008 Ship-based Line-transect Survey. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-456.

Barlow, J., and K.A. Forney. 2007. Abundance and Populations Density of Cetaceans in the California Current. Fishery Bulletin 105(4):509-526.

Barlow, J., S.L. Swartz, T.C. Eagle, and P.R. Wade. 1995. U.S. Marine Mammal Stock Assessments: Guidelines for Preparation, Background, and a Summary of the 1995 Assessments. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-OPR-6.

Barlow, J., J. Calambokidis, E.A. Falcone, C.S. Baker, A.M. Burdin, PO.J. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Babriele, R. LeDuc, D.K. Mattila, T.J. Quinn, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban, P.Wade, D. Weller, B.H. Witteveen, and M. Yamaguchi. 2011. Humpback Whale Abundance in the North Pacific Estimated by Photographic Capture-recapture with bias Correction from Simulation Studies. Marine Mammal Science 27(4):793-818.

Barre, L. 2008. NOAA Office of Protected Resources, Northwest Region. Personal Communication with Ellis Ecological Services.

Barry, P.M., B.S. Hayes, E.C. Janney, R.S. Shively, A.C. Scott, and C.D. Luton. 2007. Monitoring of Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers in Gerber and Clear Lake reservoirs 2005-2006. U.S.G.S. Western Fisheries Research Center, Klamath Falls Field Station, Klamath Falls, OR.

Barry, P.M., E.C. Janney, D.A. Hewitt, B.S. Hayes, and A.C. Scott. 2009. Population Dynamics of Adult Lost River (*Deltistes luxatus*) and Shortnose (*Chasmistes brevirostris*) Suckers in Clear Lake Reservoir, California, 2006–08. USDI- Geological Survey and US Bureau of Reclamation. Open-File Report 2009-1109.

Bart, J. 1995. Amount of Suitable Habitat and Viability of Northern Spotted Owls. Conservation Biology 9 (4):943-946.

Bart, J. and E.D. Forsman. 1992. Dependence of Northern Spotted Owls *Strix occidentalis caurina* on Old-growth Forests in the Western USA. Biological Conservation 62:95-100.

Bartol, S. M., J.A. Musick, and M.L. Lenhardt. 1999. Auditory Evoked Potentials of the Loggerhead Sea Turtle. Copeia 3:836–840.

Bash, J., C. Berman, and S. Bolton, S. 2001. Effects Of Turbidity and Suspended Solids on Salmonids . Report No. WA-RD 526.1, Washington State Department of Transportation, Seattle, Washington.

Beamis, W.E., and B. Kynard. 1997. Sturgeon Rivers: an Introduction to Acipenseriform Biogeography and Life History. Environmental Biology of Fishes 48:167-183.

Becker, B.H. 2001. Effects of Oceanographic Variation on Marbled Murrelet Diet and Habitat Selection. Ph.D Dissertation. University of California, Berkeley, CA.

Bednarz, J.C. and T.J. Hayden. 1994. The Effects of Human Activities on the Productivity of Birds of Prey in the Los Medanos area, New Mexico. Journal of Raptor Research. 28(1): 52-53.

Bellerud, B. and M.K. Saiki. 1995. Tolerance of Larval and Juvenile Lost River and Shortnose Suckers to High pH, Ammonia Concentration, and Temperature, and to Low Dissolved Oxygen Concentration. Final Report, U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR.

Bennett, A.F. 1991. Roads, Roadsides, and Wildlife Conservation: A Review. Pages 99-117 in D.A. Saunders and R.J. Hobbs (editors). Nature Conservation 2: The Role of Corridors. Surrey Beatty & Sons, Chipping Norton, Australia.

Berg, L. and T.G. Northcote. 1985. Changes in Territorial, Gill-Flaring, and Feeding Behavior in Juvenile Coho Salmon (*Oncorhynchus kisutch*) Following Short-term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Science 42:1410-1417.

Berube, M. and A. Aguilar. 1998. A New Hybrid Between a Blue Whale, *Balaenoptera musculus*, and a Fin Whale, *B. physalus*: Frequency and Implications of Hybridization. Marine Mammal Science 14(1):82-98.

Beschta, R.L. 1983. The Effects of Large Organic Debris Upon Channel Morphology: A Flume Study. Pages 63–78 in D. B. Simons, (ed.). Symposium on Erosion and Sedimentation. Simons, Li & Associates, Fort Collins, Colorado.

Beschta, R.L and R.L. Taylor. 1988. Stream Temperature Increases and Land Use in a Forested Oregon Watershed. Water Resources Bulletin 24:19-24.

Bethel, J., and K. Neal. 2003. Stream Enhancement Projects: a King County Perspective. In D. R. Montgomery, S. Bolton, D. B. Booth, and L. Wall (eds.). Restoration of Puget Sound Rivers. University of Washington Press, Seattle, Washington.

Binford, L.C., B.G. Elliott, and S.W. Singer. 1975. Discovery of a Nest and the Downy Young of the Marbled Murrelet. The Wilson Bulletin. 87: 303-440.

Birtwell. I.K. 1999. The Effects of Sediment on Fish and their Habitat. Research Document 99/139, Canadian Stock Assessment Secretariat, Fisheries and Oceans Canada. West Vancouver, B.C.

Bisson, P.A., R.E. Bilby, M.D. Bryant, and C.A. Dolloff. 1987. Large Woody Debris Forested Streams in the Pacific Northwest: Past, Present, and Future. In E.O. Salo and T.W. Cundy. (editors). Streamside Management: Forestry and Fisheries Interactions. University of Washington, Institute of Forest Resources, Contribution No. 57. Seattle, Washington.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat Requirements of Samonids in Stream. In Influences of Forest and Rangeland Management on Salmonid Fishes and Their habitats. American Fisheries Society Special Publication 19:83-138.

Blais, D.P. and D.L. Simpson. 1997. The Effects of a Buried Natural Gas Pipeline on Water Quality, Stream Habitat, and Biotic Populations within High Quality Cold Water Streams in Upstate New York. Pages 433- 441 in J.R. Williams, J.W. Goodrich-Mahoney, J.R. Wisniewski and J. Wisniewski (editors). The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier Science, Ltd., New York, NY.

Bortleson, G.C. and M.O Fretwell. 1993. A Review of Possible Causes of Nutrient Enrichment and Decline of Endangered Sucker Populations in Upper Klamath Lake, Oregon. U.S. Geological Survey Water-Resources Investigations Report 93-4087, Portland, OR.

Bottom, D.L., Miller, B.A., and K.K. Jones. 1985. A baseline survey: fish and invertebrates in the lower Umpqua River estuary, Oregon. Unpublished manuscript. ODFW, Corvallis, OR. 80 pp.

Bradley, R.W. 2002. Breeding Ecology of Radio-marked Marbled Murrelets (*Brachyramphus marmoratus*) in Desolation Sound, British Columbia. M.S. Thesis. Simon Fraser University, Burnaby, BC.

Breteler, R.J., P.D. Boehm, J.M. Neff, and A.G. Requejo. 1985. Acute Toxicity of Drilling Muds Containing Hydrocarbon Additives and Their Fate and Partitioning Among Liquid, Suspended and Solid Phases. Health and Environmental Affairs Department Report DR9, American Petroleum Institute, Battelle, MA.

British Columbia, Ministry of Transportation. 2000. Use of Explosives in or Near Fish and Fish Habitat. Technical Circular T3/00. British Columbia, Ministry of Transportation Environmental Services, Engineering Branch. Online at http://www.th.gov.bc.ca/publications/Circulars/Current/T_Circ/2000/t03-00.pdf.

Brown, A.L. 1990. Measuring the Effect of Aircraft Noise on Sea Birds. Environment International 16:587-592.

Brown, C.M., R.D. Revel, and J.R. Post. 2002. Effects of Pipeline Rights-of-Way on Fish Habitat at Two Alberta Stream Crossings. Pages 705- 715 in J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild (editors). The Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier Science, Ltd., Boston, MA.

Brusnyk, L.M., and D.A. Westworth. 1985. An Assessment of Post-construction Use of a Pipeline Corridor by Ungulates. Unpublished report for NOVA, An Alberta Corporation, Calgary, AB.

Buick, A.M. and D.C. Paton. 1989. Impact of off-road vehicles on the nesting success of hooded plovers (*Charadrius rubricollis*) in the Coorong region of South Australia. Emu 89:159-172.

Burger, A.E. 2001. Using radar to estimate populations and assess habitat associations of marbled murrelets. Journal of Wildlife Management 65:696–715.

Burtenshaw, J.C., E.M Oleson, J.A. Hildebrand, M.A. McDonald, R.K. Andrew, B.M Howe, and J.A. Mercer. 2004. Acoustic and Satellite Remote Sensing of Blue Whale Seasonality and Habitat in the North Pacific. Deep-Sea Research II 51:967-986.

Calambokidis, J., E. Falcone, A. Douglas, L. Schlender, and J. Huggins. 2010. Photographic Identification of Humpback and Blue Whales off the U.S. West Coast: results and updated abundance estimates from 2008 field season. Final Report, NMFS Southwest Fisheries Science Center, La Jolla, California.

Calambokidis, J. 2013. Updated abundance estimates of blue and humpback whales off the US west coast incorporating photo-identifications from 2010 and 2011. Document PSRG-2013-13 presented to the Pacific Scientific Review Group,

California Department of Fish and Wildlife. 2013a. OR-7 – A Lone Wolf's Story. California Department of Fish and Wildlife, Nongame Wildlife Program. Online at: http://www.dfg.ca.gov/wildlife/nongame/wolf/OR7story.html

California Department of Fish and Wildlife. 2013b. Gray Wolf OR7 Travels. California Department of Fish and Wildlife. Online: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=42104&inline=true

California Natural Diversity Database (CNDDB). 2005. Database output August 6, 2005. California Department of Fish and Game, Wildlife and Habitat Data Analysis Branch. Sacramento, CA.

Cameron, D.C. Tammi, E. Steel, J. Schimdt, and J. Evans. 2002. Evaluating the Effects of Muds on Wetlands from Horizontal Directional Drilling (HDD) within Natural Gas Transmission Line Rights-of Way. Pages 599 to 607 in J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild (editors). The Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier, Boston, MA.

Cardwell, R.D., M.I. Carr, and E.W. Sanborn. 1980. Water Quality and Flushing of Five Puget Sound Marinas. Washington Department of Fisheries, Technical Report56, Olympia.

Carretta, J.V., K.A. Forney, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, and M.M. Muto. 2007. Draft U.S. Pacific Marine Mammal Stock Assessments: U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC.

Carretta, J.V., K.A. Forney, E. Oleson, K. Martien, M.M. Muto, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, D. Lynch, L. Carswell, R.L. Brownell Jr., J. Robbins, D. K. Mattila, K. Ralls, and M.C. Hill. 2012. U.S. Pacific Marine Mammal Stock Assessments: 2011. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-TM-NMFS-SWFSC-488.

Carretta, J.V., S.M. Wilkin, M.M. Muto, and K.Wilkinson. 2013a. Sources of Human-related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2007-.2011. US Department of Commerce - National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-514 National Marine Fisheries Service. Silver Spring, MD

Carretta, J.V., E. Oleson, D.W. Weller, A.R. Lang, K.A. Forney, J. Baker, B. Hanson,, K. Martien, M.M. Muto, T. Orr, H. Huber, M.S. Lowry, J. Barlow, D. Lynch, L. Carswell, R.L. Brownell Jr., and D. K. Mattila.. 2013b. U.S. Pacific Marine Mammal Stock Assessments (Draft): 2013. U.S. Department of Commerce, Draft document available at: http://www.nmfs.noaa.gov/pr/sars/draft.htm

Carretta, J.V., E. Oleson, D.W. Weller, A.R. Lang, K.A. Forney, J. Baker, B. Hanson,, K. Martien, M.M. Muto, M.S. Lowry, J. Barlow, D. Lynch, L. Carswell, R.L. Brownell Jr., D. K. Mattila, and M.C. Hill.. 2013c. U.S. Pacific Marine Mammal Stock Assessments: 2012. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-TM-NMFS-SWFSC-504.

Carter, H.R. and K.J. Kuletz. 1995. Mortality of Marbled Murrelets Due to Oil Pollution in North America. Pages 261-269, in C.J. Ralph, G.L. Hunt, M.G. Raphael, and H.F. Piatt (technical editors). Ecology and Conservation of the Marbled Murrelet. USDA Forest Service General Technical Report PSW-GTR-152. Albany, CA.

Castelein, K. 2008. ORNHIC Personnel. Personal Communication with L. Brown, EES. January.

Carter, J.A., R.A. Harnish, G.A. McMichael, B.J. Bellgraph, and I.D. Welch. 2009. Seasonal juvenile salmonid presence and migratory behavior in the lower Columbia River. Final Report. Prepared for the US Army Corps of Engineers, Portland District. And US. Department of Energy. Contract DE-Aco5-76RL01830. Pacific Northwest National Laboratory. Richland, Washington.

Cederholm, C.J., L.G. Dominguez, and T.W. Bumstead. 1997. Rehabilitating Stream Channels and Fish Habitat Using Large Woody Debris. Pages 8-1 to 8-28 in P.A. Slaney and D. Zaldokas (editors). Fish Habitat Rehabilitation Procedures; Watershed Restoration Technical Circular No. 9. British Columbia Watershed Restoration Program, Ministry of Environment, Lands and Parks, and Ministry of Forests. Vancouver, B.C.

Chalfoun, A.D., F.R. Thompson, and R,J. Ratnaswamy. 2002. Nest Predators and Fragmentation: A Review and Meta-Analysis. Conservation Biology 16(2):306-318.

Chen, J., J.F. Franklin, T.A. Spies. 1995. Growing-Season Microclimatic Gradients from Clearcut Edges into Old-growth Douglas-fir Forests. Ecological Applications. 5: 74-86.

Chow, V.T. 1959. Open-Channel Hydraulics. Blackburn Press, Caldwell, New Jersey.

Clapham, P.J. 2009. Humpback Whale, Megaptera novaeangliae. Pages 582 to 585 in W.F. Perrin, B. Würsig, and J.F.M Thewissen (editors). Encyclopedia of Marine Mammals (Second Edition). Academic Press, Elsevier, New York.

Clinton, P. 2007. Environmental Protection Agency, Pacific Coastal Ecology Branch; Newport, Oregon, personal communication with GeoEngineers, Inc. February 2, 2007.

Coast and Harbor Engineering. 2007. Technical Report: Pacific Connector Gas Pipeline Project - Coos Bay Crossing Scour Evaluation. June.

Coast and Harbor Engineering. 2011. Jordan Cove Energy Project and Pacific Gas Pipeline – Volume 2. Coastal Engineering Modeling and Analysis. Coast and Harbor Engineering

Colton, T. 2013. LNG Carriers in Service or Under Construction. On line at http://shipbuildinghistory.com/today/highvalueships/lngactivefleet.htm

Comer, R.D. 1982. Understanding Secondary Effects of Development on Wildlife Resources inMitigation Planning. Pages 16-31 in Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecological Institute Technical Publication No. 14. Boulder, CO.

Conant, T.A., P.H. Dutton, T. Eguchi, S.P. Epperly, C.C. Fahy, M.H. Godfrey, S.L. MacPherson, E.E. Possardt, B.A. Schroeder, J.A. Seminoff, M.L. Snover, C.M. Upite, and B.E. Witherington. 2009. Loggerhead Sea turtle (*Caretta caretta*) 2009 Status Review Under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service.

Contreras, A. 1998. Birds of Coos County, Oregon. Cape Arago Audubon Society in Cooperation with Oregon Field Ornithologists. OFO Special Publication Number 12.

Coos County Planning Department. 1979. Coos Bay estuary inventory maps. Base map: Coos Bay tideland map, Div. State Lands, 1973.

Coos Watershed Association. 2006. Coos Bay Lowland Assessment and Restoration Plan. Draft. Coos Watershed Association, Charleston, Oregon. Accessed online: http://www.cooswatershed.org/assess_cblowlands.html.

Coos Watershed Association. 2008. Catching Slough, Daniel's Creek and Heads of Tide Sub-basin Assessment and Restoration Opportunities. Coos Watershed Association, Charleston, Oregon. Accessed online: http://www.cooswatershed.org/assess_cblowlands.html.

Coquille Indian Tribe. 2007. Coquille River Sub-basin Plan. Prepared for NOAA Fisheries Service.

Cordone, A.J., and D.W. Kelley. 1961. The Influences of Inorganic Sediment on the Aquatic Life of Streams. Reprint from California Fish and Game. Vol. 47, No. 2. California Department of Fish and Game, Inland Fisheries Branch. Sacramento, California. 45 pp.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fliescher, A.B. Franklin, J.F. Franklin, R. J. Guitierrez, J.M. Marzluff, and L. Sztukowski. 2004. Scientific Evaluation of the Status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Cowlitz Indian Tribe. 2007. Petition to list the Southern Eulachon (Thaleichtys pacificus) Distinct Population Segment as threatened or endangered under the federal Endangered Species Act, November 9, 2007. Cowlitz Indian Tribe, Longview, WA. http://www.nwr.noaa.gov/Other-Marine-Species/upload/Smelt_Petition_11_07.pdf (last accessed on July 17, 2009).

Cox, R. 2008. USDA Forest Service, Umpqua National Forest, Roseburg, OR. Personal Communication with Edge Environmental, Inc., October.

Csuti, B., T.A. O'Neil, M.M Shaughnessy, E. P. Gaines, and J. C. Hak. 2001. Atlas of Oregon Wildlife: Distribution, Habitat, and Natural History – Second Edition. Oregon State University Press, Corvallis, OR.

Cummings, T.E. and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Coastal Rivers Investigation Report 70-11. Fish Comm. Oregon. 22 pp.

Davis, R. 2007. Wildlife Biologist, Umpqua National Forest, North Umpqua Ranger District. Personal Communication with Edge Environmental, Inc. December.

Davis, R. 2008a. Wildlife Biologist, Umpqua National Forest, North Umpqua Ranger District. Personal Communication via email with Edge Environmental, Inc. May.

Davis, R. 2008b. Wildlife Biologist, Umpqua National Forest, North Umpqua Ranger District. Personal Communication with Edge Environmental, Inc., January.

Davis, R.J. and K.M. Dugger. 2011. Chapter 3: Habitat Status and Trend In Davis, R.J., K.M. Dugger, S. Mohoric, L. Evers, and W.C. Aney. 2011. Status and Trends of Northern Spotted Owl Populations and Habitats, The First 15 Years (1994-2008); General Tecnhical Report PNW-GTR-850; October.

Davis, R.J., K.M. Dugger, S. Mohoric, L. Evers, and W.C. Aney. 2011. Northwest Forest Plan, the First 15 Years (1994-2008); Status and Trends of Northern Spotted Owl Populations and Habitats. General Technical Report (PNW-GTR-850). U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. October.

Dawley E.M., R.D. Ledgerwood, T.H. Blahm, C.W. Sims, J.T. Durkin, R.A. Kim, A.E. Rankin, G.E. Monan, and F.J. Ossiander. 1986. Migrational Characteristics, Biological Observations, and

Relative Survival of Juvenile Salmonids Entering the Columbia River Estuary, 1966–1983. Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

Dean, G.B. 1999. Acoustic Hot-spots and Breaking Wave Noise in the Surf Zone. Journal of the Acoustical Society of America 105(6)3151-3167.

Delaney, D.K., T.G. Grubb, P. Beier, L.L. Pater, and M.H. Reiser. 1999. Effects of Helicopter Noise on Mexican Spotted Owls. Journal of Wildlife Management. 63(1): 60-76.

Delaney, D.K. and T.G. Grubb. 2001. Effects of Off-highway Vehicle Noise on Northern Spotted Owls: sound data results. A report to the Mendocino National Forest, Contract Number 43-91Z9-0-0055.

Della Rosa, L., J.K.B. Ford, and A.W. Trites. 2012. Distribution and Relative Abundance Of Humpback Whales in Relation to Environmental Variables in Coastal British Columbia and Adjacent Waters. Continental Shelf Research 306:89-104.

Dennison, W.C. and R.J. Orth. 1993. Assessing Water Quality with Submerged Aquatic Vegetation. Bioscience 43:86-94.

Department of Fisheries and Oceans Canada. 2004. Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles, and Marine Mammals. Department of Fisheries and Oceans Canada Science Advisory Section.. Habitat Status Report 2004/002. Available online: http://www.dfo-mpo.gc.ca/csas/Csas/status/2004/HSR2004_002_e.pdf

DeVore, M., and N.A. Geyer. 2003a. Olalla/Lookingglass Watershed Assessment and Action Plan. Umpqua Basin Watershed Council. Roseburg, Oregon.

Dileanis, P.D., S.E Schwarzbach, J.Bennett, et al. 1996. Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Klamath Basin, California and Oregon, 1990-92. U.A. Geological Survey Water Resources Investigations Report 9 5-4232. Sacramento, California.

Douglas, A.B., J. Calambokidis, S. Raverty, S.J. Jeffries, D.M. Lambourn, and S.A. Norman. 2008. Incidence of Ship Strikes of Large Whales in Washington State. 2007. Journal of the Marine Biological Association of the United Kingdom 88(6):1121-1132.

Downing, J. 2008. Turbidity Standards versus Actual Sediment Particles. Campbell Scientific, Inc. Logan, Utah.

Duggger, K.M., R.G. Anthony, and L.S. Andrews. 2011. Transient Dynamics of Invasive Competition: Barred Owls, Spotted Owls, Habitat, and the Demons of Competition Present. Ecological Applications 21(7):2459-2468.

Dumbauld, B., J. W. Chapman, M. E. Torchin, and A. M. Kuris. 2011. Is the Collapse of Mud Shrimp (*Upogebia pugettensis*) Populations along the Pacific Coast of North America Caused by Outbreaks of a Previously Unknown Bopyrid Isopod Parasite (*Orthione griffenis*)? Estuaries and Coasts 34:336–350.

Durkin, J.T. and R.L. Emmett. 1980. Benthic Invertebrates, Water Quality, and Substrate Texture in Baker Bay, Youngs Bay, and adjacent areas of the Columbia River estuary. NMFS, NW and Alaska Fish Center, Seattle, WA. 44 pp.

Durkin, P., and M. Follansbee. 2003. Picloram - Revised Human Health and Ecological Risk Assessment – Final Report. USDA Forest Service, Arlington, VA.

Durkin, P., and M. Follansbee. 2004. Imazapyr- Human Health and Ecological Risk Assessment – Final Report. USDA Forest Service, Arlington, VA.

Ellis Ecological Services. 2013. Estuarine Compensatory Wetland Mitigation Plan Pacific Connector Gas Pipeline Project Coos Bay Estuary. Prepared for Pacific Connector Gas Pipeline, LP. May.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume II: Species life history summaries. ELMR Report Number 8, Strategic Assessment Branch, NOS/NOAA. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean

Ellis, R.H. 1999. Fish Use of the Estuary. 1999 Monitoring Report, Tillamook Bay. Report prepared for Tillamook Bay National Estuary Project and Tillamook County Performance Partnership, Garibaldi, Oregon.

Ellis, R.H. 2002a. Fish Use of the Estuary. 2000 Monitoring Report, Tillamook Bay. Report prepared for Tillamook Bay National Estuary Project and Tillamook County Performance Partnership, Garibaldi, Oregon.

Ellis, R.H. 2002b. Fish Use of the Estuary. 2001 Monitoring Report, Tillamook Bay. Report prepared for Tillamook Bay National Estuary Project and Tillamook County Performance Partnership, Garibaldi, Oregon.

Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California. 2001. Petition to List the North American Green Sturgeon (Acipenser medirostris) as an Endangered or Threatened Species under the Endangered Species Act. National Marine Fisheries Service.

Espinosa, R. 2007. Wildlife Biologist, Bureau of Land Management – Roseburg District. Personal Communication with Edge Environmental, Inc. via email. October 19, 2007.

Espinosa, R. 2008. Wildlife Biologist, Bureau of Land Management – Roseburg District. Personal Communication with Edge Environmental, Inc. via email. September 8, 2008.

Erickson, D.L., and M.A.H. Webb. 2007. Spawning Periodicity, Spawning Migration, and Size at Maturity of Green Sturgeon, Acipenser medirostris, in the Rogue River. Environmental Biology of Fishes 79:255-268.

Fabey, M. 2008. Rotor-wash Concerns Buffet Chinook. Aerospace Daily and Defense Report. Online at: http://aviationweek.com/aw/generic/story_channel.jsp?channel=defemse&id=news/5CSR060508.xml.

Falk, M. R. and M. J. Lawrence. 1973. Acute Toxicity of Petrochemical Drilling Fluid Components and Wastes to Fish. Environment Canada, Fisheries and Marine Service Center, Regular Technical Report Service Center 73-1.

Falxa, G.A., J. Baldwin, D. Lynch, S.K. Nelson, S.L. Miller, S.F. Pearson, M.G. Raphael, C. Strong, T. Bloxton, B. Galleher, B. Hogoboom, M. Lance, and R. Young. 2009. Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan: 2008 Summary Report. Marbled Murrelet Effectiveness Monitoring Program.

Falxa, G., J. Baldwin, D. Lynch, S.L. Miller, S.K. Nelson, S.F. Pearson, M.G. Raphael, C. Strong, T. Bloxton, B. Galleher, B. Hogoboom, M. Lance, and R. Young. 2011. Marbled Murrelet Effectiveness Monitoring Northwest Forest Plan. 2009 and 2010 Summary Report. Marbled Murrelet Effectiveness Monitoring Program

Farr, R.A. and T.A. Rien. 2002. Green Sturgeon Population Characteristics in Oregon. Annual Progress Report to Sport Fish Restoration, Project F-178-R, Oregon Department of Fish and Wildlife, Portland, OR.

Farr, R.A. and J.C. Kern. 2005. Green Sturgeon Population Characteristics in Oreagon. Final Progress Report F-178-R. Oregon Department of Fish and Wildlife. Salem, Oregon.

Fay, J.A. 2003. Model of Spills and Fires from LNG and Oil Tankers. Journal of Hazardous Materials B96:171-188.

Federal Energy Regulatory Commission. 2005. Final environmental impact statement (EIS) for the Key Span LNG Facility Upgrade Project (KeySpan LNG Project). Online at: http://www.ferc.gov/industries/lng/enviro/eis/2005/05-20-05-eis.asp. Accessed April 2, 2008.

Fogarty, M.J. and T.M. Powell. 2002. An Overview of the U.S. GLOBEC Program. Oceanography. 15(2): 4-12.

Fonseca, M.S., W.J. Kenworthy, and G.W. Thayer. 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. USDC-NOAA Coastal Ocean Program, Decision Analysis Series No. 12.

Foote, A.D., R.W. Osborne, and A.R. Hoelzel. 2004. Whale-call Response to Masking Boat Noise. Nature 428:910.

Ford, J.K.B. 2009. Killer Whale (Orcinus orca). Pages 650 to 65, in W.F. Perrin, B. Würsig, and J.F.M Thewissen (editors). Encyclopedia of Marine Mammals (Second Edition). Academic Press, Elsevier, New York.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest Ecosystem Management: an Ecological, Economic, and Social Assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior; National Oceanic and Atmospheric Administration; U.S. Environmental Protection Agency.

Forman, R.T. 1995. Land Mosaics: the Ecology of Landscapes and Regions. Press Syndicate of the University of Cambridge, Cambridge, UK.

Forman R.T., and L.E. Alexander. 1998. Roads and their Major Ecological Effects. Annual Review of Ecology and Systematics. 29:207-231.

Forman, R.T., and M. Godron. 1986. Landscape Ecology. John Wiley and Sons. New York, NY.

Forney, K.A. 2007. Preliminary Estimates of Cetacean Abundance along the U.S. West Coast and within Four National Marine Sanctuaries During 2005. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-406.

Forsman, E. 1983. Methods and Materials for Locating and Studying Spotted Owls. USDA Forest Service, Pacific Northwest Research Station, OR. General Technical Report PNW-162.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and Biology of the Spotted Owl in Oregon. Wildlife Monographs. 87: 1-64.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M.Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and Breeding Dispersal of Northern Spotted Owls. Wildlife Monographs. 149: 35.

Forsman, E.D., R. G., Anthony, R.G.; K.M. Dugger, K.M., Glenn, E.M.; Franklin, A.B.; White, G.C.; Schwarz, C.J.; Burnham, K.P.; Anderson, D.R.; Nichols, J.D.; Hines, J.E.; Lint, J.B.; Davis, R.J.; Ackers, S.H.; Andrews, L.S.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Gremel, S.A.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Reid, J.A.; Rockweit, J.; Schaberl, J.; Snetsinger, T.J.; Sovern, S.G. 2011. Population Demography of Northern Spotted Owls. Studies in Avian Biology 40. Berkeley, CA:University of California Press. 106 p.

Foster, S.C., C.H. Stein, and K.K. Jones. 2001. A Guide to Interpreting Stream Survey Reports. Information Reports 2001-06. Oregon Department of Fish and Wildlife, Portland, Oregon

Franklin, A.B. and R.J. Gutiérrez. 2002. Spotted Owls, Forest Fragmentation, and Forest Heterogeneity. Studies in Avian Biology 25:203-220.

Franklin, A.L., D.R. Anderson, R.J. Gutierrez, and K.P. Burnham. 2000. Climate, Habitat Quality, and Fitness in Northern Spotted Owl Populations in Northwestern California. Ecological Monographs 70(4):539-590.

Froese, R. and D. Pauly, Editors. 2008. Fish Species Summaries. FishBase. World Wide Web electronic publication. www.fishbase.org, version 10/2008.

Fry, D.M. 1995. Pollution and Fishing Threats to Marbled Murrelets. Pages 257-260 in C.J. Ralph, G.L. Hunt, M.G. Raphael, and H.F. Piatt (technical editors). Ecology and Conservation of the Marbled Murrelet. USDA Forest Service General Technical Report PSW-GTR-152. Albany, CA.

Furniss, M.M. 1979. An annotated bibliography of the Douglas-fir beetle, Dendroctonus pseudotsugae Hopk. USDA-Forest Service, Intermountain Forest and Range Experiment Station General Technical Report INT-48.

Gabrielson, I., and S. Jewett. 1940. Birds of Oregon. Oregon State College, Corvallis, Oregon.

Gartman, D.K. 1984. The Impact of a Pipeline Crossing on the Benthos of a Pennsylvania Trout Stream. Pages 461-471 in A.E. Crabtree (editor). Proceedings of the Third International Symposium on

Environmental Concerns in Rights-of-way Management. Mississippi State University, Mississippi State, MS.

Genron, D., S. Lanham, and M. Carwardine. 1999. North Pacific Right Whale (Eubalaena glacialis) Sighting South of Baja California. (Aquatic Mammals 25.1:31-34.

GeoEngineers. 2011a. Turbidity-Nutrients-Metals Water Quality Impacts Analysis. Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Salt lake City, Utah.

GeoEngineers, Inc. 2011b. Stream Crossing Risk Analysis. Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Inc. Salt Lake City, Utah.

GeoEngineers, Inc. 2012. Revised Draft Thermal Impacts Assessment. . Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Inc. Portland, Oregon.

GeoEngineers. 2013a. Geologic Hazards and Mineral Resources Report. Pacific Connector Gas Pipeline Project, Coos Bay to Malin, Oregon. GeoEngineers, Portland, Oregon.

GeoEngineers. 2013b. Turbidity-Nutrients-Metals Water Quality Impacts Analysis. Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Salt lake City, Utah.

GeoEngineers, Inc. 2013c. Stream Crossing Risk Analysis. Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Inc. Salt Lake City, Utah.

GeoEngineers, Inc. 2013d. Thermal Impacts Assessment. Pacific Connector Gas Pipeline Coos, Douglas, Jackson, and Klamath Counties, Oregon. GeoEngineers, Inc. Portland, Oregon.

Geyer., N.A. 2003a. Middle South Umpqua Watershed Assessment and Action Plan. Umpqua Basin Watershed Council. Roseburg, Oregon.

Geyer., N.A. 2003b. Myrtle Creek Watershed Assessment and Action Plan. Umpqua Basin Watershed Council. Roseburg, Oregon.

Geyer., N.A. 2003c. South Umpqua River Watershed Assessment and Action Plan. Umpqua Basin Watershed Council. Roseburg, Oregon.

Geyer., N.A. 2003d. Upper Cow Creek Watershed Assessment and Action Plan. Umpqua Basin Watershed Council. Roseburg, Oregon.

Gilmore, R. S. Hatzigrigoris, S. Mavrakis, A. Spertos, and A. Vordonis. 2005.LNG Carrier Alternative Propulsoion Systems. Report from Maran Gas Maritime, Inc. Online: http://www.daedalus.gr/jsauxilpublic/LNG_Propulsion-7.pdf

Gisler, S. 2002. Implementation of Recovery Tasks for the Endangered Applegate's milk-vetch (*Astragalus applegatei*), Part I: population augmentation at Miller Island, Part II: Seed collection and storage. Unpublished report prepared by Oregon Department of Agriculture and submitted to Klamath Falls Fish and Wildlife Office. 9 pp.

Gisler, S.D. 2004. Developing Biogeographically Based Population Introduction Protocols for at-risk Willamette Valley plant species. Report to US Fish and Wildlife Service, Portland, Oregon. Native Plant Conservation Program, Oregon Department of Agriculture, Salem, OR.

Goldman, S.J., K. Jackson, and T.A. Bursztynsky. 1986. Erosion and Sediment Control Handbook. McGraw-Hill Book Company. New York.

Goldsborough, W.J., and W.M Kemp. 1988. Light Responses of a Submersed Macrophyte - Implications for Survival in Turbid Tidal Waters. Ecology 69: 1775-1786.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA and Southwest Fisheries Science Center, Santa Cruz, CA.

Good, C.P. and D.W. Johnston. 2009. Spatial Modeling of Optimal North Pacific Right Whale (*Eubalaena glacialis*) Calving Habitats. North Pacific Research Board Final Report 718.

Gordon, J., P.A. Wilson, J. Grossman, D. Deamon, M. Edwards, D. Lenhardt, D. Norton, and W. Sollfrey. 2005. Assessment of Navy Heavy-Lift Aircraft Options. National Defense Research Institute, RAND Corporation, Santa Monica, CA.

Governor's Watershed Enhancement Board..1999. Oregon Watershed Assessment Manual. Oregon Watershed Enhancement Board, Salem, Oregon. Accessed online: http://www.oregon.gov/OWEB/pages/docs/pubs/or_wsassess_manuals.aspx.

Gray, M. 2007. Oregon Department of Fish and Wildlife, Personal Communication with Ellis Ecological Services.

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M.L. Bonnell, and K.C. Balcomb, III. 1992. Cetacean Distribution and Abundance off Oregon and Washington, 1989-1990. In: J. J. Brueggeman (ed.). Oregon and Washington Marine Mammal and Seabird Surveys. Minerals Management Service Contract Report 14-12-0001-30426.

Greene, C.R., and S.E. Moore. 1995. Man-made Noise. Pages 101 to 158 in W.J. Richardson, C.R. Greene, C.I. Malme, and D.H. Thompson (editors). Marine Mammals and Noise. Academic Press, Elsevier Science Imprint, San Diego, California.

Gregory, R.S. and T.G. Northcote. 1993. Surface, Planktonic, and Benthic Foraging by Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in Turbid Laboratory Conditions. Canadian Journal of Fisheries and Aquatic Sciences 50: 233-240.

Gregory, S. V., K.L. Boyer, and A.M. Gurnell (eds.). 2003. The Ecology and Management of Wood in World Rivers. American Fisheries Symposium 37, Amererican. Fisheries Society, Bethesda, Maryland.

Grubb, T.G. and R.M. King. 1991. Assessing Human Disturbance of Breeding Bald Eagles with Classification Tree Models. Journal of Wildlife Management 55:501-512.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted owl (*Strix occidentalis*) in: A. Poole and F. Gill (editors). The Birds of North America, No. 179. The Academy of Natural Sciences and The American Ornithologists' Union, Washington, D.C.

Guetterman, J. 2007. Wildlife Biologist, Bureau of Land Management – Coos Bay District. Personal Communication with Edge Environmental, Inc. via email. October.

Guetterman, J. 2008a. Wildlife Biologist, Bureau of Land Management – Coos Bay District. Personal Communication with Edge Environmental, Inc. via email. September.

Guetterman, J. 2008b. Coos Bay BLM District, Personal Communication via email with Edge Environmental, Inc. February.

Hamer, T.E., and S.K. Nelson. 1998. Effects of Disturbance on Nesting Marbled Murrelets: summary of preliminary results. Unpublished report, Hamer Environmental, Mount Vernon, Washington, prepared for for U.S. Fish and Wildlife Service, Portland, OR.

Hamilton, J.B., G.L. Curtis, S.M. Snedaker, and D.K. White. 2005. Distribution of Anadromous Fishes in the Upper Klamath River Watershed Prior to Hydropower Dams – A Synthesis of the Historical Evidence. Fisheries 30(4):10-20.

Hanson, E. and M. Sytsma. 2001. Oregon Aquatic Nuisance Species Management Plan. Center for Lakes and Reservoirs, Portland State University, Portland, OR.

Harmon, M.E., J.F. Franklin, F.J Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, and K.W. Cummins. 1986. Ecology of Coarse Woody Debris in Temperate Ecosystems. Advances in Ecological Research 15:133-302.

Harper, H.W., and R. Trettel. 2002. Theoretical Modeling of Suspended Sediment, Turbidity Dynamics, and Fisher Impacts during Pipeline Construction across Streams. Pages 753 to 763, in J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild (editors). Seventh International Symposium on Environmental Concerns in Rights-of-Way Management. Elsevier, New York.

Harper, K.A., and S.E. Macdonald. 2002. Structure and Composition of Edges Next to Regenerating Clear-cuts in Mixed-wood Boreal Forest. Journal of Vegetation Science 13:535-546.

Harper, K.A., S.E. MacDonald, P.J. Burton, J. Chen, K.D. Brosofske, S.C. Saunders, E.S. Euskirchen, D. Roberts, M.S. Jaiteh, and P. Esseen. 2005. Edge Influence on Forest Structure and Composition in Fragmented Landscapes. Conservation Biology 19:768-782.Harris, H.S., S.R. Benson, K.V. Gilardi, R.H. Poppenga, T.M. Work, P.H. Dutton, and J.A.K. Mazet. 2011. Comparative Health Assessment of Western Pacific Leatherback Turtles (*Dermochelys coriacea*) Foraging off the Coast of California, 2005-2007. Journal of Wildlife Diseases 47(2):321-337.

Harris, H.S., S.R. Benson, K.V. Gilardi, R.H. Poppenga, T.M. Work, P.H. Dutton, and J.A.K. Mazet. 2011. Comparative Health Assment of Western Paciific Leatherback Turtles (*Dermochelys coriacea*) Foraging off the Coast of California, 2005-2007. Journal of Wildlife Diseases 47(2):321-337.

Harrison, E.T. R.H. Norris, and S.N. Wilkinson. 2007. The Impact of Fine Sediment Accumulation on Benthic Macroinvertbrates: Implications for River Management. Pages 139 to 144 in Wilson, A.L, R.L. Dehaan, R.J. Watts, K.J. Page, K.H. Bowmer, and A. Curtis. (editors). Proceedings of the 5th Australian Sream Management Conference. Charles Sturt University, Thurgoona, New South Wales

Hartman, W.A. and D.B. Martin. 1984. Effect of Suspended Bentonite Clay on the Acute Toxicity of Glyphosate to Daphnia pulex and Lemna minor. Bulletin of Environmental Contamination and Toxicology 33:355-361.

Hastings, M.C., and A.N. Popper. 2005. Effects of Sound on Fish. Unpublished Report, California Department of Transportation. Sacramento, California. Available Online: http://www.dot.ca.gov/hq/env/bio/files/Effects_of_Sound_on_Fish23Aug05.pdf.

Hatch, L., C. Clark, R. Merrick, S. Van Parijs, D. Ponirakis, K. Schwehr, M. Thompson, and D. Wiley. 2008. Characterizing the Relative Contributions of Large Vessels to Total Ocean Noise Fields: A Case Study Using the Gerry E. Studds Stellwagen Bank National Marine Sanctuary. Environmental Management 42: 735-752.

Hathcock, C.D., L.A. Hansen, and D.C. Keller. 2010. Occupancy of Habitats by Mexican Spotted Owls in Relation to Explosive Noise and Recreational Access at Los Alamos National Laboratory. Western Birds 41:102-106

Hay, D.E. and P.B. McCarter. 2000. Status of the Eulachon *Thaleichtys pacificus* in Canada. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario. http://www.dfo-mpo.gc.ca/csas/csas/DocREC/2000/PDF/2000_145e.pdf (last accessed on July 17, 2009)

Haycock, R.D. 2000. COSEWIC Status Report on the Oregon Spotted Frog Rana pretiosa in Canada, in COSEWIC Assessment and Status Report on the Oregon Spotted Frog Rana pretiosa in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Hayward, L.S., A.E. Bowles, J.C. Ha, S.K. Wasser. 2011. Impacts of acute and long-term vehicle exposure on physiology and reproductive success of the northern spotted owl. Ecosphere 2(6):1-20.

Hazel, J., I.R. Lawler, H. Marsh, and S. Robson. 2007. Vessel Speed Increases Collision Risk for the Green Sea Turtle *Chelonia mydas*. Endangered Species Research 3:105-113.

Hébert, P.N., and R.T. Golightly. 2006. Movements, Nesting, and Response to Anthropogenic Disturbance of Marbled Murrelets (*Brachyramphus marmoratus*) in Redwood National and State Parks, California. Unpublished report, Humboldt State University, Arcata, prepared for California and California Department of Fish and Game Report 2006-02, Sacramento, California.

Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An Overview of Sensory Effects on Juvenile Salmonids Exposed to Dissolved Copper: Applying a Benchmark concentration Approach to Evaluate Sublethal Neurobehavioral Toxicity. NOAA Technical Memorandum NMFS-NWFSC-83, Seattle, WA/

Heiser, D.W., and E.L. Finn, Jr. 1970. Observations of Juvenile Chum and Pink Salmon in Marina and Bulkhead Areas. Supplemental Progress Report, Puget Sound Studies, Division, Olympia, Washington.

Heithecker, T.D., and C.B. Halpern. 2007. Edge-related Gradients in Microclimate in Forest Aggregates Following Structural Retention Harvests in Western Washington. Forest Ecology and Management 248:163-173.

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly. 2000. Effects of Sedimentation and Turbidity on Lotic Food Webs: a Concise Review for Natural Resource Managers. Reviews in Fisheries Scienc 8(2):125-139.

Henson, P. and T.A. Grant. 1991. The Effects of Human Disturbances on Trumpeter Swan Breeding Behavior. Wildlife Society Bulletin. 19: 248-257.

Hermann, R.K., and D.P. Lavender. 2004. Douglas-Fir. USDA-Forest Service Silvics Manual Volume 1. Accessed online: http://www.na.fs.fed.us/pubs/silvics_manual/volume_1/silvics_vol1.pdf.

Hicks, L.L., D.R. Herter, and R. Early. 2001. Northern Spotted Owl Demographic Monitoring and Modeling – 5 Year Summary Report. Plum Creek Cascades Habitat Conservation Plan, May 21, 2002.

Hightower, M., L. Gritzo, A. Luketa-Hanlin, J. Covan, S. Tieszen, G. Wellman, M. Irwin, M. Kaneshige, B. Melof, C. Morrow, and D. Ragland. 2004. Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill over Water. Sandia National Laboratories Report SAND2004-6258. Albuquerque, New Mexico.

Hinton, S. A. and R. L. Emmett. 1994. Juvenile Salmonid Stranding in the Lower Columbia River, 1992 and 1993. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-NWFSC-20, 48 pp.

Hobbs, J., I. Blackburn, and A. Harestad. 2004. Survey Protocol and Standards for the Spotted Owl in British Columbia. Ministry of Water, Land and Air Protection. Victoria, B.C.

Hodge, J., and M. Buettner. 2009. Sucker Population Monitoring in Tule Lake and the Lower Lost River, 2008. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Service, Klamath Falls, Oregon.

Holst, M,, W.J. Richardson, W.R. Koski, M.A. Smultea, B. Haley, M.W. Fitzgerald, and M.Rawson. 2006, 'Effects of Large and Small Source Seismic Surveys on Marine Mammals and Sea Turtles', Abstract only. Eos Transactions American Geophysical Union 87(36)

Holt, M.M. 2008. Sound Exposure and Southern Resident Killer Whales (*Orcinus orca*): A review of current knowledge and data gaps. U.S. Department of Commerce, NOAA Technical Memmorandum NMFS-NWFSC-89.

Holt, M.M., D.P. Noren, V.Veirs, C. Emmons, and S. Veirs. 2008. Speeking Up: Killer Whales (*Orcinus orca*) Increase their Call Amplitude in Response to Vessel Noise. Journal of Acoustic Society of America 125(1):EL27-EL32.

Horkel, J.D. and W.D. Pearson. 1976. Effects of Turbidity on Ventilation Rates and Oxygen Consumption of Green Sunfish, *Lepomis cyanellus*. Transactions of the American Fisheries Society 105:107-113.

Hornig, S., A. Sterling, and S. D. Smith. 1989. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest, USA) ghost shrimp and blue mud shrimp. U.S. Fish and Wildlife Service Biological Report 82:1–14 Corvallis, OR.

Horwood, J. 2009. Sei Whale, *Balaenoptera borealis*. Pages 1001 to 1003 in W.F. Perrin, B. Würsig, and J.F.M Thewissen (editors). Encyclopedia of Marine Mammals (Second Edition). Academic Press, Elsevier, New York.

Howe, C.M., M. Berril, B.D. Pauli, C.C. Helbing, K., Werry, and N. Veldhoen. 2004. Toxicity of Glyphosate-based Pesticides to Four North American Frog Species. Environmental Toxicology and Chemistry 23(8):1928-1938.

Huff, M.H., M.G. Raphael, S.L. Miller, S.K. Nelson, and J. Baldwin, technical coordinators. 2006. Northwest Forest Plan – The First 10 Years (1994-2003): Status and Trends of Populations and Nesting Habitat for the Marbled Murrelet. General Technical Report PNW-GTR-650. USDA Forest Service, Pacific Northwest Research Station. Portland, OR.

Ice, G.G. 2008. Stream Temperature and Dissolved Oxygen. Pages 37-54 in J.D. Stednick (editor). Hydrological and Biological Responses to Forest Practices. Ecological Studies, Volume 199. Springer.

Imper, D.K. 2003. Port Orford Sewage Offshore Discharge – Proposed Drilling Location. Unpublished written communication to R. Burns, USFWS Roseburg Office, Aracta: FWO.

Imper, D. 2008. Ecologist at U.S. Fish and Wildlife Service, Arcata Office, Endangered Species Consultation & Recovery- Plants Division. Arcata, California. Personal Communication with Siskiyou BioSurvey. January.

International Gas Union. 2012. World LNG Report - 2011. International Gas Union. Online http://www.igu.org/gas-knowhow/publications/igu-publications.

Israel, J.A., J.F. Cordes, M.A. Blumberg, and B. May. 2004. Geographic Patterns of Genetic Differentiation among Collections of Green Sturgeon. North American Journal of Fisheries Management. 24: 922-931.

Israel, J.A. and B. May. 2007. Mixed Stock Analysis of Green Sturgeon from Washington State Coastal Aggregations. Unpublished Final Report. Genomic Variation Laboratory, Department of Animal Science, University of California. Davis, CA.

Jensen, A.S. and G.K. Silber. 2003. Large Whale Ship Strike Database. USDC - National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-OPR-25. National Marine Fisheries Service. Silver Spring, MD.

Johnsen R.C. and C.W. Sims. 1973. Purse seining for juvenile salmon and trout in the Columbia River estuary. Transactions of the American Fisheries Society 102:341–345.

Johnson, C.L., and R.R. Reynolds. 2002. Responses of Mexican Spotted Owls to Low-flying Military Jet Aircraft. USDA Forest Service Research Note RMRS-RN-12

Johnson, D.H. 1992. Spotted Owls, Great Horned Owls, and Forest Fragmentation in the Central Oregon Cascades. M.S. Thesis, Oregon State University, Corvallis, OR

Johnson, D.H. and T.A. O'Neil (managing directors). 2001. Wildlife-Habitat Relationships in Oregon and Washington. Oregon State University Press. Corvallis, OR.

Johnson, P.T.J., J.M. Chase, K.L. Dosch, R.B. Hartson, J.A. Gross, D.J. Larson, D.R. Sutherland, and S.R. Carpenter. 2007. Aquatic Eutrophication Promotes Pathogenic Infection in Amphibians. Proceeding of the National Academy of Sciences 104(40):15781-15786.

Jones and Stokes. 2007. Habitat Conservation Plan for the Western Snowy Plover. September. (J&S 06537.06). Portland, OR. Prepared for U.S. Fish and Wildlife Service and Oregon Parks and Recreation Department.

Kagan, J.S, J.C. Hak, B. Csuti, C.W. Kiilsgaard, and E.P. Gaines. 1999. Oregon Gap Analysis Project Final Report: A geographic approach to planning for biological diversity. Oregon Natural Heritage Program, Portland, OR.

Kastak, D., B.L. Southall, R.J. Schusterman, and C.R. Kastak. 2005. Underwater Temporary Threshold Shift in Pinnipeds; Effects of Noise Level and Duration. Journal of the Acoustical Society of America 118(5):3154-3163.

Kaye, T. 2008. Institute of Applied Ecology, Corvallis, Oregon, Personal Communication with Siskiyou BioSurvey.

Keevin, T.M., and G.L. Hempen. 1997. The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts. U.S. Army Corps of Engineers, St. Louis, Missouri.

Kelley, E.G., E.D. Forsman, and R.G. Anthony. 2003. Are Barred Owls Replacing Spotted Owls? Condor. 105(1): 45-53.

Kelley, E.G. and E.D. Forsman. 2004. Recent Records of Hybridization Between Barred Owls (Strix varia) and Northern Spotted Owls (S. occidentalis caurina). Auk. 121(3): 806-810.

Kiilsgaard, C. and C. Garrett. 1999. Oregon Current Wildlife-Habitat Types – GIS coverage. Northwest Habitat Institute. Corvallis, OR.

Kostow, K. 1995. Biennial Report on the Status of Wild Fish in Oregon. Oregon Department of Fish and Wildlife. Salem, OR.

Lahti, D.C. 2001. The "Edge Effect on Nest Predation" Hypothesis after Twenty Years. Biological Conservation 99:365-374.

Laidig, K.J., and D.S. Dobkin. 1995. Spatial Overlap and Habitat Association of Barred Owls and Great Horned Owls in Southern New Jersey. Journal of Raptor Research 29:151–157.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta. 2001. Collisions between Ships and Whales. Marine Mammal Science 17(1):35-75.

Land, B. 1974. Toxicity of Drilling Fluid components to Aquatic Biological Systems: a Literature Review. Canada Department of the Environment Research and Development Directorate Technical Report Number 487.

Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Coho Salmon. U.S. Fish and Wildlife Service Biological Report 82(11.48), U.S. Army Corps of Engineers, TR EL-82-4.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2012. The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast - 2012. The Oregon Biodiversity Information Center.Institute for Natural Resources. Portland State University, Portland, OR

Lawson, P.W. 2005. Oregon Coast Coho Salmon ESU. Pages 313-338 in T.P. Good, R.S. Waples, and P. Adams (editors). Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA and Southwest Fisheries Science Center, Santa Cruz, CA.

LBJ Enterprises. 2006. 2005 Pre-construction Wildlife Surveys for Proposed Jordan Cove liquefied natural gas plant, Coos Bay, Oregon. Prepared for SHN Consulting Engineers. LBJ Enterprises. Eureka, CA. May 10, 2006.

Leal, D. 2006. Harassment Analysis and Distance Threshold Notes. USFWS, Oregon Fish and Wildlife Office, Portland, Oregon. Online:ftp://ftp.odot.state.or.us/techserv/geo-environmental/environmental/procedural%20manuals/Biology/Biology_Manual/Docs/USFWS_harassment%20thresholds.pdf

Leedy, D.L. 1975. Highway-Wildlife Relationships. Volume 1; A State-of-the-Art Report. Federal Highway Administration Report Number FHWA-RD-76-4. Washington D.C.

Leese, G.W., and J.T. Knight. 1974. Helicopter Downwash Data. Miscellaneous Paper S-74-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lemly, A.D. 1996. Selenium in Aquatic Organisms. Pages 427-445 in W.N. Beyer, G.H. Heinz, A.W. Redmond-Norwood (editors). Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. Lewis Publishers, Boca Raton, Florida.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, Washington.

Lerum, L. 2012. Site Management Plan for Oregon Spotted Frog, (Rana pretiosa), Buck Lake Complex, Klamath County, Oregon. USDA-Forest Service. Fremont-Winema National Forest.

Liebezeit, J.R., and T.L. George. 2002. A Summary of Predation by Corvids on Threatened and Endangered Species in California and Management Recommendations to Reduce Corvid Predation. California Department of Fish and Game, Habitat Conservation Planning Branch, Sacramento, California.

Limerinos, J.T. 1970. Determination of the Manning Coefficient From Measured Bed Roughness in Natural Channels. Geological Survey Water-Supply Paper 1898-B. U.S. Geological Survey, Washington, D.C.

Lindley, S.T., M.L. Moser, D.L. Erickson, M. Belchik, D.W. Welch, R.L. Rechisky, J.T. Kelly, J. Heublein, A.P. Klimley. 2008. Marine Migration of North American Green Sturgeon. Transaction of the American 137:182-194.

Lint, J., module lead. 2001. Northern Spotted Owl Effectiveness Monitoring, Northwest Forest Plan, Annual Summary Report. Northwest Forest Plan Interagency Monitoring Program.

Lint, J. (technical coordinator). 2005. Northwest Forest Plan – the first 10 years (1994 – 2003): status and trends of northern spotted owl populations and habitat. General Technical Report PNW-GTR-648. USDA, Forest Service, Pacific Northwest Research Station. Portland, OR.

Linville, R. G., S. N. Luoma, L. Cutter, and G. A. Cutter. 2002. Increased Selenium Threat as a Result of Invasion of the Exotic Bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Little Butte Creek Watershed Council. 2003. Little Butte Creek Watershed Assessment. Little Butte Creek Watershed Council, Eagle Point, Oregon.

Lloyd, D.S. 1987. Turbidity as a Water Quality Standard for Salmonid Habitats in Alaska. North American Journal of Fisheries Management 7:34-45.

Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effects of Turbidity in Fresh Waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Lloyd's List Intelligence. 2013. Global LNG Tracker. Available online at http://www.lloydslistintelligence.com/llint/gas/index.htm

Lohn, D.R. 2007. Letter to Federal Agency Executives: Listing Status, Section 7, and Consultation Requirements for Oregon Coast Coho Salmon. USDC-NOAA, National Marine Fisheries Service Northwest Region, Regional Administrator. Seattle, WA.

Long, L. and C.J. Ralph. 1998. Regulation and Observation of Human Disturbance near Nesting Marbled Murrelets. USDA Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA.

Lorz, H.W., R.H. Williams, and C.A. Fustish. 1978. Effects of Several Metals on Smolting of Coho Salmon. Environmental Protection Agency EPA-600/3-78-90.

Luginbuhl, J.M., M.M. Marzluff, J.E. Bradley, M.G. Raphael, and D. E. Varland. 2001. Corvid Survey Techniques and the Relationship Between Corvid Relative Abundance and Nest Predation. Journal of Field Ornithology. 72: 556-572.

Luketa, A., M.M. Hightower, and S. Attaway. 2008. Breach and Safety Analysis of Spills Over Water from Large Liquefied Natural Gas Carriers. Sandia National Laboratories Report SAND2008-3153. Albuquerque, New Mexico.

Lusseau, D., D.E. Bain, R. Williams, and J.C. Smith. 2009. Vessel Traffic Disrupts the Foraging Behavior of Southern Resident Killer Whales *Orcinus orca*. Endangered Species Research 6:2110221.

Lytle, D.A., and B. L. Peckarsky. 2001. Spatial and Temporal Impacts of a Diesel Fuel Spill on Stream Invertebrates. Freshwater Biology 46:693-704.

Marbled Murrelet Effectiveness Monitoring Program. 2008. Marbled Murrelet Population Estimates, 2000-2007. Based on at-sea surveys conducted in Conservation Zones 1 - 5. Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan.

Mack, D.E., W.P. Ritche, S.K. Nelson, E. Kuo-Harrison, P. Harrison, T.E. Hamer. 2003. Methods for Surveying Marbled Murrelets in Forests: A Revised Protocol for Land Management and Research. January.

Malt, J., and D. Lank. 2007. Temporal Dynamics of Edge Effects on Nest Predation Risk for the Marbled Murrelet. Biological Conservation 140:160-173.

Malt, J., and D. Lank. 2009. Marbled Murrelet Nest Predation Risk in Managed Forest Landscapes: Dynamic Fragmentation Effects at Multiple Scales. Ecological Applications 19(5):1274-1287.

Manley, I.A. and S.K. Nelson. 1999. Habitat characteristics associated with nest success and predation at Marbled Murrelet nest trees. Pacific Seabirds 26:40 (Abstract).

Manley, I., R. Shortt, and A.E. Burger. 1992. Marbled Murrelet Activity Patterns in the Carmanah Valley on the southwest coast of Vancouver Island. Pages 71–75 in K. Vermeer, R.W. Butler, and K.H. Morgan, editors. The ecology, Status, and Conservation of Marine and Shoreline Birds on the West Coast of Vancouver Island. Occasional Paper No. 75, Canadian Wildlife Service, Pacific and Yukon Region, Delta, British Columbia.

Manville, A.M. 2000. The ABCs of Avoiding Bird Collisions at Communications Towers: the Next Steps. Electric Power Research Institute, Proceedings of the Avian Interactions Workshop. Charleston, SC.

Manville, A.M. 2005. Bird Strikes and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science – Next Steps Toward Mitigation. USDA Forest Service General Technical Report PSW-GTR-191.

Marine Turtle Specialist Group. 2004. Green Turtle Assessment. IUCN, The World Conservation Union Red List. Online at: http://www.iucn-mtsg.org/red_list/cm/MTSG_Chelonia_mydas_Assessment_April-2004.pdf.

MarineTraffic.com . 2013. AIS Marine Traffic. http://www.marinetraffic.com/ais/datasheet.aspx?datasource=V_SHIP&level1=220

Maritime Administration (MARAD). 2013. Maritime Statistics. U.S. Department of Transportation, Maritime Administration. Avalable Online: http://www.marad.dot.gov/library_landing_page/data_and_statistics/Data_and_Statistics.htm

Markarian, R.K., J.P. Nicolette, T. Barber, and L. Giese. 1994. A Critical Review of Toxicity Values and an Evaluation of the Persistence of Petroleum Products for Use in Natural Resource Damage Assessments. American Petroleum Institute Publication Number 4594.

Marshall, D.B. 1988a. Status of the Marbled Murrelet in North America with a Special Emphasis on Populations in California, Oregon, and Washington. U.S. Fish and Wildlife Service Biological Report 88(30).

Marshall, D.B. 1988b. The Marbled Murrelet Joins the Old-Growth Forest Conflict. American Birds 42: 202-212.

Marshall, D.B. 1989. The Marbled Murrelet. Pages 435-455 in Audubon Wildlife Report 1989/1990. Academic Press, Inc. San Diego, CA.

Marshall, D.B., M.G. Hunter, and A.L. Contreras (editors). 2006. Birds of Oregon: A General Reference. Oregon State University Press, Corvallis, OR.

Martin, D.E. and L.E. Benda. 2001. Patterns of Instream Wood Recruitment and Transport at the Watershed Scale. Transactions of the American Fisheries Society 130:940-958.

Martin, P.D., and M. Tyrrel. 2002. Natural Resources that may be Affected if Your Horizontal Directional Drill Fails: Open Cut Analysis of a Coastal Maine River. Pages 725-733 in J.W. Goodrich-Mahoney, D.F. Mutrie, and C.A. Guild (editors). The Seventh International Symposium on Environmental Concerns in Right-of-Way Management. Elsevier Science, Ltd., Boston, Massachusetts.

Martin, K.J., S.C. Alessi, J.C. Gaspard, A.D. Tucker, G.B. Bauer, and D.A. Martin. 2012. Under Water Hearing in the Loggerhead Turtle (*Caretta caretta*): A Comparison of Behavioral and Auditory Evoked Potential Audiograms. Journal of Experimental Biology 215:3001-3009.

Marty, J. 2005. Effects of Cattle Grazing on Diversity in Ephemeral Wetlands. Conservation Biology 19:1626-1632.

Marzluff, J.M., J.J. Millspaugh, P. Hurvitz, and M.S. Handcock. 2004. Relating Resources to a Probabilistic Measure of Space Use: Forest Fragments and Steller's Jays. Ecology 85(5):1411-1427.

Marzuluff, J.M., and M. Restani. 1999. The Effects of Forest Fragmentation on Avian Nest Predation. Pages 155-169 in J.A. Rochelle, L.A. Lehman, and J. Wisniewski (editors). Forest Fragmentation: Wildlife and Management Implications. Brill Academic Publish, Leiden, The Netherlands.

McArdle, R.E., W.H. Meyer, and D. Bruce. 1961. The yield of Douglas-fir in the Pacific Northwest. U.S. Department of Agriculture, Technical Bulletin 201. Washington, DC.

McCain, B.B., S. D. Miller, W.W. Wakefield II. 2005. Life History, Geographical Distribution, and Habitat Associations of 82 West Coast Ground Fish Species: A Literature Review. Northwest Fisheries Science Center, NMFS. Seattle, WA.

McCauley, R.D, J. Fewtrell, A.J, Duncan,C. Jenner, M.N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCab. 2000, 'Marine Seismic Surveys: A Study of Environmental Implications', APPEA Journal 2000:692-708.

McCorkle. 2012. Personal communication with Edge Environmental.

McCovey, B.W. 2007. Klamath River Green Sturgeon Acoustic Biotelemetry Monitoring FY 2007 DRAFT Report. Yurok Tribal Fisheries Program. Hoopa, CA.

McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Environmental Protection Agency, Region 10. Seattle, WA

McDonald, M.A., J.A. Hildebrand and S.C. Webb. 1995. Blue and Fin Whales Observed on a Seafloor Array in the Northeast Pacific. Journal of the Acoustic Society of America 98(2):712-721.

McDonald, M.A., J.A. Hildebrand, and S.M. Wiggins. 2006. Increases in Deep Ocean Ambient Noise in the Northeast Pacific wes of San Nicolas Island, California. Journal of the Acoustical Society of America 120(2):711-718.

McDonald, M.A., J.A. Hildebrand, S.M. Wiggins, and D. Ross. 2008. A 50 Year Comparison of Ambient Ocean Noise near San Clemente Island: A Bathymetrically Complex Coastal region off Southern California. Journal of the Acoustical Society of America 124(4):1985-1992.

McKelvey, K.S., K.B. Aubry, and Y.K. Ortega. 1999. History and distribution of Lynx in the Contiguous United States. Pages 207 to 264 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R..; Squires. Ecology and Conservation of Lynx in the United States. USDA Forest Service General Technical Report RMRS-GTR-30WWW. Fort Collins, CO

McKenna, M.F., D.Ross, S.M. Wiggins, and J.A. Hildebrand. 2012. Underwater Radiated Noise from Modern Commercial Ships. Journal of the Acoustical Society of America 131(1):92-103.

McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. USDI Fish and Wildlife Service FWS/OBS-82/10.49.

McMahon, T.A., L.A. Brannelly, M.W.H. Chatfield, P.T.J. Johnson, M.B. Joseph, V.J. McKenzie, C.L. Richards-Zawacki, M.D. Venesky, and J.R. Rohr. 2013. Chytrid Fungus *Batrachochytrium dendrobatidis* has Nonamphibian Hosts and Releases Chemicals that cause Pathology in the Absence of Infection. Proceeding of the National Academy of Sciences 110(1):210-215.

McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Frisen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation Report for the 5-Year Status Review of the Marbled Murrelet in Washington, Oregon, and California. U.S. Fish and Wildlife Service, Region 1. Portland, OR.

Meager, J.J., P. Domenici, A. Shingles, and A.C. Utne-Palm. 2006. Escape Responses in Juvenile Atlantic Cod (*Gadus morhua*): the Effect of Turbidity and Predator Velocity. Journal of Experimental Biology 209:4174-4184.

Meyer, C.B., and S.L. Miller. 2002a. Use of Fragmented Landscapes by Marbled Murrelets for Nesting in Southern Oregon. Conservation Biology 16(3):755-766.

Meyer, C.B., S.L. Miller, and C.J. Ralph. 2002b. Multi-scale landscape and seascape patterns associated with marbled murrelet nesting areas on the U.S. West Coast. Landscape Ecology 17(2): 95-115.

Meyer, C.B., S.L. Miller, and C.J. Ralph. In Review (2008). Delay in Response to Forest Fragmentation by the Marbled Murrelet. Journal of Wildlife Management.

Meyer, J.S., L.L> Irwin, and M.S. Boyce. 1998. Influence of Habitat Abundance and Fragmentation on Northern Spotted Owls in Western Oregon. Wildlife Monographs 139:3-51.

Miller, B.A. and S. Sadro. 2003. Residence Time and Seasonal Movements of Juvenile Coho Salmon in the Ecotone and Lower estuary of Winchester Creek, South Slough, Coos Bay, Oregon. Transactions of the American Fisheries Society 132:546-559.

Miller, D.R., Emmett R.L., and R.J. McConnell. 1989. Benthic Invertebrates at a Test Dredged Materials Disposal Site in the Umpqua River, Oregon. NMFS, NWFC, Seattle, WA. 20pp.

Miller, D.R., Emmett, R.L., and S.A. Hinton. 1990. A Preliminary Survey of Benthic Invertebrates in the Vicinity of the Coos Bay, Oregon, Navigation Channel. Unpublished Final Report, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Center, National Marine Fisheries Service, Seattle, WA.

Miller, J.A. and A.L. Shanks. 2005. Abundance and distribution of larval and juvenile fish in Coos Bay, Oregon: time-series analysis based on light-trap collections. Mar. Ecol. Prog. Ser. 305: 177- 191.

Miller, P.J.O., N. Biassoni, A. Samuels, and P.L. Tyack. 2000. Whale Songs Lengthen in Response to Sonar. Nature 405:903.

Miller, S.L., M.G. Raphael, G.A. Falxa, C. Strong, J. Baldwin, T. Bloxton, B.M. Gallaher, M. Lance, D. lynch, S.F. Pearson, C.J. Ralph, and R.D. Young. 2012. Recent Population Decline of the Marbled Murrelet in the Pacific Northwest. The Condor 114(4): 771-781.

Miner, J.G., and R.A. Stein. 1996. Detection of Predators and Habitat Choice by Small Bluegills: Effects of Turbidity and Alternative Prey. Transactions of the American Fisheries Society 125: 97-103.

Moeur, M., T.A. Spies, M. Hemstrom, J.R. Martin, J. Alegria, J. Browning, J. Cissel, W.B. Cohen, T.E. Demeo, S/ Healey, and R. Warbington. 2005. Northwest Forest Plan–The First 10 Years (1994-2003): Status and Trend of Late-Successional and Old-Growth Forest. USDA-Forest Service General Technical Report PNW-GTR-646. Portland, OR.

Moeur, M.; J.L. Ohmann, R.E. Kennedy, W.B. Cohen, M.J. Gregory, Z. Yang, H.M. Roberts, T.A. Spies, and M. Fiorella. 2011. Northwest Forest Plan–the First 15 Years (1994–2008): Status and Trends of Late Successional and Old Growth Forests. USDA-Forest Service General Technical Report PNW-GTR-853. Portland, OR.

Moffatt and Nichol. 2006. Report on turbidity due to dredging. Jordan Cove LNG Terminal. Coos Bay, Oregon. Prepared For Black And Veatch and Jordan Cove Energy Project, LP. MNI Project No. 5797. Jordan Cove LNG Terminal Document No. 5797RP0009. May 2006.

Moffatt and Nichol. 2007. Oregon Gateway Marine Terminal Aeolian Transport at Port Stockpile Site. Memorandum to David Evans and Associates.

Morse, T.L. and H.K. Kytomaa. 2010. The Effect of Turbulence on the Evaporation of Cryogenic Liquid Spills on Water. American Institute of Chemical Engineers, Spring Meeting. Available online at: http://www.allriskengineering.com/library_files/AIChe_conferences/AIChe_2010/data/papers/P175917.pdf

Moser, M. and S. Lindley. 2007. Use of Washington Estuaries by Subadult and Adult Green Sturgeon. Environmental Biology of Fishes. doi 10.1007/s10641-066-9028-1.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press, Berkeley, CA.

Moyle, P.B. and J.J. Cech. 2000. Fishes – An Introduction of Ichthyology. Prentice Hall, Upper Saddle River, NJ.

Mrosovsky, N., G.D.Ryan, and M.C. James. 2009. Leatherback turtles: The Menace of Plastic. Marine Pollution Bulletin 58:287-289.

Muck, J. 2010. Biological Effects of Sediment on Bull Trout and their Habitat – Guidance for Evaluating Effects. Final Report. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, Washington. Available Online at http://www.fws.gov/wafwo/CTA_S7guidance.html#TechAsst

Murcia, C. 1993. Edge Effects in Fragmented Forests: Implications for Conservation. Trends in Ecology and Evolution 10(2):58-62.

Murphy, M.L., and K.U. Koski. 1989. Input and Depletion of Woody Debris in Alaska Streams and Implications for Streamside Management. North American Journal of Fish Management 9:427-436.

Mutrie, D.F., and I.F.H. Scott. 1984. Environmental Evaluation of Water Crossing Techniques for Pipeline Construction in Canada. Pages 508-517 in A.E. Crabtree (editor). Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-way Management. Mississippi State University, Mississippi State, Mississippi.

Naslund, N.L. 1993. Why Do Marbled Murrelets Attend Old-Growth Forest Nesting Areas Year-Round? The Auk 110: 594-602.

National Audubon Society. 2013. Christmas Bird Count – Historical Results. Accessed online: http://www.audubon.org/bird/cbc/index.html.

National Marine Fisheries Service (NMFS). 1979. Designated Critical Habitat; Determination of Critical Habitat for the Leatherback Sea Turtle. Federal Register 44(58): 17710-17712.

National Marine Fisheries Service. 1991. Recovery Plan for the Humpback Whale (*Megaptera novaeangliae*). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. 105pp.

National Marine Fisheries Service. 1995. Endangered and Threatened Species: Proposed Threatened Status for Three Contiguous ESUs of Coho Salmon Ranging from Oregon Through Central California. Federal Register 60(142):38011-38030.

National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NOAA-NMFS-Environmental and Technical Services Division, Habitat Conservation Branch. Seattle, WA.

National Marine Fisheries Service. 1997a. Magnuson-Stevens Act Provision: Essential Fish Habitat (EFH). Federal Register 62(244):66531-66559.

National Marine Fisheries Service. 1997b. Guidelines for Preparing Stock Assessment Reports Pursuant to the 1994 Amendments to the Marine Mammal Protection Act. Online at: http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms_appendix2.pdf.

National Marine Fisheries Service. 1997c. Endangered and Threatened Species; Threatened Status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of Coho Salmon. Federal Register 62(87): 24588-24609.

National Marine Fisheries Service. 1997d. Investigation of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and on the Coastal Ecosystems of Washington, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-28, 172 p.

National Marine Fisheries Service. 1998a. Draft recovery plan for the fin whale (*Balaenoptera physalus*) and sei whale (*Balaenoptera borealis*). National Marine Fisheries Service, Silver Spring, MD

National Marine Fisheries Service. 1998b. Designated Critical Habitat; Green and Hawksbill Sea Turtles,. Final Rule. Federal Register 63 (170): 46693-46701.

National Marine Fisheries Service. 1999a. Endangered and Threatened Wildlife and Plants; 90-Day Finding for a Petition to List Columbia River Eulachon (*Thaleichtys pacificus*) as Endangered or Threatened. Federal Register 64(228):66601-66603

National Marine Fisheries Service. 1999b. Designated Critical Habitat; Central California Coast and Southern Oregon/Northern California Coasts Coho Salmon. Federal Register 64(86): 24049-24062.

National Marine Fisheries Service. 1999c. Designated Critical Habitat: Proposed Critical Habitat for the Oregon Coast Coho Salmon Evolutionarily Significant Unit. Federal Register 64(89):24998-25007.

National Marine Fisheries Service. 2002. Status Review for North American Green Sturgeon, *Acipenser medirostris*. National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California.

National Marine Fisheries Service. 2003. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List North American Green Sturgeon as a Threatened or Endangered Species. Federal Register 68(19): 4433-4441.

National Marine Fisheries Service. 2004. Endangered and Threatened Species: Designation of Critical Habitat for 13 Evolutionarily Significant Units of Pacific Salmon (*Oncorhynchus* spp.) and Steelhead (*O. mykiss*) in Washington, Oregon, and Idaho. Proposed rule. Federal Register 69(239): 74572-74846.

National Marine Fisheries Service. 2005a. Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. Federal Register 70 (222): 69903-69912.

National Marine Fisheries Service. 2005b. Green Sturgeon (*Acipenser medirostris*) Status Review Update. NOAA Fisheries, Southwest Fisheries Science Center, Santa Cruz, CA.

National Marine Fisheries Service. 2005c. Endangered Species Act – Section 7 Consultation Biological Opinion and Conference Opinion and Magnuson-Stevens Fisheries Conservation and Management Act Essential Fish Habitat Consultation. Port of Everett 12th Street Marina, Puget Sound Chinook, Sixth Field HUC 171100110202, Lower Snohomish River, Snohomish County, Washington State. 2004/00178. National Marine Fisheries Service, Northwest Region. June 15, 2005.

National Marine Fisheries Service. 2005d. Pacific Coast Groundfish Fishery Management Plan. Essential Fish Habitat Designation and Minimization of Adverse Impacts. Final Environmental Impact Statement. National Marine Fisheries Service, Seattle, WA.

National Marine Fisheries Service. 2006a. Endangered Fish and Wildlife; Proposed Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales. Federal Register 71(122):36299-36313.

National Marine Fisheries Service. 2006b. Draft recovery plan for the fin whale (*Balaenoptera physalus*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service. 2006c. Proposed Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2006d. Endangered and Threatened Species; Designation of Critical Habitat for Southern Resident Killer Whale, Federal Register 71 (229): 69054-69070.

National Marine Fisheries Service. 2006e. Draft Recovery Plan for the Sperm Whale (*Physeter macrocephalus*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service. 2006f. NMFS EFH Consultation: Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation De-Designation and Designation of Ocean Dredge Material Disposal Site F Pacific Ocean, Offshore of Coos Bay, Oregon Agency: U.S. Environmental Protection Agency Consultation Conducted By: National Marine Fisheries Service, Northwest Region. Date Issued: March 30, 2006. NMFS No. 2005/06225.

National Marine Fisheries Service. 2007a. Endangered and Threatened Species; Initiation of 5–year Reviews for Fin, Sperm and Southern Right Whales. Federal Register 72(13): 2649-2650.

National Marine Fisheries Service. 2007b. Green Turtle (*Chelonia mydas*). Office of Protected Resources. Online at: at http://www.nmfs.noaa.gov/pr/species/turtles/green.htm

National Marine Fisheries Service. 2007c. Office of Protected Resources. Olive Ridley Turtle. Online at: http://www.nmfs.noaa.gov/pr/species/turtles/oliveridley.htm.

National Marine Fisheries Service. 2007d. Species of Concern Fact Sheet. Green Sturgeon Northern DPS. Online at: http://www.nmfs.noaa.gov/pr/pdfs/species/greensturgeon_ detailed.pdf.

National Marine Fisheries Service. 2008a. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

National Marine Fisheries Service. 2008b. Draft Biological Report: Proposed Designation of Critical Habitat for the Southern Distinct Population Segment of North American Green Sturgeon.

National Marine Fisheries Service, Southwest Region Protected Resources Division, Long Beach, CA.

National Marine Fisheries Service. 2008c. Summary of Scientific Conclusions of the Review of the Status of Eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. Biological Review Team, National Marine Fisheries Service, Seattle, WA.

National Marine Fisheries Service. 2008d. Endangered and Threatened Species: Final Threatened Listing Determination, Final Protective Regulations, and Final Designation of Critical Habitat for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. Federal Register 73(28):7816-7873.

National Marine Fisheries Service. 2009a. Consultation letter to FERC concerning: Non-concurrence and Request for Additional Information to Initiate Consultation on the Jordan Cove Natural Gas Terminal and Pacific Connector Gas Pipeline Project, Coos, Douglas, Josephine, Jackson, and Klamath Counties, Oregon (Docket Nos. CP07-444-000 and CP07-441-000). (NMFS ref. No. 2009/03126). June 24, 2009. NOAA, NMFS Northwest Region, Seattle, WA.

National Marine Fisheries Service. 2009b. Endangered and Threatened Wildlife and Plants: Final Rulemaking To Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon. Final Rule. Federal Register 74(195): 52300-52351.

National Marine Fisheries Service. 2009c. Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for Southern Distinct Population Segment of Eulachon, Federal Register 74(48):10857-10876.

National Marine Fisheries Service. 2009d. Endangered Species Act Section 7 Biological Opinion and Conference Opinion and Magnuson-Stevens Fisheries Conservation and Management Act Essential Fish Habitat Conservation Recommendations. 2009 Operation and Maintenance Dredging in the Umpqua River and Pacific Ocean Disposal, Douglas County, Oregon (HUC # 1710030308). 2009/04536. National Marine Fisheries Service, Northwest Region. September 11, 2009.

National Marine Fisheries Service. 2009e. Endangered Species Act Section 7 Biological Opinion and Conference Opinion and Magnuson-Stevens Fisheries Conservation and Management Act Essential Fish Habitat Consultation. 2009c. Operation and Maintenance Dredging in the Rogue River and Pacific Ocean Disposal, Curry County, Oregon (HUC # 1710031008). 2009/02720. National Marine Fisheries Service, Northwest Region. September 11, 2009.

National Marine Fisheries Service. 2010a. Recovery Plan for the Fin Whale (*Balaenoptera physalus*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service. 2010b. Recovery Plan for the Sperm Whale (*Physeter macrocephalus*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service. 2010c. Endangered and Threatened Species: Proposed Rule To Revise the Critical Habitat Designation for the Endangered Leatherback Sea Turtle. Federal Register75(2):319-

National Marine Fisheries Service. 2010d. Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of Eulachon. Final Rule. Federal Register 75(52):13012-13024.

National Marine Fisheries Service. 2011a. Fin Whale (Balaenoptera phsalus) 5-year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Maryland.

National Marine Fisheries Service. 2011b. California Marine Mammal Stranding Network Database. U.S. Department of Commerce, National Marine Fisheries Service, Southwest Regional Office. La Jolla, California.

National Marine Fisheries Service. 2011c. Final Recovery Plan for the Sei Whale (*Balaenoptera borealis*). National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD

National Marine Fisheries Service. 2011d. Southern Resident Killer Whales (*Orcinus orca*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, Northwest Regional Office, Seattle, WA.

National Marine Fisheries Service. 2011e. Protective Regulations for Killer Whales in the Northwest Region under the Endangered Species Act and Marine Mammal Protection Act. Federal Register 76(72):20870-20890.

National Marine Fisheries Service. 2011f. Endangered and Threatened Species: Final Rule To Revise the Critical Habitat Designation for the Endangered Leatherback Sea Turtle. Federal Register 77(17):4170-4201.

National Marine Fisheries Service. 2011g. Endangered and Threatened Species; Determination of Nine Distinct Population Segments of Loggerhead Sea Turtles as Endangered or Threatened. Final Rule. Federal Register 76(184):58868-58952.

National Marin Fisheries Service. 2011h. Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of Eulachon. Final Rule. Federal Register 76(203):65324-65353.

National Marine Fisheries Service. 2011i. Listing Endangered and Threatened Species: Threatened Status for the Oregon Coast Coho Salmon Evolutionarily Significant Unit. Final Rule. Federal Register 76(118):35755-35771

National Marine Fisheries Service. 2012a. Listing Endangered or Threatened Species: 90-Day Finding on a Petition To Delist the Southern Resident Killer Whale; Request for Information. Federal Register 77(228):70733-70736.

National Marine Fisheries Service. 2012b. North Pacific Right Whale (*Eubalanea japonica*) Five-Year Review: Summary and Evaluation. National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD.

National Marine Fisheries Service. 2012c. Final Biological Report. Final Rule to Revise Critical Habitat Designation for Leatherback Sea Turtles. National Marine Fisheries Service, Southwest Fisheries Science Center.

National Marine Fisheries Service. 2012d. Draft Recovery Plan for the Southern Oregon Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). Public Review Draft, National Marine Fisheries Service, Southwest Regional Office, Arcata, CA.

National Marine Fisheries Service. 2013. Final Recovery Plan for the North Pacific Right Whale (*Eubalaena japonica*). National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD.

National Marine Fisheries Service. 2013b. Pacific Eulachon Southern Distinct Population Segment. Federal Recovery Outline. National Marine Fisheries Service, Northwest Region, Seattle, Washington,

National Marine Fisheries Service. 2013b. Endangered and Threatened Species; 90-Day Finding on Petitions To Delist the Eastern Distinct Population Segment of the Steller Sea Lion. Federal Register 75(238):77602-77605.

National Marine Fisheries Service and U.S. Fish and Wildlife Service (NMFS and FWS). 1998a. Recovery Plan for U.S. Pacific Populations of the Green Turtle (*Chelonia mydas*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998b. Recovery Plan for U.S. Pacific Populations of the Leatherback Turtle (*Dermochelys coriacea*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998c. Recovery Plan for U.S. Pacific Populations of the Olive Ridley Turtle (*Lepidochelys olivacea*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998d. Recovery Plan for U.S. Pacific Populations of the Loggerhead Turtle (*Caretta caretta*). National Marine Fisheries Service, Silver Spring, MD.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007a. Leatherback Sea Turtle (*Dermochelys coriacea*) 5-year Review: Summary and Evaluation. National Mrine Fisheries Service, Office of Protected Resources, Silver Springs, MD.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 2007b. Olive Ridley Sea Turtle (*Lepidochelys olivacea*) 5-year Review: Summary and Evaluation. National Mrine Fisheries Service, Office of Protected Resources, Silver Springs, MD.

National Oceanic and Atmospheric Administration (NOAA). 2008. Coast Pilot 7. NOAA-Office of Coast Survey. Online at: http://chartmaker.ncd.noaa.gov/nsd/coastpilot7.htm.

NOAA Fisheries. 2012a. Fin Whale (*Balaenopera physalus*). NOAA Fisheries, Office of Protected Resources. On line at: http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/finwhale.htm

NOAA Fisheries. 2012b. Sperm Whale (*Physeter macrocephalus*). NOAA Fisheries, Office of Protected Resources. On line at: http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/spermwhale.htm

NOAA Fisheries. 2013a. Blue Whale (*Balaenopera musculus*). NOAA Fisheries, Office of Protected Resources. On line at: http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/bluewhale.htm

NOAA Fisheries. 2013b. Interim Sound Threshold Guidance Available Online: http://www.nwr.noaa.gov/protected_species/marine_mammals/killer_whale/threshold_guidance.html

NOAA Fisheries. 2013c . Killer Whale (*Orcinus orca*). NOAA Fisheries, Office of Protected Resources. On line at: http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/killerwhale.htm

NOAA Fisheries. 2013d North Pacific Right Whale (*Eubalaena japonica*) NOAA Fisheries, Office of Protected Resources. On line at: http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rightwhale_northpacific.htm.

National Research Council. 2004. Endangered and Threatened Fishes in the Klamath River Basin – Causes of Decline and Strategies for Recovery. Committee on Endangered and Threatened Fishes in the Klamath River Basin. National Academies Press, Washington, D.C.

Natural Resource Trustees of the M/V New Carissa. 2006. Final Damage Assessment and Restoration Plan & Environmental Assessment for the M/V New Carissa Oil Spill Oregon Coast. January 2006.

Nelson, S.K. and T.E. Hamer. 1995. Nesting success and the effects of predation on marbled murrelets. Pages 89-98, In C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt (Technical editors). Ecology and conservation of the marbled murrelet. General Technical Report PSW-GTR-152. Albany, CA. Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture.

Nelson, S.K. 1997. Marbled Murrelet (Brachyramphus marmoratus). In The Birds of North America, No. 276 (A. poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists Union, Washington, D.C.

Nelson, S.K. 2005. Surveys for Marbled Murrelets in Potential Habitat in the Oregon Coast Range. Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Department of Fisheries and Wildlife, Corvalis, OR.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel Suspended Sediment and Fisheries: A synthesis for Quantitative Assessment of Risk and Impact. North American Journal of Fisheries Management 16(4):693-727.

Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. The Impact of Dredging Works in Coastal Waters: A Review of the Sensitivity to Disturbance and Subsequent Recovery of Biological Resources on the Sea Bed. Oceanography and Marine Biology: an Annual Review 36:127-178.

Nicholas, J. and H. Lorz. 1984. Stomach contents of wild chinook and juvenile hatchery coho salmon in Several Oregon estuaries. ODFW Research and Development Section. March 1984.

Nichols, F.H., J.K. Thompson, and L.E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam Potamocorbula amurensis. II. Displacement oi a former community. Marine Ecology Progress Series 66:95-101.

Nightingale, B.J. and C.A. Simenstad. 2001. Overwater Structures: Marine Issues. Washington State Transportation Center (TRAC). Washington Department of Fish and Wildlife. Washington Department of Ecology. Olympia, WA.

Nordmann, A.S., B.A Bohne, and G.W. Harding. 2000. Histopathological Differences between Temporary and Permanent Threshold Shift. Hearing Research 139:13-30.

Norman, S.A., C.E. Bowlby, M.S. Brancato, J. Calambokidis, D. Duffield, P.J. Gearin, T.A. Gornall, M.E. Gosho, B. Hanson, J. Hodder, S.J. Jeffries, B. Lagerquist, D.M. Lambourn, B. Mate, B. Norberg, R.W. Osborne, J.A. Rash, S. Riemier, and J. Scordino. 2004. Cetacean Strandings in Oregon and Washington between 1930 and 2002. Journal of Cetacean Research and Management 6(1):87-99.

Norris, T.F. 1995 Effects of Boat Noise on the Singing Behavior of Humpback Whales (Megaptera novaeangliae). M.S. Thesis, San Jose State University, San Jose, California.

North, M.P., J.F., Franklin, A.B. Carey, E.D. Forsman, and T. Hamer. 1999. Forest stand structure of the northern spotted owl's foraging habitat. Forest Science. 45(4): 520-527.

North State Resources. 2009. Technical Memorandum for Water Temperature Impacts Assessment, Pacific Connector Gas Pipeline Project. April 10, 2009.

Northern States Resources (NSR). 2012. GIS data provided to Pacific Connector from BLM and Forest Service.

Northeast-Midwest Institute (NEMW). 2007. Summary of the National Invasive Species Act of 1996 and 2003. Accessed at http://www.nemw.org.

Northwest Forest Plan Interagency Regional Monitoring Program. 2013. Data and Maps – Late Successional / Old Growth. Available online at: http://www.reo.gov/monitoring/data-maps/og-data-maps.shtml

Olson, G.S., E.M. Glenn, R.G. Anthony, E.D. Forsman, J.A. Reid, P.J. Loschl, and W.J. Ripple. 2004. Modeling Demographic Performance of Northern Spotted Owls Relative to Forest Habitat in Oregon. Journal of Wildlife Management 68(4):1039-1053.

Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP). 2007. Mapping Marine Mammals, Birds and Turtles: Sei Whale. Online at: http://seamap.env.duke.edu/species/tsn/180526.

Olegario, A. 2006. Over-wintering Diet, Growth, and Prey Available to Juvenile Coho Salmon (Oncorhynchus kisutch) in the West Fork Smith River, Oregon. M.S. Thesis, Oregon State University, Corvallis, OR.

Oregon.gov, 2012. Accessed at: http://www.oregon.gov/gov/GNRO/docs/Current%20Initiatives/2000-2010%20Housing%20Population%20and%20Area%20Census%20Data%20for%20Oregon%20Cities,%20%207-22-2012.pdf

Oregon Biodiversity Information Center. 2006. Oregon Threatened and Endangered Plant Field Guide. Online at: http://orbic.pdx.edu/index.html.

Oregon Biodiversity Information Center. 2012. Rare, Threatened, and Endangered Plants and Animals in the Vicinity of Potions of Coos, Douglas, Josephine, Jackson, Klamath, and Lane Counties. Database Output for Proposed Natural Gas Pipeline, SW Oregon Project. Institute for Natural Resources, Portland State University, Portland, Oregon.

Oregon Biodiversity Information Center. 2013. Rare, Threatened, and Endangered Species of Oregon. Institute for Natural Resources, Portland State Univeristy, Portland, Oregon

Oregon Ocean-Coastal Management Program. 2008. Oregon Coastal Atlas. Online at: http://www.coastalatlas.net/index.asp.

Oregon Department of Environmental Quality. 2002. Oregon's 2002 303(d) List. Oregon Department of Environmental Quality, Water Quality Assessment Database. Online:

Oregon Department of Environmental Quality (ODEQ). 2006. Online at: http://www. deq.state.or.us/.

Oregon Department of Environmental Quality. 2010. Turbidity Technical Review. Summary of Sources, Effects, and Issues Related to Revising the Statewide Water Quality Standard for Turbidity. State of Oregon, Department of Environmental Quality. Available online: http://www.deq.state.or.us/wq/standards/docs/Turbidity/10-WQ-022.pdf.

Oregon Department of Environmental Quality. 2013. Laboratory Analytical Storage and Retrieval (LASAR) Web Application. Accessed online: http://deq12.deq.state.or.us/lasar2/default.aspx).

Oregon Department of Fish and Wildlife. 1997. ODFW Aquatic Inventories Project Stream Habitat Distribution Coverages. Natural Production Section, Department of Fish and Wildlife, Corvallis, Oregon.

Oregon Department of Fish and Wildlife (ODFW). 2000. Oregon Guidelines for Timing of In-water Work to Protect Fish and Wildlife Resources. Online at: http://www.dfw.state.or.us/lands/0600_inwtrguide.pdf.

Oregon Department of Fish and Wildlife. 2003. Natural Resources Information Management Program. Online at: http://nripm.dfw.state.or.us/nrimp/default.aspx.

Oregon Department of Fish and Wildlife. 2005a. Fish and Wildlife Habitat Mitigation Policy. Oregon Administrative Rules Division 415.

Oregon Department of Fish and Wildlife. 2005b. Introduced Fishes Impacts (PECE Policy Format. Coastal Coho Assessment. Oregon Plan for Salmon and Watersheds. Oregon Department of Fish and Wildlife, Corvallis, OR.

Oregon Department of Fish and Wildlife. 2006a. Natural Resources Information Management Program. Online at: http://nrimp.dfw.state.or.us.

Oregon Department of Fish and Wildlife. 2006b. Oregon Conservation Strategy. Oregon Department of Fish and Wildlife, Salem, OR

Oregon Department of Fish and Wildlife. 2006b. Unpublished ODFW seining data for Coos Bay, 2004-2006, ODFW Field Office, Charleston, Oregon.

Oregon Department of Fish and Wildlife. 2008a. Oregon Guidelines for Timing of In-Water Work to Protect Fish and Wildlife Resources. Oregon Department of Fish and Wildlife, Salem, Oregon.

Oregon Department of Fish and Wildlife. 2008b. Natural Resources Information Management Program. Online at: http://nripm.dfw.state.or.us/nrimp/default.aspx.

Oregon Department of Fish and Wildlife. 2010. Oregon Wolf Conservation and Management Plan. Oregon Department of Fish and Wildlife, Salem, OR.

Oregon Department of Fish and Wildlife. 2011a. Wolverine Tracks Confirmed in Wallowa Countyfor First Time. ODFW News Release. Accessed online: http://www.dfw.state.or.us/news/2011/april/042211.asp.

Oregon Department of Fish and Wildlife. 2011b. Aquatic Inventories Project Habitat and Reach Data Coverages Metadata Date: February 2011. Oregon Department of Fish and Wildlife, Corvallis, OR.

Oregon Department of Fish and Wildlife. 2012a. Oregon Fish Habitat Distribution Data. Natural Resources Information Management Program. Accessed online: https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata.

Oregon Department of Fish and Wildlife. 2012b. Fish Counts – Gold Ray Dam. Fish Division. Accessed online: http://www.dfw.state.or.us/fish/local_fisheries/rogue_river/goldray/index.asp.

Oregon Department of Fish and Wildlife. 2012c. Estimates of the Run size of Rogue Basin Adult Coho Salmon Past Huntley Park, 1980-2011. Oregon Adult Salmonid Inventory and Sampling Project. Data Summaries. Accessed online: http://oregonstate.edu/dept/ODFW/spawn/datasumm.htm.

Oregon Department of Fish and Wildlife. 2012d. Estimated Coho Spawner Abundance. 2011 Spawning Season. Oregon Department of Fish and Wildlife, Coho Abundance. Available Online: http://oregonstate.edu/dept/ODFW/spawn/cohoabund.htm

Oregon Department of Fish and Wildlife. 2013a. About Gray Wolves. Oregon Department of Fish and Wildlife, Wildlife Division. Online: http://dfw.state.or.us/Wolves/about_gray_wolves.asp

Oregon Department of Fish and Wildlife. 2013b. Area of Known Wolf Activity - OR-7. Oregon Department of Fish and Wildlife, Wildlife Division. Online: http://www.dfw.state.or.us/Wolves/AKWA/OR7.asp

Oregon Department of Fish and Wildlife. 2013. Oregon Adult Salmonid Inventory and Sampling Project. Coho Abundance. Available Online at http://oregonstate.edu/dept/ODFW/spawn/cohoabund.htm

Oregon Department of Fish and Wildlife. 2014a. Oregon Wolf Conservation and Management 2013 Annual Report. Oregon Department of Fish and Wildlife. Salem, OR.

Oregon Department of Fish and Wildlife. 2014a. Oregon Wolf Conservation and Management 2013 Annual Report. Oregon Department of Fish and Wildlife. Salem, OR.

Oregon Department of Fish and Wildlife. 2014b. Oregon Wolf Population Statistics. Department of Fish and Wildlife. Online: http://dfw.state.or.us/Wolves/population.asp

Oregon Department of Forestry. 2004. States Forest Program: Marbled Murrelet Guidance Document. October.

Oregon Department of Forestry and Oregon Department of Fish and Wildlife. 1995. A Guide to Placing Large Wood in Streams. Oregon Department of Forestry, Forest Practices, Salem, OR. and Oregon Department of Fish and Wildlife, Habitat Conservation Division, Portland, OR.

Oregon Department of Land Conservation and Development. 1987. The Oregon Estuary Plan Book. Accessed online: http://www.inforain.org/mapsatwork/oregonestuary/. January 6, 2007.

Oregon Department of Land Conservation and Development. 1998. Dynamic Estuary Management Information System, Coos Bay, Oregon. Compact Disc Geographic Information System for the Coos Bay Estuary and Watershed in Southwestern Oregon. Oregon Department of Land Conservation and Development, Portland, OR.

Oregon Natural Heritage Information Center (ORNHIC). 2006a. Personal Sensitive Species Data Request (05/03/06).

Oregon Natural Heritage Information Center. 2006b. Oregon Threatened and Endangered Plant Field Guide. Online at: http://oregonstate.edu/ornhic/plants/index.html.

Oregon Natural Heritage Information Center (ORNHIC). 2007. Astragalus applegatei (Applegate's milk-vetch) relocation and status summary for 2007. Draft unpublished report submitted to Klamath Falls Fish and Wildlife Office.

Oregon Natural Heritage Information Center (ORNHIC). 2012.

Oregon Ocean-Coastal Management Program. 2008. Oregon Coastal Atlas. Online at: http://www.coastalatlas.net/index.asp.

Oregon Parks and Recreation Department (OPRD). 2005. Final Ocean Shores Management Plan. Online at: http://egov.oregon.gov/OPRD/PLANS/docs/masterplans/osmp_hcp/FinalOceanShoresMP052305.pdf.

Oregon Parks and Recreation Department. 2007. Habitat Conservation Plan for the Western Snowy Plover. U.S. Fish and Wildlife Service and Oregon Parks and Recreation Department, Portland, OR.

Oregon Watershed Enhancement Board. 2007. Summary of the Watershed Health Indicators for the Oregon Coast Coho ESU 2007. Oregon Watershed Enhancement Board in cooperation with Oregon Coast Watershed Councils. Salem, OR.

Pacific Fishery Management Council (PFMC). 1998. Amendment 8 to the Northern Anchovy Fishery Management Plan: The Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council. 1999. Amendment 14 to the Pacific Coast Salmon Plan Appendix A. Identification and Description of Essential Fish Habitat, Adverse Impacts, and Recommended Conservation Measures for Salmon. Pacific Fishery Management Council. Portland, OR.

Pacific Fishery Management Council. 2004. Pacific Coast Groundfish Fishery Management Plan For the California, Oregon, and Washington Groundfish Fishery as Amended through Amendment 17. Pacific Fisheries Management Council, Portland, OR.

Pacific Fishery Management Council. 2005. Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery: Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council. 2006. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation 2006. Pacific Fisheries Management Council, Portland, OR.

Pacific Fishery Management Council. 2007. Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species as Amended By Amendment 1. Pacific Fishery Management Council. Portland, OR.

Pacific Fishery Management Council. 2008. Pacific Coast Groundfish Management Plan for California, Oregon, and Washington Groundfish Fishery, as Amended through Amendment 19, including Amendment 15. Portland, OR.

Pacific Marine Environmental Laboratory. 2012. Topic 8-Conversion of dB between Air to Water. Acoustic Monitoring Program: Underwater Acoustics Tutorial. NOAA. Available Online http://oceanexplorer.noaa.gov/explorations/sound01/background/acoustics/acoustics.html.

Pacific States/British Columbia Oil Spill Task Force. 2002. West Coast Offshore Vessel Traffic Risk Management (WCOVTRM) Project. Online at: http://www.oilspilltaskforce.org/wcovtrm_report.htm.

Packman, J.J., K.J. Comings, and D.B. Booth. 1999. Using Turbidity to Determine Total Suspended Solids in Urbanizing Streams in the Puget Lowlands. Pages 158-165 in Confronting Uncertainty: Managing Change in Water Resources and the Environment. Canadian Water Resources Association Annual Meeting, Vancouver, British Columbia.

Padgett-Flohr, G.E., and M.P. Hayes. 2011. Assessment of the Vulnerability of the Oregon Spotted Frog (*Rana pretiosa*) to the Amphibian Chytrid Fungus (*Batrachochytrium dendrobatidis*). Herpetological Conservation and Biology 6(2):99-106.

Paton, P.W.C. 1994. The Effect of Edge on Avian Nest Success: How Strong is the Evidence? Conservation Biology 8(1):17-26.

Peachey, E., D. Ball, R. Parker, J.P. Yenish, T.W. Miller, D.W. Morishita, and P.J.S. Hutchinson (Compilers). 2007. Pacific Northwest Weed Management Handbook. Oregon State University, Corvallis, Oregon.

Pearl, C.A., J. Bowerman, M.J. Adams, and N.D. Chelgren. 2009. Widespread Occurrence of the Chytrid Fungus *Batrachochytrium dendrobatidis* on Oregon spotted frogs (*Rana pretiosa*). EcoHealth 6:209-218

Pearson, W.H., G.E. Johnson, J.R. Skalski, G.D. Williams, K.L. Sobocinski, J.A. Southard, M.C. Miller, R.A. Buchanan. 2006. A Study of Stranding of Juvenile Salmon by Ship Wakes along the Lower Columbia River Using Before-and-after Design: Before Phase Results. Marine Sciences Laboratory, Sequim, Washington.

Peery. M.Z., and R.W. Henry. 2010. Recoverying Marbled Murrelets via Corvid Management: A Population Viability Analysis Approach. Biological Conservation 143(11):2414-2424.

Perkins, D.L., and G.G. Scoppettone. 1996. Spawning and Migration of Lost River Suckers (*Deltistes luxatus*) and Shortnose Suckers (*Chasmistes brevirostris*) in the Clear Lake Drainage, Modoc

County, California. Final Report to California Departmetn of Fish and Game. National Biological Service, Reno Field Station, Reno, NV.

Phifer, P. 2003. White paper: Visual Harrassment Threshold Justification. *In* Appendix A, Marbled Murrelet Sound and Visual Harassment Decision Support Tools. Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted owls and Marbled Murrelets in Northwestern California. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata, California.

Phillips, R.C. 1984. The Ecology of Eelgrass Meadows in the Pacific Northwest: A community Profile. U.S. Fish and Wildlife Service. FWS/OBS-84/24.

Phillips, S.J.; Anderson, R.P.; Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling. 190: 231–259.

Phillips, S.J.; Dudik, M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography. 31: 161–175.

Piatt, J.F. J. Wetzel, K. Bell , A.R. DeGange, G.R. Balogh, G.S. Drew, T. Geernaert, C. Ladd, and G.V. Byrd. 2006. Predictable hotspots and Foraging Habitat of the Endangered Short-tailed Albatross (*Phoebastria albatrus*) in the North Pacific: Implications for Conservation. Deep-Sea Research II 53:387-398.

Platt, J.B. 1977. The Breeding Behavior of Wild and Captive Gyrfalcons in Relation to Their Environment and Human Disturbance. Ph.D. Dissertation. Cornell University, Ithaca, NY.

Plotkin, P.T. (editor). 1995. National Marine Fisheries Services and U.S. Fish and Wildlife Service Status Reviews for Sea Turtles Listed under the Endangered Species Act of 1973. National Marine Fisheries Service. Silver Spring, MD.

Popper, A.N., and M.C. Hastings. 2009. The Effects of Anthropogenic Sources of Sound on Fishes. Journal of Fish Biology 75:455-489.

Popper, A.N., T.J. Carlson, A.D. Hawkins, B.L Southall, and R.L Gentry. 2006. Interim Criteria for Injury of Fish Exposed to Pile Driving Operations: A White Paper. Accessed online: http://www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6-750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf.

Posey, M.H. 1986. Predation on a Burrowing Shrimp: Distribution and Community Consequences. Journal of Experimental Marine Biological Ecology 103:143-161.

Ralph, C. John; Hunt, George L. Jr.; Raphael, Martin G.; Piatt, John F. 1995. Overview of the Ecology and Conservation of the Marbled Murrelet in North America. Ecology and Conservation of the Marbled Murrelet. USDA Forest Service, Pacific Southwest Research Station, General Technical Report, PSW-GTR-152.

Raphael, M.G. 2006. Conservation of the Marbled Murrelet Under the Northwest Forest Plan. Conservation Biology. 20(2): 297-305. In: Huff, M. H.; Raphael, M. G.; Miller, S. L.; Nelson, S. K.; Baldwin, J., Tech. cords. Northwest Forest Plan—the first 10 years (1994-2003): Status and trends of populations and nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-

GTR-650. Portland, OR: USDA, Forest Service, Pacific Northwest Research Station: 97-146. Chapter 5.

Raphael, M.G., Galleher, B.M., M.H. Huff, S.L. Miller, K. Nelson, and R.D. Young. 2006. Spatially explicit estimates of potential nesting habitat for the marbled murrelet.

Raphael, M. G., G. A. Falxa, K. M. Dugger, B. M. Galleher,D. Lynch, S. L. Miller, S. K. Nelson, and R. D. Young. 2011. Northwest Forest Plan—the first 15 years (1994–2008): status and trend of nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-GTR-848, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon

Rasmussen, M, R. Lord, B. Vickey, C. Mcketta, D. Green, M. Green, T. Potiowsky, D. Adams, G. Letta, R. Anderson, B. Mitchell and D. Mak. 2012. The 2012 Forest Report : An Economic Assessment of Oregon's Forest and Wood Products Manufacturing Sector. Prepared for Oregon Forest Resource Institute. July.

Raymond, A., G. Lohse, and J. Heaney. 2012. 2012 Northern Spotted Owl Surveys, Myrtlewood and Umpqua Resource Areas. U.S. Department of Interior, Bureau of Land Management, Coos Bay District.

Reeves, G.H., K.M. Burnett, and E.V. McGarry. 2003. Sources of Large Wood in the Main Stem of a Fourth-order Watershed in Coastal Oregon. Canadian Journal of Forest Research 33:1363-1370.

Reeves, R.R., P.J. Clapham, R.L. Brownell, and G.K. Silber. 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Office of Protected Resources, National Fisheries Service, Silver Spring, MD. 42pp.

Reid, S.M., and Anderson, P.G. 1998. HDD not the Answer for all Sensitive Water Crossings. Environmental Effects of Mud Releases need Further Study to Improve Crossing Method Selection and Best Management Practices. Pipeline and Gas Industry, July 1998.

Reid, S.M. and P.G. Anderson. 1999. Effects of Sediment Released During Open-cut Pipeline Water Crossings. Canadian Water Resources Journal 24: 23-39.

Reid, S.M., F. Ade, and S. Metikosh. 2004. Sediment Entrainment During Pipeline Water Crossing Construction: Predictive Models and Crossing Method Comparison. Journal of Environmental Engineering and Science 3:81-88.

Rice, S.D., J.W. Short, C.C. Brodersen, T.A. Mecklenburg, D.A. Moles, C.J. Misch, D.L. Cheatham, and J.F. Karinen. 1976. Acute Toxicity and Uptake–Depuration Studies with Cook Inlet Crude Oil, Prudhoe Bay Crude Oil, No. 2 Fuel Oil, and Several Subarctic Marine Organisms. Northwest Fisheries Center Auke Bay Fisheries Laboratory.

Richardson, W.J. 1995. Documented Disturbance Reactions. Page 241-to 324 in W.J. Richardson, C.R. Greene, C.I. Malme, and D.H. Thompson (editors). Marine Mammals and Noise. Academic Press, Elsevier Science Imprint, San Diego, California.

Richardson, S. 1997. Washington State Status Report for the Olive Ridley Sea Turtle. Washington Department of Fish and Widlife, Olympia, WA.

Richter, A., and S.A. Kolmes. 2005. Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest. Reviews in Fisheries Science 13:23-49.

Rien, T.A., L.C. Burner, R.A. Farr, M.D. Howell, and J.A. North. 2001. Green sturgeon population characteristics in Oregon. Annual Progress Report. Sportfish Restoration Project F-178-R.

Ripple, W.J., S.K. Nelson, and E.M. Glenn. 2003. Forest Landscape Patterns around Marbled Murrelet Nest Sites in the Oregon Coast Range. Northwestern Naturalist 84:80-89.

Risch, D., P.J. Corkerton, W.T. Ellison, and S.M. Van Parijs. 2012. Changes in Humpback Whale Song in Response to an Acoustic Source 200 km Away PLoS ONE 7(1): e29741-

Ritter, P.W. 1984. Water Quality Concerns Associated with Pipeline Stream Crossings. Pages 447-456 in A.E. Crabtree (editor). Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-way Management. Mississippi State University, Mississippi State, Mississippi.

Rogers & Associates Forestry Consultants. 2012. Interim Report: Marbled Murrelet Habitat Surveys; Pacific Connector Gas Pipeline Project. September.

Rogers & Associates Forestry Consultants and Siskiyou BioSurvey, LLC. 2014. 2013 Marbled Murrelet Survey Report, Pacific Connector Gas Pipeline Project, Southwest Oregon. February.

Rodgers, J.A. Jr., and H.T. Smith. 1995. Set-back Distances to Protect Nesting Bird Colonies from Human Disturbances in Florida. Conservation Biology. 9: 89-99.

Romano, T.A., M.J. Keogh, C. Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder, and J.J. Finneran. 2004. Anthropogenic Sound and Marine Mammal Health: Measures of the Nervous and Immune Systems before and After Intense Sound Exposure. Canadian Journal of Fisheries and Aquatic Science 61:1124-1134.

Roninger, T. 2008. U.S. Fish and Wildlife Service, Klamath Falls Office. Personal Communication with Edge Environmental, Inc.

Rosenberg, D.K., and R.G. Anthony. 1992. Characteristics of Northern Flying Squirrel Populations in Young Second- and Old-growth Forests in Western Oregon. Canadian Journal o Zoology **70**: 161-166.

Rosenberg, K.V. and M.G. Raphael. 1986. Effects of Forest Fragmentation on Vertebrates in Douglas-fir Forests. Pages 263-272 in J. Verner, M.L. Morrison, and C.J. Ralph (editors) Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. University of Wisconsin Press. Madison, WI.

Ross, B.D. 1982. Effects of Suspended Volcanic Sediment on Coho (*O. kisutch*) and Fall Chinook (*O. tshawytscha*) Salmon Smolts in Artificial Streams. M.S. Thesis, University of Washington, Seattle, WA.

Ross, P.S., G.M. Ellis, M.G. Ikonomou, L.G. Barrett-Lennard, and R.F. Addison. 2000. High PCB Concentrations in Free-Ranging Pacific Killer Whales, *Orcinus orca*: Effects of Age, Sex and Dietary Preference. Marine Pollution Bulletin 40(6):504-515.

Ryan, T.J., C.M. Scott, and B.A. Douthitt. 2005. Sub-lethal Effects of 2,4-D Exposure on Golf Course Amphibians. USGA Turfgrass and Environmental Research Online 5(16):1-14.

Rykbost, K.A., and B.A. Charlton. 2001. Nutrient Loading of Surface Waters in the Upper Klamath Basin: Agricultural and Natural Sources. Special Report 1023, Agricultural Experiment Station, Oregon State University. Corvallis, OR.

Sandercock, F.K. 1991. Life History of Coho Salmon (*Oncorhynchus kisutch*). Pages 395 to 445 in C. Groot and L. Margolis (editors). Pacific Salmon Life Histories, University of British Columbia Press. Vancouver.

Scarborough, G.C., and Robertson, T. 2002. Evaluation of Low Technology Large Woody Debris as a Technique to Augment Fish Habitat in Streams Crossed by Transmission Corridors. Pages 777-787, in Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. Elsevier Science Ltd.

Schilling, J.W., K.M., Dugger, and R.G. Anthony. 2013. Survival and Home-range size of Northern Spotted Owls in Southwestern Oregon. Journal of Raptor Research 47(1):1-14.

Schmutzer, A.C., M.J. Gray, E.C. Burton, and D.L. Miller. 2008. Impacts of Cattle on Amphibian Larvae and the Aquatic Environment. Freshwater Biology 53:2613-2625.

Schreck, C., D. Roby, S. Clements, M. Karnowski. 2002. Juvenile Salmonid Survival in Specific Areas of the Nehalem Watershed. Annual Report, Final Draft Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University. Corvallis, Oregon.

Sears, R., and W.F. Perrin. 2009. Blue Whale – Balaenoptera musculus. Pages 120 to 124, in W.F. Perrin, B. Würsig, and J.F.M Thewissen (editors). Encyclopedia of Marine Mammals (Second Edition). Academic Press, Elsevier, New York.

Shanks, A., S.L. Schroeder, and B.L. Dlouhy.2011. Report on the Zooplankton Sampling Adjucent to the Proposed Jordan Cove LNG Terminal. University of Oregon, Oregon Institute of Marine Biology, Charleston, OR.

Shirihai, H. and B. Jarrett. 2006. Whales, Dolphins, and Other Marine Mammals of the World. Princeton University Press. Princeton, NJ.

SHN Consulting Engineers and Geologists, Inc. (SHN). 2006. Sediment Sampling Data. Laboratory Sampling Analyses performed by Columbia Analytical Services.

SHN Consulting Engineers & Geologists, Inc.. 2013. Botanical Resources Report. Jordan Cove Energy Project. SHN Engineers and Consultants. Coos Bay, Oregon.

Short, F.T., D.M. Burdick, and J.E. Kaldy. 1995. Mesocosm Experiments Quantify the Effects of Eutrophication on Eelgrass, Zostera marina. Limnology and Oceanography 40:740-749.

Singer, S.W., N.L. Naslund, S.A. Singer, C.J. Ralph. 1991. Discovery and Observation of Two Tree Nests of the Marbled Murrelet. Condor 93(2): 330-339.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, D.K. Shreffler. 1999. Impacts of Ferry Terminals on Juvenile Salmon Migrating Along Puget Sound Shorelines Phase I: Synthesis of State of Knowledge. Washington State Transportation Center (TRAC). University of Washington. Seattle, Washington. June.

Siskiyou BioSurvey (SBS). 2001. Fritillaria Survey and Habitat Analysis, unpublished report for Medford District BLM.

Siskiyou BioSurvey. 2007. 2007 Draft Biological Survey Report (Botanical, Northern Spotted Owl, Great Gray Owl, Mollusks, Marbled Murrelet, and Red Tree Vole). Prepared for Pacific Connector Gas Pipeline, LP. August.

Siskiyou BioSurvey LLC. 2008a. 2008a Biological Survey Report (Botanical, Northern Spotted Owl, Great Gray Owl, Mollusks, Marbled Murrelet, and Red Tree Vole). November 2008.

Siskiyou BioSurvey. 2008b. Summary of Federally Listed Species: Pacific Connector Gas Pipeline Project. Siskiyou BioSurvey LLC, Ecological Consultants, Eagle Point, OR. Unpublished report for Edge Environmental, Inc.

Siskiyou BioSurvey. 2008c. Personal Communication with Edge Environmental Inc. re: Applegate's Milk-vetch. June 20.

Skrabis, K.E. 2005. Resource Equivalency Analysis for Marbled Murrelets New Carissa Spill, February 1999. USDI-Office of Policy Analysis, ms-4426. Washington, D.C.

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A.N. Popper. 2010. A Noisy Spring: The Impact of Globally Rising Underwater Sound Levels on Fish. Trends in Ecology and Evolution 25(7):419-427.

Slaney, P. A., and A.D. Martin. 1997. Planning Fish Habitat Rehabilitation: Linking to Habitat Protection. Pages 1-1 to 1-23, in P.A. Slaney and D. Zaldokas (editors). Fish Habitat Rehabilitation Procedures; Watershed Restoration Technical Circular No. 9. British Columbia Watershed Restoration Program, Ministry of Environment, Lands and Parks, and Ministry of Forests. Vancouver, B.C.

Slaney, P.A., R.J. Finnigan, and R.G. Miller. 1997. Accelerating the Recovery of Log-jam Habitats: Large Woody Debris-boulder Complexes. Pages 9-1 to 9-24 in P.A. Slaney and D. Zaldokas (editors). Fish Habitat Rehabilitation Procedures; Watershed Restoration Technical Circular No. 9. British Columbia Watershed Restoration Program, Ministry of Environment, Lands and Parks, and Ministry of Forests. Vancouver, B.C.

Smith, G., J. Thrailkill, B. Tuerler, and S. Center. 2007. Oregon Fish and Wildlife Office, Portland, OR. Personal communication with Edge Environmental, Inc. via meeting. January 3.

Snyder, D.E. 2004. Invited Overview: Conclusions from a Review of Electrofishing and its Harmful Effects on Fish. Reviews in Fish Biology and Fisheries 13:445-453.

Sol Coast Consulting & Design, LLC and Parsons Brinckerhoff. 2009. Hydro-electric Feasibility Study at Upper Pony Creek Reservoir. Prepared for Coos Bay North Bend Water Board. Coos Bay, Oregon.

Southall, B. 2004. Noise Exposure Criteria: Structure of the Matrix. In: Noise Exposure Criteria Group, Plenary Meeting Two Advisory Committee on Acoustic Impacts on Marine Mammals, Arlington, Virginia. On line at: http://mmc.gov/sound/plenary2/pdf/gentryetal.pdf

Spence, B.C., T.C. Wainwright, and E.P.Bjorkstedt. 2005. Southern Oregon/Northern California Coast Coho Salmon ESU. Pages 339-363 in T.P. Good, R.S. Waples, and P. Adams (editors). Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA and Southwest Fisheries Science Center, Santa Cruz, CA.

Sprague, J.B., and W.J. Logan. 1979. Separate and Joint Toxicity to Rainbow Trout of Substances used in Drilling Fluids for Oil Exploration. Environmental Pollution 19:269-281.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 1999. An Acoustic Link Between Blue Whales in the Eastern Tropical Pacific and the Northeast Pacific. Marine Mammal Science, 15(4):1258-1268.

Stenzel, L.E., S.C. Peaslee, and G.W. Page. 1981. II. Mainland Coast. Pages 6-16 in Page, G.W. and L.E. Stenzel, (eds.). The breeding status of the snowy plover in California. Western Birds 12(1):1-40.

Stober, Q., B. Ross, C. Melby, P. Dinnel, T. Jagielo, and E. Salo. 1981. Effects of Suspended Volcanic Sediment on Coho and Chinook Salmon in the Toutle and Cowlitz Rivers. FRI-UW-8124. Fisheries Research Institute, University of Washington, Seattle, WA.

Stone, T. 2007. California Wolverine. Species Fact Sheet. USDA-Forest Service, Umpqua National Forest, Roseburg, OR. Accessed online: http://www.fs.fed.us/r6/sfpnw/issssp/documents/planning-docs/sfs-vert-ma-Gulo-gulo-luteus-2007-09-27.doc.

Stout, H.A., P.W. Lawson, D.L. Bottom, T.D. Cooney, M.J. Ford, C.E. Jordan, R.G. Kope, L.M. Kruzic, G.R. Pess, G.H. Reeves, M.D. Scheuerell, T.C. Wainwright, R.S. Waples, E. Ward, L.A. Weitkamp, J.G. Williams, and T.H. Williams. 2012. Scientific Conclusions of the Status Review for Oregon Coast Coho Salmon (*Oncorhynchus kisutch*). NOAA Technical Memorandum NMFS-NWFSC-118.

StreamNet. 2006. StreamNet GIS database. Online at: http://www.streamnet.org/online-data.html.

Strong, C.S., B.S. Keitt, W.R. McIver, C.J. Palmer, and I. Gaffney. 1995. Distribution and Population Estimates of Marbled Murrelets at Sea in Oregon During the Summers of 1992 and 1993. Pages 339-352, in C.J. Ralph, G.L. Hunt, M.G. Raphael, and H.F. Piatt (technical editors). Ecology and Conservation of the Marbled Murrelet. U.S.D.A – Forest Service General Technical Report PSW-GTR-152. Albany, CA.

Stumpf, J.P., N. Denis, T.E. Hamer, G. Johnson, and J. Verschuyl. 2011. Flight Height Distribution and Collision risk of the Marbled Murrelet *Brachyramphus marmoratus*: Methodology and Preliminary Results. Marine Ornithology 39:123–128.

Stuntzner Engineering and Forestry. 2005. Wetland Delineation Report (Amended). Stuntzner Engineering and Forestry. Coos Bay, Oregon.

Suryan, R.M., K.S. Dietrich, E.F. Melvin, G.R. Balogh, F. Sato, and K. Ozaki. 2007. Migratory Routes of Short-tailed Albatrosses: Use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska. Biological Conservation 137:450-460.

Swarthout, E.C.H. and R.J. Steidl. 2001. Flush Responses of Mexican Spotted Owls to Recreationists. Journal of Wildlife Management 65:312-317.

Tabor, R.A., G.S. Brown, V.T. Luiting. 2004. "The Effect of Light Intensity on Sockeye Salmon Fry Migratory Behavior and Predation by Cottids in the Cedar River, Washington." North American Journal of Fisheries Management 24: 128-145.

Tabor, R.A., B. Footen, K.L Fresh, M.T. Celedonia, F.Mejia, R.M. Piaskowski, D.L.Low, and L. Park. 2007. Smallmouth Bass and Largemouth Bass Predation on Juvenile Chinook Salmon and other Salmonids in the Lake Washington Basin. North American Journal of Fisheries Management 27:1174-1188.

Tallon, J.T., F.J Myerski, G.E. Mesing, J.P. Fillo. 1992. Characterization of Discharge Waters from Natural Gas Pipeline Hydrostatic Testing Operations-Volume 3. Topical Report Gas Research Institute, Environment and Safety Research Department, Chicago, IL.

Tapilatu, R.F., P.H. Dutton, M. Tiwari, T. Wibbels, H.V. Ferdinandus, W.G. Iwanggin, and B.H. Nugroho. 2013. Long-term Decline of the Western Pacific Leatherback, *Dermochelys coriacea*: A globally Important Sea Turtle Population. Ecosphere 4(2):1-15.

Tappeiner, J.C., D. Huffman, D. Marshall, T.A. Spies, and J.D. Bailey. 1997. Density, Ages, and Growth Rates in Old-growth and Young-growth forests in Coastal Oregon. Canadian Journal of Forest Research 27:638-648.

Tempel, D.J., and R.J. Gutierrez. 2003. Fecal Corticosterone Levels in California Spotted Owls exposed to Low-intensity Chainsaw Sound. Wildlife Society Bulletin 31(3):698-702

Tempel, D.J., and Gutierrez. 2004. Factors Related to fecal corticosterone levels in California spotted owls: Implications for assessing chronic stress. Conservation Biology 18(2):538-547

Teske, M.E., A.E. Kaufman, C.W. George, and G.M. Johnson. 1997. Field Measurements of Helicopter Rotor Wash in Hover and Forward Flight. Journal of Aircraft 34(6): 813-814.

Tewksbury, J.J., S.J. Heil, and T.E. Martin. 1998. Breeding Productivity does not Decline with Increasing Fragmentation in a Western Landscape. Ecology 79(8):2890-2903.

Thom, R.M., L.D. Antrim, A.B. Borde, W.W. Gardiner, D.K. Shreffler, P.G. Farley, J.G. Norris, S.W. Echeverria, and T.P. McKenzie. 1998. Puget Sound's Eelgrass Meadows: Factors Contributing to Depth Distribution and Spatial Patchiness. Puget Sound Research '98 Proceedings. Puget Sound Water Quality Action Team, Olympia, WA.

Thom, R.M., A.B. Borde, G.D. Williams, J.A. Southard, S.L. Blanto, and D.L. Woodruff. 2001. Effects of Multiple Stressors on Eelgrass Restoration Projects. Puget Sound Research 2001 Proceedings. Puget Sound Action Team, Bellevue, WA.

Thom, R.M., A.B. Borde, S. Rumrill, D.L. Woodruff, G.D. Williams, J.A. Southard, and S.L. Sargeant. 2003. Factors Influencing Spatial and Annual variability in Eelgrass (*Zostera marina* L.) Meadows in Willapa Bay, Washington, and Coos Bay, Oregon, Estuaries. Estuaries 26: 1117-1129.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Mespw, B. R. Noon, and J. Verner. 1990. A Conservation Strategy for the Northern Spotted Owl. Report of the Interagency Scientific Committee to address the conservation of the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, Fish and Wildlife Service, and National Park Service U.S. Government Printing Office 79 l-l 7 l/20026, Washington, D.C.

Thorpe, A.S., K. Rohland, and T.N. Kaye. 2006. *Fritillaria gentneri*: Population Monitoring at Pickett Creek, Josephine County, Oregon 2006 Progress Report. Institute for Applied Ecology.

Thorpe, A.S., and R.T. Massatti. 2008. *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) at Oak Basin. Institute for Applied Ecology, Corvallis, OR

Thorpe, A.S., R.T. Massatti, and T.N. Kaye. 2009. Reintroduction of *Lupinus sulphureus* ssp. *kincaidii* at Dragonfly Bend in the West Eugene Wetlands. 2009 Progress Report. Institute for Applied Ecology Corvallis, OR

Thrailkill, J. 2008. U.S. Fish and Wildlife Service, Biologist, Portland, OR. GIS data for the Northern Spotted Occupancy Map (NSOOM) within the vicinity of the PCGP Project. February.

Todd, Laura. 2007. FWS Newport, Oregon Office. Personal Communication with Robert Ellis. August.

Trask & Associates, Inc. 2012. Conservation Framework for the Northern Spotted Owl and Marbled Murrelet; Jordan Cove Energy and Pacific Connector Gas Pipeline Project. Prepared for the U.S. Fish and Wildlife Service, Ecological Services, Region 1 in collaboration with Mason, Bruce, & Girard, Inc. December.

Trask & Associates, Inc. 2013a. Personal communication with Edge Environmental, Inc.

Trask & Associates, Inc. 2013b. Conservation Framework for the Northern Spotted Owl and Marbled Murrelet: Jordan Cove Energy and Pacific Connector Gas Pipeline Project. Final. Prepared for U.S. Fish and Wildlife Service, Oregon and Klamath Falls Field Offices by PC Trask & Associates, Inc. in collaboration with Mason, Bruce & Girard, Inc. June.

Trask & Associates, Inc. 2014. Direct Effects (Disturbance and Disruption) Impact Assessment and Mitigation Guidance for NSO and MAMU. Prepared for U.S. Fish and Wildlife Service, Oregon and Klamath Falls Field Offices for Jordan Cove Energy and Pacific Connector Gas Pipeline Project by PC Trask & Associates, Inc. in collaboration with Mason, Bruce & Girard, Inc. January.

Trombulak, S.C., and C.A. Frissell. 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology 14:18-30.

Tu, M., C. Hurd, and J.M. Randall. 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Nature Conservancy. Davis, California.

Turner, S. 1999. Letter on fledge data from the Central Cascades Study area. To Kit Hershey, U.S. Fish and Wildlife Service, Portland, OR

U.S. Army Corps of Engineers. 1994. Coos Bay Navigation Improvements. Final EIS Feasibility Report. Coos Bay, OR. January.

U.S. Army Corps of Engineers. 2005. Coos Bay sediment quality evaluation report. Prepared by: Tim Sherman. Portland District Corps of Engineers CENWP-EC-HR.

U.S. Bureau of Reclamation (BOR). 2007. Biological Assessment - The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2008 to March 31, 2018 On Federally-Listed Threatened and Endangered Species. U.S. Bureau of Reclamation, Klamath Basin Area Office, Mid Pacific Region, Klamath Falls, OR.

U.S. Bureau of Reclamation. 2008. Handling Guidelines for Klamath Basin Suckers. USBR Klamath Basin Area Office, Klamath Falls, OR.

U.S. Commission on Ocean Policy. 2004. An Ocean Blueprint for the 21st Century. Final Report. Washington, D.C.

U.S. Department of Agriculture, Forest Service. 1995. Cow Creek Watershed Analysis. Umpqua National Forest, Roseburg, OR.

U.S. Department of Agriculture, Forest Service. 2005. Pacific Northwest Region Invasive Plant Program: Preventing and Managing Invasive Plants, Final Environmental Impact Statement. Pacific Northwest Region, USDA Forest Service, Portland.

U.S. Department of Agriculture, Forest Service. 2006. GIS Database provided to Edge Environmental, Inc.. August

U.S. Department of Agriculture, Forest Service. 2011. Level II Stream Survey Summary Report Spencer Creek, 2010. Fremont-Winema National Forests, Lakeview Ranger District. Steve Ruda and J.D. Jones. Unpublished and on file.

U.S. Department of Agriculture, Forest Service. 2012. GIS Database provided to Edge Environmental, Inc.. August

U.S. Forest Service and U.S. Department of the Interior, Bureau of Land Management (Forest Service and BLM). 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.

U.S. Forest Service and Bureau of Land Management. 1995. Spencer Creek Pilot Watershed Analysis. Winema National Forest and Klamath Falls Resource Area Office, Klamath Falls, Oregon.

U.S. Department of Health and Human Services. 1997. Toxicological Profile for Hydraulic Fluids. U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Atlanta, Georgia.

U.S. Department of the Interior, Bureau of Land Management. 1971. Natural resources, ecological aspects, uses and guidelines for the management of Coos Bay, OR. June 1971.

U.S. Department of the Interior, Bureau of Land Management 1995a. Record of Decision and Resource Management Plan. Bureau of Land Management, Coos Bay District. Coos Bay Oregon.

U.S. Department of the Interior, Bureau of Land Management. 1995b. Record of Decision and Resource Management Plan. Bureau of Land Management, Roseburg District. Roseburg Oregon.

U.S. Department of the Interior, Bureau of Land Management. 1997. Watershed Analysis Middle Main Coquille, North Coquille Mouth, Catching Creek. Bureau of Land Management Coos Bay District. North Bend, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 1999a. Upper Middle Fork Coquille Watershed Analysis. USDI-Bureau of Land Management, Roseburg District, Roseburg, OR.

U.S. Department of the Interior, Bureau of Land Management. 1999b. Olalla Lookingglass Watershed Analysis. USDI-Bureau of Land Management, Roseburg District, Roseburg, OR.

U.S. Department of the Interior, Bureau of Land Management. 1999c. Middle South Umpqua Watershed Analysis. USDI-Bureau of Land Management, Roseburg District, Roseburg, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 2000. East Fork Coquille Watershed Analysis. Bureau of Land Management Coos Bay District. North Bend, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 2001a. North Fork Coquille Watershed Analysis. Bureau of Land Management Coos Bay District. North Bend, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 2001b. South Umpqua Watershed Analysis and Water Quality Restoration Plan. USDI-Bureau of Land Management, Roseburg District, Roseburg, OR.

U.S. Department of the Interior, Bureau of Land Management. 2002. Myrtle Creek Watershed Analysis and Water Quality Restoration Plan. USDI-Bureau of Land Management, Roseburg District, Roseburg, OR.

U.S. Department of the Interior, Bureau of Land Management. 2005. Final North Spit Plan. An update to the Coos Bay Shorelands Plan of 1995. Coos Bay District, Umpqua Field Office.

U.S. Department of the Interior, Bureau of Land Management. 2006. GIS Database provided to Edge Environmental, Inc. July.

U.S. Department of the Interior, Bureau of Land Management. 2007. Middle Fork Coquille Analytical Watershed. Version 1.1. Bureau of Land Management, Coos Bay District, Myrtlewood Resource Area.

U.S. Department of the Interior, Bureau of Land Management. 2008a. Tough Year for Snowy Plovers on Oregon Coast. News Release. Coos Bay District. Online at: http://www.blm.gov/or/districts/coosbay/files/end_ploverseason_08.pdf.

U.S. Department of the Interior, Bureau of Land Management. 2008b. Biological Assessment for Roseburg BLM -FY 2008 - Regeneration Harvest Activities Outside of Critical Habitat. An Assessment of Effects to the Northern Spotted Owl. USDI- Bureau of Land Management, Roseburg District, Roseburg, OR.

U.S. Department of the Interior, Bureau of Land Management. 2008c. Spencer Creek Restoration Treatments Environmental Assessment: OR-014-04-08. Bureau of Land Management, Klamath Falls Resource Area, Klamath Falls, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 2010. Catching-Beaver Watershed Analysis. Umpqua Resource Area, Coos Bay District, North Bend, Oregon.

U.S. Department of the Interior, Bureau of Land Management. 2012. GIS Database provided to Edge Environmental, Inc.. July.

U.S. Department of the Interior, Bureau of Land Management and U.S. Department of Agriculture, Forest Service (BLM and Forest Service). 2006a. FY 2006-2008 Programmatic Biological Assessment For the Reinitiation of Consultation on Activities that May Affect Listed Species in the Rogue River/South Coast Province. Medford District BLM and Rogue River Siskiyou National Forests (RORSISBLM FY 06-08 BA.). August.

U.S. Department of the Interior, Bureau of Land Management, USDA Forest Service, and U.S. Fish and Wildlife Service. 2006b. Programmatic Conservation Agreement for Kincaid's Lupine (*Lupinus sulphureus* spp. *kincaidi*i) in Douglas County. Roseburg BLM, Umpqua National Forest, and the U.S. Fish and Wildlife Service. April.

U.S. Department of the Interior, Bureau of Land Management and U.S. Department of Agriculture, Forest Service (BLM and Forest Service). 2008. Biological Assessment: FY 2008-2012 Programmatic biological assessment for the initiation of consultation on Sudden Oak Death (*Phytophthora ramorum*) eradication activities that may affect listed species in the Chetco River Subbasin. Coos Bay District Bureau of Land Management and Rogue River – Siskiyou National Forest. February 21, 2008.

U.S. Department of the Interior, Bureau of Land Management Roseburg District, USDA Forest Service - Umpqua National Forest, and U. S. Fish and Wildlife Service. 2008. Management Plan for Kincaid's Lupine (*Lupinus sulphureus* ssp. *kincaidii*) in Douglas County Oregon. March 2008.

U.S. Environmental Protection Agency (EPA). 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Report EPA/ONAC 550/9-74-004. Washington, D.C.

U.S. Environmental Protection Agency. 1978. Protective Noise Levels. Condensed Version of EPA Levels Document. EPA 550/9-79-100. Environmental Protection Agency, Office of Noise Abatement and Control. Washington, D.C.

U.S. Environmental Protection Agency. 1986. Quality Criteria for Water. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C.

U.S. Environmental Protection Agency. 2001. National Management Measures to Control Nonpoint Source Pollution from Forestry. Draft. Environmental Protection Agency, Office of Water. Washington, D.C.

.U.S. Environmental Protection Agency. 2013. General Environmental Noise. Information Sheet. Environmental Protection Agency, Online: http://www.epa.sa.gov.au/xstd_files/Noise/Information%20sheet/info_noise_general.pdf

U.S. Federal Highway Administration. 1995. Highway Traffic Noise Analysis and Abatement Policy and Guidance. USDOT-Federal Highway Administration Office of Environment and Planning, Washington, D.C.

U.S. Federal Highway Administration. 2006. Construction Noise Handbook. USDOT Federal Highway Administration FHWA-HEP-06-015. Available Online: http://www.fhwa.dot.gov/environment/noise/construction_noise/handbook/

U.S. Federal Highway Administration, U.S. Fish and Wildlife Service, and Washington State Department of Transportation. 2012. Agreement for Criteria for Injury to the Marbled Murrelet form Noise. Online: http://www.wsdot.wa.gov/NR/rdonlyres/B08285E3-9E90-4615-891E-0ABB971F623D/0/MarbledMurrelet.pdf

U.S. Fish and Wildlife Service (FWS). 1970. Part 17 - Conservation of Endangered Species and Other Fish or Wildlife (First List of Endangered Foreign Fish and Wildlife as Appendix A). Federal Register 35(233): 18319-18322.

U.S. Fish and Wildlife Service. 1974. Part – 17 -Endangered Wildlife. Federal Register 39(3):1171-1176.

U.S. Fish and Wildlife Service. 1978. Listing and Protecting Loggerhead Sea Turtles as "Threatened Species" and Populations of Green and Olive Ridley Sea Turtles as Threatened Species or "Endangered Species". Final Ruile. Federal Register 43(146): 32800-32811.

U.S. Fish and Wildlife Service. 1981. U.S. Fish and Wildlife Service Mitigation Policy. Federal Register: 46(15): 7656 – 7663.

U.S. Fish and Wildlife Service. 1987. Northern Rocky Mountain Wolf Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado.

U.S. Fish and Wildlife Service. 1988. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Shortnose Sucker and Lost River Sucker. Federal Register 53(137): 27130-27134.

U.S. Fish and Wildlife Service. 1990. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Northern Spotted Owl; Final Rule. Federal Register 55(123):26114-26194.

U.S. Fish and Wildlife Service. 1992a. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Washington, Oregon and California Population of the Marbled Murrelet. Federal Register 57(191): 45328-4533.

U.S. Fish and Wildlife Service. 1992b. Endangered and Threatened Wildlife and Plants; Determination of Critical Habitat for the Northern Spotted Owl; Final Rule. Federal Register 57(10): 1796-1838.

U.S. Fish and Wildlife Service. 1992c. Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls. Endorsed by U.S. Fish and Wildlife Service. March.

U.S. Fish and Wildlife Service. 1993a. Determination of Threatened Status for the Pacific Coast Population of the Western Snowy Plover. Federal Register 58(42): 12864-12874.

U.S. Fish and Wildlife Service. 1993b. Lost River (Deltistes luxatus) and Shortnose (*Chasmistes brevirostris*) Sucker Recovery Plan. Portland, OR.

U.S. Fish and Wildlife Service. 1993c. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Plant *Astragalus applegatei* (Applegate's Milk-vetch). Federal Register 58(143): 40574.

U.S. Fish and Wildlife Service. 1994a. Endangered and Threatened Wildlife and Plants; Proposed Critical Habitat for Lost River Sucker and Shortnose Sucker. Federal Register 59(230): 61744-61759.

U.S. Fish and Wildlife Service. 1994b. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, and Vernal Pool Tadpole Shrimp, and Threatened Status for the Vernal Pool Fairy Shrimp. Federal Register 59(180): 48136-48153.

U.S. Fish and Wildlife Service. 1994c. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for *Lilium occidentale* (Western Lily). Federal Register 59(158): 42171-42176.

U.S. Fish and Wildlife Service. 1996a. Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for the Marbled Murrelet; Final Rule. Federal Register 61(102): 26256-26320.

U.S. Fish and Wildlife Service. 1996b. Interim Survey Guidelines to Permittees for Recovery Permits under Section 10(a)(1)(A) of the Endangered Species Act for the Listed Vernal Pool Branchiopods. April.

U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, OR.

U.S. Fish and Wildlife Service. 1998a. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout; Final Rule. Federal Register 63(111):31647-31674.

U.S. Fish and Wildlife Service. 1998a. A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale. U.S. Fish and Wildlife Service, Region 1. Portland, Oregon.

U.S. Fish and Wildlife Service. 1998b. Applegate's milk-vetch (*Astragalus applegatei*) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

U.S. Fish and Wildlife Service. 1998c. Recovery Plan for the Endangered Western lily *(Lilium occidentale)*. Portland, Oregon. 82 pp.

U.S. Fish and Wildlife Service. 1999a. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Pacific Coast Population of the Western Snowy Plover. Federal Register 64(234): 68507-68544.

U.S. Fish and Wildlife Service. 1999b. Endangered and Threatened Wildlife and Plants; Final Endangered Status for the Plant *Fritillaria genteri* (Gentner's fritillary). Federal Register 64(237): 69195-69203.

U.S. Fish and Wildlife Service. 1997. Recovery Plan for the Threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, OR.

U.S. Fish and Wildlife Service. 2000a. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Contiguous U.S. Distinct Population Segment of the Canada Lynx and Related Rule; Final Rule. Federal Register 65(58):15052-16086.

U.S. Fish and Wildlife Service. 2000b. Endangered and Threatened Wildlife and Plants; Final Rule to List the Short-tailed Albatross as Endangered in the United States. Final Rule. Federal Register 65(147):46643-46654.

US Fish and Wildlife Service. 2000c. Final Rule. Endangered and Threatened Wildlife and Plants; Endangered Status for ‘‘Erigeron decumbens’’ var. ‘‘decumbens’’ (Willamette Daisy) and Fender’s Blue Butterfly (‘‘Icaricia icarioides fenderi’’) and Threatened Status for ‘‘Lupinus sulphureus’’ ssp.‘‘kincaidii’’ (Kincaid’s Lupine). Federal Register 65: 3875 -3890. January 25, 2000.

U.S. Fish and Wildlife Service. 2000d. Endangered and Threatened Wildlife and Plants; Endangered Status for the Plant *Plagiobothrys hirtus* (Rough Popcornflower). Federal Register 65(16): 3366-3875.

U.S. Fish and Wildlife Service. 2001. Western Snowy Plover (*Charadrius alexandrinus nivosus*) Pacific Coast Population Recovery Plan. U.S. Fish and Wildlife, Portland, OR.

U.S. Fish and Wildlife Service. 2002a. Chapter 2, Klamath River Recovery Unit, Oregon. 82pp. *In*: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, OR.

U.S. Fish and Wildlife Service. 2002b Appendix 1, Estimates of Distances at which Incidental take of Murrelets and Spotted Owls due to Harassment are Anticipated from Sound-generating, Forest-Management Activities in Olympic National Forest. In Biological Opinion based on the review of the proposed Amendment to the Interim Programmatic Biological Assessment of the Olympic National Forest, located in Clallam, Jefferson, Mason and Gray’s Harbor Counties, Washington. U.S. Fish and Wildlife Service, Western Washington Field Office, Lacey, Washington

U.S. Fish and Wildlife Service. 2002c. Endangered and Threatened Wildlife and Plants; Notice of 90-Day Finding on a Petition To Delist the Lost River Sucker and Shortnose Sucker. Federal Register 67(93): 34422-34423.

U.S. Fish and Wildlife Service. 2002d. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for *Lomantium cookii* (Cook’s Lomantium) and *Lamnanthes floccossa* ssp. *grandiflora* (Large-flowered Woolly Meadowfoam) from Southern Oregon. Federal Register 67(216): 63004-68015.

U.S. Fish and Wildlife Service. 2003a. Guidance for the Establishment, Use, and Operation of Conservation Banks. USDI-Fish and Wildlife Service, Washington, D.C.

U.S. Fish and Wildlife Service. 2003b. Estimates of distances at which incidental take of murrelets and spotted owls due to harassment are anticipated from sound-generating, forest-management activities in Olympia National Forest. Lacey, WA.

U.S. Fish and Wildlife Service. 2003c. Biological Opinion and Letter of Concurrence of Effects on Bald Eagles, Marbled Murrelets, Northern Spotted Owls, Bull Trout, and Designated Critical Habitat for Marbled Murrelets and Northern Spotted Owls from Olympic National Forest Program Activities for August 5, 2003 to December 31, 2008. Reference number 1-3-03-F-0833. U.S. Fish and Wildlife Service. Washington State Office, Lacey, Washington.

U.S. Fish and Wildlife Service. 2003c. Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon. Federal Register 68(151): 46683-46867.

U.S. Fish and Wildlife Service. 2003d. Recovery Plan for *Fritillaria gentneri* (Gentner's Fritillary). U.S. Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service. 2003e. Recovery Plan for the Rough Popcornflower (*Plagiobothrys hirtus*). Portland, Oregon.

U.S. Fish and Wildlife Service. 2004. Northern Spotted Owl 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service. 2005a. Recovery Outline. Contiguous United States Distinct Population Segment of the Canada Lynx. U.S. Fish and Widlife Service, Montana Field Office, Helena, Montana

U.S. Fish and Wildlife Service. 2005b. Short-tailed Albatross Draft Recovery Plan. Anchorage, AK, 62pp.

U.S. Fish and Wildlife Service. 2005c. Western Snowy Plover Final Designated Habitat, GIS Data. Online at: http://criticalhabitat.fws.gov/.

U.S. Fish and Wildlife Service. 2005d. Draft: Disturbance and Disruption Distances for Northern Spotted Owls. Portland, OR

U.S. Fish and Wildlife Service. 2005d. Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon. Portland, OR. xxvi + 606 pages.

U.S. Fish and Wildlife Service. 2005e Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Fender's Blue Butterfly (*Icaricia icarioides fenderi*), *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's Lupine), and *Erigeron decumbens* var. *decumbens* (Willamette Daisy); Proposed Rule. Federal Register 70(211): 66491-66599.

U.S. Fish and Wildlife Service. 2006a. Oregon Fish and Wildlife Office, Portland, Oregon. Written Communication to Edge Environmental, Inc. July.

U.S. Fish and Wildlife Service. 2006b. Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon. Written Communication to Edge Environmental, Inc. June.

U.S. Fish and Wildlife Service. 2006c. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to Delist the Pacific Coast Population of the Western Snowy Plover. Federal Register 71(77):20607-20624.

U.S. Fish and Wildlife Service. 2006d. Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Marbled Murrelet. Federal Register. 71(176): 53838-53951.

U.S. Fish and Wildlife Service. 2006e. Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted owls and Marbled Murrelets in Northwestern California. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata, California.

U.S. Fish and Wildlife Service. 2006f. Biological Opinion for Effects to Northern Spotted Owls (*Strix occidentalis caurina*) from the Willamette Planning Province Fiscal Year 2007 – 2008 Activities that have the Potential to Adversely Affect, Due to Habitat Modification and Disturbance, on U.S. Department of the Interior; Bureau of Land Management, Eugene District and Salem District, and the U.S. Department of Agriculture; Mt. Hood National Forest, Willamette National Forest and the Columbia River Gorge National Scenic Area. U.S. Fish and Wildlife, Portland, OR. FWS Reference Number 1-7-06-F-0179.

U.S. Fish and Wildlife Service. 2006g. Draft Recovery Plan for Listed Species of the Rogue Valley Vernal Pool and Illinois Valley Wet Meadow Ecosystems. Region 1, Portland, OR.

US Fish and Wildlife Service. 2006h. Recovery Outline for *Lupinus sulphureus* ssp. kincaidii (Kincaid's lupine). US Fish and Wildlife Service, Oregon Field Office, Portland,OR. Online at http://www.fws.gov/pacific/ecoservices/endangered/recovery/documents/ LUSUKIRecoveryOutlineMarch2006.pdf

U.S. Fish and Wildlife Service. 2006i. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Fender's Blue Butterfly (*Icaricia icariodes fenderi*), *Lupinus sulphureus* ssp. *kincaidii* (Kincaid's lupine), and *Erigeron decumbens* var. *decumbens* (Willamette daisy). Federal Register 71(210): 63861-63910.

U.S. Fish and Wildlife Service. 2007a. Oregon Fish and Wildlife Office, Portland, Oregon. Written Communication to Edge Environmental, Inc. July.

U.S. Fish and Wildlife Service. 2007b. Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon. Written Communication to Edge Environmental, Inc. August.

U.S. Fish and Wildlife Service. 2007c. Yellow-billed Cuckoo, Western Distinct Population Segment. U.S. Fish and Wildlife Service, Species Assessment and Listing Priority Assignment Form, Sacramento Field Office, Sacramento, California.

U.S. Fish and Wildlife Service. 2007d. Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In 2 volumes. Sacramento, California.

U.S. Fish and Wildlife Service. 2007e. 2007 Draft Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*: Merged Options 1 and 2. Portland, OR. April.

U.S. Fish and Wildlife Service. 2007f. Endangered and Threatened Wildlife and Plants; Proposed Revised Designation of Critical Habitat for the Northern Spotted Owl (*Strix occidentailis caurina*); Proposed Rule. Federal Register 72(171): 32449-32516.

U.S. Fish and Wildlife Service. 2007g. Green Sea Turtle Fact Sheet. Online at: http://www.fws.gov/northflorida/SeaTurtles/Turtle%20Factsheets/green-sea-turtle.htm.

U.S. Fish and Wildlife Service. 2007h. Lost River Sucker (*Deltistes luxatus*) 5-Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR.

U.S. Fish and Wildlife Service. 2007i. Shortnose Sucker (*Chasmistes brevirostis*) 5-Year Review, Summary and Evaluation. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR.

U.S. Fish and Wildlife Service. 2007j. Vernal Pool Fairy Shrimp. 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Sacramento, CA.

U.S. Fish and Wildlife Service. 2008a. Short-tailed Albatross Recovery Plan. Anchorage, AK,

U.S. Fish and Wildlife Service. 2008b. Endangered and Threatened Wildlife and Plants; Revised Critical Habitat for the Marbled Murrelet (*Brachyramphus marmoratus*). Federal Register. 73(148): 44678-44701.

U.S. Fish and Wildlife Service. 2008c. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service. 2008d. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Northern Spotted Owl; Final Rule. 47326-

U.S. Fish and Wildlife Service. 2008e. Draft Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington. U.S. Fish and Wildlife Service, Portland, Oregon. x + 212 pp.

U.S. Fish and Wildlife Service. 2008f. Rough Popcornflower Endangered Species Fact Sheet. Oregon Fish and Wildlife Office. Online at: http://www.fws.gov/oregonfwo/Species/ Data/RoughPopcornflower/.

U.S. Fish and Wildlife Service. 2009a. Short-tailed Albatross (*Phoebastria albatrus*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Anchorage Field Office, Anchorage, Alaska.

U.S. Fish and Wildlife Service. 2009b. Western snowy (coastal) plover, species fact sheet. Accessed March 2009 at: http://www.fws.gov/oregonfwo/Species/Data/ WesternSnowyPlover/.

U.S. Fish and Wildlife Service. 2009c. Applegate's Milk-vetch (*Astragalus applegatei*) 5-Year Review Summary and Evaluation prepared by the U.S. Fish and Wildlife Service. Klamath, OR.

U.S. Fish and Wildlife Service. 2009d. *Lilium occidentale* (Western lily) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Arcata Field Office, Arcata, California.

(U.S. Fish and Wildlife Service. 2009d. Endangered and Threatened Wildlife and Plants; Proposed Designation of Critical Habitat for *Limnanthes floccosa* ssp. *grandiflora* (Large-flowered Woolly Meadowfoam) and *Lomatium cookii* (Cook's lomatium). Federal Register 74: 37314 -37392. July 28, 2009.

U.S. Fish and Wildlife Service. 2010a. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for Bull Trout in the Coterminous United States; Final Rule. Federal Register 75(200);63898-64070.

U.S. Fish And Wildlife Service. 2010b. Bull Trout Final Critical Habitat Justification: Rationale for Why Habitat Is Essential, and Documentation of Occupancy. U.S. Fish and Wildlife Service. Idaho Fish and Wildlife Office, Boise, Idaho.

U.S. Fish and Wildlife Service. 2010c. Gray Wolf Northern Rocky Mountains Genetic Diversity. U/S Fish and Wilflie Service,Denver Federal Center, Denver, Colorado. Online: http://www.fws.gov/mountain-prairie/factsheets/Wolf%20Tip%20Sheet_Genetic%20Diversity.pdf

U.S. Fish and Wildlife Service. 2010d. 2010 Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls. Version 1.0. February.

U.S. Fish and Wildlife Service.2010e. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for *Limnanthes floccosa* ssp. *grandiflora* (Large-Flowered Woolly Meadowfoam) and *Lomatium cookii* (Cook'sLomatium); Final Rule. . 50 CFR Part 17. Federal Register (75) No 139. 42490-42570.

U.S. Fish and Wildlife Service. 2010f. 5-Year Review. Kincaids Lupine. US Fish and Wildlife Service, Oregon Field Office, Portland,OR

U.S. Fish and Wildlife Service. 2010g. Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington. U.S. Fish and Wildlife Service, Portland, Oregon. xi + 241 pp.

U.S. Fish and Wildlife Service. 2010h. Species Assessment and Listing Priority Assignment Form. *Eremophila alpestris strigata*. U.S. Fish and Wildlife Service, Region 1, Washington Fish and Wildlife Office, Lacey, Washington.

U.S. Fish and Wildlife Service. 2011a. Endangered and Threatened Wildlife and Plants; Revised Critical Habitat for the Marbled Murrelet; Final Rule. Federal Register 76(193): 61599-61621.

U.S. Fish and Wildlife Service. 2011b. Endangered and Threatened Wildlife and Plants; Reissuance of Final Rule To Identify the Northern Rocky Mountain Population of Gray Wolf as a Distinct Population Segment and To Revise the List of Endangered and Threatened Wildlife. Federal Register 76(87):25590-25592.

U.S. Fish and Wildlife Service. 2011c. Revised Recovery Plan for the Northern Spotted Owl, (*Strix occidentalis caurina*). Region 1, U.S. Fish and Wildlife Service, Portland, OR. June. Available online: http://ecos.fws.gov/docs/recovery_plan/RevisedNSORecPlan2011_1.pdf.

U.S. Fish and Wildlife Service. 2011d. Oregon Spotted Frog - Species Assessment and Listing Priority Form. U.S. Fish and Wildlife Service, Pacific Region 1.

U.S. Fish and Wildlife Service. 2011e. Large-flowered Woolly Meadowfoam 5-Year Review Summary and Evaluation prepared by the U.S. Fish and Wildlife Service. Roseburg, OR.

U.S. Fish and Wildlife Service. 2012a. Endangered and Threatened Wildlife and Plants; Designation of Revised Critical Habitat for the Northern Spotted Owl; Final Rule. Federal Register 77(233): 71876-72068.

U.S. Fish and Wildlife Service. 2012b. Lower 48-State and Mexico Gray wolf (*Canis lupus*) listing, as revised - 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Washington Office. Arlington, VA.

U.S. Fish and Wildlife Service. 2012c. Short-tailed Albatross Fledges at Midway Atoll National Wildlife Refuge. News Release, June 14, 2012.

U.S. Fish and Wildlife Service. 2012d. Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Pacific Coast Population of the Western Snowy Plover; Final Rule. Federal Register 77(118):36728-36869.

U.S. Fish and Wildlife Service. 2012e. Protocol for Surveying Proposed Management Activities That May Impact Northern Spotted Owls. U.S. Fish and Wildlife Service. January.

U.S. Fish and Wildlife Service. 2012f. Leatherback Sea Turtle Fact Sheet. North Florida Field Office. Online at: http://www.fws.gov/northflorida/SeaTurtles/Turtle%20Factsheets/leatherback-sea-turtle.htm

U.S. Fish and Wildlife Service. 2012g. Revised recovery plan for the Lost River Sucker (*Deltistes luxatus*) and Shortnose Sucker (*Chasmistes brevirostris*). U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, CA.

U.S. Fish and Wildlife Service. 2012h. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Lost River Sucker and Shortnose Sucker; Final Rule. Federal Register 77(238):73750-73768.

U.S. Fish and Wildlife Service. 2012i. Recovery Plan for Rogue and Illinois Valley Vernal Pool and Wet Meadow Ecosystems. Region 1, Portland, Oregon. xvii +240 pages.

U.S. Fish and Wildlife Service. 2012j. Endangered and Threatened Wildlife and Plants; Listing Taylor's Checkerspot Butterfly and Streaked Horned Lark and Designation of Critical Habitat. Proposed Rule. Federal Register 77(197):61938-

U.S. Fish and Wildlife Service. 2013a. Endangered and Threatened Wildlife and Plants; Threatened Status for the Distinct Population Segment of the North American Wolverine Occurring in the Contiguous United States; Establishment of a Nonessential Experimental Population of the North American Wolverine in Colorado, Wyoming, and New Mexico. Proposed Rule. Federal Register 78(23):7864-7890.

U.S. Fish and Wildlife Service. 2013b. Endangered and Threatened Wildlife and Plants; Removing the Gray Wolf (Canis lupus) From the List of Endangered and Threatened Wildlife and Maintaining Protections for the Mexican Wolf (Canis lupus baileyi) by Listing It as Endangered. Proposed Rule. Federal Register 78(114):35664-35719.

U.S. Fish and Wildlife Service. 2013c. Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for the Western Distinct Population Segment of the Yellow-billed Cuckoo (Coccyzus americanus). Federal Register 78(192):61622-61666.

U.S. Fish and Wildlife Service. 2013d. U.S. Fish & Wildlife Responses to Applicant Questions and Comments on the October 2013 Version of the NSO/MAMU Conservation Framework Document. January 30, 2013.

U.S. Fish and Wildlife Service. 2013e. Endangered and Threatened Wildlife and Plants; Threatened Status for Oregon Spotted Frog. Proposed Rule. Federal Register 78(168):53582-53623.

U.S. Fish and Wildlife Service. 2013f. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Oregon Spotted Frog. Proposed Rule. Federal Register 78(168):53538-53579.

U.S. Fish and Wildlife Service. 2013g. Oregon Spotted Frog. Proposed Listing as Threatened. Threats Matrix Analysis. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, Washington. Online at http://www.fws.gov/wafwo/osf.html

U.S. Fish and Wildlife Service. 2013h. Olive Ridley Sea Turtle Fact Sheet. North Florida Field Office. Online at: http://www.fws.gov/northflorida/SeaTurtles/Turtle%20Factsheets/olive-ridley-sea-turtle.htm

U.S. Fish and Wildlife Service. 2013i. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Taylor's Checkerspot Butterfly and Threatened Status for the Streaked Horned Lark. Final Rule. Federal Register 78(192):61452-61503.

U.S. Fish and Wildlife Service. 2013j. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Taylor's Checkerspot Butterfly and Streaked Lark. Final Rule. Federal Register 78(192): 61506-.

U.S. Fish and Wildlife Service, USDI Bureau of Land Management, and USDA Forest Service. 2007. Methodology for estimating the number of northern spotted owls affected by proposed federal actions. Oregon Fish and Wildlife Office, Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service, Bureau of Land Management, and Forest Service. 2008. Methodology for estimating the number of northern spotted owls affected by proposed federal actions. Version 2.0. Oregon Fish and Wildlife Office, Fish and Wildlife Service, Portland, OR. September.

U.S. Fish and Wildlife Service, USDA-Forest Service, USDI-Bureau of Land Management.. 2010. Conservation Agreement for the Oregon Spotted Frog *(Rana pretiosa)* in the Klamath Basin of Oregon. U.S. Fish and Wildlife Service, Fremont-Winema National Forests Lakeview District of the Bureau of Land Management, Medford District of the Bureau of Land Management, Klamath Marsh National Wildlife Refuge. Available Online at: http://www.fs.fed.us/r6/sfpnw/issssp/documents/planning-docs/cag-ha-rana-pretiosa-2010-05-07.pdf

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. Endangered Species Act Consultation Handbook – Procedures for Conducting Section 7 Consultations and Conferences. Director, U.S. Fish and Wildlife Service and Assistant Administrator for Fisheries, National Marine Fisheries Service, Washington, D.C.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 2003. Policy for Evaluation of Conservation Efforts when Making Listing Decisions. Federal Register 68(60): 15100-15115

U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, Montana Fish, Wildlife & Parks, Nez Perce Tribe, National Park Service, Blackfeet Nation, Confederated Salish and Kootenai Tribes, Wind River Tribes, Confederated Colville Tribes, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Utah Department of Natural Resources, and USDA Wildlife Services. 2013. Northern Rocky Mountain Wolf Recovery Program 2012 Interagency Annual Report. M.D. Jimenez and S.A. Becker, eds. USFWS, Ecological Services, Helena, MT.

U.S. Geological Survey. 2003. Wentworth Grain Size Chart. Accessed online: http://pubs.usgs.gov/of/2003/of03-001/htmldocs/images/chart.pdf.

U.S. Geological Survey. 2005. NAS-Nonindigenous Aquatic Species Database, Gainesville, FL. Accessed online: http://nas.er.usgs.gov. January 9, 2007.

Upper Rogue Watershed Association. 2006. Upper Rogue Watershed Assessment. Upper Rogue Watershed Association, Medford, Oregon.

Valdimarsson, S.K.; N.B. Metcalfe, J.E. Thorpe; F.A. Huntingford. 1997. Seasonal Changes in Sheltering; Effect of Light and Temperature on Diel Activity in Juvenile Salmon." Animal Behaviour 54 (6): 1405-1412.

Vardy, D.W., A.R. Tompsett, J.L. Sigurdson, J.A. Doering, X., Zhang, J.P. Giesy, and M Hecker. 2011. Effects of Subchronic Exposure of Early Life Stages of White Sturgeon (*Acipenser transmontanus*) to Copper, Cadmium, and Zinc. Environmental Toxicology and Chemistry 30(1): 2497-2505.

Verts, B.J., and L.N. Carraway. 1998. Land Mammals of Oregon. University of California Press, Berkeley, CA.

Vogel, J.L., and D.A. Beauchamp. 1999. Effects of Light, Prey Size, and Turbidity on Reaction Distances of Lake Trout (Salvelinus namaycush) to Salmonid Prey. Canadian Journal of Fisheries and Aquatic Sciences 56:1293-1297.

Vollmar, J.E. (editor). 2002. Wildlife and Rare Plant Ecology of Eastern Merced County's Vernal Pool Grasslands. Unpublished report, Vollmar Consulting, Berkeley, CA.

Wade, P. R. 1998. Calculating Limits to the Allowable Human-caused Mortality of Cetaceans and Pinnipeds. Marine Mammal Science 14:1-37.

Wagoner, L.J., K.K. Jones, R.E. Bender, J.A. Butler, D.E. Demory, T.F. Gaumer, J.A. Hurtado, W.G. Mullarky, P.E. Reimers, N.T. Richmond and T.J. Rumreich. 1990. Coos River.

Ward, J.P., R.J. Gutierrez, and B.R. Noon. 1998. Habitat Selection by Northern Spotted Owls: The Consequences of Prey Selection and Distribution. The Condor 100:79-92

Warriner, J. S., J. C. Warriner, G. W. Page, and L. E. Stenzel. 1986. Mating System and Reproductive Success of a Small Population of Polygamous Snowy Plovers. Wilson Bulletin 98:5-37.

Washington Department of Ecology. 2009. Industrial stormwater general permit – Fact sheet. June 3, 2009 Public comment draft. http://www.ecy.wa.gov/programs/wq/stormwater/industrial/permitdocs/ISWGPdraftfs060309fin.pdf (Accessed October 2009).

Washington Department of Fish and Wildlife. 2009. Draft Wolf Conservation and Management Plan for Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Natural Resources. 1997. Final Habitat Conservation Plan. Washington Department of Natural Resources, Olympia, Washington.

Washington State Department of Transportation. 2011a. Chapter 7.0-Construction Noise Impact Assessment. Pages 7.1 - 7.62 in Biological Assessment Preparation for Transportation Projects, Advanced Training Manual Version 02-2011. Environmental Services, Washington State Department of Transportation, Olympia, WA.

Washington State Department of Transportation. 2011b. Fish Exclusion Protocols and Standards. Referenced in Biological Assessment Preparation for Transportation Projects, Advanced Training Manual Version 02-2011. Environmental Services, Washington State Department of Transportation, Olympia, WA.

Washington State Department of Transportation. 2014. Chapter 14.0 – In-water Work. Pages 14-1 to 14-9. In Biological Assessment Preparation Advanced Training Manual Version 02-2014. Washington State Department of Transportation. Available online: http://www.wsdot.wa.gov/NR/rdonlyres/07635797-DF75-48EA-90A4-65CC00CF301C/0/BA_ManualChapter14.pdf

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11:1019-1022.

Waters, T.R. 1995. Sediment in Streams: Sources, Biological Effects and Control. American Fisheries Society Monograph 7, Bethesda, Maryland

Weilgart, L.S. 2007. The Impacts of Anthropogenic Ocean Noise on Cetaceans and Implications for Management. Canadian Journal of Zoology 85:1091-1116.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status Review of Coho Salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-24, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA and Southwest Region, Long Beach, CA.

Welsh, H.H., and L.M. Ollivier. 1998. Stream Amphibians as Indicators of Ecosystem Stress: a Cast Study from California's Redwoods. Ecological Applications 8(4):1118-1132.

Werner, I. and J.T. Hollibaugh. 1993. *Potamocorbula amurensis*: Comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton. Limnology and Oceanography 38(5):949-964.

Weseman, T., and M. Rowe. 1987. Factors Influencing the distribution and abundance of Burrowing Owls in Cape Coral, Florida. Pages 129-137 in L.W. Adams and D.L. Leedy, (editors). Integrating Man and Nature in The Metropolitan Environment. Proceedings of the National Symposium on Urban Wildlife. National Institute for Urban Wildlife, Columbia, MD.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Fire Activity. Science 313(5789):940–943.

Wheeler, Chuck. 2006a. Fisheries Biologist, National Marine Fisheries Service, Roseburg, OR. Personal Communication with Edge Environmental, Inc. June 29, 2006.

Wheeler, Chuck. 2006b. Fisheries Biologist, National Marine Fisheries Service, Roseburg, OR. Personal Communication with Edge Environmental, Inc. July 19, 2006.

Wheeler, C. 2008. Oregon State Habitat Office, NMFS. Personal communication with Edge Environmental, Inc.

Whisler, J., T. Neill, and K. Melcher. 1999. 1998 sturgeon tagging Project in select coastal estuaries. Oregon Department of Fish and Wildlife. Columbia River Management. Clackamas, Oregon.

Wiggins, D.A. 2005. Yellow-billed Cuckoo (Coccyzus americanus): A Technical Conservation Assessment. USDA Forest Service, Rocky Mountain Region.

Wildland Hydrology. 1994. Chart 5-3: Key to the Rosgen Classification of Natural Rivers. Wildland Hydrology, Pagosa Springs, Colorado. Online at: http://www.wildlandhydrology.com/assets/ARM_5-3.pdf

Wille, S., B. Progulske, J. Thrailkill, B. Tuerler, and S. Livingston. 2006. Oregon Fish and Wildlife Office, Portland, OR. Personal Communication with Edge Environmental, Inc. via meeting. October 4, 2006.

Williams, R., and P. O'Hara. 2009. Modelling Ship Strike Risk to Fin, Humpback, and Killer Whales in British Columbia, Canada. Journal of Cetacean Research and Management 11:1-8.

Williamson, R.J., G.E. Fogg, M.C. Rains, and T.H. Harter. 2005. Hydrology of vernal pools at three sites, Southern Sacramento Valley, FHWA/CA/IR-2004/08. Final Report for Project F2001 IR 20, Developing a Floristic Statewide Vernal Pool Classification, and a functional model of vernal pool hydrology and water quality, sponsored by the California Department of Transportation. Dept. of Land, Air, and Water Resources, Hydrologic Sciences Graduate Group, University of California, Davis

Wilson, B., R.S. Batty, F., Daunt, and C. Carter. 2007. Collision Risks between Marine Renewable Energy Devices and Mammals, Fish and Diving Birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland,

Wilson-Jacobs, R., and E. C. Meslow. 1984. Distribution, Abundance, and Nesting Characteristics of Snowy Plovers on the Oregon coast. Northwest Science 58:40-48.

Wilson, M. V., T. Erhart, P. C. Hammond, T. N. Kaye, K. Kuykendall, A. Liston, A. F. Robinson, Jr., C. B. Schultz, and P. M. Severns. 2003. Biology of Kincaid's lupine (*Lupinus sulphureus* spp. *kincaidii* [Smith] Phillips), a threatened species of western Oregon native prairies, USA. Natural Areas Journal 23(1):72-83.

Wilson, R. A. 1980. Snowy plover nesting ecology on the Oregon coast. M.S. Thesis, Oregon State Univ., Corvallis.

World Health Organization. 1996. Environmental Health Criteria 171 – Diesel Fuel And Exhaust Emissions. United Nations Environment Programme, International Labour Organisation, World

Health Organization. Available Online at: http://www.inchem.org/documents/ehc/ehc/ehc171.htm

Wright, D.G, and G.E. Hopky. 1998. Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters. Canadian Technical Report of Fisheries and Aquatic Sciences 2107.

Würsig, B., and W.J. Richardson. 2009. Noise, Effects of. Pages 765 to 73, in W.F. Perrin, B. Würsig, and J.F.M Thewissen (editors). Encyclopedia of Marine Mammals (Second Edition). Academic Press, Elsevier, New York.

Yamamoto, S. 1985. Status report for *Astragalus applegatei*. Unpublished report on file with the U.S. Fish and Wildlife Service, Portland, Oregon.

Zabel, C. J., K.M. McKelvey, and J.P. Ward, Jr. 1995. Influence of Primary Prey on Home-range size and Habitat-use Patterns of Northern Spotted Owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433-439.

Zharikov, Y., D.B. Lank, F. Huettmann, R. Bradley, N. Parker, P. Yen, L.A. McFarlane-Tranquilla, and F. Cooke. 2006. Habitat selection and Breeding Success in a Forest-nesting Alcid, the Marbled Murrelet, in twoLlandscapes with Different Degrees of Forest Fragmentation. Landscape Ecology 21:107-120.

Zharikov, Y., D.B. Lank, and F. Cooke. 2007. Influence of landscape pattern on breeding distribution and Success in aTthreatened Alcid, the Marbled Murrelet: model transferability and management implications. Journal of Applied Ecology 44:748-759.

Zhou, X, R.W. Haynes, and R.J. Barbour. 2005. Projections of Timber Harvest in Western Oregon and Washington by County, Owner, Forest Type, and Age class. U.S.D.A.-Forest Service, Pacific Northwest Research Station General Technical. PNW-GTR-633. Portland, OR.

# APPENDIX Q-9

Literature Review Sources

**Final Research Report**
Research Project T1803, Task 42
Effects of Turbidity on Salmon

# EFFECTS OF TURBIDITY AND SUSPENDED SOLIDS ON SALMONIDS


by

Jeff Bash
Research Technician

Cara Berman
Research Scientist

Susan Bolton
Associate Professor and Director
**Center for Streamside Studies**
University of Washington, Box 352100
Seattle, Washington 98195

**Washington State Transportation Center**
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Edward Molash
Environmental Affairs



Prepared for

**Washington State Transportation Commission**
Department of Transportation
and in cooperation with
**U.S. Department of Transportation**
Federal Highway Administration

November 2001

## Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

# TECHNICAL REPORT STANDARD TITLE PAGE

| | | |
|---|---|---|
| 1. REPORT NO.<br>WA-RD 526.1 | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
| 4. TITLE AND SUBTITLE<br>EFFECTS OF TURBIDITY AND SUSPENDED SOLIDS ON SALMONIDS | | 5. REPORT DATE<br>November 2001<br>6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S)<br>Jeff Bash, Cara Berman, Susan Bolton | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Washington State Transportation Center (TRAC)<br>University of Washington, Box 354802<br>University District Building; 1107 NE 45th Street, Suite 535<br>Seattle, Washington 98105-4631 | | 10. WORK UNIT NO.<br>11. CONTRACT OR GRANT NO.<br>Agreement T1803, Task 42 |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>Research Office<br>Washington State Department of Transportation<br>Transportation Building, MS 47370<br>Olympia, Washington 98504-7370<br>Jim Toohey, Project Manager, 360-407-0885 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>Draft Research Report<br>14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

Protection of Washington State's salmonids requires that transportation officials consider the effect of suspended sediments released into streams during transportation projects. Many state and provincial criteria are based on a threshold of exceedance for background levels of turbidity. However, determining natural background levels of turbidity is a difficult endeavor.

The inconsistent correlation between turbidity measurements and mass of suspended solids, as well as the difficulty in achieving repeatability using turbidimeters contributes to concerns that turbidity may not be a consistent and reliable tool determining the effects of suspended solids on salmonids. Other factors, such as life stage, time of year, size and angularity of sediment, availability of off-channel and tributary habitat, and composition of sediment may be more telling in determining the effect of sediment on salmonids in Northwestern rivers.

For short-term construction projects, operators will need to measure background turbidities on a case by case basis to determine if they are exceeding regulations. However, transportation projects may also produce long-term, chronic effects.

To adequately protect salmonids during their freshwater residence, TSS data on physiological, behavioral, and habitat effects should be viewed in a layer context, incorporating both the spatial geometry of suitable habitat and the temporal changes associated with life history, year class, and climate variability. Spatial and temporal considerations provide the foundation to decipher legacy effects as well as cumulative and synergistic effects on salmonid protection and recovery.

| | |
|---|---|
| 17. KEY WORDS<br>Turbidity, salmonids, suspended solids | 18. DISTRIBUTION STATEMENT<br>No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616 |

| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
|---|---|---|---|
| None | None | | |

# Table of Contents

## Tables

## Summary

Human activities in Northwestern watersheds, including logging, grazing, agriculture, mining, road building, urbanization, and commercial construction contribute to periodic pulses or chronic levels of suspended sediment in streams. Suspended sediment is associated with negative effects on the spawning, growth, and reproduction of salmonids.

Effects on salmonids will differ based on their developmental stage. Suspended sediments may affect salmonids by altering their physiology, behavior, and habitat, all of which may lead to physiological stress and reduced survival rates. A sizable body of data (laboratory and field-based) has been gathered in North America focusing on the relationship between turbidity, total suspended sediments, and salmonid health. The controlled environment of laboratory studies tends to give clearer results than field studies.

Understanding the relationship between turbidity measurements, suspended sediments, and their effects on salmonids at various life stages will assist agencies implementing transportation projects to devise techniques to reduce temporary and chronic erosion and sedimentation associated with these activities. There are three primary ways in which sediment in the water column is measured: turbidity, total suspended solids, and water clarity. While these measures are frequently correlated with one another, the strength of correlation may vary widely between samples from different monitoring sites and between different watersheds. Turbidity is currently in widespread use by resource managers, partially due to the ease of taking turbidity measurements. In addition, current state regulations addressing suspended sediment are usually NTU-based. The disadvantage of turbidity is that it is only an indicator of suspended sediment effects, rather than a direct measure, and may not accurately reflect the effect on salmonids.

Protection of Washington State's salmonids requires that transportation officials consider the effect of suspended sediments released into streams during transportation projects.

Many state and provincial criteria are based on a threshold of exceedance for background levels of turbidity. However, determining natural background levels of turbidity is a difficult endeavor. Turbidity measures may be affected by 1) differing physical processes between watersheds including geologic, hydrologic and hydraulic

conditions; 2) legacy issues (activities historically conducted in the watershed); and 3) problems with instrumentation and repeatability of turbidity measurements. Altered systems may not provide accurate baseline conditions.

The inconsistent correlation between turbidity measurements and mass of suspended solids, as well as the difficulty in achieving repeatability using turbidimeters contributes to concerns that turbidity may not be a consistent and reliable tool determining the effects of suspended solids on salmonids. Other factors, such as life stage, time of year, size and angularity of sediment, availability of off-channel and tributary habitat, and composition of sediment may be more telling in determining the effect of sediment on salmonids in Northwestern rivers.

Although salmonids are found in naturally turbid river systems in the Northwest, this does not necessarily mean that salmonids in general can tolerate increases over time of suspended sediments. An understanding of sediment size, shape, and composition, salmonid species and life history stages, cumulative and synergistic stressor effects, and overall habitat complexity and availability in a watershed is required.

For short-term construction projects, operators will need to measure background turbidities on a case by case basis to determine if they are exceeding regulations. However, transportation projects may also produce long-term, chronic effects. Short-term pulses will presumably have a different effect on salmonids than chronic exposure.

To adequately protect salmonids during their freshwater residence, TSS data on physiological, behavioral, and habitat effects should be viewed in a layer context incorporating both the spatial geometry of suitable habitat and the temporal changes associated with life history, year class, and climate variability. Spatial and temporal considerations provide the foundation to decipher legacy effects as well as cumulative and synergistic effects on salmonid protection and recovery.

# I. Introduction

Human activities in Northwestern watersheds, including logging, grazing, agriculture,

mining, road building, urbanization, and commercial construction have often resulted in periodic pulses or chronic levels of suspended sediment in streams. Suspended sediment is associated with negative effects on the spawning, growth, and reproduction of salmonids (e.g., Noggle 1978, Berg 1982, Lloyd et al. 1987, Reid 1998).

Effects on salmonids will differ based on their developmental stage. Suspended sediments may affect salmonids by altering their physiology, behavior, and habitat, all of which may lead to physiological stress and reduced survival rates. A sizable body of data has been gathered in North America focusing on the relationship between turbidity, total suspended sediments, and salmonid health.

Recent listings of salmonids under the Endangered Species Act (ESA) and the desire to protect and restore declining stocks have increased interest in the relationship between the release of fine sediment and salmonid productivity and survival. The purpose of this report is to provide an analysis of the current state of the science regarding the relationship between turbidity levels and the survival, reproduction, and growth functions of salmonids. We will also examine research that measures the effect of total suspended sediment on the health of salmonids.

Transportation projects often include activities that may negatively affect water quality, via disturbance of instream sediments for bridge and culvert construction or stormwater runoff from transportation construction sites (E. Molash, pers. commun.). Road-related erosion may significantly increase chronic turbidity levels in streams (Reid 1998). Roading may also affect subsurface flows, affecting upwelling in the stream (Sedell et al. 1990). It should be noted that much of the research on the effects of roads on suspended sediment and turbidity has focused on unpaved forest roads.

Understanding the relationship between turbidity measurements, suspended sediments, and their effects on salmonids at various life stages will assist agencies implementing transportation projects to devise techniques to reduce temporary and chronic erosion and sedimentation associated with these activities. Methods such as soil covers, project staging, land clearing windows, and water treatment systems could be implemented to prevent occurrence of critical turbidity levels (E. Molash, pers. commun.).

## II. Definitions

### Measurements

There are three primary ways in which sediment in the water column is measured: turbidity, total suspended solids, and water clarity. Although these three metrics measure different aspects of suspended sediments, they are often incorrectly used in research papers (A. Steel, pers. commun.). While these measures are frequently correlated with one another, the strength of correlation may vary widely between samples from different monitoring sites and between different watersheds (Duchrow and Everhart 1971, A. Steel, pers. commun.). For example, parent material in a basin, weathering rate, texture of sediment and soils produced through weathering and erodibility all have a great influence on the amount, texture, and behavior of fine sediments in streams (Everest et al. 1987).

**Turbidity** is an optical property of water where suspended and dissolved materials such as silt, clay, finely divided organic and inorganic matter, chemicals, plankton, and other microscopic organisms cause light to be scattered rather than transmitted in straight lines. Measurements of turbidity have been developed to quickly estimate the amount of sediment within a sample of water and to describe the effect of suspended solids blocking the transmission of light through a body of water (Lloyd 1987).

Turbidity is usually measured by nephelometry – the relative measurement of light scattering through a restricted range of angles to the incident light beam. Typically, nephelometers detect light scattered by a water sample usually at 90° to the incident beam. Nephelometric turbidity units (NTUs) are used as a rough index of the fine suspended sediment content of the water (Davies-Colley and Smith 2000). In the past, turbidity was measured using Jackson Turbidity Units (JTUs). The Jackson Candle Turbidimeter was limited in that it could not measure turbidities lower than 25 JTU and was dependent on human judgment (Web Site Ref. #3). At high turbidities, JTUs and NTUs are roughly equivalent (Lloyd 1987). Please note that JTUs are only used in this report in tables culled from previous literature reviews.

**Total Suspended Solids (TSS)** represents the actual measure of mineral and organic particles transported in the water column. TSS is an important measure of erosion, and is linked to transport of nutrients, metals, and industrial and agricultural chemicals through river systems. Suspended sediment consists primarily of silt and clay-size particles that may be rapidly transported downstream and locally deposited on floodplains and overbank storage locations or may infiltrate into gravel interstices of the bed (Everest et al. 1987). Note that in older literature, TSS may also be referred to as suspended sediment concentration (SSC). This term will be used in the literature review where appropriate. Fluctuating TSS levels may influence aquatic life from fish to phytoplankton. Fine particles may carry substances that are harmful or toxic to aquatic life.

TSS is determined by measuring the residue in a well-mixed sample of water which will not pass a standard (glass fiber) filter. The residue trapped on the filter is dried (103-105 °C) and reported in units of weight per volume (typically mg/l) (Sorenson et al. 1977).

**Water clarity**, a direct measure of visible distance through water is another important measure related to the presence of sediment in the water column. Visual water clarity describes the distance that an organism can see underwater. Water clarity is affected by suspended and dissolved materials (Davies-Colley and Smith 2000). Correlations between visual water clarity and turbidity (NTU) or TSS may vary dramatically between watersheds.

Changes in water clarity alter the balance between predators and prey and may have a strong effect on individual behaviors (A. Steel, pers. commun.). Historically, water clarity has been measured with a Secchi disk, a black and white disk submerged vertically into the water until it can no longer be seen (Davies-Colley and Smith 2000).

Three water quality tests are related to sedimentation in streams:

| **Turbidity** | **Total Suspended Solids** | **Water Clarity** |
|---|---|---|
| Measure of the refractory characteristics of material in the water. Not always correlated with total suspended solids | Actual measure of the amount of sediment suspended in the water column | Measure of visual distance in the water column |

**Limitations of Using Turbidity as a Measurement**

The widespread use of turbidity as a water quality standard and indicator of suspended solid concentration can, at least in part, be attributed to the ease and cost of using a nephelometric turbidity meter in the field (Davis-Colley and Smith 2000) in comparison to the direct measurement of suspended solids. Duchrow and Everhart (1971) noted that direct measurement of settleable solids is difficult and time consuming.

Turbidity cannot always be correlated with suspended solid concentrations due to the effects of size, shape, and refractive index of particles (Sorenson et al. 1977). Duchrow and Everhart (1971) noted that turbidity measurements are primarily useful if: 1) a major portion of the total turbidity is contributed by settleable solids; 2) a relationship exists between turbidity readings and weight per unit of volume of suspended sediment and; 3) if a reliable meter is available.

Duchrow and Everhart (1971) tested different materials to determine if similar turbidity readings were obtained at the same concentration. At higher turbidity readings, they found a poor correlation between readings and suspended sediment concentrations (SSC) for all materials tested. Duchrow and Everhart (1971) questioned the use of turbidity as a parameter for establishing water quality standards, as too many factors must remain constant before a turbidity measurement can be converted to a corresponding SSC.

The relationship between turbidity and SSC may also change along a downstream gradient from a sediment source. Larger particles, which generally produce less turbidity per unit concentration than smaller particles, gradually settle out, thus shifting the turbidity versus SSC relationship to a higher NTU per unit SSC in reaches progressively farther down stream (Lloyd 1987).

Davies-Colley and Smith (2000) have suggested that water clarity is a more useful measure for determining the effect of suspended solids. These researchers suggest that turbidity is only a relative measurement that has no environmental relevance in itself, unless calibrated to clarity or some other absolute optical quantity or to suspended sediment mass concentration, at each site of interest.

This research implies that turbidity may not be a reliable tool for determining the effects of suspended solids on salmonids. The inconsistent correlation between turbidity measurements and mass of suspended solids, as well as the difficulty in achieving repeatability using turbidimeters contributes to concerns regarding this technique.

**Turbidity Meters**

The consistency of turbidimeters is an issue of concern. Duchrow and Everhart (1971) tested three different turbidimeters and found that there was a highly significant difference between readings on the same sample of suspended sediment. Further examination revealed increasing variance between readings with an increase in turbidity. Highly significant differences were also present between readings obtained on the seven materials for each meter. Recent studies in King County also noted problems with reliability and consistency of turbidimeters (D. Booth, pers. commun.).

**Summary**

Turbidity, TSS and water clarity are three common measures used to determine the effect of suspended sediment on salmonids. Turbidity is currently in widespread use by resource managers, partially due to the ease of taking turbidity measurements. In addition, current state regulations addressing suspended sediment are usually NTU-based. The disadvantage of turbidity is that it is only an indicator of suspended sediment effects, rather than a direct measure, and may not accurately reflect the effect on salmonids.

Other factors, such as life stage, time of year, size and angularity of sediment, availability of off-channel and tributary habitat, and composition of sediment may be more telling in determining the effect of sediment on salmonids in Northwestern rivers. In addition, many watersheds have been affected by land use that alters sediment input and transport, and therefore do not provide accurate baseline conditions. Unaltered systems display wide ranges of turbidity over space and time, and therefore long-term data are needed to understand baseline conditions.

## III. Natural Background Levels of Turbidity in the Pacific Northwest

Determining natural background levels of turbidity is a difficult endeavor. Turbidity measures may be affected by 1) differing physical processes between watersheds; 2) legacy issues (activities historically conducted in the watershed); and 3) problems with instrumentation and repeatability of turbidity measurements (as mentioned in the previous section).

Turbidity can vary between watersheds, based on the geology of each particular basin. For example, systems fed by glacial meltwater often have higher turbidities than other systems (Lloyd et al. 1987). In addition, tributaries and stream segments within the same system may have widely divergent background turbidities. Headwater streams tend to be less turbid then mainstems or estuaries – faster flowing water transports suspended sediment downstream quickly. The patchiness of turbidity, both spatially and temporally, influences how salmonids use a river system in various life stages (Sedell et al. 1990).

In Northwestern watersheds, natural background turbidity varies on a seasonal basis depending on when precipitation and runoff occur (higher in spring in the Fraser River, Servizi and Martens 1987) and depends on the hydrologic regime (lowland Washington streams typically see higher turbidity in fall and winter; **Appendix A)**. Increased rainfall and storm events usually produce an increase in erosion and transport of sediments deposited in streams. Monitoring at specific sites throughout a watershed would allow managers to understand the range of change that occurs at a particular site and across the watershed. Methods of monitoring turbidity vary in quality and convenience and their effectiveness changes with stream size (E. Ritzenthaler, pers. commun.).

The State of Washington's 1999 Water Quality Data Report provides water quality data points for a number of Washington state creeks and rivers, including turbidity measurements (Web Site Ref. #11). Twelve measures were taken between the end of 1998 and September of 1999. Monthly values for turbidity from this report for four sites (two on the Stilliguamish, one on the Skagit, one on the Samish) are in **Appendix A**. Note the fluctuation in turbidity at some of these monitoring stations over a twelve month period. In order to determine "natural background turbidity," continuous measurements would be necessary over time and across space. Historical and current changes to the system affecting sediment input and processes, load, and transport must also be understood. This data set does not provide enough context to determine "natural background turbidity." In addition to state water quality data, a sample of data collected by King County METRO is included in **Appendix A**. Three rivers were sampled in 1988-1999 to determine where turbidity and total suspended solids were of concern.

Without continuous monitoring throughout a basin, turbidity data only provides a series of scattered data points that are not linked to temporal or spatial parameters of the watershed. Without this context, it is difficult to make a determination regarding how turbidity levels are affecting the system. This problem is inherent in the collection of water quality data and development of water quality criteria.

**Summary**

In order to develop "natural" background turbidities, a stratified sample allowing one to differentiate between different physical and biological processes affecting watersheds is necessary. Continuous sampling across these systems may also provide information on how salmonids persist within highly variable systems. The historical legacy of systems is also an important and necessary factor to consider in evaluating this information.

## IV. Effects of Turbidity and Suspended Solids on Salmonids

Sedimentation derived from land use activities is recognized as a primary cause of habitat degradation in the range of west coast chinook, steelhead, cutthroat, and bull trout (USFWS 1998, Web Site Ref. #6). Land-use practices, through alteration of vegetation, hydrology and soil structure can alter the delivery of fine and coarse sediments to streams, thus affecting salmonid habitats. Sediment delivery rates and composition are controled by topography, climate, geology, hydrology, and vegetation (Spence et al. 1996).

The alteration of upslope hydrological and erosional processes with associated changes in instream hydrological, erosional, and depositional processes has resulted in a reduction in channel depth and increased fine and course sediment load. Logging, grazing, irrigation, stream channelization, chemical and nutrient applications, mining, agriculture, road construction, dam development and operation, and urban and rural development have played a role in altering upslope and instream physical and biological processes (Berman 1998).

**Range of Effects on Salmonids**

A range of studies have illustrated the effect of turbidity levels beyond natural background on the physiology and behavior of salmonids (Lloyd 1987, Everest et al. 1987, Newcombe and MacDonald 1991, Gregory and Northcote 1993). Lloyd (1987) suggested that high levels of suspended solids may be fatal to salmonids, while lower levels of suspended solids and turbidity may cause chronic sublethal effects such as loss or reduction of foraging capability, reduced growth, resistance to disease, increased stress, and interference with cues necessary for orientation in homing and migration.

Salmonid populations not normally exposed to high levels of natural turbidity or exposed to anthropogenic sediment sources may be deleteriously affected by levels of turbidity considered to be relatively low (18-70 NTU) (Gregory 1992). Low levels of turbidity appear to correspond to sediment concentrations that may adversely affect coldwater salmonids (Lloyd 1987).

Newcombe and MacDonald (1991) grouped effects of sediment on salmonids into three categories: lethal, sublethal and behavioral.

- ***Lethal effects*** kill individual fish, cause overall population reductions, and damage the capacity of the system to produce future populations. This category includes reductions caused by sublethal or behavioral effects.
- ***Sublethal effects*** relate to tissue injury or alteration of the physiology of an organism. Effects are chronic in nature and while not leading to immediate death, may produce mortalities and population decline over time.
- ***Behavioral effects*** are described by any effect that results in a change of activity usually associated with an organism in an undisturbed environment. These changes may lead to immediate death or population decline or mortality over time.

It is apparent that salmonids have the ability to cope with some level of turbidity at certain life stages (Gregory and Northcote 1993). Evidence of this is illustrated by the presence of juvenile salmonids in turbid estuaries prior to leaving for the ocean and in local streams characterized by high natural levels of glacial silt, and therefore high turbidity and low visibility (Gregory and Northcote 1993).

**Table 1. Effects of turbidity on salmonids**

| Physiological | Behavioral | Habitat |
|---|---|---|
| gill trauma | avoidance | reduction in spawning habitat |
| osmoregulation | territoriality | effect on hyporheic upwelling |
| blood chemistry | foraging and predation | reduction in BI habitat |
| reproduction and growth | homing and migration | damage to redds |

## Cumulative Effects

Ecological setting, landscape and evolutionary processes, and the physiological and behavioral response to sediment regime alteration are each important and contribute to our understanding of species response to turbidity. Therefore, it is important to examine a system as opposed to single effects or sites – without ecosystem based options for salmonids, species flexibility is diminished in responding to variable sediment loading (Berman 1998).

Anthropogenic disturbances often differ from natural disturbances in magnitude, frequency, and duration of events. Cumulatively, anthropogenic disturbances may decrease system heterogeneity, as well as connectivity. This reduces refuge options available to species during disturbance events. Altered levels of turbidity are just one of many conditions that may have a cumulative effect on the health and survival of salmon stocks.

While many laboratory studies have been performed to determine the effect of sediments on salmonids, the cumulative effect on salmonids is difficult to capture. Many of the effects on salmon are synergistic in nature; one effect can lead to a host of other effects that may affect the growth, reproduction, and survival of the fish. The following factors mediate effects of sediment on salmonids.

**Environmental Factors Affecting the Effect of Sediment on Salmonids**

Duration of exposure
Frequency of exposure
Toxicity
Temperature
Life stage of fish
Angularity of particle
Size of particle
Type of particle
Severity/magnitude of pulse
Natural background turbidity of area (e.g. watershed position, legacy)
Time of occurrence
Other stressors and general condition of biota
Availability of and access to refugia

Salmonid response (often measured in terms of physical stress) is dependent on environmental factors such as duration of exposure and temperature (Servizi and Martens 1992). Rogers (1969) suggested that the variability in tolerance to suspended sediment could be explained by sediment particle characteristics, water temperature, species differences and other stressors that might have synergistic effects.

An example of a synergistic effect of sediment can be illustrated by examining the avoidance response of salmonids to turbid water. Life history stages and populations sensitive to sediment loads may be forced to move to other areas of the system to avoid negative effects on survival. These "turbidity refugia" must be available and accessible.

Stream reach or segment emigration is a bioenergetic demand that may affect the growth or reproductive success of the individual.

To illustrate seasonal and population differences, an example from the Western Olympic Peninsula is provided. H. Michael (pers. commun.) suggested that fish respond differentially to TSS in summer and winter. He noted that protective mucous secretions are inadequate during summer months and thereby expose individuals to increased risks. There are also salmonid populations that thrive in glacially turbid streams. However, biological and physical mechanisms related to these systems are unclear. Finally, "turbidity refugia" such as tributaries, sloughs, off-channel habitat, and lakes are important during different parts of the year. Organismic response to variables such as TSS require further understanding and evaluation.

**Reduction in Buffering Capacity**

The overall buffering capacity of a system may be reduced by frequent sediment loading. Salmonids are known to use refugia in a river system to escape negative water quality conditions, such as high temperatures (Berman and Quinn 1991). For example, bull trout seek out side channels in the winter during high flow periods for protection (USFWS 1998). Sediment may also cover intergravel crevices fish use for shelter (Waters 1995). In laboratory experiments, it has been shown that salmonids will move to less turbid waters, if available, after a short-term pulse (Berg and Northcote 1985). Bisson and Bilby (1982) illustrated the displacement of salmonids in water with turbidities greater than 70 NTU. These results suggest that salmonids in a river system might seek out turbidity refugia when subjected to short-term pulses of sediment.

Loss of acceptable habitat and refugia as well as decreased connectivity between habitat reduces the carrying capacity of streams for salmonids. In systems lacking adequate number, distribution, and connectivity of refugia, fish may travel longer distances or to less desirable habitat and may encounter a variety of other conditions including increased bioenergetic demands.

Reid (1998) summed up the cumulative effect created by turbidity upon salmonids in a disturbed system:

> "Salmonid strategies for coping with high turbidity are likely to include use of off-channel, clean-water refugia and temporary holding at clean-water tributary mouths. These coping strategies are partially defeated by the spatial distribution of roads: road runoff discharges into low-order channels that once would have provided clean inflows, and riparian roads restrict access to flood-plain and off-channel refugia. The temporal distribution of the high-turbidity inflows also decreases the effectiveness of coping strategies: turbidities are high even during low-magnitude events when flows may not be sufficient to allow access to refugia. The combined influences of increased turbidity and restricted opportunities for escape from the effect constitute a cumulative effect. Further, traffic-related turbidity is highest during the day, when salmonids feed, and traffic produces high turbidity even during small and moderate storm flows of autumn and spring, when water is warmer than during winter floods. Because salmonid metabolic rates are temperature-dependent, salmonids may be particularly sensitive to these unseasonable bouts of high turbidity."

In consideration of the effect of increased turbidities upon salmonids, the current state of available habitat and refugia must be examined. Can a watershed, given past management practices, provide the protection needed to salmonids at various life stages if additional sediment pulses are released?

It is also important to note in reviewing the following section that much of the research undertaken to examine turbidity effects on salmonids was performed in laboratories, where control turbidities do not necessarily reflect field conditions, such as prey quantities and other potential synergistic effects.

**Research Summary**

The purpose of this section is to review recent research regarding the effect of turbidity and suspended sediments on salmonids. The research is summarized in three sections:

A. **Physiological effects**
B. **Behavioral effects**
C. **Habitat effects**

**Physiological effects** cover stressors to the physical health of salmonids attributed to the presence of high turbidity or high levels of suspended solids. Some indicators of stress to salmonids that have been studied include gill trauma, blood sugar levels, and osmoregulatory function.

**Behavioral effects** cover changes in activity attributed to increased sediment in the water column. Behavioral effects reviewed here include avoidance, changes in foraging ability, responses to predation risk, and reduced territoriality.

**Habitat effects** cover changes to spawning and rearing habitat of salmonids.

### Note on Turbidity and Sediment Studies

Most laboratory studies examine the effect of sediment on salmonids in a controlled environment, where individual variables are tested. Everest et al. (1987) note that there are significant difficulties in extrapolating laboratory findings to the field. Many laboratory survival studies use simplified unnatural gravel mixtures to test incubation and emergence of salmonid fry. Other factors that may affect results include disease organism presence, temperature, and prey availability.

The authors note that factors in streams, such as structural roughness and spawning behavior of females complicate field application of laboratory studies. Studies dealing with effects of sediment from forest management in natural environments have been less conclusive, as increased fine sediment from forest management is almost always accompanied by other environmental effects (Everest et al. 1987).

In general, studies focusing on physiological effects (gill trauma, blood chemistry, osmoregulation, and reproduction and growth) were conducted in a laboratory environment. Research on behavioral effects included both laboratory and field studies. Studies related to avoidance, territoriality, foraging and predation were primarily performed in artificial holding tanks. Field studies, however, were conducted in projects focused on abundance and diversity of prey, primary production, and homing and migration. Research related to the effect of sediment inputs on habitat were primarily performed in the field.

### A. Physiological Effects

Turbidity is associated with a number of physiological effects in Pacific salmon (Berg 1982). Researchers have used several physiological indicators to determine the effect of incremental increases of suspended sediment on salmonids. The outcome of a stress response is dependent on synergistic factors such as duration of exposure, frequency, magnitude, temperature, and other environmental variables (Servizi and Martens 1992). Some physiological indicators used by researchers include gill trauma (Berg 1982; Berg and Northcote 1985), increased levels of blood glucose, plasma glucose, plasma cortisol, and osmoregulatory ability (Redding et al. 1987; Servizi and Martens 1987). The stress response itself may compromise the organism's immune system (increasing disease susceptibility) thereby affecting mortality rates (USFWS 1998).

Among salmonids, some species may be more sensitive to suspended sediment than others, and the sensitivity of the egg and juvenile stages of most species seemingly exceed that of adults (Lloyd 1987). Owing to their extended fresh water residency, juvenile chinook, coho, and steelhead may be more sensitive to increases in suspended sediment (Noggle 1978), as opposed to pinks and chum, which spend very little time in streams after hatching.

***Gill Trauma***

The presence of suspended sediments in the water column has been shown to produce gill trauma in sockeye underyearlings (Servizi and Martens 1987), gill flaring in response to short term sediment pulses (Berg 1982; Berg and Northcote 1985), and increased coughing frequency (Servizi and Martens 1992).

Fish gills are delicate and easily damaged by abrasive silt particles. As sediment begins to accumulate in the filaments, fish excessively open and close their gills to expunge the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over gills and interfere with fish respiration (Berg 1982).

Laboratory Studies

Servizi and Martens (1987) found that the lethality of Fraser River sediments on underyearling sockeye salmon (*Oncorhynchus nerka*) increased with increasing particle size. Fines (0-740 µm) lodged in gills and caused gill trauma at 3,148 mg/l or 0.2 of the 96 h LC50 value. This value is consistent with normal levels of suspended solids measured at Hell's Gate on the Fraser River. Particle size and shape may also affect the degree of damage to the gills (Servizi and Martens 1992). The LC50 decreased as particle size increased, for particles described as angular to subangular, in their work with

Fraser River sediments. Sockeye exposed to volcanic ash by Newcomb and Flagg (1983) experienced greater mortality at lower concentrations, indicating that the combination of slightly larger, more angular particles in volcanic ash may cause higher mortality.

Cough frequency is a sublethal effect that impairs the respiratory ability of salmonids. Servizi and Martens (1992) examined the effect of sublethal concentrations of Fraser River suspended sediments on underyearling coho salmon. Cough frequency was elevated eightfold over control levels at 240 mg/l (turbidity of 30 NTUs). Berg (1982) examined the effect of a short-term sediment pulse (initially 3 days at 60 NTU, then a reduction on the seventh day to 10 NTU) on coughing frequency of juvenile coho. In two of four tests, coughing rates increased significantly when turbidity was raised to 60 NTU. As turbidity declined to 10 NTU, coughing declined or remained at pretreatment levels. Noggle (1978), upon histological examination, found suspended sediments damaged gill structures. Berg and Northcote (1985) reported increases in gill flaring after a short-term sediment pulse, reaching 60 NTU. Flaring continued as turbidity dropped to 30 and 20 NTU.

***Blood Physiology***

Measures of elevated blood sugars (Servizi and Martens 1992), plasma glucose (Servizi and Martens 1987), and plasma cortisol have all been used as indicators of stress in fishes. Physiological stress in fishes may decrease immunological competence, growth, and reproductive success.

Laboratory Studies

Servizi and Martens (1987) identified increases in plasma glucose in juvenile sockeye salmon exposed to fine sediment. Plasma glucose levels of adult sockeye increased 150 and 39% as a result of exposures to 1,500 and 500 mg/l respectively of fine sediment. Servizi and Martens (1992) noted elevated blood sugar levels in underyearling coho salmon exposed to sublethal concentrations of Fraser River suspended sediments.

Redding et al. (1987) exposed yearling coho salmon and steelhead to high (2,000-3,000 mg/l) or low (400-600 mg/l) concentrations of volcanic ash, topsoil and kaolin clay for 7-8 days. Plasma cortisol levels were elevated in both species after exposure to high levels of topsoil. Yearling steelhead exposed to high or low concentrations for 2 days also showed elevated plasma cortisol levels.

A change in blood physiology is an indicator that a fish is experiencing some level of stress. At the individual fish level, stress may affect physiological systems, reduce growth, increase disease incidence, and reduce ability to tolerate additional stressors. At the population level, the effects of stress may include reduced spawning success, increased larval mortality, reduced recruitment to succeeding life stages and overall population declines. Stress to salmonids can affect the parr-smolt transformation, resulting in impaired migratory behavior, decreased osmoregulatory competence, and reduced early marine survival (Wedemeyer and McLeay 1981).

***Osmoregulation***

Laboratory Studies

The process of smolt transformation is critical to successful transfer of juvenile salmonids from fresh to marine waters. Disruptions of this process lead to osmotic imbalances and produce sublethal effects and eventual mortality (Redding et al. 1987). During the smolt transformation process, there appears to be an increased sensitivity to total suspended solids. Noggle (1978) conducted studies to assess the effects of suspended sediment upon juvenile salmonids in the stream environment. Results indicated seasonal changes in tolerance of salmonids to suspended sediment. Bioassays conducted in summer produced LC50's less than 1,500 mg/l, while autumn bioassays showed LC50's in excess of 30,000 mg/l. Spring/summer bioassays were coincidental to smolt transformation periods. Sockeye smolts suffered a slight impairment in hypoosmoregulatory capacity when exposed 96 h to 14,407 mg/l of fine sediment (Servizi and Martens 1987).

***Reproduction and Growth***

Salmonids require gravels that have low concentrations of fine sediments for successful spawning and incubation (Spence et al. 1996). Chronic turbidity during emergence and rearing of young anadromous salmonids could affect the quantity and quality of fish produced (Sigler et al. 1984). Organic matter entering substrate interstices depletes oxygen and reduces dissolved oxygen concentrations, harming eggs (Spence et al. 1996).

Settleable solids may prevent eggs from receiving necessary oxygen and inhibit removal of waste products within the redd and may create a physical barrier to fry emergence. The greater the proportion of fine sediments in redds, the greater likelihood that fry hatching from normally developed embryos will be entrapped and unable to emerge (Everest et al. 1987). Eggs, larvae, and fingerling fish are generally more susceptible to stress by dissolved or suspended solids than are adult fish. Intrusion of fines may occur initially in the upper 10 cm of the streambed gravels (Beschta and Jackson 1979). The intrusion or infiltration of fines into streambed gravels can thus alter the quality of the bed for spawning by fish or for use by other instream biota (Everest et al. 1987).

Sediments may also alter hyporheic inputs thereby reducing the availability of upwelling areas and potentially decreasing egg to fry survival. Transportation projects may affect these zones both by contribution of sediment and interception of sub-surface flow by road networks (Sedell et al. 1990, Poole and Berman 2001).

Intragravel water flow (Vaux 1962; Cooper 1965) and availability of dissolved oxygen for developing embryos (Cooper 1965; Daykin 1965) is key to egg survival. Low dissolved oxygen can cause direct mortality or delay development of alevins (Shumway et al. 1964; Brannon 1965). Delayed emergence may lead to smaller fry that are less able to compete for environmental resources than their larger cohorts that have undergone normal development and emergence (from Everest et al. 1987). Small size may also affect migration timing and marine survival (Holtby 1988; Holtby et al. 1989).

Researchers have found an inverse relationship between fines (% sediment < 3 mm) and fry survival (Bjornn 1968; Phillips et al. 1975, Everest et al. 1987) with decreases in survival ranging up to 3.4% for each 1% increase in fine sediment < 0.850mm (Cederholm et al. 1981).

Laboratory Studies

Sigler et al. (1984) identified a significant difference in growth rates between steelhead and coho in clear versus turbid water. As little as 25 NTUs of turbidity caused a reduction in fish growth. The implication of this finding is that fish subjected to turbidity in this experiment might experience increased probability of mortality in comparison to those fish experiencing normal growth (Sigler et al. 1984).

Shelton and Pollock (1966) demonstrated that low survival of chinook eggs in an incubation channel occurred when 15 to 30% of voids in the gravel bed were filled with sediment. Crouse et al. (1981) used Substrate Score, a visual technique for evaluating stream substrate quality to determine the effect of sediment on juvenile coho salmon production. The authors found that production of juvenile coho salmon was inversely related to quantities of fine sediment. Significant decreases in fish production occurred in streams with 80% and 100% embeddedness where fine sediments (<2.0 mm) were 26 and 31% by volume of the total substrate.

Sediments less than 0.850 mm diameter were inversely correlated with survival of coho salmon in artificial streams. Coho salmon eggs in landslide affected gravels in the East Fork Miller Creek survived only 40% as well to hatching when compared to the control group and survived only 9% as well to the button-up stage of development (Cederholm and Salo 1979).

**B. Behavioral Effects**

A number of research efforts have focused on the effect of turbidity levels on salmonid behavior. Behaviors examined by researchers include avoidance, territoriality, and foraging.

***Avoidance***

In many cases, salmonids avoid turbid water. In these instances, fish must successfully emigrate to areas of lower TSS. Factors affecting emigration may include availability and connectivity of patches with lower turbidity as well as the developmental stage of the fish (Sedell et al. 1990).

<u>Laboratory Studies</u>

Sigler et al. (1984) conducted tests to determine the point at which juvenile steelhead and coho subjected to continuous clay turbidities would emigrate from an area. Tested turbidities ranged from 57 to 265 NTUs. In tanks with mean turbidities of 167 NTUs or higher, no fish were found. Fish were found in tanks with lower turbidities (57 and 77 NTUs) at numbers near carrying capacity.

Newly emerged fry appear to be more susceptible to even moderate turbidities than are older fish. Turbidities in the 25-50 NTU range (equivalent to 125-175 mg/l of bentonite clay) reduced growth and caused more young coho salmon and steelhead to emigrate from laboratory streams than did clear water (Sigler et al. 1984). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities (Lloyd et al. 1987), except when the fish have to traverse them along migration routes.

A mean avoidance of 25% was discovered for juvenile coho exposed to a 7,000 mg/l level of suspended sediment (Servizi and Martens 1992). The authors estimated that the threshold for avoidance by juvenile coho in the vertical plane was 37 NTU.

Berg (1982) found that juvenile coho exposed to a short-term pulse of 60 NTU left the water column and congregated at the bottom of an experimental tank. When the turbidity was reduced to 20 NTU, the fish returned to the water column. Bisson and Bilby (1982) subjected juvenile coho to experimentally elevated concentrations of suspended sediment. In their work, juveniles did not avoid moderate increases in turbidity when background levels were low. Significant avoidance, however, was observed at a level of 70 NTU.

Field Studies

In a study related to deposition of Mt. St. Helens ash in the Columbia River Basin, McCabe et al. (1981) noted a severe decline in the catch of juvenile chinook in upper reaches with highest ash deposition.

In addition to avoidance behavior by juveniles, suspended sediment may affect the reproductive success of returning adults. Physiological, bioenergetic and behavioral alterations stemming from increased suspended sediment loads (such as a delay in return to spawning habitat) may affect egg quality or quantity and subsequent egg development. Previous research on sublethal temperature exposure of adult chinook has illustrated this point (Berman and Quinn 1991). We hypothesize that elevated TSS may lead to similar results.

***Territoriality***

Laboratory Studies

The presence of turbid water appears to disturb normal social behavior and alter the nature of aggressive interactions. It has been suggested that the loss of territoriality and the breakdown of social structure can lead to secondary effects. Juvenile coho rearing in streams affected by frequent short-term sediment pulses with concomitant loss of territoriality may experience a decrease in growth and feeding rates, which may affect overall mortality (Berg 1982).

Juvenile coho exposed to short-term sediment pulses exhibited altered territory structure and altered feeding behavior (Berg and Northcote 1985). Normally, a dominant fish positioned upstream would consume the majority of the prey. During turbid phases, territories broke down, and subordinate fish captured a greater proportion of the prey. This was most evident at 30 and 60 NTU.

Subsequent to a sediment pulse, a breakdown in social organization among juvenile coho in an artificial stream occurred (Berg, 1982). Territoriality appeared to cease during a short-term sediment pulse, possibly due to the inability of the fish to see the positions of their neighbors. Territory was reestablished when turbidity decreased to 20 NTU. Lateral displays, a territorial action performed by salmonids, were limited under the experimental conditions. Experiments conducted by Noggle (1978) within a turbid artificial stream and clear tributary illustrated avoidance by fish of their established territories.

***Foraging and Predation***

Turbidity appears to affect a number of factors related to feeding for salmonids, including feeding rates, reaction distance, prey selection, and prey abundance. Changes in feeding behavior are primarily related to the reduction in visibility that occurs in turbid water. Effects on feeding ability are important as salmonids must meet energy demands to compete with other fishes for resources and to avoid predators. Turbidity may lead to a reduction in foraging rates, which has been linked to a decrease in growth and health of fishes (Gardner 1981).

The literature presents two major themes on the effect of turbidity on foraging. Many studies indicate that as visual feeders, the effectiveness of salmonids in obtaining food is reduced by turbidity at levels as low as 20 NTU (Berg 1982). Other research indicates that some species of salmonids (juvenile coho, steelhead, and chinook) appear to prefer slightly to moderately turbid water for foraging, as reported in studies by Sigler et al. (1984) and Gregory (1988). This behavior may represent a trade-off between predation risk and bioenergetic demand and benefits of increased growth. While ability to forage in turbid water may be reduced, the reduction in predation risk may make it worthwhile to operate in partially turbid areas (Gregory and Northcote 1993).

Suspended particulate material reduces the underwater visual range of fish, which may either act as a protective cover from predators or reduce the ability of these species to detect predators (Gregory and Levings 1996). Reduced visual clarity of waters may greatly affect the behavior of visual predators, notably fishes and piscivorous birds (Davies-Colley and Smith 2000). The reaction of salmonids to these factors is variable, as shown by the results reviewed below.

Laboratory Studies

Berg (1982) showed a decrease in feeding ability by juvenile coho in response to short-term pulses of suspended sediment in a laboratory environment. At 0 NTU, 100% of the prey items offered to the fish were consumed, whereas at 60 NTU, only 35% of introduced prey were consumed. At a turbidity level of 10 NTU, fish were noted to frequently misstrike prey items. A significant delay in the response of fish to introduced prey was noted at turbidities of 20 and 60 NTU. The acquisition of food resources in turbid waters may be reduced due to the effects of turbidity on behavior and vision. As coho are visual feeders relying on drift, reduction in feeding ability may lead to depressed growth rates (Berg 1982). Reid (1998) reported that published data suggest that feeding efficiency of juvenile coho salmon drops by 45% at a turbidity of 100 NTU. Additionally, prey behavior is also altered by TSS.

Berg and Northcote (1985) showed a reduction in reaction distance by juvenile coho to adult brine shrimp after a sediment pulse (60-20 NTU) was introduced. Prey acquisition increased as the pulse dropped from 60 NTU to 20 NTU, but remained below levels occurring prior to the pulse. The authors suggested that feeding affects were primarily the result of loss of vision. Ingestion rates decreased to below 50% at higher turbidities (30 and 60 NTU).

Gregory and Northcote (1993) assessed the effects of turbidity on the foraging behavior of juvenile chinook in the laboratory. The reaction distance of the fish to planktonic adult *Artemia* prey was measured by examining the visual ability of the subjects. The foraging rate by juvenile salmonids for surface, planktonic and benthic prey was measured across a range of turbidity levels (<1, 18, 35, 70, 150, 370, 810 NTU). For all three prey types, foraging was reduced at higher turbidities. Foraging rates for surface and benthic prey were also reduced in clear water, with highest foraging rates attained at 35-150 NTU. The authors suggested that the increased feeding rate in turbid conditions may reflect reduced risk from predators.

Gregory (1992) noted that preference for foraging in moderate turbidity appeared to be size dependent, as smaller individuals exhibited greater foraging rates in clear waters. The author suggested that it may be to the advantage of an individual to grow quickly to sizes where it is less vulnerable to predation, even if it may temporarily expose itself to greater risk by foraging in clear water.

Redding et al. (1987) observed reduced feeding rates among yearling coho and steelhead exposed to 2,000-4,000 mg/l of topsoil, kaolin clay and volcanic ash. Less food was found in the stomachs of yearling fish exposed to high concentrations of suspended topsoil, suggesting suspended solids might inhibit feeding. The authors suggested that inhibition may result from a loss of vision in turbid water or may be an indirect consequence of stress.

Boehlert and Morgan (1985) studied the effects of turbidity on feeding abilities of larval Pacific herring. Maximum feeding incidence and intensity occurred at 500 or 1,000 mg/l. Feeding was reduced at concentrations higher than 1,000 mg/l. The authors hypothesized that suspension of sediment may enhance feeding for the larvae by providing visual contrast of prey items.

Gardner (1981) showed reduced feeding rates for bluegills in turbid waters. Feeding rates in a 3 minute period declined from 14 prey per minute in clear water to 11, 10, and 7 per minute in pools of 60, 120, and 190 NTU. Gardner suggested that high (>50 NTU) levels of turbidity would reduce energy intake (through decreased feeding rates) thus reducing production of fish populations.

Vogel and Beauchamp (1999) quantified the reaction distance of adult lake trout (as predators) to rainbow trout and cutthroat as a function of light (0.17 – 261 1x; 1x is a measurement of light intensity measured with a light meter), prey size (55, 75, and 139 mm) and turbidity (0.09, 3.18, and 7.40 NTU). Reaction distances of adult lake trout to rainbow and cutthroat trout increased with increasing light (25 cm at .17 1x, to 100 cm at 17.8x). Reaction distance decreased as a decaying power function of turbidity. Vogel and Beauchamp (1999) used results to model prey detection capabilities of piscivores at varying depths and times of day in natural environments.

Gregory (1988) examined the foraging behavior of juvenile chinook in elevated turbidity in a series of laboratory experiments. Experiments determined the reaction distance to invertebrate prey, perceived risk to a model predator, and the foraging rate of chinook on benthic Tubifex worms, in turbid conditions ranging from 0 to 800 mg/l. Reaction distance and perceived risk declined inversely with turbidity. Foraging rates on Tubifex worms were highest at intermediate levels (50-200 mg/l) and lowest at 0.0 mg/l (control) and 800 mg/l. The results suggested a tradeoff between perceived risk to predation and the effects of reduced reaction distance.

Gregory (1993) illustrated this consideration with research simulating predation in both clear and turbid environments. In the absence of risk, fish occupied the bottom in clear conditions (<1 NTU). In turbid conditions (NTU = 23), fish were randomly distributed throughout the tank. In the presence of risk (bird and fish models to simulate predators), the juveniles occupied the deep parts of the tank regardless of turbidity. However, responses to simulated predation were less marked and of shorter duration in the turbid conditions. Each simulation elicited a similar response – a distinct rapid movement into deep water.

Gregory and Levings (1996) studied the effect of turbidity and artificial vegetation (as cover types) on the predation mortality of juvenile salmonids in concrete ponds. Adult coastal cutthroat trout were used as predators on juvenile chinook, chum, sockeye, and cutthroat trout. The daily predation rate was determined for each turbidity and vegetation treatment. In the presence of cover, daily predation rates were 10-75% lower. The effects of turbidity were not significant and not additive with the effects of vegetation – turbidity appeared to reduce the effectiveness of vegetation as cover for chinook and sockeye. The authors suggested that the two forms of cover affected predation risks by different mechanisms.

Ginetz and Larkin (1976) examined the predation of rainbow trout on migrant sockeye fry. Feeding rates were higher on fry at lesser turbidities and at lower stream velocities. The authors suggested that this information could be used to improve the timing of hatchery releases of fry.

***Abundance and Diversity of Prey***

The presence of fine sediment in the substrate affects the benthic community, especially those species living and feeding in the riverbottom. Effects on the benthic community may negatively affect salmonids, as they are an important food source for the fish. (Tebo 1955; Rosenberg and Wiens 1978; Cederholm and Salo 1979; Brzezinski and Holton 1983). Decreased prey abundance may affect growth rate, susceptibility to predation, competition, and susceptibility to disease.

As most experimental studies occur in a laboratory, prey abundance is controlled, usually providing more than adequate prey quantity for salmon present. In natural systems, salmonids may not be fed to satiation and stressor effects may therefore be different. It is difficult to ascertain systemic effects on both fish feeding and benthic health from these results.

Newcombe and MacDonald (1991) note that a change in sediment concentration can adversely affect secondary production by affecting algal growth, biomass, and species composition. Sediment can clog feeding structures, reducing efficiency and growth rates of filter feeders. Benthic macroinvertebrates living in the substrate are subject to scouring, which can damage respiratory organs and expose organisms to predation through dislodgement. High sediment levels and high flow rates can scour algae and reduce periphyton biomass.

Turbidity and siltation causes an overall reduction in the number of bottom organisms, which results in changes to community structure, density, and diversity. (Sorenson et al. 1977). Lloyd (1987) suggested that turbidity can account for the decrease in primary production in shallow interior Alaskan streams, and subsequent reductions in abundance of zooplankton and macroinvertebrates.

<u>Field Studies</u>

Tebo (1955) pointed to erosion and sedimentation produced by logging roads as a factor in the decrease of benthic macroinvertebrates in a river system in North Carolina. Two stations were used, above and below a logged watershed to determine effects of sedimentation on bottom fauna. At the lower station there were 7.3 organisms per square foot, in comparison to 25.5 organisms per square foot at the upper station.

Rosenberg and Wiens (1978) examined the responses of macroinvertebrates to sediment addition. Increased sediment led to an increased number of macrobenthos drifting in comparison with invertebrates in the control. Total drift was more than 3 times higher in August (sediment addition of 28.27 kg or 138,000 mg/m$^{-2}$) and more than 2 times higher in September (sediment addition of 35.88 kg or 153,000 mg/m$^{-2}$). No significant difference was found in standing crops of macrobenthos in the substrate in the control or sediment channels after sediment addition. The researchers suggested that future efforts focus on the quantitative response of macrobenthos to settled rather than suspended sediments. It was also suggested that highway and pipeline construction undertaken in watersheds of this region resulting in sediment addition be performed in the summer rather than spring or fall, providing discharge is adequate to transport added sediment.

Brzezinski and Holton (1983) examined the relationship between abundance of benthic taxa and the presence of ash in river sediments. The abundance was dependent on distribution of ash within the sediment column. When ash is the top sediment layer, amphipod abundance was zero. Amphipods were present if there were a distinct ash layer at depth (12,500 individuals/m$^2$) or if ash were mixed with sediment (13,300 individuals/m$^2$). The authors concluded that the ash affects the fauna through some physical effect, possibly related to fine grain size.

Gammon (1970) studied substrate types and their relation to benthic macroinvertebrate numbers. Moss, gravel and rubble were the most occupied substrates. Substrates with silt rated fairly low. Benthic populations residing below and above a limestone quarry which contributed approximately 40 mg/l suspended solids to the stream were examined. Suspended sediments above the quarry ranged from 13-52 mg/l, and from 21 – 250 mg/l below. Drift rates increased linearly with increasing suspended solids up to 160 mg/l. An increase of 40 mg/l suspended solids above normal resulted in a 25% increase in drift. A 90% increase in drift occurred at an increase of 80 mg/l suspended solids above normal.

***Microfauna***

The response of daphnia to suspensions of several types of solids was reviewed by EIFAC (1965). The following results were reported:

Daphnia – harmful levels of solids
Kaolinite - 102 ppm
Montmorillonite - 82 ppm
Charcoal - 82 ppm
Pond sediment – 1458 ppm

Reproduction rate increased for Daphnia at lower rates of suspended sediment.

Sorenson et al. (1977) assumed that as turbidity limits light penetration and hence aquatic algae and plant productivity, the grazing microfauna would also be limited. The abrasive action of suspended solids would also be expected to have an adverse effect on attached protozoans and micrometazoans (Sorenson et al. 1977).

Field Studies

McCabe et al. (1981) examined the effects of the deposition of Mt. St. Helens ash on demersal fish populations in the Columbia River estuary. The study revealed a change in diet habits and prey consumption by juvenile salmonids. Reduced feeding intensity and lower diet diversity reflected a reduction in *Corophium salmonis*, an amphipod frequently exploited by juvenile salmonids. The authors identified a reduced number of a normally highly used amphipod, *Corophium salmonis*.

McCabe and O'Brien (1983) determined that turbidity levels as low as 10 NTUs can cause significant declines in feeding rate, food assimilation, and reproductive potential of *Daphnia pulex*. Suspended sediment concentrations of 50-100 mg/l reduced algal carbon ingested by cladocerans to potential starvation levels. These zooplankton are an important food item for salmonid fishes.

***Primary Production***

Suspended material reduces the amount of light available to illuminate submerged objects and provide energy for plant photosynthesis. A change in light penetration through water may be expected to have far-reaching ramifications for whole aquatic ecosystems because of its influence on photosynthetic fixation of energy by aquatic plants (Davies-Colley and Smith 2000).

Major ecological parameters of suspended solids which affect photosynthesis include reduction in light penetration, abrasive action, and effects of adsorbed toxins. A reduction in light penetration may reduce primary producers, with the exception of those species that are planktonic or living on floating debris. Reduction of light may also alter oxygen relationships in surface waters. A decrease in oxygen production due to excess turbidity might be critical in some large streams (Sorenson et al. 1977). Related effects include decreased production of zooplankton and macroinvertebrates, decreased abundance and production of fish, reduced angler use and success, and decreased efficiency of some fish management techniques (Lloyd 1987).

Field Studies

A 5 NTU increase in turbidity in a clear-water lake may reduce the productive volume of that lake by about 80% and a 25 NTU increase in a clear-water stream 0.5 m deep may reduce plant production by approximately 50% (Lloyd et al. 1987). A 5 NTU increase in turbidity in a clear stream 0.5 m deep may reduce primary production by 13% or more, depending on stream depth.

Summary

The results discussed in this section indicate that TSS and turbidity have the potential to affect salmonids through alteration of prey composition and availability. TSS and turbidity appear to affect prey abundance, diversity, and behavior, in part by reducing habitat available to benthic macroinvertebrates. In addition, feeding efficiency of salmonids may be reduced, as salmon are visual predators and may not easily sight food in turbid waters. Finally, the results indicate that in some cases, a reduced level of predation risk may occur under turbid conditions.

***Homing and Migration***

Migrating salmonids avoid waters with high silt loads, or cease migration when such loads are unavoidable (Cordone and Kelley 1961). It is unknown to what degree the "bouquet" of each stream may be altered by the addition of exotic chemicals, trans-basin diversions, and increased suspended sediment levels (Bjornn and Reiser 1991).

Field Studies

High turbidity may delay migration, but turbidity alone does not seem to affect homing. Whitman et al. (1982) found that salmon preferred natal stream water without ash, but still recognized natal streams despite ash presence and attempted to ascend natal streams. Quinn and Fresh (1984) reported that the rate of straying of chinook to the Cowlitz River Hatchery was low and unaffected by the 1980 Mt. St. Helens eruption, but that many coho salmon in the Toutle River, the river most affected by the eruption, did stray to nearby streams in 1980 and 1981.

Adult chinook males showed an avoidance response to their home water in the presence of a seven-day exposure to ash suspension of 650 mg/l (Whitman et al. 1982). Experimental fish returns did not differ from control returns, indicating that homing performance was not influenced by ash.

Timing of arrival at spawning grounds by chinook that migrate upstream during snowmelt runoff can vary by a month or more, depending on the concentration of suspended solids in rivers along their migration route (Bjornn 1968). In the lower Columbia River, the upstream migration of salmon may be retarded when Secchi disk readings are less than 0.6 m (Cederholm and Salo 1979). Delays in spawning migration and associated energy expenditure may reduce spawning success (Berman and Quinn 1991).

**C. Habitat**

In addition to affecting salmonid physiology and behavior, deposited sediments may affect salmonids by altering the physical structure of the stream environment. Sediments pose a direct threat to salmonid embryos through deposition in interstitial spaces, thereby reducing oxygen rich flows and pathways for waste removal as well as potentially entombing emerging fry. Broader systemic effects of sedimentation in streams include the loss of habitat complexity and abundance, loss of refugia, and alterations to hyporheic flow (Sedell et al. 1990; Poole and Berman 2001).

***Increased Embeddedness***

Intragravel survival of salmonid embryos is dependent on a streambed structure that facilitates the influx of oxygen rich waters and the removal of waste products associated with embryo and alevin development. High levels of fines (less than 0.85 mm in diameter) in or on spawning gravels can reduce intragravel permeability (Cederholm and Salo 1979). The effect of sediment on pre-emergent survival for a particular gravel composition varies, and may depend on the salmonid species as well as hydrologic conditions of the watershed. In addition to indirect mortality, direct mortality may be caused by sediment that physically prevents fry emergence (Cederholm and Salo 1979).

***Reduction in Habitat Complexity and Abundance***

Salmonids require a variety of habitats throughout their lifetime. Sediment inputs may decrease both habitat complexity and availability. Large pools, consisting of a wide range of water depths, velocities, substrates, temperatures, and cover are characteristic of high quality habitat and channel complexity. Many of these pools have been lost in recent times, at least in part to sediment contributed by timber harvesting, roading, and historical grazing practices (USFWS 1998). Reduction in pool volume decreases rearing habitat for juveniles and holding pools for migrating adults.

Elevated sediment loads also increase frequency of channel scour and fill events, and increase channel width through aggradation. The stability of large woody debris, an important habitat component, is also compromised (Spence et al. 1996). The pool to riffle ratio present in a stream is important for provision of refugia and maintenance of hyporheic flows (see below) (Poole and Berman 2001).

***Refugia***

Refugia are created and maintained by watershed processes. Systems altered by anthropogenic activities may not contain the necessary distribution and abundance of refugia to maintain salmonid populations in the face of natural and anthropogenic disturbances. Habitat heterogeneity may provide localized refugia against turbidity extremes for fishes and other organisms. Loss of channel structure and streambed heterogeneity leads to decreases in the abundance of suitable habitat and the distribution, abundance, and connectivity of refugia. As suspended solids progressively change geomorphic channel structure, suitable habitat may become marginal and marginal habitat may become unusable (Poole and Berman 2001).

Loss of refugia as well as decreased connectivity between refugia will reduce carrying capacity of streams for salmonids. Fish may be required to travel longer distances or to less desirable habitat in systems lacking adequate number, distribution, and connectivity of refugia. Fish may suffer a variety of secondary effects from meeting these extra energy demands.

***Alterations to Hyporheic Inputs***

Hyporheic inputs throughout a watershed may contribute upwelling flows that reduce temperatures in areas where streams might normally be too warm for salmonid activity. The presence of hyporheic flows throughout a system contribute to spatial and temporal heterogeneity important to salmonids (Poole and Berman 2001). Upwelling areas are also critical to proper water exchange in salmonid redds. Bull trout have been observed selecting redd sites that correlate to areas of hyporheic exchange (Baxter and Hauer 2000).

Increasing sediment load can clog coarse streambed gravels with fine sediments, thereby decreasing streambed conductivity and reducing the exchange of ground water and surface water across the streambed. Sediment may alter the dynamics of heating, cooling, and temperature buffering. The two-way exchange between the stream channel and the hyporheic zone is perhaps the most important buffer to high stream temperatures (Poole and Berman 2001).

***Note on Bull Trout***

Bull trout are highly susceptible to sediment inputs. They require the lowest turbidity and suspended sediment levels of all salmonids for spawning, incubation, and juvenile rearing (USFWS 1998). Bull trout are strongly associated with cover, including interstitial spaces in gravel. Additionally, they have protracted embryo/alevin development with approximately 220 days required from egg deposition to fry emergence (USFWS 1998). Thus they are highly susceptible to the effects of sediment deposition and bedload movement.

Bull trout show preference for stream bottoms and deep pools of cold water. This strong association with the substrate makes them susceptible to human activities that directly or indirectly change substrate composition. There is also a strong association between juveniles and streambed cobble, and substrates low in fine sediment. Bull trout also require a large network of suitable freshwater habitat with migratory corridors, and deep pools for thermal refugia (USFWS 1998).

***Specific Road and Devegetation Effects***

Field Studies

Burns (1972) linked sedimentation with higher temperatures and low dissolved oxygen in streams. The use of bulldozers on steep slopes caused excessive sedimentation in narrow streams. During heavy rainfall after construction, erosion and road slippage caused turbidities of 3,000 ppm and deposition of as much as 0.6 m of sediment in the stream. Brown and Krygier (1971) found that sediment production doubled after road construction but before logging in one watershed, and tripled after burning and clearcutting in another watershed.

Fifteen years of heavy logging and road construction in the South Fork River in Idaho, followed by flood caused massive sedimentation of habitat. Roads were the largest contributor of sediment to the system. Spawning, rearing, and holding habitats of summer chinook and summer steelhead were inundated with fine granitic sediments, and fine sediment filled pools (Platts and Megahan 1975).

Reid (1998) used flow and turbidity data from Caspar Creek, California, to model the potential influence of the presence and use of roads on cumulative duration curves for stream turbidity. Her results suggested that a proportional increase in fine-sediment production equivalent to that measured in coastal Washington (i.e. a 5.8 fold increase due to road-related erosion) would increase the average annual duration turbidities greater than 100 NTU by a factor of 73 (i.e. from 0.5 day to 36.5 days).

Smedley et al. (1970) found that the percentage of fine sediment <0.83 mm in diameter increased in all study areas for six years during logging, and remained at elevated levels for 3 years after. Fines increased 6-8% as a result of logging. Low survival of pink salmon brood stock from 1966 was attributed to sedimentation of spawning areas (from Everest et al. 1987).

Scrivener and Brownlee (1982) showed an increase in fines between 0.3 and 9.6 mm in diameter within the top 12 cm of riffle gravels 3 years after logging was begun in the Carnation Creek Watershed.

**Previous Literature Reviews: Lloyd (1987) and Newcombe and MacDonald (1991)**

Lloyd (1987) and Newcombe and MacDonald (1991) examined research on turbidity and suspended solids to illustrate the levels of tolerance to these two measures exhibited by salmonids and other fishes at various life stages. **Table 2** provides the results of Lloyd's (1987) research, developed in an effort to determine possible turbidity criteria for Alaska cold water fisheries. **Table 3** summarizes suspended sediment effects on selected salmonids present in the Yakima basin of Washington State. This table was compiled from Newcombe and MacDonald (1991) for the Yakima River Total Maximum

Daily Load (TMDL) Report. **Table 4** includes data derived from 1) research conducted after 1991; and 2) research prior to 1991 not presented by Lloyd (1987) and Newcombe and MacDonald (1991).

Lloyd (1987) examined the use of turbidity as a water quality standard for salmonid habitats in Alaska. Lloyd suggested that evidence of trophic level changes induced by reduction in light penetration, and known direct effects of sediment and turbidity on aquatic life indicates that turbidity constitutes a useful water quality standard for protecting aquatic habitats from sediment pollution.

According to Lloyd (1987), relatively low turbidity or SSC may stress salmonids, alter behavior patterns, or lead to acute mortality. Even low turbidities near 10-25 NTU and suspended sediment concentrations near 35 ppm can have deleterious effects on fish (Berg 1982; Sigler et al. 1984; Berg and Northcote 1985).

Effects of Turbidity and Suspended Sediment on Salmonids (Lloyd 1987)

1) Reduced light penetration in lakes and streams
2) Associated with decreased production and abundance of plant material (primary production)
3) Decreased abundance of fish food organisms (secondary production)
4) Decreased production and abundance of fish

Newcombe and MacDonald (1991) suggested that the use of concentration of suspended solids alone is a poor indicator of physiological and behavioral effects. The authors suggested using both concentration and duration of exposure in a “stress index” to determine relative impacts on salmonids. The authors believe this is a convenient tool for predicting effects for a pollution episode of known intensity. The results of this work can be found in **Appendix B.**

It is important to remember that the listings below are primarily laboratory studies. For example, prey rations, temperature, disease, and intra- and interspecific encounters are controlled. Therefore, it is difficult to clearly illustrate how fish would be affected by high turbidities in the field. In addition to those factors mentioned above, most experiments cited do not account for spatial and temporal factors, such as the distribution, abundance, or availability of suitable habitat, time of year, frequency, duration, and magnitude of events, and cumulative or synergistic effects.

## Table 2. Some reported effects of turbidity and suspended sediment concentrations on salmonids outside Alaska (Lloyd 1987).

| Effect | Species[a] (life stage) | *Location* | Reported turbidity[b] or suspended sediment concentration | Reference |
|---|---|---|---|---|
| Fatal (96-h LC50) | Coho salmon (juveniles) | Washington | 1,200 mg/l | Noggle (1978) |
| Fatal (96-h LC50) | Coho salmon (juveniles) | Washington | 509; 1,217 mg/l | Stober et al. (1981) |
| Fatal (96-h LC50) | Chinook salmon (juveniles) | Washington | 488 mg/l | Stober et al. (1981) |
| Reduced survival (marked) | Chum salmon (eggs) | British Columbia | 97 mg/l | Langer (1980) |
| Reduced survival (marked) | Rainbow trout (eggs) | Great Britain | 110 mg/l | Scullion and Edwards (1980) |
| Reduced survival (marked) | Rainbow trout (eggs) | Oregon | 1,000-2,500 ppm | Campbell (1954) |
| Reduced survival (marked) | Rainbow trout (juveniles) | Great Britain | 270 ppm | Herbert and Merkens (1961) |
| Reduced survival (marked) | Rainbow trout (juveniles) | Great Britain | 200 ppm | Herbert and Richards (1963) |
| Reduced survival (marked) | Rainbow trout (juveniles) | Oregon | 1,000-2,500 ppm | Campbell (1954) |
| Reduced survival (marked) | Rainbow trout (juveniles) | Great Britain | 90 ppm | Herbert and Merkens (1961) |
| Reduced survival (marked) | Coho salmon (juveniles) | Pennsylvania | 6; 12 mg Fe/l (15-27 JTU) | Smith and Sykora (1976) |
| Reduced survival (marked) | Coho salmon (adults) | Washington | 1,400-1,600 mg/l | Stober et al. (1981) |
| Reduced abundance (marked) | Brown trout | Great Britain | 1,000; 6,000 ppm | Herbert et al. (1961) |
| Reduced abundance (marked) | Lake trout | Northwest Territories | <10 FTU | McCart et al. (1980) |
| Reduced growth (marked) | Brook trout (juveniles) | Pennsylvania | 50 mg Fe/l (86 JTU) | Sykora et al. (1972) |
| Reduced growth (slight) | Brook trout (juveniles) | Pennsylvania | 12 mg Fe/l (32 JTU) | Sykora et al. (1972) |
| Reduced growth (slight) | Rainbow trout (juveniles) | Great Britain | 50 ppm | Herbert and Richards (1963) |
| Reduced growth | Coho salmon (juveniles) | Idaho | 25 NTU | Sigler et al. (1984) |
| Reduced growth (marked) | Arctic grayling (juveniles) | Yukon | 1,000 mg/l | McLeay et al. (1984) |
| Reduced growth (slight) | Arctic grayling (juveniles) | Yukon | 100; 300 mg/l | McLeay et al. (1984) |

a Arctic grayling (*Thymallus arcticus*)
Brook trout (*Salvelinus fontinalis*)
Brown trout (*Salmo trutta*)
Chinook salmon (*Oncorhynchus tshawytscha*)
Chum salmon (*Oncorhynchus keta*)
Coho salmon (*Oncorhynchus kisutch*)
Cutthroat trout (*Salmo clarki*)
Lake trout (*Salvelinus namaycush*)
Rainbow trout (*Salmo gairdneri*)
Steelhead (anadromous *S. gairdneri*)

b Formazin (FTU), Jackson (JTU), and nephelometric (NTU) turbidity units.

c Information not available.

**Table 2 (cont.).** Some reported effects of turbidity and suspended sediment concentrations on salmonids outside Alaska (Lloyd 1987).

| Effect | Species[a] (life stage) | *Location* | Reported turbidity[b] or suspended sediment concentration | Reference |
|---|---|---|---|---|
| Reduced food conversion | Rainbow trout (juveniles) | Arizona | < 70 JTU | Olson et al. (1973) |
| Reduced feeding (cessation) | Coho salmon (juveniles) | Washington | 300 mg/l | Noggle (1978) |
| Reduced feeding | Coho salmon (juveniles) | Washington | 100 mg/l | Noggle (1978) |
| Reduced feeding | Coho salmon (juveniles) | British Columbia | 10-60 NTU | Berg (1982), Berg and Northcote (1985) Bachmann (1958) |
| Reduced feeding (cessation) | Cutthroat trout | Idaho | 35 ppm | Bachmann (1958) |
| Reduced feeding | Brown trout | Pennsylvania | 7.5 NTU | Bachman (1984) |
| Reduced feeding | Rainbow trout (juveniles) | Arizona | 70 JTU | Olson et al. (1973) |
| Reduced feeding | Arctic grayling (juveniles) | Yukon | 100; 300; 1,000 mg/L | McLeay et al. (1984) |
| Reduced condition factor | Rainbow trout (juveniles) | Great Britain | 110 mg/l | Scullion and Edwards (1980) |
| Altered diet (terrestrial instead of aquatic) | Rainbow trout (juveniles) | Great Britain | 110 mg/l | Scullion and Edwards (1980) |
| Stress (increased plasma cortisol, hematocrit, and susceptibility to pathogens) | Coho salmon (juveniles) Steelhead (juveniles) | Oregon | 500 mg/l<br><br>2,000 mg/l | Redding and Schreck (1980) |
| Stress (increased metabolic rate, susceptibility to toxicants) | Arctic grayling | Yukon | 300 mg/l | McLeay et al. (1984) |
| Stress (increased plasma glucose) | Arctic grayling (juveniles) | Yukon | 50 mg/l | McLeay et al. (1983) |
| Stress (respiratory distress) | Coho salmon (juveniles) | Pennsylvania | 6; 12 mg Fe/l (15-27 JTU) | Smith and Sykora (1976) |
| Stress (increased ventilation) | Brook trout | Lake Superior | 231 NTU | Carlson (1984) |
| Disease (fin rot) | Rainbow trout (juveniles) | Great Britain | 270 ppm | Herbert and Merkens (1961) |
| Disease (fin rot) | Rainbow trout (juveniles) | Great Britain | 100; 200 ppm | Herbert and Merkens (1961) |
| | | | | |

a Arctic grayling (*Thymallus arcticus*)
Brook trout (*Salvelinus fontinalis*)
Brown trout (*Salmo trutta*)
Chinook salmon (*Oncorhynchus tshawytscha*)
Chum salmon (*Oncorhynchus keta*)
Coho salmon (*Oncorhynchus kisutch*)
Cutthroat trout (*Salmo clarki*)
Lake trout (*Salvelinus namaycush*)
Rainbow trout (*Salmo gairdneri*)
Steelhead (anadromous *S. gairdneri*)

b Formazin (FTU), Jackson (JTU), and nephelometric (NTU) turbidity units.

c Information not available.

**Table 2 (cont.).** Some reported effects of turbidity and suspended sediment concentrations on salmonids outside Alaska (Lloyd 1987).

| Effect | Species[a] (life stage) | *Location* | Reported turbidity[b] or suspended sediment concentration | Reference |
|---|---|---|---|---|
| Avoidance | Chinook salmon (adults) | California | "Natural turbidity" | Sumner and Smith (1940) |
| Avoidance | Chinook salmon (adults) | Washington | 650 mg/l | Whitman et al. (1982) |
| Avoidance | Chinook salmon (adults) | Washington | 350 mg/l | Brannon et al. (1981) |
| Avoidance (sensitivity) | Lake trout | Lake Superior | 6 FTU | Swenson (1978) |
| Avoidance | Coho salmon (juveniles) | Washington | 70 NTU | Bisson and Bilby (1982) |
| Avoidance | Coho salmon, steelhead (juveniles) | Idaho | 22-265 NTU | Sigler (1980), Sigler et al. (1984) |
| Displacement | Coho salmon, steelhead (juveniles) | Idaho | 40-50 NTU | Sigler (1980) |
| Displacement | Arctic grayling (juveniles) | Yukon | 300; 1,000 mg/l | McLeay et al. (1984) |
| Displacement | Rainbow trout (juveniles) | Great Britain | 110 mg/l | Scullion and Edwards (1980) |
| Altered behavior (feeding) | Trout | c | 25 JTU | Langer (1980) |
| Altered behavior (less use of overhead cover) | Brook trout | Wisconsin | 7 FTU | Gradall and Swenson (1982) |
| Altered behavior (visual) | c | c | 25-30 JTU | Bell (1984) |
| Altered behavior (visual) | Coho salmon (juveniles) | British Columbia | 10-60 NTU | Berg (1982), Berg and Northcote (1985) |
| Altered behavior (loss of territoriality) | Coho salmon (juveniles) | British Columbia | 10-60 NTU | Berg (1982), Berg and Northcote (1985) |
| Altered behavior (listlessness) | Coho salmon (juveniles) | Pennsylvania | 6; 12 mg Fe/l (15-27 JTU) | Smith and Sykora (1976) |
| Change in body color | Arctic grayling (juveniles) | Yukon | 300; 1,000 mg/l | McLeay et al. (1984) |
| Change in body color | Coho salmon (juveniles) | Pennsylvania | 6; 12 mg Fe/l (15-27 JTU) | Smith and Sykora (1976) |
| Reduced tolerance to saltwater | Chinook salmon (juveniles) | Washington | 3,109 mg/l | Stober et al. (1981) |

a Arctic grayling (*Thymallus arcticus*)
Brook trout (*Salvelinus fontinalis*)
Brown trout (*Salmo trutta*)
Chinook salmon (*Oncorhynchus tshawytscha*)
Chum salmon (*Oncorhynchus keta*)
Coho salmon (*Oncorhynchus kisutch*)
Cutthroat trout (*Salmo clarki*)
Lake trout (*Salvelinus namaycush*)
Rainbow trout (*Salmo gairdneri*)
Steelhead (anadromous *S. gairdneri*)

b Formazin (FTU), Jackson (JTU), and nephelometric (NTU) turbidity units.

c Information not available.

**Table 3. Summary of suspended sediment effects on selected salmonids commonly present in the Yakima River basin (Newcombe and McDonald 1991)**

(*) indicates estimated concentration.

| Species | Concentration (mg/l) | Duration (hours) | Effect |
|---|---|---|---|
| **Chinook Salmon** | 1400* | 36 | 10% mortality of juveniles |
| | 488 | 96 | 50% mortality of smolts |
| | 82,000 | 6 | 60% mortality of juveniles |
| | 19,364 | 96 | 50% mortality of smolts |
| | 1.5-2.0 | 1,440 | Gill hyperplasia, poor condition of fry |
| | 6 | 1,440 | Reduction in growth rate |
| | 75 | 168 | Harm to quality of habitat |
| | 84 | 336 | Reduction in growth rate |
| | 1,547 | 96 | Histological damage to gills |
| | 650 | 1 | Homing performance disrupted |
| **Whitefish** | 16,613 | 96 | 50% mortality of juveniles |
| | .7 | 1 | Overhead cover abandoned |
| **Salmon (general)** | 8 | 24 | Sport fishing declines |
| **Steelhead** | 84 | 336 | Reduction in growth rate |
| **Rainbow Trout** | 19,364 | 96 | 50% mortality of smolts |
| | 157 | 1728 | 100% mortality of eggs |
| | 21 | 1152 | 62% reduction in egg to fry survival |
| | 37 | 1440 | 46% reduction in egg to fry survival |
| | 7 | 1152 | 17% reduction in egg to fry survival |
| | 90 | 456 | 5% mortality in sub-adults |
| | 171 | 96 | Histological damage |
| | 50 | 1848 | Reduction in growth rate |
| | 100 | 1 | Avoidance response |

Compiled by the Washington State Department of Ecology for "A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River."
(Web Site Ref. #10)

**Table 4. Some reported effects of turbidity and suspended sediment concentrations on salmonids: 2001 Update.** This table is derived from Lloyd (1987).

| **Effect** | **Species (life stage)** | **Location** | **Reported turbidity or suspended sediment concentration** | **Reference** |
|---|---|---|---|---|
| Activity | Creek Chubs, Brook Trout | Wisconsin | Increase in moderately turbid waters | Gradall and Swenson (1982)* |
| Avoidance | Coho salmon (underyearling) | British Columbia | After 60 NTU pulse, fish move to substrate | Berg (1982)* |
| Avoidance | Coho salmon (underyearling) | British Columbia | Approx 25% at 7,000 mg/l – estimated that the threshold for avoidance in the vertical plane was 37 NTU | Servizi and Martens (1992)* |
| Avoidance | Creek Chubs | Wisconsin | Preferred 56.6 FTU | Gradall and Swenson (1982)* |
| Blood Sugar | Coho salmon (underyearling) | British Columbia | Elevated, proportional to SS exposure | Servizi and Martens (1992)* |
| Capture success per strike | Coho salmon (juvenile) | British Columbia | 30 and 60 NTU | Berg and Northcote (1985)* |
| Cough Frequency | Coho salmon (underyearling) | British Columbia | Elevated eightfold over control levels at 240 mg/l | Servizi and Martens (1992)* |
| Feeding rates | Pacific herring (larval stage) | Oregon | Maximum feeding potential at 500 and 1000 mg/l | Boehlert and Morgan (1985)* |
| Feeding rates | Coho salmon (juvenile) | British Columbia | Prey consumption only 35% of feeding in clear water at 60 NTU | Berg (1982)* |
| Feeding rates | Coho salmon and steelhead (yearlings) | Oregon | When exposed to 2,000-3,000 mg/l of topsoil, kaolin clay, volcanic ash, 7-8 days | Redding et al. (1987)* |
| Feeding rates | Chinook salmon (juvenile) | British Columbia | Reduced at higher turbidities, highest rates at intermediate turbidity 35-150 NTU for surface and benthic prey | Gregory and Northcote (1993)* |

* laboratory study
** field study

**Table 4 (cont.).** Some reported effects of turbidity and suspended sediment concentrations on salmonids: 2001 Update. This table is derived from Lloyd (1987).

| **Effect** | **Species (life stage)** | **Location** | **Reported turbidity or suspended sediment concentration** | **Reference** |
|---|---|---|---|---|
| Feeding rates | Chinook salmon (juvenile) | British Columbia | Increased rates on surface and benthic prey in conditions of moderate turbidity (18-150 NTU) compared with lower (<1 NTU) or higher 370-810 NTU | Gregory (1992)* |
| Feeding rates | Chinook salmon (juvenile) | British Columbia | Above 150 NTU, juvenile chinook exhibit reduced feeding regardless of prey type and forager size | Gregory (1992)* |
| Feeding rates | Bluegills | North Carolina | 14 prey per minute in clear water to 1, 10, 7 per minute in pools of 60, 120, and 190 NTU. Size selectivity independent | Gardner (1981)* |
| Gill trauma | Sockeye salmon (underyearling) | British Columbia | 3,148 mg/l or 0.2 of the 96 h LC50 Value | Servizi and Martens (1987)* |
| Homing | Chinook salmon (adult) | Washington | Strong baseline preference for clean (ash-free) home water over a clean non-natal water source | Whitman et al. (1982)** |
| Impairment in hypo-osmoregulatory capacity | Sockeye salmon (underyearling) | British Columbia | Exposed 96 h to 14,407 mg/l of fine sediment | Servizi and Martens (1987)* |
| Percentage of prey ingested | Coho salmon (juvenile) | British Columbia | 30 and 60 NTU | Berg and Northcote (1985)* |
| Plasma glucose increase | Sockeye salmon (underyearling) | British Columbia | Increased 150 and 39% from exposure to 1,500 and 500 mg/l of fine sediment | Servizi and Martens (1987)* |

* laboratory study
** field study

**Table 4 (cont.) .** Some reported effects of turbidity and suspended sediment concentrations on salmonids: 2001 Update. This table is derived from Lloyd (1987).

| **Effect** | **Species (life stage)** | **Location** | **Reported turbidity or suspended sediment concentration** | **Reference** |
|---|---|---|---|---|
| Predation rates | Chinook salmon (juvenile), chum, sockeye, cutthroat trout | British Columbia | Mean predation rates were 10-75% lower than those in controls (no vegetation and clear water); addition of turbidity reduced effect | Gregory and Levings (1996)* |
| Predator avoidance | Chinook salmon (juvenile) | British Columbia | In absence of risk, juvenile chinook were distributed randomly in 23 NTU, at bottom in clear water– with risk, all at bottom, and responses less marked and of shorter duration | Gregory (1993)* |
| Prey abundance | N/A | Columbia River Estuary | Reduction in amphipods in substrate with surface layer of ash | Brzezinski and Holton (1981)** |
| Prey abundance | N/A | Northwest Territories | Sediment addition increased total drift of invertebrates (avoidance reaction) | Rosenberg and Wiens (1978)** |
| Reaction distance | Coho salmon (juvenile) | British Columbia | 30 and 60 NTU | Berg and Northcote (1985)* |
| Reaction distance | Chinook salmon (juvenile) | British Columbia | Decline with increasing turbidity | Gregory and Northcote (1993)* |

* laboratory study
** field study

**Table 4 (cont.).** Some reported effects of turbidity and suspended sediment concentrations on salmonids: 2001 Update. This table is derived from Lloyd (1987).

| **Effect** | **Species (life stage)** | **Location** | **Reported turbidity or suspended sediment concentration** | **Reference** |
|---|---|---|---|---|
| Reaction distance | Adult lake trout | Utah | Reaction distance increased w/ increasing light - <25 cm at .17 1x to about 100 cm at light threshold of 17.8 1x., declined with turbidity - > 80% of decline in reaction distance occurred over 0-5 NTU | Vogel and Beauchamp (1999)* |
| Reactive Distance | Rainbow Trout | Georgia | Reactive distances in 15 and 30 NTU treatments were only 80 and 45% respectively of those observed at ambient turbidities 4-6 NTU. | Barrett and Rosenfeld (1992)* |
| Reduced Growth | Coho salmon (juvenile) | Oregon | Significant decrease in fish production when fine sediments were 26-31% by volume | Crouse et al. (1981)* |
| Reduction in prey | Chinook salmon (juvenile) | Washington | Reduced appearance of highly utilized amphipod Corophium salmonis. | McCabe et al. (1981)** |
| Relation of turbidity and suspended solids | N/A | Alaska | Depth to which 1% of subsurface light penetrates has inverse correlation with sediment-induced turbidity | Lloyd et al. (1987)** |
| Stress (Gill Flaring) | Coho salmon (juvenile) | British Columbia | Increased at 30 and 60 NTU | Berg and Northcote (1985)* |

* laboratory study
** field study

**Table 4 (cont.).** Some reported effects of turbidity and suspended sediment concentrations on salmonids: 2001 Update. This table is derived from Lloyd (1987).

| **Effect** | **Species (life stage)** | **Location** | **Reported turbidity or suspended sediment concentration** | **Reference** |
|---|---|---|---|---|
| Stress (increased plasma cortisol) | Coho salmon and steelhead (yearlings) | Oregon | When exposed to 2-3 g/L of topsoil, 7-8 days | Redding et al. (1987)* |
| Stress (blood hematrocrits and plasma cortisol) | Coho salmon and steelhead (yearlings) | Oregon | Increased in fish exposed to high concentrations for two days, topsoil, kaolin clay, or ash. | Redding et al. (1987)* |
| Stress (resistance to bacterial pathogen) | Yearling steelhead and coho | Oregon | Vibrio anguillarum | Redding et al. (1987)* |
| Territoriality | Coho salmon (juvenile) | British Columbia | Territoriality ceases with 60 NTU pulse – re-established at 20 NTU – lateral displays minimized | Berg (1982)* |

* laboratory study
** field study

# V. Assessment of Whether Emulsion Characteristics of Turbidity Have a Significant Differential Effect on Salmonid Survival, Growth, and Reproduction

Salmonids encounter “naturally” turbid conditions in estuaries and glacially-fed streams. Managers are interested in determining whether there is something inherent in “natural” turbidity sources that make them somehow less harmful to fish then anthropogenic sediment inputs. A pertinent question is the relationship between sediment size, shape, and composition and salmonids viability.

It is difficult to determine the effect of sediments of various sizes and shapes based on laboratory experimentation owing to the complexity of natural systems. In addition to the character of the material, a number of other factors must be considered in evaluating salmonid response to suspended sediments. These factors include the life history stage, presence of cumulative stressors, availability of refugia that are well distributed, connected, and accessible, condition of biotic community, frequency and magnitude of exposure to the sediments, and the physical processes associated with hydrology, sediment input, transport, and storage present in a particular watershed. Past land use practices within a watershed are also of import.

Various types of sediment have been used in experiments developed to test the effect of suspended solids on salmonid health. Very few studies, however, provide a comparison of the effect of different sediment types and sizes on salmonids.

Davies-Colley and Smith (2000) noted that the physical and chemical, and therefore optical, character of suspended particles can vary widely between stream systems as well as within the same system. The important attributes of aquatic particles in addition to optical character include settling velocity and particle size, shape, and composition.

Based on current studies, it appears that gill injuries increase as angularity and particle size increase. Servizi and Martens (1987) studied gill injuries among underyearling sockeye exposed to fine and medium coarse sediments. The size and shape of particles appeared to affect the yearlings differentially. The study demonstrated that tolerance decreased as particle size increased, specifically for particles described as "angular to subangular." Underyearling sockeye experienced gill trauma at 3,143 mg/l, levels that have been measured at Hell's Gate on the Fraser River.

Newcomb and Flagg (in Servizi and Martens 1987) reported a 36 h LC50 of Mt. St. Helens ash to be 6,100 mg/l for sockeye smolts, whereas there were no mortalities when smolts were exposed to 14,407 mg/l of Fraser River sediments. These data suggest that sockeye smolts may be more sensitive to slightly larger, largely angular ash particles than subangular to angular particles. The 96 h LC50s of four Fraser River sediments to underyearling sockeye ranged from 1,674 to 17,560 mg/l and were related to particle size (Servizi and Martens 1987).

**Table 5. Classification of suspended solids and their probable major effects on freshwater ecosystems** (from Sorenson et al. 1977).

| | **Biochemical, Chemical, and Physical Effects** | **Biological Effects*** |
|---|---|---|
| Clays, silts, sand | Sedimentation, erosion and abrasion, turbidity (light reduction), habitat change | Respiratory interference, habitat restriction, light limitation |
| Natural organic matter | Sedimentation, DO utilization | Food sources, DO effects |
| Wastewater organic particles | Sedimentation, DO utilization, nutrient source | DO effects, eutrophication |
| Toxicants sorbed to particles | All of the above | Toxicity |

* Biological effects may result directly from pollutants (primary effect), changes due to biochemical, chemical, or physical changes (secondary), or biological interactions (tertiary effects).

**Table 6. Sediment particle size** (modified from Waters 1995).

| **Category** | **Size Range** | **Phi scale** |
|---|---|---|
| Boulder | > 256 mm | -8 |
| Cobble | 64-256 mm | -6,-7 |
| Pebble | 16-64 mm | -4,-5 |
| Gravel | 2-16 mm | -1,-2,-3 |
| Very coarse sand | 1-2 mm | 0 |
| Coarse sand | 0.5-1 mm | 1 |
| Medium sand | 0.25-0.5 mm | 2 |
| Fine sand | 0.125-0.25 mm | 3 |
| Very fine sand | 0.0625-0.125 mm | 4 |
| Silt | 4-62 um | 5,6,7,8 |
| Clay | < 4 um | 9 |

**Summary**

Additional research needs to be undertaken in this area. Laboratory results indicate that size, shape, and composition of sediment particles may have differential effects on salmonids. It is important to understand all of the mechanisms by which suspended sediments affect salmonids in order to reduce effects associated with land use.

## VI. Current State and Provincial Turbidity Standards

This section provides a review of the current turbidity requirements in Alaska, Idaho, Oregon, Washington, and British Columbia. The standards reviewed here require that turbidity be measured against a "background turbidity," established at a point upstream of the affected area. Only two of the five standards reviewed include a limit on the duration of exposure to a certain turbidity level (Idaho and British Columbia).

Best Available Technology (BAT) TSS requirements are commonly used in writing National Pollutant Discharge Elimination System (NPDES) discharge permits in Washington State. For many industrial applications, the BAT standard is 45 mg/l for a long-term average and 90 mg/l for a daily maximum (E. Molash, pers. commun.). To address watershed scale turbidity or total suspended solid issues, the four states have the option of using the Total Maximum Daily Load (TMDL) process to assess the need for overall reductions in turbidity levels and suspended sediments.

The TMDL process was established by section 303(d) of the Clean Water Act. Federal law requires states to identify sources of pollution in waters that fail to meet state water quality standards after all point sources have been permitted, and to develop cleanup plans to address pollutants of concern. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet state water quality standards. Percentages of the total maximum daily load are allocated to the various pollutant sources (Web Site Ref. #10). More detailed information on TMDLs in Washington, Oregon, and Idaho can be found in Appendix D.

A number of researchers analyzed existing state regulations for turbidity and total suspended solids to determine if the level of protection afforded to salmonids is adequate. Bisson and Bilby (1982) noted that state regulations at that time did not consider acclimation of stream biota to high turbidity, as regulations permitted only minor increases in suspended sediment when background turbidity was low, but allowed greater absolute increases as background levels rise.

Lloyd (1987) examined the use of turbidity as a water quality standard for salmonid habitats in Alaska. Lloyd's (1987) review indicated that water quality standards allowing increases in coldwater habitats of 25 NTU above ambient turbidity would provide "moderate" protection, while a standard allowing a 5 NTU increase above ambient turbidity would provide “high” protection for salmonids. This determination was based on a number of studies which indicated that turbidities as low as 10-25 NTUs can have deleterious effects on fish (Berg 1982; McCabe and O’Brien 1983; Sigler et al. 1984; Berg and Northcote 1985).

Lloyd (1987) suggested that an acceptable turbidity standard must do two things to protect aquatic habitats: prevent loss of aquatic productivity and cause no lethal or chronic sublethal effects on fish and wildlife. Other researchers have suggested the need for standards other than simple turbidity criteria to control pollution by sediment. The National Academy of Sciences and National Academy of Engineering (1973) recommended that depth of light penetration not be decreased by more than 10% and that suspended sediment concentrations be limited to specific values.

Sorenson et al. (1977) cited concern over the difficulty in setting rigid standards for suspended solids. The concentration of suspended solids in natural waters is influenced by such factors as topography, geology, soil condition, intensity and duration of rainfall, type and amount of vegetation in the drainage basin, and past and current human activity. Flowing waters may have considerable variation in SSC from day-to-day and year-to-year. Since natural variation in suspended solids is so great, the authors suggested that it is not desirable to have fixed rigid standards.

Duchrow and Everhart (1971) and Bisson and Bilby (1982) called for consideration of standards for settleable solids, as they are of primary concern in the protection of aquatic fauna. As sediment type and aquatic fauna vary across and between watersheds, specific standards might have to be applied depending on conditions within and between watersheds.

**Table 7** provides a summary of current turbidity standards for states in the Northwestern United States and British Columbia, Canada. **Table 8** provides standards for the year 1987. This is provided to show changes in regulations between 1987 and 2001. **Appendix C** provides detailed information on turbidity standards for each state and province.

**Table 7. 2001 comparison table of state and provincial turbidity standards.**

| State/Province | Standard | Notes |
|---|---|---|
| **Alaska**<br>(Web Site Ref. #1) | May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions. | Standard for growth and propagation of fish, shellfish, other aquatic life, and wildlife. *End-of-pipe unless a mixing zone has been approved*. |
| **British Columbia**<br>(Web Site Ref. #2) | Maximum Induced Turbidity – NTU or % of background:<br><br>8 NTU in 24 hours when background is less than or equal to 8<br>….<br>Mean of 2 NTU in 30 days when background is less than or equal to 8<br>________________________<br>8 NTU when background is between 8 and 80<br>….<br>10% when background is greater than or equal to 80 | Standard for aquatic life, fresh, marine, estuarine<br><br>BC regulations also include limits on Maximum Induced Suspended Sediments –mg/L or % of background and limits on streambed substrate composition (% fines at spawning sites, geometric mean diameter not less than 12 mm)<br><br>*Edge of mixing zone.* |
| **Idaho**<br>(Web Site Ref. #5) | Turbidity, below any applicable mixing zone set by the Department, shall not exceed background turbidity by more than (50) NTU instantaneously or more than twenty-five (25) NTU for more than ten (10) consecutive days. | Standard for aquatic life use designations.<br><br>*Edge of mixing zone*<br><br>(Exceedance limited to 5 NTU if a point source) |
| **Oregon**<br>(Web Site Ref. #7) | No more than ten percent cumulative increase in natural stream turbidities, as measured relative to a control point immediately upstream of the turbidity causing activities. | Limited duration activities that exceed requirements may be authorized (see Oregon Turbidity Standards Section).<br><br>*End-of-pipe unless a mixing zone has been approved.XX* |
| **Washington**<br>(Web Site Ref. #12) | Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background is > 50 NTU | For Class A Waters; for Class B waters, turbidity shall not exceed a 10 NTU increase over background turbidities of 50 NTU or less, or a 20% increase when background turbidity is greater than 50 NTU<br><br>*Edge of mixing zone* |

**Table 8. Numerical turbidity standards for protection of fish and wildlife habitats in Alaska and other states** (as cited by Lloyd 1987).

| State | Turbidity (NTU or JTU)[a] |
|---|---|
| Alaska | 25 units above natural in streams<br>5 units above natural in lakes |
| California | 20% above natural, not to exceed 10 units above natural |
| Idaho | 5 units above natural |
| Minnesota | 10 units |
| Montana | 10 units (5 above natural)[b] |
| Oregon | 10% above natural |
| Washington | 25 units above natural (5 and 10 above natural)[c] |
| Wyoming | 10 units above natural |

a Nephelometric (NTU) and Jackson (JTU) turbidity units are roughly equivalent (USEPA 1983).
b Montana places the more stringent limit on waters containing salmonid fishes.
c API (1980) reports different values in Washington for "excellent" and "good" classes of water.

## Summary

Each state and province in the northwest attempts to control sediment input to rivers by placing limits on turbidity increases above "natural background levels." Natural background turbidity levels may vary widely between watersheds due to factors such as base geology, legacy conditions, and land-cover and within a system (e.g. headwaters versus estuary). In addition, turbidity may change daily, seasonally, and annually depending on physical and biological changes in the system. This variability makes it difficult to quantify natural background turbidity.

To adequately protect salmonids during their freshwater residence, TSS data on physiological, behavioral, and habitat effects should be viewed in a layer context incorporating both the spatial geometry of suitable habitat and the temporal changes associated with life history, year class, and climate variability. Spatial and temporal considerations provide the foundation to decipher legacy effects as well as cumulative and synergistic effects on salmonid protection and recovery.

## VII. Turbidity Requirements for Hatcheries

In Washington State, hatcheries do not follow specific turbidity requirements regarding water used for hatchery operations. However, hatchery operators often have unstated guidelines to determine when turbidity levels pose a risk to eggs and juvenile salmonids. In many cases, hatchery managers rely on visual measurement rather than numeric guidelines to determine risk to developing salmonids.

Upland hatcheries are subject to regulations regarding the water released from facilities and the byproducts of hatchery operations. Hatcheries must obtain NPDES permits to address discharges from their facilities into streams.

### Controlling Turbidity and Suspended Solids in Hatchery Water

In general, hatcheries in Washington State receive water supplies from nearby creeks and rivers. In a minority of cases, groundwater or springs are used where available (H. Michael, pers. commun.). The advantage of groundwater and spring sources is 1) lower concentrations of suspended solids and 2) reduced pathogen presence from river water. There are additional costs, however, associated with using groundwater and spring sources, such as pumping the water from the source to the facility.

Hatchery operators must monitor the sediment concentration of the water and determine the point at which the condition will be deleterious to fish at various life stages. It is important for hatchery managers to determine when to "clean" eggs that are exposed to suspended sediments. Even when the water supply contains low levels of suspended sediment, operations must be observed carefully. Over a period of 3 or 4 months even a low level of sediment could eventually smother eggs (H. Michael, pers. commun.).

The Soos Creek Hatchery in Auburn does not adhere to specific turbidity criteria during operation. The staff use professional knowledge to identify when the water supply is turbid to the point of endangering the eggs. In these cases, the eggs are temporarily removed from their tanks until turbidity decreases. This emergency measure most often occurs as the result of rainfall and a subsequent storm surge. The hatchery uses water from Soos Creek for raising coho, and spring water for raising steelhead (T. Sorbo, pers. commun.).

At a hatchery on the Cowlitz River in Southwestern Washington, glaciated river water occasionally creates conditions where juveniles cannot see their food. H. Michael (pers. commun.) stated that fish require 12-18" of visibility for feeding during rearing. Reduced feeding can lead to reduced growth rates. Additionally, if glacial water slows enough in the hatchery, glacial sediment may settle and pose a risk to eggs.

**Outflow from Hatcheries**

Washington State upland hatcheries (as opposed to netpens) require NPDES discharge permits to account for all materials released from hatcheries back into the stream. The amount of settleable solids allowed from normal hatchery operations is a monthly average of 0.1 mg/l. For total suspended solids, the monthly average allowed is 5 mg/l. The instantaneous maximum allowed is 15 mg/l (H. Michael, pers. commun.).

Off-line settling basins are used to contain settleable solids from hatchery operations. These ponds are drawn down and sediments are removed on a regular basis. Dredged material is then removed for upland disposal. For the water returned to the creek from off-line settling ponds, the NPDES requirement calls for monthly release rates of 1 mg/l settleable solids, and 100 mg/l total of suspended solids.

**Summary**

Turbid water and related suspended sediment concentrations pose a threat to the health of hatchery fish. Excessive sediment in hatchery water may smother eggs by depriving them of oxygen, and reducing the ability of juveniles to capture prey. While there appears to be no specific measurement guideline for determining when the suspended sediment levels are a danger to eggs and juveniles, hatchery managers have developed methods of visually estimating risk and acting accordingly. Hatcheries are subject to discharge permits which limit the amount of sediment they may release downstream of the facility.

# VIII. Recommendations

Based on this literature review, there are a number of areas where additional research would help managers better assess the effects of suspended sediment on salmonid health, growth, and reproduction.

Regulatory requirements often force managers to focus on meeting a specific requirement at a specific location and point in time. It is difficult to quantify the direct effect of turbidity on salmonids by looking at the effect of one particular disturbance in a watershed. This does not account for cumulative sediment loading throughout the basin nor synergistic effects. If possible, transportation project managers should consider watershed-scale effects in addition to the effect of their particular project. The key questions for managers are: 1) whether there are various scale refugia accessible in the system that will allow salmonids to cope with short term sediment effects; and

2) whether other cumulative and synergistic effects magnify short-term sediment alterations.

Another important consideration is the inconsistency of turbidity measurements. When devising monitoring strategies for transportation projects, Washington State Department of Transportation (DOT) might want to consider collecting baseline TSS data, which then may be correlated with turbidity readings for future monitoring.

### Research, Monitoring, and Management Recommendations

***Measurement***

- Conduct baseline studies measuring "natural" background levels in undisturbed systems and disturbed systems, stratified by biophysical parameters.

- Prior to conducting construction projects, determine TSS concentrations and gather information on size, shape, and composition of sediment.

- Develop new exposure metrics that account for sublethal effects (as opposed to direct mortality).

- Conduct research in the field if possible – most work to date has been performed in laboratories, which may not provide an accurate picture of the effects of suspended sediment on salmonids.

- Consider use of other measurement tools, such as water clarity to determine levels of suspended sediments.

***Sediment Effects***

- Examine the effect of frequent short-term pulses of suspended sediment on salmonids.

- Conduct additional research on correlations between particle size, shape, and composition of sediments to sensitivity effects on salmonids.

- Evaluate how loss of groundwater/surface water interactions affect availability and abundance of salmonid habitat.

- Study relationships between seasonal timing and effect of sediment load on salmon.

- View TSS data on physiological, behavioral, and habitat effects in a layered context, incorporating both the spatial geometry of suitable habitat and the temporal changes associated with life history stage, year class, and climate variability. Spatial and temporal considerations provide the foundation to decipher legacy effects as well as cumulative and synergistic effects on salmonid protection and recovery.

***Management***

- Consider watershed condition when evaluating projects. Examine legacy of land use in watershed and determine how planned disturbance will contribute to cumulative effects.

- Analyze other sources of sediment contribution to the watershed, such as grazing allotments, roads and culverts, and timber harvest areas. Reduce sediment loads from these areas if possible.

- Restore tributaries and off-channel habitat to create potential turbidity refuges.

- Determine whether knowledge of salmonid survival responses to turbid flows can be used to develop mixing zones, work windows, treatment systems, and buffers that will allow fish to perform their necessary life functions during project construction and operation.

- Test a variety of existing and new technologies used to reduce TSS during road construction projects. Collect quantitative data.

Given that salmonids encounter "naturally" turbid conditions in estuaries and glacially-fed streams, as well as during flood events and have developed survival responses for those turbid conditions there are some additional critical questions for consideration . Is there something inherent in "natural" turbidity sources that makes exposure less harmful to fish? For instance, is the "angularity" of suspended sediments a factor? How about particle size ranges? During flood events, does available habitat provide "turbidity" refugia?

**Establishing Baseline Turbidity Values**

The difficulty of establishing overall "natural background turbidities" was discussed earlier in this paper. One possibility for setting baseline turbidity ranges is to measure background turbidity levels in unmanaged or "natural" areas of basins with differing morphologies. Continuous sampling would be required to define turbidity fluctuations under various hydrological conditions (such as a storm event). Once a range of conditions has been identified for the watershed, a distribution may be plotted. This distribution can be used to establish guidelines for similar watersheds.

**Regulatory Suggestions in the Literature**

Lloyd (1987) suggested that a turbidity standard could be used to address the effects of turbidity as an optical property of water and as an indicator of SSC. The effects of sedimentation on lake and stream bottoms could be addressed by separate enforceable settable solid or streambed standards. Lloyd (1987) cites a need to establish or reaffirm the levels of turbidity, and associated suspended solids concentrations that are appropriate as standards for regulating human-induced effects on aquatic systems. Turbidity standards can be tiered or graded (if necessary) to ambient water quality conditions and the level of protection desired for a body of water (Lloyd 1987).

Lloyd (1987) also suggested that any alternative standards account for the primary aspects of turbidity– extinction of light and presence of suspended sediment. Direct measurement is possible of both, but the measure of turbidity was developed to facilitate suspended sediment estimates. Light penetration can be measured in situ with portable photometers and extinction coefficients calculated with simple graphs or equations, but discrete samples cannot be removed and analyzed separately. Sediment concentration can be sampled in the field and measured gravimetrically in a laboratory. Filtering, drying and weighing procedures are required (Lloyd 1987).

Reasonable turbidity criteria that are established to protect aquatic habitats from decreased light penetration may also protect systems from high concentrations of suspended sediments and heavy metals. Separate settleable solids or streambed standards could then be applied to protect aquatic habitats from effects on benthic substrates (Lloyd 1987).

Cairns (1968) suggested that truly responsive regulations should be developed on a drainage-by-drainage basis, and should change with stream flow and other habitat conditions. Lloyd (1987) noted that this type of standard would require enormous baseline studies and almost continuous surveillance and monitoring, and subsequently questioned whether such an approach is feasible in Alaska or elsewhere.

Lloyd (1987) indicated that for salmonids, a “moderate” level of protection (SSC up to 100 mg/l) roughly translates to turbidity values up to 23 NTUs. Recommendations for a “high” level of protection (0-25 mg/l) roughly translate to turbidity values up to 7 NTUs. Stricter limits might be warranted to protect extremely clear waters, due to the dramatic initial effect of turbidity on light penetration. Naturally turbid systems might need tiered or graded standards based on ambient water quality.

USFWS (1998) suggested that managers avoid new road construction in areas vulnerable to mass wasting and in areas that may initiate or exacerbate stream bank erosion. On a larger scale, it was suggested that managers identify land management activities (upland and riparian) that have potential to contribute sediment to spawning and rearing areas above natural levels (USFWS 1998).

Castro and Reckendorf (1995) suggest that fish are not good indicators of excess sedimentation, as separating the effects of sediment from other environmental factors can be impossible in a natural system. While sometimes obvious effects of excessive fine sediment can be viewed, often effects are not apparent. The authors suggested using another indicator species, such as benthic macroinvertebrates, which are more sensitive to small changes in sediment quality and quantity, less mobile, and have shorter life cycles.

## IX. Summary

Protection of Washington State's salmonids requires that transportation officials consider the effect of suspended sediments released into streams during road construction. Numerous studies have shown that the presence of suspended sediments can have a detrimental effect on the physiology, behavior, and habitat of salmonids. Different species and even different life stages of species are susceptible to adverse effects from different levels of sediment and to sediments of different sizes.

Turbidity is the measure most commonly used by agencies to indicate the level of suspended solids in the water column. It is an indirect measure, however, and may not always be correlated with suspended solid concentrations. Turbidity may vary depending on geomorphic, hydrologic, and hydraulic factors.

Although salmonids are found in naturally turbid river systems in the Northwest, this does not necessarily mean that salmonids in general can tolerate increases over time of suspended sediments. An understanding of sediment size, shape, and composition, salmonid species and life history stages, cumulative and synergistic stressor effects, and overall habitat complexity and availability in a watershed is required.

For short-term construction projects, operators will need to measure background turbidities on a case by case basis to determine if they are exceeding regulations. However, transportation projects may also produce long-term, chronic effects. Short-term pulses will presumably have a different effect on salmonids than chronic exposure.

Turbidity standards developed by several states and provinces in this region attempt to consider natural variability in turbidity by requiring the regulated community to measure "background turbidity" upstream of any proposed activity. The background turbidity measured in these situations represents a measurement at one point in time. Regulating turbidity levels based on this type of measurement may not be protective of salmonid health.

## Bibliography


AAC (Alaska Administrative Code). 1985. Water quality standards. AAC, Title 18, Chapter 70, Juneau.

Barrett,J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Trans. Am. Fish. Soc. 121 (4): 437-443

Baxter, C.V. and F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confuentus*). Canadian Journal of Fisheries and Aquatic Sciences 57(7):1470-1481.

Berg, L. 1982. The effect of exposure to short-term pulses of suspended sediment on the behavior of juvenile salmonids. P. 177-196 in G.F. Hartman et al. [eds.] Proceedings of the Carnation Creek workshop: a ten-year review. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, Canada.

Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (*Oncohynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Berman, Cara. 1998. Oregon Temperature Standard Review. EPA Region 10. 65 pp.

Berman, C.H. and T.P. Quinn. 1991. Behavioral thermoregulation and homing by spring Chinook salmon, *Onchorhynchus tshawytscha* (Walbaum), in the Yakima River. Journal of Fish Biology 39:301-312.

Beschta, R.L., and W.L. Jackson. 1979. The intrusion of fine sediments into a stable gravel bed. J. Fish. Res. Board. Can. 36(2):204-210.

Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management 4: 371-374.

Bjornn, T.C. 1968. Survival and emergence of trout and salmon in various gravel-sand mixtures. In Proceedings, Forum on the Relation Between Logging and Salmon, p. 80-88. American Institute of Fishery Research Biologists and Alaska Department of Fish and Game, Juneau.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. P. 83-138. In W.R. Meehan [ed.] Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitat. American Fisheries Society Special Publication.

Boehlert, G.W. and J.B. Morgan. 1985. Turbidity enhances feeding abilities of larval Pacific herring, *Clupea harengus pallasi*. Hydrobiologia 123: 161-170.

Booth, D.B. 2001. Center for Urban Water Resources Management, University of Washington. Personal communication.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. Int. Pac. Salmon Fish Comm. Prog. Rep. 12. 26 p.

Brown, G.W. and J.T. Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast range. Water Resources Research 7(5): 1189-1198

Brzezinski, M.A. and R.L. Holton. 1983. A report on the macroinvertebrates of the Columbia River Estuary found in deposits of volcanic ash from the May 18, 1980 eruption of Mt. St. Helens. Estuaries 6(2):172-175.

Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society 101(1):1-17.

Cairns, J., Jr. 1968. Suspended solids standards for the protection of aquatic organisms. Engineering Bulletin Purdue University 12:16-27.

Castro, Janine and Frank Reckendorf. 1995. Effects of sediment on the aquatic environment. Potential NRCS Actions to Improve Aquatic Habitat. Working Paper No. 6. Natural Resources Conservation Service. Oregon State University, Department of Geosciences.

Cederholm, C.J. and E.O. Salo. 1979. The effects of logging road landslide siltation on the salmon and trout spawning gravels of Stequaleho Creek and the Clearwater River basin, Jefferson County, Washington, 1972-1978. FRI-UW-7915. Fisheries Research Institute, University of Washington, Seattle. 99 p.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. In Proceedings from the conference Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest? p. 38-74. Rep. 39. State of Washington Water Research Center, Pullman.

Cooper, A.C. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevins. Int. Pac. Salmon Fish. Comm. Bull. 18. 71 p.

Cordone, A.J. and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. Calif. Fish and Game 47(2):189-228.

Crouse, M.R., C.A. Callahan, K.W. Malueg, and S.E. Dominguez. 1981. Effects of fine sediments on growth of juvenile coho salmon in laboratory streams. Transactions of the American Fisheries Society 110: 281-286.

Davies-Colley, R.J. and D.G. Smith. 2000. Suspended Sediment, Turbidity and Clarity of Water, a Review. Unpublished draft.

Daykin, P.N. 1965. Application of mass transfer theory to the problem of respiration of fish eggs. J. Fish. Res. Board Can. 22(1):159-171.

Duchrow, R.M. and W.H. Everhart. 1971. Turbidity measurement. Transactions of the American Fisheries Society 4:682-690.

European Inland Fisheries Advisory Commission (EIFAC). 1965. Working Party on Water Quality Criteria for European Freshwater Fish. Water quality criteria for European freshwater fish. Report on finely divided solids and inland fisheries (EIFAC Technical Paper No. 1), Air and Water Pollution 9(3):151-168.

Everest, F.H., R.L. Beschta, J.C.Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production: a paradox. In E.O. Salo and T.W. Cundy [ed.] Streamside Management: Forestry and Fishery Interactions. University of Washington Institute of Forest Resources, Seattle, Washington.

Fox, Martin. 2001. University of Washington, College of Forest Resources. Personal communication.

Gammon, J.R. 1970. The effect of inorganic sediment on stream biota. Environmental Protection Agency, Water Pollution Control Research Series 18050 DWC12/70. Gov. Printing Office, Washington, D.C. 20402.

Gardner, M.B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Transactions of the American Fisheries Society 110: 446-450.

Ginetz, R.M. and P.A. Larkin. 1976. Factors affecting rainbow trout (*Salmo dairdneri*) predation on migrant fry of sockeye salmon (*Oncorhynchus nerka*). Journal of the Fisheries Research Board of Canada 33: 19-24.

Gradall, K.S. and W.A. Swenson. 1982. Responses of brook trout and creek cubs to turbidity. Transactions of the American Fisheries Society 111: 392-395.

Gregory, R.S. 1988. Effects of turbidity on benthic foraging and predation risk in juvenile chinook salmon, p. 65-73. In C.A. Simenstad [ed.] Effects of dredging on anadromous Pacific coast fishes. Workshop Proceedings, September 8-9, 1988. Washington Sea Grant Program, University of Washington, Seattle, USA.

Gregory, R.S. 1992. The influence of ontogeny, perceived risk of predation, and visual ability on the foraging behavior of juvenile chinook salmon. Theory and Application of Fish Feeding Ecology 18: 271-284.

Gregory, R.S. 1993. The effect of turbidity on the predator avoidance behaviour of juvenile chinook salmon (*Oncorhyncchus tshawytscha*) in turbid laboratory conditions. Canadian Journal of Fisheries and Aquatic Sciences 50: 241-246.

Gregory, R.S. and T.G. Northcote. 1993. Surface, plantonic, and benthic foraging by juvenile chinook salmon (Oncorhynchus tshawytscha) in turbid laboratory conditions. Canadian Journal of Fisheries and Aquatic Sciences 50: 233-240.

Gregory, R.S. and C.D. Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus spp*., to predation by adult cutthroat trout, *O. clarkii*. Environmental Biology of Fishes 47: 279-288.

Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 45:502-515.

Holtby, L.B., T.E. McMahon, and J.C. Scrivener. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon (*Oncorhynchus kisutch*) smolts and fry and chum salmon (*O. keta*) fry from Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1396-1405.

Joy, Joe. 2001. Washington State Department of Ecology. E-mail. February 1, 2001.

King County, Department of Natural Resources, Water and Land Resources Division. June 2000. Water Quality Monitoring in Drainage Basins No. 6, No. 10, and No. 29: A Progress Report for the City of Mercer Island.

Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management 7: 34-45.

Lloyd, D.S., J.P. Koenings, J.D. LaPerriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7: 18-33.

McCabe, G.T., T.C. Coley, R.L. Emmett, W.D. Muir, and J.T. Durkin. 1981. The effects of the eruption of Mt. St. Helens on Fishes in the Columbia River Estuary. Estuaries. 4(3):p. 247.

McCabe, G.D., and W.J. O'Brien. 1983. The effects of suspended silt on feeding and reproduction of *Daphnia pulex*. American Midland Naturalist 110:324-337.

Michael, Hal. 2001. Washington State Department of Fish and Wildlife Hatchery Program. Personal communication..

Molash, Ed. 2001. Washington State Department of Transportation. Personal communication.

NAS (National Academy of Sciences) and NAE (National Academy of Engineering). 1973. Water quality criteria 1972. U.S. Environmental Protection Agency Ecological Research Series EPA-R3-73-033.

Newcomb, T.W., and T.A. Flagg. 1983. Some effects of Mt. St. Helens volcanic ash on juvenile salmon smolts. Mar. Fish. Review 45(2): 8-12.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11: 72-82.

Noggle, C.C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. Master's thesis. University of Washington, Seattle, Washington, USA.

Phillips, R.W., R.L. Lantz, E.W. Claire, and J.R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society 104(3):461-466.

Platts, W.S., and W.F. Megahan. 1975. Time trends in channel sediment size composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. USDA For. Serv. Gen. Rep. Intermountain For. And Range Exp. Stn., Ogden, Utah. 21 p.

Poole, G.C. and C.H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27(6): 787-802.

Quinn, T.P. and K. Fresh. 1984. Homing and straying in chinook salmon (Oncorhynchus tshawytscha) from Cowlitz River Hatchery, Washington. Can. J. Fish. Aquat. Sci. Vol. 41: 1078-1082

Redding, J.M., C.B. Schreck, and F.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the American Fisheries Society 116: 737-744.

Reid, L. M. 1998. Forest roads, chronic turbidity, and salmon. EOS, Transactions, American Geophysical Union 79(45): F285. Abstract from <www.rsl.psw.fs.fed.us/people/lreid.html>

Ritzenthaler, Elizabeth. 2001. King County Department of Natural Resources. Personal communication.

Rogers, B.A. 1969. Tolerance levels of four species of estuarine fishes to suspended mineral solids. M.S. thesis, Univ. Rhode Island, Kingston, RI. 60 p.

Rosenberg, D.M. and A.P. Wiens. 1978. Effects of sediment addition on macrobenthic invertebrates in a northern Canadian river. Water Research 12: 753-763.

Scrivener, J.C., and M.J. Brownlee. 1982. An analysis of Carnation Creek gravel-quality data 1973-1981. In G. F. Hartman [ed.] Proceedings of the Carnation Creek Workshop: A ten-year review, p. 154-173. Pacific Biological Station, Nanaimo, B.C.

Sedell, J.R., G.H. Reeves, F.R. Hauer, J.A. Stanford, and C.P. Hawkins. 1990. Role of refugia in recovery from disturbance: modern fragmented and disconnected river systems. Environmental Management. 14:711-724.

Servizi, J.A. and D.W. Martens. 1987. Some effects of suspended Fraser River sediments on sockeye salmon (*Oncorhynchus nerka*), p. 254-264. In H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Servizi, J.A. and D.W. Martens. 1992. Sublethal responses of coho salmon (*Oncorhynchus kisutch*) to suspended sediments. Can. J. Fish. Aquat. Sci., Vol. 49: 1389-1395.

Shelton, J.M., and R.D. Pollock. 1966. Siltation and egg survival in incubation channels. Transactions of the American Fisheries Society 95(2):183-187.

Shumway, D.L., C.E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society 93:342-356.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113: 142-150.

Smedley, S.C., K.E. Durleg, C.C. Larson, D. Bishop, W.L. Sheridan, and F. Stephens. 1970. ADF&G completion report – projects 5-8-R and 5-19-R; July 1, 1965 to June 30, 1970. Alaska Department of Fish and Game, Juneau. 82 p.

Sorbo, Trudy. 2001. Washington Department of Fish and Wildlife. Personal communication.

Sorenson, D.L., M.M. McCarthy, E.J. Middlebrooks, and D.B. Porcella. 1977. Suspended and dissolved solids effects on freshwater biota: a review. United States Environmental Protection Agency, Report 600/3-77-042, Environmental Research Laboratory, Corvallis, Oregon, USA.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. Management Technology. TR-4501-96-6057.

Steel, Ashley. 2001. National Marine Fisheries Service. Personal communication.

Tebo, L.B. 1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. The Progressive Fish-Culturist: 64-70.

Total Maximum Daily Load Report for the Yakima River. 1997. Washington State Department of Ecology. Pp. 30-33.

United States Fish and Wildlife Service. 1998. Bull Trout Interim Conservation Guidance. 47 pp.

Vaux, W.G. 1962. Interchange of stream and intragravel water in a salmon spawning riffle. U.S. Fish and Wildlife Service Spec. Sci. Rep., Fish. 405. 11 p.

Vogel, J.L. and D.A. Beauchamp. 1999. Effects of light, prey size, and turbidity on reaction distances of lake trout (*Salvelinus namaycush*) to salmonid prey. Canadian Journal of Fisheries and Aquatic Sciences 56: 1293-1297.

Waters, Thomas F. 1995. Sediment in Streams. Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. American Fisheries Society, Bethesda, Maryland.

Wedemeyer, G.A. and D.J. McLeay. 1981. Methods for Determining the Tolerance of Fishes to Environmental Stressors. Pp. 247-268. In A.D. Pickering [ed.] Stress and fish. Academic Press, Toronto, Ont.

Whitman, R.P., T.P. Quinn, and E.L. Brannon. 1982. Influence of suspended volcanic ash on homing behavior of adult chinook salmon. Transactions of the American Fisheries Society 111: 63-69.

Wiltsey, Mike. 2001. Oregon Department of Environmental Quality. Personal communication.

## Web Sites


1 Alaska Department of Environmental Conservation. Water Quality Standards. 1999. <http://www.state.ak.us/local/akpages/ENV.CONSERV/title18/70wqs.pdf>

2 British Columbia Ministry of Environment, Lands and Parks. British Columbia Water Approved Water Quality Guidelines (Criteria) 1998 Edition. < http://www.elp.gov.bc.ca/wat/wq/BCguidelines/turbidity.html>

3 Honeywell Micro Switch Division. Turbidity Sensing: Building Block for Smart Appliances. 1995. < http://content.honeywell.com/sensing/prodinfo/iatc95/index.stm >

4 Idaho Department of Environmental Quality. Idaho TMDL Approval Status Summary as of 2/6/2001. <www2.state.id.us/deq/water/tmdls/tmdlstatus2_6_01.htm>

5 Idaho Department of Environmental Quality. Idaho State Water Quality Standards (IDAPA 58.01.02) <http://www2.state.id.us/adm/adminrules/rules/idapa58/0102.pdf>

6 National Marine Fisheries Service. Major Threats and Impacts to Pacific Salmonids. 2000. <http://www.nmfs.noaa.gov/prot_res/PR3/Fish/salmon_impacts.html>

7 Oregon State Archives. Department of Environmental Quality. Water Pollution. State-Wide Water Quality Management Plan; Beneficial Uses, Policies, Standards, and Treatment Criteria for Oregon. (Administrative Code 340-041). 2001. < http://arcweb.sos.state.or.us/rules/OARS_300/OAR_340/340_041.html >

8 Washington State Department of Ecology. Citizen's Guide to TSS and Turbidity Chapter 3: Streams. <www.ecy.wa.gov/programs/wq/plants/management/joysmanual/streamtss.html>

9 Washington State Department of Ecology. Yakima Basin Water Quality. 2001. <http://www.ecy.wa.gov/programs/wq/tmdl/watershed/yakima_wq/index.html>

10 Washington State Department of Ecology Publications. A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River. 1997. <www.ecy.wa.gov/biblio/97321.html>

11 Washington State Department of Ecology Publications. River and Stream Ambient Monitoring Report for Water Year 1999. 2001. <http://www.ecy.wa.gov/biblio/0103013.html>

12 Washington State Department of Ecology Publications. Chapter 173-201A WAC, Water Quality Standards For Surface Waters Of The State Of Washington. <http://www.ecy.wa.gov/biblio/wac173201a.html>

## Appendix A. 1999 Washington State Water Quality Data (Web Site Ref. #11)

**Table A-1. Discharge (cfs) and turbidity (NTUs) measured in Western Washington streams during 1988-99** (Web Site Ref. #11)

| Sample month | Skagit River @ Marblemount Cfs NTU | Samish River near Burlington | NF Stillaguamish @Cicero | Stillaguamish R. near Silvana |
|---|---|---|---|---|
| October | 4390 0.6 | 150 6.3 | 1420 6 | 1400 8.3 |
| November | 6330 1.1 | 450 10 | 5300 145 | 5870 60 |
| December | 7600 1.4 | 793 16 | 6600 100 | 7710 55 |
| January | 8360 0.9 | 583 7.7 | 4840 170 | 8810 55 |
| February | 7640 0.5 | 406 5.5 | 1050 19 | 2830 29 |
| March | 6190 0.8 | 359 5.4 | 2260 22 | 5210 29 |
| April | 6230 1.6 | 327 9.6 | 2120 19 | 5890 60 |
| May | 12700 4.8 | 180 6.3 | 3690 60 | 8200 50 |
| June | 7080 3 .2 | 107 3.3 | 2010 8 | 4480 17 |
| July | 10600 2.7 | 78 2.2 | 1300 3.1 | 2460 4.9 |
| August | 8550 2.2 | 62 2.7 | 641 2.1 | 1600 4.2 |
| September | 4290 0.7 | 32 1.1 | 270 1.6 | 574 1.7 |

**Table A-2. Turbidity (NTUs) measured in three Western Washington streams during 1988-99**

| | Yearly Average | Summer Range (May-Oct.) | Winter Range (Nov. – Apr.) |
|---|---|---|---|
| Cedar River | 1.1 | 0.4 – 1.2 | 1.0 – 2.0 |
| Newaukum Creek | 2.4 | 0.7 – 1.5 | 3.1 – 4.0 |
| Springbrook Creek | 22.0 | 13.0 – 44.0 | 13.0 – 35.0 |

**Table A-3. TSS (mg/l) measured in three Western Washington streams during 1988-99**

| | Yearly Average | Summer Range (May-Oct.) | Winter Range (Nov. – Apr.) |
|---|---|---|---|
| Cedar River | 3.6 | 0.6 – 5.0 | 3.5 – 6.2 |
| Newaukum Creek | 5.7 | 1.6 – 5.1 | 7.5 – 8.8 |
| Springbrook Creek | 19.8 | 8.0 – 26.0 | 6.7 – 44.0 |

Source: Metro 1990. *Quality of Local Lakes and Streams 1988-89 Status Report.* Municipality of Metropolitan Seattle, Water Resources Section, from: Washington Department of Ecology, A Citizen's Guide to Understanding and Monitoring Lakes and Streams. (Web Site Ref. #8)

## Appendix B. Tables from Newcombe and MacDonald (1991)

**Table B-1. Summary of data (in situ observations) on exposures to suspended sediment that resulted in lethal responses in salmonid fishes.** Within species groups, stress indices are arranged in increasing order. For exposure, C= concentration (mg/l) and D = duration (h).

| | ***Exposure*** | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index ($\log^e$* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Arctic grayling | 25 | 24 | 6.397 | 6% mortality of sac fry | 10 | Reynolds et al. (1988) |
| | 23 | 48 | 7.007 | 14% mortality of sac fry | 10 | Reynolds et al. (1988) |
| | 65 | 24 | 7.352 | 15% mortality of sac fry | 10 | Reynolds et al. (1988) |
| | 22 | 72 | 7.368 | 15% mortality of sac fry | 10 | Reynolds et al. (1988) |
| | 20 | 96 | 7.560 | 13% mortality of sac fry | 10 | Reynolds et al. (1988) |
| | 143 | 48 | 8.834 | 26% mortality of sac fry | 11 | Reynolds et al. (1988) |
| | 185 | 72 | 9.497 | 41% mortality of sac fry | 12 | Reynolds et al. (1988) |
| | 230 | 96 | 10.002 | 47% mortality of sac fry | 12 | Reynolds et al. (1988) |
| | 20.000 | 96 | 14.468 | 10% mortality of age-0 fish | 10 | McLeay et al. (1987) |
| | 100,000 | 96 | 16.077 | 20% mortality of age-0 fish | 10 | McLeay et al. (1987) |
| Chinook salmon | 488 | 96 | 10.755 | 50% mortality of smolts (high T*C) | 12 | Stober et al. (1981) |
| Coho salmon | 509 | 96 | 10.797 | 50% mortality of smolts (high T*C) | 12 | Stober et al. (1981) |
| Chinook and sockeye salmon | 1,400[b] | 36 | 10.827 | 10% mortality of juveniles | 10 | Newcomb and Flagg (1983) |
| Coho salmon | 1,200 | 96 | 11.654 | 50% mortality of juveniles | 12 | Noggle (1978) |
| | 1,217 | 96 | 11.668 | 50% mortality of pre-smolts (high T*C) | 12 | Stober et al. (1981) |
| Chinook and sockeye salmon | 207,000[b] | 1 | 12.240 | 100% mortality of juveniles | 14 | Newcomb and Flagg (1983) |
| | 9,400 | 36 | 12.732 | 50% mortality of juveniles | 12 | Newcombe and Flagg (1983) |
| Chum salmon | 97 | 3,912[b] | 12.847 | 77% mortality of eggs and alevins | 13 | Langer (1980) |

**Table B-1 (cont.)**. Summary of data (in situ observations) on exposures to suspended sediment that resulted in **lethal** responses in salmonid fishes. Within species groups, stress indices are arranged in increasing order. For exposure, C= concentration (mg/l) and D = duration (h).

| | *Exposure* | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index ($log^e$* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Chum salmon | 111 | 3,912[b] | 12.981 | 90% mortality of eggs and alevins | 14 | Langer (1980) |
| Chinook and sockeye salmon | 82,000 | 6 | 13.106 | 60% mortality of juveniles | 12 | Newcomb and Flagg (1983) |
| Coho salmon | 18,672 | 96 | 14.400 | 50% mortality of presmolts | 12 | Stober et al. (1981) |
| Chinook salmon | 19,364 | 96 | 14.436 | 50% mortality of smolts | 12 | Stober et al. (1981) |
| Chum salmon | 28,000 | 96 | 14.804 | 50% mortality of juveniles | 12 | Smith (1939) |
| Coho salmon | 28,134 | 96 | 14.811 | 50% mortality of smolts | 12 | Stober et al. (1981) |
| | 29,580 | 96 | 14.859 | 50% mortality of smolts | 12 | Stober et al. (1981) |
| | 35,000[b] | 96 | 15.027 | 50% mortality of juveniles | 12 | Noggle (1978) |
| Chinook and sockeye salmon | 39,400 | 36 | 15.145 | 90% mortality of juveniles | 14 | Newcombe and Flagg (1983) |
| Chum salmon | 55,000 | 96 | 15.479 | 50% mortality of juveniles | 12 | Smith (1939) |
| Whitefish | 16,613 | 96[b] | 14.282 | 50% mortality of juveniles | 12 | Lawrence and Scherer (1974) |
| Rainbow trout | 200[c] | 24 | 8.476 | 5% mortality of fry | 10 | Hebert and Richards (1963) |
| | 7 | 1,152 | 8.995 | 17% reduction in egg-to-fry survival | 10 | Slaney et al. (1977b) |
| | 21 | 1,152 | 10.094 | 62% reduction in egg-to-fry survival | 13 | Slaney et al. (1977b) |
| | 200[c] | 168 | 10.422 | 8% mortality of fry | 10 | Herbert and Richards (1963) |
| | 90 | 456 | 10.622 | 5% mortality of sub-adults | 10 | Herbert and Merkens (1961) |
| | 68 | 720[b] | 10.799 | 25% reduction in population size | 11 | Peters (1967) |
| | 37 | 1,440 | 10.883 | 46% reduction in egg-to-fry survival | 12 | Slaney et al. (1997b) |
| | 47 | 1,152 | 10.889 | 100% mortality of incubating eggs | 14 | Slaney et al. (1997b) |
| | 57 | 1,440 | 11.315 | 23% reduction in egg-to-fry survival | 11 | Slaney et al. (1997b) |
| | 270[d] | 456 | 11.721 | 10-35% mortality of sub-adults | 11 | Herbert and Merkens (1961) |

**Table B-1 (cont.)**. Summary of data (in situ observations) on exposures to suspended sediment that resulted in **lethal** responses in salmonid fishes. Within species groups, stress indices are arranged in increasing order. For exposure, C= concentration (mg/l) and D = duration (h).

| | *Exposure* | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index (log[e]* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Rainbow trout | 270[c] | 456 | 11.721 | 80% mortality of sub-adults | 13 | Herbert and Merkens (1961) |
| | 101 | 1,440 | 11.888 | 98% mortality of eggs (high metals and NH3 levels) | 14 | Turnpenny and Williams (1980) |
| Brown trout | 110 | 1,440 | 11.973 | 98% mortality of eggs | 14 | Scullion and Edwards (1980) |
| Rainbow and brown trout | 300 | 720[b] | 12.283 | 97% reduction in population size | 14 | Peters (1967) |
| Rainbow trout | 1,000-2,500 | 144 | 12.437 | 100% mortality of eggs | 14 | Campbell (1954) |
| | 157 | 1,728 | 12.511 | 100% mortality of eggs | 14 | Shaw and Maga (1943) |
| | 810[d] | 456 | 12.820 | 5-80% mortality of sub-adults | 13 | Herbert and Merkens (1961) |
| | 810[c] | 456 | 12.820 | 80-85% mortality of sub-adults | 14 | Herbert and Merkens (1961) |
| | 200[c] | 2,352 | 13.061 | 50% mortality of fry | 12 | Herbert and Richards (1963) |
| | 1,000-2,500 | 480 | 13.641 | 57% mortality of fingerlings | 12 | Campbell (1954) |
| | 4,250 | 588 | 14.731 | 50% mortality (life stage not specified) | 12 | Herbert and Wakeford (1962) |
| | 160,000 | 24 | 15.161 | 100 | 14 | D.W. Herbert, pers. commun. in Alabaster and Lloyd (1982) |
| | 49,000 | 96 | 15.363 | 50% mortality of juveniles | 12 | Lawrence and Scherer (1974) |
| | 1,000-6,000 | 1,440[b] | 15.432 | 85% reduction in population size | 14 | Herbert and Merkens (1961) |
| Brown trout | 1,040 | 8,670 | 16.024 | 85% reduction in population size | 14 | Herbert et al. (1961) |
| | 5,838 | 8,670 | 17.750 | 85% reduction in population size | 14 | Herbert et al. (1961) |

a Scientific names: Arctic grayling, *Thymallus arcticus*, chinook salmon, *Oncorhynchus tshawytscha*, coho salmon, *O. kisutch*; sockeye salmon, *O. nerka*; chum salmon, *O. keta*; whitefish, Coregonus sp.; rainbow trout, *Oncorhynchus mykiss*; brown trout, *Salmon trutta*.
b Estimated.
c Wood fiber.
d Kaolin.
e Diatomaceous earth.

**Table B-2. Summary of data on exposures to suspended sediment that resulted in sublethal responses in salmonid fishes.** Within species groups, stress indices are in increasing order. For exposure, C = concentration (mg/l) and D = duration (h).

| | ***Exposure*** | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index (log[e]* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Arctic grayling | 100 | 1 | 4.605 | Reduction in feeding rate | 4 | McLeay et al. (1984) |
| | 100 | 1,008 | 11.521 | 6% reduction in growth rate | 9 | McLeay et al. (1984) |
| | 300 | 1,008 | 12.620 | Physiological stress | 8 | McLeay et al. (1987) |
| | 300 | 1,008 | 12.620 | 10% reduction in growth rate | 9 | McLeay et al. (1987) |
| | 1,000 | 1,008 | 13.823 | 33% reduction in growth rate | 9 | McLeay et al. (1987) |
| Coho salmon | 14 | 1 | 2.639 | Reduction in feeding efficiency | 4 | Berg and Northcote (1985) |
| | 100 | 1[b] | 4.605 | 45% reduction in feeding rate | 4 | Noggle (1978) |
| | 250 | 1[b] | 5.521 | 90% reduction in feeding rate | 4 | Noggle (1978) |
| | 300 | 1[b] | 5.704 | Feeding ceased | 4 | Noggle (1978) |
| | 53.5 | 12 | 6.465 | Physiological stress, changes in behavior | 8 | Berg (1983) |
| Chinook salmon | 1.5-2.0[c] | 1,440 | 7,832 | Gill hyperplasia, poor condition of fry | 8 | Anderson, USFWS, pers. commun. |
| | 6[c] | 1,440 | 9.064 | Reduction in growth rate | 9 | MacKinlay et al. (1987) |
| | 75 | 168[b] | 9.441 | Harm to quality of habitat | 7 | Slaney et al. (1977a) |
| | 84[d] | 336 | 10.248 | Reduction in growth rate | 9 | Sigler et al. (1984) |
| | 1,547 | 96 | 11.908 | Histological damage to gills | 8 | Noggle (1978) |
| Cutthroat trout | 35 | 2 | 4.248 | Feeding ceased, cover sought | 4 | Bachmann (1958) |
| Rainbow trout | 500 | 9 | 8.412 | Physiological ill effects | 8 | Redding and Schreck (1980) |
| | 171 | 96 | 9.706 | Histological damage | 8 | Goldes (1983) |
| Steelhead | 84[d] | 336 | 10.248 | Reduction in growth rate | 9 | Sigler et al. (1984) |
| Rainbow trout | 50[c] | 960[b] | 10.779 | Reduction in growth rate | 9 | Herbert and Richards (1963) |
| | 50[f] | 960[b] | 10.779 | Reduction in growth rate | 9 | Herbert and Richards (1963) |
| Trout | 270 | 312[b] | 11.341 | Histological damage to gills | 8 | Herbert and Merkens (1961) |

**Table B-2 (cont.).** Summary of data on exposures to suspended sediment that resulted in **sublethal** responses in salmonid fishes. Within species groups, stress indices are in increasing order. For exposure, C = concentration (mg/l) and D = duration (h).

| | ***Exposure*** | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index ($log^e$* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Rainbow trout | 50[c] | 1,848 | 11.434 | Reduction in growth rate | 9 | Sykora et al. (1972) |
| Rainbow trout | 5,000-300,000 | 168 | 13.641-17.736 | Fish survived, but gill epithelium harmed | 8 | Slanina (1962) |
| Brook trout | 12[c] | 5,880 | 11.164 | Reduction in growth rate, reduced condition | 9 | Sykora et al. (1972) |
| | 100[c] | 1,176[b] | 11.675 | Reduction in growth rate | 9 | Sykora et al. (1972) |
| | 24[c] | 5,280 | 11.736 | Reduction in growth rate | 9 | Sykora et al. (1972) |

a Scientific names: cutthroat trout, *Oncorhynchus clarki*; steelhead = anadromous rainbow trout; brook trout, *Salvelinus fontinalis*
b Estimated
c Lime-neutralized iron hydroxide
d Fire clay
e Coal dust
f Wood fiber

**Table B-3. Summary of data on exposures to suspended sediment that resulted in behavioral responses in salmonid fishes.** Within species groups, stress indices are in increasing order. For exposure, C = concentration (mg/l) and D = duration (h).

| | ***Exposure*** | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **C** | **D** | **Stress index (log$^{e}$* [CxD])** | **Effect** | **Rank of Effect** | **Source** |
| Arctic grayling | 100[a] | 1 | 2.303 | Avoidance response | 3 | Suchanek et al. (1984a), Suchanek et al. (1984b) |
| Coho salmon | 54 | 0.02 | 0.077 | Alarm reaction | 2 | Berg (1983) |
| | 88 | 0.02 | 0.565 | Alarm reaction | 2 | Bisson and Bilby (1982) |
| | 4.3[b] | 1 | 1.447 | Avoidance response | 3 | Updegraff and Sykora (1976) |
| | 88 | 0.08 | 1.952 | Avoidance response | 3 | Bisson and Bilby (1982) |
| | 25 | 4 | 4.605 | Sport fishing declines | 4 | Phillips (1970) |
| Salmon | 8 | 24 | 5.257 | Sport fishing declines | 4 | A.H. Townsend, unpublished, cited in Lloyd (1985) |
| Chinook salmon | 650 | 1 | 6.477 | Homing performance disrupted | 5 | Whitman et al. (1982) |
| Coho salmon | 6,000[a] | 0 | 8.700 | Avoidance response | 3 | Noggle (1978) |
| Whitefish | 0.7 | 1 | -0.416 | Overhead cover abandoned | 3 | Lawrence and Scherer (1974) |
| Rainbow trout | 100[a] | 1 | 2.303 | Avoidance response | 3 | Suchanek et al. (1984a), Suchanek et al. (1984b) |
| | 100[c] | 0.25 | 3.219 | Coughing rate increased | 1 | Hughes (1975) |
| | 250[d] | 0.25 | 4.135 | Coughing rate increased | 1 | Hughes (1975) |
| | 66 | 1 | 4.190 | Avoidance response | 3 | Lawrence and Scherer (1974) |
| Trout | 8 | 24[a] | 5.257 | Sport fishing declines | 4 | A.H. Townsend, unpublished, cited in Lloyd (1985) |
| Rainbow trout | 665 | 1[a] | 6.500 | Overhead cover abandoned | 3 | Lawrence and Scherer (1974) |
| Brook trout | 4.5 | 168[a] | 6.628 | Overhead cover abandoned | 3 | Gradall and Swenson (1982) |

a Estimated.
b Lime-neutralized iron hydroxide.
c Coal dust.
d Wood fiber.

# Appendix C.  Individual State Turbidity Standards

The following section illustrates specific turbidity regulations for the states of Alaska, Idaho, Oregon and Washington, and the Province of British Columbia.

### Alaska State Turbidity Standards

According to Lloyd (1987), Alaska does not have a numerical standard for suspended solid concentrations in drinking water supplies.  The state has a narrative standard for sediment.

> No measurable increase in concentrations of sediment including settleable solids, above natural levels. [AAC 1985].

> Alaska has a sediment standard for the propagation of fish and wildlife:

> The percent accumulation of fine sediment in the range of 0.1 mm to 4.0 mm in the gravel bed of waters utilized by anadromous or resident fish for spawning may not be increased more than 5% by weight over natural condition (as shown from grain size accumulation graph).  In no case may the 0.1 mm to 4.0 mm fine sediment range in the gravel bed of waters utilized by anadromous or resident fish for spawning exceed a maximum of 30% by weight (as shown from grain size accumulation graph).  [AAC 1985], taken from (Lloyd 1987)

**Table C-1. Alaska state turbidity standards** (Web Site Ref. #1)

| (1) Fresh Water Uses | Turbidity (not applicable to groundwater) |
|---|---|
| (A) Water Supply (i) drinking, culinary, and food processing | May not exceed 5 nephelometric turbidity units (NTU) above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU. |
| (A) Water Supply (ii) agriculture, including irrigation and stock watering | May not cause detrimental effects on indicated use. |
| (A) Water Supply (iii) aquaculture | May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions. |
| (A) Water Supply (iv) industrial | May not cause detrimental effects on established water supply treatment levels. |
| (B) Water Recreation (I) contact recreation | May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters. |
| (B) Water Recreation (I) secondary recreation | May not exceed 10 NTU above natural conditions when natural turbidity is 50 NTU or less, and may not have more than 20% increase in turbidity when the natural turbidity is greater than 50 NTU, not to exceed a maximum increase of 15 NTU. For all lake waters, turbidity may not exceed 5 NTU above natural turbidity. |
| (C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife | Same as (1)(A)(iii). |

**Idaho State Turbidity Standards**

The Idaho Division of Environmental Quality adopted turbidity criteria for the protection of cold water biota in 1994. The criteria focus on requirements of salmon as an indicator species. The 50 NTU background turbidity is based on data suggesting that displacement of salmonids occurs at 50 NTU (Lloyd et al. 1987). The 25 NTU for 10 days limit is based on literature showing that salmonid feeding and growth are affected by prolonged exposure to turbidity over 25 NTU (Sigler et al. 1984).

Surface Water Quality Criteria for aquatic life use designations – turbidity, below any applicable mixing zone set by the Department shall not exceed background turbidity by more than fifty (50) NTU instantaneously or more than twenty-five (25) NTU for more then ten (10) consecutive days.

For comparison, turbidity criteria for water supply (measured at a public water intake) is as follows:

(1) No increase by more than five (5) NTU above natural background, measured at a location upstream from or not influenced by any human induced non-point source activity, when background turbidity is fifty (50) NTU or less.

(2) No increase by more than ten percent (10%) above natural background, measured at a location upstream from or not influenced by any human induced non-point source activity, not to exceed twenty-five (25) NTU, when background turbidity is greater than fifty (50) NTU (Web Site Ref. #5).

**Oregon State Turbidity Standards**

Oregon turbidity standards are applied to all watersheds in the state. The requirement may be applied to temporary projects affecting a stream or activities responsible for long-term sediment inputs.

In all basins, no more than 10% cumulative increase in natural stream turbidities shall be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity. The criteria for listing a water body as 303(d) limited due to turbidity is a systematic or persistent increase (of greater than 10%) in turbidity due to an operational activity that occurs on a persistent basis (e.g., dam release, irrigation return) The requirements for listing a water body include collection of TSS data since water year 1986 (10/85) on a frequent enough basis (e.g., daily) to establish a relationship between water quality and a turbidity causing activity (Oregon Administrative Code).

Limited duration activities necessary to address an emergency or to accommodate essential dredging, construction, or other legitimate activities and which cause the standard to be exceeded may be authorized provided “practicable” turbidity control techniques have been applied and one of the following has been granted:

(A) Emergency activities: Approval coordinated by the Department of Environmental Quality with Department of Fish and Wildlife under conditions they may prescribe to accommodate response to emergencies or to protect public health and welfare;

(B) Dredging, Construction or other Legitimate Activities: Permit or certification authorized under terms of Section 401 or 404 (Permits and Licenses, Federal Water Pollution Control Act) or Oregon Administrative Rule 141-085-0100 et seq. (Removal and Fill Permits, Division of State Lands), with limitations and conditions governing the activity set forth in the permit or certificate (Web Site Ref. #7).

**Washington State Turbidity Standards**

**Table C-2. Washington state turbidity standards**

| Class A Waters | Class B Waters |
|---|---|
| Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background is more than 50 NTU. | Turbidity shall not exceed 10 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 20 percent increase in turbidity when the background is more than 50 NTU |

(Web Site Ref. #12)

**British Columbia Standards**

**Table C-3. British Columbia turbidity and suspended sediment standards**

| Water Use | Maximum Induced Turbidity – NTU or % of background | Maximum Induced Suspended Sediments –mg/l or % of background | Streambed Substrate Composition |
|---|---|---|---|
| Drinking Water – raw untreated | 1 NTU when background is less than or equal to 5 | No guideline | No guideline |
| Drinking Water – raw treated | 5 NTU when background is less than or equal to 50 | No guideline | No guideline |
| Recreation and Aesthetics | Maximum 50 NTU ….. secchi disc visible at 1.2 m | No guideline | No guideline |
| Aquatic Life -fresh- -marine- -estuarine- | 8 NTU in 24 hours when background is less than or equal to 8 …. Mean of 2 NTU in 30 days when background is less than or equal to 8 | 25 mg/l in 24 hours when background is less than or equal to 25 …. Mean of 5 mg/l in 30 days when background is less than or equal to 25 | Fines not to exceed -10% as less than 2mm- -19% as less than 3mm- -25% as less than 6.35mm- at salmonid spawning sites |
| Aquatic Life -fresh- -marine- -estuarine- | 8 NTU when background is between 8 and 80 …. 10% when background is greater than or equal to 80 | 25 mg/l when background is between 25 and 250 …. 10% when background is greater than or equal to 250 | Geometric mean diameter not less than 12 mm …. Fredle number not less than 5mm |
| Terrestrial Life -wildlife- -livestock water- Irrigation Industrial | 10 NTU when background is less than or equal to 50 …. 20% when background is greater than or equal to 50 | 20 mg/l when background is less than or equal to 100 …. 20% when background is greater than or equal to 100 | No guideline |

(Web Site Ref. #2)

**European Inland Fisheries Advisory Committee (EIFAC)**

EIFAC (1965) presented five pathways that fine sediments may harm freshwater fishes:

1. By acting directly on the fish swimming in water in which solids are suspended, and either killing them or reducing their growth rate, affecting their resistance to disease
2. Preventing the successful development of fish eggs and larvae
3. By modifying natural movements and migrations of fish
4. By reducing the abundance of food available to the fish
5. By affecting the efficiency of methods of catching fish

Subsequent EIFAC recommendations:

| Level of Protection | Maximum Concentration of Suspended Solids |
|---|---|
| High | 25 mg/l |
| Moderate | 80 mg/l |
| Low | 400 mg/l |
| Very Low | over 400 mg/l |

(Protective levels established based on EIFAC Study.)

## Appendix D. Total Maximum Daily Loads

The Total Maximum Daily Load (TMDL) process was established by section 303(d) of the Clean Water Act. Federal law requires states to identify sources of pollution in waters that fail to meet state water quality standards after all point sources have been permitted and to develop cleanup plans to address pollutants of concern. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meets state water quality standards. Percentages of the total maximum daily load are allocated to the various pollutant sources. (Web Site Ref. #11).

Uses are identified for each water body, such as drinking water, contact recreation, and aquatic life support. The TMDL is meant to reflect the sum of allowable loads from a single pollutant for all point and non-point sources. TMDL calculations include a "margin of safety" to ensure protection in the case of unforeseen events or unknown sources of the pollutant. Calculation must also account for seasonable variation in background water quality (Web Site Ref. #11).

In Oregon and Washington, few rivers to date have TMDL requirements for 1) turbidity levels or 2) suspended solids.

**Umatilla TMDL (Oregon)**

The Umatilla TMDL for turbidity requires that measurements not exceed 30 NTU for 48 hours. The state collected TSS and turbidity data with automated ISCO samplers in the Umatilla, and determined that the Umatilla needed improvement in this area. The state did not focus on background concentrations. High turbidity levels in the Umatilla are associated with agricultural practices in the watershed. Upstream forested areas did not require a sediment load allocation. The TSS requirement for the Umatilla is 80-110 mg/l, except when stream flow is high (greater than 1.5 times bank) (Wiltsey, pers. commun.).

**Lower Yakima TMDL (Washington)**

The Washington State Department of Ecology conducted a TMDL evaluation of the lower Yakima River basin in 1994 and 1995. The process was conducted with the cooperation of the Yakama Nation and the USEPA. The evaluation focused on total suspended sediment (TSS) and DDT loads from irrigated agricultural areas during the irrigation season. Historical and TMDL data indicated significant correlations between TSS and turbidity, and TSS and DDT. It was assumed reductions in TSS would decrease DDT levels. Turbidity targets were recommended for mainstem and tributary sites on a 15-year implementation schedule (Web Site Ref. #10).

The Department of Ecology needed to build a "narrative criteria" argument because the state water quality criteria were written exclusively for point source rather than non-point source control. There are few turbidity (under 10) listings on the state 303(d) list because the criteria require a "background" turbidity measurement. Few monitoring agencies are equipped to establish a background NTU value when turbid conditions arise from a diffuse set of streams affected by non-point sources. The Palouse River is and example of a river with TSS concentrations in the hundreds and thousands that has escaped 303(d) listing. Glacial headwaters are not helpful in some systems either, as they may produce a high level of natural background turbidity (Joy, e-mail).

The Washington State Class A turbidity criterion was applied to the mainstem to control TSS loading. In-stream turbidity will be limited to a 5 NTU increase in the 86.4 mile reach between the confluence of the Yakima and Naches River and Benton city. A $90^{th}$ percentile turbidity target of 25 NTUs (56 mg/l TSS) for the tributaries and return drains was recommended to significantly reduce t-DDT loads and to protect aquatic communities from TSS effects. The target will require the largest return drains to reduce TSS loads 70% or more during an irrigation season with normal water availability. Based on the current correlation equation, tributary TSS concentrations will need to be further reduced to 7 mg/l to meet the 1 mg/l DDT chronic toxicity criterion for protection of aquatic life. However, more data from tributaries for TSS and t-DDT at lower TSS concentrations are needed to confirm this target (Web Site Ref. #10).

Currently, two systems in Washington State with turbidity problems are targeted for TMDL work: the upper Yakima River and tributaries, and Portage Creek in the Stillaguamish River System. The state is applying narrative type criteria for protection of aquatic life where it is unable to provide background conditions for applying turbidity criteria. (Joy, e-mail).

**Idaho TMDLs**

The State of Idaho has developed a number of TMDLs focused on reducing sediment as a pollutant. (Web Site Ref. #4)

| Watershed/Sub-Basin with sediment | TMDLs done for sediment |
|---|---|
| Paradise Creek (1997) | 1 segment |
| Lower Boise River (1998) | 3 segment |
| MF Payette River (1998) | 1 segment |
| Winchester Lake (1998) and Upper Lapwai (2003) | 1 lake for sediment, 1 river segment for sediment |
| Portneuf River (1998) | 26 segments |
| Lake Walcott (1999) | 3 segments |
| Upper Snake-Rock (1999) | 34 segments |
| Lemhi River (1998) | 7 segments |
| Coeur d'Alene Lake/Lower River (1999) | 7 segments |
| Pend Oreille (1999) | 4 segments |
| Jim Ford Creek (1999 & 2003) | 1 segments |
| Cottonwood Creek (1999 & 2003) | 6 segments |
| Little Lost (1999) | 3 segments |
| Bruneau (2000) | 3 segments |
| Palisades (2000) | 2 segments |

**Summary**

TMDLs offer an opportunity for regulators and stakeholders in a watershed to reduce pollutant loads in the system. In Washington, Oregon, and Idaho, control of sediment is of concern, particularly in agricultural areas. Sediment is a concern both for its direct physical effect on aquatic life and its ability to transport pesticides through the river system.

# Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish

**Alex De Robertis, Clifford H. Ryer, Adriana Veloza, and Richard D. Brodeur**

**Abstract:** Contrast degradation theory predicts that increased turbidity decreases the visibility of objects that are visible at longer distances more than that of objects that are visible at short distances. Consequently, turbidity should disproportionately decrease feeding rates by piscivorous fish, which feed on larger and more visible prey than particle-feeding planktivorous fish. We tested this prediction in a series of laboratory feeding experiments, the results of which indicated that prey consumption by two species of planktivorous fish (juvenile chum salmon (*Oncorhynchus keta*) and walleye pollock (*Theragra chalcogramma*)) is much less sensitive to elevated turbidity than piscivorous feeding by sablefish (*Anoplopoma fimbria*). Planktivorous feeding in the turbidity range tested (0-40 nephelometric turbidity units (NTU)) was reduced at high light intensity, but not at low light intensity. Comparatively low (5-10 NTU) turbidity decreased both the rate at which sablefish pursued prey and the probability of successful prey capture. These results suggest that turbid environments may be advantageous for planktivorous fish because they will be less vulnerable to predation by piscivores, but will not experience a substantial decrease in their ability to capture zooplankton prey.

**Resume :** La theorie de la degradation des contrastes predit qu'une turbidite accrue decroit plus la visibilite d'objets qui sont visibles a de plus grandes distances que celle d'objets visibles a de courtes distances. En consequence, la turbidite devrait faire decroitre de fa9on disproportionnee les taux d'alimentation des poissons piscivores qui se nourrissent de proies plus grandes et plus visibles par comparaison aux taux d'alimentation des poissons planctonophages qui se nourrissent de particules. Une serie d'experiences d'alimentation en laboratoire nous a permis de verifier cette prediction : la consommation de proies de deux especes de poissons planctonophages, de jeunes saumons keta (*Oncorhynchus keta*) et des goberges de l'Alaska (*Theragra chalcogramma*), est beaucoup moins affectee par une augmentation de la turbidite que la consommation de poissons par des morues charbonnieres (*Anoplopoma fimbria*). Dans la gamme des turbidites etudiees (0-40 unites nephelometriques de turbidite, NTU), l'alimentation des planctonophages est reduite aux fortes intensites de lumiere, mais non aux intensites faibles. Des turbidites relativement faibles (5-10 NTU) entrainent une reduction du taux de poursuite ainsi que de la probabilite de capture des proies chez la morue charbonniere. Ces resultats semblent demontrer qu'un environnement turbide peut etre avantageux pour les poissons planctonophages parce qu'ils y sont moins vulnerables a la predation par les poissons piscivores, sans que leur capacite a capturer des proies zooplanctoniques ne soit substantiellement reduite.

[Traduit par la Redaction]

## Introduction

Scattering and absorption of light by suspended materials in turbid waters limits visibility in aquatic environments through two primary mechanisms. Under elevated turbidity, light attenuation increases (Kirk 1985), decreasing light penetration, which impairs vision. This process is of particular importance to organisms occupying deeper waters because small turbidity-induced changes in light extinction coefficients have large cumulative effects at depth (Eiane et al. 1999). In addition to reducing ambient light intensity, turbidity can impair visibility by degrading apparent contrast (Lythgoe 1979). Scattering of light by suspended materials reduces the apparent difference in brightness between an object and its background, which decreases the visibility of the object. For an object to be visible, its apparent contrast must exceed a physiological threshold value known as the contrast threshold. The contrast threshold of fish depends on factors such as object size and light intensity (Anthony 1981) but should remain constant for a given prey and illumination. In water, the scattering of light due to suspended particles influences contrast as follows (Duntley 1962):

Received 3 January 2003. Accepted 31 August 2003. Published on the NRC Research Press Web site at http://cjfas.nrc.ca on 22 December 2003.
J17264

**A. De Robertis[1,2] and R.D. Brodeur.** Estuarine and Ocean Ecology Program, Fish Ecology Division, Northwest Fisheries Science Center, NMFS, NOAA, Hatfield Marine Science Center, Newport, OR 97365, U.S.A.
**C.H. Ryer.** Fisheries Behavioral Ecology Program, Alaska Fisheries Science Center, NMFS, NOAA, Hatfield Marine Science Center, Newport, OR 97365, U.S.A.
**A. Veloza.** Biology Department, East Stroudsburg University, East Stroudsburg, PA 18301, U.S.A.

[1]Corresponding author (e-mail: Alex.DeRobertis@noaa.gov).
[2]Present address: Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115-0070, U.S.A.

 doi: 10.1139/F03-123 

(1) $C_{\mathrm{a}} = C_0 \mathrm{e}^{-\alpha r}$

where $C_{\mathrm{a}}$ is apparent contrast, $C_0$ is inherent contrast of the object, $\alpha$ is the beam attenuation coefficient for visible light (a measure of water clarity and the sum of the absorption ($a$) and scattering ($b$) coefficients for visible light), and $r$ is the distance between the object and the eye. The degree of contrast degradation thus depends on the optical properties of the water and increases exponentially with the distance between the object and the eye. Thus, for a given increase in turbidity ($\alpha$), contrast degradation will reduce the visibility of large prey such as fish that can be seen at great distances (i.e., large $r$), much more than the visibility of small prey that can only be seen at short distances (i.e., small $r$). Likewise, contrast degradation is likely to be an important factor in near-surface waters during the day when light intensity is relatively high and prey-sighting distances are long and likely to be less important when light intensity is relatively low and prey-sighting distances are short.

Fishes are the primary visual predators in many aquatic systems and are often functionally divided into piscivores and planktivores, based on their primary prey. The ability of visually foraging fish to detect prey depends on light intensity, water clarity, and prey characteristics such as size, pigmentation, and motion (Confer et al. 1978; O'Brien 1987; Aksnes and Utne 1997). Piscivorous and planktivorous fish consume prey of different sizes, and changes in water clarity are likely to affect them in different ways. Piscivores feed on large conspicuous fish, whereas planktivorous fish feed on small, comparatively inconspicuous zooplankton. Under high light intensity in clear water, piscivores are able to detect fish prey at distances much larger than those at which planktivorous fish are able to detect zooplankton prey (Breck 1993). Thus, for a given increase in turbidity, contrast degradation should disproportionately impair prey detection by piscivores relative to planktivores. All other things being equal, moderately turbid waters may be advantageous habitats for planktivorous fish because their encounter rates with piscivorous predators are reduced more than their encounter rates with planktonic prey.

In this study, we examine the effect of turbidity-induced light scatter on feeding rates in a series of laboratory experiments using two species of fish that are planktivorous as juveniles, chum salmon (*Oncorhynchus keta*) and walleye pollock (*Theragra chalcogramma*), and a piscivore, sablefish (*Anaplopoma fimbria*). We test the prediction that increased turbidity depresses the feeding rates of piscivores more than those of planktivores. In addition, we test the hypothesis that feeding by planktivorous fish is more likely to be impaired by increases in turbidity at high light levels when zooplankton prey are visible at longer distances.

## Materials and methods

### Fish collection and maintenance

Chum salmon were raised from eggs collected from wild adults returning to Whiskey Creek, Tillamook County, Oregon, in November 2001. When the chum had completely absorbed their yolk sac, they were transferred to seawater. Juvenile walleye pollock (45-60 mm) were captured in May 2002 from Puget Sound near Port Townsend, Washington, by dip-netting them as they aggregated around a light. Fish were transported to the laboratory and held in 720-L tanks provided with a continuous flow of seawater. Pollock were held in the laboratory for 4-6 weeks before experimentation, and chum were held for 6 months before beginning experiments. Sablefish used as predators in the piscivory experiments were collected as �50-mm juveniles 32 km off the coast of Newport, Oregon, in May 2001 and were held in the laboratory for 13 months. All species were primarily fed formulated foods at rations sufficient to promote growth, but they readily consumed live prey.

### Planktivory experiments

Feeding rates of juvenile chum and pollock were measured under varying levels of turbidity and light intensity in six replicate 50 cm x 50 cm x 50 cm glass tanks supplied with flow-through seawater and located inside a light-proof blind. Each tank was equipped with a feeding tube that allowed prey to be introduced from the other side of the blind with minimum disturbance of the experimental fish. The experimental system has been described in detail elsewhere (Ryer and Olla 1999) and will be described only briefly here. Visible illumination was provided by four green 555-nm light emitting diode (LED) illuminators that could be controlled to produce irradiances between 1.9 x $10^{-7}$ and 1.0 x $10^{-3}$ $\mu E \cdot m^{-2} \cdot s^{-1}$. Green LEDs were selected to mimic the predominant wavelengths of light in coastal marine waters during both day and night (McFarland 1986). Light levels above 1.0 x $10^{-3}$ $\mu E \cdot m^{-2} \cdot s^{-1}$ were achieved by supplementing the LED illuminators with additional light emitted by a rheostat-controlled 40-W incandescent light mounted above each tank and reflected from a white ceiling 150 cm above the tank.

Fish are differentially sensitive to different wavelengths of light, and it is unclear how a shift from green to white light may have affected the response of the planktivores. However, changes in spectral composition of light in the experiments are unlikely to have biased the results to a great degree as in both these and previous experiments (Ryer and Olla 1999), planktivorous feeding in the apparatus occurred well below the change from green to multispectral illumination, and there were no large changes in prey consumption when supplemental light was first used.

Light intensity was measured with a radiometer (model 1700; International Light, Inc., Newburyport, Mass.) equipped with a photosynthetically active radiation filtered, cosine response detector. Measurements were made at the water surface with the detector pointed upwards. Illumination in the six replicate tanks differed by 6-18% depending on light level, and the values reported here represent means of the six measurements. Light measurements were made at the beginning of the study and were periodically checked to confirm that light levels were consistent thought the study period.

Turbidity was controlled by adding a bentonite clay suspension to the experimental tanks. Clays are weakly absorptive of visible light, but highly scattering (Kirk 1994), and often are the primary contributor to reductions in beam attenuation coefficient in turbid environments (Vant 1990). A predetermined amount of clay was mixed into 2 L of seawater, and the suspension was slowly added to the experimental tanks through the feeding tube. In experiments in clear water, seawater without clay was added to the tanks in the same manner. Turbidity was measured with a Hach 2100A turbidimeter (Hach, Loveland, Colo.), which quantifies the amount of light from an incandescent bulb scattered at a 90° angle in nephelometric turbidity units (NTU). Preliminary observations indicated that turbidity was reduced by -50% within 1 h as a result of settling and that fish were agitated by the increase in turbidity for <5 min. To minimize settling during experiments, but allow the fish to acclimate to changes in turbidity, the fish were allowed 30 min to acclimate. A series of preliminary experiments ($n$ = 25) established that turbidity after 35 min (i.e., at the end of trials) was reproducible to within 10% of the average level over the range of 0-40 NTU. Turbidity values reported here represent the mean of these measurements.

**General planktivory protocol**

All planktivory experiments followed a similar experimental protocol: groups of five fish were selected haphazardly from holding tanks and were acclimated to experimental tanks for 16-20 h. Before starting the experiments, the lights were set to the desired intensities, and the flow-through seawater was turned off. To prevent the loss of prey through the outflow drains, the water level in the tank was siphoned down to a height of 37 cm, which is 5 cm below the tank drain. This reduced the water volume in the tank to 93 L. The fish were allowed to acclimate for 60 min before prey introduction.

Live *Artemia salina* were used as a proxy for zooplankton prey in planktivory experiments. Prey cultures were initiated 3-4 days apart, and a subsample of 25 prey was measured daily to ensure that prey size (-2.5 mm) did not vary appreciably between trials. In each trial, 100 prey were counted and placed in a beaker containing 300 mL of seawater. The prey were poured into the experimental tank through a funnel at the end of the feeding tube, and the beaker was rinsed with 750 mL of seawater, which was then poured into the feeding tube. The fish were allowed to feed for 5 min, and the experiment was then terminated by entering the blind and rapidly removing the fish with a dip net. Any prey removed with the fish were quickly separated. Fish were measured and returned to holding tanks and were not reused in subsequent trials. The remaining prey were removed by methodically straining the tank with a fine-mesh dip net for 5 min. Preliminary trials in which prey were added to the tanks without fish and subsequently recovered indicated that almost all prey ($\bar{x}$ ± standard deviation (SD), 98.9 ± 0.3%, $n$ = 6) added through the feeding tubes were recovered, and the number of prey missing at the end of the feeding trial was taken to be the number of prey consumed. Experimental temperatures were �11 °C and ranged between 9.9 °C and 11.8 °C. Five replicate trials were conducted for a given treatment, and the order of trials was randomized in blocks of 2 and 3.

A series of preliminary experiments (5.02 x $10^{-1}$ μE·m$^{-2}$·s$^{-1}$, 0 NTU) were videotaped from above to investigate the possibility of quantifying the distance at which prey were detected by planktivores. Analysis of video records indicated that both chum and pollock began making rapid forward movements of up to 10-20 cm followed by sharp turns shortly after prey were introduced. Although prey were generally not resolved in the video records, in several cases we were able to confirm that prey were consumed as the planktivores turned. These observations suggest that prey-sighting distances by both planktivores were on the order of 20 cm at high light intensity in clear water. However, because position of individual prey could not be reliably resolved, we did not further characterize the distance at which prey were detected in the planktivory experiments.

**Light threshold of chum salmon**

Although the thresholds for visual feeding by sablefish and pollock have been previously established (Ryer and Olla 1999), the threshold for visual feeding by chum salmon, which was required to design the turbidity experiments, was unknown. We thus established the threshold for visual feeding by chum salmon in clear water (0.2 NTU, no added bentonite) by recording prey consumption at 1.14, 1.16 x $10^{-1}$, 1.20 x $10^{-2}$, 0.98 x $10^{-3}$, 1.17 x $10^{-4}$, and 0.91 x $10^{-5}$ μE·m$^{-2}$·s$^{-1}$ and in complete darkness (<1.0 x $10^{-8}$ μE·m$^{-2}$·s$^{-1}$). Mean *Artemia* length ranged from 2.2 mm to 2.6 mm. Fish length was 42.0 ± 3.3 mm ($\bar{x}$ ± SD), and the mean size of fish did not vary with illumination (analysis of variance (ANOVA), $F_{[6,168]}$ = 1.55, $p$ = 0.17). Prey consumption was analyzed by one-way ANOVA after a square-root transformation to homogenize variance (Bartlett's test $p$ = 0.21) in order to meet ANOVA assumptions. A posteriori multiple comparisons were made using Tukey's test.

**Effect of turbidity on planktivory**

We investigated the effects of elevated turbidity on planktivory by chum and pollock at two light intensities. A high light intensity was selected such that additional light would not increase feeding rates, and a lower light intensity was selected such that feeding rates were below those observed at high light intensity but above those in the dark. Based on the results of the light threshold of experiment for chum salmon and previous studies of pollock in the same apparatus (Ryer and Olla 1999), trials were conducted at 5.02 x $10^{-1}$ (high light) and 4.80 x $10^{-4}$ μE·m$^{-2}$·s$^{-1}$ (low light). These light levels correspond approximately to illumination at the water surface during sunrise or sunset and under a half moon, respectively (Macy et al. 1998).

For each species, trials were conducted at 0.2 (no added bentonite), 5.1, 9.3, 19.6, and 39.9 NTU under both high and low light conditions. To remove the confounding effects of decreased light intensity in the turbid treatments (up to 59% reduction, measured at the bottom of the tank), illumination was increased such that the measured light level at the center of the tank was approximately constant (within 5%) over all turbidity levels.

Chum used in turbidity trials averaged 47.0 ± 5.2 mm in length, and size did not vary among treatments (ANOVA, $F_{[9,240]}$ = 0.87, $p$ = 0.55). Pollock averaged 71.6 ± 7.8 mm in total length, and size did not vary among treatments (ANOVA, $F_{[9,240]}$ = 0.345, $p$ = 0.96). Mean prey size ranged between 2.2 and 2.6 mm in chum experiments and between 2.4 and 2.9 mm in pollock experiments. Prey consumption was analyzed by two-way ANOVA after a square-root transformation to homogenize variance (Bartlett's test, $p$ > 0.05 in both cases) to meet ANOVA assumptions. A posteriori multiple comparisons were made using Tukey's test.

**Piscivory experiments**

We investigated the effects of turbidity on piscivory by studying predation by 1-year-old sablefish on juvenile chum salmon at 0.4 ± 0.2, 5.1 ± 0.5, and 10.0 ± 0.5 ($\bar{x}$ ± SD) NTU, which correspond to the three lowest turbidity levels tested in the planktivory experiments. Before use in experiments, sablefish were fed shiner surfperch (*Cymatogaster aggregata*) for a week to habituate them to live prey, and then they were starved for 7-12 days to ensure that they would be motivated to feed. Six replicate trials at each turbidity level were conducted in three identical indoor flow-through circular tanks (1.3 m deep, 3 m diameter). To ensure that predator and prey would be visible to overhead video cameras under turbid conditions, water depth was held at 0.5 m at all times by means of an external standpipe. The experimental volume was 2700 L. One replicate at each of the three turbidity levels was tested in a single day, with the order of trials randomized within that day. The tanks were lit with overhead fluorescent lights, which produced a light intensity ranging from 1.29 to 1.45 $\mu E \cdot m^{-2} \cdot s^{-1}$ at the water surface. The highest turbidity level reduced light levels at the bottom of the tank by <15%, and no compensation was made for decreased light intensity in turbid treatments.

In each trial, two sablefish predators (mean length ± SD, 353.8 ± 17.8 mm) were haphazardly drawn from a holding tank and introduced to the arena to acclimate for 16-20 h. Before each trial, an overhead partition was lowered to confine the predators to half of the tank, and the seawater supply was turned off. A turbid suspension was prepared by adding pulverized kaolin to 120 L of seawater. Kaolin was used to produce the desired turbidity rather than bentonite because it was found that settling of kaolin was negligible over a period of 1-2 h. Half of the suspension was pumped into each side of the experimental tank, and an additional 30 L of seawater was used as a rinse. Preliminary turbidity measurements showed that the kaolin suspension mixed through small holes in the partition and dispersed evenly throughout the tank within several minutes. In the 0.4 NTU trials, water without kaolin was pumped into the tanks as a control. After introducing the suspension into the arena, six chum salmon (82.9 ± 11.5 mm) were drawn from a holding tank, measured, and added to the tank opposite the predators. The fish were then allowed to acclimate to conditions in the arena for 70 min. Trials were initiated by turning on the videotape recorders and raising the partition 50 cm above the water surface with a pulley system from a location outside of the field of view of the fish. Predator and prey were allowed to interact for a period of 15 min. After the conclusion of experiments, the lengths of the predators and remaining prey were measured, as were water temperature and turbidity. Tanks were drained and refilled before further use. Fish used in experiments were not used in subsequent trials. Predator size (ANOVA, $F_{[2,33]} = 0.24$, $p = 0.79$) and prey size (ANOVA, $F_{[2,105]} = 0.98$, $p = 0.38$) were not significantly different among turbidity treatments. Experimental temperatures ranged between 9.3 °C and 9.9 °C. Significant changes in prey consumption were identified using the Kruskal-Wallis test, followed with a posteriori multiple comparisons using the Nemenyi test.

To determine whether turbidity affected predator-prey encounter rates or capture success, the number of pursuits was quantified from the video records of experimental trials. Pursuits could be clearly distinguished from routine swimming by sudden acceleration, rapid changes in direction, and prey responses. In some of the clear-water trials, the predators consumed all of the prey in <15 min, and the number of encounters was normalized by the time until all prey were consumed. Capture success was calculated by dividing the number of pursuits by the number of prey consumed. Significant changes in pursuit rate and encounter rates were identified using the Kruskal-Wallis test, followed with a posteriori multiple comparisons using the Nemenyi test.

**Effect of type of suspended material**

The experiments with planktivores and piscivores differed in the material used to increase turbidity levels, which were measured in NTU. The beam attenuation coefficient of kaolin and bentonite suspensions was measured at nine turbidity levels ranging from 0 to 40 NTU with a Wetlabs C-Star 25 cm path length transmissometer (Wet Labs, Philomath, Oreg.). This instrument measures the sum of absorption and scattering coefficients at a wavelength of 660 nm.

To confirm that kaolin and bentonite had a similar effect on planktivory, the feeding rates of groups of five chum salmon on *Artemia* prey (mean length 2.7-2.9 mm) were measured at 0.3 NTU (no kaolin) and at 9.8 NTU of kaolin-induced turbidity and compared with the results of trials using bentonite (described above). Experiments were conducted at 5.02 x $10^{-1}$ $\mu E \cdot m^{-2} \cdot s^{-1}$. Experimental fish averaged 78.9 ± 12.2 mm ($\bar{x}$ ± SD) in length, and fish size did not vary between treatments (*t* test, $t_{48} = 1.40$, $p = 0.17$). Five trials were conducted at each turbidity level.

## Results

**Light threshold of chum salmon**

The relationship between prey consumption by juvenile chum salmon and log light intensity was sigmoidal (Fig. 1). There was a significant decrease in prey consumption at low light intensities (ANOVA, $F_{[6,34]} = 33.5$, $p < 0.001$; Fig. 1). The threshold illumination at which feeding increased was between $10^{-5}$ $\mu E \cdot m^{-2} \cdot s^{-1}$ and $10^{-4}$ $\mu E \cdot m^{-2} \cdot s^{-1}$ (-5 x $10^{-5}$ $\mu E \cdot m^{-2} \cdot s^{-1}$). Prey consumption reached a maximum at -1 x $10^{-1}$ $\mu E \cdot m^{-2} \cdot s^{-1}$ and did not increase with further illumination.

**Effect of light and turbidity on planktivory**

Turbidity at the tested levels of 0-40 NTU did not have a strong effect on prey consumption by juvenile chum salmon and walleye pollock except at the highest turbidity at the high illumination (Figs. 2*a*, 2*b*). Although there was a strong light effect for both species, there was a significant interaction between light and turbidity (Tables 1, 2), indicating that the effect of turbidity on prey consumption depends on light intensity. Pairwise comparisons (Tables 1, 2) identified significant turbidity effects only at the higher light intensity.

**Effect of turbidity on piscivory**

The number of chum salmon consumed by sablefish decreased significantly under elevated turbidity (Kruskal-Wallis test, $H = 13.0$, df = 2, $p < 0.001$). Pairwise comparisons revealed that the number of prey consumed was significantly higher at 0 than at 10 NTU, but prey consumption at these

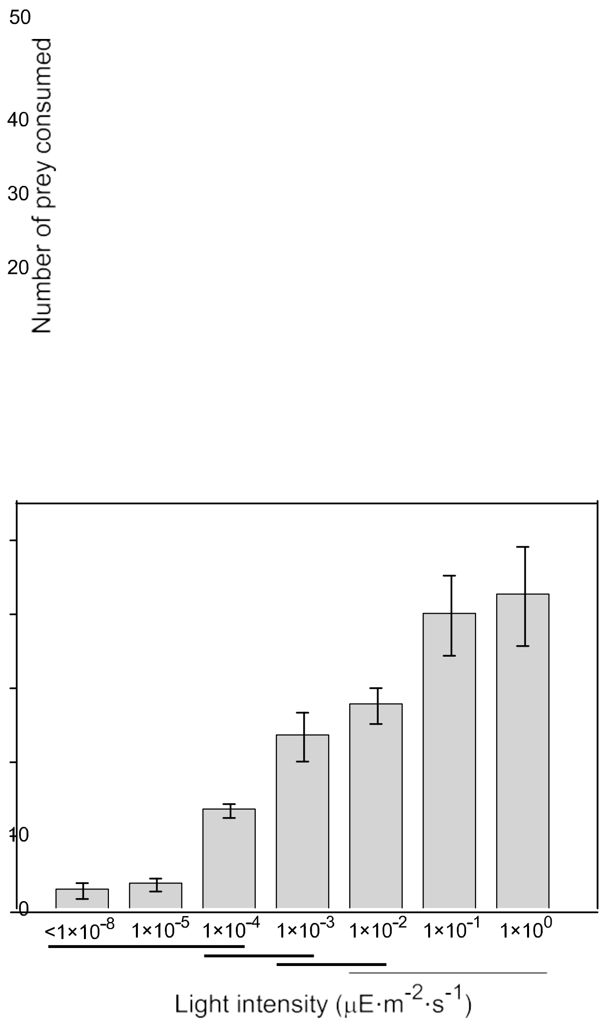


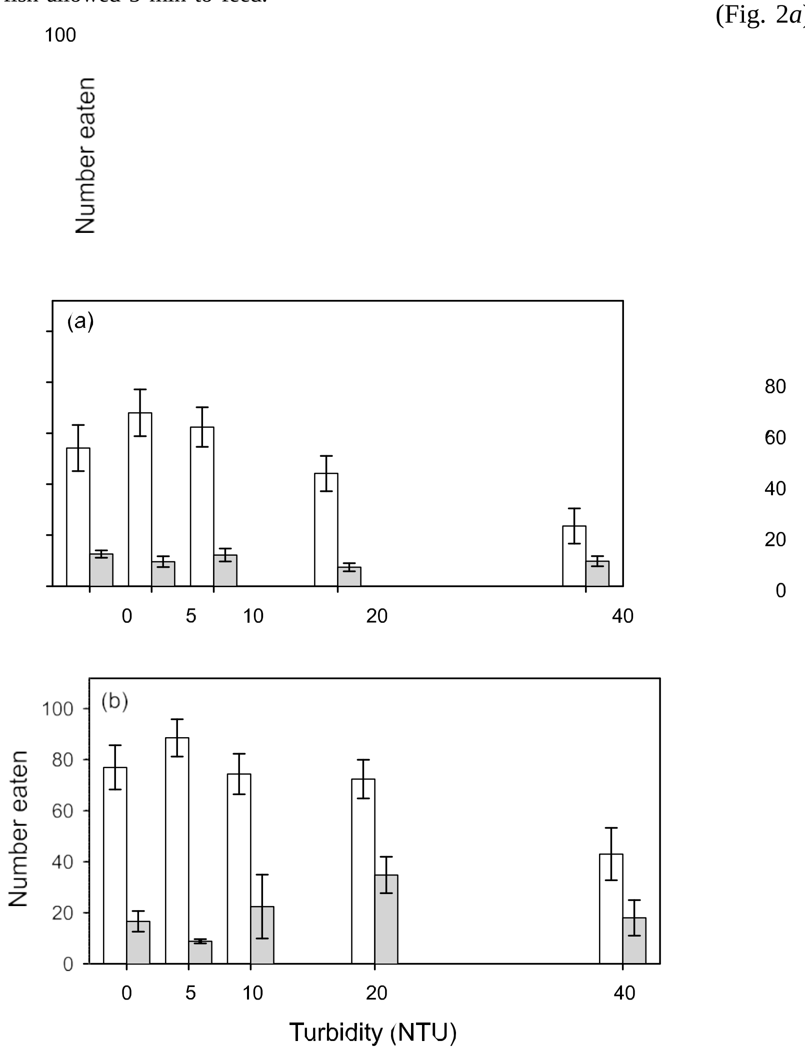

**Fig. l.** Mean number of prey (± standard error) consumed by groups of five juvenile chum salmon (*Oncorhynchus keta*) in clear (0.2 nephelometric turbidity units (NTU)) water at illuminations ranging from <1 x $10^{-8}$ (darkness) to 1 μE·m$^{-2}$·s$^{-1}$. Prey consumption at underlined light intensities does not differ significantly (Tukey's test, $p$ < 0.05). Five replicate trials were conducted at each illumination, with 100 prey per trial and fish allowed 5 min to feed.

turbidities could not be distinguished from that at 5 NTU (Nemenyi test). Predation rates were about threefold lower at 5 NTU than in clear water, and no prey were consumed in the 10 NTU trials (Fig. 3).

Analysis of the video records indicated that as turbidity increased, sablefish pursued the chum prey less often ($H$ = 9.76, df = 2, $p$ = 0.008; Fig. 4*a*). Pairwise comparisons revealed that pursuit rates were higher at 0 than at 10 NTU, but pursuit rates at neither of these turbidities could be statistically distinguished from those at 5 NTU (Nemenyi test). In clear water, the sablefish generally responded to the chum immediately after the barrier was raised, crossing the tank and initiating pursuit. Under elevated turbidity, the sablefish did not respond as rapidly to the chum and were often observed to swim around the periphery of the tank as they typically did when no prey were present in the tank. In many cases, the prey tended to occupy the central areas of the tank while the sablefish, which appeared not to detect the prey, swam around the periphery of the tank. In addition to reducing the frequency of pursuits, elevated turbidity reduced the rate of prey capture ($H$ = 11.92, df = 2, $p$ = 0.003; Fig. 4*b*). Pairwise comparisons revealed that pursuit rates were significantly higher at 0 than at 10 NTU, but capture success at either turbidity could not be statistically distinguished from that at 5 NTU (Nemenyi test).

The sablefish did not exhibit stereotyped orienting responses before pursuing chum prey, making it difficult to establish when prey detection occurred. This precluded the calculation of prey-sighting distances from the video records. However, the ability of sablefish to detect prey appeared to decrease substantially as turbidity increased. At 0 NTU, the predators often crossed the 3-m-diameter tank to pursue prey, indicating that prey were visible at distances of over 3 m. At 5 NTU, pursuits were initiated at predator-prey distances of

**Fig. 2.** Effect of turbidity (in nephelometric turbidity units (NTU)) on planktivory by juvenile (*a*) chum salmon (*Oncorhynchus keta*) and (*b*) walleye pollock (*Theragra chalcogramma*). Bars indicate the mean number (± standard error) of prey consumed by groups of five fish at five turbidity levels and two light intensities. Open bars indicate high light conditions ($5.02 \times 10^{-1}$ $\mu E \cdot m^{-2} \cdot s^{-1}$) and shaded bars indicate low light conditions ($4.80 \times 10^{-4}$ $\mu E \cdot m^{-2} \cdot s^{-1}$). Five replicate trials were conducted at each illumination, with 100 prey per trial and fish allowed 5 min to feed.




less than 1 m, and pursuit ended when predator and prey were separated by more than 1 m. Pursuits at 10 NTU were initiated when predator and prey were separated by <40 cm.

**Effect of type of suspended material**

The beam attenuation coefficient ($\alpha$) measured at 660 nm was linearly related to turbidity in NTU for both the benton- ite ($y = 1.44x$, $r^2 = 0.99$) and kaolin ($y = 0.63x$, $r^2 = 0.99$) suspensions. Given that the bentonite suspension had a higher $\alpha$ at a given NTU value, this indicates that bentonite is more absorptive than kaolin at this wavelength. However, the ef- fect of elevated turbidity on the feeding rates of chum salmon was similar regardless of the material used to generate the turbidity. At high light intensity, chum salmon consumed 56.8 ± 10.0 ($\bar{x}$ ± standard error (SE)) prey in clear water compared with 75.4 ± 6.6 at a kaolin-induced turbidity of 10 NTU. Prey consumption in clear water and 10 NTU of kaolin-induced turbidity was not significantly different ($t_8 = 1.52$, $p = 0.16$). Although these fish were �30 mm larger than the fish used in bentonite planktivory trials (see above), the observed 33% increase in prey consumption at kaolin-induced turbidity of 10 NTU relative to control fish of the same size in clear water is comparable to the 15% increase above control observed at 10 NTU generated using bentonite (Fig. 2*a*).

**Table l.** Two-way analysis of variance of juvenile chum salmon prey consumption at turbidities ranging from 0 to 40 NTU (nephelometric turbidity units) at light intensities of 5 x $10^{-4}$ and 5 x $10^{-1}$ µE·m$^{-2}$·s$^{-1}$. Turbidity levels are listed in order of descending prey consumption. Prey consumption at the underlined turbidity levels does not differ significantly (Tukey's test, $p$ < 0.05). Degrees of freedom, df.

| Factor | *F* ratio | df | *p* |
|---|---|---|---|
| Light | 149.1 | 1,49 | <0.001 |
| Turbidity | 5.1 | 4,49 | 0.002 |
| Turbidity x light | 3.8 | 4,49 | 0.01 |

| | Turbidity (NTU) | | | | |
|---|---|---|---|---|---|
| High light | 5 | 10 | 0 | 20 | 40 |
| Low light | 0 | 10 | 40 | 5 | 20 |

**Table 2.** Two-way analysis of variance of prey consumption by juvenile walleye pollock at turbidities ranging from 0 to 40 NTU (nephelometric turbidity units) at light intensities of 5 x $10^{-4}$ and 5 x $10^{-1}$ µE·m$^{-2}$·s$^{-1}$. Turbidity levels are listed in order of descending prey consumption. Prey consumption at the underlined turbidity levels does not differ significantly (Tukey's test, $p$ < 0.05). Degrees of freedom, df; NS, not significant.

| Factor | *F* ratio | df | *p* |
|---|---|---|---|
| Light | 95.3 | 1,49 | <0.001 |
| Turbidity | 2.4 | 4,49 | NS (0.07) |
| Turbidity x light | 3.2 | 4,49 | 0.02 |

| | Turbidity (NTU) | | | | |
|---|---|---|---|---|---|
| High light | 5 | 0 | 10 | 20 | 40 |
| Low light | 20 | 10 | 40 | 0 | 5 |

## Discussion

These experiments indicate that piscivorous feeding by sablefish is substantially more sensitive to elevated turbidity than planktivorous feeding by chum salmon and walleye pollock. At 10 NTU, sablefish did not successfully consume juvenile chum salmon in 15-min trials, whereas feeding by both of the planktivores was unaffected relative to clear water conditions at this turbidity level. Our behavioral observations of sablefish are consistent with the interpretation that their ability to detect and capture prey was substantially impaired at this turbidity level. Although our experiments were designed to measure prey consumption, our observations of foraging fish are similar to previous reports that at high light in clear water, piscivores are able to detect their prey at distances of metres (Breck 1993; Vogel and Beauchamp 1999), whereas planktivores are able to detect prey at distances of 10s of centimetres (O'Brien 1987; Utne 1997).

Our results are consistent with contrast degradation theory, which predicts that the visibility of objects that can be seen at a large distance in clear water will be disproportionately reduced in turbid waters compared with that of objects that are visible at a shorter distance in clear water. This effect is analogous to the familiar situation where fog has little effect on short-range vision but can greatly diminish the visibility of objects at a distance (Lythgoe 1979). These results

**Fig. 3.** Effect of turbidity (in nephelometric turbidity units (NTU)) on piscivory by sablefish (*Anoplopoma fimbria*). Bars indicate the mean (± standard error) number of chum salmon consumed by pairs of sablefish in 15-min trials ($n$ = 6), with six prey per trial.

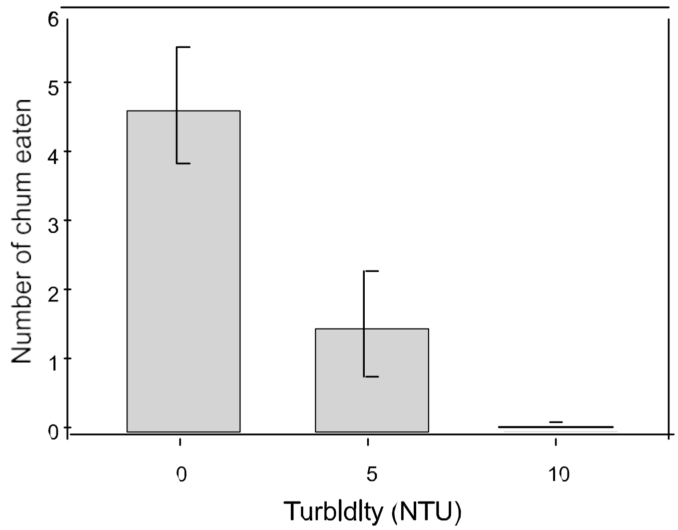
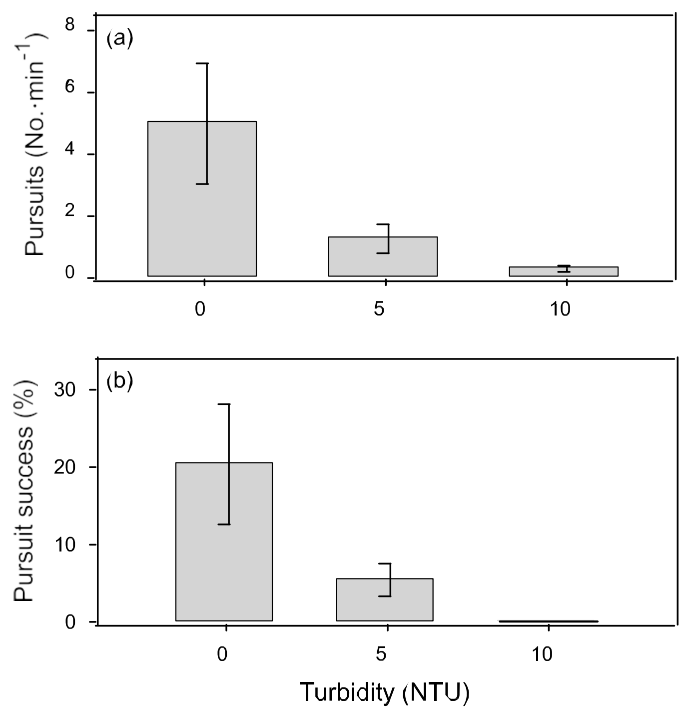



**Fig. 4.** Effect of turbidity (in nephelometric turbidity units (NTU)) on mean (± standard error) (*a*) pursuit frequency and (*b*) capture success of sablefish (*Anoplopoma fimbria*) feeding on chum salmon (*Oncorhynchus keta*) in 15-min trials ($n$ = 6).



support the "turbidity as cover" hypothesis (Gregory 1993) and suggest that elevated turbidity may be advantageous for planktivorous fish because they will be less vulnerable to piscivores but will not experience a substantial decrease in feeding opportunity. Although our experiments were conducted with saltwater species, the implications of contrast degradation should be generally applicable and should also apply to freshwater species.

Increased turbidity decreased both the rate at which sablefish pursued chum prey and the probability of prey capture. The reduction in pursuits likely reflects reduced predator-prey encounter rates resulting from a decrease in visibility. Capture success averaged -20% in clear water, and no successful pursuits were observed at 10 NTU. The generally low capture success reflects the high mobility and maneuverability of the chum prey. Reduced capture success at elevated turbidity indicates that lower prey consumption in turbid water cannot be attributed solely to a reduction in encounter rate, as has been proposed previously (Gregory and Levings 1996). Increased turbidity likely decreases capture success by increasing the probability that prey escape responses will displace the prey outside of an attacking predator's field of view. Visual encounter models based on piscivore reactive distances (e.g., Beauchamp et al. 1999), which implicitly assume constant capture success, will overestimate feeding opportunities under turbid conditions if capture success decreases in turbid environments.

Our experiment was designed to eliminate the confounding effect of decreased ambient light intensity due to light attenuation under elevated turbidities, and the effects of turbidity on planktivorous feeding observed in the experiments can be attributed primarily to increased scattering of light by suspended materials. High turbidity significantly decreased prey consumption by the two planktivores at the higher illumination, but not at the lower illumination. At lower illuminations, prey will be visible at shorter distances (Aksnes and Utne 1997), which will reduce the effects of contrast degradation relative to high illuminations resulting from a decreased path length between predator and prey. It should be noted that prey depletion over the course of planktivory experiments has the potential to result in an underestimation of prey consumption, particularly in the high light trials in which larger fractions of available prey were consumed. However, given that the trends observed in chum salmon are similar to those of pollock, which consumed more prey, the effects of prey depletion should not alter our primary conclusion that feeding by planktivores is less sensitive to turbidity than piscivores.

Although we did not observe a strong effect of turbidity on prey consumption by planktivores, lower levels of turbidity than those tested here will substantially increase light attenuation with depth. Decreased light penetration will restrict feeding by visually foraging planktivorous fish to shallower water where light levels are higher (Eiane et al. 1999). Because light attenuation increases exponentially with depth (Kirk 1985), the effects of light attenuation will be most pronounced for species that live at greater depths. As a result, the primary effect of turbidity on feeding by planktivorous fish in all but the most turbid waters may be to reduce illumination at depth and thus limit the depth at which fish are able to feed effectively.

The experiments with planktivores and piscivores differed in the material used to manipulate turbidity. The beam attenuation coefficient at 660 nm at a given turbidity (NTU) was measured to be higher for a bentonite than for a kaolin suspension. Given that NTUs are a measure of light scatter, this indicates that bentonite absorbs more light at this wavelength. This suggests that bentonite may be more disturbing to the visual system than kaolin, although this depends on light absorption at other wavelengths, the spectral distribution of ambient light, and the spectral sensitivity of the fish. If this were the case, then our interpretations would be conservative, as the experiments with planktivores were conducted with more visually disturbing suspended materials than experiments with piscivores. However, at 10 NTU, neither bentonite nor kaolin resulted in a significant change in prey consumption by chum salmon, which indicates that the use of different suspended materials does not introduce a substantial bias and cannot account for the difference in turbidity-induced prey consumption between piscivores and planktivores.

In our experiments, we used model species to simulate natural predator-prey interactions. Although all predator species are able to consume prey in complete darkness, they should be considered primarily visual predators as feeding rates in well-illuminated conditions are substantially higher than in the dark (Ryer and Olla 1999; this study). Thus, the results are primarily applicable to fish that visually search for individual prey. Although the *Artemia* used as prey were approximately the same size as natural prey consumed by juvenile chum salmon and walleye pollock (Bailey et al. 1975; Schabetsberger et al. 2000), *Artemia* have poorly developed escape responses and are less likely to escape once attacked by a planktivore. When visibility is poor, prey with more developed escape responses may decrease capture success by moving outside of the predator's reduced field of vision. Thus, although the use of *Artemia* as prey may adequately reflect encounter rates with small prey, their limited escape responses may bias our experiments as consumption of *Artemia* may be overestimated at low light intensity and high turbidity compared with consumption of more evasive prey. However, given that turbidity at the levels tested had only weak effects on planktivore feeding rate, it is unlikely that elevated turbidity greatly reduced the planktivore's visual field to the point that it would have greatly increased the ability of more evasive prey to escape. Even if *Artemia* never successfully escape planktivores and the results of the planktivory experiments can be ascribed purely to changes in encounter rate, this does not invalidate the conclusion that piscivores are more sensitive to increases in turbidity than planktivores, as significant decreases in pursuit rate by piscivorous sablefish were observed at 10 NTU, whereas no changes in prey consumption by the two planktivores were observed at this turbidity level.

A substantial body of work has demonstrated that high turbidity decreases the distance at which planktivorous fish are able to detect prey (e.g., Vinyard and O'Brien 1976; Confer et al. 1978; Utne 1997). Turbidity in many of these studies was measured based either on light absorbance or on measures of visibility to human observers, and these studies are thus not directly comparable to our experiments. Studies of particle-feeding planktivorous fish in which turbidity was measured in a comparable manner support our conclusions, as they suggest that relatively high turbidity is required to reduce prey consumption. In a comparative study of diadromous planktivores, a significant decrease in feeding rate was observed in three species at turbidities of 20, 160, and 640 NTU, whereas three other species were unaffected by turbidities as high as 640 NTU (Rowe and Dean 1998). Feeding of juvenile chinook salmon on adult *Artemia* decreases at >150 NTU, although prey-sighting distance decreases by -50% by 25 NTU (Gregory and Northcote 1993). Planktivory by bluegills is reduced at turbidities of 60 NTU (Gardner 1981). Overall, these studies indicate that moderately high levels of turbidity are required to impair feeding by planktivorous fish.

The distance at which fish are able to respond to other fish is known to decrease sharply with small increases in turbidity. Measurements of the reactive distance of lake trout to salmonid prey indicate that turbidities as low as 3 NTU will decrease reactive distances by -40% under well-illuminated conditions (Vogel and Beauchamp 1999). The distance at which bluegills are able to detect largemouth bass predators is highly dependent on turbidity, decreasing from -210 cm in clear water to �35 cm at 5 NTU (Miner and Stein 1996). These measurements are consistent with our results and suggest that turbidity greatly impairs the ability of fish to detect large, visible objects. However, previous experimental studies of prey consumption by piscivores (Vandenbyllaardt et al. 1991; Reid et al. 1999) have demonstrated statistically significant decreases in prey consumption only at substantially higher turbidities than those tested in this study (37 NTU and 100 NTU), respectively. Gregory and Levings (1996) did not detect a significant difference in predation by cutthroat trout on juvenile salmonids at turbidities as high as 87 NTU. These results may be attributable to methodological differences. Previous studies used comparatively long experimental periods (1-162 h), which constrained highly mobile predators in fairly small volumes for extended periods, and predator satiation may have masked changes in predator-prey encounter rates (Gregory and Levings 1998). This experimental bias is consistent with previous experiments in which elevated turbidity was observed to decrease feeding by piscivores in 1-h but not 4-h trials (Vandenbyllaardt et al. 1991). In addition, the piscivores in our experiments were starved, which motivated them to feed.

Increases in turbidity alter the background against which a prey item is viewed and can lead to increases in the inherent contrast between the prey and the background. This makes the prey more visible and can compensate for turbidity-induced degradation of apparent contrast. However, this does not appear to be a primary effect in our study, as piscivory by sablefish decreased sharply at elevated turbidity, and prey consumption by both species of planktivores was not significantly elevated in turbid vs. clear water. The relative importance of turbidity in increasing prey background inherent contrast decreases sharply with the distance at which prey can be seen (Fiksen et al. 2002). Thus, turbidity-induced changes in prey inherent contrast should be most important for larval fish and least important for piscivorous fish. This prediction is consistent with studies of larval fish that have shown that under well-lit conditions, elevated turbidity either has a minor effect on feeding rate (Breitburg 1988) or leads to an increase in feeding rate (Boehlert and Morgan 1985; Miner and Stein 1993).

If, as our experiments suggest, feeding by piscivores is substantially more sensitive to elevated turbidity than feeding by planktivores, then turbid habitats may be favorable for planktivorous fish, as they will be less vulnerable to attack by piscivores. Recent studies indicating that elevated turbidity makes planktivores less susceptible to predation by piscivores (Gregory and Levings 1998; Beauchamp et al. 1999; Johnson and Hines 1999) support the notion that turbid waters may be favorable habitats for planktivores. This is consistent with the distribution of small fishes in both freshwater and marine environments, where small fish are often associated with more turbid waters (e.g., Blaber and Blaber 1980; Heege and Appenzeller 1998). For example, 16 of 20 species of juvenile fishes studied in a turbid estuary were disproportionately found in waters with turbidities exceeding 10 NTU (Cyrus and Blaber 1987). In addition, planktivorous fish may respond to turbid water by decreasing predator-avoidance behaviors (Gregory 1993; Miner and Stein 1996; Abrahams and Kattenfeld 1997). This may be advantageous, as predator-avoidance behavior often comes at the cost of decreased feeding opportunities (Gilliam and Fraser 1987; Lima and Dill 1990).

Turbidity levels sufficient to reduce the effectiveness of piscivory are more likely to occur in freshwater and estuarine environments than in marine environments. Turbidity in these habitats is often high as a result of inputs of inorganic particles from land (Kirk 1985). However, turbidity may have a locally important effect in productive coastal marine habitats during dense phytoplankton blooms (Lovvorn et al. 2001), in river plumes (Grimes and Kingsford 1996), or in areas where bottom sediments are resuspended (Churchill et al. 1994). Estuaries serve as nursery areas for many marine fishes; turbidity in these habitats may often be sufficient to reduce vulnerability to visual predators (Blaber and Blaber 1980; Miller et al. 1985; Vant 1990). For instance, turbidity has the potential to reduce the mortality of juvenile salmon, such as the chum used as both predator and prey in our experiments, which often inhabit turbid freshwater and estuarine habitats. Salmonids are often associated with river plumes in the coastal ocean during their first months in the ocean, and decreased visibility in these environments is unlikely to affect planktivorous feeding but may be sufficient to reduce vulnerability to piscivorous fish and seabirds. Focused field studies (e.g., Gregory and Levings 1998) should be conducted to evaluate if turbidity reduces predation risk for planktivorous fish exposed to natural environmental conditions and predator assemblages.

In conclusion, turbidity decreases visibility in aquatic systems by decreasing light penetration and reducing apparent contrast. Our experiments suggest that there is an asymmetry in how turbidity-induced contrast degradation affects the feeding rates of visually hunting piscivorous and planktivorous fish. This asymmetry has important ecological implications, as moderately turbid aquatic environments may provide an advantage for planktivorous fish. Increased turbidity will decrease predation risk substantially more than the ability to feed on zooplankton prey. Our inferences are limited in scope because they are based on experiments with two species of planktivores and a single piscivore. However, we anticipate that our results are broadly relevant to these two trophic levels, as the expectation that piscivores are more sensitive to turbidity is based on fundamental optical principles.

## Acknowledgements

We thank Michelle Ottmar, Mara Spencer, and Richard Titgen for assistance with aquarium facilities, prey culture, and electronics, respectively. This work would not have been possible without the support of Allan Stoner and Edmundo Casillas, which is sincerely appreciated. The comments of Robert Emmett, Thomas Hurst, Dan Kreeger, and Anne Utne Palm improved the manuscript. A.D.R. was supported by a National Research Council Postdoctoral Fellowship, and A.V. was supported by Minority Summer Internship in Fisheries Behavioral Ecology by the Equal Employment Opportunity Office of the National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

## References

Abrahams, M., and Kattenfeld, M. 1997. The role of turbidity as a constraint on predator-prey interactions in aquatic environments. Behav. Ecol. Sociobiol. **40**: 169-174.

Aksnes, D.L., and Utne, A.C. 1997. A revised model of visual range in fish. Sarsia, **82**: 137-147.

Anthony, P.D. 1981. Visual contrast thresholds in the cod *Gadus morhua* L. J. Fish Biol. **l9**: 87-103.

Bailey, J.E., Wing, B.L., and Mattson, C.R. 1975. Zooplankton abundance and feeding habits of fry of pink salmon *Oncorhynchus gorbuscha* and chum salmon *O. keta* in Traitors Cove, Alaska, with speculations on the carrying capacity of the area. Fish. Bull. **73**: 846-861.

Beauchamp, D.A., Baldwin, C.M., Vogel, J.L., and Gubala, C.P. 1999. Estimating diel, depth-specific foraging opportunities with a visual encounter rate model for pelagic piscivores. Can. J. Fish. Aquat. Sci. **56**: 128-139.

Blaber, S.J.M., and Blaber, T.G. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. J. Fish Biol. **l7**: 143-162.

Boehlert, G.W., and Morgan, J.B. 1985. Turbidity enhances feeding abilities of larval Pacific herring, *Clupea harengus pallasi*. Hydrobiologia, **l23**: 161-170.

Breck, J.E. 1993. Foraging theory and piscivorous fish: are forage fish just big zooplankton? Trans. Am. Fish. Soc. **l22**: 902-911.

Breitburg, D.L. 1988. Effects of turbidity on prey consumption by striped bass larvae. Trans. Am. Fish. Soc. **ll7**: 72-77.

Churchill, J.H., Wirick, C.D., Flagg, C.N., and Pietrafesa, L.J. 1994. Sediment resuspension over the continental shelf of the Delmarva Peninsula. Deep Sea Res. **4l**: 341-363.

Confer, J.L., Howick, G.L., Corzette, M.H., Kramer, S.L. Fitzgibbon, S., and Landesberg, R. 1978. Visual predation by planktivores. Oikos, **3l**: 27-37.

Cyrus, D.P., and Blaber, S.M.J. 1987. The influence of turbidity on juvenile fishes in estuaries. Part 1. Field studies at Lake St. Lucia on the southeastern coast of Africa. J. Exp. Mar. Biol. Ecol. **l09**: 53-70.

Duntley, S.Q. 1962. Underwater visibility. *In* The sea. Vol. 1. Physical oceanography. *Edited by* M.N. Hill. John Wiley and Sons, Inc., London. pp. 452-455.

Eiane, K., Aksnes, D.L., Bagoien, E., and Kaartvedt, S. 1999. Fish or jellies — a question of visibility? Limnol. Oceanogr. **44**: 1352-1357.

Fiksen, 0., Aksnes, D.L., Flyum, M.H., and Giske, J. 2002. The influence of turbidity on growth and survival of fish larvae: a numerical analysis. Hydrobiologia, **484**: 49-59

Gardner, M.B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Trans. Am. Fish. Soc. **ll0**: 446-450.

Gilliam, J.F., and Fraser, D.F. 1987. Habitat selection under predation hazard: test of a model with foraging minnows. Ecology, **68**: 1856-1862.

Gregory, R.S. 1993. Effect of turbidity on the predator avoidance behaviour of juvenile chinook salmon (*Oncorhynchus tshawytscha*). Can. J. Fish. Aquat. Sci. **50**: 241-246.

Gregory, R.S., and Levings, C.D. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus* spp., to predation by adult cutthroat trout, *O. clarkii*. Environ. Biol. Fishes, **47**: 279-288.

Gregory, R.S., and Levings, C.D. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Trans. Am. Fish. Soc. **l27**: 275-285.

Gregory, R.S., and Northcote, T.G. 1993. Surface, planktonic, and benthic foraging by juvenile chinook salmon (*Oncorhynchus tshawytscha*) in turbid laboratory conditions. Can. J. Fish. Aquat. Sci. **50**: 233-240.

Grimes, C.B., and Kingsford, M.J. 1996. How do riverine plumes of different sizes influence fish larvae: do they enhance recruitment? Mar. Freshw. Res. **47**: 191-208.

Heege, T., and Appenzeller, A.R. 1998. Correlations of large-scale patterns of turbidity and pelagic fish biomass using satellite and acoustic methods. Adv. Limnol. **53**: 489-503.

Johnson, J.E., and Hines, R.T. 1999. Effect of suspended sediment on vulnerability of young razorback suckers to predation. Trans. Am. Fish. Soc. **l28**: 648-655.

Kirk, J.T.O. 1985. Effects of suspensoids (turbidity) on penetration of solar radiation in aquatic ecosystems. Hydrobiologia, **l25**: 195-208.

Kirk, J.T.O. 1994. Light and photosynthesis in aquatic ecosystems. Cambridge University Press, Cambridge.

Lima, S.L., and Dill, L.M. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zool. **68**: 619-640.

Lovvorn, J.R., Baduini C.I., and Hunt, G.L. 2001. Modeling underwater visual and filter feeding by planktivorous shearwaters in unusual sea conditions. Ecology, **82**: 2342-2356.

Lythgoe, J.N. 1979. The ecology of vision. Clarendon Press, Oxford.

Macy, W.K., Sutherland, S.J., and Durbin, E.G. 1998. Effects of zooplankton size and concentration and light intensity on the feeding behavior of Atlantic mackerel *Scomber scombrus*. Mar. Ecol. Prog. Ser. **l72**: 89-100.

McFarland, W.N. 1986. Light in the sea — correlations with behaviors of fishes and invertebrates. Am. Zool. **26**: 389-401.

Miller, J.M., Crowder, L.B., and Moser, M.L. 1985. Migration and utilization of estuarine nurseries by juvenile fishes: an evolutionary perspective. Contrib. Mar. Sci. **27**: 338-351.

Miner, J.G., and Stein, R.A. 1993. Interactive influence of turbidity and light on larval bluegill (*Lepomis macrochirus*) foraging. Can. J. Fish. Aquat. Sci. **50**: 781-788.

Miner, J.G., and Stein, R.A. 1996. Detection of predators and habitat choice by small bluegills: effects of turbidity and alternative prey. Trans. Am. Fish. Soc. **l25**: 97-103.

O'Brien, W.J. 1987. Planktivory by freshwater fish: thrust and parry in the pelagia. *In* Predation: direct and indirect impacts on aquatic communities. *Edited by* W.C. Kerfoot and A. Sih. University Press of New England, Hanover, N.H. pp. 3-17.

Reid, S.M., Fox, M.G., and Whillans, T.H. 1999. Influence of turbidity on piscivory in largemouth bass (*Micropterus salmoides*). Can. J. Fish. Aquat. Sci. **56**: 1362-1369.

Rowe, D.K., and Dean, T.L. 1998. Effects of turbidity on the feeding ability of the juvenile migrant stage of six New Zealand freshwater fish species. N.Z. J. Mar. Freshw. Res. **32**: 21-29.

Ryer, C.H., and Olla, B.L. 1999. Light-induced changes in the prey consumption and behavior of two juvenile planktivorous fish. Mar. Ecol. Prog. Ser. **l8l**: 41-51.

Schabetsberger, R., Brodeur, R.D., Ciannelli, L., Napp, J.M., and Swartzman, G.L. 2000. Diel vertical migration and interaction of zooplankton and juvenile pollock (*Theragra chalcogramma*) at a frontal region near the Pribilof Islands, Bering Sea. ICES J. Mar. Sci. **57**: 1283-1295.

Utne, A.C.W. 1997. The effect of turbidity and illumination on the reaction distance and search time of the marine planktivore *Gobiusculus flavescens*. J. Fish Biol. **50**: 926-938.

Vandenbyllaardt, L., Ward, F.J., Braekevelt, C.R., and McIntyre, D.B. 1991. Relationships between turbidity, piscivory and development of the retina in juvenile walleyes. Trans. Am. Fish. Soc. **l20**: 382-390.

Vant, W.N. 1990. Causes of light attenuation in nine New Zealand estuaries. Estuar. Coast Shelf Sci. **3l**: 125-137.

Vinyard, G.L., and O'Brien, W.J. 1976. Effects of light and turbidity on the reactive distance of bluegill (*Lepomis macrochirus*). J. Fish. Res. Board Can. **33**: 2845-2849.

Vogel, J.L., and Beauchamp, D.A. 1999. Effects of light, prey size, and turbidity on reaction distances of lake trout (*Salvelinus namaycush*) to salmonid prey. Can. J. Fish. Aquat. Sci. **56**: 1293-1297.

*March 2007*
Technical White Paper

---

**An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity**

Scott A Hecht[1], David H Baldwin[2], Chris A Mebane [3], Tony Hawkes[1], Sean J Gross[4], Nathaniel L Scholz[2].

[1]National Marine Fisheries Service (NMFS), Office of Protected Resources, Endangered Species Division, 510 Desmond Drive SE., Lacey, WA 98506 USA; [2] NMFS, Northwest Fisheries Science Center, Ecotoxicology and Environmental Fish Health Program, 2725 Montlake BLVD. E., Seattle, WA 98112 USA. [3] United States Geological Survey, 10095 W. Emerald St., Boise, ID 83704 USA; [4]NMFS, Washington State Habitat Office, 7600 Sand Point Way NE, Seattle, WA 98115 USA.

---

**Executive Summary**
Dissolved copper is a ubiquitous surface water pollutant that causes a range of adverse acute, chronic, and sublethal effects in fish as well as in aquatic invertebrates and algae. This technical white paper is a summary and targeted synthesis regarding sensory effects to juvenile salmonids from low-level exposures to dissolved copper (dCu). As such, the material presented in this paper does not reflect official policy of the National Marine Fisheries Service, but serves to summarize research on dCu and its impacts on salmonid sensory systems. This document is a snap shot of the existing information; undoubtedly, new information will become available that enhances our understanding of copper's effect on listed salmonids and their supporting habitat.

A large body of scientific literature has shown that fish behaviors can be disrupted at concentrations of dCu that are at or slightly above ambient concentrations (i.e. background). In this document, background is defined as surface waters with less than 3 ug/L dCu as experimental water had background dCu concentrations as high as 3 ug/L dCu. Sensory system effects are generally among the more sensitive fish responses and underlie important behaviors involved in growth, reproduction, and ultimately survival (i.e. predator avoidance). Recent experiments on the sensory systems and corresponding behavior of juvenile salmonids contribute to more than four decades of research and show that dCu is a neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations. These effects can manifest over a period of minutes to hours and can persist for weeks.

In this paper, benchmark concentrations (BMC) were calculated for dCu using an U.S. Environmental Protection Agency (EPA) methodology to provide examples of effect thresholds to assist in .evaluating effects of activities that deliver dissolved copper to surface waters. Benchmark concentrations ranged from 0.18 – 2.1 µg/L corresponding to reductions in predator avoidance behavior from approximately 8 – 57%. The BMC examples represent the dCu concentration (above background [where background is less than or equal to 3 ug/L]) expected to affect juvenile salmonids' ability to avoid predators in fresh water. These concentration thresholds for juvenile salmonid sensory and behavioral responses fall within the range of other sublethal endpoints affected by dCu such as behavior, growth, and primary production, 0.75-2.5 µg/L.

Point and non-point source discharges from anthropogenic activities frequently exceed these thresholds by one, two, and sometimes three orders of magnitude and can occur for hours to days. The United States Geological Survey (USGS) ambient monitoring results for dCu representing 811 sites across the U.S. detected concentrations ranging from 1-51 µg/L with a median of 1.2 µg/L. Additionally, typical dCu concentrations originating from road runoff from a California study were 3.4 - 64.5 µg/L, with a mean of 15.8 µg/L. Taken together, the information reviewed and presented herein indicates that impairment of sensory functions important to survival of juvenile salmonids is likely to be widespread in many freshwater aquatic habitats. Impairment of these essential behaviors may occur following ten minutes of exposure and continue for hours to days depending on concentration and duration. Due to these acute, sublethal responses i.e. within minutes, it is unlikely that avoidance or acclimation play significant roles in reducing the

effects of short term anthropogenic increases of dCu to juvenile salmonid sensory systems.

We also discuss the bioavailability of copper in aquatic habitats including the effects of water chemistry on olfactory toxicity. Avoidance behavior studies on salmonids exposed to dCu are summarized as well as representative studies of acute, chronic, and sublethal effects to salmonids. Given the large body of literature on copper and responses of aquatic ecosystems, we focused on a subset of fish sensory system studies relevant to anadromous salmonids.

**Abstract:**

Dissolved copper (dCu) is a ubiquitous, toxic pollutant in U.S. surface waters. Four decades of research with dCu, indicate toxicity to multiple fish endpoints including fish sensory systems and behaviors. This document summarizes literature on the effects of dCu to salmonid sensory systems and conducts a targeted analysis on a recent sensory system behavioral dataset. The review portion of the document discusses peer reviewed and gray literature (see Appendix) on the effects of dCu on salmonid sensory systems, associated sensory-mediated behaviors, and physiology and is intended to facilitate understanding of the effects of dCu on sensory system mediated behaviors that are important to survival, reproduction, and distribution of salmonids. The review does not address the effects of dCu on salmonid habitats although copper is also highly toxic, at low ug/L concentrations, to aquatic plants and invertebrates.

The targeted analysis was conducted with data from a recent experiment on fish olfaction and predator avoidance behavior. Results from this experiment showed that increases in dCu impaired the ability of juvenile salmonids to smell and by extension reduced their capacity to detect and respond to alarm signals (conspecific skin extracts). Impaired olfaction manifested over a period of minutes in juvenile coho. Olfaction and behavioral impairment endpoints were significantly correlated ($r^2 = 0.94$) and indicated statistically significant effects (alpha =0.05) at all concentrations tested for olfaction (2, 5, 10, 20 ug/L) and at 5, 10, and 20 µg/L for alarm response (inhibition of swimming speed reductions). However, no experimental treatments were tested below 2 µg/L which corresponded to an approximately 50% reduction in olfactory function and a 47% reduction in alarm response.

To address this critical uncertainty, we conducted a benchmark concentration (BMC) analysis with the olfactory dataset. The analysis produced BMC estimates ranging from 0.18 ($BMC_{10}$) - 2.1 ($BMC_{50}$) µg/L which corresponded to approximately 8 – 57% estimated reductions in predator avoidance response. These results indicate juvenile salmonid sensory systems and their mediated ecologically relevant behaviors are particularly sensitive to low ug/L increases. Impairment of olfaction in juvenile salmonids can manifest in minutes, last for minutes to weeks (depending on dose), and potentially result in population level consequences. These sensory effects are discussed in the context of site specific issues including the bioavailability of dCu.

## Acronyms and Glossary

Acute exposure – short term continuous exposure generally 96 hrs or less

BLM- Biotic Ligand Model

Chronic exposure – longer term continuous or pulsed exposures generally greater than 96 hrs

Confidence interval (CI) - A confidence interval is a random interval constructed from data in such a way that the probability that the interval contains the true value can be specified before the data are collected.

dCu – dissolved copper

DOC- dissolved organic carbon

$EC_p$ – effective concentration adversely affecting (p) percent of the test population or percent of measured response, e.g., 10% for an $EC_{10}$, etc.

EOG- Electro-olfactogram

$LC_{50}$ - the aqueous concentration that kills 50% of the test population

Lower-bound 90% confidence interval - is the lower half of the 90% confidence interval of the mean

Lower-bound 95% confidence interval - is the lower half of the 95% confidence interval of the mean

LOEC - Lowest observable effect concentration

Mean - is the average of the response values in a treatment population. Numerically it represents the sum of the individual response values divided by the number of individuals in a treatment.

mV- millivolts

NOAEL - No observable adverse effect level

NOEC- No observable adverse effect concentration

ORN- olfactory receptor neuron

ppb – part(s) per billion, equivalent to ug/L

Relative departure - is a prescribed change in response e.g. the concentration at which a 10% effect is predicted.

Statistical departure – uses statistical methods to select a prescribed change e.g. applying the 90% or 95% lower-bound confidence interval of the mean of the control response to select the value at which an individual salmonid's olfaction is impaired.

## Introduction

Copper, a naturally occurring element, is an essential micronutrient for plants and animals, but is also recognized as a priority pollutant under the U.S. Clean Water Act. Historical and current anthropogenic activities have mobilized significant quantities of copper. Vehicle emissions and brake pad dust [1], pesticides [2], industrial processes, mining, and rooftops [3, 4] are a few of the sources that contribute copper to the environment. These uses may lead to the unintended and, in some circumstances, intended introduction of copper into aquatic ecosytems [5, 6]. Once introduced into the aquatic environment, copper is detected in multiple forms. It can be dissolved or bound to organic and inorganic materials either in suspension or in sediment. This so called speciation of copper is dependent on site specific abiotic and biotic factors. Copper is an element, so once introduced, it will persist indefinitely, cycling through ecosystems. Copper in its dissolved state is worthy of particular scrutiny as it is highly toxic to a broad range of aquatic species including algae, aquatic invertebrates, and fishes (including anadromous salmon and steelhead within the *Oncorhynchus* and *Salmo* genera).

Currently, anadromous salmonid populations inhabit waters of Alaska, Oregon, Washington, California, Idaho, and Maine (Atlantic salmon [*Salmo salar*]). Dissolved copper (referred to as dCu herein) is consistently detected in salmonid habitats including areas important for rearing, migrating, and spawning [7, 8]. Dissolved copper is known to affect a variety of biological endpoints in fish (e.g. survival, growth, behavior, osmoregulation, sensory system, and others; reviewed in [9]). More than forty years of experimental results show that sensory systems of salmonids are particularly sensitive to dissolved copper. Recent experimental evidence showed that juvenile sensory system mediated behaviors are also affected by short term exposures to dCu.

Given the ecological significance of these behaviors to salmonids, it is important to characterize the potential effects from dCu. The growing body of scientific literature indicates that dCu is a potent neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations (see discussion below). These concentrations may stem from anthropogenic inputs of dCu to salmonid habitats. Salmonid sensory systems mediate ecologically important behaviors involved in predator avoidance, migration, and reproduction. Impairment of these behaviors can limit an individual salmonid's potential to complete its lifecycle and thus may have adverse population level consequences.

The purpose of this paper is to: (1) summarize information on the effects of dCu to the sensory systems of juvenile salmonids in freshwater (also see Appendix); (2) conduct a benchmark concentration analysis to generate examples of dCu effect thresholds; and (3) to discuss site-specific considerations for sensory system effects. As such, this white paper focuses on a single contaminant (dCu), two relevant sensory system endpoints (olfaction and alarm response behavior), and a single salmonid life stage (juvenile, < 10 months old).

## Previous studies on the effects of copper

Examples of copper's effect on a suite of selected biological endpoints from laboratory and field exposures are presented in Table 1. Additionally, the Appendix contains a targeted review and summary of some of the previous studies showing copper's effect on salmonid behavior, including avoidance and migratory disruptions. A supplemental bibliography is also attached for further information on salmonid sensory systems. The following analysis of sensory effects on juvenile salmonids primarily emphasizes recent and ongoing research conducted at the National Oceanic Atmospheric Administration's Northwest Fisheries Science Center. However, the phenomenon that copper and some other trace metals can interfere with chemoreception, alter behaviors, and influence the movements of fish was first described at least 40 years ago, and a large body of knowledge on the adverse effects of dCu has subsequently developed (Table 1).

Table 1. Selected examples of adverse effects with copper to salmonids or their prey.

| **Species (lifestage)** | **Effect** | **Effect concentration (µg/L) (Note A)** | **Effect statistic** | **Hardness (mg/L) (Note B)** | **Exposure duration** | **Source/ Notes** |
|---|---|---|---|---|---|---|
| | **Sensory and behavioral effects** | | | | | |
| Coho salmon (juvenile) | Reduced olfaction and compromised alarm response | 0.18 - 2.1 | $EC_{10}$ - $EC_{50}$ | 120 | 3 hours | [10] |
| Chinook salmon (juvenile) | Avoidance in laboratory exposures | 0.75 | LOEC | 25 | 20 minutes | [11] |
| Rainbow trout (juvenile) | Avoidance in laboratory exposures | 1.6 | LOEC | 25 | 20 minutes | [11] |
| Chinook salmon (juvenile) | Loss of avoidance ability | 2 | LOEC | 25 | 21 days | [11] |
| Atlantic salmon (juvenile) | Avoidance in laboratory exposures | 2.4 | LOEC | 20 | 20 minutes | [12] |
| Atlantic salmon (adult) | Spawning migrations in the wild interrupted | 20 | LOEC | 20 | indefinite | [12] |

| Species (lifestage) | Effect | Effect concentration (μg/L) (Note A) | Effect statistic | Hardness (mg/L) (Note B) | Exposure duration | Source/ Notes |
|---|---|---|---|---|---|---|
| Chinook salmon (adult) | Spawning migrations in the wild apparently interrupted | 10 – 25 | LOEC | 40 | indefinite | [13] |
| Coho salmon | Delays and reduced downstream migration of dCu-exposed juveniles | 5 | LOEC | 95 | 6 day | [14, 15] |
| Rainbow trout | Loss of homing ability | 22 | LOEC | 63 | 40 weeks | [16] |
| | **Ecosystem effects** | | | | | |
| | Ecosystem function: Reduced photosynthesis | 2.5 | LOEC | 49 | ~ 1 year | [17] |
| | Ecosystem structure: loss of invertebrate taxa richness in a mountain stream | 5 | LOEC | 49 | ~ 1 year | [18] |
| | **Other sublethal effects** | | | | | |
| Chinook salmon | Reduced growth (as weight) | 1.9 | $EC_{10}$ | 25 | 120 days | [19] |
| Rainbow trout | Reduced growth (as weight) | 2.8 | $EC_{10}$ | 25 | 120 days | [20] |
| Coho salmon | Reduced growth (as weight) | 21 – 22 | NOEC | 24 - 32 | 60 days | [21] |
| Steelhead | Reduced growth (as weight) | 45 – > 51 | NOEC | 24 - 32 | 60 days | [21] |
| | **Direct Lethality** **(**Note C**)** | | | | | |
| Chinook salmon (fry) | Death | 19 | $LC_{50}$ | 24 | 96 h | [22] |
| Coho salmon (fry) | Death | 28 – 38 | $LC_{50}$ | 20 – 25 | 96 h | [15] |

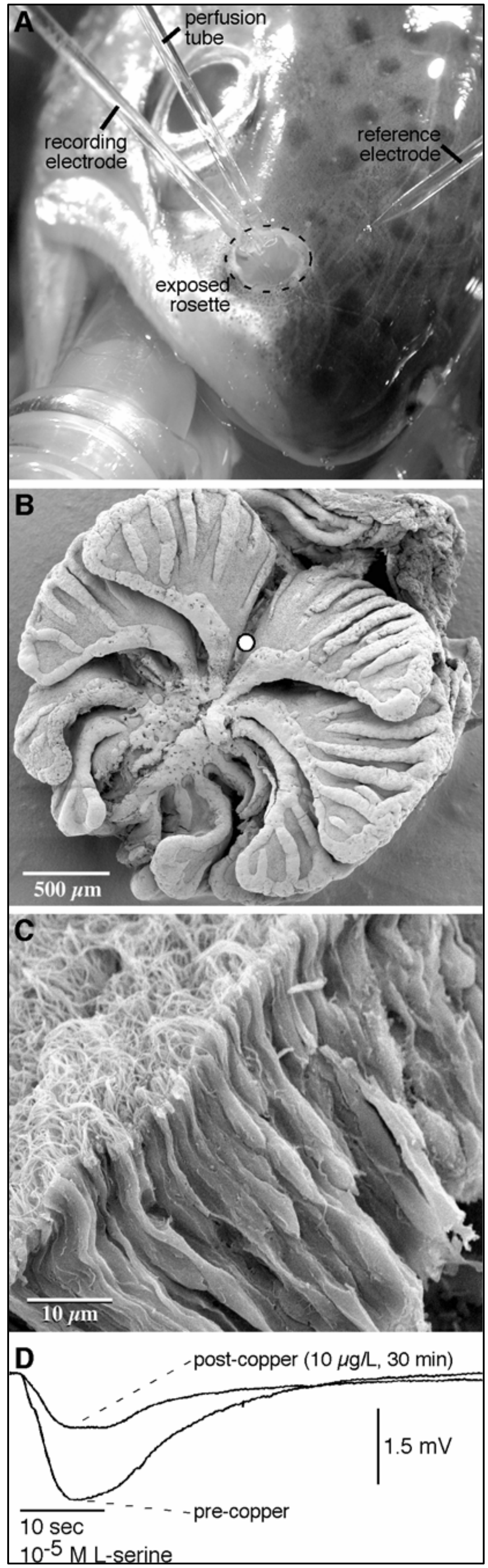
| Species (lifestage) | Effect | Effect concentration (μg/L) (Note A) | Effect statistic | Hardness (mg/L) (Note B) | Exposure duration | Source/ Notes |
|---|---|---|---|---|---|---|
| Steelhead/ Rainbow trout (fry) | Death | 9 – 17 | $LC_{50}$ | 24 – 25 | 96 h | [22, 23] |
| Coho salmon (adult) | Death | 46 | $LC_{50}$ | 20 | 96 h | [24] |
| Steelhead (adult) | Death | 57 | $LC_{50}$ | 42 | 96 h | [24] |
| Coho salmon (juvenile) | Death | 21 – 22 | NOEC | 24 – 32 | 60 days | [21] |
| Steelhead (juvenile) | Death | 24 – 28 | NOEC | 24 - 32 | 60 days | [21] |
| Steelhead (egg-to-fry) | Death | 11.9 | $EC_{10}$ | 25 | 120 days | [19] |

**Abbreviations:** LOEC – Lowest observed adverse effect concentration. Most LOEC values given are not thresholds, but were simply the lowest concentration tested; NOEC – No observed adverse effect concentration; $LC_{50}$ – the concentration that kills 50% of the test population; ECp – effective concentration adversely affecting (p) percent of the test population or percent of measured response, e.g., 10% for an EC10, etc.; Indefinite – field exposures without defined starting and ending times
**Note:** A. Effects and exposure durations stem from laboratory and field experiments, therefore in some experiments multiple routes of exposure may be present i.e. aqueous and dietary, and water chemistry conditions will likely differ (see reference for details).
**Note:** B. Hardness is reported as it can influence the toxicity of copper.
**Note:** C. Acute sensitivity of salmonids to copper probably varies by life-stage, and the swim-up fry stage is probably more sensitive than older juvenile life stages such as parr and smolts, or adults.

### Effects to anadromous salmonids' sensory systems exposed to dissolved copper

The salmonid olfactory sensory system relies on neurons (ciliated receptors) to detect and respond to cues in the aquatic environment. The receptors are in direct contact with the aqueous environment. Olfactory receptors detect chemical cues that are important in finding food, avoiding predators, navigating migratory routes, recognizing kin, participating in reproduction, and avoiding pollution. A pair of olfactory rosettes composes the peripheral portion of the olfactory system in a fish's nose (Figure 1A). Each rosette contains olfactory sensory neurons that respond to dissolved odors in water as they pass through the olfactory chamber (Figure 1B) where the olfactory receptors lie (Figure 1C). These chemical cues convey important information about the surrounding environment and underlie salmonid behaviors critical to completion of anadromous lifecycles.

Figure 1. Recording methods and features of the salmon peripheral olfactory system. A) Photograph showing the rostrum of a coho salmon during the recording of electro-olfactograms (EOGs). The mouthpiece provides chilled, anaesthetized water to the gills, while the perfusion tube delivers odor-containing solutions to the olfactory cavity. The recording electrode in the olfactory cavity and reference electrode in the skin monitor the response of the olfactory system to an odor. B) Scanning electron micrograph showing a rosette, located within an olfactory chamber of a juvenile coho salmon. Each rosette consists of lamellae (lobes) covered by an epithelium containing regions of sensory neurons. The open circle denotes the location and approximate size of the tip of the recording microelectrode. C) Scanning electron micrograph showing a cross-section from a region of sensory epithelium of a lamella. In the upper left is the apical surface containing the cilia and microvilli of the olfactory receptor neurons (ORNs). The dendrites and somata of the ORNs appear in the center within the epithelium, while the axons of the ORNs emerge from the basal surface at the lower right to produce the olfactory nerve. D) Typical odor-evoked EOGs obtained from a salmon before and after exposure to copper. A 10-second switch to a solution containing $10^{-5}$ M L-serine is shown with a horizontal bar. The EOG evoked by the odor pulse consists of a negative deflection in the voltage. A 30-minute exposure to copper reduced the amplitude of the EOG evoked in the same fish by 57%. Figure adapted from Baldwin and Scholz [25].



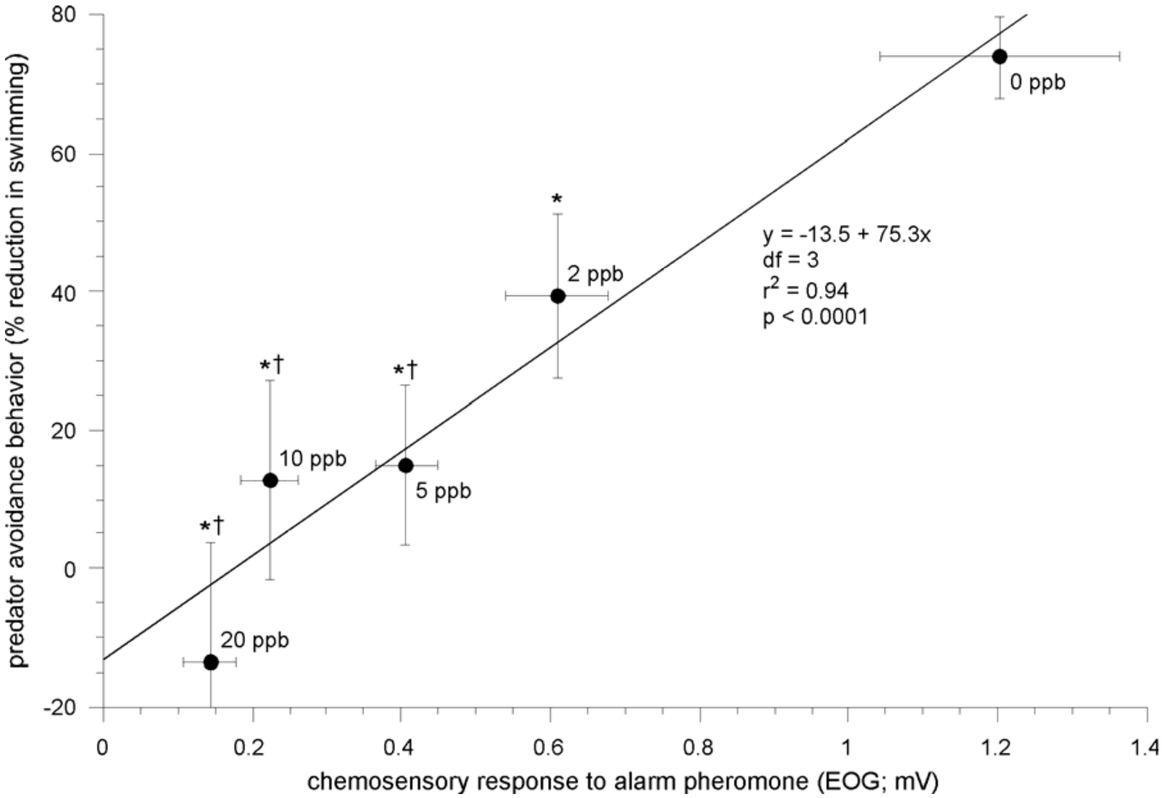
The precise mechanism by which dCu damages the olfactory system remains unknown, although direct exposure to dCu can impair and destroy olfactory sensory neurons [10, 26-28]. Impairment of olfaction (i.e. smell) can be measured by an electrophysiology technique called the electro-olfactogram (EOG) (Figure 1) [25, 28, 29]. The EOG measures olfactory receptor function in fish. Reductions in the amplitude of the EOG of copper-exposed fish compared to unexposed fish reflect functional losses in sensory capabilities. Dissolved copper's toxic effect to olfactory sensory neurons is observable as a reduction in or elimination of the EOG amplitude to a recognizable odor (Figure 1D).

Several recent studies highlight some important aspects of copper olfactory toxicity [10, 27, 30]. Baldwin et al. [27] found that the neurotoxic effects of copper in coho manifest over a timescale of minutes. At 10 minutes, EOG amplitude reductions were observed in juvenile coho exposed to 2, 5, 10, and 20 μg/L dCu above experimental background (3 μg/L). After 30 minutes at 2 μg/L dCu above experimental background, the EOG amplitude from juvenile coho salmon to odors was reduced by approximately 25% compared to controls; in 20 μg/L dCu after 30 minutes by approximately 80%. Sandahl et al. [30] found similar effects following 7 days of exposure (both in EOG reductions and copper concentrations). This result indicated that the juvenile olfactory system cannot adapt to, and correct for, continuous copper exposure for durations up to 7 days.

Recently, using EOG measurements in combination with a predator avoidance assay, Sandahl et al. [10] presented the first evidence that impaired olfaction (smell) resulted in a direct suppression of predator avoidance behavior (alarm response) by juvenile coho at environmentally relevant dCu exposures (≥2.0 μg/L; 3 hr exposure). Unexposed juveniles (control treatment) reduced their swimming speed on average by 74% (alarm response) in response to an alarm odor (conspecific skin extract). A reduction in swimming speed is a typical predator avoidance response for salmonids and many other fish. In unexposed fish, the alarm odor elicited a mean EOG response of 1.2 mV. Juvenile coho exposed to 2-20 μg/L copper exhibited measurable reductions in both EOG (50-92%) and alarm response (47 - >100%) [derived from Figure 2 in Sandahl et al., [10]]. Juvenile coho exhibited statistically significant decline in antipredator behavior at 5, 10, and 20 μg/L dCu (Figure 2).

Importantly, no concentrations of dCu below 2 μg/l were tested. This is particularly troubling because all concentrations tested (between 2-20 μg/L) significantly affected olfaction e.g. reductions in EOG amplitudes of ~ 50 - 92%. Because individual juvenile coho were significantly affected at the lowest concentration tested (2 μg/L), uncertainty remains at what concentrations salmonid olfaction is first impaired. The results of this last study provide evidence that juvenile salmon exposed to sublethal dCu concentrations at 2 μg/L (resulting in approximately 50% reductions in EOG), and likely even lower, might not recognize and respond to a predation event, and therefore have an increased risk of being eaten by other fishes or birds, an event referred to as ecological death [31].

Figure 2. Copper-induced reductions in juvenile salmonid olfactory physiology and behavior are significantly correlated. Fish exposed to dCu (3h) showed reduced olfactory sensitivity and corresponding reduction in predator avoidance behavior. Values represent treatment means (with copper exposure concentration labeled to the right); error bars represent one standard error; n=8-12 individual coho salmon; * represents a statistically significant difference in olfactory response (EOG data) compared to controls (one-way ANOVA with Dunnett post hoc test, $p<0.05$); †represents statistically significant difference in behavioral response to skin extract (% reduction in swimming) compared to controls (one-way ANOVA with Dunnett post hoc test, $p <0.05$). The line represents a statistically significant linear regression based on treatment means ($n = 5$; $p < 0.0001$; $r^2 = 0.94$). 1 ppb = 1 μg/l. Adapted from Figure 2C Sandahl et al [10].




Typically dCu concentrations in road runoff are well within the range affecting anti predator behavior (3.4 - 64.5 μg/L, with a mean of 15.8 μg/L [8]). The length of exposure is also likely to be sufficient, as stormwater runoff durations may range from a few minutes to several hours [5]. Fish may regain their capacity to detect odors fairly quickly in some cases; physiological recovery of olfactory neuron function is dose-dependent and occurs within a few hours at low copper concentrations (i.e., <25 μg/L dCu; [27]). However long-term damage is also documented. In the case of olfactory neuron cell death (i.e. ≥25 μg/l copper [11, 26]) recovery is on the order of weeks [32] and in some cases months [33].

Interestingly, another fish sensory sytem, the lateral line, is also sensitive to dCu. It is composed of mechanosensory neurons (hair cells) that collect data from the aquatic environment. Specifically, the neurons detect vibrations and other forms of water movement in the aquatic environment; thereby mediating shoaling, pursuit of prey, predator avoidance, and rheotaxis (flow orientation). In a recent study, dissolved copper (i.e., ≥20 µg/L; 3 hr exposure) killed 20% of zebra fish hair cells [34]. As mentioned earlier, juvenile Chinook olfactory epithelial cells may also be killed by increases in dCu, highlighting the similar sensitivity of olfactory and lateral line receptors to dCu. Consequently, dCu may damage or destroy either or both of these important sensory systems. Currently, we are not aware of any research on the effects of dCu to salmonid lateral lines, although the comparable sensitivities of olfactory and lateral line neurons suggest dCu affects these neurons as well.

In this paper, a benchmark dose (concentration) analysis [35] is applied to recent data from dose-response experiments on juvenile salmonids exposed to dCu [10] to determine the exposure concentrations that may adversely affect salmonid sensory systems . In previous studies, BMCs were determined for olfactory responses, however concomitant behavioral responses were not measured [27, 30]. The BMC analysis conducted herein determined concentrations of dCu that could be expected to affect juvenile salmonid olfaction and, by extension, alarm response behavior involved in predator avoidance.

## Application of the benchmark concentration analysis

The benchmark concentration (BMC), also referred to as a Benchmark dose method, has been used since 1995 by agencies such as the Environmental Protection Agency (EPA) to determine No Observable Adverse Effect Level (NOAEL) values. The method statistically fits dose-response-data to determine NOAEL values [35]. This is in contrast to other methods (e.g. using an analysis of variance) that rely on finding a No Observable Effect Concentration (NOEC) and Lowest Observable Effect Concentration (LOEC) to establish the NOAEL. Multiple difficulties arising from the traditional approach of selecting a NOAEL from dose-response data were previously identified by EPA. Specific short comings associated with traditional methods included: 1) arbitrary selection of a NOAEL based on scientific judgments; 2) experiments involving fewer animals produced higher NOAELs; 3) dose-response slopes were largely ignored; and 4) the NOAEL was limited to the doses tested experimentally [35]. These as well as other concerns with selection of an NOAEL led to the development of an alternative approach, the BMC analysis. The BMC approach uses the complete dose-response dataset to identify a NOAEL, thereby selecting an exposure concentration that may not have been tested experimentally.

The BMC is statistically defined as the lower confidence limit for a dose that produces a predetermined adverse effect relative to controls. This effect is referred to as the benchmark response [BMR]) [35]. Unlike the traditional method of selecting the NOAEL (e.g. establishing a NOEC) the BMC takes into account the full range of dose-response data by fitting it with an appropriate mathematical model. These can be linear, logarithmic, sigmoidal, etc. The BMR is generally set near the lower limit of responses (e.g. an effect concentration of 10%) that can be measured directly in exposed, or affected, animals.

In the present context, a BMC approach was used to estimate thresholds for dCu's sublethal effects on the chemosensory physiology and predator avoidance behaviors of juvenile coho salmon [10]. An example of this approach is shown in Figure 3. This methodology has been used previously to determine toxicity thresholds in Pacific salmon [27, 30, 36]. The dose-response relationship for copper's effect on the EOG was described by fitting the data with a sigmoid logistic model:

$$y = m/[(1+(x/k)^n]$$

where m = maximum EOG amplitude (fixed at the control mean of 1.2 mV)

y = EOG amplitude

x = copper concentration

k = copper concentration at half-maximum EOG amplitude ($EC_{50}$)

n = slope

For this non-linear regression, the average olfactory response of the control fish to a natural odor was used to constrain the maximum odor evoked EOG (m in the above equation). Consequently, the control fish were not used in the regression other than to set *m*. The regression incorporated the individual response of each exposed fish (n = 44 total) rather than the average values for each exposure group. As shown in Figure 3, the sigmoid logistic model was a very good fit for both the sensory and behavioral data ($r^2$= 0.94; p<0.0001). Benchmark concentrations were then determined based on the concentration at which the estimated curve intersected benchmark responses.

## Results of the benchmark concentration analysis

Examples of benchmark concentrations and responses are presented in Figure 3 and Table 2. The EPA methodology recommends using the concentration that represents a 10% reduction in response compared to controls when limited biological effects data are available [37]. This is the $BMC_{10}$ and is synonymous with the concentration producing an effect of 10% ($EC_{10}$), in this case a 10% reduction in the recorded amplitude of the salmon's chemosensory response (EOG). Since the predicted fish EOG response at the $BMC_{10}$ falls well within the olfactory response of unexposed juveniles i.e. 95% CI (control fish; Figure 3), it is more than likely that this individual response (1.08 mV) at the $BMC_{10}$ (0.18 ug/L) would not be detectable or biologically significant as an adverse response. This highlights that a BMC based purely on a relative departure (e.g. $BMC_{10}$) may not account for the variability of olfactory responses in unexposed fish.

Other BMCs were derived using statistical criteria to determine benchmark responses. For example, Table 2 shows two BMCs that were determined using the statistical departure of the lower-bound confidence interval (CI) of the control mean (unexposed fish), 1.2 mV (either the 90 or 95% CI). The selection of different CIs results in different BMCs. The CI derived BMCs represent a reasonable estimate of when an individual salmonid is likely to have a significant reduction in olfaction and a concomitant reduction in predator avoidance behavior. The relative departures from controls in Table 2 are equivalent to effective concentrations for olfactory inhibition, i.e. at the lower-bound 90% CI a BMC of 0.59 µg/L equates to a $BMC_{24.2}$. Said another way, the BMC analysis predicts a substantial 24.2 % reduction in olfaction (i.e. EOG amplitude) at 0.59 µg/L dCu. At the lower-bound 95% CI a 29.2% reduction in olfaction is predicted to occur at 0.79 ug/L.

The $BMC_{50}$ is equivalent to the $EC_{50}$ for olfactory responses (2.1 µg/L) and is very similar to the lowest observable effect concentration (LOEC) of 2 µg/L. Since the EC50 approximately equals the LOEC, it is almost certain that effects to juvenile salmonid's olfaction will occur at lower concentrations than those measured. Therefore it is appropriate and useful to apply a BMC analysis to these data to predict effects occurring between 0 and 2 µg/L dCu. The predicted effect thresholds for sensory responses in juvenile coho ranged from 0.18 - 2.1 µg/L which corresponded to reductions in predator avoidance behavior (i.e. reduced alarm response) of 8 - 57%. Comparatively, the other two studies that conducted a BMC approach with salmon olfaction datasets (e.g. EOG measures) estimated dCu BMCs from 3.6 – 10.7 ug/L ($BMC_{20}$-$BMC_{50}$) [17] and 2.3 - 3.0 ug/L ($BMC_{25}$) [15].

Together these three studies highlight that different experimental conditions including age of fish, exposure duration, and experimental background of dCu may influence BMCs. Importantly, of the three experiments that derived BMCs for olfactory impairment, the Sandahl et al [10] (i.e. the data set used in this white paper) empirically linked impaired olfaction to an ecologically relevant behavior i.e. reduced alarm behavior (Figure 2). Therefore, we believe that the dCu BMC analysis in this white paper is the most ecologically relevant of the three studies.

Figure 3. Using a benchmark concentration approach to estimate a threshold for dCu toxicity in the salmonid olfactory system. Filled circles represent treatment means; error bars represent the 95% confidence interval for each mean (n = 8-12 individual coho salmon). An asterisk indicates a statistically significant difference in the size of the olfactory response (EOG data) compared to controls (one-way ANOVA with Dunnett post hoc test, $p<0.05$). The line represents a statistically significant non-linear regression based on individual fish ($n = 44$; $p < 0.0001$; $r^2 = 0.55$). The gray band shows the 95% confidence band for the non-linear regression. The regression used a standard sigmoid function with the maximum constrained to the control mean (1.2 mV; indicated by the upper horizontal dashed line). Therefore, the control fish were not included in the non-linear regression. The lower bound of the 95% confidence interval of the control mean (0.85 mV) is indicated by the lower horizontal dashed line and is an example of a benchmark response (BMR). The large open circle shows where the regression line crosses the BMR and denotes the corresponding benchmark concentration (BMC) which, in this case, is a dCu concentration of 0.79 ug/L. Horizontal and vertical lines through the open circle highlight the 95% confidence intervals for the BMC based on the results of the non-linear regression. The small open circle shows where the regression line crosses the BMR (1.08 mV) and denotes the corresponding $BMC_{10}$ (0.18 ug/L) at which a 10% reduction in olfactory capacity is expected. Data from Sandahl et al. [10].

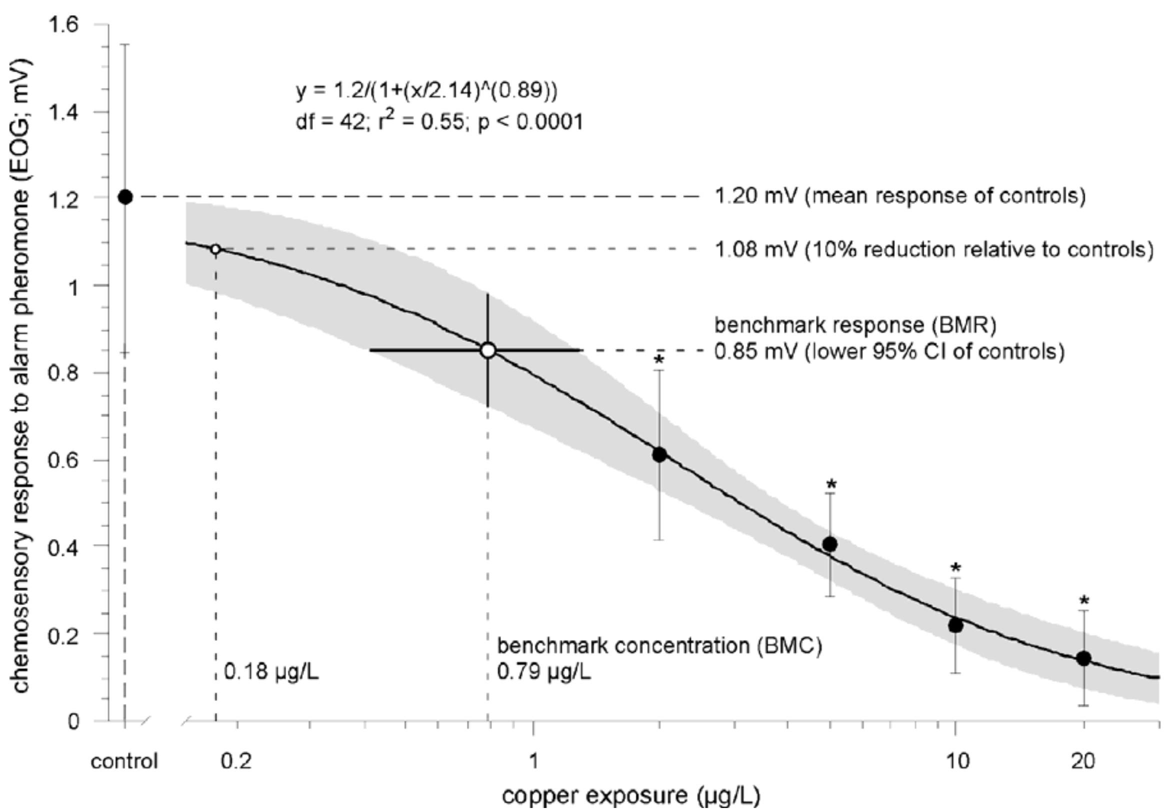


Table 2. Benchmark concentrations and benchmark responses for juvenile salmon exposed to dCu for 3 hr. Response values are a loss of olfactory function, or reduction in a chemosensory response to an alarm pheromone as measured via EOG recordings. Behavioral impairment indicates a predicted decrease in predator recognition and avoidance as indicated by a reduced alarm response. CI = confidence interval; NA = not applicable.

| **Benchmark Responses**[1] | | **Benchmark Concentrations**[2] | | **Behavioral Impairment (predicted)**[3] |
|---|---|---|---|---|
| Departure from mean of controls | | | | Departure from mean of controls |
| Statistical[4] (CI of control mean) | Relative[5] (% reduction in olfactory response) | Value[6] (µg/l) | 95% CI[7] (µg/l) | Relative[8] (% reduction in alarm response) |
| NA | 10.0 | 0.18 | 0.06 - 0.52 | 8.3 |
| Lower 90% | 24.2 | 0.59 | 0.30 - 1.16 | 25.6 |
| Lower 95% | 29.2 | 0.79 | 0.44 - 1.42 | 31.8 |
| NA | 50.0 | 2.10 | 1.60 - 2.90 | 57.2 |

[1] the predetermined level of altered response or risk at which the benchmark dose (concentration) is calculated (EPA/630/R-94/007; 02/1995)
[2] the dose (concentration) producing a predetermined, altered response for an effect (EPA/630/R-94/007; 02/1995)
[3] based on the linear regression shown in Figure 2; note behavioral responses were determined by inputting the Benchmark response value (EOG, mV) into the regression equation
[4] location of the value with respect to a confidence interval of the mean of the controls
[5] amount of reduction in the olfactory response represented by the value relative to the mean of the controls
[6] corresponding concentration, see Figure 3 and text for calculation method
[7] confidence interval for the value based on the non-linear regression
[8] amount of reduction in alarm response represented by the value relative to the mean of the controls

## Discussion of site specific considerations for sensory system effects

Below, we identify several issues to consider when applying the benchmark concentrations to real world aquatic ecosystems.

*These BMCs reflect expected impairment of chemosensory systems from short term increases of dCu above ambient concentrations.*
Specifically, the BMCs are predicated on anthropogenic increases of dCu to salmon habitats. Effects to juvenile salmonid olfaction are expected following a few minutes of exposure. Salmonids are capable of regulating the amount of internal copper via uptake

and elimination processes. These so called homeostatic mechanisms (such as metallotheionein induction) can reduce copper's toxic effects and may result in acclimation. Consequently, fish may tolerate certain copper exposures without showing overt toxicological responses, however at higher levels these mechanisms ultimately fail. The BMC examples presented in Table 2 are not expected to be alleviated by juvenile salmonid homeostatic mechanisms. This is supported by the effect concentrations presented in Table 1 and the Appendix.

Although acclimation could theoretically reduce the toxicity of dCu to the salmon olfactory system, initial evidence indicates that this is not likely for pulsed or short term exposures lasting less than a week [11]. For other measures of copper toxicity from long term exposures, evidence suggests that acclimation may not occur (Table 1, Appendix).

These BMC examples represent short term increases of dCu above ambient concentrations in surface waters (defined here as < 3 μg/L) [10, 27, 30]. It is uncertain whether fish sensory systems acclimated to higher ambient concentrations (i.e. >3 μg/L) will respond differently to additional anthropogenic loading, which might then lead to different threshold concentrations for olfaction and behavior.

*These BMCs reflect the impact of dissolved copper on olfaction and predator avoidance behavior.*
In salmonid habitats fish are rarely exposed to dCu only. In fact, exposure to complex mixtures of other toxic compounds (e.g. metals, pesticides, PAHs, etc.,) in conjunction with other multiple stressors (e.g. elevated temperatures, low dissolved oxygen, etc.,) is the norm. Equally important are exposure routes other than the water column, such as consumption of contaminated prey items (dietary) or contact with contaminated sediments. Threshold examples (BMCs) presented here are based solely on juvenile salmonids exposed to dCu. Presently, these thresholds are uncertain for multiple routes of exposure and complex mixtures of contaminants for olfaction. That being said, several studies demonstrate greater than expected toxicity to other fish endpoints from mixtures of metals [12, 38]. For example, mixtures containing zinc and copper were found to have greater than additive toxicity to a wide variety of aquatic organisms including freshwater fish [9], and other metal mixtures also yielded greater than additive toxic effects at low dissolved metal concentrations [39]. The toxic effects of metals to salmonids are also likely to be exacerbated by poor water quality conditions, including elevated temperatures, low dissolved oxygen, pesticides, and polycyclic aromatic hydrocarbons. While the interactions of multiple stressors and mixtures are beyond the scope of this document, they warrant careful consideration in site specific assessments.

*These BMCs were derived from experiments using a single freshwater source (de-chlorinated, soft municipal water).* Hardness, alkalinity, and dissolved organic carbon (DOC) are known to alter the bioavailability of dissolved copper in surface waters to the gills of fish. These water chemistry parameters can therefore influence the potential for dCu exposure in the field to cause an acute fish kill. Acute copper lethality via the gill route of exposure is typically estimated using the Biotic Ligand Model (BLM; reviewed by [40]). However, recent unpublished research by McIntyre et al. [41] suggest that these parameters may have less influence on olfactory responses especially when compared to ambient levels of hardness, alkalinity, and DOC.

The USGS has monitored hardness, alkalinity, and DOC for more than 10 years in many West Coast river basins including the Willamette River Basin, Puget Sound Basin, Yakima River Basin, and the Sacramento-San Joaquin River Basin (National Water Quality Assessment Program [NAWQA]. Several at risk species of anadromous salmonids inhabit these basins. The monitoring data indicate that surface waters within these basins typically have very low hardness and alkalinity and seasonally-affected DOC concentrations. Hardness, alkalinity, and DOC levels found in most freshwater habitats occupied by Pacific salmonids would be unlikely to confer substantial protection against dCu olfactory toxicity [27], [41-43].

Recent experimental results suggest that significant amelioration of olfactory toxicity due to hardness is unlikely in typical Pacific salmonid freshwater habitats. The experiment showed that hardness at 20, 120, and 240 mg/L Ca (experimentally introduced as $CaCl_2$) did not significantly protect juvenile coho from olfactory toxicity following 30 minute laboratory exposures to 10 µg dCu/L above an experimental background of 3 µg/L [27]. In another experiment, a 20 µg dCu/L exposure (30 minutes) in water with low hardness and alkalinity and no DOC produced an 82% inhibition in juvenile coho olfactory function [41]. A hardness of ≥ 82 mg/L Ca was needed to reduce the level of olfactory inhibition to ≤50% at 20 ug/l dCu [41]. However, 82 mg/L was never exceeded in any of the surface water samples from USGS sampled NAWQA basins [41].

Typical alkalinity values from Pacific Northwest and California streams are also unlikely to protect salmonids from olfactory toxicity (NAWQA surface water data). In fact, 0.4% of stream samples contained alkalinity levels sufficient to cut dCu's toxic impact to juvenile salmonids olfactory system in half [41]. Decreases in dCu's olfactory toxicity were obtained with large increases in alkalinity [41]. However, increasing water hardness and alkalinity had some protective effect against the olfactory neurotoxicity of dCu in coho salmon, but the effects were small with olfactory function rising to ~30% of normal (or 15% increase in olfactory function) across the range of average hardness and alkalinity levels in sampled NAWQA basins [41]. Bjerselius et al., [43] and Winberg et al., [42] found that hardness and alkalinity provided limited amelioration of olfactory responses in juvenile Atlantic salmon exposed to dCu.

Increases in DOC showed greater protection to dCu compared to increases in alkalinity and hardness. Twenty-nine percent of USGS surface water samples from West Coast basins had a DOC concentration sufficient to limit olfactory impairment to 50 percent or less at 20 µg dCu /L [41]. However, only 2% of all samples contained a DOC concentration (8 mg/L) sufficient to completely protect the olfactory responses of juvenile coho at 20 µg dCu /L [41]. This information underscores the importance of evaluating site specific DOC data to address its potential influence on olfactory toxicity.

Accordingly, we consider the BMC thresholds presented in this document to be broadly applicable to most Pacific salmonid freshwater environments as typical hardness, alkalinity, and DOC concentrations are unlikely to confer substantial protection against dCu olfactory toxicity.

*Dissolved copper's effect on salmonid olfaction in saltwater environments remains a recognized data gap and it is unclear whether the derived BMC thresholds apply to salt water environments.* Estuarine and near shore salt water environments, despite their higher salinity (in part due to increased cation concentrations) and hardness may or may not confer protection against dCu-induced olfactory toxicity. One source of this uncertainty is whether or not free copper ($Cu^{2+}$) is the sole species of copper responsible for olfactory toxicity. In freshwater, evidence suggests that $Cu^{2+}$ is not the only toxic species that adversely affects olfaction [41] and other fish endpoints including mortality [40]. Other copper species e.g. CuOH ($Cu^{1+}$) will also bind to the gill producing copper toxicity [40]. While the physiology of a salmonid's olfaction in freshwater environments is well characterized, it is unclear whether the physiological changes to olfactory systems in estuarine and marine environments alter the toxicity of dCu.

*Using the Biotic Ligand Model we calculated an acute Criterion Maximum Concentration (CMC).* The United States Environmental Protection Agency (EPA) sets acute water quality criteria by calculating an acute Criterion Maximum Concentration (CMC) [44]. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect [45].We calculated an acute CMC using the Biotic Ligand Model (BLM) [46]. Interestingly, the estimated acute CMC based on the BLM using measured and estimated water quality parameters from Sandahl et. al. [10] was 0.63 µg/L with a range from 0.34 to 3.2 µg/L, while the EPA hardness-based acute CMC [45] was 6.7 µg/L. Because the BLM-based acute criterion is sensitive to pH and DOC, the range of measured test pH values (6.5 to 7.1) and the range of estimated DOC values (0.3 to 1.5 mg/L) produced this range of BLM-based acute criterion values. It is also interesting that the acute CMC range (0.34 - 3.2 ug/L) overlapped with the olfactory based BMC range (0.18 – 2.1 ug/L).

*Juvenile salmonids may or may not be able to avoid short term increases in dCu.* Salmonids will actively avoid water containing dCu if they can detect it. However, if salmonids avoid optimal rearing and spawning habitats reductions in growth and reproductive success may occur. One study showed that chinook salmon no longer avoided copper following a 20 day exposure at a low, environmentally realistic concentration (2 ug/L) [11]. Since salmonids have the ability to avoid areas with elevated copper, in theory, if these areas were limited and did not interfere with migratory routes, juveniles might simply bypass them. Smith and Bailey [47] and Mebane [13] give examples of deriving regulatory "zones of passage" around wastewater discharges that were based upon salmonid avoidance responses. However, in areas with diffuse, nonpoint source pollution, or multiple point source discharges it may be difficult to determine "zones of passage", or available zones of passage may not even exist. Environmental circumstances may force fish to be exposed to copper they would otherwise detect and avoid, or fish will avoid using important habitats. The "zones of passage" concept would likely not apply to rearing or spawning habitats affected by dCu.

Anthropogenic loading of dCu to surface waters often occurs as stormwater runoff and other types of short term, pulsed inputs lasting a few minutes to hours and in some cases days. In this context, dCu's effect on olfaction manifests in as little as 10 minutes [27]. Recovery of affected olfactory sensory function will require hours to weeks depending on the extent of olfactory damage, which depends on both concentration and duration of exposure [28]. Acute exposure can inhibit olfactory function for months if exposure is sufficient to cause death to sensory neurons (25ug/L [11,26]) [33]. The impacts of copper on fish olfaction will likely be cumulative if full recovery is not achieved between pulses of exposure.

*These BMCs were derived using data from juvenile coho salmon.*
The examples of BMC thresholds were derived from data based on juvenile Coho salmon (4-5 month old; mean of 0.9 grams [wet weight]). These BMC examples are generally applicable to juvenile salmonids. Three hour exposures of four month old steelhead to a similar range of dCu produced comparable reductions in EOG as seen in four month old coho (Baldwin et al.,personal communication). Studies on 10 month old juvenile coho had similar reductions in olfaction compared to 4 month old fish [27, 30]. Juvenile chum salmon (2-3 month old) also showed a dose dependent reduction in EOG amplitude following exposure to dCu (3-58 ug/L) [28]. Taken together these data support applying the BMC threshold examples broadly to juvenile salmonids. While olfaction is certainly critical to all salmonid lifestages, the application of these thresholds to other life stages (i.e. smolts and adults) remains uncertain.

**Conclusions**

Dissolved copper (dCu) is a ubiquitous, bioavailable pollutant that can directly interfere with fish sensory systems and by extension important behaviors that underlie predator avoidance, juvenile growth, and migratory success (see appendix). Recent research shows that dCu not only impairs sensory neurons in a salmonid's nose, but also impairs juvenile salmonids' ability to detect and respond to predation cues. A juvenile salmonid with disrupted predator avoidance behaviors stands a much greater risk of being eaten and therefore the likelihood of surviving to reproduce is reduced. Whether this individual behavioral effect impacts a given population will depend, in part, on the number of the individuals affected and the status of the population (numbers, distribution, growth rate, etc.).

In this paper, benchmark concentrations (BMC) were calculated using an EPA methodology to provide effect threshold examples for juvenile salmonids' sensory systems. The BMC examples represent the dCu concentration (above background or ambient levels [where background is less than or equal to 3 ug/L) expected to affect juvenile salmonids' ability to avoid predators in fresh water. Benchmark concentrations ranged from 0.18 – 2.1 µg/L corresponding to reductions in predator avoidance behavior (an alarm response) from approximately 8 – 57%. Taking into account the olfactory responses of unexposed fish (e.g. control treatment), a more biologically relevant range of BMCs is 0.59 – 2.1 ug/L (Table 2). This second range of BMC thresholds for juvenile salmonid sensory and behavioral responses is similar to or slightly less than documented effect concentrations to other copper-affected sublethal endpoints such as behavior, and growth., 0.75 - 2.5 µg/L. These levels may also affect other organisms in the ecosystem upon which salmonids depend, for feeding and sheltering (Table 1 and Appendix).

The primary objective of this paper was to present examples of threshold concentrations for effects of dCu on a critical aspect of salmonid biology, olfaction. A secondary objective of this paper was to summarize a selection of recent and historical information related to the effects of dCu on salmonid sensory systems. Importantly, this overview is not a comprehensive summary of the myriad effects of copper to anadromous salmonids. However, several conclusions were made based on the studies reviewed thus far and in the appendix concerning juvenile salmonids. First, salmonid's and other fish's behavior can be disrupted at dCu concentrations in the low ppb range. Second, reduced growth and impaired swimming performance resulted following dCu exposures as discussed in the appendix. These effects may result in increased susceptibility to predation and may result in population level consequences. Third, in some freshwater systems it is likely that acute toxicity occurs from brief pulses of elevated dCu concentrations.

Taken together, the information reviewed and presented herein indicates that significant impairment of sensory functions important to survival of threatened and endangered juvenile salmonids is likely to be widespread in many freshwater aquatic habitats. Impairment of these essential behaviors may occur following ten minutes of exposure and continue for hours to weeks depending on concentration and duration. Due to these acute, sublethal responses i.e. within minutes, avoidance or acclimation are unlikely to reduce the effects of short term anthropogenic increases of dCu to juvenile salmonids.

It remains uncertain how and to what degree these short term dCu exposures of juvenile salmonids affect salmonid populations. What is certain is that salmonids use their sense of smell to avoid predation events, participate in reproduction, migrate, avoid poor water quality, and feed. Each of these olfactory-mediated behaviors is important for successful lifecycle completion.

This technical white paper is a summary and targeted synthesis regarding sensory effects to juvenile salmonids from low-level exposures to dissolved copper (dCu). As such, the material presented in this paper serves to summarize research on dCu and its impacts on salmonid sensory systems. This document is a snap shot of the existing information; undoubtedly, new information will become available that enhances our understanding of copper's effect on salmonid populations and their supporting habitat.

## Appendix:
## Other salmonid sensory effects of dissolved copper

In this appendix, results are highlighted from several studies that we thought were particularly relevant, including comparing the concentrations that have caused sensory effects to concentrations causing lethality or growth reductions in field and laboratory experiments. As such, the following review is not an exhaustive summary of copper's adverse effects to anadromous salmonids. We emphasize studies that were conducted in waters with low alkalinity and hardness (< 50 mg/L as calcium carbonate), and if reported, low concentrations of dissolved organic material. These conditions were emphasized since we believe these are the most relevant water quality conditions for an area of particular concern to us – freshwater habitats used by juvenile salmonids in the Pacific Northwest and California, USA.

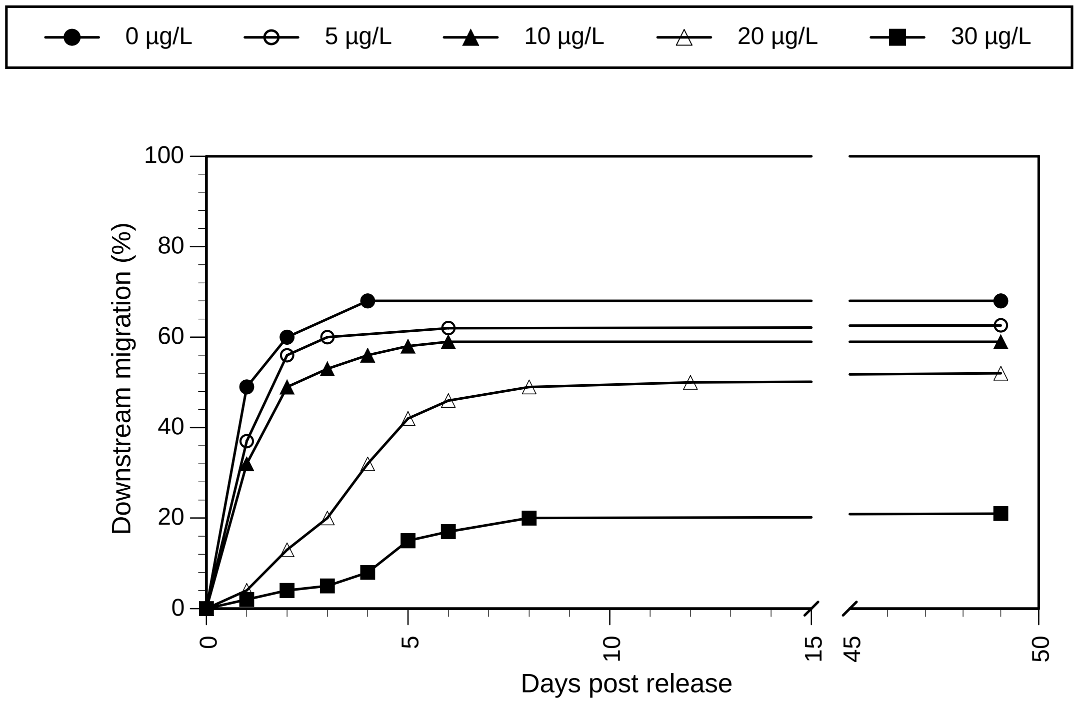
**Migratory disruption**

Laboratory and field experiments with salmonids have shown avoidance of low concentrations of copper, disruption of downstream migration by juvenile salmonids, loss of homing ability, and loss of avoidance response to even acutely lethal concentrations of copper follow long term habituation to low level copper exposure. Saucier et al. [16] examined the impact of a long-term sublethal copper exposure (22 ug/L; 37-41 weeks in duration) on the olfactory discrimination performance in rainbow trout. When controls were given a choice between their own rearing water or other waters, they significantly preferred their own rearing water, whereas both copper-exposed groups showed no preference. They concluded that their results demonstrate that a long-term sublethal exposure to copper, as it commonly occurs under "natural" conditions, may result in olfactory dysfunction with potential impacts on fish survival and reproduction.

Field studies have reported that copper impairs both upstream spawning migration of salmonids and downstream out migration of juveniles. Avoidance of copper in the wild has been demonstrated to delay upstream passage of Atlantic salmon moving past copper-contaminated reaches of the river to their upstream spawning grounds, unnatural downstream movement by adults away from the spawning grounds, and by increased straying from their contaminated home stream into uncontaminated tributaries. Avoidance thresholds in the wild of 0.35 to 0.43 toxic units were about 7-times higher than laboratory avoidance thresholds (0.05 toxic units) perhaps because the laboratory tests used juvenile fish rather than more motivated spawning adults. For this study 1.0 toxic unit was defined as an incipient lethal level, ILL (essentially a time independent $LC_{50}$), of 48 µg/l in soft water [12, 48]. Studies of home-water selection with returning adult salmon showed that addition of 44 µg/l copper to their home-water reduced the selection of their home stream by 90% [49]. Releases of about 20 µg/l from a mine drainage into a salmon spawning river resulted in 10 - 22% repulsion of ascending salmon during four consecutive years compared to 1- 2% prior to mining [49]. The upstream spawning migration of Chinook salmon in Panther Creek, Idaho may have been interrupted during the 1980s and early 1990s when the fish encountered dCu concentrations of 10- 25 µg/l. In Panther Creek, the majority of spawning habitat and historical locations of Chinook spawning were high in the watershed, upstream of copper discharges. However, Chinook were only observed spawning below the first major diluting tributary, a point above which copper concentrations averaged about 10- 25 µg/l during the times of the spawning observations [13, 50].

Sublethal copper exposure has been shown to interfere with the downstream migration to the ocean of yearling coho salmon. Lorz and McPherson [14, 15] and Lorz et al. [51] evaluated the effects of copper exposure on salmon smolts' downstream migration success in a series of 14 field experiments. Lorz and McPherson [14, 15] exposed yearling coho salmon for six to 165 days to nominal copper concentrations varying from 0 - 30 µg/l. They then marked and released the fish during the normal coho migration period and monitored downstream migration success. The fish were released simultaneously, allowing for evaluation of both copper exposure concentrations and exposure duration on migration success. All dCu exposures resulted in reduction of migration compared with unexposed control fish. Migration success decreased with both increasing copper concentrations and increased exposure time for each respective concentration. Exposure to 30 µg/l dCu for as little as 72 hours caused a considerable reduction in migration (~60%) compared to control fish. The reductions in migration following short-term exposures to dCu are illustrated in Figure 4, which was re-drawn from Lorz and McPherson [14]. Following exposure to 30 ug/L dCu, 80% of coho did not reach the migratory point in 49 days. These concentrations (5-20 ug/L) were one-tenth to one-third the 96-hour $LC_{50}$ for the same stock of juvenile coho salmon in the same water. Lorz et al. [51] further tested downstream migration with yearling coho salmon previously exposed to copper, cadmium, copper-cadmium mixtures, zinc, and copper-zinc mixtures. Copper concentrations in all tests were held at 10 µg/l. In all cases, the copper exposed fish again had poorer migratory success than did controls. The other metals did not show the dose-dependent result found for copper. These studies suggest that exposure to copper concentrations at levels found in streams subject to nonpoint copper pollution may impair downstream migration, a result of direct and indirect effects to salmon smolts, including reproductive success.

Figure 4.  Reduction in downstream migration of yearling coho salmon following 6-days exposure to copper at various concentrations.  Redrawn from Lorz and McPherson [14], their figure 19.




## Laboratory avoidance studies

Studies have shown that salmonids can detect and avoid copper at low concentrations when tested in troughs or streams that allow them to choose between concentration gradients.  To our knowledge, the lowest copper concentration reported to cause avoidance in laboratory conditions was 0.1 µg/L [52].  However, these results may have low applicability to ambient conditions because copper exposure concentrations were not analytically verified. Avoidance thresholds of 2 µg/l copper have been reported for Atlantic salmon (*Salmo salar*), concentrations that are less than one-tenth of acute LC50 values [48].  Giattina et al. [53] reported that rainbow trout appeared to detect copper concentrations down to 1.4 to 2.7 µg/L, because declines in residence time started to occur at these lower concentrations.  However, the responses were only statistically significant at 4.4 to 6.4 µg/l depending on whether fish were exposed to a gradually increasing or abruptly increasing concentration gradient respectively.  At exposure to extremely high dCu levels e.g. 330-390 µg/L, trout showed diminished avoidance and sometimes attraction to acutely lethal concentrations [11,53,54].

Chapman [54] reported that long-term sublethal copper exposures had impaired the avoidance performance of salmonids.  Steelhead trout, acclimated to low copper levels by surviving about three-months early life stage toxicity testing, subsequently failed to avoid much higher, acutely lethal concentrations.  Following about three-month continuous exposure to 9 µg/l copper (from fertilization to about 1-month after swim up) the copper-acclimated fish and control fish with no previous copper exposure were exposed to a range of copper concentrations from 10 to 80 µg/l in avoidance-preference testing. The tests used the same counter flow avoidance-preference test chambers described by Giattina et al. [53]. The acclimated trout failed to avoid even the highest copper concentrations while most of the unexposed fish avoided all concentrations.

Hansen et al. [11] and Marr et al. [55] conducted a variety of behavioral and other toxicity studies with Chinook salmon and rainbow trout exposed to copper. In these studies they used well water that was diluted with deionized water and spiked with copper to obtain a hardness, alkalinity, and pH that simulated those in Panther Creek, a mine-affected stream in Idaho. The avoidance response of the Chinook salmon was statistically significant for 0.8 and 2.8 -22.5 µg/L copper but was not significant for a 1.6 µg/L copper treatment. Since the avoidance responses (percent time spent in test water) were similar between the 0.8, 1.6, and 3 µg/L treatments, but the 1.6 µg/L treatment had fewer replicates than the other treatments (10 vs. 20), the lack of statistical significance for the 1.6 µg/L treatment was probably an artifact of the different sample sizes than a true lack of response. Rainbow trout consistently avoided copper at concentrations of 1.6 µg/L and above. To simulate avoidance responses that might result upon exposing fish to background levels of copper, Hansen et al. [11] acclimated both Chinook salmon and rainbow trout to 2 µg/L copper for 25 days, and repeated the avoidance experiments. They observed that the avoidance response of Chinook salmon was greatly dampened such that no copper treatments resulted in statistically significant responses. In contrast, the avoidance response of rainbow trout was unaffected by the acclimation. This dramatic difference between Chinook salmon and rainbow trout avoidance was so unexpected that Hansen et al. [11] ran a second set of experiments that yielded the same results. Background dCu concentrations (<4 µg/L) are commonly observed in natural waterways, yet Chinook salmon failed to avoid any higher dCu concentrations following an acclimation to a nominal 2 µg dCu/L. Importantly, if Chinook salmon will not avoid any dCu concentrations following acclimation to low dCu concentrations, the behavioral defense against chronic and acute exposures to dCu is lost, and high mortality or chronic physiological effects are probable if subsequent higher levels of dCu exposure occur. Unlike Chinook salmon, dCu-acclimated rainbow trout preferred clean water and avoided higher dCu concentrations. Other differences between Chinook salmon and rainbow trout avoidance responses to copper were that addition of 4 and 8 mg/L dissolved organic carbon (DOC) did not appreciably affect the avoidance response of Chinook salmon to copper, nor did altering pH across a range of 6.5 to 8.5. In contrast, the addition of DOC (4 and 8 mg/L) did reduce the avoidance response of rainbow trout to copper. Although variable, avoidance responses of rainbow trout were slightly stronger at pH 7.5 and 8.5 than at 6.5 [55].

A further repeated finding from these laboratory avoidance tests was that although rainbow trout, steelhead, and Chinook salmon avoided low concentrations of dCu, they were apparently intoxicated and sometimes attracted to very high concentrations [11, 53, 54]. The direct relevance of laboratory avoidance studies to the behaviors of fish in the wild is debatable since in natural waters fish likely select and move among habitats based on myriad reasons such as access to prey, shelter from predators, shade, velocity, temperature, and interactions with other fish. In contrast, laboratory preference/avoidance tests are commonly conducted under simple, highly artificial conditions to eliminate or minimize confounding variables other than the water characteristic of interest. Laboratory tests may overestimate the actual protection this behavior provides fish in heterogeneous, natural environments [56-58].

However, at least one study suggested that experimental avoidance responses observed with salmonids are relevant to fish behaviors in the wild. From 1980-1982, sub-lethal levels of a contaminant (fluoride) from an aluminum mill at the John Day Dam on the Columbia River were associated with a significant delay in salmon passage and decreased survival [59]. Salmon took an average of 36 hours to pass up the fish ladder at the Bonneville and McNary dams compared to 157 hours delay at the John Day Dam. Greater than 50% mortality occurred between the Bonneville and McNary dams (above and below the John Day dam), compared to about 2% mortality associated with the other dams. Damkaer and Dey [59] introduced similar levels of the contaminant in streamside test-flumes alongside a salmon spawning stream (Big Beef Creek, Washington). Significant numbers of adult Chinook salmon failed to move out of their holding area and continue upstream; those that did move upstream chose the non-contaminated side of the flume. By adjusting the dose, Damkaer and Dey [59] predicted a threshold detection limit for avoidance by salmon. The mill subsequently reduced its release of the contaminant to below these experimental threshold levels that did not show a response in the streamside tests. Afterwards, fish passage delays and salmon mortality between the dams decreased to 28 hours and <5%, respectively [59]. This study suggested that the delay due to avoidance of a chemical affected the spawning success of migrating adult salmonids. These results are also consistent with the field studies of salmon migration in copper-contaminated streams and from laboratory avoidance/preference testing. Experimental avoidance/preference testing thus appears to be relevant to fish behavior in nature.

### Other adverse effects

The focus of this literature synthesis is sensory effects of copper on juvenile salmonids. However, other adverse effects of copper to salmonids reported in the literature include weakened immune function and disease resistance, increased susceptibility to stress, liver damage, reduced growth, impaired swimming performance, weakened eggshells, and direct mortality [19, 20, 60-66] . While a comprehensive review of other adverse effects of copper on fish is beyond the scope of this synthesis, we discuss several studies of interest below.

Stevens [65] reported that pre-exposure to sublethal levels of dCu interfered with the immune response and reduced the disease resistance in yearling coho salmon. Juvenile coho salmon were vaccinated with the bacterial pathogen *Vibrio anguillarum* prior to copper exposure to investigate the effects of copper upon the immune response and survival. Following copper exposure (9.6 - 40 μg/L), surviving juveniles were challenged under natural conditions to *V. anguillarum*, the causative agent of vibriosis in fish. Vibriosis is a disease commonly found in wild and captive fish from marine environments and has caused deaths of coho and Chinook salmon. Coho were exposed to constant concentrations of dCu for about one month at levels that covered the range from no effect to causing 100% mortality, 9.6 - 40 µg/L. The antibody titer level against *V. anguillarum* was significantly reduced in fish exposed to 13.9 µg/L of dCu when compared to that developed in control fish. The survivors of the dCu bioassays were then exposed in saltwater holding ponds for an additional 24 days to the *V. anguillarum* pathogen. The unvaccinated, non-dCu exposed control fish had 100% mortality and the vaccinated, non-dCu exposed fish had the lowest mortality. The vaccinated, dCu-exposed fish had increasing mortality corresponding to the lower antibody titer levels which in turn corresponded to the increasing dCu exposure levels. Therefore, dCu exposure can significantly reduce a fish's immune function and disease resistance at concentrations as low as 13.9 µg/L following 30 days of exposure [65].

Schreck and Lorz [60] studied the effects of copper exposure to stress resistance in yearling coho salmon. Fish that were exposed for 7 days to 15 µg/L dCu and unexposed control fish were subjected to severe handling and confinement stress. Copper-exposed fish survived this additional stress for a median of 12-15 hours while control fish experienced no mortality at 36 hours. Schreck and Lorz concluded that exposure to copper placed a sublethal stress on the fish which made them more vulnerable to handling and saltwater adaptation. Further, they hypothesized that dCu exposure may make salmonids more vulnerable to secondary stresses such as disease and pursuit by predators.

Exposure of brook trout eggs to 17.4 µg dCu/L for 90 days resulted in weakened chorions (eggshells) and embryo deformities. After hatching, poor yolk utilization and reduced growth were demonstrated. These overall weakened conditions may reduce survival chances in the wild [67, 68]. Copper accumulation in the liver of rainbow trout caused degeneration of liver hepatocytes, which resulted in reduced ability to metabolize food, reduced growth, or eventual death [17, 63, 69]. Waiwood and Beamish [61], Chapman [19], Seim et al. [70], McKim and Benoit [62], and Marr [20] have also observed reduced growth of salmonids in response to chronic copper exposures as low as 1.9 ug/L. Waiwood and Beamish [66] reported that rainbow trout exposed to copper levels had reduced swimming performance (10, 15, 20, 30 ug/L dCu) and reduced oxygen consumption (25, 40 ug/L dCu) apparently due to gill damage and decreased efficiency of gas exchange.

In sum, there is a large body of literature showing that behavior of salmonids and other fishes can be disrupted at concentrations of dCu that are only slightly elevated above background concentrations. Further, dCu stress has been shown to increase the cost of maintenance to fish and to limit oxygen consumption and food metabolism. Reduced growth may result in increased susceptibility to predation, and impaired swimming ability may result in reduced escape reaction and prey hunting, with a possible consequence of reduced survival at the population level. We summarize selected examples of effect concentrations reported with copper for several different types of effects in Table 2. In general, typical copper exposures probably do not kill juvenile salmonids directly until concentrations greater than about 10 times that of sensory thresholds, and then only if the concentrations are sustained for at least several hours. In selecting these examples, we sought to list representative effects and concentrations rather than extreme values that could be gleaned from the literature. However, the selected examples do not constitute an exhaustive review of the effects of copper to fish; more general reviews of effects of copper to fish and other aquatic organisms are available elsewhere [9, 17, 46, 71].

**Acknowledgement:**
We thank Jim Meador, Lyndall Johnson, and Karen Peck for insightful and critical reviews of prior versions of this manuscript. We also thank Jennifer McIntyre, Neil Rickard and Scott Anderson for fruitful discussions.

**References Cited:**


1. Drapper, D., R. Tomlinson, and P. Williams, *Pollutant concentrations in road runoff: Southeast Queensland case study.* Journal of Environmental Engineering-Asce, 2000. **126**(4): p. 313-320.
2. USEPA, *Ecological Risk Assessment for Re-registration Copper-Containing Pesticides (Case#0636 Copper Sulfate, Case#0649 Group II Copper Compounds, Case#4029 Copper Salts, and Case#4025 Copper and Oxides (Cuprous oxide)).* 2005, US EPA Office of Pesticide Programs: Washington D.C. p. 117.
3. Good, J.C., *Roof Runoff as a Diffuse Source of Metals and Aquatic Toxicity in Storm Water.* Water Science and Technology, 1993. **28**(3-5): p. 317-321.
4. Thomas, P.R. and G.R. Greene, *Rainwater Quality from Different Roof Catchments.* Water Science and Technology, 1993. **28**(3-5): p. 291-299.
5. Sansalone, J.J. and S.G. Buchberger, *Partitioning and first flush of metals in urban roadway storm water.* Journal of Environmental Monitoring, 1997. **123**: p. 134-143.
6. Wheeler, A.P., P.L. Angermeier, and A.E. Rosenberger, *Impacts of new highways and subsequent landscape urbanization on stream habitat and biota.* Reviews in Fisheries Science, 2005. **13**: p. 141-164.
7. Alpers, C.N., et al., *Metals transport in the Sacramento River, California, 1996–1997—Interpretation of metal loads: v. 2*. 2000, United States Geological Survey. p. 120.
8. Soller, J., et al., *Evaluation of seasonal scale first flush pollutant loading and implications for urban runoff management.* Journal of Environmental Management, 2005. **76**(4): p. 309-318.
9. Eisler, R., *Copper hazards to fish, wildlife, and invertebrates: a synoptic review*. 1998, U.S. Geological Survey, Biological Resources Division, Biological Science Report.
10. Sandahl, J.F., et al., *A sensory system at the interface between urban stormwater runoff and salmon survival.* Environmental Science and Technology, 2007: p. in press.
11. Hansen, J.A., et al., *Differences in neurobehavioral responses of chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Oncorhynchus mykiss) exposed to copper and cobalt: Behavioral avoidance.* Environmental Toxicology and Chemistry, 1999. **18**(9): p. 1972-1978.
12. Sprague, J., P. Elson, and R. Saunders, *Sublethal copper-zinc pollution in a salmon river - A field and laboratory study.* International Journal of Air and Water Pollution, 1965. **9**: p. 531-543.
13. Mebane, C.A., *Evaluation of proposed new point source discharges to a special resource water and mixing zone determinations: Thompson Creek Mine, upper Salmon River subbasin, Idaho*. 2000, Idaho Department of Environmental Quality: Boise, Idaho. p. 126.
14. Lorz, H.W. and B.P. McPherson, *Effects of copper and zinc on smoltification of coho salmon*. 1977, Oregon Department of Fish and Wildlife and U.S. EPA Environmental Research Laboratory: Corvallis. p. 69.

15. Lorz, H.W. and B.P. McPherson, *Effects of copper or zinc in fresh water on the adaptation to sea water and ATPase activity, and the effects of copper on migratory disposition of the coho salmon (Oncorhynchus kisutch).* Journal of the Fisheries Research Board of Canada, 1976. **33**: p. 2023-2030.
16. Saucier, D., L. Astic, and P. Rioux, *The effects of early chronic exposure to sublethal copper on the olfactory discrimination of rainbow trout, Oncorhynchus mykiss.* Environmental Biology of Fishes, 1991. **30**(3): p. 345-351.
17. Leland, H.V. and J.L. Carter, *Effects of Copper on Production of Periphyton, Nitrogen-Fixation and Processing of Leaf Litter in a Sierra-Nevada, California, Stream.* Freshwater Biology, 1985. **15**(2): p. 155-173.
18. Leland, H.V., et al., *Effects of Copper on Species Composition of Benthic Insects in a Sierra-Nevada, California, Stream.* Freshwater Biology, 1989. **21**(2): p. 163-179.
19. Chapman, G.A., *[Unpublished Data on] Chinook salmon early life stage tests with cadmium, copper, and zinc in Letter of December 6, 1982 to Charles Stephan, US. EPA Environmental Research Laboratory*. 1982: Corvallis, Oregon, USA.
20. Marr, J.C.A., et al., *Relationship between copper exposure duration, tissue copper concentration, and rainbow trout growth.* Aquatic Toxicology, 1996. **36**(1-2).
21. Mudge, J.E. and et al., *Effect of varying environmental conditions on the toxicity of copper to salmon*, in *Environmental toxicology and risk assessment, ASTM STP 1216*, J.W. Gorsuch and et al., Editors. 1993, American Society for Testing and Materials (ASTM): Philadelphia, PA. p. 19-33.
22. Chapman, G.A., *Toxicities of cadmium, copper, and zinc to four juvenile stages of chinook salmon and steelhead.* Transactions of the American Fisheries Society, 1978. **107**(6): p. 841-847.
23. Marr, J.C.A., et al., *Bioavailability and acute toxicity of copper to rainbow trout (Oncorhynchus mykiss) in the presence of organic acids simulating natural dissolved organic carbon.* Canadian Journal of Fisheries and Aquatic Sciences, 1999. **56**(8): p. 1471-1483.
24. Chapman, G.A. and D.G. Stevens, *Acutely lethal levels of cadmium, copper, and zinc to adult male coho salmon and steelhead.* Transactions of the American Fisheries Society, 1978. **107**(6): p. 837-840.
25. Baldwin, D.H. and N.L. Scholz, *The electro-olfactogram: an in vivo measure of peripheral olfactory function and sublethal neurotoxicity in fish*, in *Techniques in Aquatic Toxicology, Volume 2*, G.K. Ostrander, Editor. 2005, CRC Press, Inc: Boca Raton, Florida. p. 257-276.
26. Hansen, J.A., et al., *Chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Oncorhynchus mykiss) exposed to copper: Neurophysiological and histological effects on the olfactory system.* Environmental Toxicology and Chemistry, 1999. **18**(9).
27. Baldwin, D.H., et al., *Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system.* Environmental Toxicology and Chemistry, 2003. **22**(10): p. 2266-2274.

28. Sandahl, J.F., et al., *Olfactory inhibition and recovery in chum salmon (Oncorhynchus keta) following copper exposure.* Canadian Journal of Fisheries and Aquatic Sciences, 2006. **63**(8): p. 1840-1847.
29. Scott, J.W. and P.E. Scott-Johnson, *The electroolfactogram: A review of its history and uses.* Microscopy Research and Technique, 2002. **58**(3).
30. Sandahl, J.F., et al., *Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (Oncorynchus kisutch) exposed to copper, chlorpyrifos, or esfenvalerate.* Canadian Journal of Fisheries and Aquatic Science, 2004. **61**: p. 404-413.
31. Kruzynski, G.M. and I.K. Birtwell, *A predation bioassay to quantify the ecological significance of sublethal responses of juvenile chinook salmon (Oncoryhynchus tshawytscha) to the antisapstain fungicide TCMTB.* Canadian Journal of Fisheries and Aquatic Science, 1994. **51**: p. 1780-1790.
32. Moran, D.T., et al., *Ultrastructural neurobiology of the olfactory mucosa of the brown trout, Salmo trutta.* Microscopy Research and Technique, 1992. **23**(1).
33. Evans, R.E. and T.J. Hara, *The characteristics of the electro-olfactogram (EOG): its loss and recovery following olfactory nerve section in rainbow trout (Salmo gairdneri).* Brain Res, 1985. **330**(1): p. 65-75.
34. Linbo, A.O., et al., *Dissolved copper triggers cell death in the peripheral mechanosensory system of larval fish.* Environmental Toxicology and Chemistry, 2006. **25**(2): p. 597-603.
35. USEPA, *The use of the benchmarkdose approach in health risk assessment*, in *Risk Assessment Forum*. 1995: Washington, DC. p. 69.
36. Sandahl, J.F. and J.J. Jenkins, *Pacific steelhead (Oncorhynchus mykiss) exposed to chlorpyrifos: Benchmark concentration estimates for acetylcholinesterase inhibition.* Environmental Toxicology and Chemistry, 2002. **21**(11).
37. USEPA, *The use of the benchmark dose approach in health risk assessment*. 1995, Office of Research and Development: Washington, D.C. p. EPA/630/R-94/007.
38. Norwood, W.P., et al., *Effects of metal mixtures on aquatic biota: A review of observations and methods.* Human and Ecological Risk Assessment, 2003. **9**(4): p. 795-811.
39. Playle, R.C., *Using multiple metal-Gill binding models and the toxic unit concept to help reconcile multiple-metal toxicity results.* Aquatic Toxicology, 2004. **67**: p. 359-370.
40. Niyogi, S. and C.M. Wood, *Biotic ligand model, a flexible tool for developing site-specific water quality guidelines for metal.* Environmental Science and Technology, 2004. **38**: p. 6177-6192.
41. McIntyre, J.K., et al. *Influence of water hardness, alkalinity, pH, and DOC on olfactory neurotoxicity of copper in juvenile salmon. Poster presentation.* in *Toxicis in Puget Sound: Connecting the marine environment to human health and the economy*. 2006. Seattle, WA. USA.
42. Winberg, S., et al., *The effect of Cu(II) on the electro-olfactogram (EOG) of the Atlantic salmon (Salmo salar L.) in artificial freshwater of varying inorganic carbon concentrations.* Ecotoxicol. Environ. Saf., 1992. **24**(2).

43. Bjerselius, R., et al., *Ca2+ protects olfactory receptor function against acute Cu(II) toxicity in Atlantic salmon.* Aquat. Toxicol., 1993. **25**: p. 125-138.
44. Stephan, C.E., et al., *Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses.* 1985, National Technical Information Service: Springfield, Virginia.
45. USEPA, *National recommended water quality criteria*. 2002, U.S. Environmental Protection Agency: Washington D.C. p. 36.
46. USEPA, *Aquatic life ambient freshwater quality criteria - copper, 2007 revision*. 2007, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology: Wahington D.C. p. 207.
47. Smith, E.H. and H.C. Bailey, *Preference/avoidance testing of waste discharges on anadromous fish.* Environmental Toxicology and Chemistry, 1990. **9**: p. 77-86.
48. Saunders, R.L. and J.B. Sprague, *Effects of copper-zinc mining pollution on a spawning migration of Atlantic salmon.* Wat. Res., 1967. **1**: p. 419-432.
49. Sutterlin, A. and R. Gray, *Chemical basis for homing of Atlantic salmon (Salmo salar) to a hatchery.* J Fish Res Board Can, 1973. **30**: p. 985-989.
50. Mebane, C.A., *Blackbird Mine preliminary natural resource survey*. 1994, U.S. National Oceanic Atmospheric Administration, Hazardous Material Assessment and Response Division: Seattle, WA, USA. p. 130.
51. Lorz, H.W., R.H. Williams, and C.A. Futish, *Effects of several metals on smolting of coho salmon*. 1978, Oregon Department of Fish and Wildlife and U.S. EPA Environmental Research Laboratory: Corvallis, OR, USA.
52. Folmar, L.C., *Overt avoidance reaction of rainbow trout fry to nine herbicides.* Bulletin of Environmental Contamination and Toxicology, 1976. **15**: p. 509-514.
53. Giattina, J.D., R.R. Garton, and d.G. Stevens, *The avoidance of copper and nickel by rainbow trout as monitored by a computer-based aquisition system.* Transactions of the American Fisheries Society, 1982. **111**: p. 491-504.
54. Chapman, G.A., *[Unpublished data on] acclimation, life stage differences in lethality and behavioral effects of chronic copper exposures with steelhead, in Letter of July 5, 1994 to Chris Mebane, [NOAA liaison to] EPA Region 10, Seattle, WA.* 1994, U.S. EPA Coastal Ecosytems Team: Newport, Oregon.
55. Marr, J.C.A., et al., *Fisheries toxicity injury studies, Blackbird Mine site, Idaho*. 1995, Prepared by RCG/Hagler Bailly and the University of Wyoming for the National Oceanic and Atmospheric Administration: Boulder, Co and Laramie, WY.
56. Hartwell, S.I., D.S. Cherry, and J.J. Cairns, *Field validation of avoidance of elevated metals by fathead minnows (Pimephales promelas) following in situ acclimation.* Environmental Toxicology and Chemistry, 1987. **6**(1): p. 189-200.
57. Korver, R.M. and J.B. Sprague, *Zinc avoidance by fathead minnows: computerized tracking and greater ecological significance.* Canadian Journal of Fisheries and Aquatic Science, 1989. **46**(3): p. 494-502.
58. Scherer, E. and R.E. McNoil, *Preference-avoidance responses of lake whitefish (Coregonus clupeaformis) to competing gradients of light and copper, lead, and zinc.* Water Research, 1998. **32**(3): p. 494-502.

59. Damkaer, D.M. and D.B. Dey, *Evidence of fluoride effects on salmon passage ao John Day dam, Columbia River, 1982-1986.* North American Journal of Fisheries Management, 1989. **9**(2): p. 154-168.
60. Schreck, C.B. and H.W. Lorz, *Stress response of coho salmon (Oncorhynchus kisutch) elicited by cadmium and copper and potential use of cortisol as an indicator of stress.* Journal of the Fisheries Research Board of Canada, 1978. **35**: p. 1124-1129.
61. Waiwood, K.G. and F.W.H. Beamish, *The effect of copper, hardness and pH on the growth of rainbow trout, Salmo gairdneri.* Journal of Fish Biology, 1978. **13**: p. 591-598.
62. McKim, J.M., D.A. Benoit, and J.F.R.B.C. . *Effects of long-term exposure to copper on survival, growth and reproduction (Salvelinus fontinalis).* Journal of the Fisheries Research Board of Canada, 1971. **28**: p. 655-662.
63. Farag, A.M., et al., *Physiological changes and tissue metal accumulations of rainbow trout exposed to foodborne and waterborne metals.* Environmental Toxicology and Chemistry, 1994. **13**: p. 2021-2030.
64. Farag, A.M., et al., *Characterizing aquatic health using salmonid mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River watershed, Montana.* Transactions of the American Fisheries Society, 2003. **132**(3): p. 450-467.
65. Stevens, D.G., *Survival and immune response of coho salmon exposed to copper*. 1977, U.S. EPA Environmental Research Laboratory: Corvallis, Oregon.
66. Waiwood, K.G. and F.W.H. Beamish, *Effects of copper, pH and hardness on the critical swimming performance of rainbow trout (Salmo gairdneri).* Water Research, 1978. **12**: p. 611-619.
67. McKim, J.M., *Early life stage toxicity tests*, in *Fundamentals of Aquatic Toxicology: Methods and Applications.*, G.M. Rand and S.R. Petrocelli, Editors. 1985, Hemisphere Publishing: New York, NY. p. 58-95.
68. McKim, J.M. and D.A. Benoit, *Effects of long-term exposures to copper on the survival, growth, and reproduction of brook trout.* Journal of Fisheries Research Board of Canada, 1971. **31**: p. 449-452.
69. Meyer, J.S., *Toxicity of Dietborne Metals to Aquatic Organisms*. Pellston Workshop. 2005, Pensacola, Florida, USA: Society of Environmental Toxicology and Chemistry. 303.
70. Seim, W.K., et al., *Growth and survival of developing steelhead trout (Salmo gairdneri) continuously or intermittently exposed to copper.* Canadian Journal of Fisheries and Aquatic Science, 1984.
71. Sorensen, E.M.B., *Chapter VII: Copper*, in *Metal Poisoning in Fish*, E.M.B. Sorensen, Editor. 1991, CRC Press: Boca Raton, Fl. p. 235-284.

## *Supplementary Bibliography*


**Copper Sources:**

Good JC. 1993. Roof runoff as a diffuse source of metals and aquatic toxicity in stormwater. Water Science Technology. 28: 317-322.

Thomas PR, Greene GR. 1993. Rainwater quality from different roof catchments. Water Science Technology. 28:291-297.

**Benchmark Concentration/Dose:**

Crump KS (1995) Calculation of benchmark doses from continuous data. Risk Analysis 15:79-89.

U.S. Environmental Protection Agency (1995) The use of the benchmark dose approach in health risk assessment. EPA 630/R-94/007. Office of Research and Development, Washington, D.C.

Sandahl JF, Jenkins JJ (2002) Pacific steelhead (*Oncorhynchus mykiss*) exposed to chlorpyrifos: Benchmark concentration estimates for acetylcholinesterase inhibition. Environmental Toxicology and Chemistry 21:2452-2458.

Slikker W, Crump KS, Andersen ME, Bellinger D (1996) Biologically based, quantitative risk assessment of neurotoxicants. Fundamental and Applied Toxicology 29:18-30.

**Copper and neurobiology:**

Baldwin DH, Sandahl JF, Labenia JS, Scholz NL (2003) Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22:2266-2274.

Baldwin DH, Scholz NL (2005) The electro-olfactogram: an *in vivo* measure of peripheral olfactory function and sublethal neurotoxicity in fish. In: Ostrander GK (ed) Techniques in Aquatic Toxicology, Volume 2, CRC Press, Inc, Boca Raton, Florida, p 257-276.

Bettini S, Ciani F, Franceschini V (2006) Recovery of the olfactory receptor neurons in the African *Tilapia mariae* following exposure to low copper level. Aquatic Toxicology: in press.

Beyers DW, Farmer MS (2001) Effects of copper on olfaction of Colorado pikeminnow. Environmental Toxicology and Chemistry 20:907-912.

Bjerselius R, Winberg S, Winberg Y, Zeipel K (1993) $Ca^{2+}$ protects olfactory receptor function against acute copper (II) toxicity in Atlantic salmon. Aquatic Toxicology 25:125-138.

Carreau ND, Pyle GG (2005) Effect of copper exposure during embryonic development on chemosensory function of juvenile fathead minnows (*Pimephales promelas*). Ecotoxicology and Environmental Safety 61:1-6

Chai M, Chen X (1999) Inhibition of $Cd^{2+}$, $Hg^{2+}$ and $Pb^{2+}$ on EOG responses of *Tilapia* sp. Journal of Fishery Sciences of China/Zhongguo Shuichan Kexue Beijing 6:89-

92.
Chai M, Huang Z (1996) Effect of $Ca^{2+}$ on the EOG of *Tilapia* sp. and exploration of detoxifying feasibility. Journal of Xiamen University Natural Science/Xiamen Daxue Xuebao Xiamen 35:941-946.
Chai M, Pan L (1996) Effects of heavy metal ($Cu^{2+}$, $Zn^{2+}$) on the EOG response of fish (*Tilapia* sp.). Journal of Xiamen University Natural Science/Xiamen Daxue Xuebao Xiamen 35:94-99.
Goldstein JN, Woodward DF, Farag AM (1999) Movements of adult Chinook salmon during spawning migration in a metals-contaminated system, Coeur d'Alene River, Idaho. Transactions of the American Fisheries Society 128:121-129.
Hansen JA, Marr JCA, Lipton J, Cacela D, Bergman HL (1999) Differences in neurobehavioral responses of Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*) exposed to copper and cobalt: Behavioral avoidance. Environmental Toxicology and Chemistry 18:1972-1978.
Hansen JA, Rose JD, Jenkins RA, Gerow KG, Bergman HL (1999) Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*) exposed to copper: Neurophysiological and histological effects on the olfactory system. Environmental Toxicology and Chemistry 18:1979-1991.
Hara TJ, Law YMC, Macdonald S (1976) Effects of mercury and copper on the olfactory response in rainbow trout. Journal of the Fisheries Research Board of Canada 33:1568-1573.
Hernández PP, Moreno V, Olivari FA, Allende ML (2006) Sub-lethal concentrations of waterborne copper are toxic to lateral line neuromasts in zebrafish (*Danio rerio*). Hearing Research: in press.
Julliard AK, Saucier D, Astic L (1993) Effects of chronic low-level copper exposure on ultrastructure of the olfactory system in rainbow trout (*Oncorhynchus mykiss*). Histology and Histopathology 8:655-672.
Julliard AK, Saucier D, Astic L (1995) Metal X-ray microanalysis in the olfactory system of rainbow trout exposed to low level of copper. Biology of the Cell 83:77-86.
Julliard AK, Saucier D, Astic L (1996) Time-course of apoptosis in the olfactory epithelium of rainbow trout exposed to a low copper level. Tissue and Cell 28:367-377.
Kasumyan AO (2001) Effects of chemical pollutants on foraging behavior and sensitivity of fish to food stimuli. Journal of Ichthyology 41:76-87.
Kasumyan AO, Morsi AMH (1998) Effect of heavy metals on the feeding activity and taste behavior responses of carp *Cyprinus carpio*: 1. Copper, cadmium, zinc, and lead. Journal of Ichthyology 38:393-409.
Klima KE, Applehans FM (1990) Copper exposure and the degeneration of olfactory receptors in rainbow trout (*Oncorhynchus mykiss*). Chemical Speciation and Bioavailability 2:149-154.
Linbo AO, Stehr CM, Incardona JP, Scholz NL (2006) Dissolved copper triggers cell death in the peripheral mechanosensory system of larval fish. Environmental Toxicology and Chemistry 25:597-603.
Little EE, Archeski RD, Flerov BA, Kozlovskaya VI (1990) Behavioral indicators of sublethal toxicity in rainbow trout. Archives of Environmental Contamination and Toxicology 19:380-385.

Little EE, Finger SE (1990) Swimming behavior as an indicator of sublethal toxicity in fish. Environmental Toxicology and Chemistry 9:13-19.
McPherson TD, Mirza RS, Pyle GG (2004) Responses of wild fishes to alarm chemicals in pristine and metal-contaminated lakes. Canadian Journal of Zoology 82:694-700.
Moran DT, Rowley JC, Aiken G (1986) Trout olfactory receptors degenerate in response to water-borne ions: A potential bioassay for environmental neurotoxicology? Chemical Senses 11:642.
Moran DT, Rowley JC, Aiken GR, Jafek BW (1992) Ultrastructural neurobiology of the olfactory mucosa of the brown trout, *Salmo trutta*. Microscopy Research and Technique 23:28-48.
Rehnberg B, Schreck CB (1986) Acute metal toxicology of olfaction in coho salmon: Behavior, receptors, and odor-metal complexation. Bulletin of Environmental Contamination and Toxicology 36:579-586.
Sandahl JF, Baldwin DH, Jenkins JJ, Scholz NL (2004) Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (*Oncorynchus kisutch*) exposed to copper, chlorpyrifos, or esfenvalerate. Canadian Journal of Fisheries and Aquatic Science 61:404-413.
Sandahl JF, Baldwin DH, Jenkins JJ, Scholz NL (2006) A sensory system at the interface between urban stormwater runoff and salmon survival. Conservation Biology: submitted.
Saucier D, Astic L (1995) Morphofunctional alterations in the olfactory system of rainbow trout (*Oncorhynchus mykiss*) and possible acclimation in response to long-lasting exposure to low copper levels. Comparative Biochemistry and Physiology A-Physiology 112:273-284.
Saucier D, Astic L, Rioux P (1991) The effects of early chronic exposure to sublethal copper on the olfactory discrimination of rainbow trout, *Oncorhynchus mykiss*. Environmental Biology of Fishes 30:345-351.
Saunders RL, Sprague JB (1967) Effects of copper-zinc mining pollution on a spawning migration of Atlantic salmon. Water Research 1:419-432
Starcevic SL, Zielinski BS (1997) Neuroprotective effects of glutathione on rainbow trout olfactory receptor neurons during exposure to copper sulfate. Comparative Biochemistry and Physiology, C 117C:211-219.
Tjalve H, Henriksson J (1999) Uptake of metals in the brain via olfactory pathways. Neurotoxicology 20:181-195.
Weis JS, Weis P (1996) The effects of using wood treated with chromated copper arsenate in shallow-water environments: a review. Estuaries 19:306-310.
Winberg S, Bjerselius R, Baatrup E, Doving KB (1992) The effect of copper (II) on the electro-olfactogram (EOG) of the Atlantic salmon (*Salmo salar L.*) in artificial freshwater of varying inorganic carbon concentrations. Ecotoxicology and Environmental Safety 24:167-178.

**Some overviews and reviews:**

Brown GE (2003) Learning about danger: Chemical alarm cues and local risk assessment in pre fishes. Fish and Fisheries 4:227-234.
Døving KB (1991) Assessment of animal behaviour as a method to indicate

environmental toxicity. Comparative Biochemistry and Physiology C 100:247-252.
Eisler R (1998) Copper hazards to fish, wildlife, and invertebrates: a synoptic review. Report No. USGS/BRD/BSR--1998-0002, U.S. Geological Survey, Biological Resources Division.
Halpern BP (1982) Environmental factors affecting chemoreceptors: an overview. Environmental Health Perspectives 44:101-105.
Hara TJ (1972) Electrical responses of the olfactory bulb of Pacific salmon *Oncorhynchus nerka* and *Oncorhynchus kisutch*. Journal of the Fisheries Research Board of Canada 29:1351-1355.
Hara TJ (1992) Mechanisms of olfaction. In: Hara TJ (ed) Fish Chemoreception. Chapman & Hall, London, p 150-170.
Kats LB, Dill LM (1998) The scent of death: Chemosensory assessment of predation risk by prey animals. Ecoscience 5:361-394.
Klaprat DA, Evans RE, Hara TJ (1992) Environmental contaminants and chemoreception in fishes. In: Hara TJ (ed) Fish Chemoreception. Chapman & Hall, London, p 321-342.
Scott JW, Scott-Johnson PE (2002) The electroolfactogram: A review of its history and uses. Microscopy Research and Technique 58:152-160.
Scott GR, Sloman KA (2004) The effects of environmental pollutants on complex fish behaviour: integrating behavioural and physiological indicators of toxicity. Aquatic Toxicology 68:369-392.
Shumway CA (1999) A neglected science: applying behavior to aquatic conservation. Environmental Biology of Fishes 55:183-201.
Smith RJF (1992) Alarm signals in fishes. Reviews in Fish Biology and Fisheries 2:33-63.
Sorensen EMB (1991) Chapter VII: Copper. In: Sorensen EMB (ed) Metal Poisoning in Fish. CRC Press, Boca Raton, Fl, p 235-284.
Sutterlin AM (1974) Pollutants and the chemical senses of aquatic animals - perspective and review. Chemical Senses and Flavor 1:167-178

**Studies with other metals:**

Baatrup E (1991) Structural and functional effects of heavy metals on the nervous system, including sense organs, of fish. Comparative Biochemistry and Physiology, C 100:253-257.
Baatrup E, Døving KB (1990) Histochemical demonstration of mercury in the olfactory system of salmon (*Salmo salar* L.) following treatments with dietary methylmercuric chloride and dissolved mercuric chloride. Ecotoxicology and Environmental Safety 20:277-289.
Baatrup E, Døving KB, Winberg S (1990) Differential effects of mercurial compounds on the electroolfactogram (EOG) of salmon (*Salmo salar L.*). Ecotoxicology and Environmental Safety 20:269-276.
Baker CF, Montgomery JC (2001) Sensory deficits induced by cadmium in banded kokopu, *Galaxias fasciatus*, juveniles. Environmental Biology of Fishes 62:455-464.
Beauvais SL, Jones SB, Parris JT, Brewer SK, Little EE (2001) Cholinergic and

behavioral neurotoxicity of carbaryl and cadmium to larval rainbow trout (*Oncorhynchus mykiss*). Ecotoxicology and Environmental Safety 49:84-90.
Chakrabarti P, Ghosal M, Mandal DK (1994) Microanatomical and histopathological sequels of cadmium intoxication on the olfactory epithelium of the fish *Mystus vittatus* (Bloch). Environment and Ecology 12:540-544.
Hernadi L (1993) Fine structural characterization of the olfactory epithelium and its response to divalent cations $Cd^{2+}$ in the fish *Alburnus alburnus* (Teleostei, Cyprinidae): a scanning and transmission electron microscopic study. Neurobiology 1:11-31.
Scott GR, Sloman KA, Rouleau C, Wood CM (2003) Cadmium disrupts behavioural and physiological responses to alarm substance in juvenile rainbow trout (*Oncorhynchus mykiss*). Journal of Experimental Biology 206:1779-1790.

**Selected behavioral studies (homing, alarm behavior and predation):**

Berejikian BA, Smith RJ, Tezak EP, Schroder SL, Knudsen CM (1999) Paired chemical alarm signals and complex hatchery rearing habitats affect predator behavior and survival of Chinook salmon (*Oncorhynchus tshawytscha*) juveniles. Canadian Journal of Fisheries and Aquatic Science 56:830-838.
Brown GE, Adrian Jr JC, Patton T, Chivers DP (2001) Fathead minnows learn to recognize predator odor when exposed to concentrations of artificial alarm pheromone below their behavioral-response threshold. Canadian Journal of Zoology 79:2239-2245.
Brown GE, Smith RJ (1997) Conspecific skin extracts elicit antipredator responses in juvenile rainbow trout (*Oncorhynchus mykiss*). Canadian Journal of Zoology 75:1916-1922.
Døving KB, Westerberg H, Johnsen PB (1985) Role of olfaction in the behavioral and neuronal responses of Atlantic salmon, *Salmo salar*, to hydrographic stratification. Canadian Journal of Fisheries and Aquatic Sciences 42:1658-1667.
Hatfield CT, Anderson JM (1972) Effects of two pesticides on the vulnerability of Atlantic salmon (*Salmo salar*) parr to brook trout (*Salvenius fontinalis*) predation. Journal of the Fisheries Research Board of Canada 29:27-29.
Hatfield CT, Johansen PH (1972) Effects of four insecticides on the ability of Atlantic salmon parr (*Salmo salar*) to learn and retain a simple conditioned response. Journal of the Fisheries Research Board of Canada 29:315-321.
Hiroven H, Ranta E, Piironen J, Laurila A, Peuhkuri N (2000) Behavioural responses of naive Artic charr young to chemical cues from salmonid and non-salmonid fish. Oikos 88:191-199.
Kruzynski GM, Birtwell IK (1994) A predation bioassay to quantify the ecological significance of sublethal responses of juvenile Chinook salmon (*Oncoryhynchus tshawytscha*) to the antisapstain fungicide TCMTB. Canadian Journal of Fisheries and Aquatic Science 51:1780-1790.
McLennan DA, Ryan MJ (1997) Responses to conspecific and heterospecific olfactory cues in the swordtail *Xiphophorus cortezi*. Animal Behavior 54:1077-1088.
Mirza RS, Chivers DP (2001) Chemical alarm signals enhance survival of brook charr (*Salvelinus fontinalis*) during encounters with predatory chain pickerel (*Esox niger*). Ethology 107:989-1005.

Poulin R, Marcogliese D, McLaughlin J (1999) Skin-penetrating parasites and the release of alarm substances in juvenile rainbow trout. Journal of Fish Biology 55:47-53.

Wisby WJ, Hasler AD (1954) Effect of occlusion on migrating silver salmon (*Oncorhynchus kisutch*). Journal of the Fisheries Research Board of Canada 11:472-478.

**Recovery of olfactory epithelium after damage:**

Evans RE, Hara TJ (1985) The characteristics of the electro-olfactogram (EOG): its loss and recovery following olfactory nerve section in rainbow trout (*Salmo gairdneri*). Brain Research 330:65-75.

Zielinski BS, Hara TJ (1992) Ciliated and microvillar receptor cells degenerate and then differentiate in the olfactory epithelium of rainbow trout following olfactory nerve section. Microscopy Research and Technique 23:22-27.

**Additional endpoints (focusing on growth and avoiding gill and mortality):**

Ali A, Al-Ogaily SM, Al-Asgah NA, Gropp J (2003) Effect of sublethal concentrations of copper on the growth performance of *Oreochromis niloticus*. Journal of Applied Ichthyology 19:183-188.

Beaumont MW, Butler PJ, Taylor EW (2003) Exposure of brown trout *Salmo trutta* to a sublethal concentration of copper in soft acidic water: effects upon gas exchange and ammonia accumulation. Journal of Experimental Biology 206:153-162.

Bielmyer GK, Gatlin D, Isely JJ, Tomasso J, Klaine SJ (2005) Responses of hybrid striped bass to waterborne and dietary copper in freshwater and saltwater. Comparative Biochemistry and Physiology C-Toxicology & Pharmacology 140:131-137.

Brix KV, DeForest DK, Adams WJ (2001) Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. Environmental Toxicology and Chemistry 20:1846-1856.

Buckley JT, Roch M, McCarter JA, Rendell CA, Matheson AT (1982) Chronic exposure of coho salmon to sublethal concentrations of copper. 1. Effect on growth, on accumulation and distribution of copper, and on copper tolerance. Comparative Biochemistry and Physiology C-Pharmacology Toxicology & Endocrinology 72:15-19.

Campbell HA, Handy RD, Sims DW (2002) Increased metabolic cost of swimming and consequent alterations to circadian activity in rainbow trout (*Oncorhynchus mykiss*) exposed to dietary copper. Canadian Journal of Fisheries and Aquatic Sciences 59:768-777.

Campbell HA, Handy RD, Sims DW (2005) Shifts in a fish's resource holding power during a contact paired interaction: The influence of a copper-contaminated diet in rainbow trout. Physiological and Biochemical Zoology 78:706-714.

Darwish AM, Straus DL, Griffin BR (2005) Histologic evaluation of the safety of copper sulfate to channel catfish. North American Journal of Aquaculture 67:122-128.

De Boeck G, Vlaeminck A, Blust R (1997) Effects of sublethal copper exposure on copper accumulation, food consumption, growth, energy stores, and nucleic acid content in common carp. Archives of Environmental Contamination and Toxicology 33:415-422.

Diamond J, Bowersox M, Latimer H, Barbour C, Bearr J, Butcher J (2005) Effects of pulsed contaminant exposures on early life stages of the fathead minnow. Archives of Environmental Contamination and Toxicology 49:511-519.
Furuta T, Iwata N, Kikuchi K, Namba K (2005) Effects of copper on survival and growth of larval false clown anemonefish *Amphiprion ocellaris*. Fisheries Science 71:884-888.
Galvez F, Wood CM (2002) The mechanisms and costs of physiological and toxicological acclimation to waterborne silver in juvenile rainbow trout (*Oncorhynchus mykiss*). Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology 172:587-597.
Hansen JA, Lipton J, Welsh PG, Cacela D, MacConnell B (2004) Reduced growth of rainbow trout (*Oncorhynchus mykiss*) fed a live invertebrate diet pre-exposed to metal-contaminated sediments. Environmental Toxicology and Chemistry 23:1902-1911.
Hansen JA, Lipton J, Welsh PG, Morris J, Cacela D, Suedkamp MJ (2002) Relationship between exposure duration, tissue residues, growth, and mortality in rainbow trout (*Oncorhynchus mykiss*) juveniles sub-chronically exposed to copper. Aquatic Toxicology 58:175-188.
Hansen JA, Welsh PG, Lipton J, Cacela D (2002) Effects of copper exposure on growth and survival of juvenile bull trout. Transactions of the American Fisheries Society 131:690-697.
Lorz HW, McPherson BP (1976) Effects of copper or zinc in freshwater on adaptation to seawater and Atpase activity, and effects of copper on migratory disposition of coho salmon (*Oncorhynchus kisutch*). Journal of the Fisheries Research Board of Canada 33:2023-2030.
Marr JCA, Lipton J, Cacela D, Hansen JA, Bergman HL, Meyer JS, Hogstrand C (1996) Relationship between copper exposure duration, tissue copper concentration, and rainbow trout growth. Aquatic Toxicology 36:17-30.
Rajotte JW, Couture P (2002) Effects of environmental metal contamination on the condition, swimming performance, and tissue metabolic capacities of wild yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 59:1296-1304.
Roch M, McCarter JA (1984) Metallothionein induction, growth, and survival of Chinook salmon exposed to zinc, copper, and cadmium. Bulletin of Environmental Contamination and Toxicology 32:478-485.
Sloman KA, Baker DW, Ho CG, McDonald DG, Wood CM (2003) The effects of trace metal exposure on agonistic encounters in juvenile rainbow trout, *Oncorhynchus mykiss*. Aquatic Toxicology 63:187-196.
Sloman KA, Baker DW, Wood CM, McDonald G (2002) Social interactions affect physiological consequences of sublethal copper exposure in rainbow trout, *Oncorhynchus mykiss*. Environmental Toxicology and Chemistry 21:1255-1263.
Sloman KA, Morgan TP, McDonald DG, Wood CM (2003) Socially-induced changes in sodium regulation affect the uptake of water-bome copper and silver in the rainbow trout, *Oncorhynchus mykiss*. Comparative Biochemistry and Physiology C-Toxicology & Pharmacology 135:393-403.

# The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast - 2012

David J. Lauten, Kathleen A. Castelein, J. Daniel Farrar, Adam A. Kotaich, and Eleanor P. Gaines

The Oregon Biodiversity Information Center
Institute for Natural Resources
Portland State University/INR
PO Box 751
Portland, Oregon 97207

December 21, 2012

Submitted to:

Coos Bay District Bureau of Land Management
1300 Airport Way
North Bend, Oregon 97459

Siuslaw National Forest
4077 SW Research Way
Corvallis OR, 97333

U.S. Fish and Wildlife Service
2127 SE OSU Drive
Newport, Oregon 97365
Recovery Permit TE-839094-5

Oregon Department of Fish and Wildlife
3406 Cherry Avenue NE
Salem, OR 97303

Oregon Parks and Recreation Department
725 Summer St. N.E. Suite C
Salem, OR 97301

# The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast - 2012

David J. Lauten, Kathleen A. Castelein, J. Daniel Farrar, Adam A. Kotaich, and Eleanor P. Gaines

Oregon Biodiversity Information Center
Institute for Natural Resources
Portland State University/INR
PO Box 751, Portland, Oregon 97207

## Abstract

From 5 April – 21 September 2012 we monitored the distribution, abundance and productivity of the federally Threatened Western Snowy Plover (*Charadrius nivosus nivosus*) along the Oregon coast. From north to south, we surveyed and monitored plover activity at Sutton Beach, Siltcoos River estuary, the Dunes Overlook, North Tahkenitch Creek, Tenmile Creek, Coos Bay North Spit, Bandon Snowy Plover Management Area, New River HRA and adjacent lands, and Floras Lake. Our objectives for the Oregon coastal population in 2012 were to: 1) estimate the size of the adult Snowy Plover population, 2) locate plover nests, 3) determine nest success, 4) use mini-exclosures (MEs) to protect nests from predators as needed, 5) determine fledging success, 6) monitor brood movements, 7) collect general observational data about predators, and 8) evaluate the effectiveness of predator management.

We observed an estimated 290-91 adult Snowy Plovers; a minimum of 231-238 individuals was known to have nested. The adult plover population was the highest estimate recorded since monitoring began in 1990. We monitored 314 nests in 2012; the highest number of nests since monitoring began in 1990. Overall apparent nest success was 45%. Exclosed nests (n = 22) had an 82% apparent nest success rate, and unexclosed nests (n = 289) had a 42% apparent nest success rate. Nest failures were attributed to unknown depredation, unknown cause, corvid depredation, abandonment, one egg nests, wind/weather, mammalian depredation, overwashing, adult plover depredation, and infertility. We monitored 154 broods, including 11 from unknown nests, and documented a minimum of 173 fledglings. Overall brood success was 70%, fledging success was 43%, and 1.37 fledglings per male were produced.

Continued predator management, habitat improvement and maintenance, and management of recreational activities at all sites are recommended to achieve recovery goals.

**TABLE OF CONTENTS**

## Introduction

The Western Snowy Plover (*Charadrius nivosus nivosus*) breeds along the coast of the Pacific Ocean in California, Oregon, and Washington and at alkaline lakes in the interior of the western United States (Page *et al.* 1991). Loss of habitat, predation pressures, and disturbance have caused the decline of the coastal population of Snowy Plovers and led to the listing of the Pacific Coast Population of Western Snowy Plovers as Threatened on March 5, 1993 (U.S. Fish and Wildlife Service 1993). Oregon Department of Fish and Wildlife lists the Western Snowy Plover as threatened throughout the state (ODFW 2009).

Oregon Biodiversity Information Center (ORBIC, formerly Oregon Natural Heritage Information Center) completed our 23$^{nd}$ year of monitoring the distribution, abundance, and productivity of Snowy Plovers along the Oregon coast during the breeding season. In cooperation with federal and state agencies, plover management has focused on habitat restoration and maintenance at breeding sites, non-lethal and lethal predator management, and management of human related disturbances to nesting plovers. The goal of management is improved annual productivity leading to increases in Oregon's breeding population and eventually sustainable productivity and stable populations at recovery levels. Previous work and results have been summarized in annual reports (Stern *et al.* 1990 and 1991, Craig *et al.* 1992, Casler *et al.* 1993, Hallett *et al.* 1994, 1995, Estelle *et al.* 1997, Castelein *et al.* 1997, 1998, 2000a, 2000b, 2001, and 2002, and Lauten *et al.* 2003, 2005, 2006, 2006b, 2007, 2008, 2009, 2010, and 2011). Our objectives for the Oregon coastal population in 2012 were to: 1) estimate the size of the adult Snowy Plover population, 2) locate plover nests, 3) determine nest success, 4) use mini-exclosures (MEs) to protect nests from predators as needed, 5) determine fledging success, 6) monitor brood movements, 7) collect general observational data about predators, and 8) evaluate the effectiveness of predator management. The results of these efforts are presented in this report.

## Study Area

We surveyed Snowy Plover breeding habitat along the Oregon coast, including ocean beaches, sandy spits, ocean-overwashed areas within sand dunes dominated by European beachgrass (*Ammophila arenaria*), open estuarine areas with sand flats, a dredge spoil site, and several habitat restoration/management sites. From north to south, we surveyed and monitored plover activity at Sutton Beach, Siltcoos River estuary, the Dunes Overlook, North Tahkenitch Creek, Tenmile Creek, Coos Bay North Spit (CBNS), Bandon Snowy Plover Management Area (SPMA), New River (extending from private land south of Bandon SPMA to the south end of the New River Area of Critical Environmental Concern (ACEC) habitat restoration area), and Floras Lake (Figure 1). A description of each site occurs in Appendix A. For the purposes of this report and for consistency with previous years' data, we define Bandon Beach as the area from China Creek to the mouth of New River, and Bandon SPMA as all the state land from the north end of the China Creek parking lot south to the south boundary of the State Natural Area south of the mouth of New River.

## Methods

### Abundance

In 2012, state and federal agency personnel and volunteers conducted pre-breeding window surveys at historical nesting sites between Clatsop Spit, Clatsop Co. and Pistol River, Curry Co (Elliott-Smith and Haig 2007). Pre-breeding surveys have been implemented since 2001 to locate any plovers attempting to nest at historic (currently inactive) nesting areas. Agency personnel also assisted surveying plovers during breeding season window surveys in late May and early June. Breeding season window surveys were implemented at both currently active and historic nesting areas (Elliott-Smith and Haig 2007). Historic nesting areas surveyed in either early spring or during the breeding window survey include: Clatsop Spit, Necanicum Spit, Nehalem Spit, Bayocean Spit, Netarts Spit, Sand Lake South Spit, Nestucca Spit, Whiskey Run to Coquille River, Sixes River South Spit, Elk River, Euchre Creek, and Pistol River.

**Monitoring**

Breeding season fieldwork was conducted from 5 April to 21 September 2012. Survey techniques, data collection methodology, and information regarding locating and documenting nests can be found in Castelein *et al.* 2000a, 2000b, 2001, 2002, and Lauten *et al.* 2003 and are in Appendix D. No modifications to survey techniques were implemented in 2012.

We report three measures of population size: the total number of Snowy Plovers present, the total number identified breeding, and the total number of plovers resident during the breeding season. We estimated the number of Snowy Plovers on the Oregon coast during the 2012 breeding season by determining the number of uniquely color-banded adult Snowy Plovers observed, and added an estimate of the number of unbanded Snowy Plovers present. We used the 10 day interval method described in Castelein *et al.* 2001 to estimate a minimum number of unbanded plovers, however, based on nesting records and daily observational data this method underestimates the actual number of unbanded plovers present. We use this number to give a minimum range of the number of unbanded plovers in the population. We estimated the breeding population by tallying the number of known breeding plovers. Not all plovers recorded during the summer are Oregon breeding plovers; some plovers are recorded early or late in the breeding season indicating that they are either migrant or wintering birds. Plovers that were present throughout or during the breeding season but were not confirmed breeders were considered Oregon resident plovers. We estimated an overall Oregon resident plover population by adding the known breeders with the number of plovers present but not confirmed nesting during the breeding season.

We determined the number of individual banded female and male plovers and the number of individual unbanded female and male plovers that were recorded at each nesting area along the Oregon coast from the beginning to the end of the 2012 breeding season. Data from nesting sites with a north and south component (Siltcoos, Overlook, and Tenmile) were pooled because individual plovers use both sides of these estuaries. Data from CBNS nesting sites were pooled for the same reason. We separated data from Bandon SPMA, New River HRA, and Floras Lake because of different management at these sites, despite plovers frequently moving between these areas. The total number of individual plovers recorded at each site indicates the overall use of the site, particularly where plovers congregate during post breeding and wintering. We also determined the number of individual breeding female and male plovers for each site. The number of individual breeding adults indicates the level of nesting activity for each site.

Using all nests, we calculated overall apparent nest success, which is the number of successful nests divided by the total number of nests, for all nests and for each individual site. We also calculated apparent nest success for exclosed and unexclosed nests and used Chi-squared analysis to compare the success of exclosed and unexclosed nests.

Male Snowy Plovers typically rear their broods until fledging. In order to track the broods we banded most nesting adult males, females that tended to broods, and most hatch-year birds with both a

USFWS aluminum band and a combination of colored plastic bands. Trapping techniques are described in Lauten *et al.* 2005 and 2006 (Appendix D). We monitored broods and recorded brood activity or adults exhibiting broody behavior at each site (Page et al. 2009). Chicks were considered fledged when they were observed 28 days after hatching.

We calculated brood success, the number of broods that successfully fledged at least one chick; fledging success, the number of chicks that fledged divided by the number of eggs that hatched; and fledglings per male for each site. Statistical analysis of nest, chick, and adult survival will be published in a refereed journal.

We continue to review plover productivity prior to lethal predator management activities compared to productivity after implementation of lethal predator management. We specifically continue to evaluate the changes in hatch rate, fledging rate, productivity index, and fledglings per male from years prior to lethal predator management compared to years with lethal predator management. The productivity index is a measure of overall effort based on how many eggs the plovers laid divided by the number of fledglings produced. If plovers produced high numbers of fledglings compared to eggs laid, then their productivity was high for the amount of effort (eggs laid) and the productivity index would be high. If plovers produced low numbers of fledglings compared to high numbers of eggs laid, then their productivity was low and the productivity index would be low. Data for brood success, fledging success, and fledglings per male were all normally distributed. We used t-test to compare the mean brood success, the mean fledging rate and the mean number of fledglings per male prior to predator management (1992-2001) to post predator management (2004-2011). We did not include the years 2002 and 2003 in the analysis because three sites (CBNS, Bandon Beach, and New River) had predator management in those years but all other sites did not.

**Exclosures**

From mid-May to August, we used a limited number of mini-exclosures (MEs, Lauten *et al.* 2003) to protect plover nests at North and South Overlook, North Tahkenitch, Bandon SPMA and New River as outlined in our exclosure use protocol (Appendix C). No exclosures were used on plover nests found during April and into early May due to concerns related to raptor migration (Castelein *et al.* 2001, 2002, Lauten *et al.* 2003). Exclosure use was limited in 2012 due to good unexclosed hatch rates at Siltcoos, Overlook, North Tahkenitch, and Coos Bay North Spit and due to adult plover depredation concerns in and around ME's, particularly at Tenmile. No exclosures were used at North and South Siltcoos, North and South Tenmile, Coos Bay North Spit, and Floras Lake.

**Predator Management**

Lethal predator management occurred at all active nesting areas; corvids (*Corvus sp.*) were targeted at all nesting sites. Some mammal trapping, specifically targeting red fox (*Vulpes vulpes*), striped skunks (*Mephitis mephitis*), and coyote (*Canis latrans*) occurred at specific sites. In 2011 a trapping effort targeting deer mice (*Peromyscus maniculatus*) was implemented at CBNS (Lauten *et al.*, 2011). In 2012 deer mice were again targeted on a portion of the habitat restoration area (HRA) by several students from Southwest Oregon Community College. Rodent trapping was limited to March, before the plovers were nesting. This trapping effort helped to assess the rodent population compared to the previous year's results while also potentially reducing rodent depredations on plover eggs. For information regarding the predator management program, see Burrell (2012).

## Results and Discussion

### Abundance and Monitoring

#### Window Surveys

During the pre-breeding April surveys of beaches with no current nesting activity, one plover was recorded along the Whiskey Run to Coquille River (Coos Co.) survey route, the first time a plover was detected since the pre-breeding surveys were implemented in 2001. During the May window surveys, two plovers were detected in Clatsop County; one at Fort Stevens State Park, and one at Necanicum Spit (USFWS unpublished data). Clatsop spit (Clatsop Co.), the first two plovers to be detected on the north coast during spring window surveys since 2002. The annual breeding window survey in late May counted 206 plovers (Table 1), the highest number of plovers ever detected.

#### Breeding Season Monitoring

During the 2012 breeding season, we estimated a 290-291 adult Snowy Plovers at breeding sites along the Oregon coast (Table 1). Of 290-291 plovers, 270 (93%) were banded. The number of unbanded plovers estimated by the 10 day interval method was 20-21 individuals. For the breeding season we observed 128 banded females, 142 banded males, 17-18 unbanded females, and 3 unbanded males. The totals include two banded males, one banded female, and one unbanded female plover that were killed in or around an exclosed nest, and a minimum of four other banded males and three banded female that disappeared during the breeding season.

Of the total estimated population, 231-238 plovers (79-82%) were known to have nested (Table 1), similar to the mean percentage for 1993-2011 (79%). A minimum of 94 banded females and 119 banded males nested. Approximately 12-17 unbanded females nested and 7 unbanded males were known to have nested; the number of known unbanded males that nested indicates that the 10-day interval method of estimating unbanded plovers underestimates the true number of unbanded plovers present. An additional 21 banded females and 19 banded males were present during the breeding season but were not confirmed nesting. The minimum estimated Oregon resident plover population was 271-278.

For the first time since monitoring began in 1990, all three indices to the Snowy Plover population on the Oregon coast were above 200 individuals (Table 1). The number of plovers recorded by all three indices was the highest since monitoring began in 1990 and continues to show an increasing trend in the Oregon population (Table 1). The window survey count increased by 38 individuals and the total number of plovers present increased by 37-42 individuals, while the number of breeding plovers increased by 17-24 individuals. As we have noted in previous years, increasing plover numbers and densities on the nesting area has resulted in some difficulties positively identifying all nesting individuals (Lauten *et al.*, 2010 and 2011), therefore the number of breeding individuals was likely higher than the total tallied because some individuals were not positively identified at a nest but still likely nested based on their presence throughout the breeding season. The number of resident plovers in 2012 increased by 38-45 individuals, similar to the increase in the window survey count and the total number of plovers present. In 2012, the Oregon coastal plover population was above the recovery goal set for the state. Recovery goals have not been met in other states. (U.S. Fish and Wildlife Service 2007).

#### Overwinter Survival

Adult overwinter survival is very important to maintaining and increasing populations (Sandercock 2003, USFWS 2007, Dinsmore *et al.* 2010, Lauten *et al.* 2010 and 2011). In 2011 the estimated adult plover population was 247-253, of which 220 were banded. Of these 220 banded adult plovers, 59 (27%) were not recorded in Oregon in 2012, and we received no reports of these individuals being sighted elsewhere in the range. Thus they are presumed not to have survived winter 2011-12. The overwinter return rate based on returning banded adult plovers was 73%, above the 1994-2011 mean of 64% and the fourth consecutive year the adult return rate was above 70% (Lauten *et al.*, 2008, 2009, 2010, and 2011).

Due to analysis of hatch year returns, we adjusted the 2011 fledgling total to 168 from 172. Ninety-one of the 172 hatch-year plovers from 2011 (HY11) returned to Oregon in 2012. The return rate was 53%, slightly higher than the average return rate (Table 2, 47%). Of the returning 2011 HY11 birds, 42 (46%) were females and 49 (54%) were males. Seventy of the HY11 returning plovers attempted to nest (77%), and they accounted for 34% of the banded adults. These HY11 returns exceeded the number of banded adults that did not return in 2012.

The number of unbanded plovers was lower than previous years (n = 19-24 in 2012, n = 27-33 in 2011 and n = 27-31 in 2010), and the number of adult plovers banded outside of Oregon was the same as the previous two years (n = 18 in 2011 and 2010), indicating that immigration had a limited role in the increase in plover numbers. The increase in the population in 2012 was due to a combination of high adult and juvenile return rates. As we noted in 2011 (Lauten *et al.*, 2011), studying and managing plovers in winter could result in positive management practices that have beneficial effects on plover overwinter survival and thus population levels (Brindock and Colwell 2011, Dinsmore *et al.*, 2010).

Emigration from Oregon continues to be important to smaller plover populations in Washington and Humboldt Co., California. Colwell *et al.* (2008, 2009, 2010, 2011, and 2012) has noted that Humboldt Co. populations are maintained by immigration, and Washington populations are also maintained by immigration into that population (S. Pearson, pers. comm.). High reproductive output from Oregon plovers benefits these neighboring plover populations.

During the 2012 season, we captured and rebanded 33 banded adult plovers that either had worn bands or brood band combinations which needed to be updated to unique adult combinations. Nineteen of these were males and 11 were females. We banded eight unbanded adult male plovers, three unbanded adult female plovers and 335 chicks.

## Distribution

Table 3 shows the number of individual banded and unbanded adult plovers and the number of breeding adult plovers recorded at each nesting area along the Oregon coast in 2012. Sutton Beach had no recorded plovers in 2012. The overall number of breeding plovers at Siltcoos was the same as in 2011. The number breeding was similar to the recent past (Table 3, 26 in 2011, 23 in 2010, and 24 in 2009). Overlook had slightly more plovers present and slightly more breeding plovers as compared to 2011 (Table 3, 89 plovers present and 49 breeding in 2011). This indicates a relatively stable population after several years of population increases at this site (Lauten *et al.* 2011). At North Tahkenitch in 2012, the number of plovers and the number of breeding plovers increased by about 10 individuals compared to 2011 (Table 3, 58 present and 22 breeding in 2011). Some plovers nesting at North Tahkenitch in 2012 moved from Tenmile after unsuccessfully attempting to nest at Tenmile. The number of plovers and the number of breeding plovers at Tenmile in 2012 was also similar to 2011 (Table 3, 61 plovers present, 25 breeding in 2011). CBNS had the highest increase in plover numbers and breeding plovers in 2012. There were approximately 20 more individual plovers and 20 more breeding plovers at CBNS in 2012 compared to 2011 (Table 3, 69 plovers present and 59 breeding in 2011). The number of plovers using Bandon SPMA generally reflects the number of plovers using the entire Bandon Beach/New River/Floras Lake area, as the majority of plovers from these areas tend to spend the non breeding season at Bandon SPMA. The estimated number of plovers using Bandon SPMA in 2011 (minimum 56-60) was slightly lower to the total number of plovers using Bandon SPMA in 2012 (Table 3). The number of breeding plovers in 2012 for the Bandon Beach/New River/Floras Lake area was 46, slightly below the number of breeding plovers for 2011 (n = 50). In 2012, Overlook and CBNS had the highest number of plovers for all sites, approximately 31-32% of the total plover population for each site. We recorded a total of 10 individuals at Floras Lake, including five breeding individuals, the first breeding plovers since 2009.

The increasing plover population has resulted in plovers occupying available habitat adjacent to the traditional nesting areas (Lauten *et al.* 2010 and 2011), particularly the beach between South Siltcoos to Overlook and Overlook to North Tahkenitch. In 2012 plovers continued to use these sections of beach for both nesting and brooding (Figures 2 to 4). First year nesting plovers will tend to return to areas where they successfully hatched chicks, therefore we would expect continued use of these beach areas for plover nesting and brooding in the future. Lauten *et al.* (2011) noted that the increasing plover population would likely result in plovers occupying additional beaches that were adjacent to current nesting beaches such as South Tahkenitch to the Umpqua jetty, the beach north of North Tenmile, and CBNS beach north of the FAA tower. In 2011 and 2012 plovers did nest north of the North Tenmile spit (Figure 5). At CBNS in 2012, we found one nest north of the FAA towers (Figure 6) and late in the season we found two very recently fledged unbanded birds from an unknown brood north of the FAA towers that likely came from the beach north of access point one. We also found two nests at Floras Lake in 2012 including the first nests on the CMA in 10 years, as well as two nests along the beach north of Floras Lake and south of Clay Island breach. For the first time since spring surveys have been conducted on the north coast, two plovers were detected at Clatsop spit, although they were not detected on subsequent surveys. A few banded plovers were also reported in late summer and fall along the north coast by birdwatchers (*fide* Oregon Birders On Line).

**Nest Activity**

With an increasing plover population, the number of nests found continues to increase. We located 314 nests during the 2012 nesting season (Table 4, Figures 2-9), the highest number of nests found since monitoring began in 1990. In addition we recorded a minimum of 11 broods from nests that we did not locate prior to hatching. Nest distribution was similar to 2011 (Table 4). Siltcoos, Overlook and Tenmile had similar numbers of nests in 2012 compared to 2011. North Tahkenitch had 13 more nests in 2012 compared to 2011; the increase in nests was a result of larger numbers of plovers using this site in 2012 compared to 2011. CBNS had similar numbers of nests in 2012 compared to 2011 despite an increase in the number of plovers at this site. The similar number of nests in 2012 compared to 2011 was due to high nest success and therefore a lack of multiple renest attempts. There were fewer nest attempts on South Beach in 2012 compared to 2011 and more nest attempts on the HRAs in 2012. Bandon SPMA had the highest increase in nest numbers in 2012 (n = 60) compared to 2011 (n = 37). The higher number of nests was due to repeated nest failures resulting in many renesting attempts. There were 48 nests on Bandon Beach and 12 nests on the state portion of New River spit. New River HRA had the largest decline in nest numbers in 2012 (n = 17) compared to 2011 (n = 29). The lower number of nests on the New River HRA was partly due to fewer plovers using the HRA in 2012. We suspect there may have been more nests attempts at New River HRA, but were unable to confirm this because high water early in the season prevented us from conducting as many surveys as needed. High predation pressure by corvids likely resulted in some nest attempts failing before we were able to find and document them. Floras Lake had two nests, the first nests at this site since 2009 and only the second time in 10 years that nests were found here.

The first nests were initiated about 6 April (Figure 10). Nest initiation increased through late-May, and remained high into the beginning of July. The maximum number of active nests (n = 100) during 10-day intervals occurred during 31 May – 9 June, two weeks earlier than 2011 and one week earlier than the average peak nesting period. This was the highest number of active nests during any 10 day time interval since monitoring began in 1990 and the first time 100 nests were active at the same time. The last nest initiation occurred on 19 July.

**Nest Success and Exclosures**

For the sixth consecutive year, the number of days nests were unexclosed was higher than the number of days nests were exclosed (4576 unexclosed days, 323 exclosed days, Figure 11). In 2012, exclosures were used on 8% (n = 25) of the total number of nests (n = 314), and 7% of the total number of exposure days were exclosed (n = 323/4899).

The overall annual apparent nest success rate in 2012 was 45% (Table 5), similar to the average (Table 6). The number of exclosed nests in 2012 (n = 22, 7%) was the lowest since 1991 and the lowest percentage of the total number of nests since monitoring began in 1990. Apparent nest success for exclosed nests in 2012 was 82%, higher than the average for all years ($x$ = 71%, Table 6). The number of unexclosed nests in 2012 (n = 289, 93%) was the highest since monitoring began. Apparent nest success for unexclosed nests in 2012 was 42%, higher than the overall mean ($x$ = 20%, Table 6). Nest success of unexclosed nests in 2012 was significantly lower than nest success of exclosed nests ($\chi^2 = 12.2720$, df = 1, $P < 0.01$).

**Siltcoos**

No exclosures were used at Siltcoos in 2012 (Table 5), the first time no exclosures were used on both sides of the estuary since 1993. Overall nest success for Siltcoos was 53% (Table 5), above the average for these sites (Figure 12). North Siltcoos had 40% nest success and South Siltcoos had 59% nests success. Causes of nest failure are detailed in Table 7. Despite nest depredations being the main cause of nest failure at Siltcoos, no exclosures were used in 2012 due to good corvid management and good overall nest success.

**Overlook**

At Overlook in 2012, the overall nest success was 47% (Table 5). Overall nest success for North and South Overlook was 54% and 42% respectively (Table 5), both slightly above average for these sites (Figure 12). Only four of 59 nests were exclosed at Overlook, including one on the north side and three on the south side. All four exclosed nests hatched (Table 7). Of the 15 nests that failed due to depredations or unknown cause, 10 failed at or prior to mid-May before exclosure use was a management option. The other failed nests due to unknown depredation had no evidence that corvids were responsible. Due to good overall nest success and good corvid management after mid-May, exclosure use was limited at Overlook in 2012.

**Tahkenitch**

Plover activity has increased considerably at North Tahkenitch in the past two years (Table 4). Overall nest success at North Tahkenitch in 2012 was 58% (Table 5), similar to 2011 (61%), and much higher than the average for this site (Figure 12). Of the 36 nests found, only four were exclosed, all of which hatched. Thirty-two nests were unexclosed, and 17 hatched (53%, Table 5). Causes of nest failure are detailed in Table 7. Of the 15 nest failures, five occurred prior to mid-May, so under the exclosure protocol they would not have been exclosed anyway. Due to the good overall nest success and lack of corvid depredations, exclosure use was limited at North Tahkenitch in 2012.

**Tenmile**

In 2012, Tenmile continued to have very poor nest success with only six of 46 nests successfully hatching (13%, Table 5), similar to 2011 and well below the average for these sites (Figure 12). Causes of nest failure are detailed in Table 7. Nest failures attributed to unknown cause were likely also depredated, suggesting that upwards of 88% of the failed nests at Tenmile may have been due to some depredation event. Both field and camera evidence suggests that the main culprit of nest failures at Tenmile is ravens, and we continue to work with Wildlife Services staff to eliminate the corvids. In 2012 we set up a camera on five nests at Tenmile. All five of these nests hatched, though we did record ravens approaching the nests on multiple occasions. The ravens appeared wary, possibly because of the presence of the camera, and despite evidence that the raven was aware of the eggs it did not depredate the nests. While we did not positively record any raven depredations, the video confirms that ravens are using the area and may be wary of human-related items. Despite the high level of depredations and likely depredations, we did not exclose any nests at Tenmile. Great Horned Owls have targeted adult plovers in and around exclosures at this site (Lauten *et al.* 2011), and we did not have time to run surveys to determine the presence or absence of owls. Because adult survival is the primary driver of population growth (Sandercock 2003, USFWS 2007, Dinsmore *et al.* 2010, Lauten *et al.* 2010 and 2011), we felt it was more important to reduce risk to adult survival than to nest survival. Experience from other nest sites indicates that eliminating and successfully managing corvids increases nest success to sustainable rates and allows exclosure use to be reduced, thus reducing or eliminating risks to incubating adult plovers.

**Coos Bay North Spit**

No exclosures were used at CBNS for the sixth consecutive year (Table 5). Overall nest success at CBNS was 87%, similar to 2011 (82%). Nest success at CBNS was well above average (Table 5, Figure 12) for all sites. On the HRAs, 34 of 39 nests hatched (87%), on South Spoil 13 of 15 nests hatched (87%), and on South Beach 6 of 7 nests hatched (86%). In 2012 only one nest failed to depredation. Causes of the remaining nest failures are detailed in Table 7.

**Bandon SPMA**

There were 23 more nests at Bandon SPMA in 2012 compared to 2011 (Table 4). The increase in the number of nests was partly due to poor nest success, which resulted in many renesting attempts (Table 5). Depredations were the main cause of nest failure (79%, Table 7). Many of the unknown depredations were likely caused by corvids, but there was no evidence to determine the exact cause of the depredation. Despite the high levels of nest depredations, we only used nine exclosures in 2012 (seven on the Bandon Beach side and two on the New River spit). Due to previous experience with adult plovers being depredated in and around exclosures at Bandon SPMA (Lauten *et al.*, 2006and 2011), we were cautious about erecting exclosures especially if corvid activity was relatively low. In 2012, corvid activity was often minimal, and then episodically increased resulting in nest depredations before we could erect exclosures. One exclosed nest hatched but the adults were found dead within ca. 25 m of the exclosed nest. The hatching chicks were then transported to the Newport Aquarium. The exclosure had canine tracks around it, and the canine attempted to dig under the exclosure. We believed at the time this was indication that fox had attacked the adults and the hatching nest. Another male plover that was incubating on an exclosed nest during the same period was found with a severely injured left leg. Because of these events, we pulled three of the nine exclosures to reduce the likelihood of further adult injuries or mortalities. Five of the six nests that were exclosed for the duration of incubation hatched (83%); one exclosed nest was abandoned, but may have been abandoned before erection of the exclosure. Unexclosed nest success at Bandon SPMA continues to be very poor, and overall nest success at Bandon SPMA in 2012 was well below average (Figure 12).

**New River**

Overall nest success on non-state lands at New River in 2012 was also low (29%, Table 5), and well below the average for this site (Figure 12). Ten of 18 nests were unexclosed, including one on private land and nine on the HRA; all 10 failed (Table 5). Eight nests were exclosed, and five hatched (Table 5). The causes of nest failure are detailed in Table 7. We believe corvids were the main cause of nest failure as they were present in relatively high densities all summer, particularly on the HRA. While exclosure use at New River does increase nest success, we continue to experience adult mortalities in and around exclosures at this site. In 2012, of the three exclosed nests that failed, two adults were depredated at one, and the other two exclosed nests were abandoned. The adults associated with one of these nests also disappeared, which suggests they were also depredated.

**Floras Lake**

Of the two nests found at Floras Lake, one hatched (Table 5). One nest was found on the Cooperative Management Area (CMA) and successfully hatched without an exclosure. The second nest was north of Hanson breach and was not exclosed; the nest failed to unknown depredation.

**Depredations Around Exclosures**

As of 2011, we have documented a minimum of 46 adult plovers (ca. 5% of all known adult plovers) depredated in or around exclosures (ORBIC, unpubl. data). Due to these adult losses as well as the relatively good success of both nests and broods, we continue to carefully evaluate exclosure use and minimize the number of exclosures used and the amount of time exclosures are protecting nests. In 2012, the number of days unexclosed was the highest since monitoring began, and we reduced the number of days exclosed to 7% of the total number of exposure days (Figure 11). Adult survival is very important for population growth (Sandercock 2003, USFWS 2007, and Dinsmore *et al.* 2010), therefore if nest success is relatively good, evidence of predation pressure is minimal, and fledgling productivity is good, exclosure use is not necessary. Exclosures continue to be a management tool that increases nest success, however with a reasonably large population size and good productivity, exclosure use should be carefully evaluated and minimized to the extent possible.

**Nest Failure**

Exclosed nests in 2012 had an overall failure rate of 18% (4 of 22, Table 8; three nests from Bandon SPMA B\ not included because the exclosures were removed after two adult plovers were found dead outside of an exclosed nest). Of the four failed exclosed nests, two failed to unknown causes, one was abandoned, and one had both adult plovers depredated (Table 8). The banded adult male from one of the exclosed nests that failed to unknown cause disappeared during the incubation period; it is possible he was also depredated. The female to this same nest also disappeared, but she was unbanded so it is unclear if she survived. The number of unexclosed nests that failed in 2012 (n = 167) was higher than the past three years (2011, n = 129; 2010, n = 149; 2009, n = 148). The failure rate of unexclosed nests in 2012 (58%) was similar to 2011 (54%) but lower than previous years (77% in 2010, 73% in 2009, and 73% in 2008). In 2012, the main causes of nest failure for unexclosed nests were unknown depredations, unknown cause, corvid depredations, abandonment, one egg nests, and wind/weather (Tables 7 and 8). Overall nest failures were attributed to unknown depredation, unknown cause, corvid depredation, abandonment, one-egg nests , wind/weather , mammalian depredation , overwashed , adult plover depredation , and infertility (Table 7).

In 2012, the number of one-egg nests (n = 14) and abandoned nests (n = 17) was similar to previous years (Lauten *et al.* 2007, 2008, 2009, 2010, and 2011). Since the number of these nests has been relatively stable for the past six years, we continue to believe that the causes of these abandonments are natural and are not due to exclosure use (only 9% of these nests have been exclosed), or recreational activity which remains low within the nesting areas, or monitoring activity.

**Predator Management**

No rodent depredations of nests were confirmed in 2012, the second consecutive year with no or low rodent depredations (Lauten *et al.*, 2011). In 2012, 201 deer mice were captured at CBNS (Burrell 2012) during March. Nest success at CBNS in 2012 was again very high (Table 6). It is unclear whether the rodent trapping had any real effect on nest success, however the effort does give an indication of rodent population levels. Similar rodent trapping and removal in the future would at a minimum help us gauge and understand rodent population levels and cycles at CBNS.

Corvid depredations continue to be the main source of known nest depredations (Table 8). Of the 57 unknown depredations, 32 (56%) were at Bandon SPMA and New River HRA where corvid activity was persistent all summer. Corvids were likely responsible for most of these unknown depredations. Predator management continues to have a positive effect on reducing corvid numbers, however controlling corvids is a difficult and time consuming task. Despite apparent reductions in corvid numbers, they continue to be consistently present particularly between Siltcoos to Tahkenitch, Tenmile, Bandon Beach and New River. Due to the amount of area that needs to be covered and the distance between nesting sites, we continue to recommend that Wildlife Services be funded to support three agents. See Burrell (2012) for a complete discussion of the predator management program.

**Fledging Success and Productivity**

We monitored 154 broods in 2012 including 11 broods from undiscovered nests, six more broods than in 2011 (Lauten *et al.* 2011) and the highest number of broods since monitoring began in 1990. A minimum of 173 fledglings was confirmed (Table 9), the highest number since monitoring began. Overall fledging success was 43%, near the overall average (Table 10). The overall brood success rate was 70% (Table 11), slightly higher than the average (66% +/- 10). The overall number of fledglings per male was above the recovery goal at 1.37 (Table 11). Considering data from known nests from Siltcoos to New River only (Tables 12-18), the mean fledglings per male was 1.186, near the average (Table 10). Despite good overall productivity, productivity varied between sites (Table 11).

**Siltcoos**

At Siltcoos in 2012 (Table 12), the number of eggs laid and the hatch rate were similar to 2011. There was one more brood than in 2011, and 61% of these broods successfully fledged at least one chick (Table 11). Four more chicks fledged than in 2011, which increased the fledging success rate, the productivity index, and the number of fledglings per male. However, the fledging success rate, the productivity index, and the number of fledglings per male for 2012 were below the post predator management averages for Siltcoos. Fledging success was better on the South Spit, but the North Spit had a small sample size (Table 11).

**Overlook**

At Overlook in 2012 the number of eggs laid and the number of eggs hatched were similar to 2011 (Table 13). The hatch rate was slightly lower than 2011 but similar to the post predator management average. Overlook had 31 broods, two less than 2011, and 28 were successful (Table 11). The fledging success rate, productivity index, and the number of fledglings per male were slightly lower than in 2011 but still higher than the post predator management averages.

**Tahkenitch**

North Tahkenitch had the largest increase in plover activity of any site on the Oregon coast in 2012 as measured by the number of eggs laid and the number of known breeding males compared to 2011 (Table 14). The hatch rate was lower than 2011 but slightly higher than the post predator management average. North Tahkenitch had 21 broods, seven more than in 2011, and 18 were successful (Table 11). The number of fledglings produced was the highest since monitoring began in 1993. While the fledging success rate, productivity index, and number of fledglings per male were all lower than in 2011, all three indices were higher than the post predator management averages, and Tahkenitch produced six more fledglings than in 2011. Overall productivity at this site was above recovery goals.

**Tenmile**

The effort at Tenmile as measured by the number of eggs laid in 2012 was similar to the previous three years (Table 15), however for the second consecutive year the productivity was very poor. Despite laying a minimum of 104 eggs, only 18 hatched, the second consecutive year of very low hatch rates and well below the post predator management average. Tenmile had six broods, one less than 2011, and overall brood success was 83% (Table 11). The fledging success rate improved to 50%, higher than the post predator management average. However the number of fledglings compared to the number of eggs laid was very low, and resulted in a very poor productivity index, well below the post predator management average. The number of fledglings per male was above the post predator management average, however this number is influenced by the number of known breeding males and since most nests failed, many males who unsuccessfully hatched at Tenmile were never identified. If more males had been identified, the actual number of fledglings per male would be much lower. Tenmile continues to be the only site where productivity has not increased since implementation of predator management. Poor nest success is a continuing problem at Tenmile (Table 5), especially given the number of plovers using this site (Table 3).

**Coos Bay North Spit**

The hatch rate at CBNS in 2012 was the highest on the coast, the highest since predator management was implemented in 2002, and well above the post predator management average (Table 16). CBNS had 58 broods, nine more than in 2011, and overall brood success rate was 59%. While the hatch rate was high and the number of fledglings similar to 2011, the fledging success rate declined from 2011 to 37%, below the post predator management average. This was largely due to low fledging rates on South Spoil and the HRAs. Fledging success on the beach was much higher (Table 11). The productivity index was similar to 2011 and nearly the post predator management average. Despite the relatively good productivity, the number of fledglings per male declined from 2011 and was well below the post predator management average. CBNS continues to be the most productive site on the Oregon coast.

**Bandon SPMA**

Bandon SPMA had the largest increase in the number of eggs laid compared to 2011 (Table 17). This was not due to more individual plovers but due to poor hatch rates and thus increased renesting attempts. The hatch rate was much lower than in 2011 and well below the post predator management average. Bandon SPMA had 11 broods, six fewer than in 2011, and overall brood success was 67%. The fledging success rate was slightly above the post predator management average, but the productivity index was very poor, indicating that few fledglings were produced compared to the number of eggs laid. The number of fledglings per male was near the post predator management average, and just below the recovery goal.

**New River**

The number of plovers using the New River HRA has declined since 2010, and therefore the number of eggs laid has also declined (Table 18). The hatch rate in 2012 was much lower than in 2011 and only half of the post predator management average. There were seven broods on the New River HRA; four of these fledged at least one chick. The number of young fledged has also declined since 2009 and the fledging success rate was the lowest since implementation of predator management and well below the post predator management average. The productivity index was very low and also well below the post predator management average. The number of fledglings per male was the lowest since implementation of predator management and well below the post predator management average. Corvids continue to be persistent at Bandon SPMA and New River HRA and are likely the main cause of low productivity at these sites. We recommend efforts to remove corvids at all nesting sites as they continue to be the main cause of known nest failures (Table 7) and are likely responsible for some chick mortality.

**Floras Lake**

Floras Lake had two broods, one of which was successful (Table 11). The two fledglings produced by the one successful brood were the first fledglings from Floras Lake since 2000. Due to the paucity of data from Floras Lake, we have not calculated hatch rates, fledgling rates, and productivity indices for this site.

Post predator management hatch rates have declined for Overlook, Tenmile, CBNS, Bandon SPMA, and New River HRA, but this is the result of many more nests remaining unexclosed and unexclosed nests have a lower nest success than exclosed nests (Table 6). Since the implementation of predator management, the average brood success rate (2004-2012, 72.2%) was significantly higher than the average pre predator management brood success rate, (1991-2001, 62.9%, t-stat = 2.32, df = 18, $P$ = 0.02). The overall mean post predator management fledging success rate (0.47) was significantly higher than the mean pre predator management fledging success rate (0.39, t = 1.75, df = 17, $P$ = 0.05). The post predator management fledging success rate has improved for Siltcoos, Overlook, CBNS, Bandon SPMA, and New River (Table 19). Tahkenitch and Tenmile have decreased but are still within acceptable levels. The overall mean number of fledglings per male after implementation of predator management (2004-2012; $x$ = 1.31) was significantly higher than the mean number of fledglings per male prior to the implementation of predator management (1992-2001; $x$ = 1.06, t = 2.37, df = 17, $P$ = 0.01). The mean number of fledglings per male has improved at all sites except Tenmile where it has remained relatively stable (Table 19). Productivity as measured by the average fledging success rate has improved at all sites except Tahkenitch and Tenmile since implementation of predator management (Table 19). The overall productivity data has generally improved since the implementation of predator management, and we continue to recommend that predator management be funded, as this is critical to increasing and maintaining the plover population.

**Brood Movements**

**Siltcoos, Overlook, and Tahkenitch**

Only one of four broods at North Siltcoos in 2012 was successful, and that brood remained within the nesting area for the duration of the brood rearing period.

As plover numbers have increased they have occupied available habitat along the beaches between South Siltcoos and North Tahkenitch (Lauten *et al*. 2009, 2010, and 2011). In 2012, plover nests were found along the beach south of Waxmyrtle trail, near the Carter Lake trail area, and between South Overlook and North Tahkenitch, particularly near the Overlook Loop trail (Figures 3 and 4). While many of the broods that originated on the nesting areas at South Siltcoos, Overlook and North Tahkenitch remained on or near the roped nesting areas, there was consistent brood activity on all portions of the beach between the main nesting areas. At South Siltcoos, at least two broods moved south along the beach to the Carter Lake area. Broods that originated south of Waxmyrtle trail stayed along the beach, and one brood that originated at Carter Lake moved south to North Overlook. Three broods that originated along the beach north of North Overlook also generally stayed along the beach from Carter Lake to the north end of North Overlook. At least two broods that originated from North Overlook moved to South Overlook. At least five broods from South Overlook moved south along the beach to the Overlook Loop trail area, and one of these broods even moved south to North Tahkenitch. Most broods at North Tahkenitch that originated on the nesting area stayed within and around the nesting area, although one brood moved north along the beach. Two broods that originated from the beach north of the nesting area stayed along the beach and another brood that hatched on the beach moved south to the nesting area.

**Tenmile**

There were four broods at North Tenmile in 2012, three that originated on the HRA and one that originated on the beach north of the HRA. All three broods that originated on the HRA remained on the HRA and adjacent spit area, and the brood from north of HRA moved south to the HRA and spit area and remained there until fledgling. There were only two successful broods at South Tenmile in 2012, and both broods stayed within the vicinity of the HRA.

**Coos Bay North Spit**

At CBNS brood movements are varied and often difficult to ascertain partly due to the complex structure of the nesting area in conjunction with berms along the foredune road and vegetated foredune. Broods originating from the 95HRA have the shortest distance to travel to access the beach, and some of these broods would move onto the beach and back onto the 95HRA mostly in the area of the Olson shipwreck where the foredune vegetation is still sparse in some areas. We have documented a general trend of broods originating on South Spoil, the 94HRA and 98EHRA to move westward toward the beach (Lauten *et al*. 2009, 2010, and 2011). In 2012 some broods originating from east of the foredune road did move west to the 95HRA and eventually South Beach, however some broods remained throughout the brood period on the South Spoil and HRAs. In 2012 we had definitive evidence that broods can and will use the foredune road to attempt to access the beach. In late June, BLM staff reported a male with two young chicks on the foredune road just south of the FAA towers. We found the brood well north of the 95HRA and south of the FAA towers in the middle of the foredune road and herded the brood back to the north gate at the HRAs and then onto the 95HRA. This brood had hatched from South Spoil two days prior to finding them on the foredune road. We are uncertain if the brood moved directly north of the South Spoil and onto the reroute road and then north on the foredune road, or whether they moved north along the foredune road behind the gate and further north towards the FAA tower. This brood demonstrates that broods can move several miles within a few days of hatching, and also suggests that some broods may be attempting to gain access to the beach via other routes than west to the 95HRA and over the foredune. In previous years, we have noted older broods using the foredune road in the vicinity of the north jetty (Lauten *et al*. 2011). This example suggests broods are capable of using the foredune road to access the beach. Brood use on South Beach in 2012 was extensive. We noted broods using the beach near the jetty where vehicle access is permitted, and we had multiple broods move as far north as north of the FAA towers. One brood from an undiscovered nest was found north of the FAA towers at about the time of fledgling. Based on the age of the fledglings, the brood was local, and since we did not encounter the brood along South Beach from Access point one to the north jetty, we believe it is possible the brood originated from north of the FAA towers (possibly north of Access point one).

**Bandon SPMA**

There were a total of 11 broods at Bandon SPMA in 2012, nine on the Bandon Beach side and two on the New River spit side. Two broods on the Bandon Beach side hatched below the China Creek parking lot, and both broods immediately moved south and stayed along the foredune. All the remaining broods on the Bandon Beach side also remained along the foredune or on the HRA, with brood activity as far south as the mouth of New River. We did observe brood use of the cutouts created in winter 2010-11 despite the cutouts being fairly heavily vegetated. No broods crossed the river in either direction. Both broods from the New River spit side remained at the north end of the spit. There was no brood activity north of China Creek in 2012.

**New River and Floras Lake**

There were seven broods that originated on the New River HRA in 2012. One brood remained close to the area of the nest at the northern end of the HRA and one remained fairly close to the area of the nest near Hammond breach at the south end of the HRA. Two other broods wandered fairly extensively from north of Croft Lake breach to south of New Lake breach. South of Clay Island breach, a brood that hatched along the foredune eventually moved south to Floras Lake and was noted using the beach south of the CMA. It eventually fledged west of the CMA. One other brood from Floras Lake hatched on the CMA and spent the brood period between the CMA area and upwards of a quarter mile south along the beach.

**Sightings of Snowy Plovers Banded Elsewhere**

Eighteen adult plovers banded in California were observed in Oregon in 2012. Eleven were females and seven were males. Twelve of the 18 plovers were known to have nested in Oregon in 2012. Four females were not confirmed nesting however two were present during the breeding season and may have attempted to nest but were not confirmed. Two males were not confirmed nesting however one was present all summer at Bandon SPMA and likely attempted to nest but was never confirmed; the other male appeared at the end of July and was a post breeding individual. Three females and two males originally hatched in Oregon and were subsequently rebanded at coastal nest sites in California. Fourteen other plovers, eight females and six males, were originally banded in California. One female was a hatch year 2006 bird from Salinas, Monterey Co. that has been recorded in Oregon in previous years; she nested at Overlook in 2012. Two females were hatch year 2011 plovers, one from Moss Landing Salt Ponds, Monterey Co. and one from Marina State Beach, Salinas Co. Both nested in Oregon in 2012, one at Floras Lake and one at Bandon Beach and New River. Another female was a hatch year 2011 plover from Fort Ord, Monterey Co.; she was only seen once in Oregon in 2012. The other four California originated females included a hatch year 2006 from Humboldt Co. who has been nesting at Bandon Beach and New River since 2007; an adult banded in 2008 in Humboldt Co. that has nested in Oregon in 2011 but was not confirmed nesting in 2012; another adult that was banded in 2010 in Humboldt Co. and nested in 2011 and 2012; and a hatch year 2010 plover banded in Humboldt Co. who was present in Oregon in 2011 but no known nest was confirmed in either 2011 or 2012. Of the five California originated males, one was a hatch year 2004 bird from Salinas, Monterey Co., that has been present at New River since 2005 and successfully nested at New River in 2012; one was a male banded in 2009 at Salinas, Monterey Co., who wintered at Bandon SPMA in the past two years and arrived at Bandon SPMA in late July 2012; one was a hatch year 2010 plover from Salinas, Monterey Co., who successfully nested at CBNS in 2012; one was a hatch year 2010 plover from Moss Landing Salt Ponds, Monterey Co., who nested at Bandon SPMA in 2012; and one was from Oceano Dunes, San Luis Obispo Co., who nested at Overlook in 2012.

## Habitat Restoration and Development Projects

**Sutton**

The USFS contracted the Northwest Youth Corp to handpull beachgrass on 12 acres of habitat south of Holman Vista, Sutton Beach in the winter of 2011-12. Some shellhash was mechanically spread on the HRA. In addition, 3.8 miles of beach cleanup was conducted at Baker Beach with the help of the Emerald Empire Back Country Horseman group. Seventeen people participated in this event and collected 900 pounds of trash.

**Siltcoos**

At Siltcoos, 12 acres of beachgrass was hand pulled by the Northwest Youth Corp on both sides of the estuary in winter 2011-12. Beachgrass hummocks near areas covered by oyster shell were mechanically treated. Some oyster shell was spread on both the north and south side of the estuary.

**Overlook**

At Overlook 20 acres of beachgrass was handpulled on the south side in winter 2011-12. Herbicides were sprayed on 20 acres of beachgrass on both the north and south side. Beachgrass hummocks near areas covered by oyster shell were mechanically treated. Some oyster shell was spread on both the north and south side.

**Tahkenitch**

At Tahkenitch, 40 acres of beachgrass was handpulledand an additional 40 acres were sprayed with herbicides in winter 2011-12. Beachgrass hummocks near areas covered by oyster shell were mechanically treated. Some oyster shell was spread on the HRA.

**Tenmile**

At Tenmile, beachgrass was handpulled on 10 acres on the north side and 23 acres on the south side in the winter of 2011-12. Herbicides were sprayed on 23 acres on South Tenmile. Some shellhash was spread on North Tenmile.

**Coos Bay North Spit**

At CBNS in winter 2011-12, BLM disked 148 acres of habitat restoration area and parts of the spoil. Some hand pulling of sea rocket was also completed. Shell hash (ca. 300 cubic yards) was spread on 26 acres of previously treated habitat and 3 additional acres on BLM lands.

**Bandon SPMA**

At Bandon SPMA there was no habitat restoration work in winter 2011-12.

**New River**

At New River HRA, BLM bulldozed and improved 20 acres of habitat from the north end of Hammond breach to the south end of New Lake breach. A breach naturally occurred at Clay Island.

## Recommendations

### Signing of Restricted Areas

Signing and roping for the 2013 nesting season should again be implemented to inform the public of plover nesting habitat and direct the public away from the nesting areas. Ropes and signs should be installed as early in the season as practical so that the closed sections of beach are adequately protected throughout the season and the public understands which sections of beach are closed and the message is consistent throughout the nesting season and from year to year. Installing ropes and signs at the beginning of the season also reduces the need to respond to individual nests that are within closed beach sections but not roped and signed. This reduces the disturbance to those nests when ropes and signs have to be installed after a nest is found. High tides early in the season often make posting areas a challenge, and while it is important to have signs in place beginning on 15 March, in areas where the ocean is regularly lapping against the foredune, signs should not be erected or placement should be delayed. Maintenance of signs is important to keep violations to a minimum. To maximize the effectiveness of signs and ropes, each site should continue to be evaluated and ways to improve the signing and ropes should be considered.

### General Recommendations

Below are general recommendations. We also provide additional site-specific comments and management recommendations in Appendix B.

Maintaining, improving, and expanding the nesting areas is essential to maintaining a healthy and sustainable plover population. Despite years of treatment, European beachgrass continues to annually resprout resulting in degraded nesting habitat. When new habitat is created, such as the cutouts at Bandon SPMA (Lauten *et al.*, 2011), it is important to annually maintain the habitat or it quickly degrades resulting in reduced plover use. With an increasing plover population, any reduction in available nesting habitat can result in high nest densities which may attract predators or result in plovers nesting on open beach and along the foredune where disturbance from recreational activity is more likely. Increased nest density could lead to density dependent predator relationships which could cause increased nest depredations. Increased chick numbers on the landscape may attract additional avian predators (Neuman *et al.* 2004). Expansion of the nesting areas would increase the available habitat for plovers and could help alleviate predation pressure. Creation of cutouts along sections of beach that have nesting plovers but no nesting area behind the foredune would give the plovers safe areas to nest and brood away from recreational activity on the beach. We continue to support additional shell hash on any nesting area as it has proven to be a beneficial management technique. We continue to recommend that additional habitat be created and maintained at South Overlook, North Tenmile, Bandon SPMA and New River HRA. We support any efforts to find new and effective treatments of European beachgrass that could result in reduced resprouting, less density of beachgrass, and ultimately reduced need to annually treat nesting areas and therefore reduced funding for annual habitat maintenance.

The OPRD Habitat Conservation Plan (ICF International 2010) will be fully implemented at occupied Snowy Plover Management Areas (SPMAs) and Recreation Management Areas (RMAs) in

2013. Seasonal recreation restrictions (March 15 - September 15) include no dogs in these occupied areas.. Educating the public about the new rules will be essential both before and during the nesting season. Staff dedicated to recreational monitoring and volunteers continue to help reduce violations and educate the public about plovers and dog related issues, and we recommend that these aspects of management continue and be funded. At Siltcoos and Bandon Beach where parking lots and recreational activities are adjacent to nesting plovers, monitoring by staff and volunteers is essential to improving plover success and reducing disturbance issues.

- Continue intensive breeding season monitoring; continue monitoring plover populations and productivity to ensure recovery goals are maintained.
- Maintain, enhance and expand habitat restoration areas. Spread shell hash to enhance nesting substrate.
- Selectively use mini-exclosures in conjunction with predator management to reduce the risks to adult plovers, decrease the time monitors spend around individual nests, and decrease disturbance to plovers. Determine exclosure use dependent on predation pressure, density of plover nests, and nest locations.
- Expand use of cameras to help determine causes of nest failures; coordinate with Wildlife Services to set up and maintain cameras.
- Increase and/or maintain predator management at all sites and explore ways of better understanding the activity patterns and population levels of predators, particularly corvids. Fully fund three Wildlife Services employees.
- Continue to coordinate with federal and state agency employees regarding time frames of any habitat management work to be completed to minimize disturbance to nesting activity and broods.
- Coordinate agency activities in restricted areas with plover biologists to minimize disturbance to nesting and brood rearing.
- Continue and explore ideas to document and monitor human disturbance by various recreational users in plover nesting areas.
- Continue to expand and refine volunteer efforts to monitor recreational use.
- Design educational programs to inform and educate the local communities and annual visitors about plover issues.
- Design informative/interactive presentations for school children.

## Acknowledgments

We would like to thank Josh Novotny, Andrew Walch, and Mike Burrell of Wildlife Services for their assistance in the field and thoughtful insight about predators; Chris Bryers, Chuck Littlejohn, Greg McUne, Jerry Phillips, RJ Rapelje, and Trisha Wymore of OPRD for their hours educating the public and monitoring recreational activity on the beach; Morgan Bell and Theresa Bolch of BLM for their diligence monitoring recreational activity at CBNS; Andrew Testo of BLM and Cathy Boden and Statia Ryder of South Coast Watershed Association for monitoring and education with recreationists and campers at New River and Floras Lake; Crystal Mullins and Rachel Lytton of Forest Service for their many hours maintaining signs and ropes, monitoring recreational activity and interacting with the public; volunteers John and Sue Ewan, Kim and Else Ireland, Gary and Mary Van Hooser, Michael and Diane Chacon, Lester and Pam Trout, Larry and Mollie Folmar, Bonnie Womble, John and Bonnie Gee, and Doug and Gloria Williams spent numerous hours educating the public at China Creek parking lot on Bandon Snowy Plover Management Area; volunteers Carol Blysma, Mike and Pat Brooks, Calvin and Beth Smith, and Brian and Gail Ogram for USFS; field rangers from the Forest Service's Valuing People and Places Program provided snowy plover information to visitors at the Dunes Day Use Area; Ted Gage and Carrie Pope of BLM Law Enforcement, Tim Slater of Coos County Sheriff's Department, Oliver Grover, Tyler Smith, and Sara Wassam of the USFS Dunes National Recreation Area Law Enforcement , and Ed Lagrone of Lane Co. Sheriffs's Department; Liz Kelly, Madeleine Vander Heyden, and Laura Todd of the US Fish and Wildlife Service; Mark Stern, Ken Popper, and Karen Gleason of The Nature Conservancy; Stuart Love, Bill Kinyoun, and Martin Nugent of the Oregon Department of Fish and Wildlife; Charlie Bruce, retired ODFW volunteer; Kip Wright, Steve Langenstein, Kerrie Palermo, Sharon Morse, Megan Harper, and all the managers at Coos Bay BLM District whose support is invaluable; Calum Stevenson, Larry Becker, and Vanessa Blackstone of the Oregon Parks and Recreation Department; Ben Fisher and his staff at Bullard's Beach State Park; Cindy Burns, Melissa Shelley and Paul Thomas of the USFS Mapleton Ranger District; Dave Williams of Wildlife Services; Sean McAllister and Ron LeValley in Humboldt Co., CA,; Mark Colwell and students at Humboldt State Univ., Arcata, CA,; Jim Watkins of US Fish and Wildlife Service, Humboldt Co.; Gary Page, Lynne Stenzel, Doug George, Kris Neumann, Jenny Erbes, and Carlton Eyster of Point Reyes Bird Observatory; special thanks to Frances Bidstrup of Point Reyes Bird Observatory who coordinates all banding information and who is essential to the project; to anyone and everyone who we may have accidentally forgotten – we sincerely appreciate the support, assistance, and input of all, without which the program would not be a success.

## Literature Cited

Brindock, K.M., and M.A. Colwell. 2011. Habitat selection of Western Snowy Plovers during the nonbreeding season. Journal of Wildlife Management 75(4):786–793

Burrell, M. 2012. Integrated Predator Damage Management Report for the Western Snowy Plover (*Charadrius alexandrinus nivosus*) 2011 Breeding Season. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Casler, B.R., C.E. Hallett, and M.A. Stern. 1993. Snowy Plover nesting and reproductive success along the Oregon coast - 1993. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay.

Castelein, K.A., D.J. Lauten, R. Swift, and M.A. Stern. 1997. Snowy Plover distribution and reproductive success along the Oregon coast - 1997. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Castelein, K.A., D.J. Lauten, R. Swift, M.A. Stern, and K.J. Popper. 1998. Snowy Plover distribution and reproductive success along the Oregon coast - 1998. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, K.J. Popper, J.A. Fukuda, and M.A. Stern. 2000a. Snowy Plover distribution and reproductive success along the Oregon coast – 1999. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, K.J. Popper, D.C. Bailey, and M.A. Stern. 2000b. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast – 2000. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, L.N. Renan, S.R. Pixley, and M.A. Stern. 2001. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast - 2001. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, S.R. Pixley, L.N. Renan, M.A. Stern, and C. Grinnell. 2002. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast - 2002. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Colwell, M.A., K.M. Brindock, N.S. Burrell, M.A. Hardy, J. J. Muir, S.A. Peterson, S.E. McAllister, K.G. Ross and R.R. LeValley. 2008. Final Report: 2008 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2. Unpublished report submitted to MRB Research, Inc.

Colwell, M.A., N.S. Burrell, M.A. Hardy, K. Kayano, J.J. Muir, W. J. Pearson, S. A. Peterson, K.A. Sesser, and R.R Thiem. 2009. Final report: 2009 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Submitted to MRB Research, Inc., and California Department of Fish and Game.

Colwell, M.A., N.S. Burrell, M.A. Hardy, S.E. McAllister, W.J. Pearson, S.A. Peterson, K.G. Ross, and K.A. Sesser. 2010. Final report: 2010 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Submitted to MRB Research, Inc.and California Department of Fish and Game.

Colwell, M.A., L.J. Eberhart-Phillips, R.R. LeValley, S.E. McAllister, A.M. Patrick, W.J. Pearson, and S.A. Peterson. 2011. Final report: 2011 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Submitted to MRB Research, Inc.and California Department of Fish and Game.

Craig, D.P., M.A. Stern, K.A. Mingo, D.M. Craig, and G.A. Rosenberg. 1992. Reproductive Ecology of the Western Snowy Plover on the South Coast of Oregon, 1992. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay.

Dinsmore, S. J., M. B. Wunder, V. J. Dreitz, and F. L. Knopf. 2010. An assessment of factors affecting population growth of the Mountain Plover. Avian Conservation and Ecology 5(1): 5.

Elliot-Smith, E., and S.M. Haig. 2007. Western Snowy Plover breeding window survey protocol – final draft. Unpublished report prepared for USFWS.

Estelle, V., T.J. Mabee, and A.H. Farmer. 1996. Effectiveness of predator exclosures for Pectoral Sandpiper nests in Alaska. Journal of Field Ornithology 67:447-452.

Estelle, V.B., C.E. Hallett, M.R. Fisher and M.A. Stern. 1997. Snowy Plover distribution and reproductive success along the Oregon coast - 1996. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Hallett, C.E., B.R. Casler, M.A. Platt, M.A. Stern. 1994. Snowy Plover distribution and reproductive success along the Oregon coast - 1994. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Dunes National Recreation Area, Reedsport, and the Coos Bay District Bureau of Land Management, Coos Bay.

Hallett, C.E., B.R. Casler, M.A. Platt, M.A. Stern. 1995. Snowy Plover distribution and reproductive success along the Oregon coast - 1995. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Hardy, M.A, and M. A. Colwell. 2008. The impact of predator exclosures on snowy plover nesting success: A seven-year study. Wader Study Group Bulletin 115:161-166.

ICF International. 2010. Habitat Conservation Plan for the Western Snowy Plover. August. (ICF 06537.06.) Portland, OR. Prepared for Oregon Parks and Recreation Department.

Isaksson, D., J. Wallander, and M. Larsson. 2007. Managing predation on ground-nesting birds: The effectiveness of nest exclosures. Biological Conservation 136:136-142.

Johnson, M. and L.W. Oring. 2002. Are nest exclosures an effective tool in plover conservation. Waterbirds 25:184-190.

Larson, M.A., M.R. Ryan, and R.K. Murphy. 2002. Population viability of piping plovers: Effects of predator exclusion. Journal of Wildlife Management 66:361-371.

Lauten, D.J., K.A. Castelein, B.V. Smithers, K.C. Jander, E. Elliot-Smith, and E.P. Gaines. 2003. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2003. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, E. Seckinger, E. Kolkemo, and E.P. Gaines. 2005. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2004. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, E. Seckinger, and E.P. Gaines. 2006. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2005. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, S. Weston, K. Eucken, and E.P. Gaines. 2006b. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2006. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, Raya Pruner, Marvin Friel, and E.P. Gaines. 2007. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2007. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, D.C. Bailey, T. Lewis, and E.P. Gaines. 2008. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2008. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, H.G. Herlyn, and E.P. Gaines. 2009. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2009. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2010. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2010. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2011. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2011. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Neuman, K. K, G. W. Page, L E. Stenzel, J. C. Warriner, and J. S. Warriner. 2004. Effect of Mammalian Predator Management on Snowy Plover Breeding Success. Waterbirds 27(3):257-263.

Niehaus, A.C., D.R. Ruthrauff, and B.J. McCaffery. 2004. Response of predators to western sandpiper nest exclosures. Waterbirds 27:79-82

Nol, E., and R.J. Brooks. 1982. Effects of predator exclosures on nesting success of killdeer. Journal of Ornithology 53:263-268.

ODFW. 2009. Oregon Administrative Rules, Oregon Department of Fish and Wildlife, Division 100 Wildlife Diversity Plan. http://www.dfw.state.or.us/OARs/100.pdf

Page, G.W., L.E. Stenzel, W.D. Shuford, and C.R. Bruce. 1991. Distribution and abundance of the snowy plover on its western North American breeding grounds. J. Field Ornithol. 62:245-255.

Pauliny, A., M. Larsson, and D. Blomqvist. 2008. Nest predation management: Effects on reproductive success in endangered shoredbirds. Journal of Wildlife Management 72:1579-1583.

Pearson, S.F., C. Sundstrom, W. Ritchie, and K. Gunther. 2009. Washington State Snowy Plover Population Monitoring, Research, and Management: 2009 Nesting Season Research Progress Report. Washington Department of Fish and Wildlife, Wildlife Science Division, Olympia.

Rimmer, D.W., and R.D. Deblinger. 1990. Use of predator exclosures to protect piping plover nests. Journal of Field Ornithology 61:217-223.

Sandercock, B.K. 2003. Estimation of survival rates for wader populations: a review of mark recapture methods. Wader Study Group Bulletin. 100:163-174

Stern, M.A., J.S. McIver, and G.A. Rosenberg. 1990. Investigations of the western Snowy Plover at the Coos Bay North Spit and adjacent sites in Coos and Curry Counties, 1990. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, Oregon.

Stern, M.A., J.S. McIver, and G.A. Rosenberg. 1991. Nesting and reproductive success of the Snowy Plovers along the south Oregon coast, 1991. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland and the Coos Bay District Bureau of Land Management, Coos Bay

U.S. Fish and Wildlife Service. 1993. Final rule. Endangered and threatened wildlife and plants; Determination of threatened status for the Pacific coast population of the western snowy plover. Federal Register 58 FR 12864 03/05/93.

U.S. Fish and Wildfife Service. 2006. Endangered and threatened wildlife and plants: Proposed special rule pursuant to Section 4(d) of the Endangered Species Act for the Pacific coast distince population segment of the Western Snowy Plover. Federal Register 71(77): 20625-20636.

U.S. Fish and Wildlife Service. 2007. Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In two volumes. Sacramento, California. xiv + 751pp.

Vaske, J.J., D.W. Rimmer, and R.D. Deblinger. 1994. The impact of different predator exclosures on piping plover nest abandonment. Journal of Field Ornithology 65:201-209.

**Table 1.** Population estimates of the Western Snowy Plover on the Oregon Coast, 1990-2012. For Window Survey, first number is counted plovers minus duplicate band combos and unidentified plovers, number in parenthesis is total head count without considering duplicate combos or unknown plovers.

| YEAR | WINDOW SURVEY | # SNPL BREEDING | # SNPL PRESENT |
|---|---|---|---|
| 1990 | 59 | - | - |
| 1991 | 35 | - | - |
| 1992 | 28 | - | - |
| 1993 | 45 | 55-61 | 72 |
| 1994 | 51 | 67 | 83 |
| 1995 | 64 (67) | 94 | 120 |
| 1996 | 85 | 110-113 | 134-137 |
| 1997 | 73 (77) | 106-110 | 141 |
| 1998 | 57 (59) | 75 | 97 |
| 1999 | 49 (51) | 77 | 95-96 |
| 2000 | NC | 89 | 109 |
| 2001 | 71 (85) | 79-80 | 111-113 |
| 2002 | 71 (76) | 80 | 99-102 |
| 2003 | 63 | 93 | 102-107 |
| 2004 | 82 (83) | 120 | 136-142 |
| 2005 | 100 | 104 | 153-158 |
| 2006 | 91 | 135 | 177-179 |
| 2007 | 125 | 162 | 181-184 |
| 2008 | 98-105 | 129 | 188-200 |
| 2009 | 136-143 (139-146) | 149-150 | 199-206 |
| 2010 | 158 | 175 | 232-236 |
| 2011 | 168 | 214 | 247-253 |
| 2012 | 206 | 231-238 | 290-291 |

**Table 2.** Number of Snowy Plover fledglings, number of previous year fledglings returning, return rate, number nesting, and percent nesting in first year of return along the Oregon coast, 1990 - 2012.

| Year | # of Fledglings | # of HY birds from previous year sighted on OR coast | Return Rate (#HY/#Fled) | # that nested on OR coast | % nested on OR coast |
|---|---|---|---|---|---|
| 2012 | 173 | 91 | 53% | 70 | 77% |
| 2011 | 172[a] | 53 | 63% | 45 | 85% |
| 2010 | 84 | 54 | 50% | 38 | 70% |
| 2009 | 107 | 35 | 48% | 26 | 74% |
| 2008 | 73 | 52 | 42% | 27 | 52% |
| 2007 | 124 | 32 | 29% | 26 | 81% |
| 2006 | 110 | 29 | 37% | 23 | 79% |
| 2005 | 78 | 43 | 40% | 33 | 77% |
| 2004 | 108 | 26 | 43% | 21 | 81% |
| 2003 | 60 | 14 | 45% | 14 | 100% |
| 2002 | 31 | 18 | 56% | 15 | 83% |
| 2001 | 32 | 23 | 53% | 14 | 61% |
| 2000 | 43 | 31 | 58% | 25 | 81% |
| 1999 | 53 | 18 | 56% | 12 | 67% |
| 1998 | 32 | 14 | 34% | 11 | 79% |
| 1997 | 41 | 30 | 64% | 18 | 60% |
| 1996 | 47 | 18 | 32% | 10 | 55% |
| 1995 | 57 | 37 | 66% | 13 | 35% |
| 1994 | 56 | 16 | 44% | 8 | 50% |
| 1993 | 36 | 10 | 30% | 6 | 60% |
| 1992 | 33 | 6* | 38% | 2 | 33% |
| 1991 | 16 | No chicks banded in 1990 | | | |
| 1990 | 3 | x | x | | |

* - minimum number sighted

| | |
|---|---|
| Average return rate = 47% | 47% |
| SD = 11.3% | 0.113143 |
| Average percent of returning HY birds that nest in first season = 69% | 69% |
| SD = 16.9% | 0.169162 |

[a] - adjusted from 168 to 172 based on hatch year returns

Table 3. Number of Adult Snowy Plovers at each nesting area on the Oregon Coast, 2012.

| | Females | | | | Males | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Banded | | Unbanded | | Banded | | Unbanded | | Total | |
| **Site** | **# banded** | **# nested** | **# unbanded** | **# nested** | **# banded** | **# nested** | **# unbanded** | **# nested** | **# plovers** | **# nested** |
| **Sutton** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Siltcoos** | 31 | 12 | 2 | 1 | 32 | 13 | 2 | 1 | 67 | 27 |
| **Overlook** | 43 | 19 | 6 | 3-5 | 41 | 25 | 4 | 4 | 94 | 51-53 |
| **N Tahkenitch** | 31 | 11 | 2-3 | 1-2 | 33 | 19 | 1 | 0 | 67-68 | 31-32 |
| **Tenmile** | 34 | 14 | 2 | 1? | 21 | 6 | 1-2 | 0 | 58-59 | 20-21 |
| **CBNS** | 37 | 28 | 3-5 | 3-4 | 48 | 44 | 2 | 2 | 90-92 | 77-78 |
| **Bandon SPMA** | 32 | 14 | 1-2 | 1 | 34 | 14 | 1 | 0 | 68-69 | 29 |
| **New River HRA** | 7 | 4 | 3-4 | 3 | 13 | 7 | 1 | 0 | 24-25 | 14 |
| **Floras Lake** | 4 | 2 | 0 | 0 | 5 | 3 | 1 | 0 | 10 | 5 |

**Table 4**. Number of nests for selected sites on the Oregon Coast 1998 – 2012; cells tally nests only and not broods from undiscovered nests. The number of broods from undiscovered nests is totaled for each year only.

| Site Name | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SU | 8 | 3 | 7 | 15 | 3 | 1 | 0 | 0 | 4 | 3 | 0 | 0 | 1 | 0 | 0 |
| SI: | | | | | | | | | | | | | | | |
| North | 1 | 4 | 8 | 0 | 0 | 0 | 7 | 8 | 12 | 15 | 30 | 14 | 17 | 13 | 10 |
| South | 3 | 17 | 14 | 14 | 10 | 7 | 4 | 9 | 13 | 13 | 6 | 9 | 24 | 21 | 22 |
| OV: | | | | | | | | | | | | | | | |
| North | | 2 | 8 | 12 | 5 | 7 | 11 | 11 | 9 | 13 | 14 | 9 | 21 | 29 | 28 |
| South | | 0 | 0 | 3 | 3 | 1 | 3 | 5 | 1 | 3 | 1 | 5 | 16 | 28 | 31 |
| TA | | | | | | | | | | | | | | | |
| North | 0 | 0 | 4 | 7 | 8 | 13 | 8 | 11 | 4 | 10 | 5 | 6 | 7 | 23 | 36 |
| South | 6 | 3 | 1 | 6 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | | | | |
| TM: | | | | | | | | | | | | | | | |
| North | 0 | 0 | 1 | 2 | 3 | 5 | 9 | 6 | 10 | 20 | 12 | 13 | 13 | 15 | 17 |
| South | 11 | 5 | 5 | 6 | 9 | 12 | 8 | 11 | 12 | 21 | 16 | 41 | 30 | 35 | 29 |
| CBNS: | | | | | | | | | | | | | | | |
| SB | 6 | 0 | 1 | 1 | 2 | 3 | 2 | 4 | 0 | 8 | 5 | 19 | 17 | 16 | 7 |
| SS | 5 | 2 | 5 | 3 | 2 | 9 | 8 | 9 | 14 | 12 | 18 | 16 | 14 | 15 | 15 |
| HRAs | 7 | 12 | 22 | 13 | 15 | 11 | 16 | 16 | 18 | 19 | 26 | 30 | 33 | 26 | 39 |
| BSPMA | | | | | | | | | | | | | | | |
| BB | 1 | 2 | 2 | 6 | 5 | 5 | 17 | 31 | 23 | 30 | 28 | 31 | 26 | 28 | 48 |
| NR spit | 1 | 8 | 1 | 1 | 2 | 7 | 7 | 11 | 9 | 16 | 6 | 10 | 12 | 9 | 12 |
| NR HRA | | 3 | 4 | 10 | 7 | 5 | 6 | 1 | 7 | 14 | 27 | 27 | 27 | 29 | 17 |
| NR other | 25 | 17 | 12 | 12 | 5 | 4 | 11 | 11 | 11 | 5 | 2 | 3 | 3 | 2 | 1 |
| FL | 4 | 0 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 |
| **Tot nst** | **78** | **78** | **100** | **111** | **89** | **91** | **117** | **144** | **147** | **202** | **196** | **236** | **261** | **289** | **314** |
| **Tot brd[a]** | **3** | **1** | **2** | **0** | **1** | **4** | **2** | **3** | **15** | **4** | **3** | **8** | **2** | **4** | **11** |

[a] – broods from undiscovered nests only; these broods are not tallied in the total number of nests

SU – Sutton, SI – Siltcoos, OV – Overlook, TA – Tahkenitch, TM – Tenmile, CBNS – Coos Bay North Spit (SB - South Beach, SS – South Spoil, BSPMA – Bandon Snowy Plover Management Area (BB - Bandon Beach, NR spit - New River spit), NR HRA – New River HRA, NR other - private and other owned lands, FL – Floras Lake

**Table 5.** Apparent nest success of Snowy Plovers on the Oregon Coast, 2012.

| | | Nests Exclosed | | | Nests Not Exclosed | | | Exclosed Nests | Nests Not Exclosed | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Total #** | **Hatch** | **Fail** | **Unknown** | **Hatch** | **Fail** | **Unknown** | **App Nest Success** | **App Nest Success** | **Overall Nest Success** |
| **Sutton** | 0 | - | - | | - | - | | - | - | - |
| **Siltcoos** | | | | | | | | | | |
| North | 10 | - | - | | 4 | 5 | 1 | - | 40% | 40% |
| South | 22 | - | - | | 13 | 9 | | - | 59% | 59% |
| Combined | 32 | | | | 17 | 14 | 1 | | 53% | 53% |
| **Overlook** | | | | | | | | | | |
| North | 28 | 1 | - | | 14 | 13 | | 100% | 52% | 54% |
| South | 31 | 3 | - | | 10 | 18 | | 100% | 36% | 42% |
| Combined | 59 | 4 | | | 24 | 31 | | 100% | 44% | 47% |
| **N Tahkenitch** | 36 | 4 | - | | 17 | 15 | | 100% | 53% | 58% |
| **Tenmile** | | | | | | | | | | |
| North | 17 | - | - | | 4 | 13 | | - | 24% | 24% |
| South | 29 | - | - | | 2 | 27 | | - | 7% | 7% |
| Combined | 46 | | | | 6 | 40 | | | 13% | 13% |
| **CBNS** | | | | | | | | | | |
| South Beach | 7 | - | - | | 6 | 1 | | - | 86% | 86% |
| South Spoil | 15 | - | - | | 13 | 2 | | - | 87% | 87% |
| HRAs | 39 | - | - | | 34 | 5 | | - | 87% | 87% |
| Combined | 61 | | | | 53 | 8 | | | 87% | 87% |
| **Bandon SPMA** | 60[a] | 5 | 1 | | 3 | 48 | | 83% | 6% | 14% |
| **New River** | | | | | | | | | | |
| HRA | 17 | 5 | 3 | | 0 | 9 | | 63% | 0% | 29% |
| Other Lands | 1 | 0 | 0 | | 0 | 1 | | 0% | 0% | 0% |
| **Floras Lake** | 2 | - | - | | 1 | 1 | | - | 50% | 50% |
| **Totals** | 314 | 18 | 4 | | 121 | 167 | 1 | 82% | 42% | 45% |

a – Three nests not included in analysis because they were exclosed, and then exclosure was removed before hatching; all three nests hatched.

**Table 6. Apparent nest success of exclosed and unexclosed Snowy Plover nests on the Oregon coast, 1990 - 2012.**

| Year | All nests (%) | Exclosed (%) | Not Exclosed (%) |
|---|---|---|---|
| 1990 | 31 | * | 28 |
| 1991 | 33 | 75 | 9 |
| 1992 | 67 | 85 | 11 |
| 1993 | 68 | 83 | 27 |
| 1994 | 75 | 80 | 71 |
| 1995 | 50 | 65 | 5 |
| 1996 | 56 | 71 | 10 |
| 1997 | 48 | 58 | 14 |
| 1998 | 56 | 72 | 8 |
| 1999 | 56 | 64 | 0 |
| 2000 | 38 | 48 | 0 |
| 2001 | 35 | 68 | 0 |
| 2002 | 44 | 66 | 6 |
| 2003 | 51 | 77 | 9 |
| 2004 | 62 | 85 | 8 |
| 2005 | 48 | 72 | 14 |
| 2006 | 47 | 66 | 32 |
| 2007 | 42 | 71 | 35 |
| 2008 | 34 | 49 | 30 |
| 2009 | 33 | 76 | 25 |
| 2010 | 35 | 72 | 23 |
| 2011 | 50 | 71 | 48 |
| 2012 | 45 | 86 | 42 |
| Average = | 48.00 | 70.91 | 19.78 |
| STDEV = | 12.30 | 10.35 | 17.69 |

* Multiple experimental designs used, data not included

**Table 7.** Causes of Snowy Plover nest failure at survey sites along the Oregon coast, 2012.

| Site Name | Tot Nsts | # Fail | Depredations | | | | | Other | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corvid | Unk | Canine | Skunk | Adult plover | Wind-Weather | Overwash | Abandon | One Egg Nest | Infer | Unk cause |
| **Siltcoos:** | | | | | | | | | | | | | |
| **North** | 10 | 5 | 1 | 2 | | | | 1 | | | | | 1 |
| **South** | 22 | 9 | 3 | 2 | | | | 1 | 1 | 1 | | | 1 |
| **Overlook** | | | | | | | | | | | | | |
| **North** | 28 | 13 | | 4 | | | | | 1 | 4 | 1 | | 3 |
| **South** | 31 | 18 | 3 | 5 | | | | 3 | | 2 | 5 | | |
| **N Tahkenitch** | 36 | 15 | | 3 | 1[a] | | | 3 | | 3 | 1 | | 4 |
| **Tenmile:** | | | | | | | | | | | | | |
| **North** | 17 | 13 | 5 | 2 | | | | 1 | | 1 | | | 4 |
| **South** | 29 | 27 | 5 | 5 | | | | | 1 | | 2 | | 14 |
| **Coos Bay North Spit:** | | | | | | | | | | | | | |
| **South Beach** | 7 | 1 | | | | | | | 1 | | | | |
| **South Spoil** | 15 | 2 | | | | | | | | 1 | 1 | | |
| **HRAs** | 39 | 5 | | 1 | | | | | | 2 | 1 | 1 | |
| **Bandon SPMA** | 60 | 49 | 8 | 26 | 2[b] | 1 | | 2 | | 3 | 3 | | 4 |
| **New River HRA** | 17 | 12 | 1 | 6 | 1[c] | | 1 | | | | | | 3 |
| **Other lands** | 1 | | | | | | | | | | | | 1 |
| **Floras Lake** | 2 | 1 | | 1 | | | | | | | | | |
| **TOTALS** | **314** | **171** | 26 | 57 | 4 | 1 | 1 | 11 | 4 | 17 | 14 | 1 | 35 |

[a] – coyote depredation
[b] – 2 fox depredation
[c] – 1 fox depredations

**Table 8.** Cause of failure for Snowy Plover nests protected by predator exclosures and nests unprotected by predator exclosures along the Oregon coast, 2012.

| Cause of Failure | | Exclosed | Unexclosed | Totals |
|---|---|---|---|---|
| **Egg Depredation** | **Corvid** | | 26 | 26 |
| | **Unknown** | | 57 | 58 |
| | **Canine** | | 4 | 4 |
| | **Skunk** | | 1 | 1 |
| **Depredation** | **Adult Plover** | 1 | | |
| **Other** | **Wind/Weather** | | 11 | 11 |
| | **Overwashed** | | 4 | 4 |
| | **Infertile** | | 1 | 1 |
| | **One Egg Nests** | | 14 | 14 |
| | **Abandoned** | 1 | 16 | 17 |
| | **Unknown Cause** | 2 | 33 | 33 |
| **Totals** | | 4 | 167 | 171 |

**Table 9.** Total number of young fledged from select sites on the Oregon Coast 1998-2012, includes fledglings from broods from undiscovered nests.

| Site Name | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SU | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| SI: | | | | | | | | | | | | | | | |
| North | 2 | 4 | 0 | 0 | 0 | 0 | 7 | 2 | 11 | 7 | 5 | 8 | 4 | 4 | 1 |
| South | 4 | 2 | 7 | 0 | 0 | 2 | 5 | 7 | 7 | 4 | 3 | 11 | 4 | 8 | 16 |
| OV: | | | | | | | | | | | | | | | |
| North | | 3 | 5 | 1 | 2 | 3 | 3 | 5 | 8 | 12 | 3 | 7 | 12 | 27 | 22 |
| South | | 0 | 0 | 1 | 0 | 0 | 3 | 2 | 0 | 1 | 0 | 2 | 7 | 23 | 23 |
| TA: | | | | | | | | | | | | | | | |
| North | 0 | 0 | 2 | 4 | 1 | 3 | 6 | 8 | 5 | 2 | 0 | 1 | 3 | 20 | 26 |
| South | 1 | 1 | 3 | 4 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | | | | |
| TM: | | | | | | | | | | | | | | | |
| North | 0 | 0 | 0 | 0 | 3 | 1 | 3 | 6 | 12 | 13 | 3 | 2 | 3 | 1 | 5 |
| South | 3 | 7 | 5 | 4 | 3 | 9 | 9 | 5 | 7 | 14 | 6 | 19 | 13 | 5 | 4 |
| CBNS: | | | | | | | | | | | | | | | |
| SS | 6 | 5 | 3 | 4 | 2 | 7 | 13 | 9 | 11 | 7 | 17 | 4 | 2 | 6 | 10 |
| SB | 2 | 0 | 0 | 1 | 1 | 3 | 0 | 8 | 1 | 10 | 7 | 17 | 13 | 22 | 15 |
| HRAs | 1 | 23 | 6 | 6 | 8 | 14 | 22 | 6 | 19 | 9 | 16 | 10 | 5 | 28 | 33 |
| BSPMA | | | | | | | | | | | | | | | |
| BB | 1 | 1 | 0 | 1 | 0 | 4 | 16 | 11 | 12 | 13 | 2 | 6 | 6 | 16 | 11 |
| NR spit | 0 | 2 | 0 | 0 | 0 | 1 | 10 | 0 | 3 | 12 | 2 | 1 | 0 | 5 | 1 |
| NR HRA | | 2 | 1 | 3 | 3 | 7 | 5 | 1 | 7 | 16 | 7 | 17 | 12 | 7 | 4 |
| NR other | 11 | 4 | 4 | 3 | 3 | 4 | 6 | 8 | 7 | 4 | 2 | 2 | 0 | 0 | 0 |
| FL | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Total** | **32** | **54** | **43** | **32** | **31** | **60** | **108** | **78** | **110** | **124** | **73** | **107** | **84** | **172[a]** | **173** |

[a] – adjusted from 168 to 172 based on hatch year returns

SU – Sutton, SI – Siltcoos, OV – Overlook, TA – Tahkenitch, TM – Tenmile, CBNS – Coos Bay North Spit (SB - South Beach, SS – South Spoil, BSPMA – Bandon Snowy Plover Management Area (BB - Bandon Beach, NR spit - New River spit), NR HRA – New River HRA, NR other - private and other owned lands, FL – Floras Lake

**Table 10**. Overall fledging success, total number of fledglings, and mean number of fledglings/male on the Oregon Coast, 1990 – 2012.

| Year | % Fledging Success[a] | # Fledglings[b] | Mean # Fled/Male[a] |
|---|---|---|---|
| 1990 | 11 | 3 | - |
| 1991 | 45 | 16 | - |
| 1992 | 41 | 34 | 1.250 |
| 1993 | 42 | 36 | 1.000 |
| 1994 | 50 | 56 | 1.483 |
| 1995 | 50 | 58 | 1.194 |
| 1996 | 32 | 47 | 0.881 |
| 1997 | 30 | 41 | 0.833 |
| 1998 | 26 | 32 | 0.833 |
| 1999 | 43 | 54 | 1.268 |
| 2000 | 41 | 43 | 0.973 |
| 2001 | 34 | 32 | 0.842 |
| 2002 | 29 | 31 | 0.700 |
| 2003 | 47 | 60 | 1.061 |
| 2004 | 55 | 108 | 1.645 |
| 2005 | 41 | 78 | 1.259 |
| 2006 | 48 | 110 | 1.559 |
| 2007 | 54 | 124 | 1.494 |
| 2008 | 47 | 73 | 1.060 |
| 2009 | 50 | 107 | 1.288 |
| 2010 | 35 | 84 | 0.920 |
| 2011 | 47 | 172 | 1.371 |
| 2012 | 43 | 173 | 1.186 |
| | Overall = 40.9 $\pm$ 10.3 | Total = 1568 | Mean = 1.148 |

a – does not include fledglings from broods from undiscovered nests, nor any data from Sutton Beach and Floras Lake
b – total number of fledglings including from broods from undiscovered nests

**Table 11.** Fledgling success, brood success, and number of fledglings per male for Snowy Plovers on the Oregon Coast, 2012.

| Site Name | Total # Broods* | % Brood Success* | Total # Eggs Hatched | Min. # Fledged From Known Nests | Min. # Fledged From Undiscovered Nests | % Fledging Success** | # of Breeding Males[a] | # of Fledglings/ Male* | # of Fledglings/Male – Combined[c] |
|---|---|---|---|---|---|---|---|---|---|
| Siltcoos: | | | | | | | | | |
| North Siltcoos | 4 | 25% | 7 | 1 | | 14% | 3 | 0.33 | 1.15 (13) |
| South Siltcoos | 14 | 71% | 31 | 14 | 2 | 45% | 10 | 1.60 | |
| Overlook | | | | | | | | | |
| North Overlook | 16 | 88% | 36 | 20 | 2 | 56% | 12 | 1.83 | 1.80 (25) |
| South Overlook | 15 | 93% | 34 | 20 | 3 | 59% | 14 | 1.64 | |
| North Tahkenitch | 21 | 86% | 56 | 26 | | 46% | 19 | 1.37 | 1.37 (19) |
| Tenmile: | | | | | | | | | |
| North Spit | 4 | 75% | 12 | 5 | | 42% | 3 | 1.67 | 1.50 (6) |
| South Spit | 2 | 100% | 6 | 4 | | 67% | 5 | 0.80 | |
| Coos Bay N. Spit | | | | | | | | | |
| South Spoil | 13 | 54% | 33 | 10 | | 30% | 10 | 1.00 | 1.23 (44) |
| South Beach | 8 | 100% | 16 | 11 | 4 | 69% | 8 | 1.88 | |
| HRA | 37 | 51% | 86 | 29 | 4 | 34% | 33 | 1.00 | |
| Bandon SPMA | 11 | 63% | 30 | 12 | | 40% | 14 | 0.86 | 0.86 (14) |
| New River | | | | | | | | | |
| HRA | 7 | 57% | 13 | 2 | 2 | 15% | 7 | 0.29 | 0.29 (7) |
| Other lands | 0 | | | | | | | | |
| Floras Lake | 2 | 50% | 3 | 2 | | 67% | 2 | 1.00 | 1.00 (2) |
| **TOTALS** | **154** | **70%** | **363** | **156** | **17** | **43%** | **126**[b] | **1.37** | |
| **TOTAL FLEDGED** | | | | **173** | | | | | |

% Brood success = # broods with at least 1 chick fledged / total # of broods
% Fledging Success = # of young fledged / # of eggs hatched
* Includes broods from undiscovered nests:
** Does not include fledglings from undiscovered nests because we do not know how many eggs hatched from those nests.
[a] – number of known individual breeding males for each site
[b] – number of known breeding males in entire population; this is not a tally of known males from each site as some males may have nested at more than one location
[c] – number of fledglings for both sites combined and number of known individual breeding males for both sites combined Sample size of males in parenthesis.

**Table 12. Productivity of Snowy Plovers at Siltcoos, Lane Co., Oregon coast, 1993-2012.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Siltcoos | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 92 | 38 | 41% | 15 | 39% | 16% | 15 | 13 | 1.15 |
| | 2011 | 87 | 36 | 41% | 11 | 31% | 13% | 11 | 13 | 0.85 |
| | 2010 | 105 | 30 | 29% | 8 | 27% | 8% | 8 | 10 | 0.80 |
| | 2009 | 54 | 28 | 52% | 17 | 61% | 31% | 17 | 11 | 1.55 |
| | 2008 | 68 | 22 | 32% | 8 | 36% | 12% | 8 | 9 | 0.88 |
| | 2007 | 67 | 24 | 36% | 11 | 46% | 16% | 11 | 10 | 1.10 |
| | 2006 | 60 | 22 | 37% | 13 | 60% | 22% | 11 | 5 | 2.20 |
| | 2005 | 44 | 17 | 39% | 9 | 53% | 20% | 9 | 7 | 1.29 |
| | 2004 | 31 | 18 | 58% | 12 | 67% | 39% | 12 | 5 | 2.40 |
| | 2003 | 16 | 5 | 31% | 2 | 40% | 13% | 2 | 4 | 0.50 |
| | 2002 | 28 | 8 | 29% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | 2001 | 33 | 1 | 3% | 0 | 0% | 0% | 0 | 3 | 0.00 |
| | 2000 | 55 | 19 | 35% | 7 | 37% | 13% | 7 | 8 | 0.88 |
| | 1999 | 59 | 21 | 36% | 6 | 29% | 10% | 6 | 8 | 0.75 |
| | 1998 | 10 | 10 | 100% | 6 | 60% | 60% | 6 | 3 | 2.00 |
| | 1997 | 8 | 4 | 50% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | 1996 | 7 | 3 | 43% | 0 | 0% | 0% | 0 | 1 | 0.00 |
| | 1995 | 12 | 6 | 50% | 2 | 33% | 17% | 2 | 3 | 0.67 |
| | 1994 | 9 | 4 | 44% | 1 | 25% | 11% | 1 | 3 | 0.33 |
| | 1993 | 1 | 0 | 0% | 0 | 0% | 0% | 0 | 0 | 0.00 |
| Pre-pred mang (1993-2003) | total | 238 | 81 | | 24 | | | 24 | 37 | |
| | AVE | | | 38% | | 20% | 11% | | | 0.47 |
| | STDEV | | | 26% | | 21% | 17% | | | 0.61 |
| Post-pred mang (2004-2012) | total | 608 | 235 | | 104 | | | 104 | 83 | |
| | AVE | | | 41% | | 47% | 20% | | | 1.36 |
| | STDEV | | | 9% | | 14% | 10% | | | 0.59 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 13. Productivity of Snowy Plovers at Overlook, Douglas Co., Oregon coast, 1999-2012.**

**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Overlook | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 158 | 73 | 46% | 40 | 55% | 25% | 40 | 25 | 1.60 |
| | 2011 | 152 | 80 | 53% | 48 | 60% | 32% | 41 | 22 | 1.86 |
| | 2010 | 92 | 39 | 42% | 15 | 38% | 16% | 15 | 15 | 1.00 |
| | 2009 | 31 | 14 | 45% | 9 | 64% | 29% | 9 | 5 | 1.80 |
| | 2008 | 34 | 5 | 18% | 2 | 40% | 6% | 2 | 3 | 0.67 |
| | 2007 | 46 | 19 | 41% | 11 | 58% | 24% | 11 | 9 | 1.22 |
| | 2006 | 28 | 18 | 64% | 8 | 44% | 29% | 8 | 4 | 2.00 |
| | 2005 | 42 | 16 | 38% | 7 | 44% | 17% | 7 | 5 | 1.40 |
| | 2004 | 39 | 14 | 36% | 6 | 43% | 15% | 6 | 6 | 1.00 |
| | 2003 | 17 | 9 | 53% | 3 | 33% | 18% | 3 | 4 | 0.75 |
| | 2002 | 24 | 13 | 54% | 2 | 15% | 8% | 2 | 4 | 0.50 |
| | 2001 | 39 | 10 | 26% | 2 | 20% | 5% | 2 | 4 | 0.50 |
| | 2000 | 22 | 8 | 36% | 5 | 63% | 23% | 5 | 7 | 0.71 |
| | 1999 | 6 | 6 | 100% | 3 | 50% | 50% | 3 | 2 | 1.50 |
| Pre-pred mang (1999-2003) | total | 108 | 46 | | 15 | | | 15 | 21 | |
| | AVE | | | 54% | | 36% | 21% | | | 0.79 |
| | STDEV | | | 28% | | 20% | 18% | | | 0.41 |
| Post-pred mang (2004-2012) | total | 622 | 200 | | 146 | | | 139 | 94 | |
| | AVE | | | 43% | | 50% | 21% | | | 1.39 |
| | STDEV | | | 13% | | 10% | 8% | | | 0.46 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 14. Productivity of Snowy Plovers at Tahkenitch, Douglas Co., Oregon coast, 1993-2012.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Tahkenitch | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 104 | 56 | 54% | 26 | 46% | 25% | 26 | 19 | 1.37 |
| | 2011 | 59 | 37 | 63% | 19 | 51% | 32% | 18 | 9 | 2.00 |
| | 2010 | 14 | 7 | 50% | 3 | 43% | 21% | 2 | 3 | 1.00 |
| | 2009 | 13 | 6 | 46% | 1 | 17% | 8% | 1 | 2 | 0.50 |
| | 2008 | 14 | 0 | 0% | 0 | 0% | 0% | 0 | 1 | 0.00 |
| | 2007 | 23 | 6 | 26% | 2 | 33% | 9% | 2 | 4 | 0.50 |
| | 2006 | 12 | 9 | 75% | 4 | 44% | 33% | 4 | 3 | 1.33 |
| | 2005 | 26 | 14 | 54% | 8 | 57% | 31% | 8 | 4 | 2.00 |
| | 2004 | 21 | 14 | 67% | 6 | 43% | 29% | 6 | 5 | 1.20 |
| | 2003 | 37 | 17 | 46% | 3 | 18% | 8% | 3 | 10 | 0.30 |
| | 2002 | 30 | 16 | 53% | 6 | 38% | 20% | 6 | 5 | 1.20 |
| | 2001 | 36 | 22 | 61% | 8 | 36% | 22% | 8 | 8 | 1.00 |
| | 2000 | 15 | 6 | 40% | 5 | 83% | 33% | 5 | 2 | 2.50 |
| | 1999 | 9 | 1 | 11% | 1 | 100% | 11% | 1 | 2 | 0.50 |
| | 1998 | 18 | 11 | 61% | 1 | 9% | 6% | 1 | 4 | 0.25 |
| | 1997 | 41 | 10 | 24% | 6 | 60% | 15% | 6 | 7 | 0.86 |
| | 1996 | 51 | 21 | 41% | 8 | 38% | 16% | 8 | 9 | 0.89 |
| | 1995 | 21 | 16 | 76% | 12 | 75% | 57% | 12 | 7 | 1.71 |
| | 1994 | 9 | 8 | 89% | 1 | 13% | 11% | 1 | 3 | 0.33 |
| | 1993 | 0 | 0 | 0% | 0 | 0% | 0% | 0 | 0 | 0.00 |
| Pre-pred mang (1993-2003) | total | 267 | 128 | | 51 | | | 51 | 57 | |
| | AVE | | | 46% | | 43% | 18% | | | 0.87 |
| | STDEV | | | 27% | | 33% | 16% | | | 0.73 |
| Post-pred mang (2004-2012) | total | 286 | 149 | | 67 | | | 66 | 47 | |
| | AVE | | | 48% | | 37% | 21% | | | 1.10 |
| | STDEV | | | 23% | | 18% | 12% | | | 0.68 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 15. Productivity of Snowy Plovers at Tenmile, Coos Co., Oregon coast, 1992-2012.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Tenmile | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 104 | 18 | 17% | 9 | 50% | 7% | 9 | 6 | 1.50 |
| | 2011 | 117 | 18 | 15% | 4 | 22% | 3% | 4 | 10 | 0.40 |
| | 2010 | 113 | 51 | 45% | 16 | 31% | 14% | 16 | 18 | 0.89 |
| | 2009 | 117 | 27 | 23% | 16 | 59% | 14% | 16 | 9 | 1.78 |
| | 2008 | 77 | 21 | 27% | 8 | 38% | 10% | 8 | 8 | 1.00 |
| | 2007 | 89 | 43 | 48% | 27 | 63% | 30% | 27 | 19 | 1.42 |
| | 2006 | 59 | 28 | 47% | 16 | 57% | 27% | 16 | 10 | 1.60 |
| | 2005 | 49 | 21 | 43% | 8 | 38% | 16% | 8 | 8 | 1.00 |
| | 2004 | 50 | 29 | 58% | 12 | 41% | 24% | 12 | 9 | 1.33 |
| | 2003 | 43 | 20 | 47% | 10 | 50% | 23% | 10 | 8 | 1.25 |
| | 2002 | 32 | 14 | 44% | 3 | 21% | 9% | 3 | 8 | 0.38 |
| | 2001 | 24 | 10 | 42% | 4 | 40% | 17% | 4 | 4 | 1.00 |
| | 2000 | 18 | 14 | 78% | 5 | 36% | 28% | 5 | 4 | 1.25 |
| | 1999 | 13 | 8 | 62% | 7 | 88% | 54% | 7 | 3 | 2.33 |
| | 1998 | 20 | 8 | 40% | 3 | 38% | 15% | 3 | 4 | 0.75 |
| | 1997 | 6 | 6 | 100% | 4 | 67% | 67% | 4 | 2 | 2.00 |
| | 1996 | 11 | 6 | 55% | 4 | 67% | 36% | 4 | 4 | 1.00 |
| | 1995 | 13 | 11 | 85% | 2 | 18% | 15% | 2 | 4 | 0.50 |
| | 1994 | 18 | 3 | 17% | 3 | 100% | 17% | 3 | 2 | 1.50 |
| | 1993 | 24 | 15 | 63% | 5 | 33% | 21% | 5 | 5 | 1.00 |
| | 1992 | 27 | 19 | 70% | 14 | 74% | 52% | 14 | 7 | 2.00 |
| Pre-pred mang (1992-2003) | total | 249 | 134 | | 64 | | | 64 | 55 | |
| | AVE | | | 59% | | 53% | 30% | | | 1.25 |
| | STDEV | | | 23% | | 26% | 19% | | | 0.61 |
| Post-pred mang (2004-2012) | total | 775 | 256 | | 116 | | | 116 | 98 | |
| | AVE | | | 36% | | 44% | 16% | | | 1.21 |
| | STDEV | | | 16% | | 14% | 9% | | | 0.43 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 16. Productivity of Snowy Plovers at Coos Bay North Spit, Coos Co., Oregon coast, 1992-2012.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | CBNS | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 175 | 135 | 77% | 50 | 37% | 29% | 50 | 44 | 1.14 |
| | 2011 | 156 | 109 | 70% | 52 | 48% | 33% | 52 | 31 | 1.69 |
| | 2010 | 160 | 40 | 25% | 20 | 50% | 13% | 20 | 17 | 1.18 |
| | 2009 | 171 | 58 | 34% | 28 | 48% | 16% | 28 | 22 | 1.27 |
| | 2008 | 125 | 63 | 50% | 40 | 63% | 32% | 38 | 19 | 2.00 |
| | 2007 | 108 | 45 | 42% | 26 | 58% | 24% | 26 | 12 | 2.17 |
| | 2006 | 86 | 54 | 63% | 22 | 41% | 26% | 22 | 14 | 1.57 |
| | 2005 | 80 | 38 | 48% | 23 | 61% | 29% | 21 | 12 | 1.75 |
| | 2004 | 73 | 42 | 58% | 31 | 74% | 42% | 31 | 15 | 2.06 |
| | 2003 | 57 | 29 | 51% | 21 | 72% | 37% | 20 | 9 | 2.22 |
| | 2002 | 48 | 21 | 44% | 11 | 52% | 23% | 11 | 10 | 2.22 |
| | 2001 | 49 | 21 | 43% | 11 | 52% | 22% | 11 | 8 | 1.38 |
| | 2000 | 75 | 23 | 31% | 9 | 39% | 12% | 9 | 6 | 1.50 |
| | 1999 | 38 | 35 | 92% | 26 | 74% | 68% | 26 | 10 | 2.60 |
| | 1998 | 49 | 18 | 37% | 9 | 50% | 18% | 9 | 8 | 1.13 |
| | 1997 | 64 | 32 | 50% | 12 | 38% | 19% | 12 | 11 | 1.09 |
| | 1996 | 77 | 48 | 62% | 20 | 42% | 26% | 17 | 14 | 1.21 |
| | 1995 | 53 | 35 | 66% | 20 | 57% | 38% | 19 | 11 | 1.72 |
| | 1994 | 50 | 44 | 88% | 29 | 66% | 58% | 28 | 12 | 2.33 |
| | 1993 | 26 | 18 | 69% | 9 | 50% | 35% | 9 | 7 | 1.29 |
| | 1992 | 32 | 21 | 66% | 9 | 43% | 28% | 9 | 7 | 1.29 |
| Pre-pred mang (1992-2001) | total | 513 | 295 | | 154 | | | 149 | 94 | |
| | AVE | | | 60% | | 51% | 32% | | | 1.55 |
| | STDEV | | | 20% | | 12% | 18% | | | 0.52 |
| Post-pred mang (2002-2012) | total | 1239 | 634 | | 324 | | | 319 | 206 | |
| | AVE | | | 51% | | 55% | 28% | | | 1.75 |
| | STDEV | | | 15% | | 12% | 9% | | | 0.42 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 17. Productivity of Snowy Plovers at Bandon Snowy Plover Management Area, Coos Co., Oregon coast, 1995-2012.**

**Number of eggs laid, number hatched, hatch rate, # fledged, fledgling success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Bandon SPMA | total # eggs laid | total # hatched | hatch rate | total # fledged | fledgling success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2012** | 160 | 30 | 19% | 12 | 40% | 8% | 12 | 14 | 0.86 |
| | **2011** | 92 | 43 | 47% | 21 | 49% | 23% | 21 | 15 | 1.40 |
| | **2010** | 87 | 36 | 41% | 6 | 17% | 7% | 6 | 12 | 0.50 |
| | **2009** | 95 | 20 | 21% | 7 | 35% | 7% | 7 | 12 | 0.58 |
| | **2008** | 85 | 8 | 9% | 3 | 38% | 4% | 3 | 15 | 0.20 |
| | **2007** | 114 | 40 | 35% | 24 | 60% | 21% | 23 | 16 | 1.44 |
| | **2006** | 75 | 29 | 39% | 11 | 38% | 15% | 7 | 8 | 0.88 |
| | **2005** | 111 | 45 | 41% | 11 | 24% | 10% | 11 | 17 | 0.65 |
| | **2004** | 71 | 48 | 68% | 26 | 54% | 37% | 25 | 15 | 1.67 |
| | **2003** | 33 | 14 | 42% | 3 | 21% | 9% | 3 | 7 | 0.43 |
| | **2002** | 16 | 4 | 25% | 0 | 0% | 0% | 0 | 4 | 0.00 |
| | **2001** | 16 | 8 | 50% | 1 | 13% | 6% | 1 | 3 | 0.33 |
| | **2000** | 9 | 0 | 0% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | **1999** | 26 | 16 | 62% | 3 | 19% | 12% | 3 | 9 | 0.33 |
| | **1998** | 6 | 3 | 50% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | **1997** | 34 | 9 | 26% | 0 | 0% | 0% | 0 | 6 | 0.00 |
| | **1996** | 12 | 8 | 67% | 1 | 13% | 8% | 1 | 3 | 0.33 |
| | **1995** | 37 | 11 | 30% | 6 | 55% | 16% | 6 | 6 | 1.00 |
| **Pre-pred mang (1995-2001)** | **total** | 140 | 55 | | 11 | | | 11 | 31 | |
| | **AVE** | | | 41% | | 14% | 6% | | | 0.28 |
| | **STDEV** | | | 23% | | 20% | 6% | | | 0.36 |
| **Post-pred mang (2002-2012)** | **total** | 939 | 317 | | 124 | | | 118 | 135 | |
| | **AVE** | | | 35% | | 34% | 13% | | | 0.78 |
| | **STDEV** | | | 16% | | 18% | 11% | | | 0.53 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 18. Productivity of Snowy Plovers at New River HRA, Coos Co., Oregon coast, 1999-2012.**

**Number of eggs laid, number hatched, hatch rate, # fledged, fledgling success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Year | total # eggs laid | total # hatched | hatch rate | total # fledged | fledgling success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 46 | 13 | 28% | 2 | 15% | 4% | 2 | 6 | 0.33 |
| | 2011 | 59 | 26 | 44% | 7 | 27% | 12% | 7 | 10 | 0.70 |
| | 2010 | 71 | 24 | 34% | 12 | 50% | 17% | 12 | 15 | 0.80 |
| | 2009 | 76 | 38 | 50% | 16 | 42% | 21% | 16 | 13 | 1.23 |
| | 2008 | 54 | 28 | 52% | 7 | 25% | 13% | 7 | 12 | 0.58 |
| | 2007 | 38 | 24 | 63% | 14 | 58% | 37% | 14 | 8 | 1.75 |
| | 2006 | 18 | 14 | 78% | 6 | 43% | 33% | 6 | 6 | 1.00 |
| | 2005 | 3 | 2 | 67% | 1 | 50% | 33% | 1 | 1 | 1.00 |
| | 2004 | 18 | 11 | 61% | 5 | 45% | 28% | 5 | 4 | 1.25 |
| | 2003 | 14 | 10 | 71% | 7 | 70% | 50% | 7 | 5 | 1.40 |
| | 2002 | 18 | 8 | 44% | 3 | 38% | 17% | 3 | 4 | 0.75 |
| | 2001 | 21 | 11 | 52% | 3 | 27% | 14% | 3 | 5 | 0.60 |
| | 2000 | 11 | 10 | 91% | 1 | 10% | 9% | 1 | 4 | 0.25 |
| | 1999 | 9 | 6 | 67% | 2 | 33% | 22% | 2 | 3 | 0.67 |
| Pre-pred mang (1999-2001) | total | 41 | 27 | | 6 | | | 6 | 12 | |
| | AVE | | | 70% | | 23% | 15% | | | 0.51 |
| | STDEV | | | 20% | | 12% | 7% | | | 0.23 |
| Post-pred mang (2002-2012) | total | 415 | 198 | | 80 | | | 80 | 84 | |
| | AVE | | | 54% | | 42% | 24% | | | 0.98 |
| | STDEV | | | 16% | | 16% | 13% | | | 0.41 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 19. Average Snowy Plover productivity on the Oregon coast pre- and post-predator management, 1992-2012.**

| | Siltcoos | | Overlook | | Tahkenitch | | Tenmile | | CBNS | | Bandon SPMA | | New River HRA | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-pred mang (1993-2003) | Post-pred mang (2004-2012) | Pre-pred mang (1999-2003) | Post-pred mang (2004-2012) | Pre-pred mang (1993-2003) | Post-pred mang (2004-2012) | Pre-pred mang (1992-2003) | Post-pred mang (2004-2012) | Pre-pred mang (1992-2001) | Post-pred mang (2002-2012) | Pre-pred mang (1995-2001) | Post-pred mang (2002-2012) | Pre-pred mang (1999-2001) | Post-pred mang (2002-2012) |
| **ave hatch rate** | 38%+/-26% | 41%+/-9% | 54%+/-28% | 43%+/-13% | 46%+/-27% | 48%+/-23% | 59%+/-23% | 36%+/-16% | 60%+/-20% | 51%+/-15% | 41%+/-23% | 35%+/-16% | 70%+/-20% | 54%+/-16% |
| | | | | | | | | | | | | | | |
| **ave fledging success rate** | 20%+/-21% | 47%+/-14% | 36%+/-20% | 50%+/-10% | 43%+/-33% | 37%+/-18% | 53%+/-26% | 44%+/-14% | 51%+/-12% | 55%+/-12% | 14%+/-20% | 34%+/-18% | 23%+/-12% | 42%+/-16% |
| | | | | | | | | | | | | | | |
| **ave productivity index** | 11%+/-17% | 20%+/-10% | 21%+/-9% | 21%+/-8% | 18%+/-16% | 21%+/-12% | 30%+/-19% | 16%+/-9% | 32%+/-18% | 28%+/-9% | 6%+/-6% | 13%+/-11% | 15%+/-7% | 24%+/-13% |
| | | | | | | | | | | | | | | |
| **ave # of fledglings/male** | 0.47+/-0.61 | 1.38+/-0592 | 0.79+/-0.41 | 1.39+/-0.46 | 0.87+/-0.73 | 1.10+/-0.68 | 1.25+/-0.61 | 1.21+/-0.43 | 1.55+/-0.52 | 1.75+/-0.42 | 0.28+/-0.36 | 0.78+/-0.53 | 0.51+/-0.23 | 0.98+/-0.41 |

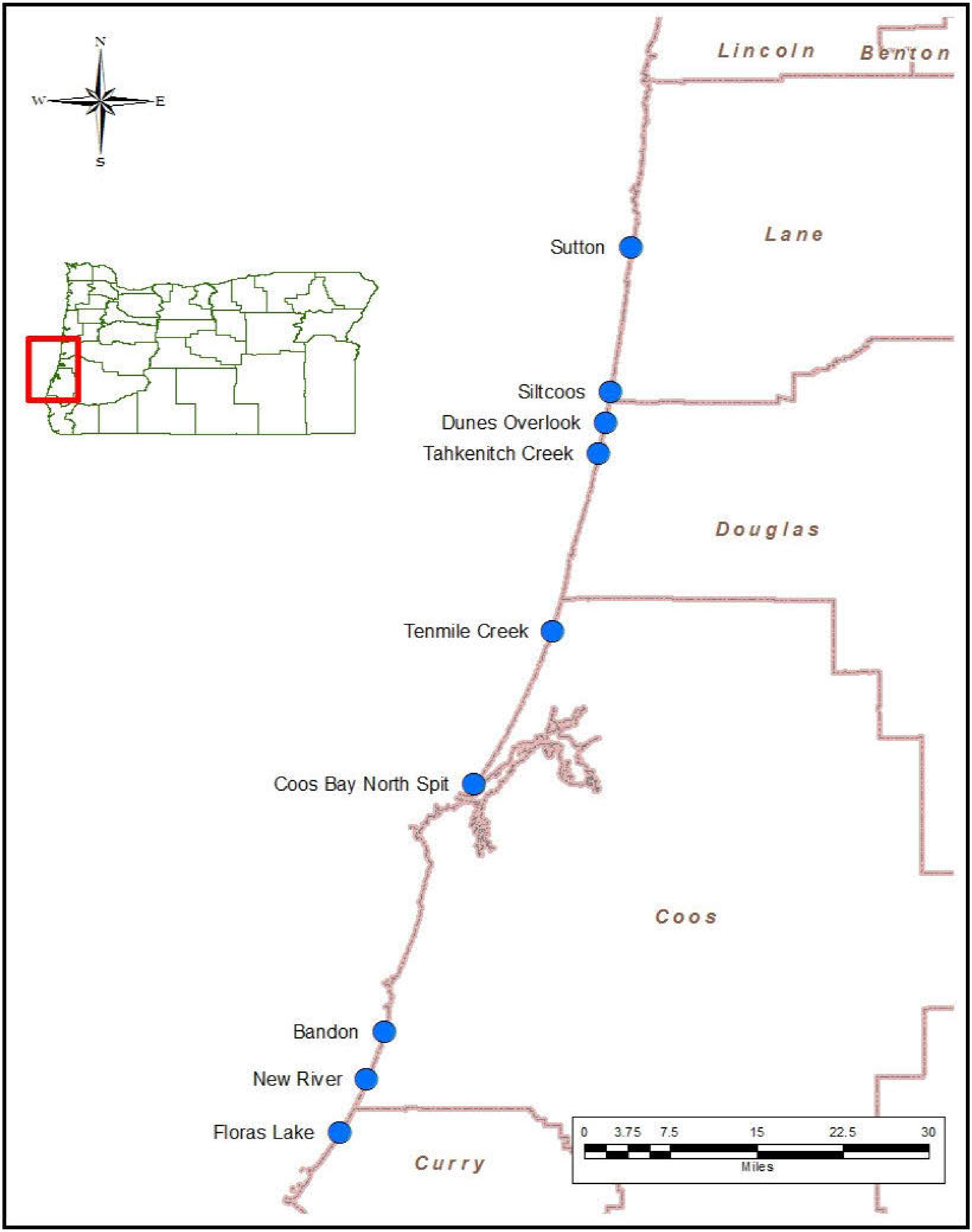



Figure 1. Snowy Plover monitoring locations along the Oregon coast, 2012

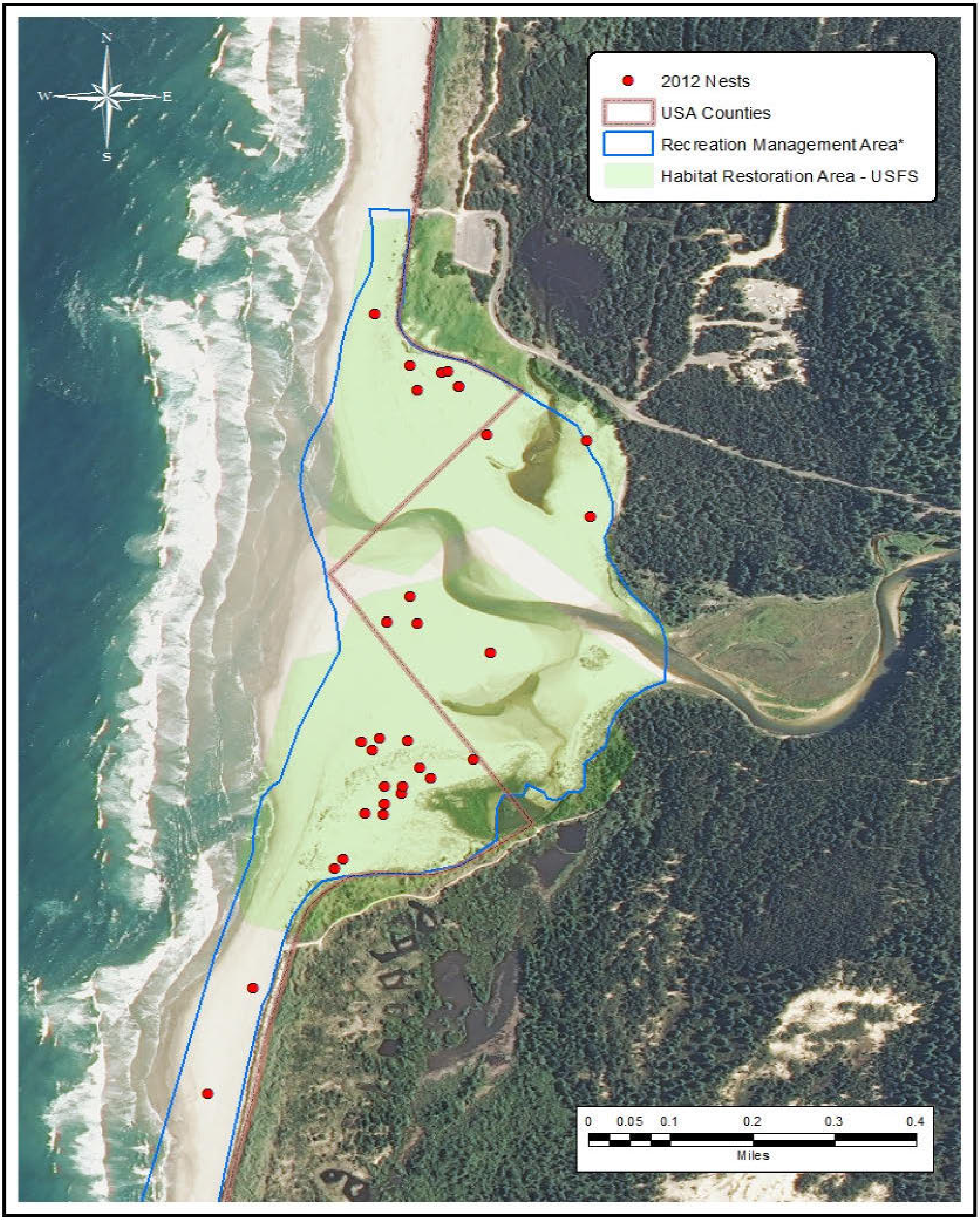



**Figure 2. Snowy Plover nest locations at Siltcoos Beach, Oregon, 2012**
*Layer provided by Oregon Parks and Recreation Department


**Figure 3. Snowy Plover nest locations at Dunes Overlook, Oregon, 2012**

*Layer provided by Oregon Parks and Recreation Department

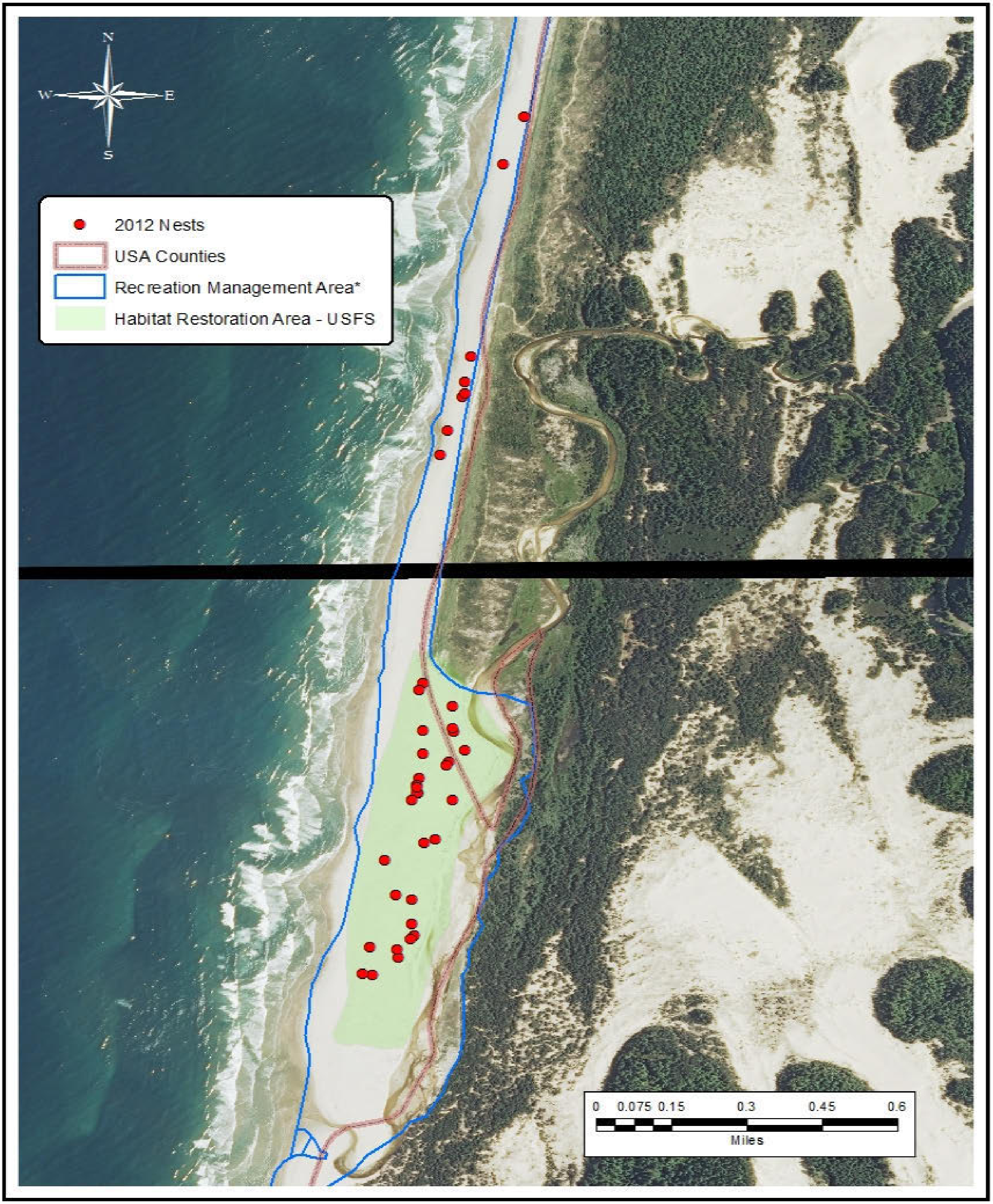



Figure 4. Snowy Plover nest locations at Tahkenitch Creek, Oregon, 2012
*Layer provided by Oregon Parks and Recreation Department

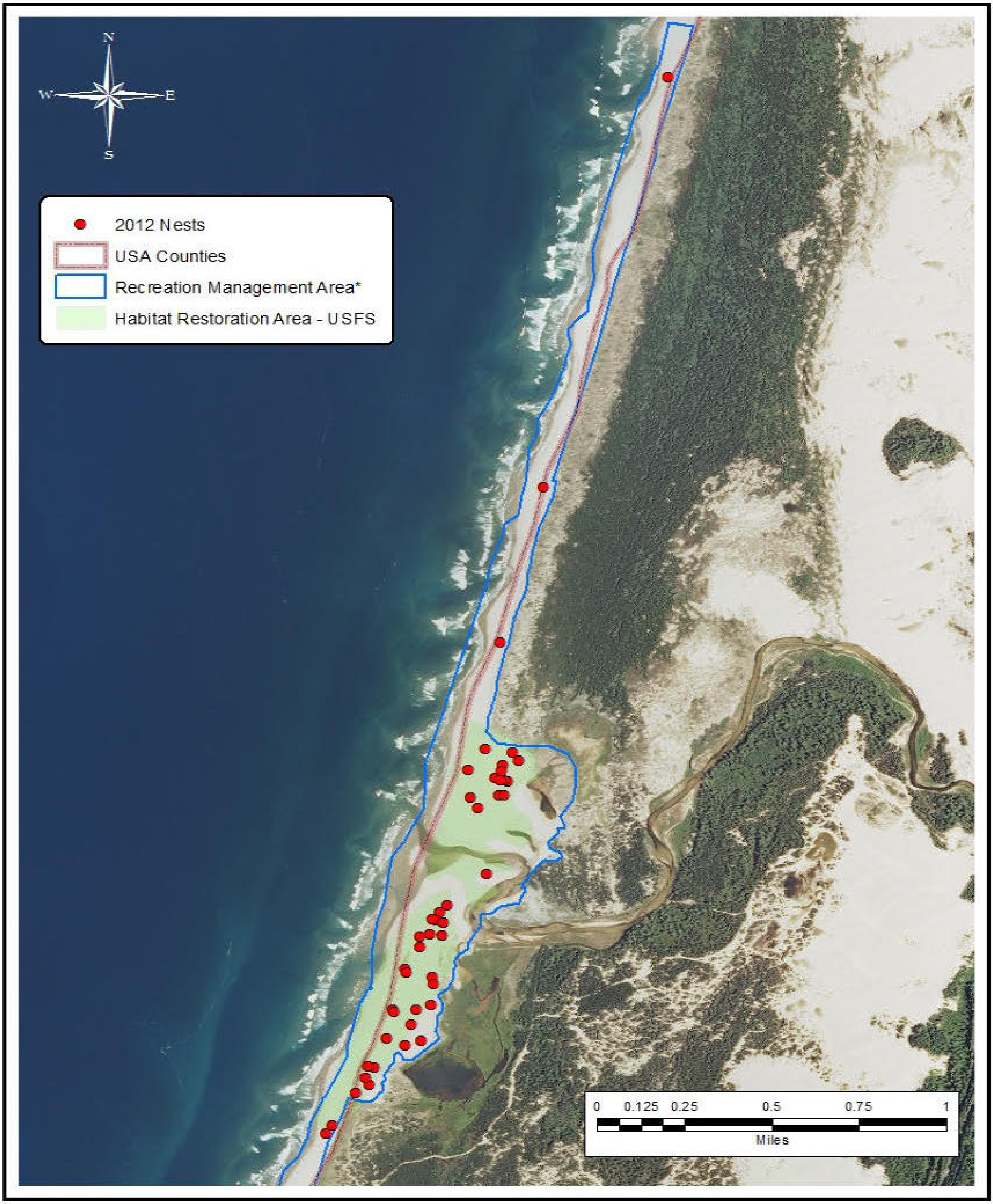



Figure 5. Snowy Plover nest locations at Tenmile Creek, Oregon, 2012
*Layer provided by Oregon Parks and Recreation Department


**Figure 6. Snowy Plover nest locations at Coos Bay North Spit, Oregon, 2012**
***Layer provided by Oregon Parks and Recreation Department**

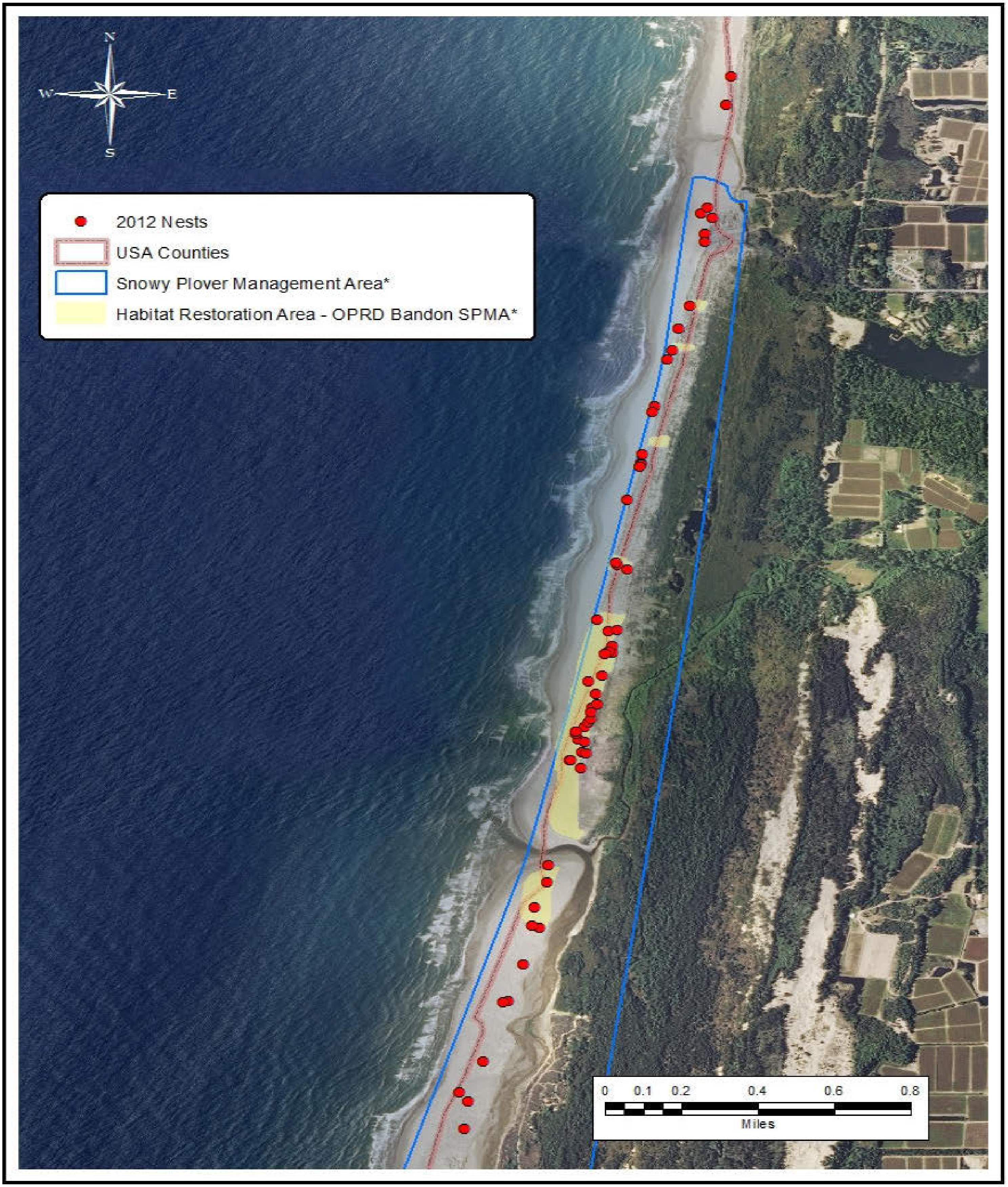



Figure 7. Snowy Plover nest locations at Bandon Snowy Plover Management Area, Oregon, 2012

*Layer provided by Oregon Parks and Recreation Department


**Figure 8. Snowy Plover nest locations at New River, Oregon, 2012**
*Layer provided by Oregon Parks and Recreation Department

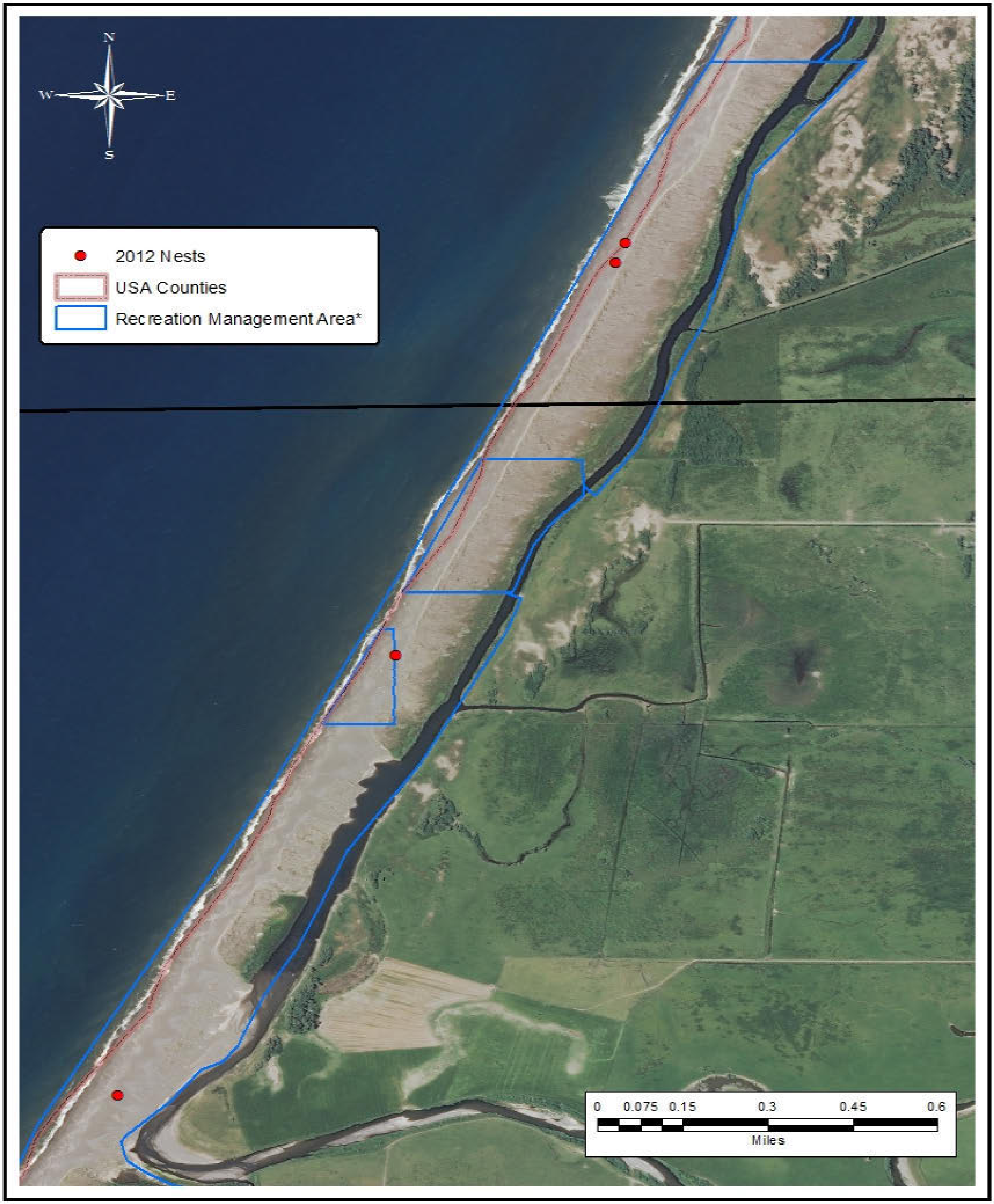



**Figure 9. Snowy Plover nest locations at Floras Lake, Oregon, 2012**
***Layer provided by Oregon Parks and Recreation Department**

Figure 10. Number of active Snowy Plover nests within 10-day intervals on the Oregon coast, 2012. Dashed lines represent +/- 2 standard deviations.

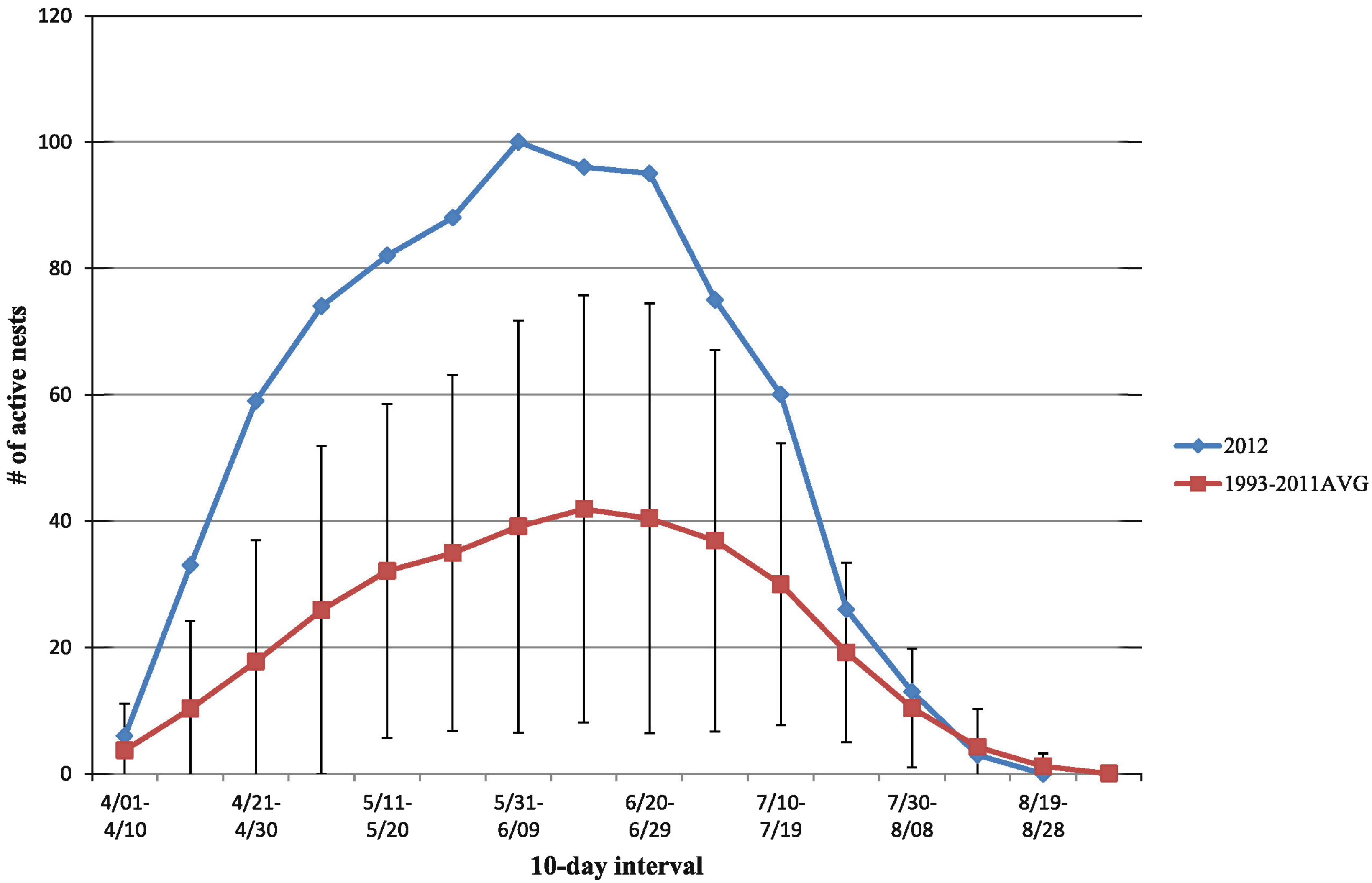


Figure 11. The number of exclosed and unexclosed days of Snowy Plover nests along the Oregon coast, 1992 – 2012.

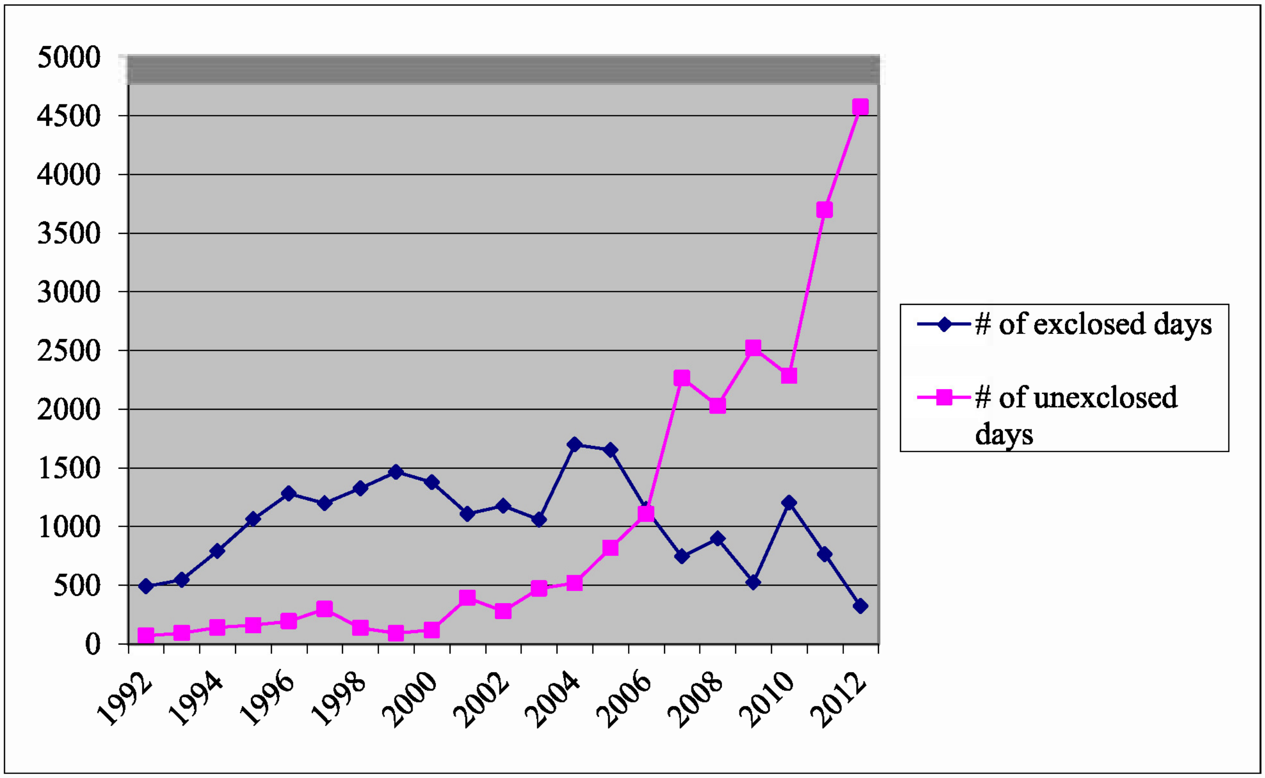
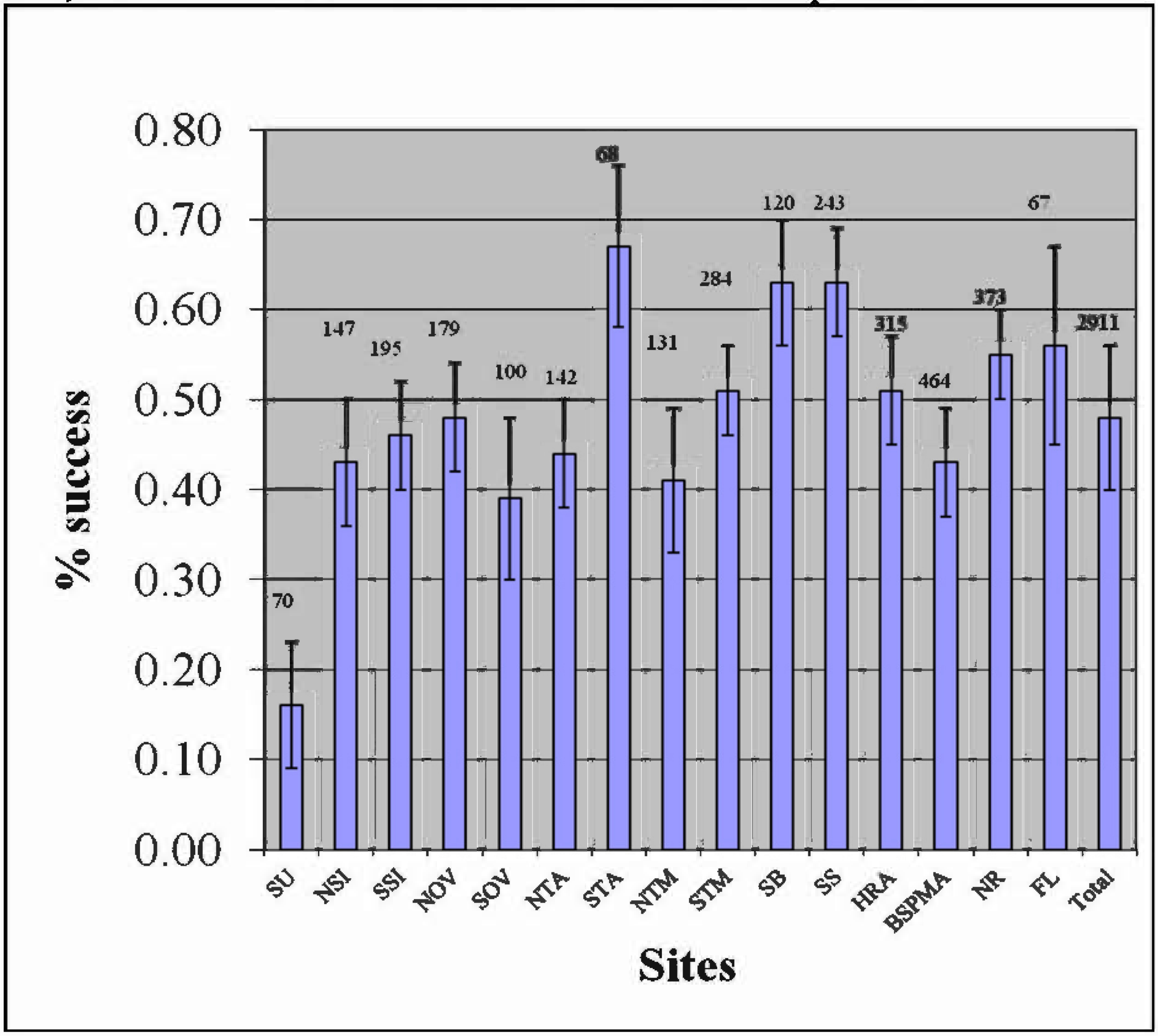


Figure 12. Mean percent nest success for Snowy Plovers along the Oregon coast, 1990-2012, with standard error bars. Number above each bar is the sample size.



## APPENDIX A.

**Study Area**

The study area encompassed known nesting areas along the Oregon coast including all sites between Berry Creek, Lane Co., and Floras Lake, Curry Co. (Fig. 1). Survey effort was concentrated at the following sites, listed from north to south:

**Sutton Beach**, Lane Co. - the beach north of Berry Creek south to the mouth of Sutton Creek.

**Siltcoos**: North Siltcoos, Lane Co. (Figure 2). - the north spit, beach, and open sand areas between Siltcoos River mouth and the parking lot entrance at the end of the paved road on the north side of the Siltcoos River; and South Siltcoos, Lane Co. - the south spit, beach, and open sand areas between Siltcoos River mouth and south to Carter Lake trail beach entrance.

**Dunes Overlook Clearing**, Douglas Co. (Figure 3). – the area directly west of the Oregon Dunes Overlook off of Hwy 101 including the beach from Carter Lake trail to the north clearing, and south to the Overlook trail south of the south clearing.

**Tahkenitch Creek**, Douglas Co. (Figure 4) - Tahkenitch North Spit - the spit and beach on the north side of Tahkenitch Creek including the beach north to Overlook trail.

**Tenmile**: North Tenmile, Coos and Douglas Cos. (Figure 5) - the spit and ocean beach north of Tenmile Creek, north to the Umpqua River jetty; and South Tenmile, Coos Co. - the south spit, beach, and estuary areas within the Tenmile Estuary vehicle closure, and continuing south of the closure for approximately 1/2 mile.

**Coos Bay North Spit (CBNS)**, Coos Co. (Figure 6): South Beach - the beach between the north jetty and the F.A.A. towers; and South Spoil/HRAs - the south dredge spoil and adjacent habitat restoration areas (94HRA, 95HRA, 98HRA);

**Bandon Snowy Plover Management Area**, Coos Co. (Figure 7): This site includes the Bandon SPMA and all nesting areas from north of China Creek to the south end of state land south of the mouth of New River.

**New River**, Coos Co. (Figure 8) - the privately owned beach and sand spit south of Bandon Snowy Plover Management Area south to BLM lands, and the BLM Storm Ranch Area of Critical Environmental Concern habitat restoration area (HRA).

**Floras Lake**, Curry Co. (Figure 9) – the beach and overwash areas west of the confluence of Floras Creek and the beginning of New River, north to Hansen Breach.

The following additional areas were either surveyed in early spring or the breeding window survey: Clatsop Spit, Necanicum Spit, Nehalem Spit, Bayocean Spit, Netarts Spit, Sand Lake South Spit, Nestucca Spit, Whiskey Run to Coquille River, Sixes River South Spit, Elk River, Euchre Creek, and Pistol River.

## APPENDIX B.

**Recommendations for Management of Recreational Activities and Habitat Restoration for sites with Snowy Plovers along the Oregon Coast - 2012.**

**Sutton:**

- Continue to manage the nesting areas particularly at the Sutton Beach HRA; consider spreading shell hash or woody debris to improve the nesting substrate.
- Continue predator management when and if plovers are nesting to reduce predation pressure on broods, particularly corvids.
- Rope and sign around Sutton Beach HRA; rope and sign any other areas if plovers are detected using the beach.
- Place signs notifying people of current dog regulations.

**Siltcoos North and South Spits:**

- Continue predator management to reduce the number of corvids using the nesting area. Continue to reduce the feral cat population in the area. Continue to monitor and possibly remove coyotes that are using and possibly denning near the nesting area.
- Continue signage along river, especially east of nesting area and on any "islands" that may develop to alert kayak/canoe users about plover management activities.
- Continue to post the area with updated maps of the estuary and beach at several locations. These areas include the Stagecoach Trailhead, the north parking lot, and both ends of the Waxmyrtle Trail.
- Erect ropes and signs prior to 15 March, to be as effective as possible. Place signs and ropes on east and south side of the north spit nesting area as well as continued signage to the west and north.
- Enforce dog regulations on the spits and near the estuary during nesting season.
- Continue the use of campground plover hosts/volunteers to educate people and restrict them from closed areas. Use hosts/volunteers, especially during peak periods on weekends, and stagger their hours to cover evenings. Have hosts/volunteers in contact with Law Enforcement Officers to improve enforcement of the closures, and have them engage people on the beach before violations occur.
- Continue to extend appropriate signing to both riverbanks, to prevent hikers from walking up the closed estuary.
- Rope and sign along the foredune south of Waxmyrtle trail access to the Carter Lake trail area; monitor this area for roosting, nesting and brooding plovers.

**Overlook:**

- Continue predator management to control corvid use of the area. Monitor Northern Harrier and Great Horned Owl use of the area and consider removal if harriers and owls continue to pose problems to breeding plovers.
- Continue to rope and sign both north and south closures for Snowy Plover nesting habitat by 15 March.
- Continue to improve and enlarge the restoration area, especially to the south towards Tahkenitch.
- Erect and maintain interpretive signing at the beginning of the Overlook trailhead (near viewing platforms). This signing is intended to provide more information on the ecology of the Snowy Plover and the reasoning for current management techniques and restricted areas.
- Enforce current dog regulations.

**Tahkenitch:**

- Continue to maintain and improve the habitat.
- Continue predator management to control corvid use of the area. Identify if Great Horned Owls or other avian predators are hunting the area. Remove if necessary.
- Continue to rope and sign all suitable habitat. Place signs along east and south edge outside of the roped area to prevent hiking and camping near nesting area.
- Enforce current dog regulations.

**Tenmile North and South Spits:**

- Continue predator management to control corvid use of the area; continue to monitor coyote use and possibly remove coyotes if warranted. Monitor and remove Great Horned Owls if necessary. Evaluate rodent populations and depredations.
- Continue to maintain and improve the south side for nesting. Consider expanding and improving habitat on the north side.
- Continue to rope and sign plover nesting habitat on both north and south spits.
- Enforce vehicle closure to prevent violators from driving in the habitat restoration areas.
- Enforce current dog regulations.

**Coos Bay North Spit:**

- Continue predator management of the area for corvids, feral cats, skunks, and raccoons; monitor the coyote population and remove coyotes if warranted; continue early season rodent trapping to reduce rodent population.
- Continue to improve and maintain the habitat restoration areas. Continue to spread shell hash to improve nesting substrate.
- Maintain gaps in the berm along the 95HRA to facilitate brood movement from the 94HRA and 98WHRA to the 95HRA and to the beach. Maintain small vegetation free gaps in the foredune to facilitate brood access to the beach without destabilizing the foredune.
- Continue to rope and sign the beach as early in the nesting season as possible; avoid erecting signs where the ocean is repeatedly lapping against the foredune to reduce sign loss.
- Clearly sign all entrance points on the spit that the beach is street legal vehicles only.
- Continue closure of the foredune road through the nesting area. Consider a permanent reroute of the foredune road.
- Enforce current dog regulations.

**Bandon:**

- Continue predator management to control mammal and corvid populations.
- Continue to improve and maintain the habitat restoration area north of New River/Twomile Creek. Maintain and improve "cutouts" along the foredune to increase available nesting habitat for plovers; consider additional cutouts along foredune.
- Sign and rope the entire beach from China Creek overwash to the Habitat Restoration Area near the mouth of Twomile Creek/New River before the nesting season.
- Enforce current dog regulations.
- Monitor hiker use from Bandon to Blacklock Point, and check the beach and HRA on weekends for illegal camping activity. Consider beginning a permit system for hikers and campers.

- In 2012, there was probable take of two adult plovers at an exclosed nest at Bandon SPMA. There have been ongoing violations and vandalism at this site. We recommend frequent ranger patrols of this area and continued use of volunteers in the parking lot.
- Based on BLM registrations and monitors' observations, the number of hikers along the coast trail between Bandon SPMA and Floras Lake was reduced in 2012, however, there was some illegal camping along the New River area. New signs with maps have helped educate hikers. We recommend this education effort be continued.

**New River:**

- Continue predator management to control mammal and corvid populations.
- Continue to improve and maintain the habitat restoration area.
- Sign the foredune north of the HRA along the foredune.
- Place interpretive signs near the Lower Fourmile access along the river to inform the public of plover activity.
- Sign State Parks lands on the open spit south of the mouth of New River.
- Enforce current dog regulations.
- Use interpretive specialist to help monitor recreational activities in the area and explain the management efforts in the area.
- Continue to close the gate at the Storm Ranch for 15 April- 15 September.
- Illegal camping continues in the New River area although new signs and maps have. Hikers will need to continue to be informed about new regulations regarding dogs. We recommended that a permit process be considered to help educate hikers, limit their numbers, ensure that they do not have dogs, are legally camping, and are in compliance .

**Floras Lake:**

- Monitor the site for any plover activity.
- Enforce dogs on leash rules at all times.
- Continue to hire an on-site interpretive specialist, to contact the public, monitor the beach, and present slide shows.

## APPENDIX C

**Recovery Unit 1 (Oregon & Washington)**
**Exclosure Use Guidelines Developed by Oregon Biodiversity Information Center for the Western Snowy Plover Working Team**
**2/27/2012**

Nest exclosures are mesh fences that surround a Western Snowy Plover (*Charadrius nivosus nivosus*) nest and act to keep out predators. Nest exclosures have been used in Oregon since 1991 to protect plover nests from depredation by mammalian and avian predators. Prior to implementation of comprehensive predator management, plovers have suffered high rates of nest depredation. Exclosures have been successful at increasing nest success rates (Table 1) (Stern *et al.* 1990, 1991, Craig *et al.* 1992, Casler *et al.*1993, Hallett *et al.*1994, 1995, Estelle *et al.*1997, Castelein *et al.*1997, 1998, 2000a, 2000b, 2001, 2002, Lauten *et al.*2003, 2005, 2006, 2006b, 2007, 2008, 2009, 2010, 2011). Predators that prey on snowy plover eggs include mammalian predators such as skunk (*Mephitis sp.*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), mice (*Peromyscus* sp.), and weasel (*Mustela sp.*); and avian predators, mostly American crows (*Corvus brachyrhynchos*) and common ravens (*Corvus corax*).

Since 1990, we have found 2650 snowy plover nests along the Oregon coast, of which 1057 (40%) have been exclosed. Over the years we have had to adapt exclosure techniques in response to predator behavior around exclosures. (see Castelein *et al.*2000a, 2000b, 2001, Lauten *et al.*2003).

In 1995 we began seeing evidence of adult snowy plover depredations in or immediately outside exclosures. From 1995 to 2011 we documented a minimum of 48 adult losses associated with exclosure use. These losses include 21 cases where blood, feathers, or plover body parts were found in or adjacent to exclosures and 27 cases where incubating adults disappeared from an established, exclosed nest. Forty-eight adult losses associated with 1057 exclosed nests indicate that exclosures subject adult plovers to additional predation risk (approximately 4%). Similar threats associated with exclosures have been reported in other plover populations (Murphy *et al.*2003, Hardy and Colwell 2008, Pearson *et al.*2009). We do not have information on how many adults may be lost at nests not associated with exclosures.

Predator exclosures increase snowy plover hatching success and the number of chicks hatched per male, but not fledging success or the number of chicks fledged per male (Neuman *et al.*2004). In Oregon, they pose an additional risk to incubating adults and may negatively impact adult survival. As in Washington, exclosure use in Oregon has been a management technique, not part of a study of their effectiveness in increasing the overall plover population. We are working with Steve Dinsmore (Department of Natural Resource Ecology and Management, Iowa State University) to evaluate the effectiveness of exclosure use on nest success and adult survival. Preliminary results indicate that, predictably, exclosure use has a strong positive impact on nest success. Further analysis is underway to determine potential impacts of exclosure use on adult success and fledging success (Dinsmore et al., unpublished data) (see Pearson *et al.*2009, Neuman *et al.*2004).

Scott Pearson *et al.* (2009) conducted a search of existing literature on the effects of nest exclosures on nest success for plovers and other ground nesting species (primarily shorebirds). Their findings are summarized below:

- Nest survival of exclosed nests was significantly higher in ten studies (Rimmer and Deblinger 1990, Melvin *et al.*1992, Estelle *et al.*1996, Johnson and Oring 2002, Lauten *et al.*2004, Niehaus *et al.*2004, Isaksson *et al.*2007, Hardy and Colwell 2008, Pauliny *et al.*2008, Pearson *et* *al.*unpublished), and there was no difference in two studies (Nol and Brooks 1982, Mabee and Estelle 2000).

- Exclosed nests appear to be only vulnerable to reptilian and small mammal predators while unexclosed nests are vulnerable to predators of all sizes (Mabee and Estelle 2000).
- No difference in fledging success between exclosed and unexclosed nests in four studies (Hardy and Colwell 2008, Pauliny *et al.*2008, Lauten *et al.*2004, Pearson *et al.* unpublished data) and higher fledging success for exclosed nests in two studies (Larson *et al.*2002, Melvin *et al.*2002). There was no difference in fledging success between exclosed and unexclosed nests for all studies involving snowy plovers.
- Adult mortality associated with exclosures was reported in six of the eight studies that included or mentioned this response variable (Murphy *et al.*2003, Lauten *et al.*2004, Isaksson *et al.*2007, Hardy and Colwell 2008, Pauliny *et al.*2008, Pearson *et al.*unpublished). Only three studies compared adult mortality between exclosed and unexclosed nests and two reported significant increases in adult mortality associated with exclosures (Murphy *et al.*2003 and Isacsson 2007) and one reported no difference (Pauliny *et al.*2008).
- Adult mortality appears to be largely attributable to raptors and appears to be episodic (Murphy *et al.*2003, Neuman et a. 2004, Hardy and Colwell 2008) and differs among habitats (Murphy *et al.*2003).
- Larson *et al.*2002 examined the effect of exclosures on population growth for piping plovers and found the effect to be positive.
- Abandonment was higher for exclosed nests in two studies where this was compared directly (Isaksson et al., 2007, Hardy and Colwell 2008).
- Abandonment was not associated with the construction process, size, shape, mesh size and fence height (Vaske *et al.*1994). Covered exclosures are more likely to be abandoned than uncovered exclosures (Vaske *et al.*1994).
- Exclosures increased incubation length by one day but did not influence chick condition (Isaksson *et al.*2007).
- Egg hatchability was higher in three studies (Melvin *et al.*1992, Isaksson *et al.*2007, Pauliny *et al.*2008) but no difference was observed in one study (Hardy and Colwell 2008).
- Breeding adults may receive false messages regarding site quality and encouragement to continue to breed in sink habitats (Hardy and Colwell 2008). This is an important research question that should be examined but no data support this contention.

Our data and that of others (Murphy *et al.*2003, Hardy and Colwell 2008, Pearson *et al.*2009) indicate that adult plovers are at increased risk of predation while in exclosures. In the absence of research to quantify that risk, and based on the above information, we developed the following guidelines for exclosure use in Oregon:

- Since raptors appear to be the primary threat to adult plovers in exclosures, delay use of exclosures until peak raptor migration has passed. Currently, we have identified May 15 as a suitable cutoff, but this date could be altered as needed.

- Delaying exclosure use until May 15 allows field personnel time to assess causes of early nest failures, although weather conditions can make accurate assessment difficult. During this time, and contingent on funding, we recommend an owl survey be run at each site.

- If nests are being lost primarily to mice, exclosures will not help the problem, and may pose additional risk if the mice are being preyed upon by raptors. In this case exclosure use is not appropriate.

- If corvids and/or large mammals are identified as the main predator at a site, removal of the predators should be the primary goal with exclosures used as a supplemental measure to help protect nests.

- Any use of exclosures should be accompanied by close monitoring to evaluate their effectiveness (Hardy and Colwell 2008) and to detect predators of adult plovers early (Pauliny *et al.*2008). Weather permitting, exclosed nests should be checked at least twice per week. If conditions do not allow checks twice a week, exclosure use should be seriously reconsidered.

- Adult predation associated with exclosures is often episodic (Castelein *et al.* 2000b, Lauten *et al.* 2006). Once adult predation is suspected, all exclosures should be removed from the site and their use discontinued for the season.

- To minimize the risk of episodic predation on adult plovers, additional caution should be used when placing exclosures within sight of each other (this puts multiple adults at risk).

- Exclosures should not be placed along the foredune.

- Exclosures should not be placed in a windy location that might result in nest drifting. Since the ME's are 4 feet per side, the nest is only about 2 feet from each sidewall. If the nest begins to drift, it could come close to a sidewall, and a predator such as a raccoon could reach in and grab the eggs. If an exclosed nest is in a potentially windy location, it must be monitored frequently to ensure the safety of the nest and adults (especially on windy days).

# Appendix D

## Snowy Plover Monitoring Methods

### Nest Surveys

Monitoring began the first week in April and continued until all broods fledged, typically by mid-September. We used two teams of two biologists; one team covering Tenmile and sites north, and the other covering Coos Bay North Spit and sites south (Fig. 1). In some years this division has been modified to accommodate staff needs. All data collected in the field was recorded in field notebooks and later transferred onto computer. Surveys were completed on foot and from an all-terrain vehicle (ATV). Data recorded on nest surveys included:

- site name
- weather conditions
- start time and stop time
- direction of survey
- number of plover seen, broken down by age and sex
- band combinations observed
- potential predators or tracks observed
- violations/human disturbance observed

Weekly surveys were attempted, but were not always possible due to increasing workload associated with an increased plover population. Additional visits were made to check nests, band chicks, or monitor broods.

### Population Estimation

We estimated the number of Snowy Plovers on the Oregon Coast by determining the number of individually color banded adult Snowy Plovers recorded during the breeding season, and then adding an estimated number of unbanded Snowy Plovers. We determined the number of unbanded Snowy Plovers observed within ten-day intervals during the breeding season, selected the highest count of unbanded birds and then subtracted the number of adults that were banded subsequently. We also determined the number of plovers known to have nested at the study sites, including marked birds and a conservative minimum estimate of the number of unbanded plovers.

### Nest Monitoring

We located nests using methods described by Page et al. (1985) and Stern et al. (1990). We found nests by scoping for incubating plovers, and by watching for female plovers that appeared to have been flushed off a nest. We also used tracks to identify potential nesting areas. We defined a nest as a nest bowl or scrape with eggs or tangible evidence of eggs in the bowl, i.e. egg shells. We predicted hatching dates by floating eggs (Westerkov 1950) and used a schedule, developed by G. Page based on a 29-day incubation period (Gary Page, pers comm). We attempted to monitor nests once a week at minimum. We checked nests more frequently as the expected date of hatching approached. We defined a successful nest as one that hatched at least one egg. A failed nest was one where we found buried or abandoned eggs, infertile eggs, depredated eggs, signs of depredation (e.g. mammalian or avian tracks or eggshell remains not typical of hatched eggs or nest cup disturbance) or eggs disappeared prior to the expected hatch date and were presumed to have been predated. In some instances we found nests with only one egg; often there was no indication of incubation or nest defense, and it was uncertain to what extent the nest was abandoned, or simply a "dropped" egg. Because it was difficult to make this determination, we considered all one egg clutches as nest attempts, and classified them as abandoned when there was no indication of incubation or nest defense. Data recorded at nest checks included:

- nest number
- number of eggs in nest
- adult behavior
- description of area immediately around nest
- whether or not the nest is exclosed
- GPS location

**Brood Monitoring**

We monitored broods during surveys and other field work, and recorded brood activity or males exhibiting brood defense behavior at each site. "Broody" males will feign injury, run away quickly or erratically, fly around and/or vocalize in order to distract a potential threat to his chicks. Information recorded when broods were detected included:

- Number of adults and chicks
- Band combinations of adults/chicks seen
- Sex of adults
- Behavior of adults
- Brood location

**Banding**

Adults were normally trapped for banding on the nest, during incubation, using a lilly pad trap and noose carpets. Lilly pad traps are small circular traps made of hardware cloth with a blueberry net top. The traps have a small door that the plover will enter. Noose carpets are 4" x 30" lengths of hardware cloth covered with small fishing line nooses. Plovers walk over the carpets and the nooses snag their legs. We limited attempts to capture adults to 20 minutes per trapping attempt. Chicks were captured for banding by hand, usually in the nest bowl. Banding was completed in teams of two to minimize time at the nest and disturbance to the plovers.

# APPENDIX Q-11
## Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast
## (Lauten et al., December 2013)

# The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast - 2013

David J. Lauten, Kathleen A. Castelein, J. Daniel Farrar, Melissa F. Breyer, and Eleanor P. Gaines

The Oregon Biodiversity Information Center
Institute for Natural Resources
Portland State University/INR
PO Box 751
Portland, Oregon 97207

December 30, 2013

Submitted to:

Coos Bay District Bureau of Land Management
1300 Airport Way
North Bend, Oregon 97459

Siuslaw National Forest
4077 SW Research Way
Corvallis OR, 97333

U.S. Fish and Wildlife Service
2127 SE OSU Drive
Newport, Oregon 97365
Recovery Permit TE-839094-5

Oregon Department of Fish and Wildlife
3406 Cherry Avenue NE
Salem, OR 97303

Oregon Parks and Recreation Department
725 Summer St. N.E. Suite C
Salem, OR 97301

# The Distribution and Reproductive Success of the Western Snowy Plover along the Oregon Coast - 2013

David J. Lauten, Kathleen A. Castelein, J. Daniel Farrar, Melissa F. Breyer, and Eleanor P. Gaines

Oregon Biodiversity Information Center
Institute for Natural Resources
Portland State University/INR
PO Box 751, Portland, Oregon 97207

## Abstract

From 26 March – 19 September 2013 we monitored the distribution, abundance and productivity of the federally Threatened Western Snowy Plover (*Charadrius nivosus nivosus*) along the Oregon coast. From north to south, we surveyed and monitored plover activity at Sutton Beach, Siltcoos River estuary, the Dunes Overlook, North and South Tahkenitch Creek, Tenmile Creek, Coos Bay North Spit, Bandon Snowy Plover Management Area, New River HRA and adjacent lands, and Floras Lake. Our objectives for the Oregon coastal population in 2013 were to: 1) estimate the size of the adult Snowy Plover population, 2) locate plover nests, 3) determine nest success, 4) use mini-exclosures (MEs) to protect nests from predators as needed, 5) determine fledging success, 6) monitor brood movements, 7) collect general observational data about predators, and 8) evaluate the effectiveness of predator management.

We observed an estimated 304 adult Snowy Plovers; a minimum of 190-191 individuals was known to have nested. The adult plover population was the highest estimate recorded since monitoring began in 1990. We monitored 381 nests in 2013; the highest number of nests since monitoring began in 1990. Overall apparent nest success was 24%. Exclosed nests (n = 18) had an 83% apparent nest success rate, and unexclosed nests (n = 362) had a 21% apparent nest success rate. Nest failures were attributed to unknown depredation, unknown cause, avian depredation, corvid depredation, one-egg nests, wind/weather, abandonment, mammalian depredation, overwashed, infertility, and adult plover depredation. We monitored 101 broods, including eight from unknown nests, and documented a minimum of 103 fledglings. Overall brood success was 71%, fledging success was 39%, and 1.04 fledglings per male were produced.

Continued predator management, habitat improvement and maintenance, and management of recreational activities at all sites are recommended to maintain recovery goals.

**TABLE OF CONTENTS**

## Introduction

The Western Snowy Plover (*Charadrius nivosus nivosus*) breeds along the coast of the Pacific Ocean in California, Oregon, and Washington and at alkaline lakes in the interior of the western United States (Page *et al.* 1991). Loss of habitat, predation pressures, and disturbance have caused the decline of the coastal population of Snowy Plovers and led to the listing of the Pacific Coast Population of Western Snowy Plovers as Threatened on March 5, 1993 (U.S. Fish and Wildlife Service 1993). Oregon Department of Fish and Wildlife lists the Western Snowy Plover as threatened throughout the state (ODFW 2009).

Oregon Biodiversity Information Center (ORBIC, formerly Oregon Natural Heritage Information Center) completed our 24$^{th}$ year of monitoring the distribution, abundance, and productivity of Snowy Plovers along the Oregon coast during the breeding season. In cooperation with federal and state agencies, plover management has focused on habitat restoration and maintenance at breeding sites, non-lethal and lethal predator management, and management of human related disturbances to nesting plovers. The goal of management is improved annual productivity leading to increases in Oregon's breeding population and eventually sustainable productivity and stable populations at recovery levels. Previous work and results have been summarized in annual reports (Stern *et al.* 1990 and 1991, Craig *et al.* 1992, Casler *et al.* 1993, Hallett *et al.* 1994, 1995, Estelle *et al.* 1997, Castelein *et al.* 1997, 1998, 2000a, 2000b, 2001, and 2002, and Lauten *et al.* 2003, 2005, 2006, 2006b, 2007, 2008, 2009, 2010, 2011, and 2012). Our objectives for the Oregon coastal population in 2013 were to: 1) estimate the size of the adult Snowy Plover population, 2) locate plover nests, 3) determine nest success, 4) use mini-exclosures (MEs) to protect nests from predators as needed, 5) determine fledging success, 6) monitor brood movements, 7) collect general observational data about predators, and 8) evaluate the effectiveness of predator management. The results of these efforts are presented in this report.

## Study Area

We surveyed Snowy Plover breeding habitat along the Oregon coast, including ocean beaches, sandy spits, ocean-overwashed areas within sand dunes dominated by European beachgrass (*Ammophila arenaria*), open estuarine areas with sand flats, a dredge spoil site, and several habitat restoration/management sites. From north to south, we surveyed and monitored plover activity at Sutton Beach, Siltcoos River estuary, the Dunes Overlook, North and South Tahkenitch Creek, Tenmile Creek, Coos Bay North Spit (CBNS), Bandon Snowy Plover Management Area (SPMA), New River (extending from private land south of Bandon SPMA to the south end of the New River Area of Critical Environmental Concern (ACEC) habitat restoration area), and Floras Lake (Figure 1). A description of each site occurs in Appendix A. For the purposes of this report and for consistency with previous years' data, we define Bandon Beach as the area from China Creek to the mouth of New River, and Bandon SPMA as all the state land from the north end of the China Creek parking lot south to the south boundary of the State Natural Area south of the mouth of New River.

## Methods

### Abundance

Pre-breeding surveys have been implemented since 2001 to locate any plovers attempting to nest at historic (currently inactive) nesting areas. In 2013, pre-breeding window surveys at historical nesting sites between Clatsop Spit, Clatsop Co. and Pistol River, Curry Co (Elliott-Smith and Haig 2007) were not conducted due to budget restraints. Agency personnel assisted surveying plovers during breeding season window surveys in late May. Breeding season window surveys were implemented at both currently active and historic nesting areas (Elliott-Smith and Haig 2007). Historic nesting areas surveyed in either early spring or during the breeding window survey include: Clatsop Spit, Necanicum Spit, Nehalem Spit, Bayocean Spit, Netarts Spit, Sand Lake South Spit, Nestucca Spit, Whiskey Run to Coquille River, Sixes River South Spit, Elk River, and Euchre Creek. Pistol River was not surveyed in 2013.

**Monitoring**

Breeding season fieldwork was conducted from 26 March to 19 September 2013. Survey techniques, data collection methodology, and information regarding locating and documenting nests can be found in Castelein *et al.* 2000a, 2000b, 2001, 2002, and Lauten *et al.* 2003 and are in Appendix D. No modifications to survey techniques were implemented in 2013.

We report three measures of population size: the total number of Snowy Plovers present, the total number identified breeding, and the total number of plovers resident during the breeding season. We estimated the number of Snowy Plovers on the Oregon coast during the 2013 breeding season by determining the number of uniquely color-banded adult Snowy Plovers observed, and added an estimate of the number of unbanded Snowy Plovers present. We used the 10 day interval method described in Castelein *et al*. 2001 to estimate a minimum number of unbanded plovers, however, based on nesting records and daily observational data this method likely underestimates the actual number of unbanded plovers present. We estimated the breeding population by tallying the number of known breeding plovers. Not all plovers recorded during the summer are Oregon breeding plovers; some plovers are recorded early or late in the breeding season indicating that they are either migrant or wintering birds. Plovers that were present throughout or during the breeding season, whether or not they were confirmed breeders, were considered Oregon resident plovers. We estimated an overall Oregon resident plover population by adding the known breeders with the number of plovers present but not confirmed nesting during the breeding season.

We determined the number of individual banded female and male plovers and the number of individual unbanded female and male plovers that were recorded at each nesting area along the Oregon coast from the beginning to the end of the 2013 breeding season. Data from nesting sites with a north and south component (Siltcoos, Overlook, Tahkenitch, and Tenmile) were pooled because individual plovers use both sides of these estuaries. Data from CBNS nesting sites were pooled for the same reason. We separated data from Bandon SPMA, New River HRA, and Floras Lake because of different management at these sites, despite plovers frequently moving between these areas. The total number of individual plovers recorded at each site indicates the overall use of the site, particularly where plovers congregate during post breeding and wintering. We also determined the number of individual breeding female and male plovers for each site. The number of individual breeding adults indicates the level of nesting activity for each site.

Using all nests, we calculated overall apparent nest success, which is the number of successful nests divided by the total number of nests, for all nests and for each individual site. We also calculated apparent nest success for exclosed and unexclosed nests and used Chi-squared analysis to compare the success of exclosed and unexclosed nests.

Male Snowy Plovers typically rear their broods until fledging. In order to track the broods we banded most nesting adult males, females that tended to broods, and most hatch-year birds with both a USFWS aluminum band and a combination of colored plastic bands. Trapping techniques are described in Lauten *et al*. 2005 and 2006 (Appendix D). We monitored broods and recorded brood activity or adults exhibiting broody behavior at each site (Page *et al*. 2009). Chicks were considered fledged when they were observed 28 days after hatching.

We calculated brood success, the number of broods that successfully fledged at least one chick; fledging success, the number of chicks that fledged divided by the number of eggs that hatched; and fledglings per male for each site.

We continue to review plover productivity prior to lethal predator management activities compared to productivity after implementation of lethal predator management. We specifically continue to evaluate the changes in hatch rate, fledging rate, productivity index, and fledglings per male from years prior to lethal predator management compared to years with lethal predator management. The productivity index is a measure of overall effort based on how many eggs the plovers laid divided by the number of fledglings produced. If plovers produced high numbers of fledglings compared to eggs laid, then their productivity and the resulting index was high for the amount of effort (eggs laid). If plovers produced low numbers of fledglings relative to high numbers of eggs laid, then their productivity and the resulting index was low. Data for brood success, fledging success, and fledglings per male were all normally distributed. We used t-test to compare the mean brood success, the mean fledging rate and the mean number of fledglings per male prior to predator management (1992-2001) to post predator management (2004-2013). We did not include the years 2002 and 2003 in the analysis because three sites (CBNS, Bandon Beach, and New River) had predator management in those years but all other sites did not.

**Exclosures**

From mid-May to August, we used a limited number of mini-exclosures (MEs, Lauten *et al.* 2003) to protect plover nests at South Siltcoos, North Overlook, North Tenmile, Bandon SPMA and New River as outlined in our exclosure use protocol (Appendix C). No exclosures were used on plover nests found during April and into early May due to concerns related to raptor migration (Castelein *et al.* 2001, 2002, Lauten *et al.* 2003). Exclosure use was limited in 2013 because presence of avian predators (Northern Harriers (*Circus cyaneus*) and Great Horned Owls (*Bubo virginianus*)) resulted in concerns about depredations of adult plovers in and around ME's. No exclosures were used at North Siltcoos, South Overlook, North and South Tahkenitch, South Tenmile, and Coos Bay North Spit.

**Predator Management**

Lethal predator management occurred at all active nesting areas; corvids (*Corvus sp*.) were targeted at all nesting sites. Mammal trapping targeting red fox (*Vulpes vulpes*) and striped skunks (*Mephitis mephitis*) occurred at Bandon SPMA and New River (Burrell 2013). In 2011 and 2012 a trapping effort targeting deer mice (*Peromyscus maniculatus*) was conducted at CBNS (Lauten *et al*., 2011 and 2012). In 2013 there was a less extensive effort to trap deer mice on a portion of the habitat restoration area (HRA) by several students from Southwest Oregon Community College. Rodent trapping was limited to March, before the plovers were nesting (Burrell 2013).

## Results and Discussion

### Abundance and Monitoring

#### Window Surveys

During the May breeding window surveys, no plovers were detected outside of the current known nesting areas (USFWS unpublished data). The annual breeding window survey in late May counted 215 plovers (Table 1), the highest number of plovers ever detected.

#### Breeding Season Monitoring

During the 2013 breeding season, we estimated 304 adult Snowy Plovers at breeding sites along the Oregon coast (Table 1). Of 304 plovers, 281 (92%) were banded. The number of unbanded plovers estimated by the 10 day interval method was 23 individuals. For the breeding season we observed 126 banded females, 155 banded males, 14 unbanded females, and 9 unbanded males. The totals include nine banded males and six banded females, all resident or breeding individuals, which disappeared during the breeding season.

Of the total estimated population, 190-191 plovers (63%) were documented nesting (Table 1), below the mean percentage for 1993-2012 (79%). A minimum of 83 banded females and 84 banded males nested. Approximately 14-15 unbanded females nested and nine unbanded males were known to have nested. An additional 42 banded females and 67 banded males were present during the breeding season but were not confirmed nesting. The estimated Oregon resident plover population was 299-300.

The total number of plovers present and the window survey totals were the highest numbers since monitoring began in 1990 (Table 1), though the rate of population increase was smaller than in the recent past. The number of plovers detected breeding declined by approximately 43 individuals (Table 1) due to difficulties positively identifying all nesting individuals. In 2013, many nests failed early in the incubation period, resulting in an inability to positively identify the associated adults. The actual number of breeding individuals was certainly higher as nearly all adults that are resident birds attempt to nest (ORBIC, personal obs.). The number of resident plovers in 2013 was higher than in 2012 (n = 271-278). The number of resident plovers is likely a better index of the estimated number of plovers breeding along the Oregon coast. In 2013, the Oregon coastal plover population was above the recovery goal set for the state (U.S. Fish and Wildlife Service 2007).

#### Overwinter Survival

As has been noted in the past, adult overwinter survival has an important effect on population size (Sandercock 2003, USFWS 2007, Dinsmore *et al*. 2010, Lauten *et al*. 2010, 2011, and 2012). Of the 273 banded plovers recorded in 2012 (corrected from 270 in Lauten *et al.* 2012), 96 (40%) were not recorded in 2013 and we received no reports of these individuals being sighted elsewhere in the range. The overwinter return rate based on returning banded adult plovers was 65%, equal to the 1994-2013 mean of 64.8% but below the previous four years (2009 = 72%, 2010 = 78%, 2011 = 75%, and 2012 = 72%; Lauten *et al*., 2009, 2010, 2011, and 2012).

Based on returns of chicks banded in 2012, we adjusted the 2012 fledgling total to 172 from 180. Ninety-one of the 180 hatch-year plovers from 2012 (HY12) returned to Oregon in 2013. The return rate was 51%, slightly above the average return rate (Table 2, 47%). Of the returning HY12 birds, 40 (44%) were females and 51 (56%) were males. Fifty-one of the HY12 returning plovers were confirmed breeding (56%), and they accounted for 31% of the banded breeding adults. The relatively low rate of confirmed breeding by HY12 plovers was likely due to nests failing early in the incubation period, before monitors could identify nesting adults, and not due to HY12 plovers not attempting to nest. The number of HY12 returns was slightly less than the number of banded adults that did not return in 2013. The average return rates for both adults and hatch year birds contributed to maintaining the plover population, but because the return rates were not above average, the overall plover population did not substantially increase from 2012 (Table 1).

During the 2013 season, we captured and rebanded 18 banded adult plovers with brood band combinations that needed to be updated to unique adult combinations. Thirteen were males and five were females. We banded two unbanded adult male plovers, one unbanded adult female plover and 196 chicks.

**Distribution**

Table 3 shows the number of individual banded and unbanded adult plovers and the number of breeding adult plovers recorded at each nesting area along the Oregon coast in 2013. Sites with high levels of nest loss early in the incubation period resulted in lower numbers of documented breeding plovers. Positive identification of nesting adults increases with nest age because monitors have multiple opportunities to identify nesting adults and because both adults are often present when nests hatch. Five plovers were recorded at Sutton Beach in 2013; there were no plovers recorded at Sutton Beach in 2012. The number of plovers at Siltcoos increased from 67 in 2012 to 91 in 2013. The number of breeding plovers at Siltcoos was similar to previous years (Table 3, 27 in 2012, 26 in 2011, 23 in 2010, and 24 in 2009). Fewer plovers were recorded at Overlook in 2013 compared to 2012 (83 in 2013 compared to 94 in 2012), however the number of breeding adults documented was considerably less (16 in 2013 compared to 51-53 in 2012). More plovers were recorded at Tahkenitch in 2013 (n = 82) compared to 2012 (n = 67-68), however the number of breeding plovers was lower (22 in 2013 compared to 31-32 in 2012). The number of plovers recorded at Tenmile in 2013 increased compared to 2012 (72 in 2013 compared to 58-59 in 2012) and the number of breeding plovers also increased (34-35 in 2013 compared to 20-21). The increase in the number of breeding plovers was related to improved nest success at this site. The number of plovers recorded at CBNS in 2013 was the same as 2012 (n = 92), however the number of breeding plovers declined from 77-78 in 2012 to 52 in 2013. The number of plovers using Bandon SPMA in 2013 slightly increased compared to 2012 (76 in 2013 compared to 68-69 in 2012) and the number of breeding plovers increased (46 in 2013 compared to 29 in 2012). The increase in the number of breeding plovers is partially attributed to higher nest success in 2013 compared to 2012. The number of plovers recorded at New River HRA in 2013 was the same as in 2012 (n = 24). The number of breeding plovers increased from 14 in 2012 to 22 in 2013; the increase in breeding adults was attributed to much higher nest success in 2013 compared to 2012. Only one plover was recorded at Floras Lake in 2013.

We have noted in previous reports that the increased plover population has resulted in plovers occupying available habitat adjacent to the traditional nesting areas (Lauten *et al*. 2010, 2011, and 2012). Lauten *et al*. (2011 and 2012) noted the possibility that the increasing plover population would likely result in plovers occupying additional beaches, such as South Tahkenitch to the Umpqua jetty, the beach north of North Tenmile, and CBNS beach north of the FAA tower. As in 2011 and 2012, plovers did nest north of the North Tenmile spit (Figure 5). At CBNS in 2012, we found one nest north of the FAA towers; in 2013 we found nine nests north of the FAA towers (Figure 6). In 2013 six nests and one brood from an undiscovered nest were found at South Tahkenitch south of Threemile Creek. Plovers and nest scrapes were observed on the beach south of South Tenmile and north of Horsefall Beach, but no nests were found.   The plover population size did not increase substantially between 2012 and 2013 (Table 1).  The increased nesting attempts north of the FAA tower and at South Tahkenitch were mostly due to high nest failure rates; when plovers repeatedly fail they will often move to new locations to renest.  Due to plovers' propensity to nest in subsequent years where they have successfully hatched, and due to the increasing population size, we expect the plovers to continue to occupy and nest on the sections of beach adjacent and between the main nesting sites.

**Nest Activity**

We located 381 nests during the 2013 nesting season (Table 4, Figures 2-9), the highest number of nests found since monitoring began in 1990.  In addition we recorded eight broods from nests that we did not locate prior to hatching.  The increase in the number of nests from 2012 was mostly due to nest failures and therefore repeated renesting attempts.  Sutton had one nest attempt in 2013, the first nest since 2010.  Siltcoos had 11 more nests in 2013 compared to 2012; eight were on the south side (Table 4).  Overlook had a similar number of nests in 2013 compared to 2012.  Tahkenitch had a large increase in nest numbers in 2013 compared to 2012.  There were 16 more nest attempts on the north side of the creek, and for the first time since 2003, plovers were confirmed nesting on the south side of the creek.  The number of plovers and thus the number of nests at Tahkenitch has increased substantially since 2010.  At Tenmile, the north side had a similar number of nests compared to 2012, while the south side had a decrease in the number of nests compared to 2012; in addition four of the broods from undiscovered nests were at North Tenmile.  CBNS had the largest increase in the number of nests; 45 more nests were found in 2013 compared to 2012.  The large number of nests found at CBNS was due to poor nest success and resulting repeated nesting attempts.  South Spoil had similar numbers of nests in 2013 compared to 2012, while the HRAs had an increase of 19 nests.  South Beach also had a large increase in nest attempts (29 more nest attempts in 2013 compared to 2012).  .  Nine nests were found along the open section of beach north of the FAA towers after repeated failed nest attempts either on the nesting area or further south on the beach.  Bandon SPMA had a similar number of nests in 2013 compared to 2012.  There were 44 nests on Bandon Beach and 20 nests on the state portion of New River spit.  The number of nests at New River HRA declined; there were nine nests attempts in 2013 compared to 17 in 2012 and two broods from undiscovered nests were on the New River HRA.  The lower number of nests on the New River HRA was due to increased nest success, as the number of plovers using the New River HRA remained stable.  There were three nests found on private lands along New River, all north of the HRA.  Floras Lake had no nesting activity in 2013.

The first nests were initiated about 26 March (Figure 11).  Nest initiation increased through early May at which time there was a steep decline in nest activity due to nest failure.  Plovers initiated renest attempts in late May into early June, with peak nest activity (n = 109) occurring during the 10 June – 19 June time interval.  This was the highest number of active nests during any 10 day time interval since monitoring began in 1990.  The last nest initiation occurred on 20 July.

**Nest Success and Exclosures**

The number of days nests were unexclosed was higher than the number of days nests were exclosed (Figure 12).  In 2013, exclosures were used on 5% (n = 19) of the total number of nests (n = 381), and 6% of the total number of exposure days were exclosed (n = 253/4548).

The overall annual apparent nest success rate in 2013 was 24% (Table 5), the lowest rate since monitoring began in 1990 (Table 6).  Nineteen nests were exclosed in 2013 (5%), the fewest since 1991.  Apparent nest success for exclosed nests in 2013 was 83%, higher than the average for all years ($x$ = 71%,

Table 6). The number of unexclosed nests in 2013 (n = 362, 95%) was the highest since monitoring began. Apparent nest success for unexclosed nests in 2012 was 21%, near the overall mean ($x$ = 20%, Table 6). Nest success of unexclosed nests in 2013 was significantly lower than nest success of exclosed nests ($\chi^2 = 32.6931$, df = 1, $P < 0.01$).

**Sutton**

There was only one nest at Sutton Beach in 2013 early in the season (Table 5). Two eggs were laid but incubation was not confirmed before it failed quickly due to unknown cause (Table 7). There was no other plover activity at Sutton after April.

**Siltcoos**

No exclosures were used at North Siltcoos in 2013 (Table 5); three of 13 nests successfully hatched (23%). Two exclosures were used at South Siltcoos, and three of 28 unexclosed nests successfully hatched (12%). Overall nest success for Siltcoos was 19% (Table 5), well below the average for these sites (Figure 13). The main cause of nest failure at Siltcoos was unknown cause and unknown depredation (Table 7). Corvid activity at Siltcoos was considered moderate with crows being more prevalent at North Siltcoos and ravens present early and late in the season. One nest was depredated by a Northern Harrier based on tracks at the nest site, and harrier activity was regularly noted. Due to raptor activity and concerns about adult plovers in and around exclosures, we limited the use of exclosures at Siltcoos.

**Overlook**

The overall nest success at Overlook in 2013 was 5% (Table 5). Three of 33 nests hatched at North Overlook (9%) and no nests were successful at South Overlook (Table 5), both well below average for these sites (Figure 13). Only one nest was exclosed at Overlook, on the north side, and it failed after the adult male associated with the nest disappeared. We found raptor tracks around the exclosure, which we believe were Northern Harrier, leading us to conclude the male was depredated. One nest at South Overlook failed with evidence of Northern Harrier at the nest site, and another nest at South Overlook also had evidence of an avian predator but we were uncertain if it was harrier or corvid. Seven total nests failed due to corvids and 36 other nests failed to unknown depredation (Table 7). Six other nests failed due to unknown cause. Six of the seven corvid depredated nests occurred prior to 15 May, before implementation of exclosure use. After 15 May corvid activity was not considered high, but harrier activity was consistently observed. Due to the evidence that harriers were regularly hunting the nesting area, we did not erect exclosures.

**Tahkenitch**

Plover activity continued to increase at Tahkenitch since 2009 (Table 4). There was an increase in the number of nests at North Tahkenitch, but this was due to poor nest success. Only six of 52 nests hatched at North Tahkenitch (12%, Table 5), much lower than the average for this site (Figure 13). Due to nest failures, plovers moved south of the creek and for the first time since 2003 nests were found at South Tahkenitch. Six nests and one brood from an undiscovered nest were found at South Tahkenitch; only one of the nests hatched (17%). The main cause of nest failure at North Tahkenitch was unknown cause and unknown depredation (Table 7). Five nests failed to avian depredation, including three that had evidence of Northern Harrier (at one nest a harrier was filmed depredating the nest). We did not document any corvid depredations at North Tahkenitch. Northern Harrier activity was noted at North Tahkenitch throughout the season. Due to the harrier activity, we did not erect exclosures. In July, we received reports that plovers were nesting along the South Tahkenitch creek area, as far south as Three Mile Creek. A brood was discovered already hatched well south of the Threemile Creek area, and six more nests were found, including one as far south as the south end of Threemile Lake. Raven activity was high in the area (partly due to a large sea lion carcass); two of the nests were found already depredated by ravens and three others failed the day after discovery.

**Tenmile**

For four of the past five years Tenmile has had relatively poor nest and hatch success (Table 15). In 2013, Tenmile had an overall nest success rate of 42%, much higher than in 2012 (13%). Nine of 19 nests successfully hatched at North Tenmile (47%), above the average for this site (Figure 13). Six of 17 nests hatched at South Tenmile (35%), much higher than in 2012 (7%) but below the average for this site (Figure 13). The main causes of nest failure at Tenmile were unknown cause, corvid depredation, and unknown depredation (Table 7). We used only two exclosures at North Tenmile. Exclosure use was minimized due to previous issues with Great Horned Owls at Tenmile targeting plovers around exclosures (Lauten *et al*. 2011). In 2013 Great Horned Owl tracks were noted throughout the season, most often on at South Tenmile. Successful removal of ravens at Tenmile in 2013 contributed to the improved nest success (Burrell 2013). Fewer corvids reduces the need for exclosures, and thus reduces the threat of adults being depredated near exclosures.

**Coos Bay North Spit**

At CBNS in 2013 overall nest success was 27% (Table 5). Nest success on the HRAs was 17% and on South Spoil was 33%, both well below average (Figure 13). Nest success was better on South Beach (42%), but still below average (Figure 13). Of the nine nests north of the FAA towers, only one hatched. Many renest attempts due to low nest success contributed the high number of nests. The main cause of nest failure was unknown depredation (Table 7), however 15 nests were confirmed depredated by Northern Harrier (either video evidence or tracks at the nest site). This is the first year we have confirmed harrier depredations of nests. We suspect that most if not all of the unknown depredations at CBNS were caused by harriers because corvid activity was very low to non-existent all summer. We did not erect any exclosures because we were concerned that the harriers would target and depredate adult plovers. Seven adults disappeared from CBNS this summer, however we cannot be certain these were harrier depredations .Wildlife Services removed two harriers from CBNS, but it was towards the end of the nesting season (Burrell 2013). We hope the removal of these harriers will result in future benefits and better nest success in the coming year.

**Bandon SPMA**

Nest success at Bandon SPMA in 2013 was 33%, much higher than in 2012 (14%) but below the average for this site (Figure 13). Only seven nests of 44 hatched (16%) on the north side of New River (from north of China Creek south to the mouth of New River); 15 of 20 nests hatched on the south side of the New River mouth (75%). Eight total exclosures were erected; four on the north side and four on the south side. Of the four nests that were exclosed on the north side, three successfully hatched, however, a male associated with one of the exclosed nests and one of the chicks disappeared upon hatching. The female successfully raised one of the two remaining chicks. We suspect the male and first chick were depredated near the exclosure when the nest hatched. The fourth exclosed nest was found with one hatched chick and two hatching eggs, but the adults disappeared at hatching and we suspect they were depredated. We collected the hatched chick and two eggs, which were then transported to the Oregon Coast Aquarium (OCA) in Newport, where the eggs were hatched and the three chicks raised to fledge age. They were later released at the New River spit. We did not include this nest in our calculations of nest success in Table 5 since the nest only partially hatched in the field. The cause of the depredations was not known, however we repeatedly noted Great Horned Owl tracks at Bandon SPMA all summer, and we noted both Northern Harriers and Peregrine Falcons hunting the SPMA. Three of the four exclosed nests on the south side hatched; the nest that did not hatch was infertile. The main cause of nest failure was unknown cause and unknown depredation (Table 7). Corvid activity at Bandon SPMA in 2013 was relatively low; however at least three nests were depredated by corvids (all on the north side). In late April, at a time when corvid activity was low and plover nests had been relatively successful, Wildlife Services found a dog running unattended on the nesting area north of the New River mouth. Within days, we found eight of 11 the nests failed, with several eggs removed from the nest bowl but not eaten, and missing eggs at other nests. Poor weather conditions prevented us from determining a cause of these failures, but we suspect the lost dog may have been responsible. We have rarely noted predators leaving or removing eggs from nests without depredating them.. Due to concerns about raptors, and a lack of corvid activity, we minimized the use of exclosures in 2013.

**New River**

Overall nest success on non-state lands at New River in 2013 was very good with two of three nests successfully hatching on private lands (67%) and seven of nine nests successfully hatching on the BLM HRA (78%, Table 5), above the average for this site (Figure 13). One nest was exclosed on private land and five nests were exclosed on the HRA; five of these six nests hatched (83%). Four of six unexclosed nests also hatched (67%). Three nests failed, one to infertility and two to unknown depredation (Table 7). We did not document any adult mortalities around exclosed nests at New River in 2013. Corvid activity, particularly ravens, was fairly consistent until mid to late season when activity was minimal.

**Nest Failure**

Exclosed nests in 2013 had an overall failure rate of 17% (3 of 18, Table 8; one nest from Bandon SPMA is not included because the hatched chick and two unhatched eggs were transported to the OCA when adults disappeared at hatching and were presumed depredated). Of the three failed exclosed nests, two failed to infertility and one had an adult plover depredated and was subsequently abandoned (Table 8). The number of unexclosed nests that failed in 2013 (n = 285) was higher than any previous year. The failure rate of unexclosed nests in 2013 (79%) was higher than in 2012 (58%) and 2011 (54%) but similar to 2008 – 2010 (73%, 73%, and 77% respectively). In 2013, the main causes of nest failure for unexclosed nests were unknown depredation, unknown cause, avian depredation, and corvid depredation (Tables 8). Additional causes of nest failure included one-egg nests, wind/weather, abandonment, mammalian depredation, overwashed, infertility, and adult plover depredation (Table 7).

**Predator Management**

There was a limited effort to trap rodents at CBNS in 2013; 26 deer mice were captured during March (Burrell 2013). It remains unclear whether the rodent trapping has had any real effect on nest success. In the previous two years over 200 rodents were trapped at CBNS (Burrell 2011 and 2012). During these years nest success at CBNS was high (82% in 2011 and 87% 2012; Lauten *et al*., 2011 and 2012). In 2013, despite the limited trapping effort, only two nests on the CBNS HRA had evidence that rodents caused the nest failures (Table 7). Continuing rodent trapping and removal in the future would at a minimum help us gauge and understand rodent population levels and cycles at CBNS.

In the past, corvid depredations have been the main cause of known nest depredations (Stern *et al.* 1990 and 1991, Craig *et al.* 1992, Casler *et al.* 1993, Hallett *et al.* 1994, 1995, Estelle *et al.* 1997, Castelein *et al.* 1997, 1998, 2000a, 2000b, 2001, and 2002, and Lauten *et al*. 2003, 2005, 2006, 2006b, 2007, 2008, 2009, 2010, 2011, and 2012). In 2013, the main known causes of nest failure were avian depredation and corvid depredation (Table 7). Corvids continue to be the most serious threat to plover nests, however in 2013 for the first time we identified Northern Harriers depredating nests. We identified 20 nests that had either harrier prints at the nest site or harriers were captured on remote cameras depredating nests (Table 7). Known harrier depredations occurred at CBNS and from South Siltcoos to North Tahkenitch. At CBNS 15 nests had positive evidence of harrier depredations (either tracks or pictures from cameras), and because corvids were not present at CBNS during this time, suspect that the majority of nests that failed to unknown depredation (n = 38) were likely from harrier. On Forest Service land, one nest at South Siltcoos, two nests at South Overlook, and five nests at North Tahkenitch had positive evidence of harrier depredation. We suspect that some of the unknown depredations particularly at Overlook and North Tahkenitch were caused by harriers. It is possible, despite the distance between South Siltcoos and North Tahkenitch, that the same individual harrier was causing these nest failures. Harriers have been identified depredating plover nests in the Monterey Bay area both in the past and in 2013 (G. Page, pers. comm.) as well as at the San Francisco Bay National Wildlife Refuge (Demers and Robinson-Nilsen 2012). Many depredations attributed to harriers at both CBNS and Forest Service occurred shortly after initiation, indicating that the harriers were very efficient at finding and depredating nests. Burrell (2013) documents Wildlife Services' response and efforts to capture and remove the harriers, particularly from CBNS and North Tahkenitch. At CBNS a female harrier was photographed depredating four plover nests; this female was targeted and removed. Another harrier, a juvenile, was also eventually removed from CBNS. No harriers were removed from Forest Service lands. We are hopeful that the removal of the individual suspected to be causing nest depredations at CBNS will result in improved nest success next season. On Forest Service lands we suspect the harriers will continue to depredate nests. We are also concerned that higher nest densities of plovers on the nesting areas may result in continued attraction of harriers and other potential nest and plover predators (such as Great Horned Owl).

Predator management continues to have a positive effect on reducing corvid numbers at all sites and removing non-native red fox from the Bandon SPMA and New River area. Corvids are an annual problem at all sites. In 2013, Wildlife Services was funded to support three agents, allowing them to more completely cover the occupied nesting sites and provide more effective predator management. We believe this had a positive effect on the plover reproductive success. See Burrell (2013) for a complete discussion of the predator management program.

**Fledging Success and Productivity**

There were a total of 101 broods in 2013 (Table 11), however two broods were not included in productivity data because both broods were transported to the OCA and later release at fledge age. We monitored 99 broods in the field including 8 broods from undiscovered nests, substantially fewer than in 2012 (n = 154 broods, Lauten *et al*. 2012). We confirmed a minimum of 98 fledglings from the 99 broods (Table 11), and a total of 103 fledglings including the five chicks raised at the OCA (Table 9). Overall fledging success was 39%, near the overall average (Table 10). The overall brood success rate was 71% (Table 11), slightly higher than the average (67% +/- 10). The overall number of fledglings per male was 1.04 (Table 11). Considering data from known nests from Siltcoos to New River only (Tables 12-18), the mean fledglings per male was 0.926, below the average (Table 10). We caution that due to many nests failures, and due to the relatively short time many nests were active before failing, we undoubtedly failed to identify all the males that attempted to nest in 2013. As noted above, the documented number of breeding individuals was much lower than the number of resident individuals, indicating that the true number of breeding individuals was higher than the number we positively identified breeding. The failure to identify all known breeding males biases the number of fledglings per male; we believe that the number of fledglings per male is high and would likely be lower if all males who attempted to nest were successfully identified.

**Siltcoos**

There were nine broods at Siltcoos in 2013 (Table 11), half the number of broods as in 2012 (Lauten *et al*. 2012); 44% of the broods were successful compared to 61% in 2012. More eggs were laid in 2013 compared to 2012 (Table 12), however the hatch rate was considerably lower than in 2012 and well below the post predator management average. Only four chicks fledged from known nests in 2013, resulting in the lowest fledge rate at Siltcoos since 2002, well below the post predator management average. Due to the high number of eggs laid and the low number of fledglings produced, the productivity index for Siltcoos in 2013 was extremely low, indicating poor productivity for this site. The number of fledglings per male was well below 1.00 and well below the post predator management average for this site (Table 11 and 12).

**Overlook**

The number of eggs laid at Overlook in 2013 was similar to the previous two years (Table 13), however only nine eggs hatched resulting in the lowest hatch rate ever and well below the post predator management average. There were only three broods at Overlook (Table 11) substantially fewer than the previous two years (n = 31 broods in 2012, n = 33 broods in 2011). Two of the broods were successful and they fledged three chicks (Table 11 and 13). The fledging success rate was well below the post predator management average (Table 13). Due to the high number of eggs laid but few fledglings produced, the productivity index was extremely low, indicating poor productivity for this site. The number of fledglings per male was well below 1.00 and below the post predator management average for this site (Table 11 and 13).

**Tahkenitch**

The number of eggs laid at Tahkenitch was the highest number since monitoring began at this site in 1993 (Table 12), however only 14 eggs hatched resulting in a very low hatch rate well below the post predator management average. Of the nests that hatched, broods were very successful (Table 11) and the fledgling success rate was well above the post predator management average for this site (Table 14). However, the number of fledglings was considerably less than the previous two years (Table 14), and due to the high number of eggs laid, the productivity index was very low, indicating that there was much effort at this site (as measured by the number of eggs laid) but poor productivity (as measured by the total number of fledglings produced). The number of fledglings per male was higher than the post predator management average (Table 14), however this is based on only identifying five males from known nests. Due to the high number of nests at Tahkenitch (Table 4), there were undoubtedly many more males who attempted to nest at Tahkenitch but were not positively identified.

**Tenmile**

Productivity at Tenmile improved by all measures in 2013 and was substantially better than the previous two years (Table 15). The number of eggs laid was slightly less than the previous four years, however the hatch rate was much higher than the previous two years and was near the post predator management average (Table 15). There were 19 total broods, 13 more than in 2012, and brood success was high (Table 11). Twenty-three total fledglings were produced including 19 from known nests, the highest number of fledglings produced at Tenmile since 2007. The fledging success rate was 51%, above the post predator management average (Table 15). The productivity index was 20%, higher than the previous five years and above the post predator management average (Table 15). The number of fledglings per male was above the post predator management average (Table 15).

**Coos Bay North Spit**

Due to high nest failure rates (Table 5), the number of eggs laid at CBNS in 2013 was the highest ever for any year or any individual site (Table 16). The hatch rate was considerably lower than the previous two years, similar to 2010 when the lowest rate ever was recorded for this site, and well below the post predator management average (Table 16). There were 29 total broods at CBNS in 2013, nearly half the number recorded in 2012 (n = 58; Table 11). Brood success was very poor on the South Spoil and the HRAs, however was much better on South Beach (Table 11). Fledging success was also very poor on South Spoil and the HRAs (Table 11); the overall fledging success rate was the lowest ever recorded for CBNS, and substantially below the post predator management average (Table 16). Due to the high level of effort and relatively low number of fledglings, the productivity index was the lowest ever recorded for this site and well below the post predator management average (Table 16). The number of fledglings per male for CBNS was below 1.00 for the first time and well below the post predator management average (Table 16).

**Bandon SPMA**

The number of eggs laid at Bandon SPMA was the highest ever for this site (Table 17). The hatch rate improved from 2012 but was still low and slightly below the post predator management average (Table 17). We monitored 21 broods at the SPMA (not including one brood raised at the OCA and later released), nearly double the number of broods compared to 2012 (n = 11), and they had a very good brood success rate of 71% (Table 11). The fledging success rate was slightly above the post predator management average (Table 17). Despite the improved hatch rate and relatively good fledging success rate, the productivity index was low due to the high number of eggs laid, and was below the post predator management average (Table 17). The number of fledglings per male was near the post predator management average (Table 17), and just below the recovery goal.

**New River**

The number of plovers recorded at the New River HRA and adjacent areas remained similar to 2012 (Table 3; in 2012 n = 24), however the number of eggs laid at this site declined (Table 18). The decline in the number of nests (Table 4) and the number of eggs laid was due to an increase in nest success, and the number of eggs hatched in 2013 and was much higher than the post predator management average (Table 18). The high nest success and hatch rate resulted in fewer nest attempts and therefore a reduction in the number of eggs laid. Brood success was also very good in 2013 (Table 11), and overall fledging success was higher than the post predator management average (Table 18). Due to the number of fledglings produced at New River in 2013, the productivity index was very high and well above the post predator management average. The number of fledglings per male was over 1.00 for the first time since 2009 and above the post predator management average (Table 18).

Post predator management hatch rates declined for Overlook, Tenmile, CBNS, Bandon SPMA, and New River HRA while remaining stable at Siltcoos and Tahkenitch (Table 19). The decline in hatch rates is attributed to the decreased use of exclosures (Figure 12); unexclosed nests have a lower nest success rate than exclosed nests (Table 6). The post predator management average brood success rate (2004-2012, 72.1%) was significantly higher than the average pre predator management brood success rate (1991-2001, 62.9%, t-stat = 2.42, df = 19, $P = 0.01$). The overall mean post predator management fledging success rate (0.46) was higher than the mean pre predator management fledging success rate (0.39, t = 1.60, df = 18, $P = 0.06$). The post predator management fledging success rate has improved for Siltcoos, Overlook, Bandon SPMA, and New River and has remained relatively stable at Tahkenitch and CBNS (Table 19). Tenmile has decreased but was still within acceptable levels. The overall post predator management mean number of fledglings per male (2004-2012; $x = 1.25$) was significantly higher than the pre predator management mean number of fledglings per male (1992-2001; $x = 1.06$, t = 1.91, df = 18, $P = 0.04$). The mean number of fledglings per male has improved at all sites except Tenmile where it has remained relatively stable (Table 19). The overall productivity data has generally improved since the implementation of predator management, and we continue to recommend that predator management be funded, as this is critical to increasing and maintaining the plover population.

**Brood Movements**

**Siltcoos, Overlook, and Tahkenitch**

Plovers (both nests and broods) continue to occupy the beaches between South Siltcoos and North Overlook and South Overlook and North Tahkenitch (see Figures 3-5; Lauten *et al*. 2009, 2010, 2011, and 2012). Due to increasing plover numbers and high nest failures in 2013, plovers also occupied the beach at South Tahkenitch south of Threemile Creek. Since plovers were successful at both nesting and brood rearing along these lengths of beach, we would expect plovers to continue to occupy these areas in the future.

Only one of three broods at North Siltcoos in 2013 was successful, and that brood remained on the spit and within the nesting area for the duration of the brood rearing period. There were six total broods from South Siltcoos, and three were successful (Table 11) including one brood from an undiscovered nest. One of the successful broods hatched on the roped nesting area at South Siltcoos and moved south to the Carter Lake trail area within three days of hatching and then was found at South Overlook six days after hatching. The brood from the undiscovered nest also moved from South Siltcoos to North Overlook over an eight day period.

Two of three broods were successful from North Overlook. One brood hatched on the beach north of North Overlook and remained on the beach until fledged. The other successful brood hatched at the south end of North Overlook and seven days later was noted at South Overlook. The brood remained at South Overlook until fledged.

There were five broods from North Tahkenitch, four from the nesting area and one that hatched along the beach north of the nesting area. The brood that hatched along the beach north of the nesting area stayed along the beach until fledged. One of the broods from the nesting area was confirmed fledged at South Overlook. Two broods remained on the nesting area; one of these broods hatched at the south end of the spit and spent most of the brood rearing period at the north end of the HRA. The fifth brood failed within two days of hatching. There were two successful broods from South Tahkenitch, one from an undiscovered nest. Both of these broods were located in the Threemile Creek area and remained in this area. This area is open to motor vehicle use. Forest Service roped the area and the broods remained in and around the roped section of beach.

**Tenmile**

Of the 13 broods from North Tenmile in 2013, four, including three broods from undiscovered nests, originated on the beach north of the HRA. Three of these broods were successful; two remained on the beach north of the HRA and one of the broods moved south to the HRA. Three broods that originated on the HRA moved north along the beach up to a half mile during the brood period. Most broods that originated on the HRA remained on the HRA and the adjacent spit area. At South Tenmile, all broods originated on the HRA or the beach adjacent to the HRA. Only one brood moved south of the HRA along the beach but remained within the closed area; all other broods remained on or adjacent to the HRA.

**Coos Bay North Spit**

At CBNS in 2013 only one of four broods from the South Spoil and two of 10 broods from the HRAs were successful. The one brood from South Spoil moved west to the 94HRA and 98EHRA where it remained for the brood period. Both broods from the HRAs originated on the 95HRA; one brood remained on the 95HRA until it fledged. The other brood, which hatched early in May, moved immediately to the beach and remained there until it fledged. There was very poor success of broods from South Spoil and the HRAs in 2013 (Table 11). There is no data as to the cause of brood failures due to the difficulty assessing when and why chicks do not survive; however, nest failure data and observational data indicated that Northern Harriers were present on a regular basis. It is possible that harriers were depredating broods as well as nests. In 2013 both the berms along the foredune road and the foredune itself have become wide and covered in dense beachgrass. The dense vegetation prevents brood movement between the east side of the foredune road and the west side, and also from the 95HRA to the beach. Food resources for broods are best on the beach. We believe improving habitat to enhance brood movement west towards the beach would benefit brood and chick survival. We recommend that openings in the berms along the foredune road be created and maintained each season and the width of the berms be reduced to eliminate some of vegetation. We also recommend that pathways be created through the foredune to permit easy access to the beach by broods and some vegetation be removed from the east side of the foredune to reduce the width. We recognize that destabilizing the foredune is not acceptable; therefore we recommend just removal of the top vegetation without lowering the foredune.

Broods on South Beach were much more successful than broods originating from the nesting area (Table 11). Twelve of 15 broods were successful. All broods hatched within the closed area except one brood that hatched just south of access point 2, well north of the FAA towers. This brood failed within a week of hatching. Another brood that hatched near the FAA towers but just south of I-beam also failed within a week of hatching. Seven broods hatched at the far south end of the beach north of the I-beam near the jetty. Three of these broods used the jetty area throughout the brood period including the area open to motor vehicles south of the I-beam to the jetty. Two of these broods repeatedly were noted along the jetty and around the parking area at the base of the jetty. One of the broods was found on the foredune road; one chick was found along the edge of the foredune road near the bay beach. This chick was picked up and returned by monitors to the beach; it was later confirmed fledged. All the remaining broods remained within the closed section of beach.

**Bandon SPMA**

There were six broods, four of which were successful, on the north side of New River at Bandon SPMA. One brood hatched early in the season on the north side of China Creek. The male and one chick remained on the north side of the creek for the first two weeks. The male then disappeared; he was a resident Bandon SPMA bird and we believe he may have been depredated. The chick remained on the north side of the creek by itself until it was fledged. One brood hatched along the west edge of cutout 3 and spent the brood period wandering the beach from the China Creek overwash area south to the area around cutout 3. A third brood hatched along the foredune south of cutout 3. The male and one chick disappeared at hatching; we believe the male was depredated. The female brooded the remaining two chicks, eventually moving south and spending most of the brood period along the south end of the HRA south of the I-beam. She fledged one chick. The fourth brood hatched on the HRA and remained on and adjacent to the HRA for the brood period.

There were 15 broods that originated on the south side of the mouth of New River at Bandon SPMA; 11 were successful. Fourteen of the 15 broods hatched on the north end of the spit; one brood hatched near the southern boundary of the SPMA. Eight of the broods that hatched at the north end of the spit remained on the north half of the spit. Two other broods from the north end of the spit crossed New River and raised their broods on and adjacent to the HRA. The brood that hatched near the southern boundary of the SPMA quickly moved his brood south to just north of the BLM HRA. He remained in this area and successfully fledged one chick.

**New River**

There were two broods that hatched on private land. One brood hatched on Michael Keizer's property just south of the Bandon SPMA. This brood stayed in this vicinity, using both the overwashes and the river side, and eventually at fledge age was noted on the New River spit portion of the Bandon SPMA. A second brood that nested on the beach adjacent to private land between Keizer's property and the BLM HRA moved north along the beach and was noted on near the southern boundary of the Bandon SPMA. The brood was confirmed fledged on the New River spit portion of the Bandon SPMA. Eight of nine broods that originated on the BLM HRA successfully fledged. One brood that hatched along the north end of the HRA disappeared after the first week of the brood period and was later confirmed fledged on the New River spit portion of the Bandon SPMA. We believe the brood had moved north during the brood period and may have even been using the river. Three broods originated north of Croft Lake breach; two broods remained on the HRA and along the beach north of Croft Lake and one brood eventually moved just north of the HRA and fledged. One brood originated north of New Lake breach and moved south, spending the brood period between New Lake and Hammond breaches. Three broods originated south of New Lake breach and remained in this area for the brood period.

**Sightings of Snowy Plovers Banded Elsewhere**

Fifteen adult plovers banded in California were observed in Oregon in 2013. Six were females and nine were males. Nine of the 15 plovers were known to have nested in Oregon in 2013. Four females were confirmed nesting and two were present during the breeding season and may have attempted to nest but were not confirmed. Five males were confirmed nesting and three others were present during the breeding season and may have attempted to nest but were not confirmed. One male arrived post breeding season. Four females and five males originally hatched in Oregon and were subsequently rebanded at coastal nest sites in California. Six other plovers, two females and four males, were originally banded in California. One female was banded as a hatch year 2006 from Humboldt Co. and has been nesting at Bandon Beach and New River since 2007; the second female was banded in 2010 in Humboldt Co. and nested in Oregon in 2011, 2012, and 2013. Of the four California originated males, one was a hatch year 2004 bird from Salinas, Monterey Co., that has been present at New River since 2005 and successfully nested at New River in 2013; one was a hatch year 2010 plover from Moss Landing Salt Ponds, Monterey Co., who nested at Bandon SPMA in 2013; one was a hatch year 2010 bird from Oceano Dunes, San Luis Obispo Co., that was confirmed nesting in 2012 but we did not confirm nesting in 2013; and one was a hatch year 2011 bird from Centerville, Humboldt Co. who arrived at the end of July and was present in August at Bandon SPMA.

## Habitat Restoration and Development Projects

**Sutton**

Beachgrass hummocks were mechanically treated on the Sutton Beach HRA in the winter of 2012-13. Some oyster shell was manually spread on the HRA. In addition, 3.8 miles of beach cleanup was conducted at Baker Beach with the help of the Emerald Empire Back Country Horseman group. Twenty five participated in this event and collected 920 pounds of trash.

**Siltcoos**

At Siltcoos in winter 2012-13, 3 acres of beachgrass was hand pulled by the Northwest Youth Corp on the south side of the estuary in winter 2012-13. Beachgrass hummocks near areas covered by oyster shell were mechanically treated. Some oyster shell was spread on the south side of the estuary. No work occurred on the north side of the estuary due to the Siltcoos River moving north during the winter and losing most of the HRA on the north side.

**Overlook**

At Overlook, 20 acres of beachgrass and hummocks were mechanically treated in winter 2012-13. Some oyster shell was spread on both the north and south side.

**Tahkenitch**

At Tahkenitch, 19 acres of beachgrass and hummocks were mechanically treated in winter 2012-13. Some oyster shell was spread on the HRA.

**Tenmile**

At Tenmile, 12 acres of beachgrass hummocks were mechanically treated on the north side in the winter of 2012-13. Some oyster shell was spread on North Tenmile.

**Coos Bay North Spit**

The 95HRA and 98EHRA at CBNS were disked once in November 2012 and once in February 2013 to limit the amount of invasive beachgrass on all BLM HRAs. Shell hash was purchased from Coos Watershed Association, cleaned of debris, and applied to 6 acres in the 98EHRA and 95HRA to provide improved nesting habitat.

Before the disking occurred in the fall 2012, a botanist collected seeds of sensitive species to be used for restoration work in other coastal areas. Approximately 300,000 pink sandverbena (*Abronia umbellata breviflora*) seeds were collected and spread at other coastal sites. (J. Sperling, pers. com.) In October 2012, the Youth Corp spent 40 hours at the north spit pulling non-native sea rocket, sour dock and dandelion.

There was only limited disking of the 94HRA and South Spoil on ACOE lands.

**Bandon SPMA**

At Bandon SPMA, OPRD conducted maintenance actions on approximately 62 acres of habitat in winter 2012-13. All four cutouts along the foredune were bulldozed and treated with glyphosate. Five acres on the HRA north of the mouth of New River were bulldozed. On the south side of the mouth of New River approximately 58 acres were treated with glyphosate and imazapyr.

**New River**

At New River in winter 2012-13, 15 acres of the HRA were bulldozed between New Lake breach and Croft Lake Breach.

## Recommendations

**Signing of Restricted Areas**

Signing and roping for the 2014 nesting season should again be implemented to inform the public of plover nesting habitat and direct the public away from the nesting areas. Ropes and signs should be installed as early in the season as practical so a clear, consistent message is conveyed to the public throughout the nesting season and between years, and so that the closed sections of beach are adequately protected throughout the season. Installing ropes and signs at the beginning of the season also reduces the need to respond to individual nests that are within closed beach sections but are not roped and signed. This reduces the disturbance to those nests when ropes and signs have to be installed after a nest is found. High tides early in the season often make posting areas a challenge, and while it is important to have signs in place beginning on 15 March, in areas where the ocean is regularly lapping against the foredune, signs should not be erected or placement should be delayed. Maintenance of signs is important to keep violations to a minimum. To maximize the effectiveness of signs and ropes, each site should continue to be evaluated and ways to improve the signing and ropes should be considered.

**General Recommendations**

Below are general recommendations. We also provide additional site-specific comments and management recommendations in Appendix B.

Maintaining, improving, and expanding the nesting areas is essential to maintaining a healthy and sustainable plover population. Despite years of treatment, European beachgrass continues to annually resprout resulting in degraded nesting habitat. When new habitat is created, such as the cutouts at Bandon SPMA (Lauten *et al*., 2011), it is important to annually maintain the habitat or it quickly degrades resulting in reduced plover use. With an increasing plover population, any reduction in available nesting habitat can result in high nest densities which may attract predators or result in plovers nesting in sub-optimal habitat, where predation or disturbance from recreational activity is more likely. Increased nest density could lead to increased nest depredations. Increased chick numbers on the landscape may attract additional avian predators (Neuman *et al*. 2004). Expansion of the nesting areas would increase the available habitat for plovers and could help alleviate predation pressure. Creation of cutouts along sections of beach that have nesting plovers but no nesting area behind the foredune would give the plovers safe areas to nest and brood away from recreational activity on the beach. We continue to support additional shell hash on any nesting area as it has proven to be a beneficial management technique. We continue to recommend that additional habitat be created and maintained at South Overlook, North Tenmile, Bandon SPMA and New River HRA. We support any efforts to find new and effective treatments of European beachgrass that could result in reduced resprouting, less density of beachgrass, and ultimately reduced maintenance costs.

We recommend increased use of cameras to help document causes of nest failure and to positively identify individual raptors that are preying on plovers so land management agencies can effectively manage this threat. We recommend monitoring staff and Wildlife Services staff continue to document raptor activity in and around the nesting areas.

Continued efforts to educate the public about the OPRD Habitat Conservation Plan (ICF International 2010) and beach rules will be essential both before and during the nesting season. Staff dedicated to recreational monitoring and volunteers continue to help reduce violations and educate the public about plovers and dog related issues, and we recommend that these aspects of management continue and be funded. At Siltcoos and Bandon Beach where parking lots and recreational activities are adjacent to nesting plovers, monitoring by staff and volunteers is essential to improving plover success and reducing disturbance issues.

- Continue breeding season monitoring; continue monitoring plover populations and productivity to ensure recovery goals are maintained.
- Maintain, enhance and expand habitat restoration areas. Spread shell hash to enhance nesting substrate.
- Selectively use mini-exclosures in conjunction with predator management to reduce the risks to nests and adult plovers, decrease the time monitors spend around individual nests, and decrease disturbance to plovers. Determine exclosure use dependent on predation pressure, density of plover nests, and nest locations.

- Expand use of cameras to help determine causes of nest failures; coordinate with Wildlife Services to set up and maintain cameras.
- Increase and/or maintain predator management at all sites and explore ways of better understanding the activity patterns and population levels of predators, particularly corvids. Fully fund three Wildlife Services employees.
- Continue to coordinate with federal and state agency employees regarding time frames of any habitat management work to be completed to minimize disturbance to nesting activity and broods.
- Coordinate agency activities in restricted areas with plover biologists to minimize disturbance to nesting and brood rearing.
- Continue and explore ideas to document and monitor human disturbance by various recreational users in plover nesting areas.
- Continue to expand and refine volunteer efforts to monitor recreational use.
- Design educational programs to inform and educate the local communities and annual visitors about plover issues.
- Design informative/interactive presentations for school children.

## Acknowledgments

We would like to thank Micah Bell, Zack Perdue, Jeremiah Psiropoulos and Mike Burrell of Wildlife Services for their assistance in the field and thoughtful insight about predators; RJ Rapelje, and Trisha Wymore of OPRD for their hours educating the public and monitoring recreational activity on the beach; Morgan Bell and Theresa Bolch of BLM for their diligence monitoring recreational activity at CBNS; Grace Larsen of BLM, Park Ranger Emily Erwin, and Cathy Boden and Statia Ryder of South Coast Watershed Association for monitoring and education with recreationists and campers at New River and Floras Lake; Crystal Mullins and Anjanette Butler of Forest Service for their many hours maintaining signs and ropes, monitoring recreational activity and interacting with the public; volunteers Bruce & Mary Lou Dickson, Larry Hudomint, Gary and Mary Van Hooser, Don & Nita Derricott, John Gee, Kim & Else Ireland, and Pat Holper spent numerous hours educating the public at China Creek parking lot on Bandon Snowy Plover Management Area; volunteers Andy and Jan Ogg for USFS; Interpretive Specialists Dave Thompson, Interpretive beach rangers Brian Hoeh, Renee Plourde, Michelle Schuett, Ana Miller-tur-Kuile, Ann Parkin, David Diaz, Meghan Avila, Eliza Spear, and Dylan Wellner from the Forest Service; Ted Gage and Carrie Wostal of BLM Law Enforcement, Adam Slater of Coos County Sheriff's Department, Oliver Grover, Melissa Wise, Tyler Smith, Derrick Scott, and Cody Martin of the USFS Dunes National Recreation Area Law Enforcement , and Ed Lagrone of Lane Co. Sheriffs's Department; Dan Elbert, Madeleine Vander Heyden, and Laura Todd of the US Fish and Wildlife Service; Mark Stern, Ken Popper, and Karen Gleason of The Nature Conservancy; Stuart Love, Bill Kinyoun, and Martin Nugent of the Oregon Department of Fish and Wildlife; Charlie Bruce, retired ODFW volunteer; Kip Wright, Kerrie Palermo, Megan Harper, and all the managers at Coos Bay BLM District whose support is invaluable; Calum Stevenson, Larry Becker, and Vanessa Blackstone of the Oregon Parks and Recreation Department; Ben Fisher, Carl M. Krigbaum, Jerry Phillips, Chuck Littlejohn, Chris Bryers, Nick Schoeppner, Julie Kirby, and all the staff at Bullard's Beach State Park; Cindy Burns, Melissa Shelley and Paul Thomas of the USFS Mapleton Ranger District; Dave Williams of Wildlife Services; Sean McAllister in Humboldt Co., CA,; Mark Colwell and students at Humboldt State Univ., Arcata, CA,; Jim Watkins of US Fish and Wildlife Service, Humboldt Co.; Gary Page, Lynne Stenzel, Doug George, Kris Neumann, Jenny Erbes, and Carlton Eyster of Point Reyes Bird Observatory; special thanks to Frances Bidstrup of Point Reyes Bird Observatory who coordinates all banding information and who is essential to the project; to anyone and everyone who we may have accidentally forgotten – we sincerely appreciate the support, assistance, and input of all, without which the program would not be a success.

**Literature Cited**


Burrell, M. 2011. Integrated Predator Damage Management Report for the Western Snowy Plover (*Charadrius alexandrinus nivosus*) 2011 Breeding Season. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Burrell, M. 2012. Integrated Predator Damage Management Report for the Western Snowy Plover (*Charadrius alexandrinus nivosus*) 2011 Breeding Season. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Burrell, M. 2013. Integrated Predator Damage Management Report for the Western Snowy Plover (*Charadrius alexandrinus nivosus*) 2013 Breeding Season. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Casler, B.R., C.E. Hallett, and M.A. Stern. 1993. Snowy Plover nesting and reproductive success along the Oregon coast - 1993. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay.

Castelein, K.A., D.J. Lauten, R. Swift, and M.A. Stern. 1997. Snowy Plover distribution and reproductive success along the Oregon coast - 1997. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Castelein, K.A., D.J. Lauten, R. Swift, M.A. Stern, and K.J. Popper. 1998. Snowy Plover distribution and reproductive success along the Oregon coast - 1998. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, K.J. Popper, J.A. Fukuda, and M.A. Stern. 2000a. Snowy Plover distribution and reproductive success along the Oregon coast – 1999. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, K.J. Popper, D.C. Bailey, and M.A. Stern. 2000b. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast – 2000. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, L.N. Renan, S.R. Pixley, and M.A. Stern. 2001. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast - 2001. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Castelein, K.A., D.J.Lauten, S.R. Pixley, L.N. Renan, M.A. Stern, and C. Grinnell. 2002. The distribution and reproductive success of the Western Snowy Plover along the Oregon Coast - 2002. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Craig, D.P., M.A. Stern, K.A. Mingo, D.M. Craig, and G.A. Rosenberg. 1992. Reproductive Ecology of the Western Snowy Plover on the South Coast of Oregon, 1992. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay.

Demers, S.A., and C.W. Robinson-Nilsen. 2012. Monitoring Western Snowy Plover nests with remote surveillance systems in San Francisco Bay, California. Journal of Fish and Wildlife Management 3(1):123-132.

Dinsmore, S. J., M. B. Wunder, V. J. Dreitz, and F. L. Knopf. 2010. An assessment of factors affecting population growth of the Mountain Plover. Avian Conservation and Ecology 5(1): 5.

Elliot-Smith, E., and S.M. Haig. 2007. Western Snowy Plover breeding window survey protocol – final draft. Unpublished report prepared for USFWS.

Estelle, V., T.J. Mabee, and A.H. Farmer. 1996. Effectiveness of predator exclosures for Pectoral Sandpiper nests in Alaska. Journal of Field Ornithology 67:447-452.

Estelle, V.B., C.E. Hallett, M.R. Fisher and M.A. Stern. 1997. Snowy Plover distribution and reproductive success along the Oregon coast - 1996. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Hallett, C.E., B.R. Casler, M.A. Platt, M.A. Stern. 1994. Snowy Plover distribution and reproductive success along the Oregon coast - 1994. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, the Dunes National Recreation Area, Reedsport, and the Coos Bay District Bureau of Land Management, Coos Bay.

Hallett, C.E., B.R. Casler, M.A. Platt, M.A. Stern. 1995. Snowy Plover distribution and reproductive success along the Oregon coast - 1995. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, and the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes National Recreational Area, Reedsport.

Hardy, M.A, and M. A. Colwell. 2008. The impact of predator exclosures on snowy plover nesting success: A seven-year study. Wader Study Group Bulletin 115:161-166.

ICF International. 2010. Habitat Conservation Plan for the Western Snowy Plover. August. (ICF 06537.06.) Portland, OR. Prepared for Oregon Parks and Recreation Department.

Isaksson, D., J. Wallander, and M. Larsson. 2007. Managing predation on ground-nesting birds: The effectiveness of nest exclosures. Biological Conservation 136:136-142.

Johnson, M. and L.W. Oring. 2002. Are nest exclosures an effective tool in plover conservation. Waterbirds 25:184-190.

Larson, M.A., M.R. Ryan, and R.K. Murphy. 2002. Population viability of piping plovers: Effects of predator exclusion. Journal of Wildlife Management 66:361-371.

Lauten, D.J., K.A. Castelein, B.V. Smithers, K.C. Jander, E. Elliot-Smith, and E.P. Gaines. 2003. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2003. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, E. Seckinger, E. Kolkemo, and E.P. Gaines. 2005. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2004. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, E. Seckinger, and E.P. Gaines. 2006. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2005. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, S. Weston, K. Eucken, and E.P. Gaines. 2006b. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2006. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, Raya Pruner, Marvin Friel, and E.P. Gaines. 2007. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2007. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, D.C. Bailey, T. Lewis, and E.P. Gaines. 2008. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2008. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, H.G. Herlyn, and E.P. Gaines. 2009. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2009. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2010. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2010. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2011. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2011. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Lauten, D.J., K.A. Castelein, J.D. Farrar, A.A. Kotaich, and E.P. Gaines. 2012. The Distribution and Reproductive Success of the Western Snowy Plover Along the Oregon Coast – 2012. Unpublished report for the Oregon Department of Fish and Wildlife – Nongame Program, Portland, the Coos Bay District Bureau of Land Management, Coos Bay, and the Dunes Recreational Area, Reedsport.

Mabee, T. J. & V.B. Estelle. 2000. Nest fate and vegetation characteristics for Snowy Plover and Killdeer in Colorado, USA. Wader Study Group Bulletin 93: 67–72.

Melvin, S. M., L.H. MacIvor, and C.R. Griffin. 1992. Predator exclosures: A technique to reduce predation at Piping Plover nests. Wildlife Society Bulletin 20, 143–148.

Murphy, R. K., I.M. Michaud, D. R. Prescott, J.S. Ivan, B.J. Anderson, and M.L.French-Pombier. 2003. Predation on adult Piping Plovers at predator exclosure cages. Waterbirds 26:150–155.

Neuman, K. K, G. W. Page, L E. Stenzel, J. C. Warriner, and J. S. Warriner. 2004. Effect of Mammalian Predator Management on Snowy Plover Breeding Success. Waterbirds 27(3):257-263.

Niehaus, A.C., D.R. Ruthrauff, and B.J. McCaffery. 2004. Response of predators to western sandpiper nest exclosures. Waterbirds 27:79-82

Nol, E., and R.J. Brooks. 1982. Effects of predator exclosures on nesting success of killdeer. Journal of Ornithology 53:263-268.

ODFW. 2009. Oregon Administrative Rules, Oregon Department of Fish and Wildlife, Division 100 Wildlife Diversity Plan. http://www.dfw.state.or.us/OARs/100.pdf

Page, G.W., L.E. Stenzel, and C.A. Ribic. 1985. Nest site selection and clutch predation in the Snowy Plover. The Auk 102:347-353.

Page, G.W., L.E. Stenzel, W.D. Shuford, and C.R. Bruce. 1991. Distribution and abundance of the snowy plover on its western North American breeding grounds. J. Field Ornithol. 62:245-255.

Page, G. W., L. E. Stenzel, J. S. Warriner, J. C. Warriner and P. W. Paton. 2009. Snowy Plover (Charadrius nivosus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/154

Pauliny, A., M. Larsson, and D. Blomqvist. 2008. Nest predation management: Effects on reproductive success in endangered shoredbirds. Journal of Wildlife Management 72:1579-1583.

Pearson, S.F., C. Sundstrom, W. Ritchie, and K. Gunther. 2009. Washington State Snowy Plover Population Monitoring, Research, and Management: 2009 Nesting Season Research Progress Report. Washington Department of Fish and Wildlife, Wildlife Science Division, Olympia.

Rimmer, D.W., and R.D. Deblinger. 1990. Use of predator exclosures to protect piping plover nests. Journal of Field Ornithology 61:217-223.

Sandercock, B.K. 2003. Estimation of survival rates for wader populations: a review of mark recapture methods. Wader Study Group Bulletin. 100:163-174

Stern, M.A., J.S. McIver, and G.A. Rosenberg.  1990.  Investigations of the western Snowy Plover at the Coos Bay North Spit and adjacent sites in Coos and Curry Counties, 1990. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland, Oregon.

Stern, M.A., J.S. McIver, and G.A. Rosenberg.  1991.  Nesting and reproductive success of the Snowy Plovers along the south Oregon coast, 1991. Unpublished report for the Oregon Department of Fish and Wildlife-Nongame Program, Portland and the Coos Bay District Bureau of Land Management, Coos Bay

U.S. Fish and Wildlife Service.  1993.  Final rule.  Endangered and threatened wildlife and plants; Determination of threatened status for the Pacific coast population of the western snowy plover. Federal Register 58 FR 12864 03/05/93.

U.S. Fish and Wildlife Service.  2007.  Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*).  In two volumes.  Sacramento, California. xiv + 751pp.

Vaske, J.J., D.W. Rimmer, and R.D. Deblinger. 1994. The impact of different predator exclosures on piping plover nest abandonment. Journal of Field Ornithology 65:201-209.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. The Journal of Wildlife Management 14: 56–67.

**Table 1.** Population estimates of the Western Snowy Plover on the Oregon Coast, 1990-2013. For Window Survey, first number is counted plovers minus duplicate band combos and unidentified plovers, and the number in parenthesis is total head count without considering duplicate combos or unknown plovers.

| YEAR | WINDOW SURVEY | # SNPL BREEDING | # SNPL PRESENT |
|---|---|---|---|
| 1990 | 59 | - | - |
| 1991 | 35 | - | - |
| 1992 | 28 | - | - |
| 1993 | 45 | 55-61 | 72 |
| 1994 | 51 | 67 | 83 |
| 1995 | 64 (67) | 94 | 120 |
| 1996 | 85 | 110-113 | 134-137 |
| 1997 | 73 (77) | 106-110 | 141 |
| 1998 | 57 (59) | 75 | 97 |
| 1999 | 49 (51) | 77 | 95-96 |
| 2000 | NC | 89 | 109 |
| 2001 | 71 (85) | 79-80 | 111-113 |
| 2002 | 71 (76) | 80 | 99-102 |
| 2003 | 63 | 93 | 102-107 |
| 2004 | 82 (83) | 120 | 136-142 |
| 2005 | 100 | 104 | 153-158 |
| 2006 | 91 | 135 | 177-179 |
| 2007 | 125 | 162 | 181-184 |
| 2008 | 98-105 | 129 | 188-200 |
| 2009 | 136-143 (139-146) | 149-150 | 199-206 |
| 2010 | 158 | 175 | 232-236 |
| 2011 | 168 | 214 | 247-253 |
| 2012 | 206 | 233-238 | 293-294 |
| 2013 | 215 | 190-191 | 304 |

**Table 2.** Number of Snowy Plover fledglings, number of previous year fledglings returning, return rate, number nesting, and percent nesting in first year of return along the Oregon coast, 1990 - 2013.

| Year | # of Fledglings | # of HY birds from previous year sighted on OR coast | Return Rate (#HY/#Fled) | # that nested on OR coast | % nested on OR coast |
|---|---|---|---|---|---|
| 2013 | 103 | 91 | 51% | 51 | 56% |
| 2012 | 180[a] | 92 | 51% | 70 | 76% |
| 2011 | 172 | 53 | 63% | 45 | 85% |
| 2010 | 84 | 54 | 50% | 38 | 70% |
| 2009 | 107 | 35 | 48% | 26 | 74% |
| 2008 | 73 | 52 | 42% | 27 | 52% |
| 2007 | 124 | 32 | 29% | 26 | 81% |
| 2006 | 110 | 29 | 37% | 23 | 79% |
| 2005 | 78 | 43 | 40% | 33 | 77% |
| 2004 | 108 | 26 | 43% | 21 | 81% |
| 2003 | 60 | 14 | 45% | 14 | 100% |
| 2002 | 31 | 18 | 56% | 15 | 83% |
| 2001 | 32 | 23 | 53% | 14 | 61% |
| 2000 | 43 | 31 | 58% | 25 | 81% |
| 1999 | 53 | 18 | 56% | 12 | 67% |
| 1998 | 32 | 14 | 34% | 11 | 79% |
| 1997 | 41 | 30 | 64% | 18 | 60% |
| 1996 | 47 | 18 | 32% | 10 | 55% |
| 1995 | 57 | 37 | 66% | 13 | 35% |
| 1994 | 56 | 16 | 44% | 8 | 50% |
| 1993 | 36 | 10 | 30% | 6 | 60% |
| 1992 | 33 | 6* | 38% | 2 | 33% |
| 1991 | 16 | No chicks banded in 1990 | | | |
| 1990 | 3 | x | x | | |

* - minimum number sighted

| | |
|---|---|
| Average return rate = 47% | 47% |
| SD = 11.0% | 0.110352 |
| Average percent of returning HY birds that nest in first season = 68% | 68% |
| SD = 16.7% | 0.167004 |

[a] - adjusted from 172 to 180 based on hatch year returns

**Table 3.** Number of Adult Snowy Plovers at each nesting area on the Oregon Coast, 2013.

| | Females | | | | Males | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Banded | | Unbanded | | Banded | | Unbanded | | Total | |
| Site | # banded | # nested | # unbanded | # nested | # banded | # nested | # unbanded | # nested | # plovers | # nested |
| Sutton | 1 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 5 | 0 |
| Siltcoos | 41 | 12 | 2 | 1 | 46 | 10 | 2 | 0 | 91 | 23 |
| Overlook | 38 | 9 | 4 | 1 | 39 | 5 | 2 | 1 | 83 | 16 |
| Tahkenitch | 35 | 14 | 3 | 0 | 39 | 6 | 5 | 2 | 82 | 22 |
| Tenmile | 32 | 13 | 4 | 3-4 | 32 | 14 | 4 | 4 | 72 | 34-35 |
| CBNS | 37 | 24 | 5 | 4 | 47 | 23 | 3 | 1 | 92 | 52 |
| Bandon SPMA | 30 | 20 | 7 | 2 | 36 | 24 | 3 | 0 | 76 | 46 |
| New River HRA | 6 | 5 | 3 | 3 | 14 | 12 | 1 | 0 | 24 | 22 |
| Floras Lake | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

**Table 4**. Number of nests for selected sites on the Oregon Coast 1998 – 2013 cells tally nests only and not broods from undiscovered nests. The number of broods from undiscovered nests is totaled for each year only.

| Site Name | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SU | 8 | 3 | 7 | 15 | 3 | 1 | 0 | 0 | 4 | 3 | 0 | 0 | 1 | 0 | 0 | 1 |
| SI: | | | | | | | | | | | | | | | | |
| North | 1 | 4 | 8 | 0 | 0 | 0 | 7 | 8 | 12 | 15 | 30 | 14 | 17 | 13 | 10 | 13 |
| South | 3 | 17 | 14 | 14 | 10 | 7 | 4 | 9 | 13 | 13 | 6 | 9 | 24 | 21 | 22 | 30 |
| OV: | | | | | | | | | | | | | | | | |
| North | | 2 | 8 | 12 | 5 | 7 | 11 | 11 | 9 | 13 | 14 | 9 | 21 | 29 | 28 | 33 |
| South | | 0 | 0 | 3 | 3 | 1 | 3 | 5 | 1 | 3 | 1 | 5 | 16 | 28 | 31 | 28 |
| TA | | | | | | | | | | | | | | | | |
| North | 0 | 0 | 4 | 7 | 8 | 13 | 8 | 11 | 4 | 10 | 5 | 6 | 7 | 23 | 36 | 52 |
| South | 6 | 3 | 1 | 6 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | 6 |
| TM: | | | | | | | | | | | | | | | | |
| North | 0 | 0 | 1 | 2 | 3 | 5 | 9 | 6 | 10 | 20 | 12 | 13 | 13 | 15 | 17 | 19 |
| South | 11 | 5 | 5 | 6 | 9 | 12 | 8 | 11 | 12 | 21 | 16 | 41 | 30 | 35 | 29 | 17 |
| CBNS: | | | | | | | | | | | | | | | | |
| SB | 6 | 0 | 1 | 1 | 2 | 3 | 2 | 4 | 0 | 8 | 5 | 19 | 17 | 16 | 7 | 36 |
| SS | 5 | 2 | 5 | 3 | 2 | 9 | 8 | 9 | 14 | 12 | 18 | 16 | 14 | 15 | 15 | 12 |
| HRAs | 7 | 12 | 22 | 13 | 15 | 11 | 16 | 16 | 18 | 19 | 26 | 30 | 33 | 26 | 39 | 58 |
| BSPMA | | | | | | | | | | | | | | | | |
| BB | 1 | 2 | 2 | 6 | 5 | 5 | 17 | 31 | 23 | 30 | 28 | 31 | 26 | 28 | 48 | 44 |
| NR spit | 1 | 8 | 1 | 1 | 2 | 7 | 7 | 11 | 9 | 16 | 6 | 10 | 12 | 9 | 12 | 20 |
| NR HRA | | 3 | 4 | 10 | 7 | 5 | 6 | 1 | 7 | 14 | 27 | 27 | 27 | 29 | 17 | 9 |
| NR other | 25 | 17 | 12 | 12 | 5 | 4 | 11 | 11 | 11 | 5 | 2 | 3 | 3 | 2 | 1 | 3 |
| FL | 4 | 0 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 0 |
| **Tot nst** | **78** | **78** | **100** | **111** | **89** | **91** | **117** | **144** | **147** | **202** | **196** | **236** | **261** | **289** | **314** | **381** |
| **Tot brd[a]** | **3** | **1** | **2** | **0** | **1** | **4** | **2** | **3** | **15** | **4** | **3** | **8** | **2** | **4** | **11** | **8** |

[a] – broods from undiscovered nests only; these broods are not tallied in the total number of nests

SU – Sutton, SI – Siltcoos, OV – Overlook, TA – Tahkenitch, TM – Tenmile, CBNS – Coos Bay North Spit (SB - South Beach, SS – South Spoil, BSPMA – Bandon Snowy Plover Management Area (BB - Bandon Beach, NR spit - New River spit), NR HRA – New River HRA, NR other - private and other owned lands, FL – Floras Lake

**Table 5.** Apparent nest success of Snowy Plovers on the Oregon Coast, 2013.

| | | Nests Exclosed | | | Nests Not Exclosed | | | Exclosed Nests | Nests Not Exclosed | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Total #** | **Hatch** | **Fail** | **Unknown** | **Hatch** | **Fail** | **Unknown** | **App Nest Success** | **App Nest Success** | **Overall Nest Success** |
| **Sutton** | 1 | - | - | | 0 | 1 | | - | 0% | 0% |
| **Siltcoos** | | | | | | | | | | |
| North | 13 | - | - | | 3 | 10 | | - | 23% | 23% |
| South | 30 | 2 | 0 | | 3 | 25 | | 100% | 12% | 17% |
| Combined | 43 | 2 | 0 | | 6 | 35 | | 100% | 17% | 19% |
| **Overlook** | | | | | | | | | | |
| North | 33 | 0 | 1 | | 3 | 29 | | 0% | 9% | 9% |
| South | 28 | - | - | | 0 | 28 | | - | 0% | 0% |
| Combined | 61 | 0 | 1 | | 3 | 57 | | 0% | 5% | 5% |
| **Tahkenitch** | | | | | | | | | | |
| North | 52 | - | - | | 6 | 46 | | - | 12% | 12% |
| South | 6 | - | - | | 1 | 5 | | - | 17% | 17% |
| Combined | 58 | | | | 7 | 51 | | | 12% | 12% |
| **Tenmile** | | | | | | | | | | |
| North | 19 | 2 | 0 | | 7 | 10 | | 100% | 41% | 47% |
| South | 17 | - | - | | 6 | 11 | | - | 35% | 35% |
| Combined | 36 | | | | 13 | 21 | | 100% | 36% | 42% |
| **CBNS** | | | | | | | | | | |
| South Beach | 36 | - | - | | 15 | 21 | | - | 42% | 42% |
| South Spoil | 12 | - | - | | 4 | 8 | | | 33% | 33% |
| HRAs | 58 | - | - | | 10 | 48 | | | 17% | 17% |
| Combined | 106 | | | | 29 | 77 | | | 27% | 27% |
| **Bandon SPMA** | 64 [a] | 6 | 1 | | 15 | 41 | | 86% | 27% | 33% |
| **New River** | | | | | | | | | | |
| HRA | 9 | 4 | 1 | | 3 | 1 | | 80% | 75% | 78% |
| Other Lands | 3 | 1 | 0 | | 1 | 1 | | 100% | 50% | 67% |
| **Floras Lake** | 0 | - | - | | - | - | | - | - | - |
| **Totals** | 381 [a] | 15 | 3 | | 77 | 285 | | 83% | 21% | 24% |

a – One nest not included in analysis because adults depredated, one chick hatched, two eggs and chick taken to aquarium.

**Table 6. Apparent nest success of exclosed and unexclosed Snowy Plover nests on the Oregon coast, 1990 - 2013.**

| Year | All nests (%) | Exclosed (%) | Not Exclosed (%) |
|---|---|---|---|
| 1990 | 31 | * | 28 |
| 1991 | 33 | 75 | 9 |
| 1992 | 67 | 85 | 11 |
| 1993 | 68 | 83 | 27 |
| 1994 | 75 | 80 | 71 |
| 1995 | 50 | 65 | 5 |
| 1996 | 56 | 71 | 10 |
| 1997 | 48 | 58 | 14 |
| 1998 | 56 | 72 | 8 |
| 1999 | 56 | 64 | 0 |
| 2000 | 38 | 48 | 0 |
| 2001 | 35 | 68 | 0 |
| 2002 | 44 | 66 | 6 |
| 2003 | 51 | 77 | 9 |
| 2004 | 62 | 85 | 8 |
| 2005 | 48 | 72 | 14 |
| 2006 | 47 | 66 | 32 |
| 2007 | 42 | 71 | 35 |
| 2008 | 34 | 49 | 30 |
| 2009 | 33 | 76 | 25 |
| 2010 | 35 | 72 | 23 |
| 2011 | 50 | 71 | 48 |
| 2012 | 45 | 86 | 42 |
| 2013 | 24 | 83 | 21 |
| Average = | 47.00 | 71.43 | 19.83 |
| STDEV = | 12.99 | 10.42 | 17.31 |

* Multiple experimental designs used, data not included

**Table 7.** Causes of Snowy Plover nest failure at survey sites along the Oregon coast, 2013.

| **Site Name** | **Tot Nsts** | **# Fail** | **Depredations** | | | | | **Other** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Corvid** | **Unk** | **Avian** | **Mammal** | **Adult plover** | **Wind-Weather** | **Overwash** | **Abandon** | **One Egg Nest** | **Infer** | **Unk cause** |
| **Sutton** | 1 | 1 | | | | | | | | | | | 1 |
| **Siltcoos:** | | | | | | | | | | | | | |
| **North** | 13 | 10 | | 3 | | | | 1 | 1 | | 2 | | 3 |
| **South** | 30 | 25 | | 7 | 1 | | | 3 | | 3 | 2 | | 9 |
| **Overlook** | | | | | | | | | | | | | |
| **North** | 33 | 30 | 4 | 20 | | | 1 | | | 1 | 1 | | 3 |
| **South** | 28 | 28 | 3 | 16 | 2 | | | | | 3 | 1 | | 3 |
| **Tahkenitch** | | | | | | | | | | | | | |
| **North** | 52 | 46 | | 16 | 5 | | | 4 | | 1 | | | 20 |
| **South** | 6 | 5 | 3 | 1 | | | | | | | | | 1 |
| **Tenmile:** | | | | | | | | | | | | | |
| **North** | 19 | 10 | 4 | 2 | | | | | | | 1 | 1 | 2 |
| **South** | 17 | 11 | 3 | 2 | | | | | | | | | 6 |
| **Coos Bay North Spit:** | | | | | | | | | | | | | |
| **South Beach** | 36 | 21 | | 2 | 4 | 1[a] | | | 2 | 2 | 1 | | 9 |
| **South Spoil** | 12 | 8 | | 7 | | | | | | | 1 | | |
| **HRAs** | 58 | 48 | | 29 | 11 | 2[b] | | | | 1 | 4 | | 1 |
| **Bandon SPMA** | 64 | 42 | 3 | 16 | | | | 4 | | | | 1 | 18 |
| **New River HRA** | 9 | 2 | | 1 | | | | | | | | 1 | |
| **Other lands** | 3 | 1 | | 1 | | | | | | | | | |
| **TOTALS** | **381** | **288** | 20 | 123 | 23[c] | 3 | 1 | 12 | 3 | 11 | 13 | 3 | 76 |

[a] – raccoon depredation
[b] – 2 rodent depredation
[c] – 20 Northern Harrier depredations, 3 unknown avian depredations

**Table 8.** Cause of failure for Snowy Plover nests protected by predator exclosures and nests unprotected by predator exclosures along the Oregon coast, 2013.

| Cause of Failure | | Exclosed | Unexclosed | Totals |
|---|---|---|---|---|
| **Egg Depredation** | **Corvid** | | 20 | 20 |
| | **Unknown** | | 123 | 123 |
| | **Avian** | | 23 | 23 |
| | **Mammalian** | | 3 | 3 |
| **Depredation** | **Adult Plover** | 1 | | 1 |
| **Other** | **Wind/Weather** | | 12 | 12 |
| | **Overwashed** | | 3 | 3 |
| | **Infertile** | 2 | 1 | 3 |
| | **One Egg Nests** | | 13 | 13 |
| | **Abandoned** | | 11 | 11 |
| | **Unknown Cause** | | 76 | 76 |
| **Totals** | | 3 | 285 | 288 |

**Table 9.** Total number of young fledged from select sites on the Oregon Coast 1998-2013, includes fledglings from broods from undiscovered nests.

| Site Name | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SU | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| SI: | | | | | | | | | | | | | | | | |
| North | 2 | 4 | 0 | 0 | 0 | 0 | 7 | 2 | 11 | 7 | 5 | 8 | 4 | 4 | 1 | 2 |
| South | 4 | 2 | 7 | 0 | 0 | 2 | 5 | 7 | 7 | 4 | 3 | 11 | 4 | 8 | 16 | 3 |
| OV: | | | | | | | | | | | | | | | | |
| North | | 3 | 5 | 1 | 2 | 3 | 3 | 5 | 8 | 12 | 3 | 7 | 12 | 27 | 22 | 3 |
| South | | 0 | 0 | 1 | 0 | 0 | 3 | 2 | 0 | 1 | 0 | 2 | 7 | 23 | 27 | 0 |
| TA: | | | | | | | | | | | | | | | | |
| North | 0 | 0 | 2 | 4 | 1 | 3 | 6 | 8 | 5 | 2 | 0 | 1 | 3 | 20 | 26 | 9[b] |
| South | 1 | 1 | 3 | 4 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | | | | | 3 |
| TM: | | | | | | | | | | | | | | | | |
| North | 0 | 0 | 0 | 0 | 3 | 1 | 3 | 6 | 12 | 13 | 3 | 2 | 3 | 1 | 5 | 15 |
| South | 3 | 7 | 5 | 4 | 3 | 9 | 9 | 5 | 7 | 14 | 6 | 19 | 13 | 5 | 5 | 8 |
| CBNS: | | | | | | | | | | | | | | | | |
| SS | 6 | 5 | 3 | 4 | 2 | 7 | 13 | 9 | 11 | 7 | 17 | 4 | 2 | 6 | 10 | 2 |
| SB | 2 | 0 | 0 | 1 | 1 | 3 | 0 | 8 | 1 | 10 | 7 | 17 | 13 | 22 | 16 | 18 |
| HRAs | 1 | 23 | 6 | 6 | 8 | 14 | 22 | 6 | 19 | 9 | 16 | 10 | 5 | 28 | 34 | 3 |
| BSPMA | | | | | | | | | | | | | | | | |
| BB | 1 | 1 | 0 | 1 | 0 | 4 | 16 | 11 | 12 | 13 | 2 | 6 | 6 | 16 | 11 | 8[c] |
| NR spit | 0 | 2 | 0 | 0 | 0 | 1 | 10 | 0 | 3 | 12 | 2 | 1 | 0 | 5 | 1 | 14 |
| NR HRA | | 2 | 1 | 3 | 3 | 7 | 5 | 1 | 7 | 16 | 7 | 17 | 12 | 7 | 4 | 12 |
| NR other | 11 | 4 | 4 | 3 | 3 | 4 | 6 | 8 | 7 | 4 | 2 | 2 | 0 | 0 | 0 | 3 |
| FL | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | |
| **Total** | **32** | **54** | **43** | **32** | **31** | **60** | **108** | **78** | **110** | **124** | **73** | **107** | **84** | **172** | **180[a]** | **103** |

[a] – adjusted from 172 to 180 based on hatch year returns

[b] - includes 2 fledglings raised at Oregon Coast Aquarium

[c] - includes 3 fledglings raised at Oregon Coast Aquarium

SU – Sutton, SI – Siltcoos, OV – Overlook, TA – Tahkenitch, TM – Tenmile, CBNS – Coos Bay North Spit (SB - South Beach, SS – South Spoil, BSPMA – Bandon Snowy Plover Management Area (BB - Bandon Beach, NR spit - New River spit), NR HRA – New River HRA, NR other - private and other owned lands, FL – Floras Lake

**Table 10**. Overall fledging success, total number of fledglings, and mean number of fledglings/male on the Oregon Coast, 1990 – 2013.

| Year | % Fledging Success[a] | # Fledglings[b] | Mean # Fled/Male[a] |
|---|---|---|---|
| 1990 | 11 | 3 | - |
| 1991 | 45 | 16 | - |
| 1992 | 41 | 34 | 1.250 |
| 1993 | 42 | 36 | 1.000 |
| 1994 | 50 | 56 | 1.483 |
| 1995 | 50 | 58 | 1.194 |
| 1996 | 32 | 47 | 0.881 |
| 1997 | 30 | 41 | 0.833 |
| 1998 | 26 | 32 | 0.833 |
| 1999 | 43 | 54 | 1.268 |
| 2000 | 41 | 43 | 0.973 |
| 2001 | 34 | 32 | 0.842 |
| 2002 | 29 | 31 | 0.700 |
| 2003 | 47 | 60 | 1.061 |
| 2004 | 55 | 108 | 1.645 |
| 2005 | 41 | 78 | 1.259 |
| 2006 | 48 | 110 | 1.559 |
| 2007 | 54 | 124 | 1.494 |
| 2008 | 47 | 73 | 1.060 |
| 2009 | 50 | 107 | 1.288 |
| 2010 | 35 | 84 | 0.920 |
| 2011 | 47 | 172 | 1.371 |
| 2012 | 44 | 180 | 1.223 |
| 2013 | 39 | 103[c] | 0.926 |
| | Overall = 40.9 $\pm$ 10.1 | Total = 1680 | Mean = 1.139 |

a – does not include fledglings from broods from undiscovered nests, nor any data from Sutton Beach and Floras Lake

b – total number of fledglings including from broods from undiscovered nests

c - includes five chicks raised at Oregon Coast Aquarium

**Table 11.** Fledgling success, brood success, and number of fledglings per male for Snowy Plovers on the Oregon Coast, 2013.

| Site Name | Total # Broods* | % Brood Success* | Total # Eggs Hatched | Min. # Fledged From Known Nests | Min. # Fledged From Undiscovered Nests | % Fledging Success** | # of Breeding Males[a] | # of Fledglings/ Male* | # of Fledglings/Male – Combined[c] |
|---|---|---|---|---|---|---|---|---|---|
| Siltcoos: | | | | | | | | | |
| North Siltcoos | 3 | 33% | 9 | 2 | - | 22% | 5 | 0.40 | 0.50 (10) |
| South Siltcoos | 6 | 50% | 13 | 2 | 1 | 15% | 5 | 0.40 | |
| Overlook | | | | | | | | | |
| North Overlook | 3 | 67% | 9 | 3 | - | 33% | 5 | 0.60 | 0.50 (6) |
| South Overlook | 0 | - | - | - | - | - | 1 | - | |
| Tahkenitch | | | | | | | | | |
| North Tahkenitch | 6[d] | 80% | 12 | 7 | - | 58% | 5 | 1.40 | 1.43 (7) |
| South Tahkenitch | 2 | 100% | 2 | 1 | 2 | 50% | 2 | 1.50 | |
| Tenmile: | | | | | | | | | |
| North Tenmile | 13 | 92% | 22 | 11 | 4 | 50% | 14 | 1.07 | 1.21 (19) |
| South Tenmile | 6 | 83% | 15 | 8 | - | 53% | 6 | 1.33 | |
| Coos Bay N. Spit | | | | | | | | | |
| South Spoil | 4 | 25% | 10 | 2 | - | 20% | 3 | 0.67 | 0.95 (24) |
| South Beach | 15 | 80% | 39 | 18 | - | 46% | 15 | 1.20 | |
| HRA | 10 | 20% | 21 | 3 | - | 14% | 8 | 0.38 | |
| Bandon SPMA | 22[e] | 71% | 51 | 19 | - | 37% | 23 | 0.83 | 0.83 (23) |
| New River | | | | | | | | | |
| HRA | 9 | 89% | 18 | 9 | 3 | 50% | 9 | 1.33 | 1.25 (12) |
| Other lands | 2 | 100% | 5 | 3 | - | 60% | 3 | 1.00 | |
| **TOTALS** | **101[f]** | **71%** | **228** | **88** | **10** | **39%** | **94** | **1.04** | |
| **TOTAL FLEDGED** | | | | **103[g]** | | | | | |

% Brood success = # broods with at least 1 chick fledged / total # of broods

% Fledging Success = # of young fledged / # of eggs hatched

* Includes broods from undiscovered nests:

** Does not include fledglings from undiscovered nests because we do not know how many eggs hatched from those nests.

[a] – number of known individual breeding males for each site

[b] – number of known breeding males in entire population; this is not a tally of known males from each site as some males may have nested at more than one location

[c] – number of fledglings for both sites combined and number of known individual breeding males for both sites combined. Sample size of males in parenthesis.

[d] – includes one brood that hatched but chicks later captured and raised at Oregon Coast Aquarium and later release; this brood not included in calculations.

[e] – includes one brood that was raised at Oregon Coast Aquarium and later released; this brood not included in calculations.

[f] – includes two broods raised at Oregon Coast Aquarium; these broods not included in calculations.

[g] – includes 5 fledglings raised at Oregon Coast Aquarium.

**Table 12. Productivity of Snowy Plovers at Siltcoos, Lane Co., Oregon coast, 1993-2013.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Siltcoos | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 102 | 22 | 22% | 4 | 18% | 4% | 4 | 10 | 0.4 |
| | **2012** | 92 | 38 | 41% | 15 | 39% | 16% | 15 | 13 | 1.15 |
| | **2011** | 87 | 36 | 41% | 11 | 31% | 13% | 11 | 13 | 0.85 |
| | **2010** | 105 | 30 | 29% | 8 | 27% | 8% | 8 | 10 | 0.80 |
| | **2009** | 54 | 28 | 52% | 17 | 61% | 31% | 17 | 11 | 1.55 |
| | **2008** | 68 | 22 | 32% | 8 | 36% | 12% | 8 | 9 | 0.88 |
| | **2007** | 67 | 24 | 36% | 11 | 46% | 16% | 11 | 10 | 1.10 |
| | **2006** | 60 | 22 | 37% | 13 | 60% | 22% | 11 | 5 | 2.20 |
| | **2005** | 44 | 17 | 39% | 9 | 53% | 20% | 9 | 7 | 1.29 |
| | **2004** | 31 | 18 | 58% | 12 | 67% | 39% | 12 | 5 | 2.40 |
| | **2003** | 16 | 5 | 31% | 2 | 40% | 13% | 2 | 4 | 0.50 |
| | **2002** | 28 | 8 | 29% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | **2001** | 33 | 1 | 3% | 0 | 0% | 0% | 0 | 3 | 0.00 |
| | **2000** | 55 | 19 | 35% | 7 | 37% | 13% | 7 | 8 | 0.88 |
| | **1999** | 59 | 21 | 36% | 6 | 29% | 10% | 6 | 8 | 0.75 |
| | **1998** | 10 | 10 | 100% | 6 | 60% | 60% | 6 | 3 | 2.00 |
| | **1997** | 8 | 4 | 50% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | **1996** | 7 | 3 | 43% | 0 | 0% | 0% | 0 | 1 | 0.00 |
| | **1995** | 12 | 6 | 50% | 2 | 33% | 17% | 2 | 3 | 0.67 |
| | **1994** | 9 | 4 | 44% | 1 | 25% | 11% | 1 | 3 | 0.33 |
| | **1993** | 1 | 0 | 0% | 0 | 0% | 0% | 0 | 0 | 0.00 |
| **Pre-pred mang (1993-2003)** | **total** | 238 | 81 | | 24 | | | 24 | 37 | |
| | **AVE** | | | 38% | | 20% | 11% | | | 0.47 |
| | **STDEV** | | | 26% | | 21% | 17% | | | 0.61 |
| **Post-pred mang (2004-2013)** | **total** | 710 | 257 | | 108 | | | 108 | 93 | |
| | **AVE** | | | 39% | | 44% | 18% | | | 1.26 |
| | **STDEV** | | | 10% | | 16% | 11% | | | 0.63 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 13. Productivity of Snowy Plovers at Overlook, Douglas Co., Oregon coast, 1999-2013.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Overlook | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 152 | 9 | 6% | 3 | 33% | 2% | 3 | 6 | 0.5 |
| | **2012** | 158 | 73 | 46% | 40 | 55% | 25% | 40 | 25 | 1.60 |
| | **2011** | 152 | 80 | 53% | 48 | 60% | 32% | 41 | 22 | 1.86 |
| | **2010** | 92 | 39 | 42% | 15 | 38% | 16% | 15 | 15 | 1.00 |
| | **2009** | 31 | 14 | 45% | 9 | 64% | 29% | 9 | 5 | 1.80 |
| | **2008** | 34 | 5 | 18% | 2 | 40% | 6% | 2 | 3 | 0.67 |
| | **2007** | 46 | 19 | 41% | 11 | 58% | 24% | 11 | 9 | 1.22 |
| | **2006** | 28 | 18 | 64% | 8 | 44% | 29% | 8 | 4 | 2.00 |
| | **2005** | 42 | 16 | 38% | 7 | 44% | 17% | 7 | 5 | 1.40 |
| | **2004** | 39 | 14 | 36% | 6 | 43% | 15% | 6 | 6 | 1.00 |
| | **2003** | 17 | 9 | 53% | 3 | 33% | 18% | 3 | 4 | 0.75 |
| | **2002** | 24 | 13 | 54% | 2 | 15% | 8% | 2 | 4 | 0.50 |
| | **2001** | 39 | 10 | 26% | 2 | 20% | 5% | 2 | 4 | 0.50 |
| | **2000** | 22 | 8 | 36% | 5 | 63% | 23% | 5 | 7 | 0.71 |
| | **1999** | 6 | 6 | 100% | 3 | 50% | 50% | 3 | 2 | 1.50 |
| **Pre-pred mang (1999-2003)** | **total** | 108 | 46 | | 15 | | | 15 | 21 | |
| | **AVE** | | | 54% | | 36% | 21% | | | 0.79 |
| | **STDEV** | | | 28% | | 20% | 18% | | | 0.41 |
| **Post-pred mang (2004-2013)** | **total** | 774 | 209 | | 149 | | | 142 | 100 | |
| | **AVE** | | | 39% | | 48% | 20% | | | 1.31 |
| | **STDEV** | | | 17% | | 11% | 10% | | | 0.51 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 14. Productivity of Snowy Plovers at Tahkenitch, Douglas Co., Oregon coast, 1993-2013.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Tahkenitch | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 141 | 14 | 10% | 8 | 57% | 6% | 8 | 5 | 1.60 |
| | **2012** | 104 | 56 | 54% | 26 | 46% | 25% | 26 | 19 | 1.37 |
| | **2011** | 59 | 37 | 63% | 19 | 51% | 32% | 18 | 9 | 2.00 |
| | **2010** | 14 | 7 | 50% | 3 | 43% | 21% | 2 | 3 | 1.00 |
| | **2009** | 13 | 6 | 46% | 1 | 17% | 8% | 1 | 2 | 0.50 |
| | **2008** | 14 | 0 | 0% | 0 | 0% | 0% | 0 | 1 | 0.00 |
| | **2007** | 23 | 6 | 26% | 2 | 33% | 9% | 2 | 4 | 0.50 |
| | **2006** | 12 | 9 | 75% | 4 | 44% | 33% | 4 | 3 | 1.33 |
| | **2005** | 26 | 14 | 54% | 8 | 57% | 31% | 8 | 4 | 2.00 |
| | **2004** | 21 | 14 | 67% | 6 | 43% | 29% | 6 | 5 | 1.20 |
| | **2003** | 37 | 17 | 46% | 3 | 18% | 8% | 3 | 10 | 0.30 |
| | **2002** | 30 | 16 | 53% | 6 | 38% | 20% | 6 | 5 | 1.20 |
| | **2001** | 36 | 22 | 61% | 8 | 36% | 22% | 8 | 8 | 1.00 |
| | **2000** | 15 | 6 | 40% | 5 | 83% | 33% | 5 | 2 | 2.50 |
| | **1999** | 9 | 1 | 11% | 1 | 100% | 11% | 1 | 2 | 0.50 |
| | **1998** | 18 | 11 | 61% | 1 | 9% | 6% | 1 | 4 | 0.25 |
| | **1997** | 41 | 10 | 24% | 6 | 60% | 15% | 6 | 7 | 0.86 |
| | **1996** | 51 | 21 | 41% | 8 | 38% | 16% | 8 | 9 | 0.89 |
| | **1995** | 21 | 16 | 76% | 12 | 75% | 57% | 12 | 7 | 1.71 |
| | **1994** | 9 | 8 | 89% | 1 | 13% | 11% | 1 | 3 | 0.33 |
| | **1993** | 0 | 0 | 0% | 0 | 0% | 0% | 0 | 0 | 0.00 |
| **Pre-pred mang (1993-2003)** | **total** | 267 | 128 | | 51 | | | 51 | 57 | |
| | **AVE** | | | 46% | | 43% | 18% | | | 0.87 |
| | **STDEV** | | | 27% | | 33% | 16% | | | 0.73 |
| **Post-pred mang (2004-2013)** | **total** | 427 | 163 | | 75 | | | 74 | 52 | |
| | **AVE** | | | 45% | | 39% | 21% | | | 1.15 |
| | **STDEV** | | | 25% | | 18% | 12% | | | 0.66 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 15. Productivity of Snowy Plovers at Tenmile, Coos Co., Oregon coast, 1992-2013.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Tenmile | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 95 | 37 | 39% | 19 | 51% | 20% | 19 | 14 | 1.36 |
| | **2012** | 104 | 18 | 17% | 9 | 50% | 7% | 9 | 6 | 1.50 |
| | **2011** | 117 | 18 | 15% | 4 | 22% | 3% | 4 | 10 | 0.40 |
| | **2010** | 113 | 51 | 45% | 16 | 31% | 14% | 16 | 18 | 0.89 |
| | **2009** | 117 | 27 | 23% | 16 | 59% | 14% | 16 | 9 | 1.78 |
| | **2008** | 77 | 21 | 27% | 8 | 38% | 10% | 8 | 8 | 1.00 |
| | **2007** | 89 | 43 | 48% | 27 | 63% | 30% | 27 | 19 | 1.42 |
| | **2006** | 59 | 28 | 47% | 16 | 57% | 27% | 16 | 10 | 1.60 |
| | **2005** | 49 | 21 | 43% | 8 | 38% | 16% | 8 | 8 | 1.00 |
| | **2004** | 50 | 29 | 58% | 12 | 41% | 24% | 12 | 9 | 1.33 |
| | **2003** | 43 | 20 | 47% | 10 | 50% | 23% | 10 | 8 | 1.25 |
| | **2002** | 32 | 14 | 44% | 3 | 21% | 9% | 3 | 8 | 0.38 |
| | **2001** | 24 | 10 | 42% | 4 | 40% | 17% | 4 | 4 | 1.00 |
| | **2000** | 18 | 14 | 78% | 5 | 36% | 28% | 5 | 4 | 1.25 |
| | **1999** | 13 | 8 | 62% | 7 | 88% | 54% | 7 | 3 | 2.33 |
| | **1998** | 20 | 8 | 40% | 3 | 38% | 15% | 3 | 4 | 0.75 |
| | **1997** | 6 | 6 | 100% | 4 | 67% | 67% | 4 | 2 | 2.00 |
| | **1996** | 11 | 6 | 55% | 4 | 67% | 36% | 4 | 4 | 1.00 |
| | **1995** | 13 | 11 | 85% | 2 | 18% | 15% | 2 | 4 | 0.50 |
| | **1994** | 18 | 3 | 17% | 3 | 100% | 17% | 3 | 2 | 1.50 |
| | **1993** | 24 | 15 | 63% | 5 | 33% | 21% | 5 | 5 | 1.00 |
| | **1992** | 27 | 19 | 70% | 14 | 74% | 52% | 14 | 7 | 2.00 |
| **Pre-pred mang (1992-2003)** | **total** | 249 | 134 | | 64 | | | 64 | 55 | |
| | **AVE** | | | 59% | | 53% | 30% | | | 1.25 |
| | **STDEV** | | | 23% | | 26% | 19% | | | 0.61 |
| **Post-pred mang (2004-2013)** | **total** | 870 | 293 | | 135 | | | 135 | 112 | |
| | **AVE** | | | 36% | | 45% | 17% | | | 1.23 |
| | **STDEV** | | | 15% | | 13% | 9% | | | 0.41 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 16. Productivity of Snowy Plovers at Coos Bay North Spit, Coos Co., Oregon coast, 1992-2013.**
**Number of eggs laid, number hatched, hatch rate, # fledged, fledging success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | CBNS | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 266 | 70 | 26% | 23 | 33% | 9% | 23 | 24 | 0.96 |
| | **2012** | 175 | 135 | 77% | 50 | 37% | 29% | 50 | 44 | 1.14 |
| | **2011** | 156 | 109 | 70% | 52 | 48% | 33% | 52 | 31 | 1.69 |
| | **2010** | 160 | 40 | 25% | 20 | 50% | 13% | 20 | 17 | 1.18 |
| | **2009** | 171 | 58 | 34% | 28 | 48% | 16% | 28 | 22 | 1.27 |
| | **2008** | 125 | 63 | 50% | 40 | 63% | 32% | 38 | 19 | 2.00 |
| | **2007** | 108 | 45 | 42% | 26 | 58% | 24% | 26 | 12 | 2.17 |
| | **2006** | 86 | 54 | 63% | 22 | 41% | 26% | 22 | 14 | 1.57 |
| | **2005** | 80 | 38 | 48% | 23 | 61% | 29% | 21 | 12 | 1.75 |
| | **2004** | 73 | 42 | 58% | 31 | 74% | 42% | 31 | 15 | 2.06 |
| | **2003** | 57 | 29 | 51% | 21 | 72% | 37% | 20 | 9 | 2.22 |
| | **2002** | 48 | 21 | 44% | 11 | 52% | 23% | 11 | 10 | 2.22 |
| | **2001** | 49 | 21 | 43% | 11 | 52% | 22% | 11 | 8 | 1.38 |
| | **2000** | 75 | 23 | 31% | 9 | 39% | 12% | 9 | 6 | 1.50 |
| | **1999** | 38 | 35 | 92% | 26 | 74% | 68% | 26 | 10 | 2.60 |
| | **1998** | 49 | 18 | 37% | 9 | 50% | 18% | 9 | 8 | 1.13 |
| | **1997** | 64 | 32 | 50% | 12 | 38% | 19% | 12 | 11 | 1.09 |
| | **1996** | 77 | 48 | 62% | 20 | 42% | 26% | 17 | 14 | 1.21 |
| | **1995** | 53 | 35 | 66% | 20 | 57% | 38% | 19 | 11 | 1.72 |
| | **1994** | 50 | 44 | 88% | 29 | 66% | 58% | 28 | 12 | 2.33 |
| | **1993** | 26 | 18 | 69% | 9 | 50% | 35% | 9 | 7 | 1.29 |
| | **1992** | 32 | 21 | 66% | 9 | 43% | 28% | 9 | 7 | 1.29 |
| **Pre-pred mang (1992-2001)** | **total** | 513 | 295 | | 154 | | | 149 | 94 | |
| | **AVE** | | | 60% | | 51% | 32% | | | 1.55 |
| | **STDEV** | | | 20% | | 12% | 18% | | | 0.52 |
| **Post-pred mang (2002-2013)** | **total** | 1505 | 674 | | 347 | | | 342 | 230 | |
| | **AVE** | | | 49% | | 53% | 26% | | | 1.69 |
| | **STDEV** | | | 16% | | 13% | 10% | | | 0.46 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 17. Productivity of Snowy Plovers at Bandon Snowy Plover Management Area, Coos Co., Oregon coast, 1995-2013.**

**Number of eggs laid, number hatched, hatch rate, # fledged, fledgling success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Bandon SPMA | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 185 | 51 | 28% | 19 | 37% | 10% | 19 | 23 | 0.83 |
| | 2012 | 160 | 30 | 19% | 12 | 40% | 8% | 12 | 14 | 0.86 |
| | 2011 | 92 | 43 | 47% | 21 | 49% | 23% | 21 | 15 | 1.40 |
| | 2010 | 87 | 36 | 41% | 6 | 17% | 7% | 6 | 12 | 0.50 |
| | 2009 | 95 | 20 | 21% | 7 | 35% | 7% | 7 | 12 | 0.58 |
| | 2008 | 85 | 8 | 9% | 3 | 38% | 4% | 3 | 15 | 0.20 |
| | 2007 | 114 | 40 | 35% | 24 | 60% | 21% | 23 | 16 | 1.44 |
| | 2006 | 75 | 29 | 39% | 11 | 38% | 15% | 7 | 8 | 0.88 |
| | 2005 | 111 | 45 | 41% | 11 | 24% | 10% | 11 | 17 | 0.65 |
| | 2004 | 71 | 48 | 68% | 26 | 54% | 37% | 25 | 15 | 1.67 |
| | 2003 | 33 | 14 | 42% | 3 | 21% | 9% | 3 | 7 | 0.43 |
| | 2002 | 16 | 4 | 25% | 0 | 0% | 0% | 0 | 4 | 0.00 |
| | 2001 | 16 | 8 | 50% | 1 | 13% | 6% | 1 | 3 | 0.33 |
| | 2000 | 9 | 0 | 0% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | 1999 | 26 | 16 | 62% | 3 | 19% | 12% | 3 | 9 | 0.33 |
| | 1998 | 6 | 3 | 50% | 0 | 0% | 0% | 0 | 2 | 0.00 |
| | 1997 | 34 | 9 | 26% | 0 | 0% | 0% | 0 | 6 | 0.00 |
| | 1996 | 12 | 8 | 67% | 1 | 13% | 8% | 1 | 3 | 0.33 |
| | 1995 | 37 | 11 | 30% | 6 | 55% | 16% | 6 | 6 | 1.00 |
| Pre-pred mang (1995-2001) | total | 140 | 55 | | 11 | | | 11 | 31 | |
| | AVE | | | 41% | | 14% | 6% | | | 0.28 |
| | STDEV | | | 23% | | 20% | 6% | | | 0.36 |
| Post-pred mang (2002-2013) | total | 1124 | 372 | | 143 | | | 137 | 158 | |
| | AVE | | | 35% | | 34% | 13% | | | 0.79 |
| | STDEV | | | 16% | | 17% | 10% | | | 0.51 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 18. Productivity of Snowy Plovers at New River HRA, Coos Co., Oregon coast, 1999-2013.**

**Number of eggs laid, number hatched, hatch rate, # fledged, fledgling success rate, and productivity index based on all known nests. Number of fledglings per male based on nests with known adult males only, therefore number of fledglings may vary from total number of fledglings.**

| | Year | total # eggs laid | total # hatched | hatch rate | total # fledged | fledging success rate | productivity index[a] | # fledged from known males | # of known breeding males | # of fledglings/ male |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | 35 | 23 | 68% | 12 | 52% | 34% | 12 | 11 | 1.09 |
| | **2012** | 46 | 13 | 28% | 2 | 15% | 4% | 2 | 6 | 0.33 |
| | **2011** | 59 | 26 | 44% | 7 | 27% | 12% | 7 | 10 | 0.70 |
| | **2010** | 71 | 24 | 34% | 12 | 50% | 17% | 12 | 15 | 0.80 |
| | **2009** | 76 | 38 | 50% | 16 | 42% | 21% | 16 | 13 | 1.23 |
| | **2008** | 54 | 28 | 52% | 7 | 25% | 13% | 7 | 12 | 0.58 |
| | **2007** | 38 | 24 | 63% | 14 | 58% | 37% | 14 | 8 | 1.75 |
| | **2006** | 18 | 14 | 78% | 6 | 43% | 33% | 6 | 6 | 1.00 |
| | **2005** | 3 | 2 | 67% | 1 | 50% | 33% | 1 | 1 | 1.00 |
| | **2004** | 18 | 11 | 61% | 5 | 45% | 28% | 5 | 4 | 1.25 |
| | **2003** | 14 | 10 | 71% | 7 | 70% | 50% | 7 | 5 | 1.40 |
| | **2002** | 18 | 8 | 44% | 3 | 38% | 17% | 3 | 4 | 0.75 |
| | **2001** | 21 | 11 | 52% | 3 | 27% | 14% | 3 | 5 | 0.60 |
| | **2000** | 11 | 10 | 91% | 1 | 10% | 9% | 1 | 4 | 0.25 |
| | **1999** | 9 | 6 | 67% | 2 | 33% | 22% | 2 | 3 | 0.67 |
| **Pre-pred mang (1999-2001)** | **total** | 41 | 27 | | 6 | | | 6 | 12 | |
| | **AVE** | | | 70% | | 23% | 15% | | | 0.51 |
| | **STDEV** | | | 20% | | 12% | 7% | | | 0.23 |
| **Post-pred mang (2002-2013)** | **total** | 450 | 221 | | 92 | | | 92 | 95 | |
| | **AVE** | | | 55% | | 43% | 25% | | | 0.99 |
| | **STDEV** | | | 16% | | 15% | 13% | | | 0.39 |

[a] - productivity index = number of fledglings/number of eggs laid

**Table 19. Average Snowy Plover productivity on the Oregon coast pre- and post-predator management, 1992-2013.**

| | Siltcoos | | Overlook | | Tahkenitch | | Tenmile | | CBNS | | Bandon SPMA | | New River HRA | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-pred mang (1993-2003) | Post-pred mang (2004-2013) | Pre-pred mang (1999-2003) | Post-pred mang (2004-2013) | Pre-pred mang (1993-2003) | Post-pred mang (2004-2013) | Pre-pred mang (1992-2003) | Post-pred mang (2004-2013) | Pre-pred mang (1992-2001) | Post-pred mang (2002-2013) | Pre-pred mang (1995-2001) | Post-pred mang (2002-2013) | Pre-pred mang (1999-2001) | Post-pred mang (2002-2013) |
| **ave hatch rate** | 38%+/-26% | 39%+/-10% | 54%+/-28% | 39%+/-17% | 46%+/-27% | 45%+/-25% | 59%+/-23% | 36%+/-15% | 60%+/-20% | 49%+/-16% | 41%+/-23% | 35%+/-16% | 70%+/-20% | 55%+/-16% |
| | | | | | | | | | | | | | | |
| **ave fledging success rate** | 20%+/-21% | 44%+/-16% | 36%+/-20% | 48%+/-11% | 43%+/-33% | 39%+/-18% | 53%+/-26% | 45%+/-13% | 51%+/-12% | 53%+/-13% | 14%+/-20% | 34%+/-17% | 23%+/-12% | 43%+/-15% |
| | | | | | | | | | | | | | | |
| **ave productivity index** | 11%+/-17% | 18%+/-11% | 21%+/-9% | 20%+/-10% | 18%+/-16% | 21%+/-12% | 30%+/-19% | 17%+/-9% | 32%+/-18% | 26%+/-10% | 6%+/-6% | 13%+/-10% | 15%+/-7% | 25%+/-13% |
| | | | | | | | | | | | | | | |
| **ave # of fledglings/male** | 0.47+/-0.61 | 1.26+/-0.63 | 0.79+/-0.41 | 1.31+/-0.51 | 0.87+/-0.73 | 1.15+/-0.66 | 1.25+/-0.61 | 1.23+/-0.41 | 1.55+/-0.52 | 1.69+/-0.46 | 0.28+/-0.36 | 0.79+/-0.51 | 0.51+/-0.23 | 0.99+/-0.39 |

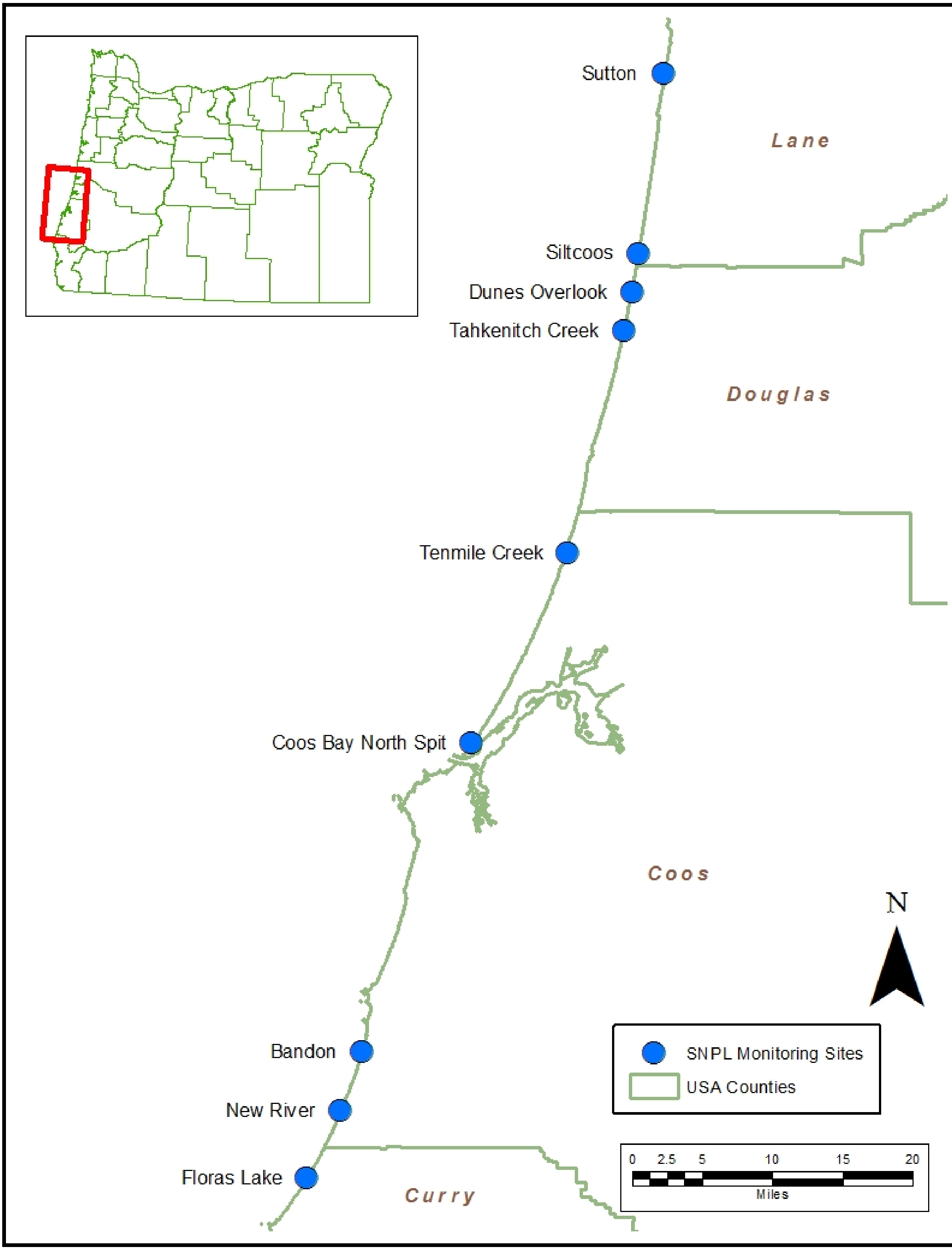



Figure 1. Snowy Plover monitoring locations along the Oregon coast, 2013.

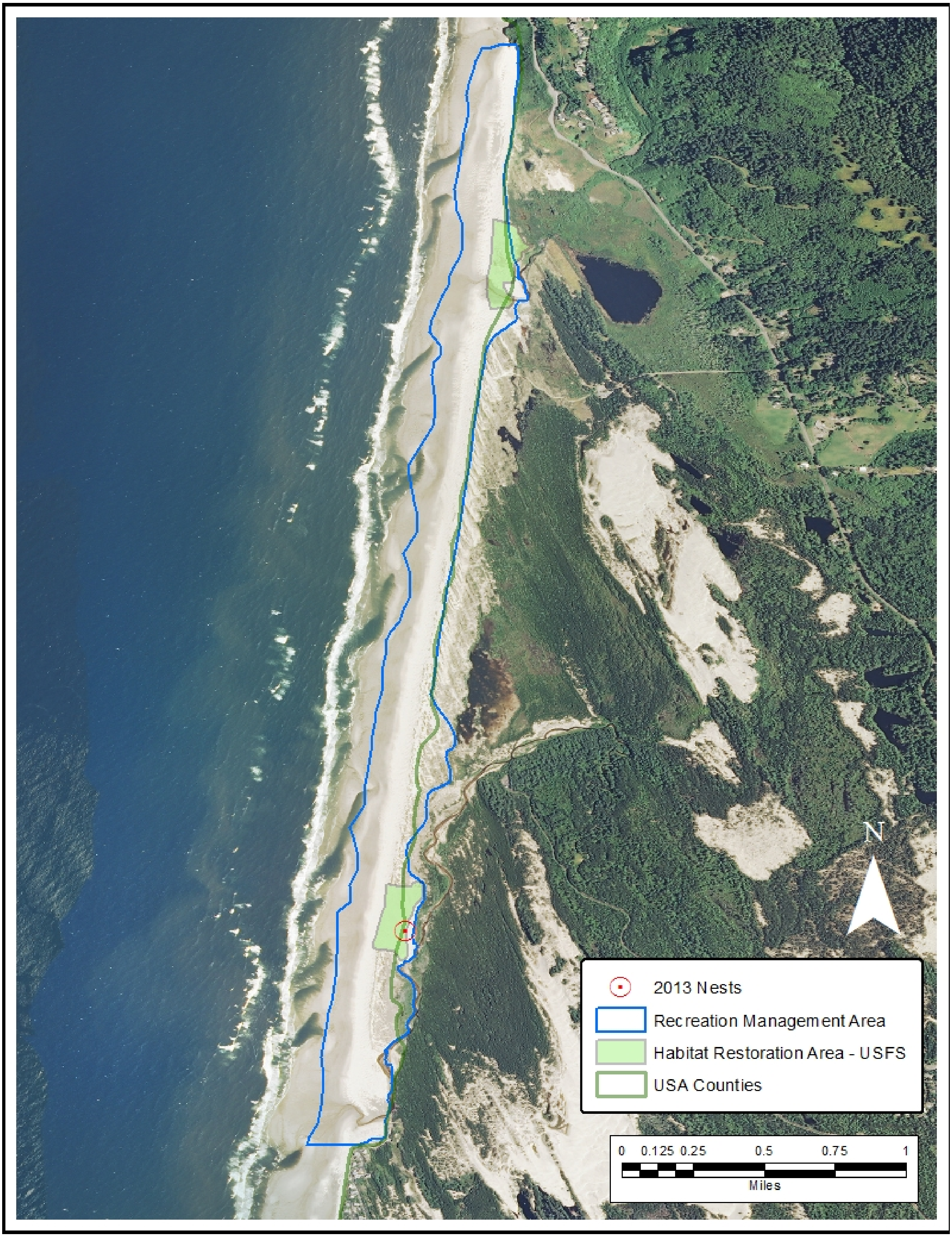



Figure 2. Snowy Plover nest locations at Sutton Beach, Oregon, 2013

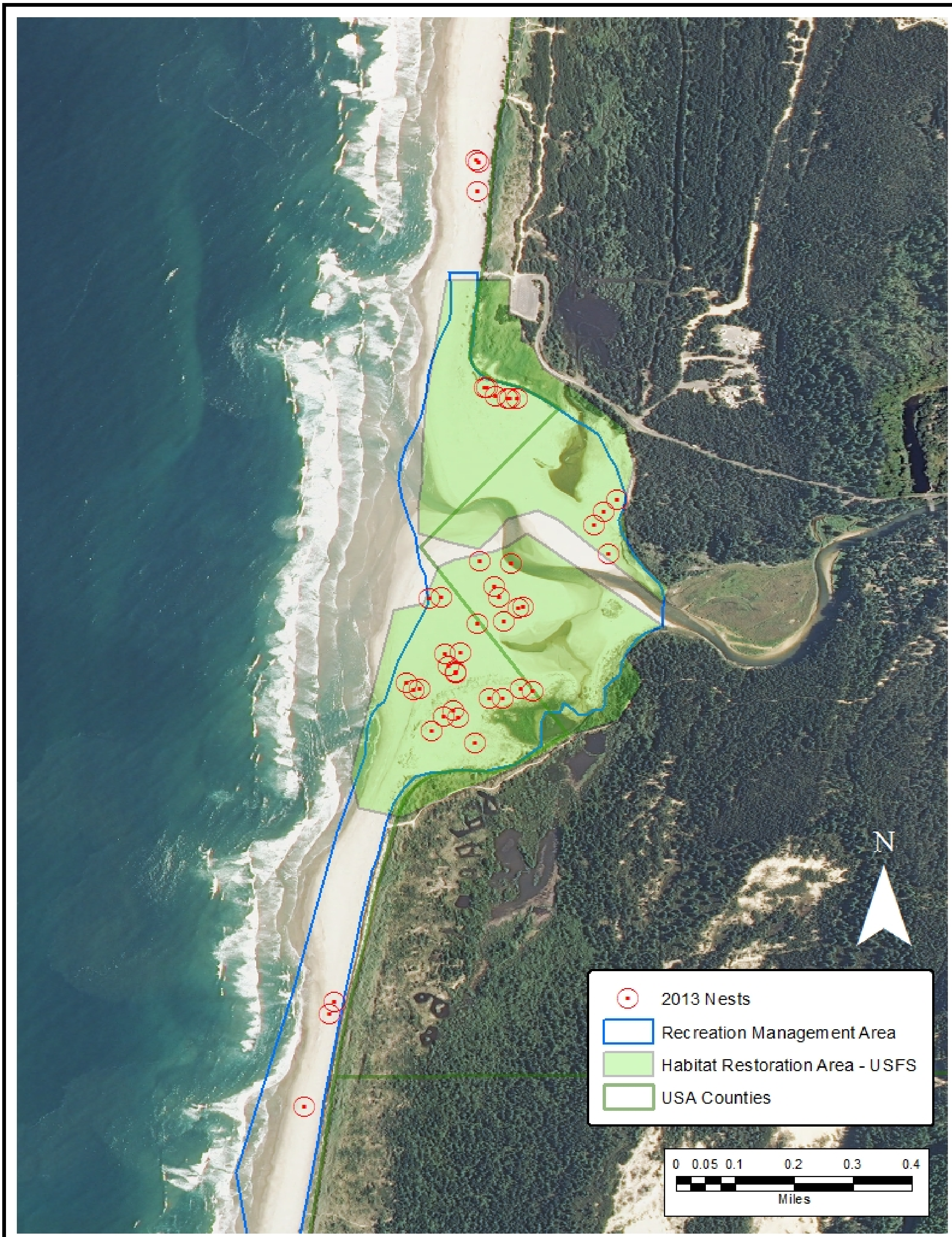



Figure 3. Snowy Plover nest locations at Siltcoos Estuary, Oregon, 2013


Figure 4. Snowy Plover nest locations at Dunes Overlook, Oregon, 2013


Figure 5. Snowy Plover nest locations at Tahkenitch Creek, Oregon, 2013

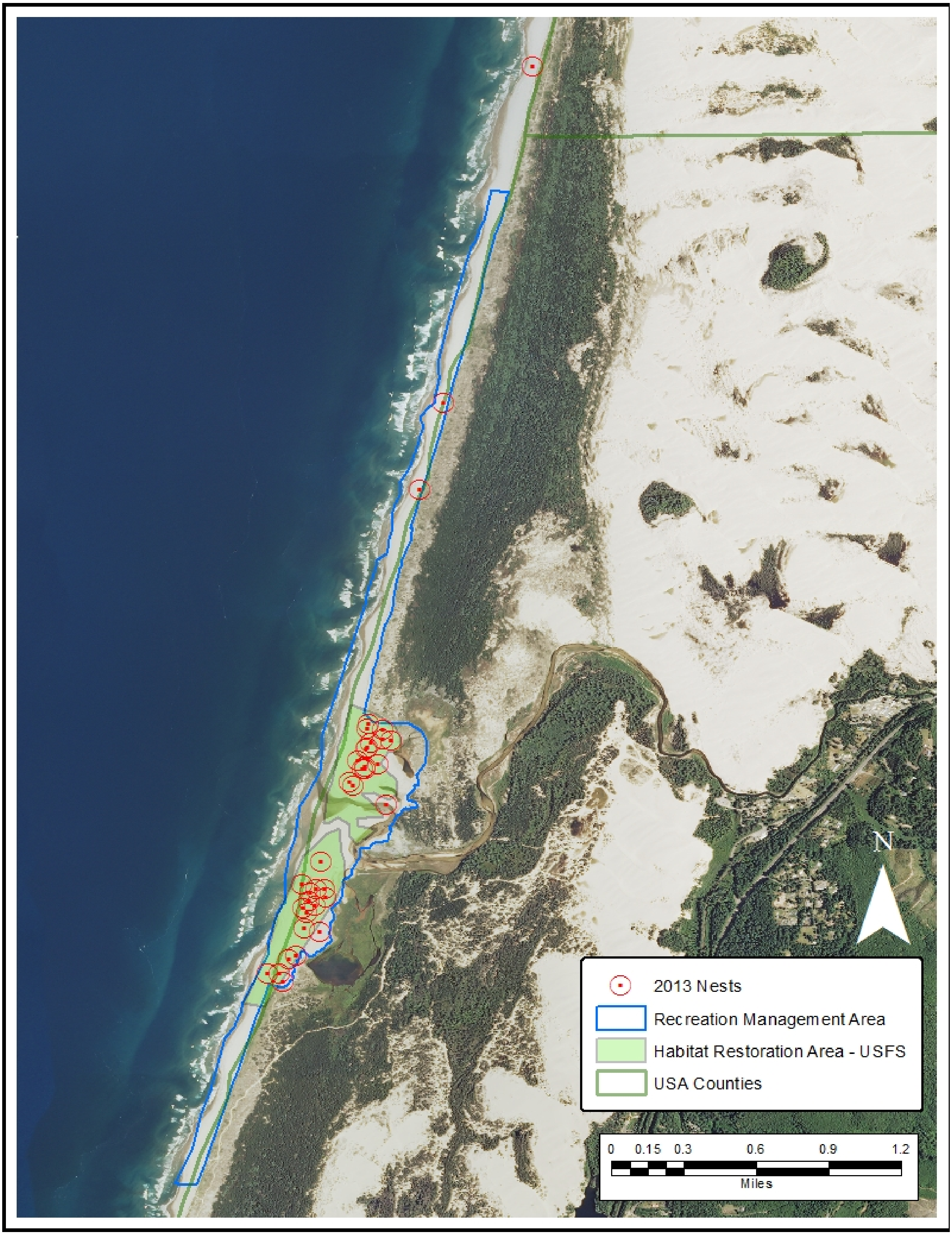



Figure 6. Snowy Plover nest locations at Tenmile Creek, Oregon, 2013

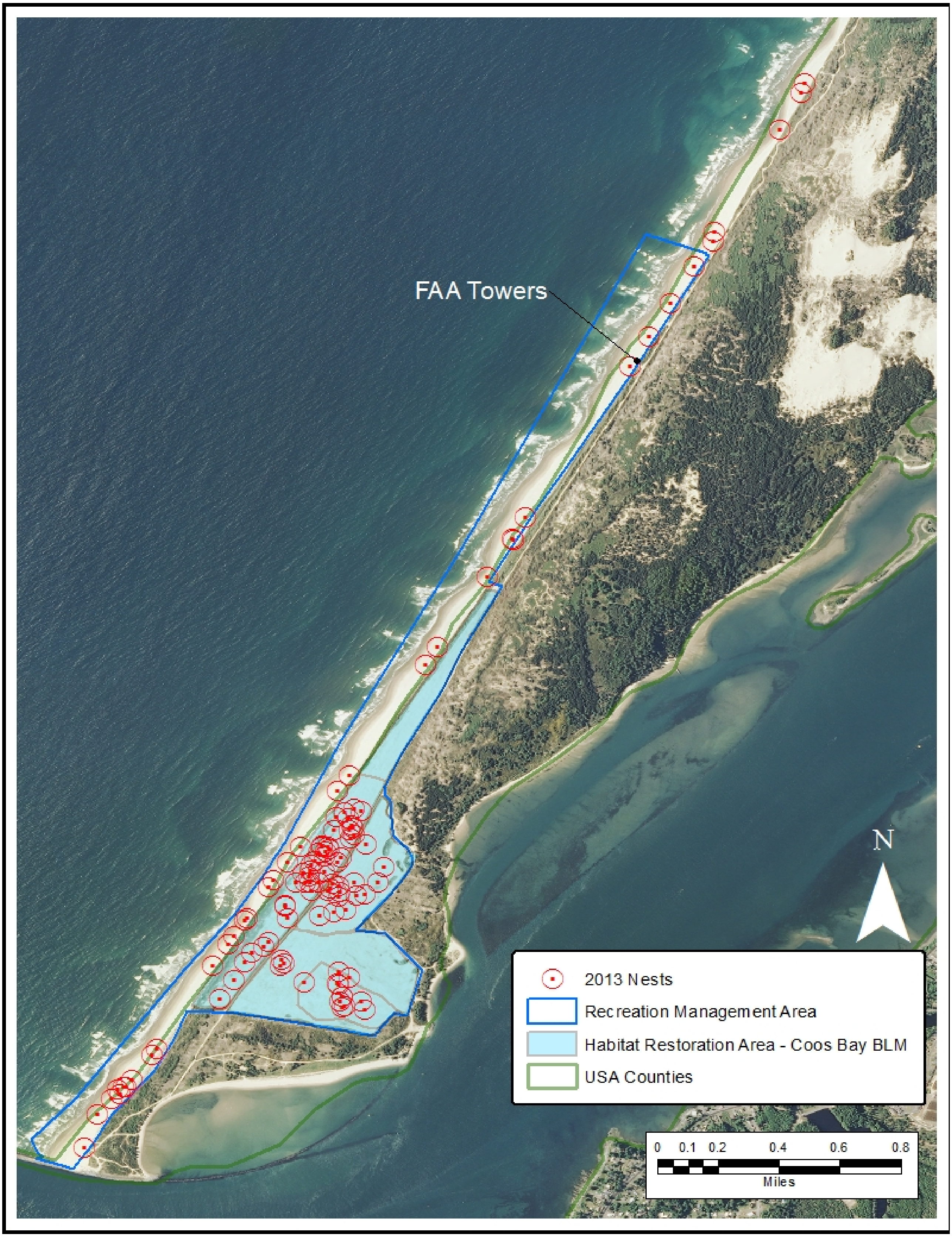



Figure 7. Snowy Plover nest locations at Coos Bay North Spit, Oregon, 2013

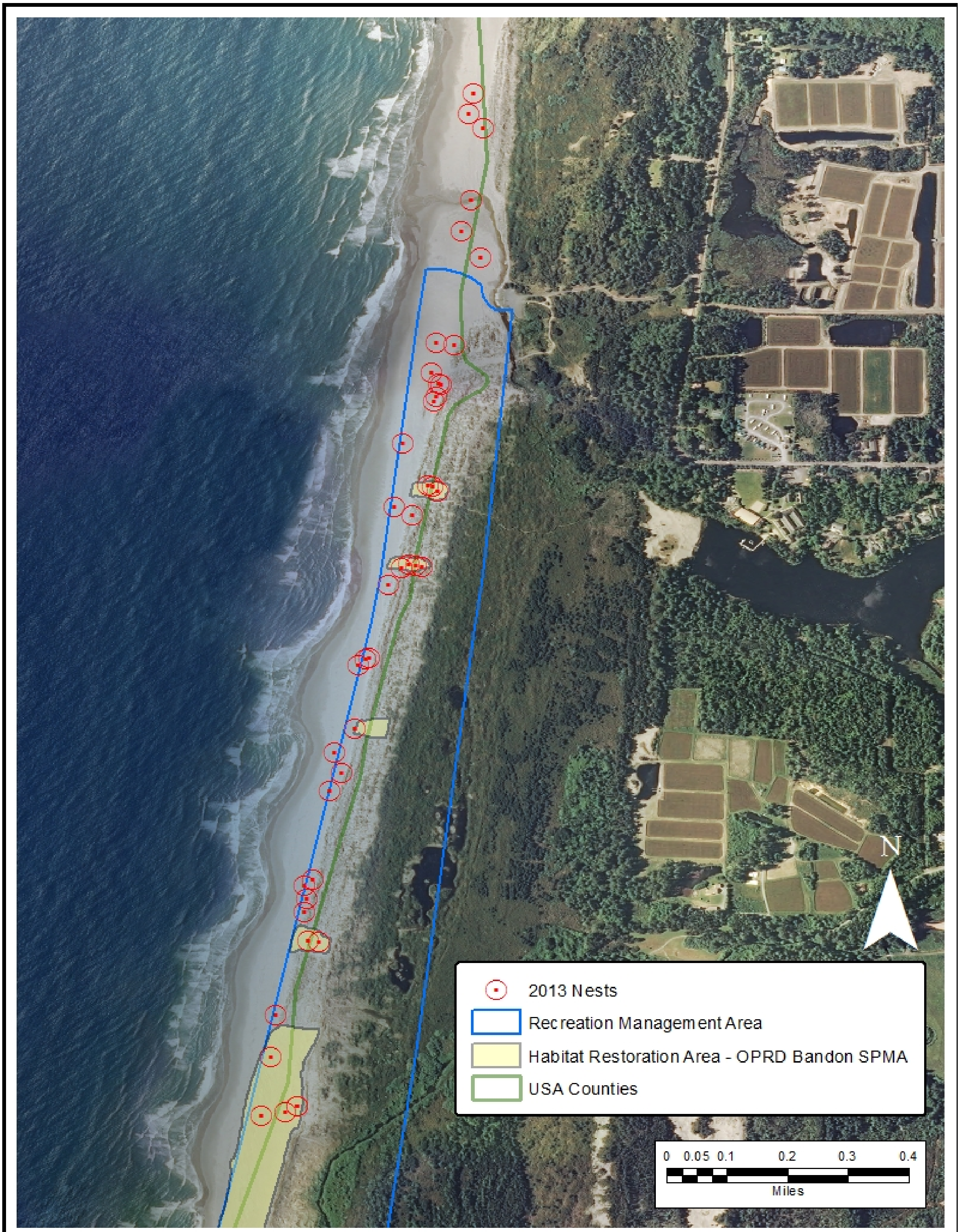



Figure 8. Snowy Plover nest locations at Bandon Beach, Oregon, 2013

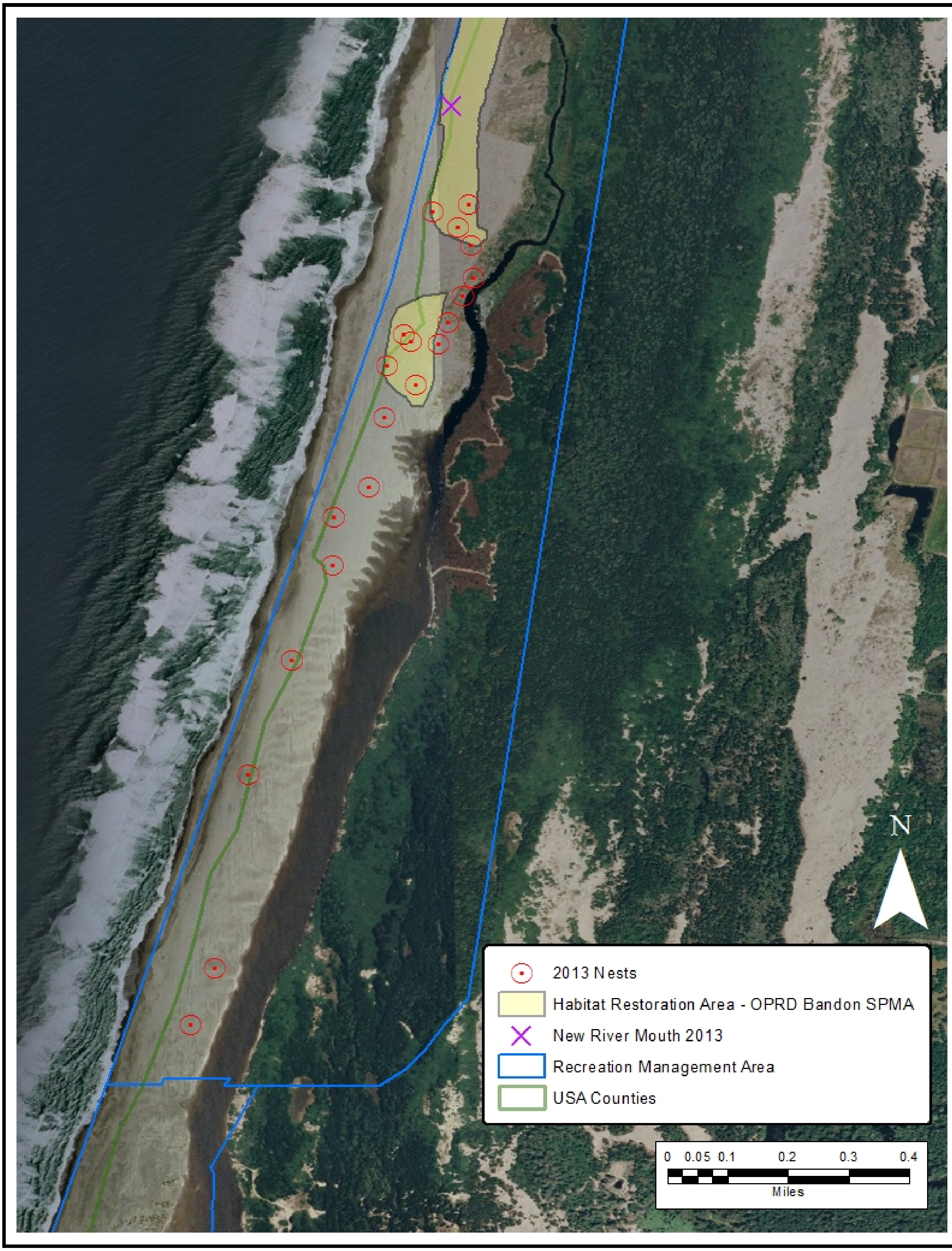



Figure 9. Snowy Plover nest locations at Bandon/New River, Oregon

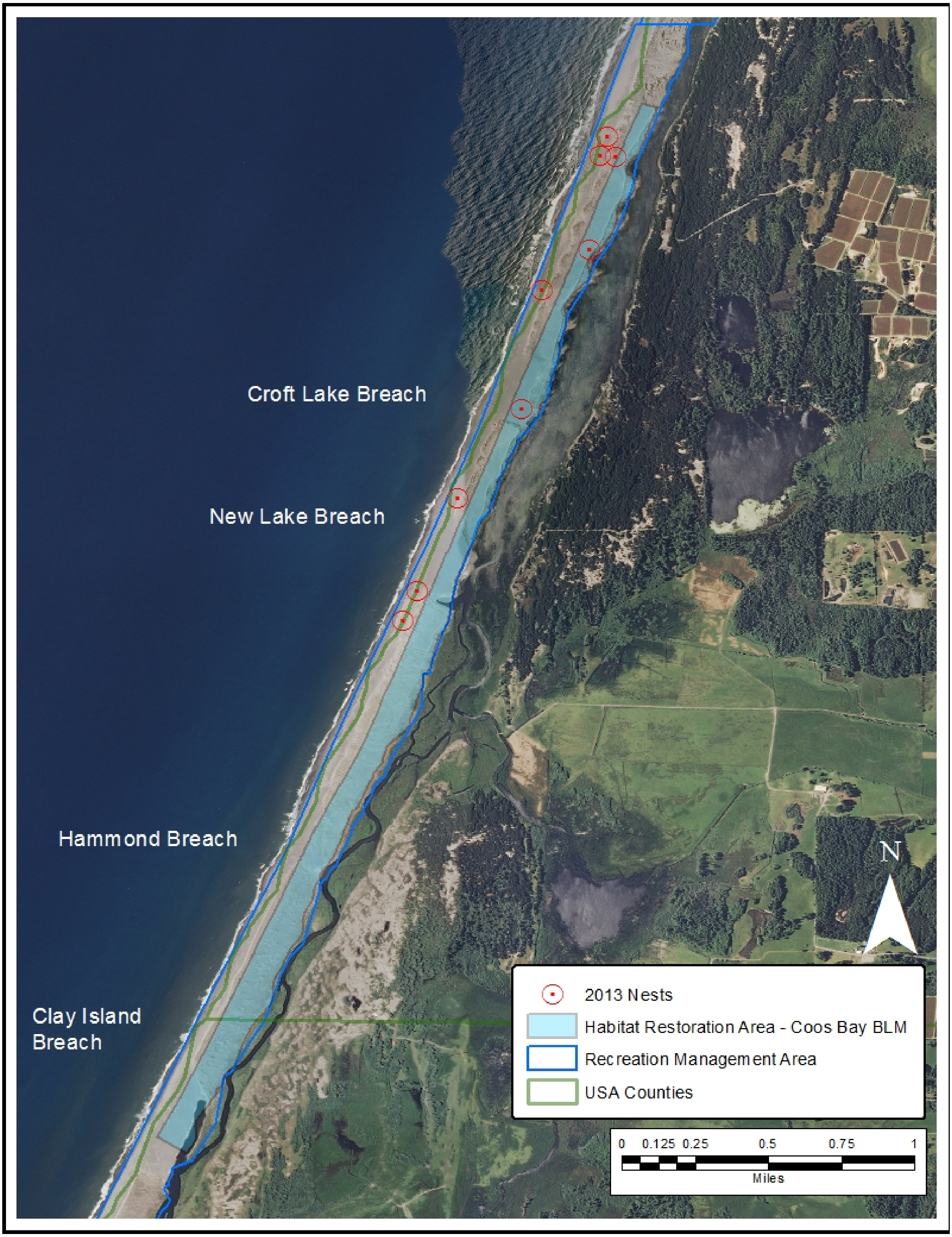



Figure 10. Snowy Plover nest locations at New River HRA, Oregon, 2013

Figure 11. Number of active Snowy Plover nests within 10-day intervals on the Oregon coast, 2013. Dashed lines represent +/- 2 standard deviations.

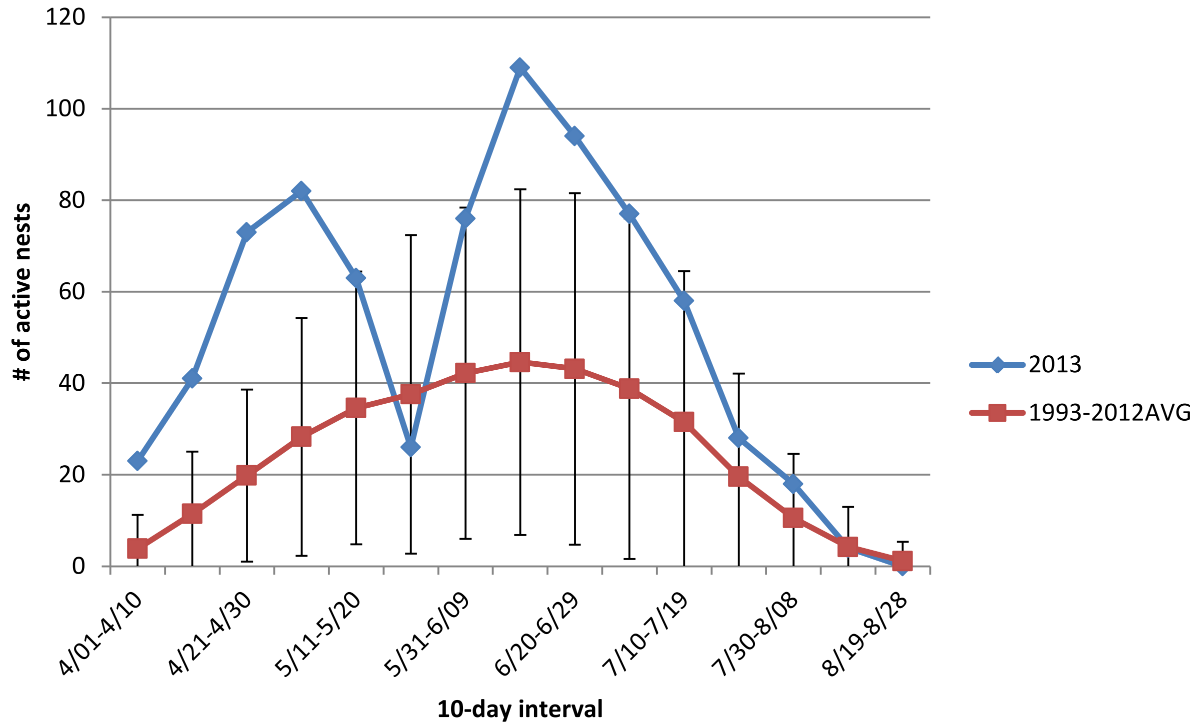


Figure 12. The number of exclosed and unexclosed days of Snowy Plover nests along the Oregon coast, 1992 – 2013.

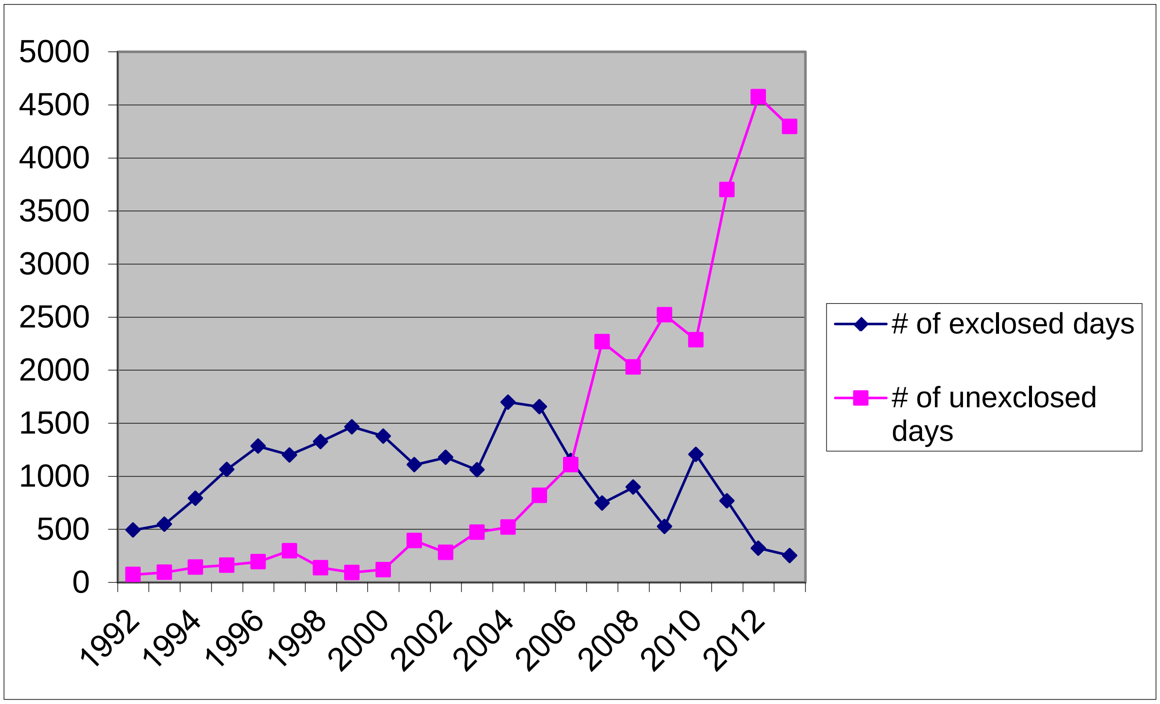
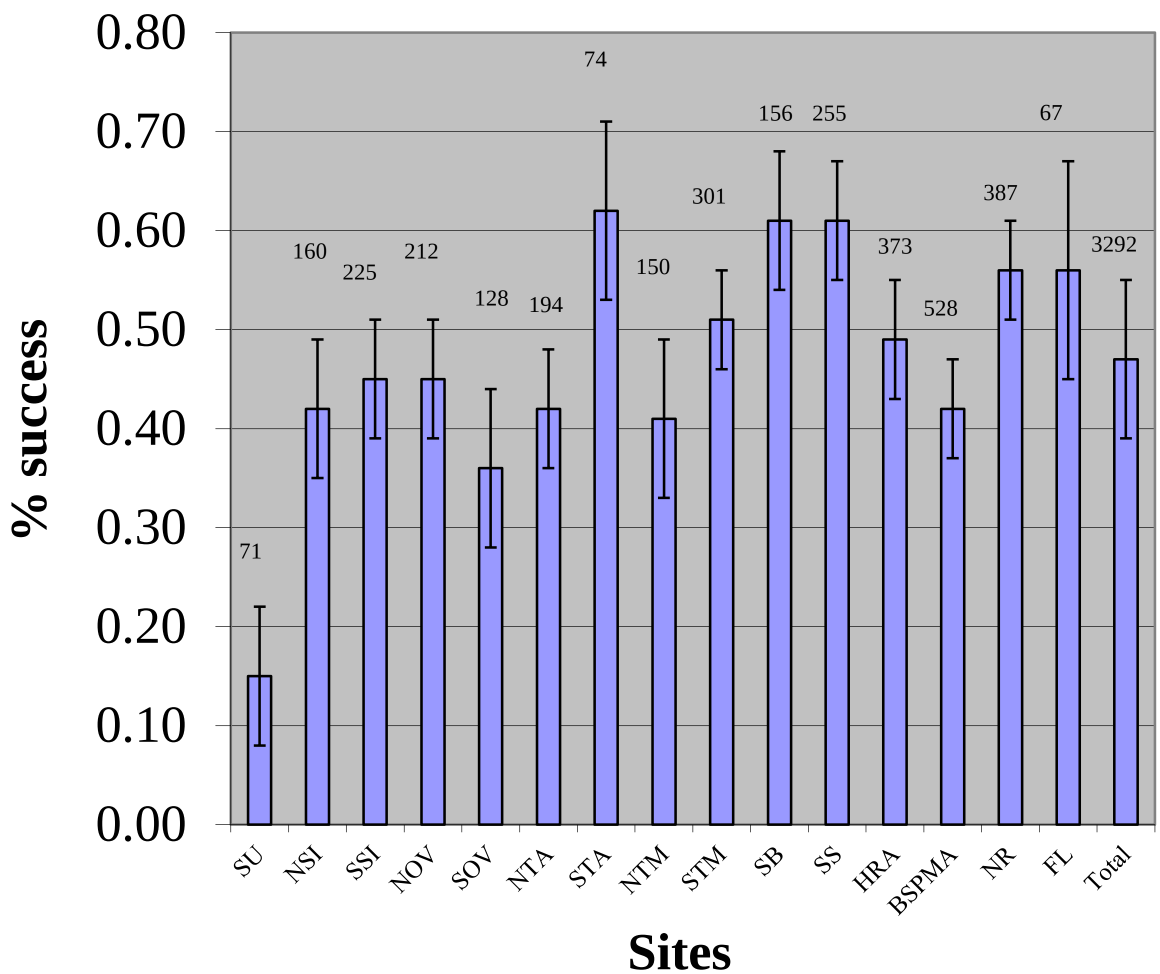


Figure 13. Mean percent nest success for Snowy Plovers along the Oregon coast, 1990-2013, with standard error bars. Number above each bar is the sample size.



## APPENDIX A.

**Study Area**

The study area encompassed known nesting areas along the Oregon coast including all sites between Berry Creek, Lane Co., and Floras Lake, Curry Co. (Fig. 1). Survey effort was concentrated at the following sites, listed from north to south:

**Sutton Beach**, Lane Co. (Figure 2) - the beach north of Berry Creek south to the mouth of Sutton Creek.

**Siltcoos**: North Siltcoos, Lane Co. (Figure 3). - the north spit, beach, and open sand areas between Siltcoos River mouth and the parking lot entrance at the end of the paved road on the north side of the Siltcoos River; and South Siltcoos, Lane Co. - the south spit, beach, and open sand areas between Siltcoos River mouth and south to Carter Lake trail beach entrance.

**Dunes Overlook Clearing**, Douglas Co. (Figure 4). – the area directly west of the Oregon Dunes Overlook off of Hwy 101 including the beach from Carter Lake trail to the north clearing, and south to the Overlook trail south of the south clearing.

**Tahkenitch Creek**, Douglas Co. (Figure 5) - Tahkenitch North Spit - the spit and beach on the north side of Tahkenitch Creek including the beach north to Overlook trail; and South Tahkenitch – from the south side of Tahkenitch Creek to south of Threemile Creek north of the north Umpqua River jetty.

**Tenmile**: North Tenmile, Coos and Douglas Cos. (Figure 6) - the spit and ocean beach north of Tenmile Creek, north to the Umpqua River jetty; and South Tenmile, Coos Co. - the south spit, beach, and estuary areas within the Tenmile Estuary vehicle closure, and continuing south of the closure for approximately 1/2 mile.

**Coos Bay North Spit (CBNS)**, Coos Co. (Figure 7): South Beach - the beach between the north jetty and the F.A.A. towers; and South Spoil/HRAs - the south dredge spoil and adjacent habitat restoration areas (94HRA, 95HRA, 98HRA);

**Bandon Snowy Plover Management Area**, Coos Co. (Figures 8 and 9): This site includes the Bandon SPMA and all nesting areas from north of China Creek to the south end of state land south of the mouth of New River.

**New River**, Coos Co. (Figures 9 and 10) - the privately owned beach and sand spit south of Bandon Snowy Plover Management Area south to BLM lands, and the BLM Storm Ranch Area of Critical Environmental Concern habitat restoration area (HRA).

**Floras Lake**, Curry Co. – the beach and overwash areas west of the confluence of Floras Creek and the beginning of New River, north to Hansen Breach.

The following additional areas were either surveyed in early spring or the breeding window survey: Clatsop Spit, Necanicum Spit, Nehalem Spit, Bayocean Spit, Netarts Spit, Sand Lake South Spit, Nestucca Spit, Whiskey Run to Coquille River, Sixes River South Spit, Elk River, Euchre Creek, and Pistol River.

## APPENDIX B.

**Recommendations for Management of Recreational Activities and Habitat Restoration for sites with Snowy Plovers along the Oregon Coast - 2013.**

**Sutton:**

- Continue to manage the nesting areas particularly at the Sutton Beach HRA; consider spreading shell hash or woody debris to improve the nesting substrate.
- Continue predator management when and if plovers are nesting to reduce predation pressure on broods, particularly corvids.
- Rope and sign around Sutton Beach HRA; rope and sign any other areas if plovers are detected using the beach.

**Siltcoos North and South Spits:**

- Continue predator management to reduce the number of corvids using the nesting area. Continue to reduce the feral cat population in the area. Continue to monitor and possibly remove coyotes that are using and possibly denning near the nesting area.
- Continue signage along river, especially east of nesting area and on any "islands" that may develop to alert kayak/canoe users about plover management activities.
- Continue to post the area with updated maps of the estuary and beach at several locations. These areas include the Stagecoach Trailhead, the north parking lot, and both ends of the Waxmyrtle Trail.
- Erect ropes and signs prior to 15 March, to be as effective as possible. Place signs and ropes on east and south side of the north spit nesting area as well as continued signage to the west and north.
- Enforce dog regulations on the spits and near the estuary during nesting season.
- Continue the use of campground plover hosts/volunteers to educate people and restrict them from closed areas. Use hosts/volunteers, especially during peak periods on weekends, and stagger their hours to cover evenings. Have hosts/volunteers in contact with Law Enforcement Officers to improve enforcement of the closures, and have them engage people on the beach before violations occur.
- Continue to extend appropriate signing to both riverbanks, to prevent hikers from walking up the closed estuary.
- Rope and sign along the foredune south of Waxmyrtle trail access to the Carter Lake trail area; monitor this area for roosting, nesting and brooding plovers.

**Overlook:**

- Continue predator management to control corvid use of the area. Monitor Northern Harrier and Great Horned Owl use of the area and consider removal if harriers and owls continue to pose problems to breeding plovers.
- Continue to rope and sign both north and south closures for Snowy Plover nesting habitat by 15 March.
- Continue to improve and enlarge the restoration area, especially to the south towards Tahkenitch.
- Erect and maintain interpretive signing at the beginning of the Overlook trailhead (near viewing platforms). This signing is intended to provide more information on the ecology of the Snowy Plover and the reasoning for current management techniques and restricted areas.
- Enforce current dog regulations.

**Tahkenitch:**

- Continue to maintain and improve the habitat.
- Continue predator management to control corvid use of the area. Identify if Great Horned Owls or other avian predators are hunting the area. Remove if necessary.
- Continue to rope and sign all suitable habitat. Place signs along east and south edge outside of the roped area to prevent hiking and camping near nesting area.
- Enforce current dog regulations.

**Tenmile North and South Spits:**

- Continue predator management to control corvid use of the area; continue to monitor coyote use and possibly remove coyotes if warranted. Monitor and remove Great Horned Owls if necessary. Evaluate rodent populations and depredations.
- Continue to maintain and improve the south side for nesting. Consider expanding and improving habitat on the north side.
- Continue to rope and sign plover nesting habitat on both north and south spits.
- Enforce vehicle closure to prevent violators from driving in the habitat restoration areas.
- Enforce current dog regulations.

**Coos Bay North Spit:**

- Continue predator management of the area for corvids, feral cats, skunks, and raccoons; monitor the coyote population and remove coyotes if warranted; continue early season rodent trapping to reduce rodent population.
- Continue to improve and maintain the habitat restoration areas. Continue to spread shell hash to improve nesting substrate.
- Maintain gaps in the berm along the 95HRA to facilitate brood movement from the 94HRA and 98WHRA to the 95HRA and to the beach. Maintain small vegetation free gaps in the foredune to facilitate brood access to the beach without destabilizing the foredune.
- Continue to rope and sign the beach as early in the nesting season as possible; avoid erecting signs where the ocean is repeatedly lapping against the foredune to reduce sign loss.
- Clearly sign all entrance points on the spit that vehicle use on the beach is limited to street legal vehicles only.
- Continue closure of the foredune road through the nesting area. Consider a permanent reroute of the foredune road.
- Enforce current dog regulations.

**Bandon:**

- Continue predator management to control mammal and corvid populations.
- Continue to improve and maintain the habitat restoration area north of New River/Twomile Creek. Maintain and improve “cutouts” along the foredune to increase available nesting habitat for plovers; consider additional cutouts along foredune.
- Sign and rope the entire beach from China Creek overwash to the Habitat Restoration Area near the mouth of Twomile Creek/New River before the nesting season.
- Enforce current dog regulations.
- Monitor hiker use from Bandon to Blacklock Point, and check the beach and HRA on weekends for illegal camping activity. Consider beginning a permit system for hikers and campers.

**New River:**

- Continue predator management to control mammal and corvid populations.
- Continue to improve and maintain the habitat restoration area.
- Sign the foredune north of the HRA along the foredune.
- Place interpretive signs near the Lower Fourmile access along the river to inform the public of plover activity.
- Sign State Parks lands on the open spit south of the mouth of New River.
- Enforce current dog regulations.
- Use interpretive specialist to help monitor recreational activities in the area and explain the management efforts in the area.
- Continue to close the gate at the Storm Ranch for 15 April- 15 September.
- Consider a permit process for hikers/campers to help educate hikers, limit their numbers, ensure that they do not have dogs, are legally camping, and are in compliance.

**Floras Lake:**

- Monitor the site for any plover activity.
- Enforce dogs on leash rules at all times.
- Continue to hire an on-site interpretive specialist, to contact the public, monitor the beach, and present slide shows.

## APPENDIX C

**Recovery Unit 1 (Oregon & Washington)**
**Exclosure Use Guidelines Developed by Oregon Biodiversity Information Center for the Western Snowy Plover Working Team**
**2/27/2012**

Nest exclosures are mesh fences that surround a Western Snowy Plover (*Charadrius nivosus nivosus*) nest and act to keep out predators. Nest exclosures have been used in Oregon since 1991 to protect plover nests from depredation by mammalian and avian predators. Prior to implementation of comprehensive predator management, plovers have suffered high rates of nest depredation. Exclosures have been successful at increasing nest success rates (Table 1) (Stern *et al.* 1990, 1991, Craig *et al.* 1992, Casler *et al.*1993, Hallett *et al.*1994, 1995, Estelle *et al.*1997, Castelein *et al.*1997, 1998, 2000a, 2000b, 2001, 2002, Lauten *et al.*2003, 2005, 2006, 2006b, 2007, 2008, 2009, 2010, 2011). Predators that prey on snowy plover eggs include mammalian predators such as skunk (*Mephitis sp.*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), mice (*Peromyscus* sp.), and weasel (*Mustela sp.*); and avian predators, mostly American crows (*Corvus brachyrhynchos*) and common ravens (*Corvus corax*).

Since 1990, we have found 2650 snowy plover nests along the Oregon coast, of which 1057 (40%) have been exclosed. Over the years we have had to adapt exclosure techniques in response to predator behavior around exclosures. (see Castelein *et al.*2000a, 2000b, 2001, Lauten *et al.*2003).

In 1995 we began seeing evidence of adult snowy plover depredations in or immediately outside exclosures. From 1995 to 2011 we documented a minimum of 48 adult losses associated with exclosure use. These losses include 21 cases where blood, feathers, or plover body parts were found in or adjacent to exclosures and 27 cases where incubating adults disappeared from an established, exclosed nest. Forty-eight adult losses associated with 1057 exclosed nests indicate that exclosures subject adult plovers to additional predation risk (approximately 4%). Similar threats associated with exclosures have been reported in other plover populations (Murphy *et al.*2003, Hardy and Colwell 2008, Pearson *et al.*2009). We do not have information on how many adults may be lost at nests not associated with exclosures.

Predator exclosures increase snowy plover hatching success and the number of chicks hatched per male, but not fledging success or the number of chicks fledged per male (Neuman *et al.*2004). In Oregon, they pose an additional risk to incubating adults and may negatively impact adult survival. As in Washington, exclosure use in Oregon has been a management technique, not part of a study of their effectiveness in increasing the overall plover population. We are working with Steve Dinsmore (Department of Natural Resource Ecology and Management, Iowa State University) to evaluate the effectiveness of exclosure use on nest success and adult survival. Preliminary results indicate that, predictably, exclosure use has a strong positive impact on nest success. Further analysis is underway to determine potential impacts of exclosure use on adult success and fledging success (Dinsmore et al., unpublished data) (see Pearson *et al.*2009, Neuman *et al.*2004).

Scott Pearson *et al.* (2009) conducted a search of existing literature on the effects of nest exclosures on nest success for plovers and other ground nesting species (primarily shorebirds). Their findings are summarized below:

- Nest survival of exclosed nests was significantly higher in ten studies (Rimmer and Deblinger 1990, Melvin *et al.*1992, Estelle *et al.*1996, Johnson and Oring 2002, Lauten *et al.*2004, Niehaus *et al.*2004, Isaksson *et al.*2007, Hardy and Colwell 2008, Pauliny *et al.*2008, Pearson *et* *al.*unpublished), and there was no difference in two studies (Nol and Brooks 1982, Mabee and Estelle 2000).

- Exclosed nests appear to be only vulnerable to reptilian and small mammal predators while unexclosed nests are vulnerable to predators of all sizes (Mabee and Estelle 2000).
- No difference in fledging success between exclosed and unexclosed nests in four studies (Hardy and Colwell 2008, Pauliny *et al.*2008, Lauten *et al.*2004, Pearson *et al.* unpublished data) and higher fledging success for exclosed nests in two studies (Larson *et al.*2002, Melvin *et al.*1992). There was no difference in fledging success between exclosed and unexclosed nests for all studies involving snowy plovers.
- Adult mortality associated with exclosures was reported in six of the eight studies that included or mentioned this response variable (Murphy *et al.*2003, Lauten *et al.*2004, Isaksson *et al.*2007, Hardy and Colwell 2008, Pauliny *et al.*2008, Pearson *et al.*unpublished). Only three studies compared adult mortality between exclosed and unexclosed nests and two reported significant increases in adult mortality associated with exclosures (Murphy *et al.*2003 and Isacsson 2007) and one reported no difference (Pauliny *et al.*2008).
- Adult mortality appears to be largely attributable to raptors and appears to be episodic (Murphy *et al.*2003, Neuman et a. 2004, Hardy and Colwell 2008) and differs among habitats (Murphy *et al.*2003).
- Larson *et al.*2002 examined the effect of exclosures on population growth for piping plovers and found the effect to be positive.
- Abandonment was higher for exclosed nests in two studies where this was compared directly (Isaksson et al., 2007, Hardy and Colwell 2008).
- Abandonment was not associated with the construction process, size, shape, mesh size and fence height (Vaske *et al.*1994). Covered exclosures are more likely to be abandoned than uncovered exclosures (Vaske *et al.*1994).
- Exclosures increased incubation length by one day but did not influence chick condition (Isaksson *et al.*2007).
- Egg hatchability was higher in three studies (Melvin *et al.*1992, Isaksson *et al.*2007, Pauliny *et al.*2008) but no difference was observed in one study (Hardy and Colwell 2008).
- Breeding adults may receive false messages regarding site quality and encouragement to continue to breed in sink habitats (Hardy and Colwell 2008). This is an important research question that should be examined but no data support this contention.

Our data and that of others (Murphy *et al.*2003, Hardy and Colwell 2008, Pearson *et al.*2009) indicate that adult plovers are at increased risk of predation while in exclosures. In the absence of research to quantify that risk, and based on the above information, we developed the following guidelines for exclosure use in Oregon:

- Since raptors appear to be the primary threat to adult plovers in exclosures, delay use of exclosures until peak raptor migration has passed. Currently, we have identified May 15 as a suitable cutoff, but this date could be altered as needed.

- Delaying exclosure use until May 15 allows field personnel time to assess causes of early nest failures, although weather conditions can make accurate assessment difficult. During this time, and contingent on funding, we recommend an owl survey be run at each site.

- If nests are being lost primarily to mice, exclosures will not help the problem, and may pose additional risk if the mice are being preyed upon by raptors. In this case exclosure use is not appropriate.

- If corvids and/or large mammals are identified as the main predator at a site, removal of the predators should be the primary goal with exclosures used as a supplemental measure to help protect nests.

- Any use of exclosures should be accompanied by close monitoring to evaluate their effectiveness (Hardy and Colwell 2008) and to detect predators of adult plovers early (Pauliny *et al.*2008). Weather permitting, exclosed nests should be checked at least twice per week. If conditions do not allow checks twice a week, exclosure use should be seriously reconsidered.

- Adult predation associated with exclosures is often episodic (Castelein *et al*. 2000b, Lauten *et al.* 2006). Once adult predation is suspected, all exclosures should be removed from the site and their use discontinued for the season.

- To minimize the risk of episodic predation on adult plovers, additional caution should be used when placing exclosures within sight of each other (this puts multiple adults at risk).

- Exclosures should not be placed along the foredune.

- Exclosures should not be placed in a windy location that might result in nest drifting. Since the ME's are 4 feet per side, the nest is only about 2 feet from each sidewall. If the nest begins to drift, it could come close to a sidewall, and a predator such as a raccoon could reach in and grab the eggs. If an exclosed nest is in a potentially windy location, it must be monitored frequently to ensure the safety of the nest and adults (especially on windy days).

## Appendix D

### Snowy Plover Monitoring Methods

#### Nest Surveys

Monitoring began the first week in April and continued until all broods fledged, typically by mid-September. We used two teams of two biologists; one team covering Tenmile and sites north, and the other covering Coos Bay North Spit and sites south (Fig. 1). In some years this division has been modified to accommodate staff needs. All data collected in the field was recorded in field notebooks and later transferred onto computer. Surveys were completed on foot and from an all-terrain vehicle (ATV). Data recorded on nest surveys included:

- site name
- weather conditions
- start time and stop time
- direction of survey
- number of plover seen, broken down by age and sex
- band combinations observed
- potential predators or tracks observed
- violations/human disturbance observed

Weekly surveys were attempted, but were not always possible due to increasing workload associated with an increased plover population. Additional visits were made to check nests, band chicks, or monitor broods.

#### Population Estimation

We estimated the number of Snowy Plovers on the Oregon Coast by determining the number of individually color banded adult Snowy Plovers recorded during the breeding season, and then adding an estimated number of unbanded Snowy Plovers. We determined the number of unbanded Snowy Plovers observed within ten-day intervals during the breeding season, selected the highest count of unbanded birds and then subtracted the number of adults that were banded subsequently. We also determined the number of plovers known to have nested at the study sites, including marked birds and a conservative minimum estimate of the number of unbanded plovers.

#### Nest Monitoring

We located nests using methods described by Page et al. (1985) and Stern et al. (1990). We found nests by scoping for incubating plovers, and by watching for female plovers that appeared to have been flushed off a nest. We also used tracks to identify potential nesting areas. We defined a nest as a nest bowl or scrape with eggs or tangible evidence of eggs in the bowl, i.e. egg shells. We predicted hatching dates by floating eggs (Westerskov 1950) and used a schedule, developed by G. Page based on a 29-day incubation period (Gary Page, pers comm). We attempted to monitor nests once a week at minimum. We checked nests more frequently as the expected date of hatching approached. We defined a successful nest as one that hatched at least one egg. A failed nest was one where we found buried or abandoned eggs, infertile eggs, depredated eggs, signs of depredation (e.g. mammalian or avian tracks or eggshell remains not typical of hatched eggs or nest cup disturbance) or eggs disappeared prior to the expected hatch date and were presumed to have been predated. In some instances we found nests with only one egg; often there was no indication of incubation or nest defense, and it was uncertain to what extent the nest was abandoned, or simply a “dropped” egg. Because it was difficult to make this determination, we considered all one egg clutches as nest attempts, and classified them as abandoned when there was no indication of incubation or nest defense. Data recorded at nest checks included:

- nest number
- number of eggs in nest
- adult behavior
- description of area immediately around nest
- whether or not the nest is exclosed
- GPS location

**Brood Monitoring**

We monitored broods during surveys and other field work, and recorded brood activity or males exhibiting brood defense behavior at each site. "Broody" males will feign injury, run away quickly or erratically, fly around and/or vocalize in order to distract a potential threat to his chicks. Information recorded when broods were detected included:

- Number of adults and chicks
- Band combinations of adults/chicks seen
- Sex of adults
- Behavior of adults
- Brood location

**Banding**

Adults were normally trapped for banding on the nest, during incubation, using a lilly pad trap and noose carpets. Lilly pad traps are small circular traps made of hardware cloth with a blueberry net top. The traps have a small door that the plover will enter. Noose carpets are 4" x 30" lengths of hardware cloth covered with small fishing line nooses. Plovers walk over the carpets and the nooses snag their legs. We limited attempts to capture adults to 20 minutes per trapping attempt. Chicks were captured for banding by hand, usually in the nest bowl. Banding was completed in teams of two to minimize time at the nest and disturbance to the plovers.

**APPENDIX Q-12**
**Nest Success and the Effects of Predation on Marbled Murrelets**

# Chapter 8
# Nest Success and the Effects of Predation on Marbled Murrelets

**S. Kim Nelson**[1] **Thomas E. Hamer**[2]

**Abstract**: We summarize available information on Marbled Murrelet (*Brachyramphus marmoratus*) productivity and sources of mortality compiled from known tree nests in North America. We found that 72 percent (23 of 32) of nests were unsuccessful. Known causes of nest failure included predation of eggs and chicks ($n$ = 10), nest abandonment by adults ($n$ = 4), chicks falling from nests ($n$ = 3), and nestlings dying ($n$ = 1). The major cause of nest failure was predation (56 percent; 10 of 18). Predators of murrelet nests included Common Ravens (*Corvus corax*) and Steller's Jays (*Cyanocitta stelleri*); predation of a nest by a Great Horned Owl (*Bubo virginianus*) was also suspected. We believe that changes in the forested habitat, such as increased amounts of edge, are affecting murrelet productivity. Successful nests were significantly further from edges ($\bar{x}$ = 155.4 versus 27.4 m) and were better concealed ($\bar{x}$ = 87.2 versus 67.5 percent cover) than unsuccessful nests. The rate of predation on Marbled Murrelet nests in this study appear higher than for many seabirds and forest birds. If these predation rates are representative of rates throughout the murrelet's range, then the impacts on murrelet nesting success will be significant. We hypothesize that because this seabird has a low reproductive rate (one egg clutch), small increases in predation will have deleterious effects on population viability. Rigorous studies, including testing the effects of various habitat features on recruitment and demography, should be developed to investigate the effects of predation on Marbled Murrelet nesting success.

Nesting success in seabirds is influenced by a variety of physical and biological factors, including food availability, habitat quality, energetics, predation, and climatic conditions (Croxall 1987, Nettleship and Birkhead 1985, Vermeer and others 1993). Because the effects of these factors can vary spatially and temporally, seabird nesting success can be highly variable among years (Birkhead and Harris 1985; Boekelheide and others 1990; De Santo and Nelson, this volume). For example, in some years, anomalous warm oceanographic conditions (El Niño) cause a decrease in prey availability, thus impacting nesting attempts and nest success (Ainley and Boekelheide 1990, Hodder and Greybill 1985, Vermeer and others 1979). In addition, disturbance to nesting habitat (e.g., habitat loss, modification) and associated cumulative impacts can affect the ability of seabirds to successfully reproduce (Evans and Nettleship 1985; Gaston 1992, Reville and others 1990).

[1] Research Wildlife Biologist, Oregon Cooperative Wildlife Research Unit, Oregon State University, Nash 104, Corvallis, OR 97331-3803

[2] Research Biologist, Hamer Environmental, 2001 Highway 9, Mt. Vernon, WA 98273

The influence of these biological and physical factors on the nesting success of Marbled Murrelets (*Brachyramphus marmoratus*) is not fully known. In order to completely address this issue, well designed studies investigating the conditions that directly influence murrelet reproduction are needed. However, data are available on murrelet nesting success from tree nests that have been located and monitored in North America. In this paper, we summarize this information on murrelet productivity and sources of mortality. In addition, because predation was the major cause of nest failure, we discuss the implications of predation on this threatened, forest-nesting seabird.

## Methods

We compiled information on nest success and failure from published and unpublished records of 65 Marbled Murrelet tree nests found in North America between 1974 and 1993. The sample size of tree nests were distributed by state and province as follows: Alaska ($n$ = 18), British Columbia ($n$ = 9), Washington ($n$ = 6), Oregon ($n$ = 22), and California ($n$ = 10) (*table 1*). Success and failure of nests were determined through intensive monitoring of nesting activity, or evidence collected at the nest. The outcomes of nests were compared between regions (Alaska versus British Columbia, the Pacific Northwest and northern California). Nests were considered to fail if: (1) the chick or egg disappeared, fell out of the nest, or was abandoned; (2) the chick died; (3) unfaded eggshell fragments were found during the breeding season in nest cups without fecal rings; or (4) predation was documented. Nests were considered or assumed to be destroyed by a predator based on one or more of the following: (1) predation was observed, (2) the egg or chick disappeared prematurely between nest observations and neither were located on the ground after a thorough search of the area, and (3) evidence, such as puncture marks on eggs, or albumen or blood on eggshell fragments, was discovered and predators were aware of the nest location or seen in the immediate area. In addition to data from active nests, information on eggs, nestlings, and hatch-year birds found on the ground were compiled from published and unpublished records between 1900 and the present.

We used a Mann-Whitney U-test to compare the characteristics of nests that were successful with those of nests that failed because of predation. Variables used in the analysis were those that could have an effect on nest exposure or concealment: distance to edge, canopy cover, stand size, percent cover above the nest cup, nest height, distance of the

***Table 1—Marbled Murrelet tree nests by state or province, site, year, and outcome.***

| State or province / Nest site/year found | Nest outcome: Successful | Failed | Unknown | Reason for failure[1] | Predator[2] |
|---|---|---|---|---|---|
| Alaska | | | | | |
| Kelp Bay 1984[a] | – | 1 | – | Abandoned egg | – |
| Naked Island 1991/92[b] | – | 7 | 3 | ?Predation of egg (n = 1)<br>Abandoned egg (n = 3)<br>Unknown/egg stage (n = 2)<br>Unknown/chick stage (n = 1) | ?Steller's Jay<br>?Common Raven[3]<br>—<br>— |
| Kodiak 1992[b] | – | – | 2 | — | — |
| Chugach 1992[b] | – | – | 1 | — | — |
| Afognak 1992[b] | – | – | 2 | — | — |
| Prince of Wales 1992[c] | – | – | 1 | — | — |
| SE Alaska 1993[d] | – | 1 | – | Predation of egg or chick | — |
| British Columbia | | | | | |
| Walbran 1990/91[e] | – | – | 2 | — | — |
| Carmanah 1992[f] | – | – | 1 | — | — |
| Walbran 1992[f] | – | – | 2 | — | — |
| Clayoquot 1993[g] | – | – | 2 | — | — |
| Carmanah 1993[g] | – | – | 1 | — | — |
| Caren 1993[h] | 1 | – | – | — | — |
| Washington | | | | | |
| Lake 22 1991[i] | 2 | – | – | — | — |
| Jimmycomelately 1991[i] | – | – | 1 | — | — |
| Heart of Hills 1991[i] | – | 1 | – | Chick fell out | — |
| Olympic 1991[i] | – | – | 1 | — | — |
| Nemah 1993[j] | 1 | – | – | — | — |
| Oregon | | | | | |
| Five Rivers 1990[k] | – | 1 | – | Chick fell out | — |
| Valley of Giants 1990[k] | – | 1 | – | Predation of chick | ?Great Horned Owl |
| Five Rivers 1991[k] | 1 | – | – | — | — |
| Valley of Giants 1991[k] | – | 1 | – | Predation of egg | ?Common Raven |
| Cape Creek 1991[k] | – | 1 | – | Predation of egg | ?Common Raven |
| Siuslaw #1 1991[k] | 1 | – | – | — | — |
| Siuslaw #2 1991[k] | – | 1 | – | Predation of chick | ?Steller's Jay |
| Boulder Warnike 1992[k] | – | 1 | – | ?Predation of chick | ? |
| Valley of Giants 1992[k] | – | 1 | – | Predation of egg | ?Common Raven |
| Copper Iron 1992[k] | 1 | – | – | — | — |
| Valley of Giants 1993[l] | – | – | 8 | — | — |
| Green Mountain 1993[l] | – | – | 2 | — | — |
| Five Rivers 1993[l] | – | – | 1 | — | — |
| Five Mile Flume 1993[l] | – | – | 1 | — | — |
| California | | | | | |
| "J" Camp 1974[m] | – | 1 | – | Chick fell out | — |
| Waddell Creek 1989[n] | – | 1 | – | Predation of chick | Steller's Jay |
| Opal Creek 1989[n] | – | 1 | – | Predation of egg | Common Raven |
| Father 1991/92[o] | 2 | – | – | — | — |
| Palco 1992[p] | – | 1 | 2 | Chick died | — |
| Prairie Creek State Park 1993[i] | – | 1 | – | Unknown | — |
| Jedediah Smith State Park 1993[i] | – | 1 | – | Unknown | — |

***Table 1—continued***

[1] ?Predation = predation known or suspected based on available evidence.
[2] ?Predator = suspected predator; species seen in vicinity of nest.
[3] Common Raven flushed adult off one of these nests; this may have had an impact on its abandonment which occurred 2 days later.
[a] Quinlan and Hughes, 1990
[b] Naslund and others, in press
[c] Twelve Mile Arm nest; Brown, pers. comm.
[d] Unusual ground level nest located on tree roots above 11 m cliff in Log Jam Creek; Brown, pers. comm.
[e] Manley and Kelson, in press
[f] Jordan and Hughes, in press
[g] Hughes, pers. comm.
[h] P. Jones, pers. comm.
[i] Hamer, unpublished data
[j] Ritchie, pers. comm.
[k] Nelson, unpublished data; Nelson and Peck, in press
[l] Nelson, unpublished data
[m] Binford and others 1975.
[n] Singer and others 1991.
[o] Singer and others, in press.
[p] Kerns, pers. comm.

nest from the trunk, limb diameter at the nest, and nest substrate type (i.e., moss or duff). Edges were defined as unnatural openings, including, but not limited to, roads and clearcuts. Differences in the mean characteristics (ranks) were considered significant at $P < 0.05$.

# Results and Discussion

## Nest Success and Failure

Nesting success or failure was documented at 49 percent (32 of 65) of the nests (*table 2*). Timing of discovery (after the nesting season), limited evidence, or inadequate monitoring prevented conclusions about the outcomes at the remainder of nests. Therefore we limit our discussion to these 32 tree nests.

Seventy-two percent (23 of 32) of the nests were unsuccessful (*tables 1* and *2*). Known causes of nest failure included predation of eggs and chicks, nest abandonment by adults, chicks falling from nests, and nestlings dying (*tables 1* and *3*). Nesting success of 28 percent is lower than reported for 17 other alcid species ( $\bar{x}$ = 57 percent, range = 33–86) (De Santo and Nelson, this volume), and for 11 species of sub-canopy and canopy nesting neotropical landbird migrants ( $\bar{x}$ = 51 percent, range = 20–77) (Martin 1992). However, some species of seabirds (e.g., Xantus' Murrelet [*Synthliboramphus hypoleucus*]) and forest nesting neotropical migrants (e.g., Western Kingbird [*Tyrannus verticalis*]), also experienced low nesting success (33 and 20 percent, respectively) in some years (Martin 1992; Murray and others 1983). Hatching and fledging success of Marbled Murrelet nests were 67 and 45 percent, respectively. Fledging success was also lower than reported for all other alcid species ( $\bar{x}$ = 78 percent, range = 66–100, $n$ = 16) (De Santo and Nelson, this volume).

For all nests, 52 percent of the failures occurred during the egg stage, whereas in Washington, Oregon, and California most (62 percent) failed during the chick stage (*table 3*). The difference in stage of failure between the southern portion of the murrelet's range and all known nests can be explained by greater abandonment of eggs at nests in Alaska (Naslund, pers. comm.). The high incidence of abandonment in eggs in Alaska between 1991 and 1994 may have been related to limited food resources (Kuletz, pers. comm.).

Failure during the egg stage was caused by abandonment and predation. Failure during the chick stage occurred because of predation, death from a burst aorta (Palco nest in California), and falling from the nest. Chicks may fall from nests because nests are located on small platforms, or in response to unfavorable weather conditions, such as high winds, or other natural and unnatural disturbances. In Oregon, a 6-day-old chick may have fallen from its ridgetop nest tree (Five Rivers) because of gusty winds that occurred during a midday storm. Chicks are also occasionally very active on the nest, picking at nesting material, changing positions, snapping at insects, exercising their wings, and pacing on the nest limb (see Nelson and Hamer, this volume a). They could easily fall from the nest platform during these times of activity. In addition, predator activity could cause chicks to fall from the nesting platform.

In addition to failure documented at active nests, nestlings, fledglings, and eggs have been found on the ground during the breeding season at numerous sites throughout North America (*table 4*). Chicks and eggs located on the ground probably fell from nests as indicated above. However, eggs could also be carried by predators and dropped in locations distant from nest sites.

Fledglings have been discovered on the ground at varying distances from the ocean during the breeding season (up to 101 km inland). Many of these birds still retained an egg tooth and small traces of down on their head and back, indicating recent fledging. Marbled Murrelet hatch-year birds

***Table 2—Summary of Marbled Murrelet nest success and failure by state and province***

| State/province | Nest outcome | | |
|---|---|---|---|
| | Successful | Failed | Unknown |
| Alaska | 0 | 9 | 9 |
| British Columbia | 1 | 0 | 8 |
| Washington | 3 | 1 | 2 |
| Oregon | 3 | 7 | 12 |
| California | 2 | 6 | 2 |
| Overall total | 9 (14 pct.) | 23 (35 pct.) | 33 (51 pct.) |
| Total for Washington, Oregon, and California | 8 (22 pct.) | 14 (39 pct.) | 14 (39 pct.) |

***Table 3—Type and stage of Marbled Murrelet nest failure***

| Type of failure | Number (pct.) | Stage of failure | |
|---|---|---|---|
| | | Egg | Chick |
| All nests | | | |
| Predation | 10[1] (43) | 5 (56) | 4 (44) |
| Unknown | 5[1] (22) | 2 (50) | 2 (50) |
| Abandonment | 4 (17) | 4 (100) | 0 |
| Chick fell out | 3 (13) | – | 3 (100) |
| Chick died | 1 ( 4) | – | 1 (100) |
| Total | 23[2] (100) | 11 (52) | 10 (48) |
| Nests in Washington, Oregon, and California | | | |
| Predation | 8 (57) | 5 (62) | 3 (38) |
| Unknown | 2[1] (14) | 0 | 1 (100) |
| Abandonment | 0 | 0 | 0 |
| Chick fell out | 3 (21) | – | 3 (100) |
| Chick died | 1 ( 7) | – | 1 (100) |
| Total | 14[1] (100) | 5 (38) | 8 (62) |

[1] One nest failed at unknown stage.
[2] Two nests failed at unknown stage.

***Table 4—Marbled Murrelet chicks, eggs, and juveniles found on the ground by state and province - an indication of additional nest failure***[1]

| State/province | Number grounded chicks | Number whole eggs | Number grounded juveniles |
|---|---|---|---|
| Alaska | 1 | 1 | 5 |
| British Columbia | 3 | 0 | 6 |
| Washington | 3 | 2 | 9 |
| Oregon | 2 | 1 | 4 |
| California | 3 | 0 | 22 |
| Overall | 12 | 4 | 46 |

[1] Data from Atkinson, pers. comm.; Confer, pers. comm.; Carter and Erickson 1992; Carter and Sealy 1987b; Hamer, unpublished data; Kuletz, pers. comm.; Leschner and Cummins 1992b; Mendenhall 1992; Nelson, unpublished data; Nelson and others 1992; Rodway and others 1992; S.W. Singer, pers. comm.

are believed to fly directly from inland nest sites to the ocean after fledging (Nelson and Hamer, this volume a; Quinlan and Hughes 1990). Their travel to the ocean may be unsuccessful, however, because of navigational problems or exhaustion. Unlike other alcids, hatch-year Marbled Murrelets must fly relatively long distances to reach the sea without the benefit of past flight experience, wing muscle development that comes with flight, or adult guidance. The large number of juveniles found on the ground while dispersing from nest sites raises questions about the relationship between murrelet energetics, location of the nest in relation to the ocean, and nesting success. Given that some hatch-year birds become grounded each year, and may be unable to take flight again, nest success may actually be much lower than our estimates from nest observations.

### Failure because of predation

The major cause of nest failure was predation. Forty-three percent of all nests and 57 percent of nests in Washington, Oregon and California failed as a result of predation (*table 3*). Predation rates were higher (56 and 67 percent, respectively) when excluding unknown causes of failure, which could have included predation. Known predators of murrelet nests include Common Ravens (*Corvus corax*) and Steller's Jays (*Cyanocitta stelleri*) (Naslund 1993; Singer and others 1991) (*table 1*). Predation of a nest by a Great Horned Owl (*Bubo virginianus*) is also suspected. Other potential predators in forests include several species of forest owls, accipiters and American Crows (*Corvus brachyrhynchos*). No Marbled Murrelet nests are known to have been destroyed by mammalian predators, although raccoons (*Procyon lotor*), marten (*Martes americana*), fisher (*Martes pennanti*), and several species of rodents are potential predators.

Predation rates on murrelet nests appear higher than other alcids, perhaps with the exception of areas with introduced or high numbers of predators. For example, 44 percent of the eggs laid by a population of Xantus' Murrelets on Santa Barbara Island in California were taken by deer mice (*Peromyscus* spp.) during periods of egg neglect (Murray and others 1983). Rates of predation on murrelet nests also appear higher than those observed for many forest birds, with the exception of some species of sub-canopy and canopy nesting neotropical migrants (e.g., $\bar{x}$ = 42 percent, range = 18-67 percent) (Martin 1992). However, the impacts of predation on the nesting success of species that lay clutches of two or more eggs (e.g., Xantus' Murrelets, Yellow-rumped Warbler [*Dendroica coronata*]) may be less than on species that lay only one egg, such as Marbled Murrelets.

Predation on Marbled Murrelet nests has been observed or documented during both the egg and nestling stages, but most (56 percent) occurred during the egg stage (*table 3*). Predation during the egg stage is most likely to occur if an incubating adult neglects or abandons the nest. Seabirds are known to completely abandon their nests during years in which prey availability is limited (i.e., during El Niño events) (Ainley and Boekelheide 1990, Hodder and Greybill 1985, Vermeer and others 1979). In addition, seabirds may neglect their eggs for short periods to maximize foraging time and accumulate sufficient energy reserves for the lengthy incubation shifts (Boersma and Wheelwright 1979, Gaston and Powell 1989, Murray and others 1983). During this time, the eggs are subject to a variety of negative factors including predation, heat loss, and exposure to the elements.

Murrelets have been observed leaving their eggs unattended for short periods of time (2–3 hrs on several days) (Naslund 1993; Nelson and Peck, in press), and during such a time in Oregon (Cape Creek nest), an egg was taken by a predator (most likely a Common Raven). In addition, murrelets regularly left their egg unattended in the afternoon, evening, and early morning hours during a 5-day period at a nest in Alaska (Naked Island 1992), and the nest subsequently failed (Naslund and others, in press). Eggs were also abandoned when adults were flushed from the nest by a predator in California (Opal Creek) and Alaska (Naked Island) (Naslund 1993; Naslund and others, in press; Singer and others 1991). The eggs from these nests were later observed or believed to have been destroyed by a Common Raven and Steller's Jay, respectively.

In Oregon, additional egg predation was determined by finding blood and albumen on eggshell fragments. The egg disappeared from the 1991 Valley of the Giants nest after three weeks of incubation. Upon climbing the nest tree, a large eggshell fragment with blood stains was found in the nest cup. The suspected predator was a Common Raven that flew directly adjacent to the nest branch on its daily foraging forays. At the 1992 Valley of the Giants nest, eggshell fragments with blood and albumen were found at the base of a large Douglas-fir (*Pseudotsuga menziesii*) tree. An empty nest cup was subsequently discovered. The predator was most likely a Common Raven observed near the nest tree on several occasions.

In Oregon, chicks disappeared or were killed by predators at three nests during the 1991 and 1992 breeding seasons. A 3-week-old chick at the Siuslaw #2 nest was killed when its skull was pierced by a predator. Two species of corvids (Steller's Jay or Gray Jay [*Perisoreus canadensis*]) detected in the nest tree and adjacent area are the suspected predators. At the Boulder Warnicke nest, a 3-week-old chick disappeared from the nest. The predator could have been any one of the corvids that were present in the area or landed in the nest tree: Steller's Jays, Gray Jays, or Common Ravens. A 6-day-old chick disappeared at the Valley of Giants 1990 nest between 2100 and 0600 hrs on 6 August. A Great Horned Owl was heard calling from an adjacent tree (within 10 m) during this time period, and is the suspected predator.

Marbled Murrelets have limited defenses and their primary protection against predation at the nest is to avoid detection (Nelson and Hamer, this volume a; Nelson and Peck, in press). Therefore, the nestling depends on its cryptic plumage and the location of the nest for safety. If a predator discovers the nest, the chick will attempt to defend itself with aggressive behaviors as witnessed by Naslund (1993) and Singer and others (1991), when a Steller's Jay attacked a 4-day-old chick at the Waddell Creek nest in California. The chick rotated its sitting position on the nest to constantly face the predator, reared up its body and head, opened its beak, and jabbed at the predator. The chick was unable to ward off the jay and was carried away.

Nesting attempts also may fail because adults have been killed on their way to or at nest sites. In forests of southeast and southcentral Alaska, Sharp-shinned Hawks (*Accipiter striatus*) and Northern Goshawks (*Accipiter gentilis*) are known to prey on adult murrelets (Marks and Naslund 1994; Naslund, pers. comm.). In addition, Peregrine Falcons (*Falco peregrinus*) and Common Ravens have been observed chasing Marbled Murrelets just above and within the forest canopy, respectively (Hamer, unpubl. data; Hunter, pers. comm.; Suddjian, pers. comm.). A Peregrine Falcon was successful in capturing a Marbled Murrelet at one such site in central California (Suddjian, pers. comm.).

Predation of adults at the nest site also can occur. There are two known records from California and Alaska. A Common Raven flushed an adult murrelet from a nest in California (Opal Creek), and was later seen carrying what appeared to be a partial carcass (Naslund 1993, Singer and others 1991). In Alaska, an adult was killed by a Sharp-shinned Hawk seconds after it landed on a suspected nest limb (Naked Island) (Marks and Naslund 1994).

**Potential for Bias**

The Marbled Murrelet nests at which predation has been studied may not be an unbiased sample. The high predation rates recorded at these nests could be biased because many of the nests were located in fragmented areas and near forest edges (*table 5*) rather than in the centers of large, dense stands. Thus, there is the possibility that nest sites located by researchers are also those more easily located by predators (see below). At present we lack information to evaluate this source of potential bias.

In addition, it has been suggested that researchers studying these nests had an impact on their success (see Götmark 1992; Martin and Geupel 1993). We believe the disturbance to the nests was minimal, except at two. In southeast Alaska, researchers approached very close to an unusual murrelet nest located on tree roots near ground level (Brown, pers. comm.). The adult was flushed or disturbed on five occasions, which may have contributed to its failure (egg or newly hatched chick disappeared). The "J" Camp nest in California also failed from direct human intervention (Binford and others 1975). No human impacts are suspected at nests where the chick fell out ($n$ = 1 in Oregon) or died ($n$ = 1 in California), or where nests were found after they had failed ($n$ = 1 each in Washington and Oregon, $n$ = 2 in California). At all other nests, human impacts were also limited because: (1) some nests were monitored infrequently ($n$ = 8 in Alaska and $n$ = 2 in Oregon); (2) predators knew the location of the nest on day of and probably prior to discovery, and, additionally, precautions (e.g., limiting noises and number of observers near nest; see Martin and Geupel 1993) were implemented to minimize disturbance and predator attraction ($n$ = 1 in Oregon, $n$ = 2 in California); and (3) nests were monitored from >25 m horizontal distance from the nest and precautions (see above) were implemented ($n$ = 17). For (2) and (3) above, predators were occasionally attracted to the observer's location on the ground (especially Steller's Jays), but not to the nest site, >18 m above the ground. In contrast, intensive disturbance occurred at three successful nests. In Oregon, the only nest tree that was climbed while active was successful, and in Washington, chicks at two nests fledged despite regular climbing (approximately once a day for 9–20 days) to collect nestling growth and development data.

*Table 5—Characteristics of successful Marbled Murrelet tree nests compared with those that failed because of predation*

| State/province Site/year | Outcome[1] | Distance to edge[2] (m) | Canopy cover (pct.) | Stand size (ha) | Nest concealment (pct.) | Nest height (m) | Limb diameter (cm) | Distance from trunk (cm) | Substrate |
|---|---|---|---|---|---|---|---|---|---|
| British Columbia | | | | | | | | | |
| Caren 1993[a] | 1 | 700 | 70 | 800 | 100 | 18.0 | 20.0 | 0 | moss |
| Washington | | | | | | | | | |
| Lake 22 1991[b] | 1 | 55 | 58 | 405 | 70 | 31.4 | 10.7 | 45.6 | moss |
| Lake 22 1991[b] | 1 | 65 | 74 | 405 | 95 | 27.7 | 36.5 | 57.0 | duff |
| Nemah 1993[c] | 1 | 10 | 65 | 142 | 80 | - -[3] | - - | - - | moss |
| Oregon | | | | | | | | | |
| Valley of Giants 1990[d] | 0 | 20 | 44 | 149 | 70 | 56.0 | 34.5 | 33.0 | moss |
| Five Rivers 1991[d] | 1 | 75 | 49 | 46 | 80 | 50.3 | 38.0 | 116.2 | moss |
| Valley of Giants 1991[d] | 0 | 28 | 50 | 149 | 80 | 50.3 | 41.0 | 17.1 | duff |
| Cape Creek 1991[d] | 0 | 16 | 65 | 138 | 95 | 44.2 | 10.0 | 762.0 | moss |
| Siuslaw #1 1991[d] | 1 | 56 | 60 | 89 | 85 | 60.3 | 23.3 | 152.0 | moss |
| Siuslaw #2 1991[d] | 0 | 64 | 52 | 47 | 80 | 51.5 | 13.0 | 230.0 | duff |
| Boulder Warnicke 1992[d] | 0 | 32 | 19 | 3 | 80 | 61.0 | 21.6 | 46.0 | moss |
| Valley of Giants 1992[d] | 0 | 15 | 66 | 149 | 70 | 52.0 | 47.0 | 35.0 | moss |
| Copper Iron 1992[d] | 1 | 300 | 93 | 542 | 75 | 49.0 | 34.0 | 1.0 | moss |
| California | | | | | | | | | |
| Waddell Creek 1989[e] | 0 | 10 | 40 | 1700 | 25 | 38.5 | 36.3 | 61.0 | moss |
| Opal Creek 1989[e] | 0 | 34 | 40 | 1700 | 40 | 43.7 | 47.7 | 122.0 | moss |
| Father 1991[f] | 1 | 69 | 40 | 1700 | 100 | 41.1 | 61.0 | 0 | duff |
| Father 1992[f] | 1 | 69 | 40 | 1700 | 100 | 53.2 | 42.0 | 0 | duff |

[1] 1 = successful, 0 = failed.
[2] Edge = Distance to nearest unnatural edge (road or clearcut).
[3] Data not available.
[a] P. Jones, pers. comm.
[b] Hamer, unpublished data.
[c] Ritchie, pers. comm.
[d] Nelson, unpublished data; Nelson and Peck, in press.
[e] Singer and others 1991.
[f] Singer and others, in press.

## Habitat Characteristics and Predation of Nests

The effect of predators on avian nesting success can vary significantly with geographic location, and is dependent upon the species of predators present, accessibility of nests, type and dimension of the habitat, topography, and vegetative complexity (vertical and horizontal diversity) (Chasko and Gates 1982; Martin 1992; Marzluff and Balda 1992; Paton 1994; Reese and Ratti 1988; Yahner 1988; Yahner and others 1989). For example, alcids nesting on islands relatively free of mammalian predators, or on cliffs inaccessible to terrestrial predators, experience lower predation rates than species nesting in accessible sites and with abundant predators (Ainley and Boekelheide 1990; Hudson 1985). Because many species of birds have evolved in association with predators, the long term impacts of predation on avian nesting success are expected to be minimal in natural situations. However, rapid and unnatural changes, such as the introduction of mammalian predators (cats, goats, mice, pigs, raccoons, rats) and habitat modification, can have significant impacts on nesting success of seabirds (Bailey and Kaiser 1993; Ewins and others 1993; Gaston 1992; Murray and others 1983), and neotropical migrants (Chasko and Gates 1982; Martin 1992), respectively. In these cases, predation can be a major factor affecting avian population viability (Martin 1992).

Significant changes have occurred in the forested landscapes of the United States over the past century, including loss of late-successional forests, habitat fragmentation, and increases in the amount of edge (Hansen and others 1991; Harris 1984; Morrison 1988; Perry, this volume; Thomas and Raphael 1993). These changes have affected the abundance and distribution of many avian predators and forest nesting birds. For example, populations of corvids and

Great Horned Owls are increasing in numbers throughout the western United States, especially in response to increases in habitat fragmentation and human disturbance (Johnson 1993; Marzluff 1994; Marzluff and Balda 1992; Robbins and others 1986; Rosenberg and Raphael 1986; Yahner and Scott 1988). In contrast, numerous neotropical migrant species are declining in numbers because they are unable to adjust to fragmentation and rapidly changing habitat conditions (Hagan and Johnson 1992; Hansen and others 1991, Hejl 1992, Martin 1992, Morrison and others 1992, Rosenberg and Raphael 1986). The Marbled Murrelet was listed as a threatened species in 1992 as changes in the forested landscape appear to be negatively impacting their populations (U.S. Fish and Wildlife Service 1992).

Although the relationship between predator numbers, habitat fragmentation, and predation on Marbled Murrelet nests has not been specifically studied, we believe, based on the following data, that changes in their habitat, such as increased amounts of edge, may significantly affect their nesting success. First, evidence from murrelet nests in this study suggests that distance to edge, stand size, canopy closure, percent cover above the nest cup (nest concealment), and distance of the nest from the tree trunk may be affecting predation rates (*table 5*). In a comparison of these habitat characteristics between successful nests ($n$ = 9) and nests that failed because of predation ($n$ = 8, excluding Alaska), we determined that successful nests were located significantly farther from edges (U = 2.9, $n$ = 16 trees, $P < 0.05$) (*table 5*). All successful nests were located >55 m ( $\bar{x}$ = 166.3, $n$ = 8 trees, *s.e.* = 82.3) from an edge (road or clearcut), with the exception of the Nemah nest in Washington, which was located within 10 m of an old road near the center of a 142 ha forest. In contrast, all nests that failed because of predation were located within 64 m ( $\bar{x}$ = 27.4, *s.e.* = 6.0) of an edge. In a review of numerous artificial nest predation studies, Paton (1994) found evidence that predation of bird nests is higher within 50 m of edges. This result supports our hypothesis that murrelet nests near edges may be more vulnerable to predation than those located in the stand interior. In addition, nest concealment was significantly greater at successful nests ( $\bar{x}$ = 87.2 percent, *s.e.* = 3.9) compared with nests that failed because of predation ( $\bar{x}$ = 67.5 percent, *s.e.* = 8.2) (U = 2.3, $n$ = 17, $P < 0.05$) (*table 5*). Nest concealment has been shown to decrease predation rates (Chasko and Gates 1982; Marzluff and Balda 1992; Martin and Roper 1988). Stand size (532.0 versus 407.4 ha, $n$ = 11 stands) and canopy closure near nests (63.6 versus 47.0 percent, $n$ = 16 plots) were higher and nests located closer to the trunk (46.5 versus 163.3 cm) at successful sites, but were not significantly different from nests that failed because of predation.

Second, it has been suggested that changes in forests where boundaries are contiguous with secondary succession may not create the same predation problems as those observed in static, simple forests in urban and agricultural areas that are defined by distinct boundaries (Rosenberg and Raphael 1986; Rudnicky and Hunter 1993). However, numerous studies in the eastern United States provide empirical evidence that edge effects in a forest dominated landscape (forest/clearcut edge) are similar to those in forest/urban or agricultural settings. For example, in studies of eastern neotropical migrants, predation was lower in the forest interior (>50 m from the edge) compared with edge habitat (Chasko and Gates 1982; Yahner and Scott 1988). Predation was also lower in areas with high vegetative heterogeneity and concealing cover (Chasko and Gates 1982).

Evidence from artificial nest studies in forests of the Pacific Northwest also suggests that predation of birds' nests may be affected by habitat fragmentation and forest management. On Vancouver Island, British Columbia, Bryant (1994) demonstrated that artificial ground and shrub nests located along forest/clearcut edges (within 100 m) were subject to higher predation rates than those in the forest interior (100–550 m from the edge). In the Oregon Coast Range, predation on artificial shrub nests was higher in clearcuts and shelterwood (20–30 green tress >53 cm d.b.h./ha) stands than in stands with group selection cuts (1/3 volume removed in 0.2 ha openings) and unmanaged (control) stands (Chambers, pers. comm.). Additionally, in the Oregon Cascades, Vega (1994) found that predation on ground nests was significantly greater in clearcuts compared with retention stands (12 trees/ha and 7.5 snags/ha), and predation on shrub nests was highest in retention stands compared to the other treatment types (clearcuts and mature stands). Steller's Jays, the suspected predator of the shrub nests, were more abundant in the retention stands, where they probably used the remnant trees for perching (see Wilcove 1985; Yahner and Wright 1985).

Third, despite differences in results among nest predation studies (e.g., Rudnicky and Hunter 1993 versus Yahner and Scott 1988), existing evidence strongly indicates that avian nesting success declines near edges (Paton 1994). In addition, regardless of the type of edge, fragmentation of forests often reduces structural complexity and heterogeneity of stands, and exposes remnant patches to edge effects (Hansen and others 1991; Harris 1984; Lehmkuhl and Ruggerio 1991). Because of increases in the amount of edge, productivity of interior forest species is generally impacted (Lehmkuhl and Ruggerio 1991; Reese and Ratti 1988; Yahner and others 1989), and generalist species, which benefit from the ecotone, usually increase in numbers (Yahner and Scott 1988). In addition, as vegetative complexity and canopy volume are reduced through fragmentation, bird nests (especially those located in shrubs or trees) may be more conspicuous and easier for avian predators to locate (Rudnicky and Hunter 1993; Vega 1994; Wilcove 1985; Yahner and Cypher 1987; Yahner and others 1989; Yahner and Scott 1988).

The rates of predation on Marbled Murrelet nests in this study appear higher than for many seabirds and forest birds. If the observed predation rates are representative of predation rates throughout the murrelet's range, then the impacts of predation on murrelet nesting success is significant and of concern (Wilcove 1985). Even if these high predation rates are localized to certain states or areas within states, the combination of low annual nesting success, low fecundity rates (Beissinger, this volume), and low or declining population sizes (Carter and Erickson 1992; Kelson and others, in press; Kuletz, 1994), could impact the survival and recovery of this threatened seabird.

## Conclusions

Results from this study suggest that predation on murrelet nests may be relatively high compared with many alcids and forest nesting birds. Because Marbled Murrelets have no protection at nest sites other than the ability to remain hidden (Nelson and Hamer, this volume a), the availability of safe nest sites will be imperative to their survival. If logging and development (e.g., clearing land, creating patches of habitat, thinning stands) within the murrelet’s range has resulted in increased numbers of predators or predation rates, and has made murrelet nests easier to locate because of increased amounts of edge and limited numbers of platforms with adequate hiding cover, then predation on murrelet nests could be significantly higher in such situations. In addition, areas heavily used by humans for recreational activities (i.e., picnic and camping grounds) can attract corvids (Marzluff and Balda 1992, Singer and others 1991) and may increase the chance of nest predation within these areas. Therefore, we hypothesize that because this seabird has low reproductive rates (one egg clutch), small increases in predation will have deleterious effects on murrelet population viability.

Rigorous studies should be developed to investigate the effects of predator numbers, predator species, predator foraging success, landscape patterns, habitat types, and forest structural characteristics on Marbled Murrelet nesting success. In implementation of these studies, hypotheses on the effects of various habitat features on fitness components (recruitment and demography) should be tested (Martin 1992, Paton 1994). At the same time, the effects of these hypotheses on coexisting species and the interacting effects these species have on one another should be evaluated (Martin 1992).

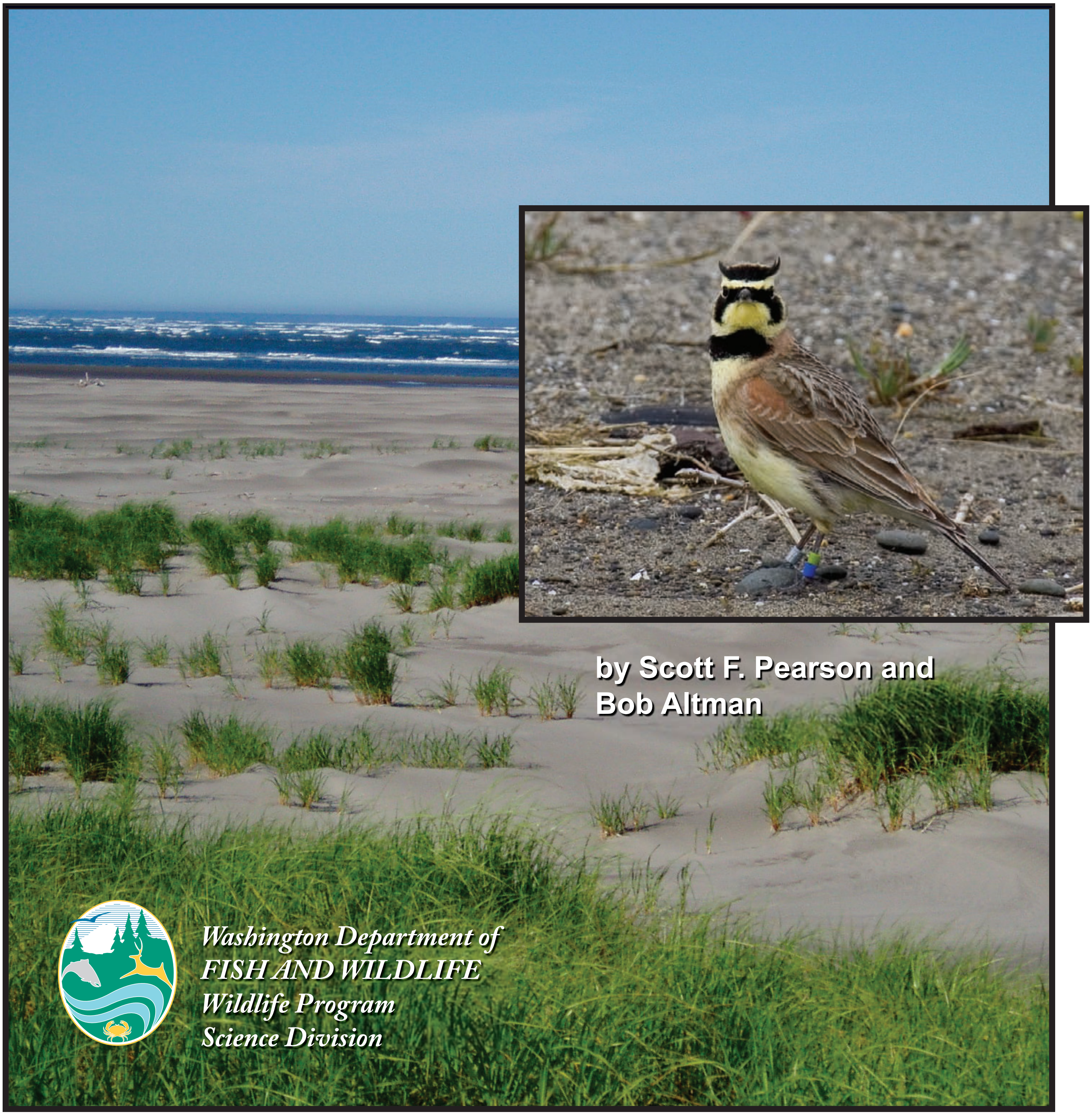
## Acknowledgments

We are grateful to the biologists who kindly shared their data with us; special thanks go to Jim Atkinson, Alan Burger, Stephanie Hughes, John Hunter, Paul Jones, Kevin Jordan, John Kelson, Steve Kerns, Kathy Kuletz, Irene Manley, Ray Miller, Nancy Naslund, Bill Ritchie, Steve and Stephanie Singer, and David Suddjian for their time and generosity. We also thank Alan Burger, George Hunt, John Marzluff, Robert Peck, Steve Speich, and several anonymous reviewers for providing valuable comments on earlier drafts of this manuscript. Support for preparation of this manuscript was provided by the Oregon Department of Fish and Wildlife, USDA Forest Service, USDI Bureau of Land Management, and the U.S. Fish and Wildlife Service, U.S. Department of the Interior. This is Oregon State University Agricultural Experiment Station Technical Paper 10,540.

# APPENDIX Q-10
# Range-wide Streaked Horned Lark Assessment and Preliminary Conservation Strategy
# (Pearson and Altman, September 2005)

**STATE OF WASHINGTON** **September 2005**

# Range-wide Streaked Horned Lark (*Eremophila alpestris strigata*) Assessment and Preliminary Conservation Strategy



by Scott F. Pearson and Bob Altman

*Washington Department of*
*FISH AND WILDLIFE*
*Wildlife Program*
*Science Division*

*Cover photograph of banded male Streaked Horned Lark at Damon Point by David Maloney and cover photograph of Midway Beach by Mark Hopey. Title page illustration of female Horned Lark by Darrell Pruett.*

**Recommended Citation:**

**Pearson, S.F., and B. Altman. 2005. Range-wide Streaked Horned Lark (*Eremophila alpestris strigata*) Assessment and Preliminary Conservation Strategy. Washington Department of Fish and Wildlife, Olympia, WA. 25pp.**

# Range-wide Streaked Horned Lark (*Eremophila alpestris strigata*) Assessment and Preliminary Conservation Strategy

Scott F. Pearson[1] and Bob Altman[2]

September 2005

[1]Washington Department of Fish and Wildlife
Wildlife Program
Wildlife Science Division
600 Capitol Way North
Olympia, WA  98501-1091

[2] American Bird Conservancy
311 NE Mistletoe Circle
Corvallis, OR 97330

## TABLE OF CONTENTS

# ACKNOWLEDGMENTS

U.S. Fish and Wildlife Service, Department of Defense (Ft Lewis and McChord Air Force Base), The Nature Conservancy, Washington Department of Natural Resources, and Washington Department of Transportation provided funding for the research associated with this document. Ft. Lewis and The Nature Conservancy provided funding for producing this document. Kevin Fort, Randy Moore, Douglas J. Robinson, and Derek Stinson all provided helpful comments on previous versions of this document. Mark Hopey and Hannah Anderson provided helpful suggestions and comments and Hannah produced figures 1 and 2. Derek Stinson created the cover layout. Thank you all!

# INTRODUCTION

The Streaked Horned Lark (*Eremophila alpestris strigata*) is a rare subspecies of the Horned Lark that breeds and winters in Oregon and Washington. Recent Streaked Horned Lark research has focused on documenting changes in the subspecies breeding range (Rogers 2000), inventorying and locating current breeding (Altman 1999, Rogers 1999, MacLaren and Cummins 2000, Pearson and Hopey 2004, 2005) and wintering (Robinson and Moore unpubl., Pearson et al. 2005) populations in Oregon and Washington, identifying breeding and foraging habitat (Altman 1999, Rogers 2000, Pearson 2003, Pearson and Hopey 2004, 2005), and experimenting with methods to improve Lark habitat (Pearson and Hopey 2005). In addition, British Columbia recently completed a status report on the Lark (Beauchesne and Cooper 2003) and another has been drafted by Washington Department of Fish and Wildlife (Stinson 2005).

The goal of this report is not to duplicate the efforts of others but to provide a range-wide review of the current wintering and breeding range, list of habitat requirements and estimates of wintering and breeding population numbers. In addition, we identify population threats, recommendations for addressing these threats and we present a preliminary conservation strategy. Because others have attempted to reconstruct this subspecies historic wintering and breeding ranges and to describe its life history (Rogers 2000, Beauchesne and Cooper 2003, Stinson 2005), we spend little effort on these topics. The management recommendations and conservation strategy presented here are initial thoughts and need critical review, revision and development. If the subspecies is listed as Endangered in Washington as recommended, a recovery strategy will be developed for the State. Canada is currently writing a recovery plan. In addition to these efforts, we strongly recommend developing a range-wide conservation plan (including a metapopulation model) and establishing a range-wide (Oregon, Washington, British Columbia) working group to develop recovery strategies and facilitate recovery actions.

Several lines of evidence suggest that the Streaked Horned Lark is vulnerable to extinction and should be a conservation priority. The Streaked Horned Lark is a recognized subspecies of the Horned Lark (AOU 1957) and genetic data indicate that the Streaked Horned Lark is unique, isolated, and has little genetic diversity (Drovetski et al. in press). The breeding range of the Lark has contracted over time; it no longer breeds in the northern Puget trough (San Juan Islands and other Puget Sound sites north of Tacoma), southern British Columbia, along the Washington Coast north of Grays Harbor, and in the Rogue River Valley (Rogers 2000, Beauchesne and Cooper 2003, Stinson 2005). Although no systematic range-wide attempt has been made to estimate the total population of this subspecies, results from winter and breeding surveys suggest that the entire population of this subspecies is likely less than 1,000 birds (see discussion below). Remaining breeding populations and their habitats face imminent threats posed by land development, incompatible land uses, human activities, predation, and non-native species. Wintering populations are potentially threatened by stochastic events and by a lack of suitable habitat in the Willamette Valley. Very few of the sites used by the Lark for breeding or wintering are protected and no sites are managed primarily for Larks.

Conservation efforts to date, have focused on identifying and monitoring Lark populations, identifying habitat features important to successful breeding, testing methods for creating appropriate breeding habitat, restoring degraded habitats, and restricting some human uses on breeding sites. For example, Ft. Lewis has restricted recreational activities on a breeding site and Olympia Airport has modified mowing dates and times to minimize impacts to Lark nests.

Because the subspecies migrates between Oregon and Washington and because the remaining breeding populations are found in the Puget lowlands, Columbia River/coastal Washington, and Willamette Valley, we recommend that local and regional recovery strategies consider range-wide population dynamics and threats so that recovery actions can be coordinated and focused on the activities that are most likely to result in increased Lark populations.

## TAXONOMY

The Horned Lark (*Eremophila alpestris*) is a member of the family Alaudidae (larks) in the order Passeriformes. Of the 76 species of lark, it is the only lark native to North America. The Horned Lark has 21 described subspecies in North America based on differences in size and plumage color (American Ornithologists' Union 1957). There is a high degree of overlap in plumage and color between many subspecies (Behle 1942). The breeding range of the Streaked Horned Lark appears to be allopatric with other subspecies (Behle 1942). The size and color of the Streaked Horned Lark approaches that of *E. a. insularis* and *E. a. sierrae* to the south but is smaller and more brightly colored (brighter yellows and reddish browns) than *E. a. alpina* which breeds above treeline in the Olympic and Cascade Mountains.

Drovetski et al. (in press), collected tissue samples from 32 Streaked Horned Larks in the Puget lowlands, Washington coast and the Columbia River and the haplotype from these samples was compared to those from 60 horned larks from Alaska, alpine Washington, eastern Washington and Oregon and coastal California. Although, the Streaked Horned Lark was found to be closely related to coastal California birds, it is genetically unique and isolated. Streaked Horned Larks appear to have remarkably low genetic diversity; all 32 sampled shared the same haplotype. All other localities sampled had multiple haplotypes despite smaller sample sizes. These genetic data indicate that the Streaked Horned Lark is unique, isolated, and has little genetic diversity and suggests that it is a conservation priority.

## CONSERVATION STATUS

- Listed as a federal Candidate species under the U.S. Endangered Species Act
- Committee On the Status of Endangered Wildlife Species in Canada lists the Streaked Horned Lark as Endangered
- On the Red list in British Columbia. This list includes any indigenous species or subspecies that have or are candidates for Extirpated, Endangered, or Threatened status in British Columbia
- Listed as a candidate for listing as Threatened, Endangered or Sensitive by Washington Department of Fish and Wildlife (28 October 1998). The Washington Department of Fish and Wildlife recently recommended that the Streaked Horned Lark be listed as Endangered in the State of Washington (Stinson 2005).
- Listed as State Sensitive by the Oregon Department of Fish and Wildlife (Critical Status; Oregon Sensitive Species List, 1997)
- A priority species for conservation by Oregon-Washington Partners in Flight (Altman 2000) and British Columbia Partners in Flight (Fraser et al. 1999)
- NatureServe rounded global conservation status is a G5T1 indicating that it is a critically imperiled subspecies of a widespread and common species.

## HISTORIC BREEDING RANGE

The Streaked Horned Lark historically bred in prairie and open coastal habitats from the southwestern corner of British Columbia (southeastern Vancouver Island, lower Fraser River Valley; Fraser et al. 1999) through the Puget trough and Willamette Valley (as far south as Eugene, Oregon) and into the Rogue River Valley (from Medford north to Eagle Point; Figure 1). In addition, Larks were found on open coastal habitats in western Washington (Smith et al. 1997, Jewett et al. 1953; Figure 1). For a detailed description of the Larks historic breeding range refer to Rogers 2000, Beauchesne and Cooper 2003, and Stinson 2005.

## CURRENT BREEDING RANGE

In Washington, Rogers (1999) identified 124 townships to survey for Larks and 31 were considered high priority because of recent Lark records (1960 or later) or because they contained suitable habitat. Rogers (1999) detected 49 singing males in 11 of the 86 townships surveyed. MacLaren and Cummins (2000) re-surveyed these occupied sites, the two remaining high priority sites that were not surveyed by Rogers (2000), and an additional 33 lower priority sites. MacLaren and Cummins (2000) did not locate additional occupied sites but did detect 65 Larks at the previously identified 11 occupied sites. Additional surveys by Pearson and Hopey (2004, 2005) on Ft. Lewis, the outer coast of Washington and lower Columbia River resulted in the identification of additional sites occupied by Larks (Appendix I). It is unlikely that many additional occupied sites will be identified in Washington because all of the high priority and many of the lower priority sites have been surveyed. In addition, requests to birding listserves asking birders to report sightings of Horned Larks in western Washington have not resulted in the location of any additional populations.

Altman (1999) conducted a broad-scale survey for Larks and other grassland birds in the Willamette Valley in 1996 and 1997. This survey consisted of 544 roadside point count stations along with more intensive survey methods consisting of transects, territory mapping and nest monitoring. Altman (1999) selected point count stations where target species (Oregon Vesper Sparrow, Streaked Horned Lark, Western Meadowlark, Grasshopper Sparrow, and Common Nighthawk) were known to occur or where appropriate habitat occurred. In addition, he attempted to spread his sampling points throughout the valley floor and foothills of the Willamette Valley and a broad range of potentially suitable habitat. Using this approach, he detected 154 Streaked Horned Larks within 100 m of point count stations.

To our knowledge, similar types of surveys have not been conducted in British Columbia. Campbell et al. (1997) considered the Streaked Horned Lark to be extremely rare in the lower Fraser River Valley and Fraser et al. (1999) considered it extirpated on southeastern Vancouver Island. Beauchesne (2002) conducted a survey for Vesper Sparrows on southern Vancouver Island, which uses habitat similar to the Lark, and noted a single male Streaked Horned Lark on the Nanaimo Airport on Vancouver Island but it was not located again in 2003 despite intensive searching. Today the Streaked Horned Lark is believed to be extirpated from British Columbia (Beauchesne 2003).

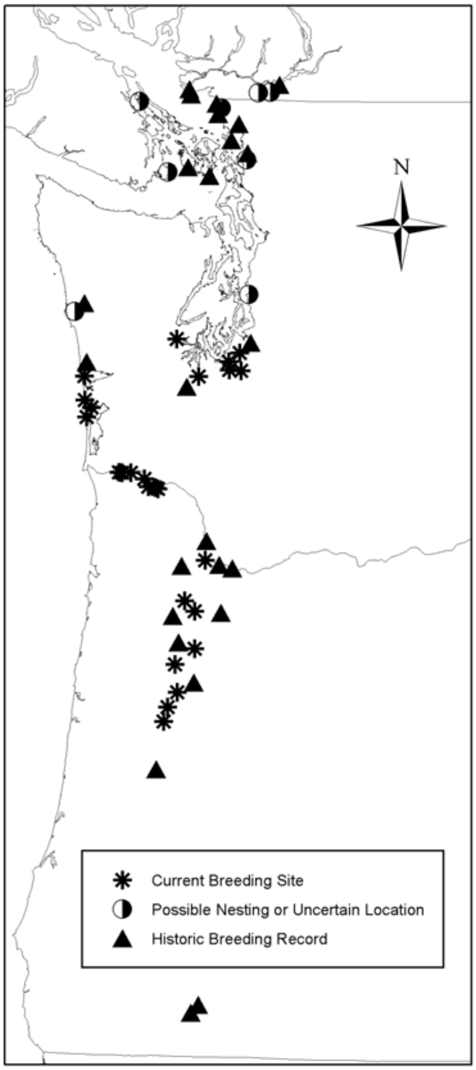



**Figure 1. Current and historic Streaked Horned Lark breeding localities and possible historic nesting or uncertain breeding season locations. Information from Altman (1999), Rogers (2000), Pearson and Hopey (2005), Stinson (2005).**

Results from these U.S. and Candian surveys indicate that the Streaked Horned Lark currently breeds on prairie remnants (n = 2) and airports (n = 4) in the southern Puget lowlands, on beaches and accreted lands near Grays Harbor and Willapa Bays (n = 4), on dredge spoil islands in the Columbia River (n = 6), an industrial site along the lower Columbia River in Oregon, and on a number of agricultural, pasture, grass, and mudflat habitats in the Willamette Valley from Portland to Eugene (Figure 1, Appendix I). In addition, the Streaked Horned Lark has been reported as an irregular breeder on the south jetty of the Columbia River (M. Patterson personal communication).

The Lark no longer breeds in southern British Columbia, the northern Puget trough (San Juan Islands and other coastal areas north of Tacoma), along the Washington Coast north of Grays Harbor, and in the Rogue River Valley (Rogers 2000, Beauchesne and Cooper 2003, Stinson 2005.).

## CURRENT WINTER RANGE

In Oregon, Robinson and Moore (2004) surveyed 18 5-minute lat/long Willamette Valley blocks selected at random and a total of 295 point counts within those blocks during the winter of 2003-2004. To locate larks, they drove every non-major highway road (roads other than Interstate 5) in each block and they located 15-20 point count stations in every block. Using this method, they detected only 19 Streaked Horned Larks from 6 point count Stations. In addition, they conducted additional surveys on large expanses of agricultural land that were known or suspected to be occupied by Larks. They found Streaked Horned Larks to be present in the Willamette and Columbia River valleys throughout the winter. Most of the Streaked Horned Larks were found in open agricultural lands of Linn, Benton, Polk, and Marion Counties. The only other substantial group of Streaked Horned Larks was located at the Port of Portland in Multnomah County on a large dredge spoil expanse.

Pearson et al. (2005) conducted a winter (2004/2005) inventory of known wintering and breeding localities in Washington and Oregon. They conducted 51 visits to 28 sites [Puget Sound n = 5, Washington coast n = 4, Columbia River n = 7, Willamette and Rogue Valleys n = 12 (Figure 2, Appendix II)]. No Streaked Horned Larks were observed at twelve of the 28 sites surveyed. Larks were found in large flocks consisting of Streaked Horned Larks and other subspecies of

Horned Lark (up to 170 birds in a flock) in the Willamette Valley, variable sized flocks of Larks on Columbia River islands (1-69 birds) and Oregon Coast (12-30 birds) and in pairs or small flocks (4-5 birds) in the Puget lowlands (Appendix II). Of the 542 Streaked Horned Larks observed during this survey, 72% were observed in the Willamette Valley, 20% on Columbia River islands or floodplain, 8% on Washington coast, and 1% on a Puget Sound airport and prairie (see Appendix II). In addition to these confirmed winter sightings, the Streaked Horned Lark may over winter on the southern Oregon coast (Coos County; subspecies unknown but may be *strigata*; Contreras 1998). On the northern Oregon coast it appears to be an annual migrant in fall and occasional (irregular) wintering species (M. Patterson personal communication).

Several lines of evidence suggest that birds in the Puget lowlands are migrating south for the winter: 1) only 3 birds were observed in the southern Puget lowlands during the 2004-2005 winter survey (Pearson et al 2005) and there were likely more than 216 breeding birds in the lower Puget trough during the previous breeding season (Pearson and Hopey 2005); and 2) birds banded in the southern Puget Sound region during the breeding season were re-sighted to the south in the Willamette Valley during the winter (Pearson et al. 2005). Multiple re-sights of banded birds throughout the winter in the Willamette Valley, Columbia River and on the Washington Coast suggests that some of these birds are staying in these regions throughout the winter.

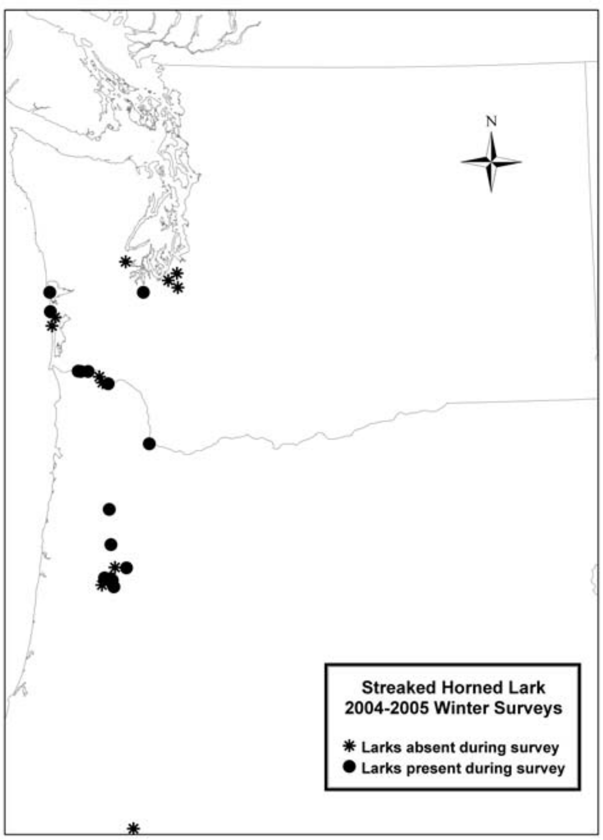



**Figure 2. Oregon and Washington localities where Streaked Horned Larks were present and absent during 2004-2005 winter surveys (Pearson et al. 2005).**

## HABITAT REQUIREMENTS

### Breeding Habitat

For a detailed description of Lark breeding habitat see Altman (1999) and Pearson and Hopey (2005).

**Puget Trough** (Pearson and Hopey 2005)

- Large expanses of grass dominated habitat (airports or native prairies; minimum area has yet to be determined) with very few or no trees or woody shrubs.
- Sparsely vegetated habitat dominated by relatively short annual grasses and native bunch grasses (3.9 – 13.3 inches tall).

- Avoided areas with sod forming (rhizomatous) grasses.
- Relatively high percent of bare ground (16%; particularly associated with dirt, gravel and cobbles) as the ground cover as opposed to a moss/lichen or thatch dominated ground cover.
- Around the nest site (0.5 m radius around the nest), females are selecting areas within territories with fewer non-vegetated areas and less cover of annual and perennial grass.
- Unvegetated habitats (dirt roads, taxiways or runways) used for foraging, singing and take-off sites for flight displays.

**Washington Coast and Lower Columbia River** (Pearson and Hopey 2005)

- Sparsely vegetated expanses of sand adjacent to the ocean or Columbia River. Areas dominated by grasses and forbs with few or no trees and shrubs.
- Selecting sparsely vegetated areas with more wood and cover of annual grasses with less algae (indicator of areas effected by very high tides) than adjacent areas in the same habitat type.
- Ground layer is dominated by sand (approx. 68%) with little thatch; moss or lichen are absent on the coast but present on the Columbia River islands.
- Sparsely vegetated (approximately 35% of the area with no vegetation).
- Dominated by relatively short annual grasses (0.6 – 8.7 inches).
- Around the nest site (0.5 m radius around the nest), females are selecting areas with fewer non-vegetated areas, more thatch and perennial forbs and shorter vegetation.

**Willamette Valley** (Altman 1999)

- Large expanses of herbaceous dominated habitat (cultivated grass fields, moderate to heavily grazed pasture, fallow fields, roadside shoulders), Christmas tree farms and wetland mudflats.
- Dominated by short grasses (0-6 inches).
- Relatively high percent of bare ground (17%) for territories.
- A higher percent cover of bare ground (31%) for nest sites.

## Winter Habitat

**Puget Trough** (Pearson et al. 2005)

- Only three wintering Larks were observed in the Puget lowlands. Two were found on the Olympia Airport (1 male and 1 female) and one bird was observed on 13$^{th}$ Division Prairie. All three birds were using the same habitats that are used by breeding birds and that is described above.

**Washington Coast and Lower Columbia River** (Pearson et al. 2005)

- On the Washington coast, Larks were found on dune and beach habitat adjacent to open water with few or no trees and shrubs.
- Larks on the lower Columbia River were primarily found on sparsely vegetated dredge spoils (see description under breeding habitat above).

**Willamette Valley** (Robinson and Moore 2004, Pearson et al. 2005)

- High percent of bare ground (sites with flocks > 20 birds averaged greater than 85% bare ground) and large expanse of treeless area. Most birds use agricultural fields, particularly rye grass fields with sparse ground cover.
- Winter habitats used in Willamette Valley are very unusual with respect to characteristics of dominant land cover. Larks are using fields that have apparently been fallow for a few months. The fields have sparse, patchy weedy cover with very little rye grass. Occasionally they are in annual rye grass fields with sparse cover, but more typically they avoid those fields. Perennial rye grass is almost universally avoided during winter.

## Breeding Season Foraging Habitat

**Puget Trough** (Rogers 2000, SFP and Mark Hopey pers. obs.)

- On Puget prairies, Larks select sites with low vegetation (mean = 4.2 inches), and with low vegetation density (Rogers 2000).
- Forages in sparsely vegetated prairie and grasslands, gravel roads, and runway and taxiway aprons on airports.

**Washington Coast and Lower Columbia River** (SFP and Mark Hopey pers. obs.)

- Sparsely vegetated dunes and beaches (same habitat that is used for territories and nesting).
- Forage in the wrack line and intertidal habitat.
- Sparsely vegetated dredge spoils along the Columbia River.

**Willamette Valley** (Altman 1999)

- Recently plowed or burned fields
- Row crops and vegetable fields with dirt rows between vegetation

# BREEDING POPULATION ESTIMATES

Rogers 2000, Pearson (2003) and Pearson and Hopey (2004, 2005) estimated the number of territories and total numbers of breeding birds at 16 sites in the Puget lowlands (n = 6), Washington coast (n = 4), and Columbia River islands (n = 6) (Appendix I). This work included intensive territory mapping and nest monitoring (n = 8 sites, > 10 visits/site/season) and estimates of the number of territories and the number of breeding birds during surveys (n = 8 sites, 1-5 visits/site/season) (see Appendix I).

As discussed above, Altman (1999) conducted a broad-scale survey for Larks and other grassland birds in the Willamette Valley in 1996 and 1997. This survey consisted of 544 roadside point count stations and more intensive survey methods (transects, territory mapping and nest monitoring) at additional sites. During point count surveys, birds occurred in 16 of the 41 regions established. Abundance was <0.5 birds/count in all regions except one, which had a relative abundance of 0.7 birds/count. We used the number of birds counted during point counts, intensive territory mapping and those observed outside of these activities (B. Altman's field notes) to estimate the number of birds in the Willamette Valley during the breeding season.

Using information from these studies and surveys, we estimate that there are approximately 774 Streaked Horned Larks with 222 birds (29%) in the Puget lowlands, 86 birds (11%) on the Washington coast, 68 birds (9%) on the lower Columbia River, and 398 birds (51%) in the Willamette Valley (Appendix I). These numbers should be used cautiously as population estimates because: 1) all populations and birds may not have been counted; 2) multiple techniques and different amounts of effort went into generating population estimates at different locations; 3) surveys were conducted by different people in the Willamette Valley than in other locations; and 4) inventories occurred during different years, some nearly 8 years apart; and 5) populations may be spatially and temporally dynamic (especially in the Willamette Valley where birds breed in agricultural fields that are managed differently over time). These data were gathered in such a way that it is very difficult if not impossible to put confidence intervals around these estimates.

## WINTER POPULATION ESTIMATES

As discussed above, Robinson and Moore (2004) conducted a Streaked Horned Lark survey during the winter of 2003/2004 and found Streaked Horned Larks at 16 sites on the islands and flood plain of the lower Columbia River and in agricultural fields in the Willamette Valley. They identified 382 confirmed Streaked Horned Larks with an additional 209 Streaked Horned Larks for a potential total of 591 Streaked Horned Larks.

As discussed above, Pearson et al. (2005) conducted a winter (2004/2005) inventory of known wintering and breeding localities in Washington and Oregon. They conducted 51 visits to 28 sites [Puget Sound n = 5, Washington Coast n = 4, Columbia River n = 7, Willamette and Rogue Valleys n = 12 (Figure 2, Appendix II)]. Using the maximum Streaked Horned Lark count during any one visit to a site, we estimate that the maximum number of Streaked Horned Larks at all of the sites we surveyed was 542 birds (Appendix II).

Caution should be used when using either of these winter counts as an estimate of the total Streaked Horned Lark population for two reasons: 1) not all potential wintering locations were surveyed suggesting that this may be a low estimate; and 2) the re-sighting of banded birds in different locations during the winter suggest that birds move among Columbia River islands and between Columbia River islands and the Washington coast during the winter. The movement of birds among sites could result in double counting birds and ultimately an overestimate of the population size.

## THREATS

Below and in Appendix III, we describe the threats observed while conducting winter (2 years) and breeding season (5 years) research.

### Human Activities

- Streaked Horned Larks are actively establishing territories and breeding from late March to early August. The following activities appear to influence Lark behavior by causing them to become alert or fly or the activities directly destroy nests (Pearson and Hopey 2004): mowing, moving vehicles (including ORVs), model airplane flying (and likely kite flying), fireworks, dog walking, and gatherings of people and/or vehicles. Activities that keep Larks away from nests for extended periods of time (more than an hour) are particularly disruptive and may result in nest abandonment.

- Flush distances depend on breeding stage and type of disturbance. In general, activities that occur within 30 m (mean + 1 SD of the mean flushing distance) are more likely to cause flush events than more distant activities (Pearson and Hopey 2004). Our observations suggest that birds are more likely to flee in response to pedestrian and dog activity than vehicle activity.
- Activities associated with the deposition of dredge spoils immediately adjacent to breeding and wintering birds could negatively affect nesting (increase nest abandonment or prevent nesting) and foraging (cause birds to flee or to spend more time alert and less time foraging). On Miller Sands, two nests were abandoned after equipment was staged immediately next to them. Also on Miller Sands, the deposition of dredge spoils on a known Lark breeding area 2004 likely resulted in nest failure.
- Because Larks nest on the ground and often near dirt roads, their nests are vulnerable to vehicle traffic especially along active airport taxiways, roads on Puget prairie sites, beaches with vehicle traffic, and roads adjacent to agricultural sites. Loss of nests associated with vehicle activity has been documented in the Willamette Valley (Altman 1999) and Puget lowlands.
- Mowing may be both a blessing and curse for the Streaked Horned Lark. All of the airport sites are mowed and the mowing may be partially responsible for maintaining suitable habitat at these sites. At the same time, mowing results in direct mortality of nests and may cause some nest abandonment (Pearson and Hopey 2005). Gray Army Airfield reduced the frequency of mowing and adjusted the timing of mowing to minimize impacts to larks for three breeding seasons. Olympia Airport continues to modify its mowing regime to minimize impacts to breeding larks.
- Between 1985 and 2004, there were 1,422 Horned Lark collisions with US Air Force aircraft, which was the highest number of aircraft collisions for any species (BASH 2004). However, there were only 228 Horned Lark collisions out of 51,154 strikes with civilian aircraft reported between 1990 and 2003 (Cleary et al. 2004). None of the civilian aircraft collisions resulted in injury and the total cost associated with Horned Lark collision damages was estimated to be $250 (Cleary et al. 2004). Larks currently breed on Shelton and Olympia Airports and Gray Army Airfield and McChord Air Force Base and have been found dead along the runways at McChord Air Force Base and Gray Army Airfield.

## Pesticides and Herbicides

- Beason (1995) reports direct mortality of Horned Larks from exposure to Carbofuran (a carbamate pesticide) and Fenthion (an organophosphorus cholinesterase-inhibiting insecticide applied to crops).

## Habitat Loss or Change

### Historic Habitat Loss

- *British Columbia*: historical habitat was likely restricted to sparsely-vegetated sites such as spits, beaches, and grasslands. Due primarily to the conversion to agriculture and urban development, the grasslands associated the Gary oak ecosystem of British Columbia has declined by at least 95% (Hebda and Aitkens 1993). The amount of open dune, grass and bryophyte areas on Vancouver Island have declined by 6 – 52% depending on the site (Beauchesne and Cooper 2003). An inventory of sensitive ecosystems on Vancouver Island and the Gulf Islands indicates that naturally occurring, sparsely vegetated habitats (e.g., sand dunes, gravel and sand spits) are the rarest terrestrial ecosystem in eastern Vancouver Island (Ward et al. 1998). Page (2003) compared aerial photographs of sand dune habitats over a 40-year period and estimated that the amount of dune habitats on southern Vancouver Island declined by 6 to 50% depending on locality.

- *Washington*: In the Puget lowlands, historic Lark habitat was confined to prairie habitats associated with gravelly outwash soils. Crawford and Hall (1997) estimated the historic distribution of grasslands in the southern Puget Sound region by mapping grassland soils. Currently, grasslands occupy approximately 22% of their historic area and prairies dominated by native species occupy approximately 3% of their historic area. The loss of these grasslands has been attributed to urban development (33%), forest invasion or conversion (32%) and agriculture conversion (30%; Crawford and Hall 1997). Along the coast, Lark habitat was historically and is currently associated with sparsely vegetated beach habitat (foredune). Although we know of no estimates of the amounts of sparsely vegetated dune and open beach habitat that has been lost to the invasion of non-native beachgrasses (*Ammophila spp.*), it is likely considerable. Non-native beachgrass cover has increased by 574% in a fifty-year period in portions of the Pacific coast (Buell et al. 1995) and is the dominant foredune vegetation in the range of the Lark on the Washington coast (Seabloom and Wiedemann 1994). Once dune and beach habitat is densely vegetated by beachgrasses, it is no longer used by Larks (Pearson and Hopey 2004).
- *Oregon*: More than 99% of the pre-settlement grasslands used by Larks in the Willamette Valley have been lost (Johannessen et al. 1971, Towle 1982). Initially these grasslands were lost to agriculture but, despite the habitat change, Larks continued to use appropriate agricultural lands. More recently, there has been extensive urban/residential development in Willamette Valley, which is replacing the agricultural fields and other fallow fields used by breeding and wintering Larks. There has also been conversion of suitable agricultural habitat such as pastures or fallow fields to non-suitable agricultural lands such as rowcrops, orchards, and nurseries.

**Ongoing Habitat Loss or Change**

- To maintain and deepen the Columbia River shipping channel, the Army Corps of Engineers deposits dredge spoils on many of the islands used by breeding Larks. The timing, location and the amount of deposited materials can have dramatic impacts on the Lark. The un-vegetated landscape created by depositing dredge spoils is not used by Larks for the first year or two after deposition. Consequently, depositing spoils on Lark breeding or wintering sites can have negative impacts on Lark use of a site. Once the spoils are sparsely vegetated, they are quickly colonized by Larks (especially island spoils where ORV traffic does not occur)
- Sandy habitats on the coast of Washington continue to be colonized by non-native beachgrasses (*Ammophila spp*). Larks do not use habitats with a dense covering of beachgrass for breeding or over-wintering.
- Robinson and Moore counted 61 Streaked Horned Larks at the Multnomah County site (see Appendix II) during the winter of 2004/2005 but counted 150-200 Larks in the previous two years. This decline may be the result of changes in habitat conditions. Some grading occurred at the site in preparation for development resulting in completely unvegetated habitat and other parts of the site continued to be colonized by vegetation resulting in a higher percent cover of vegetation, which made it less suitable to wintering

Larks. In addition, there are survey markers on the site indicating that it will likely be developed in the near future.

- In the Willamette Valley, over-wintering site fidelity appears to be low among years. Pearson et al (2005) re-surveyed all sites during the 2004/2005 winter where Larks were found during the 2003/2004 winter. They found Larks to be present at only one of these previously occupied sites during the 2004/2005 winter. This low site fidelity may occur because of the dynamic nature of over wintering habitat. Sites with Larks and appropriate habitat in 2003/2004 had inappropriate habitat and no Larks in 2004/2005. These sites moved from being fallow in 2003/2004 to being densely vegetated with annual rye grass in 2004/2005. During the winter, Larks appear to move across the landscape in search of appropriate habitat and, when appropriate habitat is discovered, they use it. During the winter of 2004/2005, very few agricultural fields were in a condition appropriate for over wintering Larks suggesting that this habitat type may be limiting.
- The Olympia Airport is currently extending the runway and is planning on building several new hangars. In addition, they have proposed developing a considerable portion of the remaining open grassland habitat with buildings, roads and taxiways which may make the site unsuitable to breeding and wintering Larks.
- Gray Army Airfield is currently extending the West ramp into areas used by breeding Larks in previous years.

## Lack of Protected Habitat

- Agricultural habitats and suitable horned Lark habitat in the Willamette valley are almost entirely privately owned and land uses can vary dramatically from year to year.
- Many of the islands in the Columbia River and on the coast of Washington are publicly owned offering opportunities for strategic conservation planning.
- The primary purpose of municipal and military airfields is for air traffic and military training. Larks are perceived as being at odds with aircraft safety because Horned Larks collide with aircraft (see discussion above). To minimize bird-aircraft collisions, McChord AFB regularly flies falcons to scare birds off the airfield and started also using dogs in 2005. These dogs walk and run through Lark habitat and cause the birds to become alert and fly. Gray Army Airfield is planning on adding an additional 130 rotary wing aircraft to the airfield within the next year. These aircraft are a different type than what is currently using the site. The air temperature and wind velocity of the rotor and engine down blasts from these new aircraft may impact Lark use of the site.

## Predation

- Over 200 Lark nests have been monitored in the Puget lowlands, Washington coast, Columbia River and in the Willamette Valley and predation was the primary source of nest failure at nearly all sites studied to date (Pearson and Hopey 2005, Altman 1999). The predation rates at the Puget lowland sites and Columbia River/Washington coast sites are considerably higher than that reported for other grassland breeding birds.

## Stochastic and Small Population Threats

- There appear to be very few Streaked Horned Larks remaining in the world (probably between 500 and 1000 birds) and preliminary genetics work suggests that the remaining birds have little genetic diversity. This result suggests that the Streaked Horned Lark population may already be experiencing the deleterious effects of inbreeding or the results of a small founder population. The remaining populations are vulnerable to all of the threats small populations commonly face (e.g., vulnerability to environmental and demographic variability and to the loss of genetic variability).

- Most of the over-wintering streaked horned Larks are found on the lower Columbia River and Willamette Valley suggesting the importance of these habitats to wintering Larks. Birds in these two regions are found in large flocks (up to 125 Streaked Horned Larks in a single flock in the Willamette Valley and up to 61 Streaked Horned Larks in a single flock on the Lower Columbia) that are vulnerable to changes in habitat or stochastic events (e.g., weather events such as ice storms).

## Ecological Processes

- On the Washington coast, breeding and over-wintering Larks use sparsely vegetated sandy areas. The dynamic process of erosion and accretion of sandy soils create this habitat type. After new land is created through accretion, it gradually becomes vegetated and is ultimately colonized by non-native beach grasses. There is a fairly narrow window of time when the habitat is sparsely vegetated and appropriate for Larks. Consequently, maintaining the dynamic process of accretion and erosion along the coast and within Grays Harbor and Willapa Bays is critical to maintaining Lark habitat (and Snowy Plover habitat). This process can be altered by activities that reduce the amount of sand export or effect the movement of sand along the coast (e.g., changes in hydrology and currents).
- Fire was historically important in maintaining open grassland habitats in the Puget lowlands and Willamette Valley. Larks preferentially use recently burned habitats in the late summer (Pearson and Hopey 2005). Ft. Lewis uses prescribed fire as a management tool to improve lark habitat at 13$^{th}$ Division Prairie.

# RECOMMENDATIONS FOR ADDRESSING THREATS

## Human Activities

- Alter the timing or location of the activities that disturb breeding birds (listed above) to avoid Lark breeding habitats.
- When possible, we recommend that most activities within 30 m of breeding Larks be restricted.
- To avoid disturbing (flushing, reducing the amount of time foraging and increasing the amount of time spent fleeing or being alert) breeding Larks or to avoid nest abandonment associated with disturbance, we recommend that dredge spoils not be deposited on active breeding localities during the breeding season.
- To minimize the negative impacts of mowing on Larks, we recommend that mowing occur during non-peak breeding times: before breeding starts in mid-April, the second week of June, and at the end of the breeding season (late July – early August). The early and late mowings occur outside the breeding season and we recommend the mid-season mowing because the curve of clutch initiation dates suggests that there is a break in clutch initiations between the first and second clutches, which occurs in the first or second week of June (Pearson and Hopey 2005). We recommend waiting until the second week of June when more of the fledglings are likely to be able to flee from an approaching mower. We also recommend mowing very low before and/or after the breeding season and higher (6-8 inches) during the breeding season. We have noted that mowing with the mowing deck very close to the ground results in more nests being destroyed.

- In the Willamette Valley, we recommend encouraging farming practices that create and maintain bare ground within grass and forb dominated fields.
- On coastal sites, we recommend that beach access be restricted to daytime foot traffic only and that if dogs are allowed they should only be allowed on a leash.
- We recommend using volunteers along the coast (especially at Midway Beach and Damon Point) to encourage people to avoid Lark (and Snowy Plover) nesting areas and to educate users about the bird's vulnerability and sensitivity to human activities.
- We do not recommend the creation of additional trails, facilities or access to Lark breeding sites on publicly owned sites (especially at Damon Point and Midway Beach).

## Habitat Loss or Change

- Spoils that are sparsely vegetated with annual grasses and a mixture of forbs are used by over-wintering Larks. Consequently, keeping an adequate amount of habitat in appropriate successional stages is critical to maintaining Columbia River Lark populations.
- In addition to creating new wintering and breeding habitat, dredge spoils can be used to convert unsuitable habitats into suitable habitats. For example, if spoils are colonized by Scotch broom (*Cytisus scoparus*) or horsetail (*Equisetum sp.*) (habitats not used by Larks) they can be converted to appropriate habitats by depositing additional spoils.
- Control non-native beachgrasses on coastal areas and Scotch broom and non-native rhizomatous grasses on Puget lowland sites. Experimental control of beachgrasses has occurred in Oregon and Washington to improve Snowy Plover habitat.
- The use of sparsely vegetated agricultural fields in the Willamette Valley by wintering Larks indicates the need to maintain this habitat type in the long-term.
- For breeding habitat, maintain relatively short grasses and forbs with little or no woody vegetation [0-6 inches (Altman 1999); 3.9 – 13.3 inches (Person and Hopey 2005)] and a relatively high percent of bare ground [17% (Altman 1999); 16% (Pearson and Hopey 2005)]. Altman (1999) recommended a higher percent cover of bare ground (31%) for Streaked Horned Lark nest sites. For foraging, Streaked Horned Larks select sites with low vegetation (mean = 4.2 inches), and with low vegetation density during the breeding season (Rogers 2000). A review of the effects of management practices on the Horned Lark (Dinkins et al. 2003) also indicates that Larks prefer areas with short, sparse herbaceous vegetation with little or no woody vegetation.
- Altman (2000) provided a list of specific recommendations for the Willamette Valley including: maintain or provide small patches of suitable habitat within native and agricultural grasslands that have 20-50% cover of bare or sparsely vegetated ground, herbaceous vegetation <12 in (30 cm) tall, and located where minimum human or environmental disturbances occur.

## Lack of Protected Habitat

- Create incentives for private land owners to maintain appropriate Lark habitats in the Willamette Valley.
- Consider expanding National Wildlife Refuge status to some of the islands created by dredge spoils on the lower Columbia River so that they can be actively managed for Lark habitat.

## Predation

- See research needs below.

- Predator numbers (especially corvids) increase in response to increased food availability. Eliminating human sources of food in proximity to breeding locations (e.g., State Parks and parking areas adjacent to coastal breeding areas and fast food restaurants adjacent to airport sites) such as uncovered garbage and littered food scraps may indirectly help reduce predator numbers or help prevent their numbers from increasing.

## Stochastic and Small Population Threats

- Increase the amount and spatial extent of Lark wintering habitat to reduce the potential for severe population loss associated with stochastic events (sudden changes in habitat or weather events).
- Increase the number of breeding populations with high reproductive success and high post-fledging survival.
- Altman (2000) recommended establishing >10 breeding populations (>20 pairs/population) in the Willamette Valley. In addition, Altman (2000) recommended delineating 11 Grassland Bird Conservation Areas in the Valley to focus conservation efforts.

## Ecological Processes

- Maintain the dynamic processes that create accreted habitats on the Washington coast and in Willapa Bay and Grays Harbor.
- On Puget prairies, fire appears to improve post-breeding habitat for Larks (Pearson and Hopey 2005) and may improve breeding habitat conditions. We recommend the use of late summer (late August or early September) prescribed fires where and when it is likely to result in appropriate habitat structure and species composition. Conifers colonize Puget prairies in the absence of fire or mechanical tree removal (Lang 1961).

# RESEARCH NEEDS

- Develop a metapopulation model (including populations in the Willamette Valley, lower Columbia River/Washington coast and Puget lowlands) to identify population sources and sinks. This model is critical to the development of recovery goals.
- Use the population model to set population goals by subpopulation (Willamette Valley, lower Columbia River/Washington coast, Puget lowlands, northern Puget trough/Georgia Basin).
- Explore methods for creating a functioning Lark metapopulation on the lower Columbia River using dredge spoils.
- Identify Lark nest predators and develop a strategy to reduce predation
- Evaluate survivorship of fledglings and sources of fledgling mortality because post-fledgling survival is often critical to population growth in birds
- Quantify over-wintering habitat selection
- Examine the relative importance of different wintering sites to Lark survival
- Further quantify movement patterns between breeding sites and movement patterns among wintering sites
- Research methods for controlling non-native beachgrasses on the coast and non-native pasture grasses on Puget prairie sites

- Determine whether the processes of accretion and erosion on the outer Washington coast and in Grays Harbor and Willapa Bays are adequate for maintaining Lark habitat over time.
- Develop a population monitoring strategy that includes a direct or indirect measure of fitness (reproduction and survival).

# PROPOSED CONSERVATION STRATEGY

Because the threats faced by the Streaked Horned Lark vary regionally, we recommend a regionally based conservation strategy and the establishment of a region-wide working group (British Columbia, Washington, and Oregon) to develop recovery goals and objectives. Ultimately, we recommend developing time-lines and specific actions for all proposed strategies. In addition, we recommend developing methods for evaluating the outcome of each action.

Successful implementation of specific conservation strategies ultimately requires landowner and public involvement and commitment. Consequently, we recommend engaging landowners and the public in developing a conservation strategy.

For our conservation strategy, we have intentionally divided the historic and current breeding/wintering range into five regions that are geographically and ecologically distinct. However, the lower Columbia River and Washington coast could be combined into a single recovery region because banded birds appear to move freely between these areas during the winter and breeding season suggesting that this area functions as a metapopulation.

## Northern Puget trough and Georgia Basin

**First Priority**

- Identify sites that have suitable breeding habitat or that can be restored for Lark reintroduction.

**Second Priority**

- Protect identified sites.
- Manage sites for lark habitat (appropriate structure and species composition).
- Conduct Lark reintroduction feasibility study.
- Investigate reintroduction techniques.

**Third Priority**

- Reintroduce larks to restored and protected habitats if determined appropriate and feasible.

## Puget Lowlands

**First Priority**

- On Puget prairie breeding sites, control Scotch broom and invasive grasses and reinstate the use of late summer fire.
- Investigate methods for reducing Lark nest predation rates.
- At breeding sites, limit vehicle access and activities that disturb breeding larks (dogs off leash, fireworks, kite flying, large gatherings of people, trampling, etc.).

- On airport sites, alter mowing regimes (where possible and where it would not conflict with safety) as recommended above and minimize human activities adjacent to breeding sites.
- Also on airport sites, minimize development on remaining grasslands or immediately adjacent to remaining grasslands.
- Develop a population monitoring strategy that includes a direct or indirect measure of fitness (reproduction and survival).
- Conduct Lark reintroduction feasibility study
    - Identify sites (number to be determined by metapopulation model) for lark reintroductions
    - At identified introduction sites, initiate management activities that create appropriate habitat conditions (appropriate structure and species composition).
    - Investigate methods for translocating Larks.

**Second Priority**

- Once the habitat is appropriate for Larks at the reintroduction sites and methods for translocation have been developed, initiate passive reintroduction program (playbacks with decoys). If the passive introduction fails, then attempt to translocate birds.

## Washington Coast

**First Priority**

- Control invasive beachgrasses at known breeding sites. This activity will also benefit snowy plovers that nest adjacent to Larks.
- At breeding sites, limit vehicle access and activities that disturb breeding larks (dogs off leash, fireworks, kite flying).
- Limit human access to nest sites.
- Reduce the amount of food available to crows and ravens.
- Investigate methods for reducing Lark and Snowy Plover nest predation rates.

**Second Priority**

- Develop a plan to maintain the dynamic processes of erosion and accretion along the outer coast and within Grays Harbor and Willapa Bays.
- Develop a core group of volunteers along the coast (especially at Midway Beach and Damon Point) to encourage people to avoid Lark (and Snowy Plover) nesting areas and to educate users about the bird's vulnerability and sensitivity to human activities.
- Develop a population monitoring strategy that includes a direct or indirect measure of fitness (reproduction and survival).

**Third Priority**

- Develop education signs along beach access points about the sensitivity of Larks and Snowy Plovers to specific activities (off leash dog walking, pedestrian, vehicle or horseback riding in nesting areas, etc.).

## Columbia River

**First Priority**

- Prevent additional deposition of dredge spoils on known lark breeding sites until a comprehensive strategy is developed.

**Second Priority**

- Develop a temporally and spatially explicit plan for the deposition of dredge spoils that maintains well distributed habitats (numerous sites along the length of the lower Columbia River from the confluence with the Willamette to the River's mouth) in the appropriate habitat condition (see description above) over time.
- Develop a population monitoring strategy that includes a direct or indirect measure of fitness (reproduction and survival)

**Third Priority**

- Develop a series of protected islands within the USFWS refuge system along the lower Columbia River

## Willamette Valley

**First Priority**

- Secure commitment and designate three areas as lands managed for Lark habitat (e.g., public lands such as refuges, parks, The Nature Conservancy preserves). These areas will be necessary to serve as permanent core areas for population maintenance and sources for population expansion.

  Birds in the Willamette Valley use human managed habitats that provide appropriate habitat conditions. These sites are ephemeral in nature both between seasons and within seasons (as vegetation matures from late winter through summer). Thus we recommend establishing sites dedicated to Lark habitat that would be managed to provide appropriate habitat year round. This core population would then be supplemented by breeding birds finding appropriate habitats in the dynamic landscape outside the core.

**Second Priority**

- Secure commitment from private landowners either voluntarily or through incentives or cost-share programs for management activities that create or maintain breeding or wintering habitat These areas will be necessary to serve as short-term satellite areas for population distribution and expansion. The location of these sites should be evaluated based on the presence of existing Lark populations, the proximity to existing populations, or the ability of the site to support breeding and/or wintering Larks.

**Third Priority**

- Encourage land management that supports populations of Horned Larks through education and outreach activities. Lands outside the core and satellite areas that are purposefully or incidentally managed for Horned Larks should be considered as marginal habitat because of the uncertainity of their suitability from year to year due to changes in field type.

## REFERENCES


Altman, B. 1999. Status and conservation of grassland birds in the Willamette Valley. Unpublished report submitted to Oregon Dept. Fish and Wildlife, Corvallis.

Altman, B. 2000. Conservation strategy for landbirds in the lowlands and valleys of western Oregon and Washington. Version 1.0. Oregon-Washington Partners in Flight.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. American Ornithologists' Union, Washington, D.C.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1980. Terrestrial plant ecology. Benjamin/Cummings Publishing Co., Menlo Park, California, USA.

BASH (Bird/wildlife Aircraft Strike Hazard Team). 2004. Top 50 USAF Wildlife Strikes by Count. Aviation Safety Division, U.S. Air Force (http://afsafety.af.mil/AFSC/Bash/stats/web_spec_count_stat.html).

Beason, R.C. 1995. Horned Lark (*Eremophila alpestris*). In The Birds of North America, No. 195 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Beauchesne, S.M. 2002. Coastal Vesper Sparrow inventory, southeastern Vancouver Island, May to July 2002. Report prepared for the Garry Oak Ecosystems Vertebrates at Risk Recovery Action Group, Victoria, B.C.

Beauchesne, S., and J. Cooper. 2003. COSEWIC status report on the Horned Lark *Strigata* subspecies *Eremophila alpestris strigata*. Status report prepared for the Committee on the Status of Endangered Wildlife in Canada. COSEWIC Secretariat c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario.

Behle, W.H. 1942. Distribution and variation of the Horned Larks (*Otocoris alpestris*) of Western North America. University of California Publications in Zoology 46:205-316.

Best, L.B. 1978. Field sparrow reproductive success and nesting ecology. Auk 95:9-22.

Bock, C.E., J.H. Bock, and B.C. Bennett. 1999. Songbird abundance in grasslands at a suburban interface on the Colorado High Plains. Pages 131-136 in P.D. Vickery and J.R. Herkert, editors. Ecology and conservation of grassland birds of the Western Hemisphere. Studies in Avian Biology 19.

Bonham, C.D. Measurements for terrestrial vegetation. John Wiley and Sons, New York, NY.

Bowles, J.H. 1898. Notes on the Streaked Horned Lark. Osprey 3:53-54.

Bowles, J.H. 1900. Nesting of the Streaked Horned Lark. Condor 2:30-31.

Browning, M. 1975. Distribution and occurrence of the birds of Jackson County and surrounding areas. U.S. Museum of Natural History, Wash. D.C.

Buell, A.C., A.J. Pickart, and J.D. Stuart. 1995. Introduction history and invasion patterns of *Ammophila arenaria* on the north coast of California. Conservation Biology 9(6):1587-1593

Campbell, W.R., N.K. Dawe, I. McTaggart-Cowan, J.M. Copper, G.W. Kaiser, M.C.E. McNall, and G.E.J. Smith. 1997. The birds of British Columbia, volume 3, Passerines, Flycatchers through Vireos. University of British Columbia Press, Vancouver, British Columbia.

Chappell, C.B., M.S. Mohn Gee, B. Stephens, R. Crawford, and S. Farone. 2001. Distribution and decline of native grasslands and oak woodlands in the Puget lowland and Willamette Valley ecoregions, Washington. Pages 124-139 in Reichard, S.H., P.W. Dunwiddie, J.G. Gamon, A.R. Kruckeberg, and D.L. Salstrom eds. Conservation of Washington's native plants and ecosystems. Washington Native Plant Society, Seattle. 223pp.

Cleary, E.C., R.A. Dolbeer, and S.E. Wright. 2004. Wildlife strikes to civil aircraft in the United States 1990-2003. Federal Aviation Administration National Wildlife Strike Database Serial Report Number 10.

Contreras, A. 1998. Birds of Coos County, Oregon: status and distribution. Cape Arago Audubon Society and Oregon Field Orntihologists Special Publication 12. Eugene.

Crawford, R.C., and H. Hall. 1997. Changes in the south Puget prairie landscape. Pages 11-15 in P. Dunn and K. Ewing, editors. Ecology and conservation of the south Puget sound prairie landscape. The Nature Conservancy , Seattle, WA.

Davis, S.K., and D.C. Duncan. 1999. Grassland songbird occurrence in native and crested wheatgrass pastures of southern Saskatchewan. Studies in Avian Biology 19:211-218.

Dawson, L.W., and J.H. Bowles. 1909. The birds of Washington. Occidental Press, Seattle, Washington.

Dinkins, M.F., A.L. Zimmerman, J.A. Dechant, B.D. Parkin, D.H. Johnson, L.D. Igl, C.M. Goldade, and B.R. Euliss. 2003. Effects of management practices on grassland birds: Horned Lark. Northern Prairie Wildlife Research Center, Jamestown, ND. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/literatr/grasbird/hola/hola.htm (Version 12 Dec2003).

Drovetski, S.V., S.F. Pearson, and S. Rohwer. In press. Streaked horned lark *Eremophila alpestris strigata* has distinct mitochondrial DNA. Conservation Genetics *in press*.

Dubois, A.D. 1935. Nests of horned larks and longspurs on a Montana prairie. Condor 37:56-72.

Fernandez-Juricic, E. 2000. Local and regional effects of pedestrians on forest birds in a fragmented landscape. Condor 102:247-255.

Fraser, D. F., W.L. Harper, S.G. Cannings, and J.M. Cooper. 1999. Rare birds of British Columbia. Ministry of Environment, Lands and Parks Wildlife Branch and Resources Inventory Branch, Victoria, British Columbia, Cananda.

Gabrielson, I.N., and S.G. Jewett. 1940. The birds of Oregon. Oregon State University Press, Corvallis, Oregon.

Gilligan, J., D. Rogers, M. Smith, and A. Contreras. 1994. Birds of Oregon. Cinclus Press, McMinnville, Oregon.

Hartman, C.A., and L.W. Oring. 2003. Orientation and microclimate of horned lark nests: The importance of shade. Condor 105:158-163.

Heckert, J. R. 1994. Breeding bird communities of midwestern prairie fragments: the effects of prescribed burning and habitat-area. Natural Areas Journal 14:128-135.

Hensler, G.L., and J.D. Nichols. 1981. The Mayfield method of estimating nest success: A model, estimators and simulating nesting success. Wilson Bulletin 93:42-53.

Hosmer, D.W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York.

Jewett, S.G., W. P. Taylor, W.T. Shaw, and J.W. Aldrich. 1953. Birds of Washington State. University of Washington Press, Seattle, Washington.

Johnson, D.H. 1979. Estimating nest success: The Mayfield method and an alternative. Auk 96:651-661.

Johannessen, C.L., Davenport, W.A., Millet, A., McWilliams, S. 1971. The vegetation of the Willamette Valley. Annals of the Association of American Geographers 61:286-302.

Johnson, R.G., and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54:106-111.

Lafferty, K.D. 2001. Disturbance to wintering western snowy plovers. Biological Conservation 101:315-325.

Lang, F.A. 1961. A study of vegetation change on the gravelly prairies of Pierce and Thurston Counties, Washington. Masters thesis, University of Washington.

Lebreton, J.D., K.P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monographs 62:67-118.

MacLaren, P.A. and E.B. Cummins. 2000. Streaked Horned Lark Surveys in Western Washington. Report funded by USFWS.

Martin, T.E., and G.R. Geupel. 1993. Nest-monitoring plots: Methods for locating nest and monitoring success. Journal of Field Ornithology 64:507-519.

Martin, T.E., and J.J. Roper. 1988. Nest predation and nest-site selection of a western population of the Hermit Thrush. Condor 90:51-57.

Martin, T.E., C. Paine, C.J. Conway, W.M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD Field Protocol. Document available from Montana Cooperative Wildlife Research Unit, Univ. of Montana, Missoula, MT. 59812; web site: http://pica.wru.umt.edu/bbird/

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Miller, S.G., R.L. Knight, and C.K. Miller. Influence of recreational trails on breeding bird communities. Ecological Applications 8:162-169.

Nelson, K.J., and K. Martin. 1999. Thermal aspects of nest-site location for vesper sparrows and horned larks in British Columbia. Studies in Avian Biology 19:137-143.

Nur, N., S.L. Jones, and G.R. Geupel. 1999. A statistical guide to data analysis of avian monitoring programs. U.S. Fish and Wildlife Service, BTP-R6001-1999.

Owens, R.A., and M.T. Myres. 1973. Effects of agriculture upon populations of native passerine birds of an Alberta fescue grassland. Canadian Journal of Zoology 51:697-713.

Page, N. 2003. COSEWIC Status Report on the Sand-verbena Moth *Copablepharon fuscum* in Canada. Status report prepared for the Committee on the Status of Endangered Wildlife in Canada. COSEWIC Secretariat c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario.

Pearson, S.F. 2003. Breeding Phenology, nesting success, habitat selection, and census methods for the streaked horned lark in the Puget lowlands of Washington. Natural Areas Program Report 2003-2. Washington Department of Natural Resources. Olympia, WA.

Pearson, S.F., and M. Hopey. 2004. Streaked Horned Lark inventory, nesting success and habitat selection in the Puget lowlands of Washington. Natural Areas Program Report 2004-1. Washington Department of Natural Resources, Olympia, WA.

Pearson, S.F., and M. Hopey. 2005. Streaked Horned Lark nest success, habitat selection, and habitat enhancement experiments for the Puget lowlands, coastal Washington and Columbia River Islands. Natural Areas Program Report 2005-1. Washington Dept. of Natural Resources. Olympia, WA.

Pearson, S.F., M. Hopey, W. D. Robinson, R. Moore. 2005. Range, abundance and movement patterns of wintering Streaked Horned Larks in Oregon and Washington. Natural Areas Program Report 2005-2. Washington Dept. of Natural Resources. Olympia, WA.

Pietz, P.J., and D.A. Granfors. 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. Journal of Wildlife Management 64:71-87.

Pringle, R.F. 1990. Soil survey of Thurston County, Washington. US Department of Agriculture Soil Conservation Service.

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75:255-260.

Renfrew, R.B., and C.A. Ribic. 2003. Grassland passerine nest predators near pasture edges identified on videotape. Auk 120:371-383.

Robbins, C.S. 1970. Recommendations for an international standard for a mapping method on bird census work. Audubon Field Notes 24:723-726.

Rogers, R.E. 1999. The Streaked Horned Lark in Western Washington. Unpublished Report. Washington Department of Fish and Wildlife, Olympia, Washington.

Rogers, R.E. 2000. The status and microhabitat selection of Streaked Horned Lark, Western Bluebird, Oregon Vesper Sparrow, and Western MeadowLark in Western Washington. Masters Thesis, The Evergreen State College, Olympia, Washington.

Rohrbaugh, R.W. Jr., D. L. Reinking, D. H. Wolfe, S. K. Sherrod, and M. A. Jenkins. 1999. Effects of prescribed burning and grazing on nesting and reproductive success of three grassland passerine species in tallgrass praire. Studies in Avian Biology No. 19:165-170.

Seabloom, E.W., and A.M. Wiedemann. 1994. Distribution and effects of *Ammophila breviligulata* Fern. (American beachgrass) on the foredunes of the Washington coast. Journal of Coastal Research 10(1):178-188.

Stewart, R.E., and H.A. Kantrud. 1972. Population estimates of breeding birds in North Dakota. Auk 89:766-788.

Stinson, D. W. 2005. Draft Washington State Status Report for the Mazama Pocket Gopher, Streaked Horned Lark, and Taylor's Checkerspot. Washington Department of Fish and Wildlife, Olympia.138+ xii pp.

Suckley, G. and J.G. Cooper. 1860. The natural history of Washington Territory. Baillire Brothers, New York, New York.

Thomas, K., R.G. Kvitek, C. Bretz. 2003. Effects of human activity on the foraging behavior of sanderlings (*Calidris alba*). Biological Conservation 109:67-71.

Towle J.C. 1982. Changing geography of the Willamette Valley woodlands. Oregon Historical Quarterly, 83:66-87.

Vickery, P. D., M. L. Hunter, Jr., and J. V. Wells. 1999. Effects of herbicide treatment on habitat selection in grassland birds in southern Maine. Studies in Avian Biology No. 19:149-159.

Van der Zande, N.N., W.J. terKeurs, and W.J. van der Weuden. 1980. The impact of roads on the densities of four bird species in an open field habitat - evidence of a long-distance effect. Biological Conservation 18:299-321.

Ward, P., G. Radcliffe, J. Kirby, J. Illingworth, and C. Cadrin. 1998. Sensitive ecosystems inventory: east Vancouver Island and Gulf Islands 1993-1997. Volume 1: methodology, ecological descriptions and results. Technical Report Series Number 320, Canadian Wildlife Service, Delta, B.C. 146pp.

Wiens, J.A. 1973. Patterns and process in grassland bird communities. Ecological Monographs 43:237-270.

# APPENDIX I

**Estimated number of territories and total number of larks at all known breeding sites in Oregon and Washington.**

| Location | County | # Territories | # Birds | Year | Source |
|---|---|---|---|---|---|
| **Puget Trough** | | | | | |
| 13th Division Prairie | Pierce | 18 | 36 | 2004 | 1 |
| Artillary Impact Area | Pierce | 10 | 20 | 2003 | 2 |
| McChord AFB | Pierce | 31 | 62 | 2004 | 1 |
| Gray Army Airfield | Pierce | 31 | 62 | 2004 | 1 |
| Olympia Airport | Thurston | 18 | 36 | 2002 | 3 |
| Sanderson Field | Mason | 3 | 6 | 1999 | 4 |
| **Totals** | | **111** | **222** | | |
| **Washington Coast** | | | | | |
| Damon Point | Grays Harbor | 17 | 34 | 2004 | 1 |
| Midway Beach | Pacific | 21 | 42 | 2004 | 1 |
| Graveyard Spit | Pacific | 3 | 6 | 2004 | 1 |
| Ledbetter Point | Pacific | 2 | 4 | 2004 | 1 |
| **Totals** | | **43** | **86** | | |
| **Lower Columbia River** | | | | | |
| Rice Island | Clatsop, Wahkiakum | 12 | 24 | 2004 | 1 |
| Miller Sands | Clatsop | 3 | 6 | 2004 | 1 |
| Pillar Rock Island (Jim Crow Island | Clatsop | 6 | 12 | 2004 | 1 |
| West Wallace Island | | 1 | 2 | 2004 | 1 |
| Coffeepot Island | Wahkiakum | 2 | 4 | 2004 | 1 |
| Whites Island (east end of Puget) | Wahkiakum | 8 | 16 | 2004 | 1 |
| Rivergate (N. Portland) | Multnomah | - | 4 | | 5 |
| **Totals** | | **?** | **68** | | |
| **Willamette Valley** | | | | | |
| Northern Valley | Yamhill, Multnomah, Clackamas | - | 26 | 1996 | 6 |
| Central Valley | Marion, Polk | - | 166 | 1996 | 6 |
| Southern Valley | Lane, Linn, Benton | - | 102 | 1996 | 6 |
| Incidental sightings | All valley counties | - | 80 | 1996-97 | 7 |
| Incidental Sightings | All valley counties | - | 24 | Since 1997 | 8 |
| **Totals** | | **?** | **398** | | |
| **Grand Totals** | | **?** | **774** | | |

Sources: 1 = Pearson and Hopey (2005); 2 = Pearson and Hopey (2004); 3 = Pearson (2003); 4 = Rogers (2000); 5 = Elain Stewart personal communication (Metropolitan Wildlife Area Manager); 6 = Altman 1999; 7 = detections outside point counts and intensive studies areas during the Altman (1999) project; 8 = detections reported by others at locations different than those reported in Altman (1999).

## APPENDIX II

**Number of visits and maximum number of Horned Larks (all subspecies), Streaked Horned Larks (STHL), female Streaked Horned Larks, male Streaked Horned Larks and unknown sex of Streaked Horned Larks at sites in Oregon and Washington during the winter of 2004-05.**

| Site | State | Visits | HOLA | STHL | Female STHL | Male STHL | Unknown Sex STHL | County |
|---|---|---|---|---|---|---|---|---|
| **Puget Sound** | | | | | | | | |
| McChord AF Base | WA | 1 | 0 | 0 | 0 | 0 | 0 | Pierce |
| Gray Army Airfield | WA | 2 | 0 | 0 | 0 | 0 | 0 | Pierce |
| 13th Division Prairie | WA | 4 | 7 | 1 | 1 | 0 | 0 | Pierce |
| Olympia Airport | WA | 3 | 5 | 2 | 1 | 1 | 0 | Thurston |
| Shelton Airport | WA | 2 | 0 | 0 | 0 | 0 | 0 | Macon |
| **Coastal Washington** | | | | | | | | |
| Damon Point | WA | 2 | 12 | 12 | 4 | 6 | 2 | Grays Harbor |
| Midway Beach | WA | 3 | ~30 | 30 | 6 | 6 | ~18 | Pacific |
| Graveyard Spit | WA | 1 | 0 | 0 | 0 | 0 | 0 | Pacific |
| Ledbetter Point | WA | 1 | 0 | 0 | 0 | 0 | 0 | Pacific |
| **Columbia River** | | | | | | | | |
| Whites Island | WA | 2 | 20 | 18 | 9 | 6 | 3 | Wahkiakum |
| Lark Island[1] | OR | 1 | 0 | 0 | 0 | 0 | 0 | Clatsop |
| Coffeepot Island | WA | 1 | 0 | 0 | 0 | 0 | 0 | Wahkiakum |
| Pillar Rock Island[2] | OR | 1 | 2 | 2 | 1 | 1 | 0 | Clatsop |
| Miller Sands | OR | 1 | 1 | 1 | 0 | 0 | 1 | Clatsop |
| Rice Island | WA/ OR | 1 | 27 | 27 | 9 | 10 | 8 | Clatsop/ Wahkiakum |
| Rivergate (N. Portland) | OR | 4 | 69 | 61 | 23 | 28 | 10 | Multnomah |
| **Willamette Valley** | | | | | | | | |
| Livermore Rd. | OR | 3 | 24 | 23 | 14 | 19 | 0 | Polk |
| Harvest | OR | 1 | 4 | 0 | 0 | 0 | 0 | Linn |
| Dawson Rd. | OR | 2 | 1 | 0 | 0 | 0 | 0 | Benton |
| Creek Rd. | OR | 11 | ~170 | ~125 | 0 | ~60 | ~65 | Linn |
| Peoria Rd. | OR | 1 | 2 | 2 | 1 | 1 | 0 | Linn |
| Nicewood Rd. | OR | 1 | 1 | 0 | 0 | 0 | 0 | Linn |
| Cook Rd. | OR | 1 | 4 | 0 | 0 | 0 | 0 | Linn |
| Blatchford Rd | OR | 1 | 35 | 35 | 13 | 12 | 10 | Linn |
| Polk/Benton Co. line | OR | 1 | 43 | 43 | 20 | 23 | 0 | Polk-Benton |
| Guerber Rd | OR | 2 | ~100 | ~80 | 0 | 0 | ~80 | Benton |
| Malpass Rd | OR | 4 | 110 | 80 | 0 | 0 | 80 | Linn |
| **Rogue Valley** | | | | | | | | |
| Ashland | OR | 1 | 12 | 0 | 0 | 0 | 0 | Jackson |
| **Grand Totals** | | | **~676** | **~542** | **102** | **~163** | **~277** | |

[1]Lark island is our name for an un-named island located just upstream of Tenasillahe Island across a narrow slough
[2]Pillar Rock Island is also known as Jim Crow Island

# APPENDIX III

**Imminence and magnitude of threats to the Streaked Horned Lark populations in the Puget lowlands, Washington coast, lower Columbia River, and Willamette Valley.**

| Population | Threat Category | Specific Threats | Magnitude[1] | Immediacy[2] |
|---|---|---|---|---|
| **Puget Lowlands** | | | | |
| | Habitat loss/change | Development of Lark habitat is occurring at Gray Army Airfield and Olympia Airport (nesting and foraging habitat is being paved and structures are being built). Development is planned for foraging areas outside of the Gray Army Airfield and additional development is planned for the grasslands at the Olympia Airport | High | Imminent |
| | Human activities | Events such as Rodeo and the air show at McChord AFB, planned increase in helicopter activity and change in type of aircraft used at Gray Army Airfield, collisions with aircraft, and use of dogs to remove birds from airports. | Moderate to High | Imminent |
| | Predation | Documented threat in Pearson and Hopey (2005) | High | Imminent |
| | Ecological processes | Loss of fire on prairie sites but it is being reintroduced at 13th Division Prairie | Moderate | Imminent |
| | Non-native species | Invasive and nonnative species such as Scotch broom, rhizomatous grasses, and spotted knapweed. Results in change in habitat structure and loss of appropriate breeding habitat | High | Imminent |
| **Washington Coast** | | | | |
| | Habitat loss/change | Suitable habitat is succeeding to non-native beachgrasses dominated habitat not used by larks. | Moderate | Imminent |
| | Human activities | Pet dogs off leash, dogs and people in nesting areas, horses, kite flying, fireworks, off road vehicles | Moderate | Imminent |
| | Predation | Documented in Pearson and Hopey (2005) and Pearson and Hopey (unpubl.) | Moderate in 2004<br>High in 2005 | Imminent |
| | Ecological processes | Change in accretion and erosion patterns associated with dams, dikes, channeling, etc. | ?? | ?? |
| | Non-native species | Beach grasses (coastal Washington sites) results in change in habitat structure and loss of appropriate breeding habitat. | High | Imminent |
| **Columbia River** | | | | |
| | Habitat loss/change | Development occurring at the Rivergate site. Habitat succession to inappropriate habitat is ongoing. | Moderate | Imminent |
| | Human activities | Activities associated with dredging appeared to result in the failure of at least 2 nests on Miller Sands in 2005 | Low to Moderate | Imminent |
| | Predation | Documented in Pearson and Hopey (2005) | Moderate in 2004<br>High in 2005 | Imminent |
| | Ecological processes | Loss of flooding along the lower Columbia River | ?? | ?? |
| | Non-native species | Scotch broom, others? | Moderate to low | Imminent |
| **Willamette Valley** | | | | |
| | Habitat loss/change | Urban and suburban development, changes in farming practices | High | Imminent |
| | Human activities | Vehicle and farm equipment (Altman 1999) | Moderate | Imminent |
| | Predation | Documented in Altman (1999) | High | Imminent |
| | Ecological processes | Loss of fire | Low | Imminent |
| | Non-native species | On prairie sites - Scotch broom, rhizomatous grasses, Himalayan blackberry | Moderate to Low | Imminent |
| | Pesticides | Potential associated with farming (documented for the species but not the subspecies | ?? | Non-imminent |
| **Overall** | | | | |
| | Small Population | Small population size has been documented (certainly less than 1000 birds and probably less than 850 birds – see above), little or no genetic variability suggesting inbreeding or population bottleneck (Drovetski et al in press). | High | Imminent |
| | Winter concentration | Most of the worlds population can be found in a couple of flocks in the Willamette Valley and lower Columbia River during the winter making them vulnerable to stochastic events | ?? | Non-imminent |

[1]High magnitude threats are threats that are likely to reduce the overall population, decrease the reproductive potential of the population, or significantly decrease the area used for foraging and breeding. These changes are likely to lead to extinction, local extirpation, or significant declines in local populations. Low magnitude threats negatively impact population size, reproductive success, or survival but are not likely to lead to extinction, extirpation, or significant population declines in the short term.
[2]Imminent threats are occurring and non-imminent threats have the potential to occur but have not yet occurred.

Ecotoxicology (2013) 22:139–147
DOI 10.1007/s10646-012-1010-4

# Sensitivity of early life stages of white sturgeon, rainbow trout, and fathead minnow to copper

David W. Vardy · Johanna Oellers · Jon A. Doering · Henner Hollert · John P. Giesy · Markus Hecker

Accepted: 18 October 2012 / Published online: 5 November 2012


**Abstract** Populations of white sturgeon (WS; *Acipenser transmontanus*) are in decline in several parts of the United States and Canada, attributed primarily to poor recruitment caused by degradation of habitats, including pollution with contaminants such as metals. Little is known about sensitivity of WS to contaminants or metals such as copper (Cu). Here, acute (96 h) mortalities of WS early life stages due to exposure to Cu under laboratory conditions are reported. Two standard test species, rainbow trout (*Oncorhynchus mykiss*) and fathead minnow (*Pimephales promelas*), were exposed in parallel to determine relative sensitivity among species. Swim-up larvae [15 days post-hatch (dph)] and early juveniles (40–45 dph) of WS were more sensitive to Cu ($LC_{50} = 10$ and 9–17 μg/L, respectively) than were yolksac larvae (8 dph; $LC_{50} = 22$ μg/L) and the later juvenile life stage (100 dph; $LC_{50} = 54$ μg/L). WS were more sensitive to Cu than rainbow trout and fathead minnow at all comparable life stages tested. Yolksac larvae of rainbow trout and fathead minnow were 1.8 and 4.6 times, respectively, more tolerant than WS, while swim-up and juvenile life stages of rainbow trout were between 1.4- and 2.4-times more tolerant than WS. When plotted in a species sensitivity distribution with other fishes, the mean acute toxicity value for early life stage WS was ranked between the 1st and 2nd centile. The WS life stage of greatest Cu sensitivity coincides with the beginning of active feeding and close association with sediment, possibly increasing risk. WS early life stages are sensitive to aqueous copper exposure and site-specific water quality guidelines and criteria should be evaluated closely to ensure adequate protection.

**Keywords** Fish · Metal · Ecotoxicology · Early life stage sensitivity

## Introduction

Sturgeon (Acipenseridae) are among the largest freshwater fish in the world. Some species can live more than

**Electronic supplementary material** The online version of this article (doi:10.1007/s10646-012-1010-4) contains supplementary material, which is available to authorized users.

D. W. Vardy (✉) · J. A. Doering · J. P. Giesy · M. Hecker
Toxicology Centre, University of Saskatchewan,
44 Campus Dr., Saskatoon, SK S7N 5B3, Canada
e-mail: d.vardy@usask.ca

J. Oellers · H. Hollert
Institute for Environmental Research, RWTH University,
Aachen, Germany

J. Oellers
Research Institute for Ecosystem Analysis and Assessment,
Gaiac, Aachen, Germany

J. P. Giesy
Department of Biomedical Veterinary Sciences, University of
Saskatchewan, Saskatoon, SK, Canada

J. P. Giesy
Zoology Department and Center for Integrative Toxicology,
Michigan State University, East Lansing, MI, USA

J. P. Giesy
Department of Biology and Chemistry and State Key Laboratory
for Marine Pollution, City University of Hong Kong, Kowloon,
Hong Kong, SAR, China

M. Hecker
School of the Environment & Sustainability, University of
Saskatchewan, Saskatoon, SK, Canada

M. Hecker
Cardno ENTRIX Inc., Saskatoon, SK, Canada

100 years, weigh more than 800 kg and reach lengths of more than 6 m. Sturgeon are also among the most archaic fish species with prehistoric ancestors dating back an estimated 175 million years (UCWSRI 2002). Presently, however, populations of sturgeon are threatened globally and have been decreasing over the past century in Northern Europe, Asia, and North America (Birstein 1993; Coutant 2004; Gisbert and Williot 2002). In North America, populations of white sturgeon (WS; *Acipenser transmontanus*) have been reported to be declining in the northwestern United States and British Columbia, Canada. Populations of WS have been listed as endangered in parts of Canada (COSEWIC 2012) and the USA (U.S. Fish and Wildlife Service 2012). Decreases in populations of sturgeon in the Columbia, Fraser, and Sacramento–San Joaquin rivers and their tributaries have been attributed primarily to poor annual recruitment (Coutant 2004; DFO 2007; Scott and Crossman 1998; UCWSRI 2002). Results of some simulation models of population trends and demographics have predicted that without implementation of successful remedial efforts WS will become virtually extinct in these rivers within 50 years (DFO 2007; Irvine et al. 2007; Paragamian et al. 2005; Paragamian and Hansen 2008; UCWSRI 2002).

Possible hypotheses for failures of recruitment of WS include, among others, overharvesting, habitat alteration, changes in flow regime, decreased water quality, such as temperature, turbidity, total dissolved gases, pollution, poor nutrition, genetic bottlenecks or inbreeding depression, predation by introduced species such as walleye (*Sander vitreus*), inter-specific competition, pathogens, and disease (Birstein 1993; Coutant 2004; Gisbert and Williot 2002; Irvine et al. 2007; Kruse and Scarnecchia 2002; Luk'yanenko et al. 1999; Paragamian and Hansen 2008; UCWSRI 2002). In some of the larger North American rivers, such as the Columbia, metals are of particular concern due to past and present activities of mines, metallurgical facilities, pulp and paper mills, as well as other industrial and municipal sources (UCWSRI 2002). Copper (Cu), for example, is often found in contaminated systems at concentrations that are greater than naturally occurring levels (Grosell 2012; Kamunde and Wood 2003; Niyogi and Wood 2003). Concentrations of Cu in clean natural freshwaters are typically in the lower µg/L range (e.g. 0.2–2 µg/L), but thresholds for lethality on fishes can occur at concentrations that are only 10-fold greater (Grosell 2012; Wood 2001). In addition, effects on more sensitive endpoints, including behaviour, chemosensory, and olfaction, have been recorded within the lower µg/L concentration range (Grosell 2012). In general, little is known about the potential toxicity of metals, such as Cu, to WS, or the tolerance of WS relative to other fishes.

Water quality guidelines and criteria are typically based upon effects concentrations (e.g. $LC_{50}$s) for aquatic organisms and are estimates of the concentration of a contaminant in the environment that is expected to protect 95 % of a group of diverse genera, assuming an appropriate number and variety of taxa are used for calculations (CCME 2007, EPA 1985). In cases where a species is deemed commercially or recreationally important and its threshold value is more sensitive than the calculated guideline or criteria, that particular species mean acute value (SMAV) will supersede (EPA 1985). These estimates, however, are only based upon species for which there are existing toxicity data that meet acceptable standards and often do not consider life stage specific sensitivities unless existing data indicates significant differences. Consequently, there is uncertainty whether an endangered species such as the WS that is recreationally, commercially, and culturally important (UCWSRI 2002) but has little to no existing toxicity data is protected by current guidelines and criteria.

Fish are generally most sensitive to effects of contaminants such as metals during early life stages (Hutchinson et al. 1998; McKim 1977). Previous work has indicated differences in sensitivity among early life stages of WS (Vardy et al. 2011), and studies of the effects of contaminants and life stage-specific sensitivities are important for making informed regulatory decisions. Life stage-specific sensitivity of WS is of particular interest given their early life history strategies. Early life stages of sturgeon inhabit benthic habitats, on surface sediments or in interstitial space between stones. There is some debate among researchers over the exact timing and sequence of certain behavioral events during WS early life stage development, these events possibly being influenced by differences in availability of appropriate substrata (McAdam 2011), but there is a general acceptance that early life stages of WS are in close contact with the substratum and exhibit distinct hiding and drifting phases (Brannon et al. 1983, 1985; Deng et al. 2002; Kynard and Parker 2005). Yolksac stage WS tend to hide/burrow in refugia (Brannon et al. 1983, 1985; Gessner et al. 2009; McAdam 2011; Richmond and Kynard 1995; personal observation in the laboratory). Prior to transitioning to exogenous feeding, sturgeon swim up in the water column (presumably to be transported by currents to more suitable foraging grounds; Auer and Baker 2002; Gessner et al. 2009; McAdam 2011) before returning to the bottom during the juvenile life stage, where they begin to scavenge and prey on benthic species and spend much of their life closely associated with sediments. Therefore, in addition to exposure to pollutants in the water column, sturgeon can be exposed to contaminants associated with sediments (Feist et al. 2005; Kruse and Scarnecchia 2002) or contaminants released into the sediment–water interface. Sediments are sinks for pollutants and often contain high concentrations of metals, which can be released back into porewater and the water column following remobilization

(Salomons et al. 1987; Sullivan and Taylor 2003). Thus, WS could be exposed chronically to lesser concentrations of metals, or, during certain life stages and for shorter periods of time, to greater concentrations of metals at the sediment–water interface. For this reason, and to generate data to develop species sensitivity distributions (SSDs) in support of deriving protective acute water quality guidelines and criteria, it is necessary to determine both acute and chronic toxicity of metals to WS. The results of chronic studies on survival and growth have been presented previously (Vardy et al. 2011).

The primary objective of this study was to establish acute toxicity data for the effect of Cu on early life stages of WS that can be used in risk assessments. Early life stage WS were exposed to increasing concentrations of dissolved Cu, bracketing environmentally relevant concentrations and those expected to be lethal. In addition, rainbow trout (*Oncorhynchus mykiss*) and fathead minnow (*Pimephales promelas*) were exposed to Cu in the laboratory, in parallel to WS, to provide paired information for use in species sensitivity comparisons.

## Methods

### Test materials

Copper(II) sulfate pentahydrate (Chemical Abstracts Service (CAS) number 7758-99-8; purity 99.995 %) was obtained from Sigma-Aldrich (Oakville, ON, Canada) and was dissolved in laboratory reverse osmosis water.

### Experimental fish

Fertilized WS eggs were collected at the Kootenay Trout Hatchery, Fort Steele, BC, Canada, from a minimum of four breeding pairs of adult WS caught in the Columbia River near Waneta, Canada. Fertilized eggs were transported to the Aquatic Toxicology Research Facility (ATRF), University of Saskatchewan, Saskatoon, SK, Canada where the embryos were raised under standard culturing conditions (Conte et al. 1988) until the desired life stages were achieved. Eyed embryos of rainbow trout were obtained from the Trout Lodge (Summer, WA, USA) and incubated in McDonald-type hatching jars (Aquatic Ecosystems, Apopka, FL, USA) until hatch. Fathead minnows were obtained from Osage Catfisheries (Osage Beach, MO, USA) and several generations were produced to insure healthy progeny.

### Exposure methods

Acute (96 h) toxicity of Cu was determined in accordance with the methods described by the American Society for Testing and Materials (ASTM 2007), with minor modifications. The exposure design consisted of sets of laboratory-based 96 h static renewal tests with mortality as the measurement endpoint. Laboratory water (carbon and biofiltered city water) was adjusted to simulate natural conditions of the Columbia River near Trail, BC, Canada. Target hardness of ~65 mg/L and dissolved organic carbon (DOC) concentrations of ~2.5 mg/L were achieved by mixing laboratory water with reverse osmosis water in a 1:1 ratio. Target temperatures of 12 ± 1, 16 ± 1 and 20 ± 1 °C for rainbow trout, WS, and fathead minnows, respectively, were achieved by immersing the exposure chambers in chilled or heated water baths or by use of environmental control chambers. All fish were tested under a 16:8 h light:dark cycle of illumination by use of standard daylight fluorescent lighting. Culture conditions for the fish (DOC, hardness, temperature, photoperiod) were the same as exposure conditions with the difference that fish were fed between one and four times a day, depending on life stage. For testing the yolksac life stage (8 dph) fish were exposed to increasing concentrations of Cu in 0.5 L high-density polyethylene (HDPE) test containers. Identical but larger 5 and 20 L test containers were used during toxicity tests with later life stages. Loading densities remained less than the recommended 0.5 g/L and fish were not fed during the acclimation and exposure period (ASTM 2007). The various life stages, expressed as dph, and species tested are described in Table 1.

Concentrated stock solutions of Cu were prepared separately in individual HDPE carboys and allowed to equilibrate for 48 h prior to making dilutions to obtain test solutions. Exposures were conducted in triplicate or quadruplicate for each treatment group; each test chamber contained 10–15 individuals with 50 % solution renewal every 12 h. Fish were acclimatized to the exposure chambers for 24 h prior to the addition of test solutions. Exposure chambers were cleaned once a day and dead fish were removed, length and weight measured, and preserved for potential use in future experiments.

### Water chemistry analyses

Basic water quality parameters, including temperature, pH, dissolved oxygen and conductivity, were measured daily by use of Symphony Electrodes (VWR, Mississauga, ON, Canada, Cat No. 11388-328) or YSR electrodes (YSR Inc., Yellow Springs, OH, USA). Typically, subsamples were collected during water changes from each replicate of each concentration and used for individual analysis. Hardness, alkalinity, ammonia, nitrates, nitrites, and chlorine were collected following a similar sampling scheme but only at the initiation and termination of experiments, and analyzed by use of LaMotte colorimetric and titrator test kits

**Table 1** Acute median lethal concentrations ($LC_{50}$s) for Cu exposure for white sturgeon (*Acipenser transmontanus*), rainbow trout (*Oncorhynchus mykiss*), and fathead minnow (*Pimephales promelas*) early life stages expressed in days post-hatch (dph)

96 h $LC_{50}$ for copper exposure (µg/L)

| Fish species | Life stage | | | | | | Water quality criteria | |
|---|---|---|---|---|---|---|---|---|
| | Yolksac (8 dph) | Swim-up (15 dph) | Juvenile (40 dph) | Juvenile (45 dph) | Later Juvenile (100 dph) | SMAV[a] | CMC[b] | CWQG[c] |
| White sturgeon (*Acipenser transmontanus*) | 22 (20–25) | 10 (8–12) | 9 (7–12) | 17 (14–21) | 54 (47–62) | 18 | 7.9 (±1.5) | 2 |
| Rainbow trout (*Oncorhynchus mykiss*) | 40 (34–46) | 21 (18–23) | 22 (20–25) | 24 (20–28) | | 26 | 8.5 (±3.0) | 2 |
| Fathead minnows (*Pimephales promelas*) | 102 (78–135) | | | | | 102 | 11.8 | 2 |

Values in parentheses for LCs represent 95 % CI, values in parentheses for water quality criteria represent SD

[a] SMAV refers to the species mean acute value

[b] CMC refers to the Criteria Maximum Concentration for fresh water species. The mean freshwater criteria is presented and calculated from the various life stage experiments for each specie using the Biotic Ligand Model (EPA 2007b)

[c] CWQG refers to the Canadian Water Quality Guidelines for the protection of aquatic life adjusted to the present study's hardness (CCME 2003)

(Chestertown, MD, USA) or samples were sent to Columbia Analytical Services (CAS; Kelso, WA, USA) for external analyses. Water samples for analysis of concentrations of Cu in exposure chambers were also collected following the same sampling scheme at initiation and termination of the experiment. Water for Cu analysis was collected from each treatment group into acid-cleaned polyethylene bottles and filtered through a 0.45 µm polycarbonate filter. Filtered water was acidified with ultrapure nitric acid to pH $< 2$. Quantification of Cu was performed by use of inductively coupled plasma mass spectrometry (ICP-MS) following EPA method 6020 and ILM05.2D (Creed et al. 1994). All calculations and reported values pertaining to Cu concentrations are based on the average measured concentrations in the treatment groups. DOC analysis was performed using a TOC analyzer (TOC-5050A, Shimadzu, Mandel Scientific, Guelph, ON, Canada).

### Data analysis and statistics

Mortality was calculated and the proportion of fish dead in each of the exposure chambers of a given Cu concentration was compared to that of the controls. $LC_{50}$s for each of the species were calculated by use of TOXSTAT® software (Western EcoSystems Technology 1996). To assess the relative sensitivity of early life stages of WS to Cu, relative to those of other fishes, a species sensitivity distribution (SSD) was calculated for Cu (Posthuma et al. 2002). The SSD for freshwater fishes was derived based on toxicity data obtained from: EPA's ECOTOX database (EPA 2007a), information on Cu sensitivity of three different sturgeon species published by Dwyer et al. (2005), and the data obtained during this study. Data considered for the derivation of the SSD were exclusively from 96 h toxicity studies that reported $LC_{50}$ values. Species mean (geomean) acute values (SMAVs) were calculated where data from multiple studies were available. If only one data point was available for a species, this was used as the SMAV in the SSD. To facilitate comparisons among tests without confounding the comparison by differences in hardness, all data included in the SSD were adjusted to a hardness of 50 mg $CaCO_3$/L by use of the Criteria Maximum Concentration (CMC) regression equation for Cu, as outlined by the US EPA for calculating freshwater dissolved metals criteria that are hardness dependent (EPA 2009).

## Results

### Exposure verification

Measured concentrations of Cu (Table 2) were comparable to nominal concentrations, and on average, were within 95 % of each other (see Supplementary Data). However, there were small detectible concentrations of Cu in the controls, but these concentrations were less than the least dose of each metal concentration. Generally, measured concentrations were less than nominal concentrations.

### Water quality

Average water temperatures for all treatment groups during the WS, rainbow trout, and fathead minnow exposures were 16 °C (±0.9), 13 °C (±0.5), and 22 °C (±0.1), respectively. The average dissolved oxygen saturation, pH,

**Table 2** Mean ± standard deviation (SD; numbers in parentheses) measured exposure concentrations for copper during acute (96 h) static renewal exposure experiments with white sturgeon (WS; *Acipenser transmontanus*), rainbow trout (RT; *Oncorhynchus mykiss*), and fathead minnow (FM; *Pimephales promelas*) early life stages expressed as days post-hatch (dph)

| Treatment | Fish species | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WS life stages (dph) | | | | | RT life stages (dph) | | | | FM life stages (dph) |
| | 8 Measured (μg/L) | 15 Measured (μg/L) | 40 Measured (μg/L) | 45 Measured (μg/L) | 100 Measured (μg/L) | 8 Measured (μg/L) | 15 Measured (μg/L) | 40 Measured (μg/L) | 45 Measured (μg/L) | 8 Measured (μg/L) |
| Control | 1.3 (±0.6) | 0.4 (±0.0) | 0.4 (±0.0) | 0.4 (±0.0) | 0.8 (±0.2) | 1.3 (±0.7) | 0.3 (±0.1) | 2.4 (±2.5) | 1.2 (±0.6) | 1.4 (±0.8) |
| 1 | 1.8 (±0.2) | 2.8 (±0.1) | 1.6 (±0.1) | 2.0 (±0.1) | 8.3 (±0.1) | 1.8 (±0.6) | 2.1 (±0.1) | 9.7 (±0.7) | 2.6 (±0.1) | 2.1 (±0.5) |
| 2 | 2.7 (±N/A)[a] | 4.7 (±0.2) | 3.8 (±0.2) | 3.7 (±0.1) | 17 (±N/A)[a] | 3.5 (±0.6) | 3.8 (±0.0) | 20 (±1.4) | 4.0 (±0.0) | 3.6 (±0.7) |
| 3 | 5.9 (±0.1) | 8.3 (±0.1) | 11 (±0.4) | 7.3 (±0.1) | 36 (±N/A)* | 8.0 (±0.7) | 7.6 (±0.0) | 40 (±2.2) | 8.4 (±0.3) | 8.6 (±0.7) |
| 4 | 8.2 (±N/A)[a] | 20 (±0.9) | 21 (±1.3) | 15 (±0.2) | 74 (±21.6) | 19 (±3.6) | 15 (±0.2) | 74 (±8.5) | 15 (±0.4) | 23 (±1.9) |
| 5 | 21 (± 1.8) | 30 (± 0.1) | 42 (± 1.7) | 29 (± 0.1) | 150 (± N/A)* | 38 (± 2.4) | 29 (± 0.0) | 146 (± 14.6) | 30 (± 0.5) | 43 (± 1.0) |
| 6 | 38 (±0.2) | 52 (±3.2) | 85 (±2.1) | 56 (±0.4) | 282 (±24.4) | 78 (±11.5) | 59 (±0.5) | 296 (±18.7) | 63 (±2.4) | 85 (±12.4) |
| 7 | 86 (±10.7) | | 171 (±2.1) | | | 155 (±32.3) | | | | 195 (±9.3) |
| 8 | 151 (±0.4) | | | | | | | | | |
| 9 | 382 (±5.2) | | | | | | | | | |

[a] SD was not calculated due to lack of concentration measurements

and conductivity for all treatment groups were 86 % (±8.7), 7.5 (±0.2), and 187 μS/cm (±25.5), respectively. Mean hardness was 57 mg/L $CaCO_3$ (±12.4) and the concentration of dissolved organic carbon was 2.2 mg/L (±0.5). The average total concentration of ammonia, expressed as nitrogen (N) for all treatment groups was less than the limit of detection (<0.025 mg/L). There were no significant differences in all other measured water quality parameters among treatment groups of any given experiment (summary of analytical methods, method detection limits, method blanks, and mean water quality parameters for individual exposures are provided as Supplementary Data).

## Lethal concentrations

$LC_{50}$s were successfully calculated for all life stages of each species that was tested (Table 1). Average survival of unexposed control fish was 90 % or greater in all experiments (see supplementary data for summary of mean mortality for individual exposures). WS were most sensitive to Cu at 15 and 40 dph, followed by 45 and then 8 dph. WS exposed to Cu at a later life stage (100 dph) were more tolerant than were earlier life stages (Fig. 1). $LC_{50}$s for toxicity of Cu to WS were less than those for rainbow trout and fathead minnows for all comparable life stages tested (Fig. 1; Table 1). $LC_{50}$s for WS swim-up larvae and juvenile life stages were between 1.4- and 2.4-times more sensitive than rainbow trout. Rainbow trout were least sensitive at 8 dph, followed by the later life stages, which exhibited comparable sensitivities to each other. Fathead minnow (8 dph) were more tolerant than WS and rainbow trout at all life stages tested.

## Species sensitivity distribution

The SSD that was developed based on 59 freshwater fishes, including the data of the various life stages of the three species studied here (Fig. 2), demonstrated that WS that were 8, 15, 40, 45, or 100 dph were ranked in the 14th, 1st, 2nd, 3rd, and 28th centile, respectively. The SMAV for WS ranked in the 2nd centile. Rainbow trout from the present study at 8, 15, 40, and 45 dph ranked in the 22nd, 13th, 9th, and 10th centile, respectively. The SMAV for rainbow trout calculated solely from the present study, when averaged among all life stages, ranked in the 8th centile, the SMAV for rainbow trout calculated solely from the ECOTOX database ranked in the 23rd centile, and the overall SMAV for rainbow trout, calculated from the ECOTOX database and values generated during the present study, ranked in the 16th centile. Based on the results of the present study, fathead minnow (8 dph) ranked in the 46th centile, while the SMAV for fathead minnow,

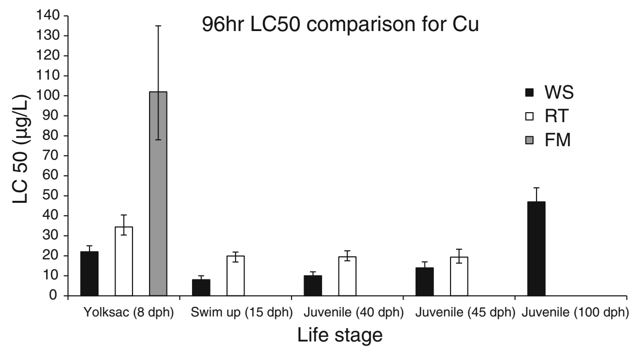



**Fig. 1** Comparison of median lethal concentrations ($LC_{50}$s) of white sturgeon (WS; *Acipenser transmontanus*), rainbow trout (RT; *Oncorhynchus mykiss*), and fathead minnow (FM; *Pimephales promelas*) life stages [days post-hatch(dph)] exposed to copper. *Error bars* represent confidence intervals for measured $LC_{50}$s

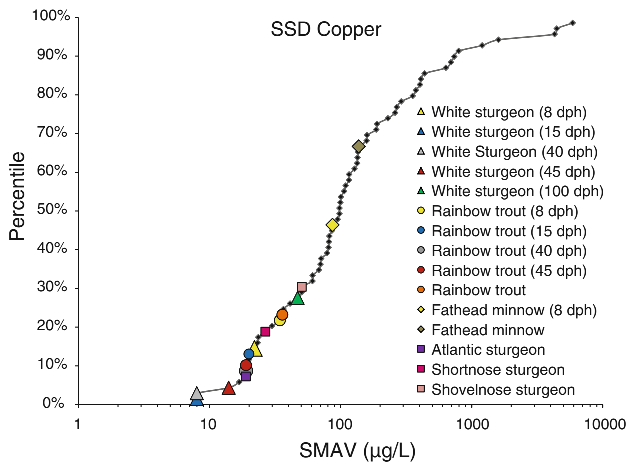



**Fig. 2** Species sensitivity distribution (SSDs) for copper. Values for species with life stages, expressed as days post-hatch (dph), are from experiments conducted at the University of Saskatchewan. Atlantic, shortnose, and shovelnose sturgeon values are from Dwyer et al. (2005), and all other species values are from the ECOTOX database (EPA 2007a). The Species Mean Acute Value (SMAV) is the geometrical mean $LC_{50}$ for a given species

calculated from the ECOTOX database, ranked in the 67th centile. The overall SMAV for fathead minnow, calculated from the ECOTOX database and the present study's findings, ranked in the 59th centile. Early life stage Atlantic (*Acipenser oxyrinchus*), shortnose (*Acipenser brevirostrum*), and shovelnose (*Scaphirhynchus platorynchus*) sturgeon based on data from Dwyer et al. (2005) ranked in the 7th, 19th, and 30th centile, respectively.

## Discussion

Based on findings of the present study, early life stage WS appear to be among the most sensitive fishes to acute Cu exposure, relative to other freshwater fishes. Three of the five life stages tested for WS were the most sensitive fishes in the SSD. The SMAV for WS was calculated and plotted in the SSD and WS were ranked the most sensitive species overall. Similarly, all other early life stage sturgeon incorporated in the same SSD, including Atlantic, shortnose, and shovelnose sturgeon, were relatively sensitive and ranked in the 23rd centile or less. In studies conducted by Dwyer et al. (2005), it was concluded that sturgeon in general should be considered a sensitive species in contaminant assessments, and results from the present study are consistent with these findings. Results of previous studies have shown that some standard test species, such as rainbow trout, are relatively sensitive to certain metals, whereas others, such as fathead minnow, are more tolerant (Besser et al. 2007; Dwyer et al. 2005; Taylor et al. 2000). LC values for the effects of Cu on rainbow trout and fathead minnow determined during the present study were slightly less, but generally consistent with previously reported SMAVs.

Post-hatch, early life stages of fish are generally considered more sensitive to contaminants than adults (Hutchinson et al. 1998; McKim 1977, McKim et al. 1978). In the present study, five early life stages of WS and four early life stages of rainbow trout were exposed to Cu to compare life stage specific sensitivity. For both species, the later larval/early juvenile life stages (15–45 dph) were more sensitive to the effects of Cu than was the yolksac (8 dph) life stage, and in the case of WS, the later juvenile life stage (100 dph). Greater sensitivity to Cu following the initial yolksac life stage and greater tolerance during the later juvenile life stage was observed for WS (Fig. 1). The observed differences in tolerance might be due to the fact that 8 dph larvae are still absorbing their yolksacs whereas at 15 dph larvae have begun to switch to exogenous feeding and are more physically active, leading to greater exposure since rates of respiration are increased and more water is forced over the gills. Rainbow trout, however, did not display a similar trend in sensitivity to Cu following 8 dph that was observed in WS. This might be due to differences in duration and timing of development of rainbow trout and WS, such that the observed sensitivities to Cu among the time periods (dph) tested might not be entirely comparable between species. Under culture conditions, rainbow trout embryos are typically incubated much longer than WS (4–14 weeks, depending on water temperatures, compared to 1 week for WS), and absorption of the yolksac can occur over a period twice as long. Therefore, longer development might result in less of a difference in sensitivity to Cu of post-yolksac larvae because rainbow trout are not transitioning through similar developmental stages as WS at comparable ages and at the same speed.

Significant differences in sensitivities among early life stages could have major implications in risk assessment and development of water quality guidelines and criteria. Risk assessments based on the assumption that younger fish tend to be more sensitive to contaminants than older fish could result in considerable underestimations of sensitivity if post-yolksac early life stages are not considered, as demonstrated in the present study, and lead to under-protection of certain species. Currently, in Canada and the United States, there is no requirement to evaluate differences in sensitivities among life stages when developing water quality guidelines and criteria. In the United States, differences in life stage sensitivity are taken into account but only if existing data demonstrates that there are differences of more than a factor of two (EPA 1985). If no toxicity data exist for various life stages of a species, then differences in sensitivities among life stages are not considered when calculating criteria or assessing potential for effects. To overlook these potential differences with a vulnerable population of fish could result in significant under-protection. Yolksac larvae of WS have greater tolerance to Cu toxicity compared to succeeding life stages, but since these earlier life stages might be in more intimate contact with biologically available metals in contaminated sediments, they might be more at risk than would be indicated solely by their tolerance to Cu concentrations. Greater exposure to Cu during the transition to exogenous feeding, however, is detrimental since previous studies have shown that WS are inherently sensitive during this period of development (Vardy et al. 2011). This poses an increased threat to early life stage juveniles that return to the bottom to feed and are at greater risk of exposure to sediment bound contaminants.

Early life stages of WS are sensitive to aqueous copper exposure and site-specific water quality guidelines and criteria should be evaluated closely to ensure adequate protection when sturgeons are of concern. The Canadian water quality guideline for the protection of aquatic life for Cu, adjusted to the present study's hardness of 57 mg/L $CaCO_3$, is 2 μg/L (CCME 2003). In the United States, criteria for protection of aquatic life for Cu are site-specific and freshwater criteria are calculated by use of the biotic ligand model (BLM; EPA 2007b). Based on the present study's water quality parameters for WS, the water quality acute criteria for Cu, recommended by the US EPA for protection of aquatic life (CMC; EPA 2007b, 2009), would be between 6.4 and 9.5 μg/L. In order to assess the degree of protection of WS in relation to water quality guidelines and criteria, one half the species mean acute value (½ SMAV) was calculated. This is similar, but on a species level, to EPA water quality criteria methods where one half final acute values (FAVs) are calculated. In the present study, ½ SMAV for WS is above the Canadian water quality guideline but falls within the calculated range for US criteria (Table 1). When half the $LC_{50}$ values for the individual life stages of WS are examined, some thresholds are less than US criteria. This merits further investigation, especially at the more sensitive life stages, to assess the level of protection in relation to water quality criteria for Cu.

This study provides a portion of much needed toxicity data for early life stage WS and identified significant differences in sensitivities among early life stages of fish. $LC_{50}$ values from the present study predicted similar trends in early life stage WS sensitivity when compared to chronic early life stage WS threshold values for Cu (chronic values: 19 dph = 9.9 μg/L and 58 dph = 12.4 μg/L; Vardy et al. 2011). When feasible, contaminant exposure studies should include different life stages to help elucidate possible differences in life stage sensitivities in order to develop more comprehensive water quality guidelines and criteria. WS are sensitive to Cu exposure and water quality guidelines and criteria may need to be evaluated on a site-by-site basis when WS early life stages are present in order to ensure protection. Other endpoints, such as effects of Cu exposure on olfaction, chemosensory, and/or behavior, for example, could also be investigated with WS because these endpoints have been shown to be the most sensitive endpoints in other fish species (Grosell 2012). In addition, alternate routes of exposure, such as from contaminated sediment or dietary uptake, warrant further investigation as water-only exposures may represent variable proportions of total exposure depending upon life stage.

**Acknowledgments** This research was funded by an unrestricted grant from Teck American. This work was approved by the University of Saskatchewan's Animal Research Ethics Board, and adhered to the Canadian Council on Animal Care guidelines for humane animal use. The Aquatic Toxicology Research Facility and Toxicology Graduate program at the University of Saskatchewan was instrumental in conducting this research. The authors would like to thank M. Adzic, B. Tendler, and the U.S. EPA. Thanks to R. Santore and A. Ryan for their BLM support, and a special thanks to R. Ek and the team at the Kootenay Trout Hatchery for facilitating this research. The research was supported in part by a Discovery Grant from the National Science and Engineering Research Council of Canada, a Grant from the Western Economic Diversification Canada, and the UROP Abroad program of the RWTH Aachen University, Germany. The authors wish to acknowledge the support of an instrumentation grant from the Canada Foundation for Infrastructure. Prof. Giesy was supported by the Canada Research Chair program, an at large Chair Professorship at the Department of Biology and Chemistry and State Key Laboratory in Marine Pollution, City University of Hong Kong, and the Einstein Professor Program of the Chinese Academy of Sciences.

## References

ASTM (2007) Standard guide for conducting acute toxicity tests on test materials with fishes, macroinvertebrates, and amphibians. American Society for Testing and Materials, West Conshohocken, p E729

Auer NA, Baker EA (2002) Duration and drift of larval lake sturgeon in the Sturgeon river, Michigan. J Appl Ichthyol 18:557–564
Besser JM, Mebane CA, Mount DR, Ivey CD, Kunz JL, Greer IE, May TW, Ingersoll CG (2007) Sensitivity of mottled sculpins (*Cottus bairdi*) and rainbow trout (*Onchorhynchus mykiss*) to acute and chronic toxicity of cadmium, copper, and zinc. Environ Toxicol Chem 26:1657–1665
Birstein VJ (1993) Sturgeons and paddlefishes: threatened fishes in need of conservation. Conserv Biol 7:773–787
Brannon E, Melby CL, Brewer SD (1983) Columbia river white sturgeon (*Acipenser transmontanus*) enhancement. Project No. 1983–31600. BPA report DOE/BP-363
Brannon E, Brewer S, Setter A, Miller M, Utter F, Hershberger W (1985) Columbia River white sturgeon (*Acipenser transmontanus*) early life history and genetics study. Project Rep. 1983–31600. BPA report DOE/BP-18952–1
CCME (2003) CCME guidelines for the protection of aquatic life. Environment Canada. Canadian Council of Ministers of the Environment. http://www.waterquality.ec.gc.ca/waterqualityweb/guidelines.aspx?catId=1. Accessed 28 Feb 2012
CCME (2007) A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. In: Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg
Conte FS, Doroshov SI, Lutes PB, Strange EM (1988) Hatchery manual for the white sturgeon *Acipenser transmontanus* Richardson with application to other North American Acipenseridae. University of California, Division of Agriculture and Natural Resources, Oakland
COSEWIC (2012) Government of Canada. Wildlife species search: white sturgeon. Committee on the status of endangered wildlife in Canada. http://www.cosewic.gc.ca/eng/sct1/searchdetail_e.cfm. Accessed 28 Feb 2012
Coutant CC (2004) A riparian habitat hypothesis for successful reproduction of white sturgeon. Rev Fish Sci 12:23–73
Creed JT, Brockhoff CA, Martin TD (1994) Determination of trace elements in water and wastes by inductively coupled plasma-mass spectrometry. Environmental Monitoring System Laboratory Office of Research and Development U.S. Environmental Protection Agency, Cincinnati. Method 200.8, Revision 5.4
Deng X, Van Eenennaam JP, Doroshov SI (2002) Comparison of early life stages and growth of green and white sturgeon. In: Van Winkle W, Anders PJ, Secor DH, Dixon DA (eds) Biology, management, and protection of North American sturgeon. American Fisheries Society, Bethesda, pp 237–247
DFO (2007) Recovery potential assessment for white sturgeon. Department of Fisheries and Ocean. Can Sci Advis Sec Sci Advis Rep 2007/014
Dwyer FJ, Mayer FL, Sappington LC, Buckler DR, Bridges CM, Greer IE, Hardesty DK, Henke CE, Ingersoll CG, Kunz JL, Whites DW, Augspurger T, Mount DR, Hattala K, Neuderfer GN (2005) Assessing contaminant sensitivity of endangered and threatened aquatic species: part I. Acute toxicity of five chemicals. Arch Environ Contam Toxicol 48:143–154
EPA (1985) Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. U.S. Environmental Protection Agency, Washington. EPA/833/R-85/100
EPA (2007a) ECOTOX user guide: ECOTOXicology database system. Version 4.0. U.S. Environmental Protection Agency, Washington. http:/www.epa.gov/ecotox/. Accessed 20 Feb 2011
EPA (2007b) 2007 Revision of aquatic life ambient freshwater quality criteria—Copper. U.S. Environmental Protection Agency, Office of Water Report, Washington. EPA-822-R-07-001
EPA (2009) National recommended water quality criteria. Appendix B. Parameters for calculating freshwater dissolved metals criteria that are hardness-dependent. U.S. Environmental Protection Agency, Washington. http://www.epa.gov/waterscience/criteria/wqctable/. Accessed 28 Feb 2012
Feist G, Webb M, Gundersen D, Foster E, Schreck C, Maule A, Fitzpatrick M (2005) Evidence of detrimental effects of environmental contaminants on growth and reproductive physiology of white sturgeon in impounded areas of the Columbia River. Environ Health Perspect 113:1675–1682
Gessner J, Kamerichs CM, Kloas W, Wuertz S (2009) Behavioural and physiological responses in early life phases of Atlantic sturgeon (*Acipenser oxyrinchus* Mitchill 1815) towards different substrates. J Appl Ichthyol 25:83–90
Gisbert E, Williot P (2002) Advances in the larval rearing of Siberian sturgeon. J Fish Biol 60:1071–1092
Grosell M (2012) Copper. In: Wood CM, Farrell AP, Brauner CJ (eds) Homeostasis and toxicology of non-essential metals, vol 31a, fish physiology. Academic Press, London, pp 53–133
Hutchinson TH, Solbe J, Kloepper-Sams PJ (1998) Analysis of the ecetoc aquatic toxicity (EAT) database III—comparative toxicity of chemical substances to different life stages of aquatic organisms. Chemistry 36:129–142
Irvine RL, Schmidt DC, Hildebrand LR (2007) Population status of white sturgeon in the lower Columbia River within Canada. Am Fish Soc 136:1472–1479
Kamunde CN, Wood CM (2003) Environmental chemistry, physiological homeostasis, toxicology, and environmental regulation of copper, an essential element in freshwater fish. Australas J Ecotoxicol 10:1–20
Kruse GO, Scarnecchia DL (2002) Assessment of bioaccumulated metal and organochlorine compounds in relation to physiological biomarkers in Kootenai River white sturgeon. J Appl Ichthyol 18:430–438
Kynard B, Parker E (2005) Ontogenetic behavior and dispersal of Sacramento River white sturgeon, *Acipenser transmontanus*, with a note on body color. Environ Biol Fishes 74:19–30
Luk'yanenko VI, Vasil'ev AS, Luk'yanenko VV, Khabarov MV (1999) On the increasing threat of extermination of the unique Caspian sturgeon populations and the urgent measures required to save them. J Appl Ichthyol 15:99–102
McAdam SO (2011) Effects of substrate condition on habitat use and survival by white sturgeon (*Acipenser transmontanus*) larvae and potential implications for recruitment. Can J Fish Aquat Sci 68:812–822
McKim JM (1977) Evaluation of tests with early life stages of fish for predicting long-term toxicity. J Fish Res Board Can 34:1148–1154
McKim JM, Eaton JG, Holcombe GW (1978) Metal toxicity to embryos and larvae-early juveniles of eight species of freshwater fish II: copper. Bull Environ Contam Toxicol 19:987–993
Niyogi S, Wood CM (2003) Effects of chronic waterborne and dietary metal exposures on gill metal-binding: implications for the biotic ligand model. Hum Ecol Risk Assess 9:813–846
Paragamian VL, Hansen MJ (2008) Evaluation of recovery goals for endangered white sturgeon in the Kootenai River, Idaho. N Am J Fish Manag 28:463–470
Paragamian VL, Beamesderfer RCP, Ireland SC (2005) Status, population dynamics, and future prospect of the endangered Kootenai River white sturgeon population with and without hatchery intervention. Trans Am Fish Soc 134:518–532
Posthuma L, Suter GW, Trass TP (2002) Species sensitivity distributions in ecotoxicology. Lewis, New York
Richmond AM, Kynard B (1995) Ontogenetic behaviour of shortnose sturgeon, *Acipenser brevirostrum*. Copeia 1:172–182
Salomons W, de Rooij NM, Kerdijk H, Bril J (1987) Sediments as a source for contaminants. Hydrobiology 149:13–30
Scott WB, Crossman EJ (1998) Freshwater fishes of Canada. Galt House Publications, Oakville

Sullivan P, Taylor KG (2003) Sediment and porewater geochemistry in a metal contaminated estuary, Dulas Bay, Anglesey. Environ Geochem Health 25:115–133

Taylor LN, McGeer JC, Wood CM, McDonald GD (2000) Physiological effects of chronic copper exposure to rainbow trout (*Oncorhynchus mykiss*) in hard and soft water: evaluation of chronic indicators. Environ Toxicol Chem 19:2298–2308

UCWSRI (2002) Upper Columbia White Sturgeon Recovery Plan. Upper Columbia White Sturgeon Recovery Initiative. Technical Report. BC, Canada. http://uppercolumbiasturgeon.org/RecoveryEfforts/Recovery.html. Accessed 28 Feb 2012

U.S. Fish and Wildlife Service (2012) Environmental conservation online system. Species profile: white sturgeon (*Acipenser transmontanus*). http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=E087. Accessed 28 Feb 2012

Vardy DW, Tompsett AR, Sigurdson JL, Doering JA, Zhang X, Giesy JP, Hecker M (2011) Effects of sub-chronic exposure of early life stages of white sturgeon (*Acipenser transmontanus*) to copper, cadmium and zinc. Environ Toxicol Chem 30:2497–2505

Wood CM (2001) Toxic responses of the gill. In: Schlenk D, Benson WH (eds) Target organ toxicity in marine and freshwater teleosts, vol 1, Organs. Taylor and Francis, London. pp 1–89